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IEA 97

PROCEEDINGS

of the 13th Triennial Congress
of the International
Ergonomics Association
Tampere, Finland 1997

6.1.89

Work and Work Place Design Using Empirical Shop Floor Information and Virtual Reality Techniques

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1. Introduction

Work place design based on traditional ergonomic science has, to a large extent, been delimited by information collected from studies of individual human beings. This research approach has not been proven to influence industry shop floor work to an extent corresponding to what could be expected from research efforts (Winkel and Westgaard, 1995). Thus the practitioners are left to decide about the detailed work place design, neglecting scientific knowledge.

The accelerating development within technical as well as social sciences, combined with the industrial development of production systems has, in fact, blurred the vision and method arsenal available for those interested in fitting the production system to the man. However, new prospects have, at the same time, been made available through expanding personal computer and Virtual Reality (VR) techniques implying untraditional analysis procedures for work and work place design as will be illustrated in this paper.

The aim of this paper is to illuminate the feasibility of such a prospect, using personal computer-, video- and VR-techniques to amalgamate empirical shop floor information especially collected for design purposes with computer models of work. Two case studies, denoted case I and case II, will be shortly described from which an integration will be discussed.

2. Case I: Assembly of automobiles analysed by combining personal computer and video techniques

Within the context of our research and development work in co-operation with Volvo Car Corporation, we were able to video-record full-pace assembly work in the Volvo Uddevalla plant during the closing down period in 1992 – 93, using one camcorder for each operator. In order to analyse this and similar material, we have developed specialised equipment consisting of a computer-synchronised video recorder enabling appropriate activities to be defined and registered as a file with unambiguous and precise connection to the video tape through time coding (Engström and Medbo, 1996).

This equipment makes it possible to: (1) Allow the recorded operators themselves to perform analysis; (2) Perform analysis quickly – it has proved possible to perform an analysis of 20 different types of activities in "real time", i.e. the analysis requires as much time as the video recording; (3) Repeat the analysis at the same or more detailed level, as well as add other types of information to the data file and (4) Perform parallel analyses, e.g. time-and-motion analyses, loss analyses (Wild, 1975) and ergonomic analyses. Hence the analysis and assessment of e. g. assembly work is facilitated by the "true" shop floor data.

The work in this case study was recorded using the equipment mentioned above. The work on the automobile was facilitated by a tilting device allowing adjustment in height, as well as rotation of the automobile body up to 180° around its mid axis. The work of two assembly operators was studied by an ergonomically trained researcher from Lindholmen Development in Gothenburg doing the characterisation of the body postures and estimating forces (Sperling et al, 1993) as well as counting the arm and shoulder movements as reported in Engström Jonsson and Medbo (1996).

Another study (Engström, Johansson and Kadefors, 1996) based on a questionnaire was used to collect information on the physical work load, psychosocial factors and work related musculoskeletal symptoms during a one year period. Physical work load factors showed only a few significant associations with musculoskeletal symptoms. This may in part be explained by the generally rather good ergonomic conditions with relatively short durations of combined extreme work postures and by the tilting devices facilitating the work or by the fact that the questionnaire did not illuminate combined extreme work postures.

3. Case II: Loading of refrigerators analysed by personal computer based VR-technique

This case, concerning manual loading of refrigerators, was originally documented and analysed by the personal computer and video techniques mentioned above in order to grasp some fundamental characteristics of the work as well as to understand the case itself (Johansson et al, 1995). Thereafter a personal computer based VR-technique was used to elaborate on the potential of VR in job planning.

Another interest was the possibility of gaining time at unloading by having the refrigerators positioned in an optimal unloading sequence on the delivery truck to speed up the unloading and to increase the compacting on the truck for economic and environmental reasons.

Thus a remedial suggestion by the company was to plan the load in advance using VR-technique. Therefore an attempt with a realistic 3D visualisation of the loading and unloading procedure was made to allow the loaders to fill a virtual truck. Using a VR programming environment (Superscape), a prototype was built and demonstrated to interested parties. At this initial stage, very little computer intelligence was incorporated. The prototype was well received, but initiated a discussion concerning other angles of approach including a rephrasing of the original question of issue.

4. Results and discussion

Case study 1 deals with an analysis of complex work with human, product and process characteristics. For a number of reasons such as combined extreme work positions, collective working, spread out work in a complex environment, this work is extremely difficult to model by available computer techniques. Aggregated data collected by the techniques used in this case study give however a good base for work and work place design.

The work in case study II is less complicated to model since it was a question of one operator piling rectangular objects on or besides each other. However this case study revealed the vagueness in the original question of issue. Was it primarily a question of method to visualise optimal loading for the operator, to support the operator for optimal loading, or to crystallise the practice for managers involved in different other development projects? In this case a scaled-down puzzle representing trucks and refrigerators proved to be more feasible to collectively achieve an agreement on future development work. Although this insight might not have appeared if the VR-technique prototype had been omitted.

For different reasons both cases did prove to be unsuitable for a prompt transmission into 3D models using e. g. VR-techniques. This fact underlines the importance of carefulness in selecting initial angles of support and the danger of having "an answer" looking for a problem instead of vice versa.

The sample of techniques applied in case I and II constitutes an embryo of a "tool box" for work and work place design. It might help the users to obtain a good basic understanding of the prerequisites implied by specific products and processes.

Knowledge and experience from different experts and also users ought to be included in the analysis procedure in order to support the implementation phase and in order to create a basis for continuous improvements. Dynamic 3D computer models, as can be realised as virtual environments (Wilson et al, 1996), may be a powerful support for co-operative planning (Akselsson et al, 1990; Bengtsson et al, 1996). However, case study II pointed at the fact that, for specific cases, there may be other methods supporting collective analysis procedures, which give faster results, are less expensive, require less pre-understanding and have a higher degree of user-friendliness.

In case II the goal or the prerequisites were not clear at the start. Probably the case had got another end if the puzzle had to be completed many times with slight changes in the interior of the pile of products. Then all the pile had to be rebuilt each time, which is boring and time-consuming. A virtual pile may be rebuilt very quickly. A similar scenario is obtained if we assume so many parameters in the optimisation process, so it is difficult for the loader/planner to take them all into account. Then there would be an incitement to build intelligence into the VR-model, which would be helpful in suggesting and evaluating different loading patterns.

An example of intelligence, which could be built into a VR-application, is explored in the EU-project "Applications of Neural Networks to Integrated Ergonomics" (ANNIE) – a project in which the authors are engaged. Its main aim is to create a computer based analysis procedure which, from both an ergonomic and a productivity point of view, evaluate the work of a mannequin in a virtual environment.

The results from our case studies, as well as the arguing above, imply that analysis procedures for work and work place design, as e. g. ANNIE, ought to be based on empirical shop floor information especially collected for design purposes by similar equipment as described above. Physical models have also an important role as a complement, a learning media, a substitute to computer based techniques or in order to focus on the modelling. Complexity, need for flexibility, possibilities and need for built in intelligence, user-friendliness, frequency of utilisation, etc. also ought to be important factors when considering the use of VR-techniques in planning of work and workplaces.

Also empirical shop floor data should be supported by product and process information as has been the case in the design of some plants in the Swedish automotive industry (Engström et al, 1995).

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