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Importance Of Ergonomic Evaluation By Digital Human Modeling

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Abstract
over the last few years there has been a massive development and use of information technology. These technologies are probably the only answer to success in a highly globalized and turbulent market environment. The development of computer and communication technology enables that the methods of engineering work can be changed from scratch. This trend in digitalization has an effect on ergonomics. Digital Human Modeling is the state of the art technology for virtual ergonomic evaluation of products and workstations. Ergonomic evaluations using Digital Mock-up and Digital Human Models which are computer generated two dimensional or three dimensional structure of a human representing the complex physical and cognitive aspects of human beings are economical in the long run when compared with traditional ergonomic evaluation process in a typical product or process development sequences Traditional ergonomic evaluation methods for studying human performance and productivity, involves physical mock ups and trial with real human beings are found to be time consuming and quite expensive. This paper reviews the literature of Digital Human Modeling and provides overview of up-to-date research in virtual ergonomics evaluation technology through DHM. An Attempt has also been made to highlight future research direction in many areas

Keywords: digital human modelingt; ergonomic evaluation; simulation

I. INTRODUCTION

Ergonomics is according to IEA (International Ergonomics Association,2000) defined as a scientific discipline concerned with the understanding of interactions among human and other elements of a system, and the profession that applies theory, principles, data and methods to design in order to optimize human well-being and overall system performance[1]. Ergonomics promotes a holistic approach in which considerations of physical, cognitive, social, organizational, environmental and other relevant factors are taken into account. Physical ergonomics is concerned with human anatomical, anthropometric, physiological and biomechanical characteristics as they relate to physical activity. Applying a scientific, evidence-based approach to ergonomics process is important with the goal to identify ergonomic risk factors, quantify then, and then make measurable improvements to the workplace, ensuring that jobs and tasks are within workers' capabilities and limitations [2].

Traditional ergonomic evaluation methods for studying human performance and productivity, involves physical mock ups and trial with real human beings are found to be time consuming and quite expensive. As computer technology has become advanced and affordable, spreading its tentacles in each and every scientific discipline(s), ergonomics proved to be no exception [3].

II. IMPORTANCE OF DHM

A. Ergonomics and musculoskeletal disorders (MSDs)

Ergonomics is the science of fitting jobs to people. The discipline encompasses a body of knowledge about physical abilities and limitations as well as other human characteristics that are relevant to job design. Essentially ergonomics is the relationship between the worker and the job and focuses on the

design of work areas to enhance job performance. Ergonomics can help prevent injuries and limit secondary injuries as well as accommodate individuals with various disabilities; including those with musculoskeletal disorders (MSDs). Disorders Musculoskeletal of the system that is caused precipitated or aggravated by repeated exertions or movements of the body. MSDs are caused from wear and tear on tendons, muscles, and sensitive nerve tissue caused by continuous use or pressure over an extended period of time [4]. Through ergonomic assessment and related interventions not only the WMSDs risk factors will be explored but also some practical ways for the prevention of awkward postures are introduced. According to WHO (1985), there are some factors that create or aggravate work-related disorders, such as work demands, social and cultural factors, work place characteristics, and environmental factors. In this respect, as ergonomics covers all of the mentioned farms, it has an important role in occupational health [5].

B. Digital human modeling

The development of computer and communication technology enables that the methods of engineering work can be changed from scratch. This trend in digitalization has an effect on ergonomics [6]. As computer technology has become advanced and affordable, spreading its tentacles in each and every scientific discipline(s), ergonomics proved to be no exception. In today's scenario, Digital Human Modeling (DHM) is fast becoming an integral part of Computer Aided Ergonomics (CAE). It is the state of the art technology for virtual ergonomic evaluation of products and workstations. Simulations/ergonomic evaluations using Digital Mock-up and Digital Human Models (computer generated two dimensional or three dimensional structure of a human representing the complex physical and cognitive aspects of human beings) are economical in the long run when compared with traditional ergonomic evaluation process in a typical product/process development sequences. Repeated trials which were otherwise not easily possible in traditional ergonomic investigations are now achievable due to virtual simulations using DHMs [7]. DHM can be used advantageously to a great extent in developing countries for variety of applications and its diverse scope of application is yet to be explored to its full potential Further it is deemed important to highlight that traditional ergonomic evaluation techniques based on trial and error method using physical mock-ups and real human, has proved to be time consuming, costly and mostly overlook anthropometric and biomechanical aspects involved in performing tasks [8]. Virtual evaluations of a CAD product with digital manikins have the potential to overcome known drawbacks of traditional ergonomic evaluation methods [9]. As a technology, digital human modeling (DHM) which has always been at the forefront of ergonomic research is being propelled at an unprecedented tempo in the digital age by the advancement of computer technology. DHM is a means to create, manipulate, and control human representations and human–machine system scenes on computers for interactive ergonomics and design problem solving.

C. Digital human modeling:evaluation tools

Digital Evaluation tools could be divided in three groups:

- Quantitative evaluation tools
- Semi-quantitative tools
- Tools for discomfort, anthropometry, human Anthropometry, human performance, and cognition Quantitative tools are used to evaluate working postures and physical workloads, considering specific risk factors related to a single posture/movement or to a complete task [10].

TABLE I.

