Digital Human Modeling Approach in Ergonomic Evaluations

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Abstract: ***Digital human modeling (DHM) reduces the product design and manufacturing task cycle time by eliminating the need to construct physical setup. This paper discusses the current research on digital human modelling, their capabilities and issues generating with the growing demands of technology. With the latest computer technology, human manikin has been modified which can easily simulate and replicate the actual workplace scenario. Anthropometric databases developed which are essential part of any DHMs software are also discussed. Limitations in current DHM model are also discussed.***

Keywords: Digital human modeling; Ergonomics; Anthropometry

1. Introduction

Digital human modeling (DHM) is an ergonomic tool which is used to simulate workplaces in order to solve ergonomic related problems. It is an emerging tool and has been widely accepted by the ergonomists and experts involved in the product design. DHM technology studies different aspects of the human behavior and provides platform for area of new research. It provides 3D visualization of human being involved in activities and gives guidelines that how to do ergonomic analysis and how to design a workstation. It has the capability to solve ergonomic issues and eliminate work related injuries initially in the design phase of the process. Bowman [1] stated that this technology sets a way to initially check the rough designs which further help to eliminate problems related to ergonomics in his research. Human models are invented for the purpose of visualizing the human –workspace interaction in the 3D graphics early in the product design. Digital humans /avatars/ manikin are being incorporated in the software , easily manipulated to see who can reach, fit and so on and also assess for the work related injuries. DHM provides a mean to manipulate or locate manikin / avatar/ operator anywhere in the workspace according to the requirement of the task. Operator must be configured properly to accommodate large anthropometric data and also DHM tools have the capability to simulate different operators with different anthropometric data.

We can evaluate human interaction with the machines in his workspace to analyze reach capabilities, visibility, comfort level. Few models are incorporated with dynamics in order to predict motions, required torques and energy consumption as formulated by Kim JH (Dynamics and motion planning of redundant using optimization with application to human motion).

Badler and Chaffin et al [2] stated that by using DHM technology and considering it initially in the product design to virtually visualizing the human interaction helps in eliminating the need of physical prototypes and further testing .This elimination will give rise to a reduced cost and shorten time.

Hendrick et al [3] and Oxenburgh et al [4] found that activities causing injuries to the workers affect the staff turnover and increase the rate of sick leaves. To compensate this, industries have to rehabilitate and replace the staff which consumes industry resources and cost them a huge amount. This will effect product efficiency and cause disturbances in the industry.

Axelsson et al [5] and Eklund et al [6] examined that product quality has degraded to the extent of 30-50% to the total quality resulted from ergonomic related problems. Therefore these tools have been introduced so early in the design process to facilitate an effective production. Porter et al [7] stated that digital human tools assist ergonomists to visualize human vehicle interaction which was earlier done by using physical mock ups which was time consuming and expensive process are now evaluated by DHM tools. Integration of human factors which was earlier carried out in laboratories is replaced by digital humans interacting with machines in virtual environment. With the growing research in this field or technological improvements, a more effective and efficient model would be generated and applicable to design, human workspace analysis, ergonomic evaluation, visualization and modification.

2. Current Research options available in DHM

DHM is an emerging tool allow assistance in design, manufacturing and ergonomic evaluation. Though different DHM models are developed with different capabilities still there are common analysis that can be done by using DHM technologies. Here are some common listed capabilities and functions:

- The ability to move the manikins in predefined motions
- The ability to create customizable 3D manikins
- Reach analysis
- Posture analysis
- Push/Pull analysis
- Carrying analysis
- RULA based motion (Rapid Upper Limb Analysis)

Modifications are still going on in order to develop more robust and efficient DHM model. Kilpatrick [8] made a first attempt to generate a computer model to predict seated postures during manual tasks. There was a provision to scale

3D avatar by using anthropometric database existing at that time. As the research continues DHM models was reconfigured to analyze posture during stand, stoop and kneel activities. Also stress was given on the appearance of avatar. It version had been improved from fully enfleshed and realistic looking human graphic embedded in 3-D CAD system to a avatar with deformable skin as in SANTOS human given by Abdel- Malek et al [9]. Many efforts have been generated on research area on anthropometric aspects of human modelling. Anthropometry databases were generated to accommodate a variety of human sizes and shapes but somewhat how digital human models are limited in capturing large variations. Anthropometry integration in DHMs is discussed in next paragraph. All DHM models rely on CAD systems for the objects to be used in the analysis. If we want to check the reach of driver inside the vehicle, for that case vehicle geometry is imported from CAD software. The past two decades have seen significant advancements in technology and it is in large part due to computers. Conti & Erlandson et al [10] proposed on the basis of sophistication of the software and analysis requirement fidelity level of the DHM software has been classified as low, medium and high fidelity model.

