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Digital Human Modeling and Simulation in Product and Workplace Design: Indian Scenario

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ABSTRACT
'Digital Human Modeling (DHM)', the process of CAD representation of human body form or its parts for virtual ergonomic evaluation of human-product compatibility, is being used popularly and effectively all over the world. Application of DHM has been proved to be beneficial for considerable reduction of project time-scale; design and manufacturing cost; occupational hazards; and for improvement of quality, productivity and efficiency in diverse industrial sectors. While researchers, educators and engineers from developed and developing countries are harnessing advantages of DHM techniques, scenario of adopting this technology in India is not very promising till date. Following extensive literature review, an attempt has been made in current paper to document present status of DHM application and research in India. Indian academic and research institutions along with various industries which are using DHM have been investigated. Though the number of reported studies on application of DHM techniques by Indian researchers is quite good, there are only few research papers (published from India) which contribute towards research and development of digital manikin or its body parts for software development. Root causes for less adoption of DHM in India has been highlighted in the present review to find out solutions intended for encouraging its wide adoption.
Keywords **-** CAD, DHM, digital manikin, human factors, virtual ergonomics

I. INTRODUCTION

Modeling and Simulation (M&S) has gained significant foothold in all scientific disciplines. Modeling refers to representation of a system/model whereas simulation may refer to operation of model in a particular system of interest [1]. Modeling and Simulation are performed in both real physical as well as in virtual environment (VE). VE is computer generated 3D graphics environment where various types of modeling and simulation activities can be performed [2]. Foremost benefit of M&S in computer graphics environment is the capability to perform detailed investigations without building physical prototype.

1.1 DHM AND VIRTUAL ERGONOMICS

Digital Human Modeling and Simulation (DHMS) refer to digital representation of human inserted into a simulation or virtual environment to facilitate prediction of safety and/or performance [3]. Further, digital human modeling may also refer to procedure of building, creating or designing virtual human models (also known as 'digital manikin') to represent complex physical and cognitive aspects of human beings. Ergonomics (or human factors) is the scientific discipline concerned with understanding interactions among humans and other elements of a system, and applies theory, principles, data and methods to design in order to optimize human well-being and overall system performance [4]. Practitioners of ergonomics and ergonomists deal with design and evaluation of tasks, jobs, products, environments and systems in order to make them compatible with needs, abilities and limitations of humans. Physical ergonomics discusses human anatomical, anthropometric, physiological and biomechanical characteristics (as they relate to physical compatibility) and areas of focus include working postures, materials handling, repetitive movements, work related musculoskeletal disorders, workplace layout, safety and health [4]. VE is highly relevant to applied ergonomics in design of objects/products [2]. Ergonomics analysis performed in virtual environment may be stated as virtual ergonomics. Physical and virtual ergonomics are differentiated using an illustration in Fig. 1.