Quantitative evaluation tools	
Lower Back Analysis (LBA)	determines the forces acting on the low back by evaluating postures and load conditions.
Static Strength Prediction (SSP)	estimates the percentage of the working population able to perform (in terms of muscular static strength) a task.
NIOSH	calculates a recommended weight limit and a lifting index for a given manual lifting/lowering action or an overall index in the case of multiple tasks.
Predetermined Time Standards (PTS)	quantifies the time required to perform a task by dividing it into a set of elementary movements.
Rapid Upper Limb Assessment RULA)	identifies the manual tasks, mainly of handling of low loads at high frequency, which expose workers to increased risk of upper limb disorders, taking into account posture, muscular strain, weight, duration and frequency of the tasks

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Quantitative evaluation tools	
Metabolic Energy Expenditure (MEE)	characterizes the requirements of tasks in terms of metabolic energy expenditure.
Manual Handling Limits (MHL)	assesses tasks that require carrying, lifting, lowering, pushing or pulling in relation to the percentage of working population able to execute the tasks.
Fatigue Analysis (FA)	determines whether, after each task, there is an adequate recovery time able to avoid excessive physical fatigue for the worker.
Ovako Working Posture Analysis (OWAS)	estimates the possible discomfort related to the posture taken by the worker.
Force Solver (FS)	predicts the maximum acceptable force that a human could exert under the prescribed conditions.

Fig. 1. *Quantitative evaluation tools*

- **Semi-quantitative tools**

Semi-quantitative tools are used to visualize or analyze the manikin's interaction with the environment. Examples of such tools are Eye View (EV), View Cones (VC), Reach Zones (RZ), Collision Detection (CD), and Foot Prints (FP).

- **Tools for discomfort, anthropometry, human**

Anthropometry, human performance, and cognition are used for many applications, such as to support vehicle interior design or to create manikins with specific anthropometric measurements [11].

III. APPLICATION OF DHM

Throughout the globe, diverse industrial sectors are harnessing benefits of DHM applications. Some of them include automobile, aviation and aerospace, defense research, healthcare, general industrial applications, clothing and textile, service and animation, agricultural division, product design and applications of DHM technology in reference to various industrial sectors and also manufacturing shop-floor [3]. In India, available literatures indicate that DHMS are being used in diverse application fields by Indian engineers, designers and people from other professions.

- **Automobile Sector**

DHM has ability to improve efficiency and ergonomics of assembly operations using participatory ergonomic approach. It is capable to optimize comfort, reach, fit, and vision for user/occupant [12] and thus improve vehicle design in accordance with sound ergonomic principles [13]. DHM is helpful in achieving quicker and cost effective design process as this software can be used in design, modification, visualization, analysis of workplace layouts/product interactions in automobile industry and has potential to be used in operator training [14]. Mueller and Maier[15] stated that user centered vehicle layout can be generated systematically from ergonomic point of view using DHMs giving due consideration to trunk loading and unloading movements.

- **Aviation and Aerospace Technology**

"Open Skies" policy of various Governments across world has led to the foray of many companies in this sector resulting increased air travel. DHM is now playing a significant role in this sector to improve passenger amenities and will be sought after by aeronautic industries. These software are being used in assessing comfort of airplane passenger seats from user's perspective [16]. Manikins can be accurately positioned for accommodation related investigations in cockpit design [17]. Fighter aircraft pilots are required to make split second decisions in real battlefield situations based on visual inputs from cockpit displays/instrumentation. Presence of displays in blind spot regions can prove to be fatal. DHM can be productively used to perform vision analysis for pilots in a jet aircraft as shown in a case study [18].

- **Defense Research**

Differently built human models representing diverse anthropometry of army personnel are used to evaluate their workstations easily [19]. Manikins can be accurately positioned for accommodation related investigations in cockpit design [16]. Fighter aircraft pilots are required to make split second decisions in real battlefield situations based on visual inputs from cockpit displays/ instrumentation. Presence of displays in blind spot regions can prove to be fatal. DHM can be productively used to perform vision analysis for pilots in a jet aircraft as shown in a case study [18].

- **Healthcare Industry**

Simulation using DHM with respect to ladder climbing scenario for an under-knee amputee was performed with an aim to design comfortable limb prosthesis for complex motions [20]. Surgeries can be performed effectively and efficiently as [21] explains application of DHMs to identify

ergonomic problems while performing laparos-copic surgery in an operation room.

- **General Industrial Applications**

DHMs are now being used in secondary manufacturing sectors to develop ergonomically sound workplace [22]. evaluation of manual material handling and user interface evaluation in shop floor [23], biomechanical and vision analysis while using a machine tool [24], and so on.

- **Clothing Sector, service and animation**

A survey on CAD methods in 3D garment design gives ample insights in visualizing role of DHM in this sector [25]. In addition to that hand loom industries have several ergonomic problems which need to be evaluated by DHMs. People today are short of time and seek convenience in their everyday life. DHM has started to cater the needs of service sector too.

- **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. 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, reach ability and comfort. Designers can subsequently utilize a human model in the creation, modification, presentation and analysis to ensure enough clearance and space to human for their ease and comfortable movement within workplace [26].

IV. DISCUSSION AND CONCLUSION

DHM software are now successfully being used in various sectors including military research. automobile sector, aerospace and aviation technology, industrial applications, health care and occupational safety, service industry 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. It is expected that present review on DHM an aid for ergonomic evaluation would deliver a concrete knowledge. Adoption of DHM looks very promising in near future.

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