TIME DEMANDS OF VIRTUAL ERGONOMIC MODELLING – EXPERIMENTAL STUDY

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Abstract

The paper presents results of experimental study of time demand when using digital human models for workplace optimization. Virtual ergonomics or performing ergonomic analyses with computer modelling help is quite common in these days. However the difference between classic pen and paper evaluation against computerized evaluation from the time demand point of view is still in discussion. This paper presents results of six workplaces evaluation with the help of digital human models. Selected workplaces were quite similar, but not identical. A universal methodology approach has been proposed. With the help of this methodology six workplaces have been analyzed together with time observation for individual phases. Each workplace has been analyzed by different engineer but those engineers were at the same level with skills and knowledge. The difficulties during workplace evaluation and time demand are presented in the paper.

Keyword: time demand; digital human models; virtual ergonomics; 3D models; ergonomic analyses

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1. Introduction

Many areas of man's performance in these days are supported by information and communication technologies and computers including the ergonomics. In the ergonomics area one of the most common computer applications are digital human models (DHM). Digital human representations in various forms are increasingly being incorporated in the computer-aided design of human-machine systems, such as a driver-vehicle system or a manufacturing workstation. With the computing power and computational methods available today, we are able to render digital human models that are more sophisticated and realistic than the ones produced a decade ago [1]. The implementation of digital human modeling technology allows easier and earlier identification of ergonomics problems, and lessens or sometimes even eliminates the need for physical mock-ups and real human subject testing [2].

DHM-tools have been introduced in industry to facilitate a faster and more cost efficient design process. Virtual technology allows ergonomists and engineers to perform virtual builds, and the rapid adoption of virtual tools pose an opportunity to integrate considerations of ergonomics into early design stages [3]. The ability to verify the suitability of the workplaces or the products during theirs development is probably the most significant benefit of digital ergonomic modelling. The fact that majority of all errors can be debugged before the actual physical model is constructed reflects dramatically in financial savings. This so-called proactive approach [4], when we try to precede possible problems, is currently the trend [5] and regarding to energy, material and other resources savings in the context of sustainable development becomes the only right way. It is easier to prevent problems in the early stages when theirs removal is very simple and inexpensive than later in production phases when production slowing or damage of workers health threatens. The opposite of proactive approach is so called reactive approach [4] which distinguishing feature is that the solution to problems is searched after they occur, but this may be in many cases too late.

The DHM-tools are applied in the design, modification, visualization and analysis of human workplace layouts and/or product interactions. Focus of research within ergonomics simulation has primarily been related to improve the simulation tools with more enhanced functionalities resulting in better and more accurate posture and motion algorithms and biomechanical models [6][7][8]. Several studies such as [1][9] have been carried out to compare the functionalities of different DHM tools. All these studies show that the outcomes of the different tools are fairly accurate. However nearly none of the contemporary researches investigate the time demands of ergonomic analyses with DHM. This was the goal of our research.

Time demand of ergonomics analyses was studied for two currently most famous and widely used [10] software applications which contain DHM and are suitable for manufacturing planning and optimization. The software are Delmia V5 (developer Dassault Systèmes) and its ergonomics module V5 Human and Tecnomatix (developer Siemens) with ergonomics module Jack. Each software has its strengths and weaknesses however the main functionalities are almost the same. Both contain very detailed DHM which is composed by around seventy segments connected by joints to ensure positioning of the model in all possible degrees of freedom. This is necessary for ensuring the most authentic interpretation of the actual situation. It is possible to scale both models to individual heights and weight or by population percentiles. Basic anthropometric characteristics are determined by population selection. What differs by the mentioned software is certain computational capacity represented by ergonomic analyses that can be performed. From this point of view is Jack better as it has bigger amount of possible analyses. Beside simple analysis of the visual field and reach distances, which are presented in both software, we have a choice of more sophisticated analyses focused on the working posture evaluation, material handling, used forces, energy expenditure, time consumption and more. These analyses, however, are not entirely new, indeed, they have been known for several years, perhaps even decades. Each analysis is backed by many years of research. The analyses can be used by so called pen and paper style, however it is believed that computer technology dramatically reduces the time required to perform these analyses.