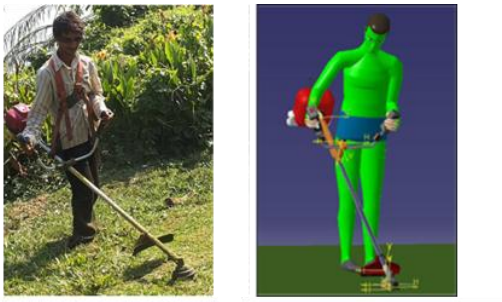


Figure 1: Physical and Virtual Ergonomics

1.2 ADVANTAGES OF DHM SOFTWARE

Anthropometric and biomechanical characteristics should be considered for designing a human compatible product beneficial for intended/targeted users, apart from other factors like aesthetics, maintainability, durability, product semantics, legal aspects etc. [5]. Workplace should also exhibit human centeredness/compatibility, as human beings spend considerable amount of time confined to manmade environment in workplace designed for them consisting of installed equipment, supportive furniture etc. [5]. Product and workplace designers/engineers would admit that huge additional cost and time are involved in redesigning an installed and mass produced entity for correcting problems/ glitches. Proactive ergonomics investigations and evaluations in initial phase of design development would definitely ensure human centric/compatible/friendly product and workplaces from physical ergonomics perspective. Proactive ergonomics evaluations for products and workplaces might not be completely possible in traditional ergonomics evaluation practices. On contrary, DHM helps in proactively evaluating products and workplaces as assessment is done in computer assisted virtual/Computer Aided Design (CAD) environment. DHM is used for wide range of applications viz. investigating and validating product and workplace geometry, safety and functional features, working postures, manual material handling, push and pull characteristics, vision and reach features, lift and carry activities, clearance and interference issues, compression and shear forces acting on lumbar segments, comfort body joint angles, range of body joint angle movements, body stability, body's center of gravity etc. Presently, advantage of DHMS lies in its ability to replace investigations and repeated trials using real physical mockups and humans for physical ergonomics evaluation purposes[6]. Therefore, significant reductions in costs are realized in design and development of products and workplaces. Research and development is in progress to incorporate cognitive aspects of humans into DHMs. Complete data pertaining to physical and cognitive aspects of human populations across globe will be embedded into DHMS software in near future. Time is not far when DHM will completely change the face of ergonomics.

1.3 GLOBAL USE OF DHM IN VARIOUS INDUSTRIAL SECTORS

Throughout the globe, diverse industrial sectors are harnessing benefits of DHM applications. Some of them include automobile [7][8][9], aviation and aerospace [10][11][12], defense research [13][14][15], healthcare [16][17][18], general industrial applications [19][20][21] , clothing and textile [22][23][24], service and animation [25][26][27], agricultural division [28][29][30], product design [31][32] and so forth. Fig. 2 demonstrates the applications of DHM technology in reference to various industrial sectors [6] and also manufacturing shop-floor [33].

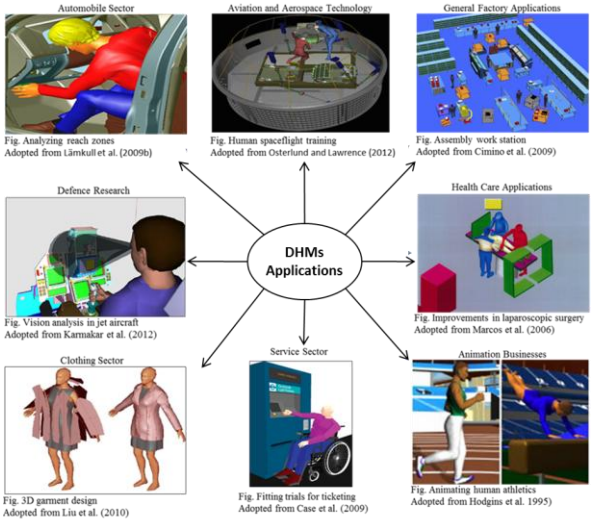


Figure2: Application of DHM in various industries [6]

II. AIM

Present paper is an attempt to highlight state of affairs with regard to application, research and development of Digital Human Modeling and Simulation in India.

III. METHODOLOGY

Systematic literature survey with help of appropriate key words from various sources (scientific databases, internet search engines, general information brochures) has been carried out to get pertinent information. First, articles have been categorized under three themes namely, application oriented, research and development initiatives, and review based. Then, available data have been subsequently arranged in rational sequence for benefit

of readers. Observations from literatures have been elaborated in following paragraphs along with providing the list of academic institutions, research and development organizations, and industries which are presently adopting DHM technology in India.

IV. OBSERVATION FROM LITERATURE REVIEW

Number of manuscripts published under various categories based on work performed in India is shown below in Fig. 3.