3. Anthropometry concept in DHM

Anthropometry focuses on the physical measurement of the human body and used to study differences between groups: - Race, Age, Sex and Body type. It accounts for the variability to be considered while designing any product respective to the humans. It necessitates the requirement of space in designing human variability. In DHM anthropometry is one of the most important aspects to be considered for initial phase of the design process to be simulated. Different anthropometric databases were incorporated in DHMs to be easily referenced to determine the shape and size of the avatar in simulation process. For example, simple dropdown menus can be used to create standard 5^{th}, 50^{th}, and 95^{th} percentile male and female manikin. Since anthropometry depends on biological factors, social factors and demographical factors, therefore it is necessary to consider these factors early in the design factors. Pheasant et al [11] developed estimation techniques to predict the lengths of relevant anthropometry using stature. Only knowledge of single input is necessary to obtain the estimates. Proportionality constants are being used in this respect for calculating the mean or 50^{th} percentile ratio of the length of each measure in interest to stature. It provides a useful and well-illustrated collection of anthropometric data and a method of estimating unknown anthropometric dimensions from data on stature. It is not time consuming as survey methods which is also expensive. Drillis and Contini [12] published the first mathematical relationships on body segment parameters in relation to stature. They provided a mean to estimate the lengths of body segments while knowing only stature. As an example every year a survey on stature data has been conducted by National Health and Nutrition Examination Survey (NHANES).

Anthropometry gets maximum attention in DHMs as it accommodates a variety of populations. Population variability is the major concerns but factors on which it depends are also important. From the previous review it has been given that Sex differences are well known and do not require any study or elaboration. Synder et al [13] and Miall et al [14] discussed the anthropometric changes between coherts and changes in stature with growing age between adult samples within the population. Scaling of an avatar to represent designated population from an existing anthropometric database available is not an easy process. Because complications begin whenever we select a given posture then each time it effects how the size of multiple segments combines with each other to provide that posture. Another problem arises that correlation of one body segment's attribute with another is not consistent between people.

With the advancement of computer technology and growing need to make avatar look like a realistic human, a stress has been given on anthropometry to consider large population in order to simulate large operators. Seidl et al [15] proposed an approach used in this context which is provided with ANTHROPROS project to visually locate avatar of varied demographic groups with deformable skin to simulate different sizes and shapes which can be configured to approximate a set of anthropometric dimensions. As the number of survey done by Society of Automotive Engineers (SAE) in 1995 it has been illustrated that there is deficient data on 3D anthropometry and also need is there to include clothing, gloves and helmets. From the past two decade, with newer 3-D scanning methods combined with new geometric statistical methods, this aspect will continue to improve in the near future.

4. Limitations in the current DHM

Though a vast research has been done on digital human modeling for evaluating design and human space interaction, it has some limitations which give new challenges in the area of research. Current digital human models appear to be limited by our understanding of human behavior rather than computer technology. How human behaves exactly during the execution of tasks is not known till date. Also the basic principles behind human posture and motion are also limited in knowledge. Deficiency in 3D anthropometry database and strength determination model accuracy is also limited. As an example Lindbeck & Kjellberg [16] stated that people with back and other musculoskeletal impairments or people working close to their physical capacities are not predicted well. Several biomechanics models were developed which predicts strength and estimates the stresses on the tissues but in spite of these estimation, one problem occurs in the muscle model is "tissue redundancy". This concept was given in a review by Erdemir, McLean, Herzog, and van den Bogert [17] in which individual muscle activation patterns vary greatly among individuals while performing simple movements.

With the growing demand and usability of digital human modeling, focus has been given on cognitive issues also. Earlier it was related to anthropometry but now day's cognitive demands have become more important. Cognitive models study the human behavior and finds how the operator would react in complex situations. This will help designers to understand human behaviors in more detail as how an avatar/manikin reacts when driver takes a sharp turn to merge into traffic without collision. Liu et al [18] developed a queuing network–model human processor (QN-MHP) cognitive model with Tsimhoni and Reed to predict time required in making these complex decisions. Thus, the main research challenge currently lies in the development of a combination of cognitive and anthropometric models.