2. Methodology

To examine the time demand for performing ergonomic analysis with previously mentioned software tools we have designed a universal methodology according to basics presented by [11][12]. We have divided the analysis process into four phases.

- The first step is always to collect all necessary workplace information (like workplace dimensions or worker data) in order to create the most accurate model possible of the real workplace, on which analyses and experiments will be performed. It is necessary to establish a complete work environment, including the facilities, machines, equipment, and tools in the digital environment. Hence, we have to take the objects' dimension data from the engineering department, if available, or measure directly at the workstation.
- Next step involves construction of digital workplace or the environment that is being evaluated and setting the DHM with its properties. Again we have to communicate with engineering department because some model (usually machines, fixtures or tools) may be already available in 3D. If missing they need to be modelled. Those model are subsequently put together to create whole model. Finally the DHM is inserted and its properties like population group, sex, height and weight are set to ensure that the analyses will be performed for concrete workers.

- Third step involves task simulation and evaluation of these tasks with ergonomic analyses and interpretation of the results. This part is always individual. It depends on the issues we need to solve. In our research the engineers were assigned with the task to perform 3 ergonomic analyses suitable for identified problems.
- The final step involves suggestions for improvement and theirs re-evaluation. Re-evaluation is very important to be sure if the proposed changes will have its effects. As this research is only experimentally base, in this phase we created approximately 10 page length report of the whole ergonomic evaluation with suggested proposals for improvement.

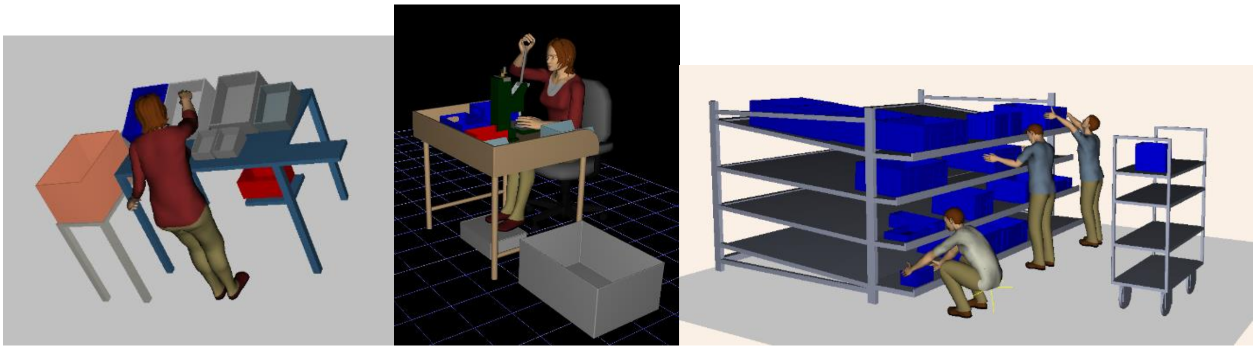
The experiment (ergonomic analysis) was performed on six industrial workplaces. For each workplace one engineer who will perform the analysis was selected. The selection of DHM-tool in which he/she will perform the analysis was up to his/her decision. DHM-tools are complex and using them requires good expertise in different fields. It is necessary to know ergonomics but also to have CAD skills and to have a detailed knowledge of the various features of the workplace being designed/evaluated [3]. Each engineer had average skill with 3D modeling software and DHM software. During the ergonomics analysis engineers were assigned to fill the timesheet of their progress and to divide it into previously mentioned four phases. Three performed ergonomic analyses have been selected according to workplace individual needs from the set of these:

- Fatigue and Recovery [13][14]
- Force Solver [15]
- Lower Back Analysis [16]
- Manual Handling Limits - lifting and lowering, carrying, pushing or pulling [17]
- Metabolic Energy Expenditure [18]
- Biomechanical Analysis [19]
- NIOSH [20]
- Ovako Working Posture Analysis (OWAS) [21]
- Predetermined Time Standards [22]
- Rapid Upper Limb Assessment (RULA) [23]
- Static Strength Prediction [24]