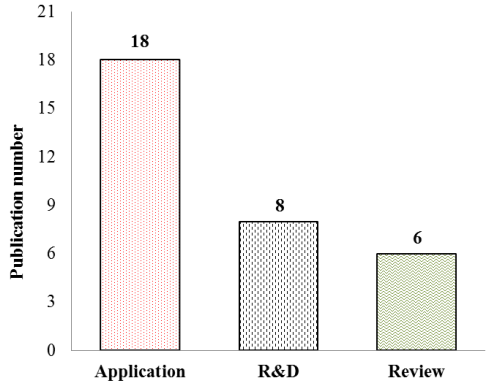
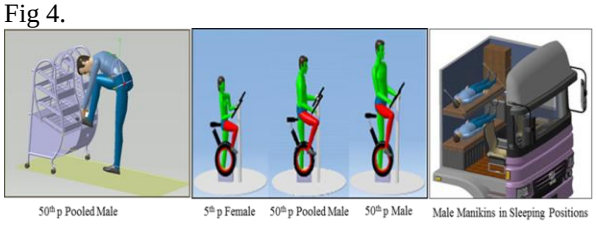


Figure 3. Digital Human Modeling and Simulation endeavors in India

4.1 APPLICATION ORIENTED

Available literatures indicate that DHMS are being used in diverse application fields by Indian engineers, designers and people from other professions. These applications of DHMS deal with human engineering evaluation of workstations in aviation [34], work posture analysis of foundry men through rapid upper limb assessment [35], interior design of long haul truck cabin for improved ergonomics and comforts [36], design and spatial layout of playing equipment's in playground for primary school children [37], ingress-egress of an army vehicle in simulated environment from ergonomics perspective [38], anthropometric size measurement of Indian driving population [39], reconstructing solid model from 2d scanned images of biological organs for finite element simulation [40], modeling for anthropometry [41], case study for vision analysis of pilots in jet aircraft [42], three dimensional whole body scanning [43], working posture examination and improvement in cast house workstation [44], design of playground equipment [45], automotive ergonomics for urban warfare vehicle [46], ergonomics evaluation of shoe rack concept product [47], occupant packaging [48], road accident reconstruction [49], proactive ergonomics for product (ergometer) design innovation [50] and evaluation of manual material handling in bearing manufacturing system and redesign of the workstation [51] situated in eastern part of India. Glimpse of DHM based applications are pictorially represented in Fig 4.

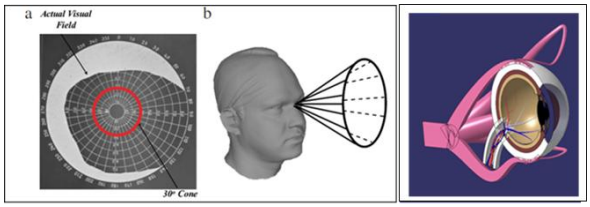


Images adopted from Ref. no. 47, 50 and 36, respectively

Figure 4. DHM used in various applications fields

4.2 RESEARCH - DEVELOPMENT INITIATIVES

Articles categorized under research and development initiatives for DHM are scant. Available papers/ abstracts include research activities related to hand postures inspired from classical 'mudras' [52], task dependent boundary mannequins in statistical DHM [53], comparative study of human model constructions in different 3D digital human modeling software [54], 3D reconstruction of biological organs from 2D image sequences [55], 3D physiological CAD model in pedagogy of physiology and medical sciences [56], vision modeling framework [57], relation based posture modeling [58], measurement and representation of range of motion of body joints on unit cube using electromagnetic trackers [59] etc. Example of DHM centered research and development activities in India are illustrated in Fig. 5.



Images adopted from Ref. no. 56 and 55.

Figure 5. DHM in research and development activities

4.3 REVIEW BASED

Few review articles related to application aspects and overview of the technology, have also been published by Indian authors. Review articles addressed topics concerning industry specific applications of DHM [6], DHMS in secondary manufacturing [60], virtual ergonomics in manufacturing shop floor aided by DHM with reference to industrially developing countries [33], CAD in DHM for human computer interaction in ergonomics assessment [61], DHM approach in ergonomic evaluations [62], virtual ergonomic evaluation of tractor operator's workplace [63] and applications of DHM in agricultural engineering [64].

