Applications of DHM in Agricultural Engineering: A Review

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Keywords: digital human modeling, CAD, agriculture, farm machinery, ergonomics, virtual evaluation

Abstract. Research towards developing user-compatible, ease in use and safe agricultural equipment with proper consideration of human factors using cutting edge technology like Digital Human Modeling (DHM) and simulation is very important in today's scenario. This technology offers new possibilities to integrate ergonomics principles into design process from the very beginning (conceptual phase) to solve complex problems in many engineering disciplines. However, its application is till very limited in agricultural sector. This paper provides overview of up-to-date research in virtual ergonomics evaluation technology (through DHM) and its applications in agriculture. Attempt has also been made to highlight future research direction in many areas of agricultural sectors where DHM might contribute potentially for ergonomic interventions to reduce drudgery and chances of errors and accidents. Authors have also identified reasons behind less adoption of this technology in agricultural sectors and tried to highlight strategies to be followed for wide adoption.

Introduction

Agriculture is still recognized as one of the most hazardous industry, following mining and construction because of the nature of agricultural machines and conditions under which they are operated [1]. On one hand, use of local artisans made primitive tools/equipment are found ineffective/not well suited with user's physical capacity in developing and least developed countries and thus causes physical strain and fatigue which very often not only results in less productivity but also leads to accidents and injuries. On the other hand, rapid mechanization in agriculture in different developed and developing countries is creating challenges like hazardous work environment and increased number of accidents. Therefore, agricultural tools/equipment and workplaces are needed to be designed considering human factor issues using state-of-the-art technologies as described in subsequent sections.

Ergonomics/Human factors in agriculture: Professionals and researchers from diverse fields are in constant attempt for improvement of agricultural hand tools, farm machineries, agricultural vehicles etc. to provide more user friendly facilities. Now-a-days it is well known that incorporation of ergonomics principle in any product/workplace or process design can offer better performance, productivity and at the same time reduction in errors and accidents in any sector [2]. Agricultural sector is not an exception for the same. As incidents of accident and other occupational health hazards are very highly associated with agricultural operations, enough research and development are still needed and fruitful results are to be implemented in a cost-effective manner to ameliorate present situation.

Conventional ergonomics approach in agriculture: Application of ergonomics principles in agriculture has a long history. Traditional ergonomics evaluation process involve full-size physical mock-up, selection of a representative sample of potential users for executing a series of appropriate

human factors evaluations and it is also time consuming, reactive, incomplete, sporadic, and in many cases difficult, too [3]. Although it is well understood that use of scientific and technological advancements will improve the quality as well as productivity with less time and cost but the use of traditional approach of ergonomic evaluation is still in practice for improvement of existing designs of farm tools and implements [4-9]

Need of virtual ergonomics evaluation techniques in agriculture: Virtual designing and evaluation technology is now widely accepted as a major breakthrough in scientific and technological advancement which leads new possibilities to solve intricate problems, not only in engineering but also in other applied areas including agricultural sector. Need for implementation of virtual ergonomics evaluation technology in agriculture can be perceived by recognizing the problems associated with traditional methods for design, development and ergonomic evaluation. There is no doubt that usage of computer aided technology has brought avant-garde changes in many multidisciplinary scientific fields. Unfortunately, this technology has not got momentum, particularly in agricultural sectors where farming tools and equipment are still evaluated by traditional ergonomic assessment methods. Digital human modeling (DHM) software allows configurations and design changes in the virtual design stage, thus reducing the risk of ergonomics problems in development stages before making the actual prototype. It would go a long way toward bringing the principles of ergonomics and elucidating the scope and benefits of its applications.

Aim and Objectives

To date, most of the applications of DHM research are associated with sectors like Aviation, Aerospace, Military research and Automobile, while limited information is available on use of the same in agricultural sectors particularly for ergonomic design and evaluation of farm machineries/equipment. Moreover, available information is discrete in nature and there is a strong need of a concrete knowledge base regarding application of DHM in agriculture to strengthen and promote further research in this sector. Thus, the aim of the present review is to highlight existing scenario of DHM applications in agricultural sectors for design and development of cost effective agricultural tools/equipment. Attempt has also been made to find out reasons behind less adoption of these technologies in agricultural sectors and to highlight strategies to be followed for their wide adoption to design and develop safe, efficient and user-friendly farm tools and/or machineries and operator's workplace.

DHM –important tool for virtual ergonomics

Computer-aided technology enables many novel approaches in modeling, design and fabrication of farm tools and machines. CAD is mainly used for detailed engineering of 3D models and/or 2D drawings of physical components under a wide variety of representations. However, digital human representations in various forms are now being incorporated in computer-aided design of human-machine systems for simulating man-machine interactions in virtual environment as real-world conditions. Digital Human Modeling (DHM) is special CAD software for developing 2D or 3D digital manikin (virtual human) from anthropometric and biomechanical databases for proactive ergonomic evaluation of product and workplace [10]. DHM software are now successfully being used in various sectors including military research [11,12], automobile sector [13,14], aerospace and aviation technology [15,16], industrial applications [17-19], health care and occupational safety [20-22], service industry [23,24] etc. DHM tools provide complete digital humans to explore infinite number of ergonomic scenarios including human size scaling, evaluation of posture, motion, reach, and vision within a computer-rendered environment [25-27,10]. Adoption of DHM looks very promising for improvement of agricultural tools, equipment as well as for off-road vehicle such as tractor and power tiller to make it more productive, efficient and comfortable to use.