3. Results

Six industrial workplaces were subjected to ergonomic analysis. Three workplaces were labeled as assembly, one workplace was the storage and two workplaces were with machine interaction. From the total number three workplaces were analyzed with Tecnomatix Jack and other three workplaces with Delmia V5 Human software. Individual workplaces were quite similar regarding workplace complexity. They composed from five to eight components like working tables, racks, packaging (boxes) and machines. Each workplace was optimized with one DHM. The workplaces preview can be seen on Figure 1. Detailed description is in Table 1. The table contains software, in which the study was conducted, the type of study or workplace, where the study was performed, the number of objects in the workplace, from which it is possible to read the complexity of the workplace and the number of pages of the final report. On each workplace only one worker was analyzed thus only one DHM model was used.

The numbers of hours that engineers spent on each workplace analysis phases are noted also in the Table 1. The duration was marked in precision on 0.5 hour. We can say in general that complex analysis of one workplace ranged from 14 to 24.5 hours depending on the complexity of the workplace. Obtained mean value was 19.5 hour.



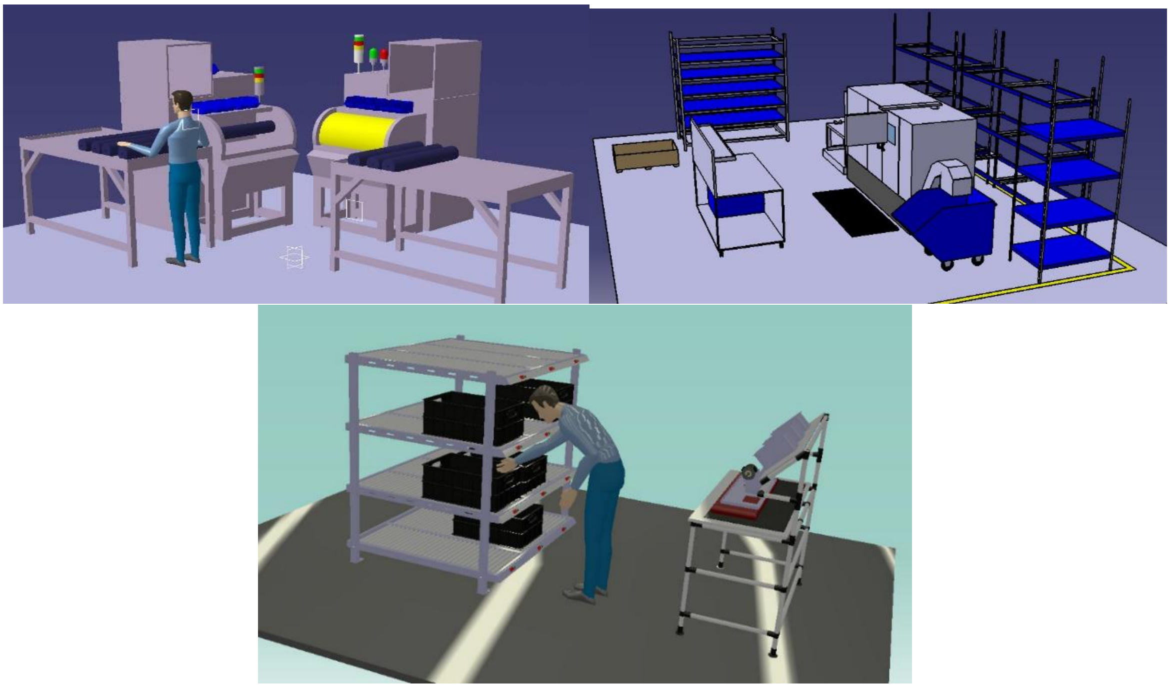


Fig. 1. Visualization of 3D models of analyzed workplaces - first row TX Jack, second and third row Delmia V5 Human