5. Conclusion and Recommendations

- Digital human models are very effective in doing ergonomics evaluation and will become more popular in the future.
- These models are helpful in evaluating human workspace scenario and assist designers to analyze reach, visual limitations, clearances and other task related analysis.
- There are some limitations in the anthropometry databases and biomechanical models in predicting strength, yet research has to be done to improve biomechanical models those related to dynamic task simulations.
- Integration of anthropometry should be improved while considering 3D anthropometry and effect of clothing on performance are still being study.
- Cognitive integration in DHMs has become more demanding, will inspire more research and the potential benefits from such work are countless.

It has been concluded that groups studying DHMs are fully involved in providing and developing a robust digital human models that are capable of simulate a large variety of tasks with different operators. This paper will help in knowing the potential benefits and upcoming challenges in developing and using this technology.

References

[1] Bowman, D., 2001. Using digital human modelling in a virtual heavy vehicle development environment. In: Chaffin, D. (Ed.), Digital Human Modelling for Vehicle and Workplace Design. Society of Automotive Engineers, Inc., Warrendale, USA.

[2] Badler, N.I., Phillips, C.B., and Webber, B.L., 1993. Simulating Humans: Computer Graphics, Animation, and Control, Oxford University Press, Oxford. Chaffin, D.B., 2001. Digital Human Modeling for Vehicle and Workplace Design, SAE, Warrendale, PA.

[3] Hendrick, H.W., 1996. The Ergonomics of Economics is the Economics of Ergonomics. Human Factors and Ergonomics Society, Annual Meeting. University of Southern California, USA.

[4] Oxenburgh, M., Marlow, P., Oxenburgh, A., 2004. Increasing Productivity through Health and Safety: The Financial Returns from a Safe Working Environment. Taylor& Francis, ISBN 0-415-24331-9.

[5] Axelsson, J., 1995. The use of some ergonomic methods as tools in quality improvement. In: Proceedings of the 13th International conference on Production Research. Freund Publishing House, Tel Aviv, Israel, pp. 721–723.

[6] Eklund, J., 1995. Relationships between ergonomics and quality in assembly work. Applied Ergonomics 26, 15–20.

[7] Porter, J.M., Case, K., Freer, M.T., Bonney, M.C., 1993. Computer aided ergonomics design of automobiles. In: Peacock, B., Karwowski, W. (Eds.), Automotive Ergonomics. Taylor & Francis, London, UK.

[8] Kilpatrick, K. E. (1970). Computer aided workplace design. *Journal of Methods–Time Measurement*, *14*(4), 24–33.

[9] Abdel-Malek, K., Yang, J., Marler, T., Beck, S., Mathai, A., Zhou, X., et al. (2006). towards a new generation of virtual humans. International Journal of Human Factors Modelling and Simulation, 1(1), 1–39.

[10] Conti, G., & Erlandson, R. (2009). M.R.S. A.R.R.A. and virtual Ergonomic Assessments.

[11] S. T. PHEASANT (1982): A technique for estimating anthropometric data from the parameters of the distribution of stature, Ergonomics, 25:11, 981-992

[12] Drillis, R., and Contini, R., 1966. Body Segment Parameters. Office of Vocational Rehabilitation Engineering & Science, New York, cited in [4].

[13] SYNDER, R.G., SCHNEIDER, L.W., OWINGS, C.L., REYNOLDS, H.M., GOLOMB, D.H., AND SCHORK, M.A., 1977, Anthropometry of infants, children and youths to age 18, for product safety design. Report Number DB-270277. Consumer product Safety Committee, U.S. Department of commerce, Bethesda, D.

[14] MIALL, W.F., ASHCROFT, M.T., LOVELL, H.G., and MOORE, F., 1967, A Longitudinal study of the decline of adult height with age in two Welsh communities. *HumanBilogy*, *39*. 445-454.

[15] Seidl, A. (2004). The RAMSIS and ANTHROPOS human simulation tools. In N. Delleman, C. Haslegrave, & D. Chaffin (Eds.), *Working postures and movements: Tools for evaluation and engineering* (pp. 445–454). Boca Raton, FL: CRC Press.

[16] Lindbeck, L., & Kjellberg, K. (2001). Gender differences in lifting technique. Ergonomics, 44, 202–214.

[17] Erdemir, A., McLean, S., Herzog,W., & van den Bogert, A. (2007). Model-based estimation of muscle forces exerted during movements. Clinical Biomechanics, 22, 131–154.

[18] Liu, Y., Feyen, R., & Tsimhoni, O. (2006). Queuing network-model human processor (QN-MHP): A computational architecture for multitask performance in human-machine systems. *ACM Transactions on Computer-Human Interaction*, *13*, 37–70.

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