Applications of DHM in agricultural sector

Traditional human factors assessments for design and evaluation of workstations and vehicles involves manual measurements, user interfaces, and basic imagery or video recording to assess risks and identify possibility for improvement. Innovations in human factors and ergonomics assessments with computer-aided techniques, specifically the use of DHM, have proven to be very useful tools [28, 29]. Using these tools, the visual scope and reach envelope of specific range of populations can be analyzed (e.g., EAI Jack) [25]. Furthermore, when integrated with virtual environments, DHM facilitates evaluation of workplace design, human reach, clearance and strength capability and safety analysis [30]. Physical mock-up is no longer necessary, and multiple aspects can be assessed with CAD which provides an efficient platform for digital mock-ups in virtual environments [31-34].

Compared to other industries, DHM have been late coming into agriculture. Available literature suggests that steps have been initiated only in recent past by few researchers (Figure 1) such as Fathallah et al. (2009)[35] who investigated the abilities of varying anthropometric characteristics of youth operators to reach farm tractor controls by using SAMMIE CAD. Dooley (2012) [36] in his paper, discussed about physical and cognitive aspects of ergonomics in modern product development including agricultural vehicle. He inserted digital manikin in operator workplace (seat) and prescribed the relationship of pedals and steering wheel to floor and seat index point. Deisinger et al. (2000) [37] carried out a pilot project (with collaboration of John Deere Company in Mannheim, Germany) for analysis of reach envelope, visual field and force isodyne using ERGONAUT tool in a Virtual Environment (VE) for analysis of virtual and real data in a mixed mock-up. Computer models of digital human and the power carrier were developed by Wu et al. (2012) [38] using CAD software packages SolidWorks, I-DEAS and Jack to investigate the controllability of driving, driver's degree of comfort in driving, and the lumbar force condition of the operator while lifting cargo from cargo-bench of the carrier. Ying et al. (2010) [39] designed tractor cab and a combine harvester cab using OpenGL 3D computer graph software. The cabs were evaluated by a manikin of 50th percentile for various hand and foot controls using virtual environment through the mixture of OpenGL and Multigen Vega Prime.

Figure 1. Application of DHMs for ergonomic evaluation of agricultural equipment/workplace

Discussions and Conclusion

Application of DHM is becoming increasingly popular today among designers and manufactures as it increases productivity, reduces design time-frame and decreases associated costs. Core functionality of DHM software is realistic display of anthropometric data and efficient analysis of

ergonomic questions concerning sight, maximum force, reachability and comfort [40, 10, 16]. Designers can subsequently utilize a human model in the creation, modification, presentation and analysis [41] to ensure enough clearance and space to human for their ease and comfortable movement within workplace. From previous sections, it is very clear that DHM might have potential to contribute positively in agricultural sector. It is evident from tractor cab design and evaluation by various researchers [42,43]. There is no doubt about the fact that DHM is gradually gaining momentum in agricultural engineering setting such as tractor operator's workplace for operator cabs, adjustments for brake reach and linkages, seat position and seat height, visibility and for many more controls. Globally, most of the industries are steadily harnessing wide range of applications and benefits that DHM technologies offer, to replace and streamline traditional design systems and processes, increase efficiencies and productivity. However, application of these technologies to agriculture sector is still in its infancy. Although, farm equipment manufacturers are aware of the fact that traditional methods of designing and manufacturing are often costly, risky, high energy demanding, more time consuming, needing physical mock-ups and trial with real human subjects testing but in many instances they cannot afford initial investments or expenditure towards infrastructure development for modern technologies like DHM. There is an urgent need for creating general awareness about benefits offered by these technologies for their wide adoption. Awareness among researchers, scientists, engineers, designers and entrepreneurs could be achieved through organizing seminars, conferences, workshops etc. on this topic. Another hindrance for less adoption of DHM technologies is huge initial investments or expenditure towards infrastructure development and human resource training for these technologies. So, it is time to think how cost can be reduced to make it affordable for small scale manufactures. Integration of features of DHM software in general CAD software may reduce cost to some extent and would resolve many problems of file transfer from CAD to DHM software or vice versa. Moreover, further research is required for user friendly DHM software development and making manikins more realistic.

It is expected that present review on applications of DHM in agricultural sector would deliver a concrete knowledge base for those who are interested in agricultural engineering and ergonomics for farm machinery/tools design or agricultural workplace evaluation. Readers would be motivated to carry out further research in this line for transforming agricultural modernization from stagnation to growth.

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