From the hourly demand it is obvious that most time demanding is the objects creation phase and their composition into the overall concept of the workplace. This phase ranged from 6.5 hours to 12 hours. Workplaces created in Delmia V5 Human needed more time for creation than those in TX Jack. The reason is that those workplaces were little bit bigger than the others and also the components were done in more detailed way. Performing the ergonomic analysis and obtaining results (mean value 4.1 hours) were just a little bit longer as the initial data collection (mean value 3.3 hours for measurement of the workplace, photos and working instruction acquisition). Summaries of the results for further decisions were the quickest phase with mean value of 3.2 hours. It must be said that engineers performing this study might have slightly different experiences with used software and also theirs work might be influenced by other factors. However this simple comparison shows that there are no big time differences when utilizing Tecnomatix Jack 8.0 and Delmia V5 Human. Highly experienced ergonomists might complete the whole examined process in short time span. Also a comparison of time demand for evaluation of the same workplace in both systems would be great but it wasn't done in this case.

Used software	Jack 8.0	Jack 8.0	Jack 8.0	Delmia V5	Delmia V5	Delmia V5	
Type of study	assembly	assembly	storage	machine interaction	machine interaction	assembly	
Number of objects in the model	2x table 6x box	1x table 1x manual press 6x box	1x rack 1x trolley 6x KLT	2x calibrating machine 2x conveyor 1x product	1x machine 2x rack 1x table 1x box for waste	1x assembly table 1x rack 5x KLT 1x product	
Number of report pages	9	11	10	14	11	10	**Average**
1. data collection [h]	4	2	2	3	4	4.5	**3.3**
2. creation of objects and workplace model [h]	8	8.5	6.5	11	8	12	**9.0**
3. ergonomic analyses [h]	4	3.5	2.5	5	4.5	5	**4.1**
4. report [h]	4	3	3	3	3	3	**3.2**
Σ	**20**	**17**	**14**	**22**	**19.5**	**24.5**	**19.5**

Table 1. Time demand and complexity of ergonomic studies

4. Conclusion

Virtual ergonomics and digital human models are in these days becoming quite common in product or process development in big industrial companies. Especially automotive or aerospace industries are the leaders and determine trends in this area. The most common applications of DHM are driver-vehicle system design and a manufacturing workstation optimization. In our research we have focused on the second part the workplace analysis. We have performed analyses of six different industrial workplaces with assembly, machine and storage characteristics. Three workplaces were analyzed in Tecnomatix Jack 8.0 the other three in Delmia V5 Human. The analyses were divided into four parts. The data collection, virtual workplace creation, ergonomic analyses performance and documentation phase. For each of this phases the time duration was captured. The whole process last from 14 hours minimally to 24.5 hours maximally. The mean value was 19.5 hour. As various engineers with slightly different software skills have performed the analyses the time span for individual phases was very similar. The most time demanding phase was the object creation. Currently we have new technologies at our disposal that can also reduce time for this phase. The technologies like 3D scanning of the objects or even motion capture for human motion tracking will lead virtual ergonomics to further development. The next research in this area can be focused directly on the time demand of these technologies usage.

The near future will likely lead to better visualization of the DHM, to simplification of theirs usage and user friendliness. Also an expansion of ergonomic analysis by new knowledge is quite a certain thing. Already within the Tecnomatix new implementation of EAWS method (European Assembly Worksheet) appears. In conclusion we can say that with further development of information and communication technologies ergonomics and especially virtual ergonomics won’t definitely step aside.