4.4 ACADEMIC INSTITUTIONS, RESEARCH ORGANIZATIONS AND INDUSTRIES ADOPTING DHM IN INDIA

4.4.1 Academic/Research Institutions

- Center for Product Design and Management, Indian Institute of Science, Bangalore
- Dept. of Design, Indian Institute of Technology Guwahati
- Dept. of Human Engineering & Human Factors, Indian Air Force, Bangalore
- M.S. Ramaiah School of Advanced Studies, Bangalore
- Dept. of Industrial Engineering and Management, Indian Institute of Technology, Kharagpur
- National Institute of Technology, Silchar
- National Institute of Technology, Rourkela
- VIT University, Vellore
- National Institute of Technology and Industrial Engineering, Mumbai
- PSG College of Technology, Coimbatore
- National Institute of Technology, Jalandhar
- PEC University of Technology, Chandigarh

4.4.2 Research and Development Organizations

- Defence Institute of Physiology and Allied Sciences, Delhi
- Automotive Research Association of India, Pune
- Hindustan Aeronautics Limited, Bangalore
- Aeronautical Development Agency, Bangalore

4.4.3 Industries

- JSW ISPAT Steel Ltd., Maharashtra
- EDS Technologies Pvt. Ltd., Bangalore
- Automobile Industries (TATA, Maruti, GM etc.)
- Product Manufacture (LG, Whirlpool etc.)
- L&T Engineering Services, Bangalore
- L&T IES, Bangalore

Authors of the present paper believe that there may be few more Indian academic institutes, research organizations and industries which are associated with DHMS research and applications but presently there is no published article/paper from their end.

V. DISCUSSION

Developed countries are widely using DHMS technology for manifold applications and have realized immense benefits. Use of this technology is still in nascent stages among many developing countries [33]. DHMS related accomplishments are still at its early stages of development in Indian scenario involving very few individuals, institutions and organizations. Tremendous scope exists for application of this technology in various sectors. Contributions to this technology in terms of research and development initiatives are rarely visible in India. Very limited efforts have been taken to highlight scope of application, research and development in various sectors through suitable reviews. Less or very low adoption DHMS in a country like India are due to lack of awareness about benefits offered by virtual ergonomics evaluation techniques, lack of expertise and contextual knowledge of CAD; Computer Aided Engineering (CAE) and Ergonomics among researchers, huge initial investments or expenditure towards infrastructure development and human resource training for these technologies [64]. Some other common problems associated with this technology are difficulty of file transfer from CAD to DHM software or vice versa, unrealistic or robot like appearance of digital manikins, difference in results from software to software, lack of trained human resources for providing training by software sellers/suppliers [6]. Awareness among researchers, scientists, engineers, designers and entrepreneurs could be achieved through organizing seminars, conferences, workshops etc. on this topic. Strategies for wide adoption of DHMS technology in developing countries like India should include integrating features of DHM tools in general CAD software which may result in reduction of cost to some extent and resolve many problems of file transfer from CAD to DHM software or vice versa, research initiatives for development of user friendly DHM software and making manikins more realistic, incorporation of manikins representing Indian anthropometric dimensions, subsidizing software initially to make it more economical and accessible, formation of technical body/society dedicated for advancing and popularizing use of DHM technology.

VI. CONCLUSION

Present review constitutes a concrete knowledge base regarding present status of DHM use for ergonomic evaluation of product and workplaces in India. This may be used as ready reference for further study. Present manuscript is expected to provide policy makers in academia and industry with necessary information in a concise manner for deliberating and implementing strategies for application of this technology besides promoting research and development. Readers would be motivated to carry out further research in their respective disciplines to get numerous benefits of DHM software. More R&D activities are required for making customized human model representing Indian population.

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