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6. References

[1] B. Das, A.K. Sengupta, Computer-aided human modelling programs for workstation design, Ergonomics 38 (1995) 1958-1972.
[2] X. Zhang, D.B. Chaffin, A three-dimensional dynamic posture prediction model for simulating in-vehicle seated reaching movements: development and validation, Ergonomics 43 (2000) 1314-1330.
[3] D. Lämkull, L. Hanson, R. Örtengren, A comparative study of digital human modelling simulation results and their outcomes in reality: A case study within manual assembly of automobiles, International Journal of Industrial Ergonomics 39 (2009) 428-441.
[4] R. Feyen, Y. Liu, D.B. Chaffin, G. Jimmerson, B. Joseph, Computer-aided ergonomics: A case study of incorporating ergonomics analyses into workplace design, Applied Ergonomics 31 (2000) 291-300.
[5] M. Hovanec, H. Pačaiová, F. Hrozek, M. Varga, Proactive ergonomics based on digitalization using 3D scanning and workplace modeling in Texnomatix Jack with Augmented Reality, Nase More 61 (2014) 22-26.
[6] D.B. Chaffin, Improving digital human modelling for proactive ergonomics in design, Ergonomics 48 (2005) 478 – 491.
[7] A. Seidl, RAMSIS: a new CAD-tool for ergonomics analysis of vehicles developed for the german automotive industry, Automotive Concurrent/Simultaneous Engineering, SAE, Special Publications 1233 (1997) 51–57.
[8] N. Badler, Virtual humans for animation, ergonomics, and simulation, Proceedings of the IEEE Nonrigid and Articulated Motion Workshop, 1997, pp. 28-36.
[9] P. Polasek, M. Bures, M. Simon, Comparison of digital tools for ergonomics in practice, Procedia Engineering 100 (2015) 1277 – 1285.
[10] J. Watch, S. Przybylinski, CAM software market leaders named by cimdata (2011), [online][18. 3. 2015], available from http://www10.mcadcafe.com/nbc/articles/1/988502/CAM-Software-Market-Leaders-Named-by-CIMdata
[11] S.W. Chang, M.J.J. Wang, Digital human modelling and workplace evaluation: Using an automobile assembly task as an example, Human Factors and Ergonomics in Manufacturing 17 (2007) 445-455.
[12] M. Bures, New approach to ergonomic design of an industrial workplaces, Proceedings of International Conference on Industrial Engineering and Engineering Management IEEM, Hong Kong, China, 2009, pp. 881-884.
[13] W. Rohmert, Problems in determining rest allowances. Part 1: Use of modern methods to evaluate stress and strain in static muscular work, Applied Ergonomics 4 (1973) 91-95.
[14] W. Rohmert, Problems in determining rest allowances. Part 2: Determining rest allowance in different human tasks, Applied Ergonomics 4 (1973) 158-162.

[15] J. Chiang, A. Stephens, J. Potvin, Automotive manufacturing task analysis: An integrated approach, SAE Technical Papers, Digital Human Modeling for Design and Engineering Conference and Exhibition, Pittsburgh, 2008.
[16] U. Raschke, B.J. Martin, D.B. Chaffin, Distributed Moment Histogram: A neurophysiology based method of agonist and antagonist trunk muscle activity prediction, Journal of Biomechanics 29 (1996) 1587-1596.
[17] V.M. Ciriello, S.H. Snook, The design of manual handling tasks: revised tables of maximum acceptable weights and forces, Ergonomics 34 (1991) 1197-1213.
[18] A. Garg, D.B. Chaffin, G.D. Herrin, Prediction of metabolic rates for manual materials handling jobs, American Industrial Hygiene Association Journal 39 (1978) 661-674.
[19] A.B. Schultz, G.B.J. Andersson, Analysis of loads on the lumbar spine, Spine 6 (1981) 76–82.
[20] T.R. Waters, V. Putz-Anderson, A. Garg, L.J. Fine, Revised NIOSH equation for the design and evaluation of manual lifting tasks, Ergonomics 36 (1993) 749-776.
[21] M. Mattila, W. Karwowski, M. Vilkki, Analysis of working postures in hammering tasks on building construction sites using the computerized OWAS method, Applied Ergonomics 24 (1993) 405– 412.
[22] H. B. Maynard, G. J. Stegemerten, J. L. Schwab, Methods Time Measurement, McGraw-Hill Book Company Inc., New York, 2012.
[23] L. McAtamney, E.N. Corlett, RULA: A survey method for the investigation of work related upper limb disorders, Applied Ergonomics 24 (1993) 91–99.
[24] D.B. Chaffin, G.B.J. Andersson, B.J. Martin, Occupational Biomechanics, Wiley, 2006.