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A Survey on Visualization in Industrial Ergonomics

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Abstract
The field of ergonomics is widely used in industry and other fields close to human work. This paper presents an overview about the state of the art in virtual ergonomics with regard to visualization issues. We consider some of the most popular ergonomics tools and their analysis functions like visibility and accessibility of objects or the ergonomic stress of specific extremities. Advantages and disadvantages are discussed with respect to aspects of intuitive and reliable information display.

1. Introduction

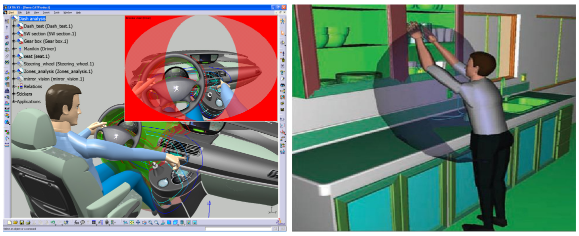
Two of the most important properties of visualization are its direct applicability to different practical fields and its need to rely on producing outputs for the complex human visual system. Rogowitz et al. [RTB96] show that already small changes of color-mappings can lead to a variety of different interpretations. Especially in research and industry (industrial production), experts use visual analytics tools to detect ergonomic problems. Ergonomics is a branch of human engineering, which considers the interaction of humans and their environment with regard to their physical health particularly at their workplace. Therefore it takes care of stress and safety at work. Although many ergonomists still use tables in hard copy for their analysis, a survey recently carried out by Mühlstedt [Müh12] showed the importance of ergonomics software tools in all areas of product planning, manufacture, and evaluation of products and workspaces. Especially the analysis function in the matter of visualization (as picture or video) next to the analysis of accessibility (see Figure 1(b)), visibility (see Figure 1(a)), and posture are relevant to the ergonomists. However, users of current ergonomics tools often have to invest plenty of time and effort to handle the analysis process, due to several shortcomings. The survey yielded that the market of ergonomics tools mainly consists of three digital human models (DHM). Many of them support the analysis of accessibility, visibility, and physical stress. During their work, ergonomists utilize the visualizations to analyze the current work place and work flow and come up with possible improvements. Furthermore, they need to manage different motions and timing restrictions of the relevant processes.

2. Related Work

Ergonomics tools often have multiple windows to steer simulations and to adjust the DHM and its environment. Plumlee et al. [PW06] investigated the effects of multiple windows with respect to the visual working memory. The DHM is one of the most important aspects of ergonomics tools. In order to get better test scores it would be helpful to test whether and how a DHM reacts on changes in its immediate surrounding. Therefore it is beneficial, if there exist mechanisms to steer the simulation. Investigations about these features were made by Waser et al. [WRF*11] with regard to steering a flood simulation. A task of a worker often consists of several parts. Possibilities to handle such event sequences and the time gaps between events are discussed by Wongsuphasawat et al. [WGP*11]. With regard to an interactive time-series visualization, Aigner et al. [ARH12] evaluated a combination of quantitative data and qualitative abstractions. It is similar to ergonomics tools, where every motion of a DHM produces a lot of data which has to be interpreted and evaluated for every time step. Kang Le et al. [LDC12] considered some parts of the field of visualization in ergonomics to reduce the gap between real and simulated time. Such gaps arise when real-world procedures are represented symbolically e.g. knocking in a nail.

3. State of the Art

Considering ergonomic problems during the product design process can avoid costs for subsequent changes. We examined four analysis instruments: visibility, accessibility, posture and load handling. An investigation of the visibility can be achieved through a simple line (beginning at the head of



(a) (b)

Figure 1: Different representations of analysis functions in ergonomics tools. (a) Representation of visibility through simulation of binocular vision (Dassault and Systèmes [DS13]). (b) Representation of accessibility via translucent sphere (Siemens PLM [SP13]).

the DHM) to visualize the view direction. The field of view is typically represented by vision cones which are drawn into the scene semitransparent. Sometimes the planners are also able to consider the person's perspective (see Figure 1(a)). There are three areas on the binocular vision. An outer opaque area, which represents the area outside the view field of the DHM. The second area is drawn semitransparent and illustrates a the maximal visible area. Finally, the central region, visualized transparent, symbolizes the optimal vision area. The planner can exactly reenact the vision of the DHM. Unfortunately, the planner does not see objects in the opaque area. This might be necessary for a change of placement of the objects around the virtual human. Moreover, the vision cone itself can also occlude objects. Another analysis method is the examining of accessibility of machines, tools, etc. from the location of the DHM. Accessibility is typically visualized by a surface up to where the DHM's hands or feet can reach something (see Figure 1(b)). The representation of accessibility is an important step in the product planning and the subsequent construction. For example, the development of a car: First one has to create an automobile such that the driver can control all necessary instruments from the sitting position. On the other hand the worker has to reach all locations at the car which are necessary to assemble it. Both procedures have to be realized as ergonomic as possible. Due to the visualization of accessibility, the planner can realize at a glance whether an item is reachable by the DHM or not. Therefore, a designer can create a better product from the start and reduce costs for some subsequent changes. A third aspect, we have considered, is the analysis of posture and load handling. One popular system is RULA (rapid upper limb assessment) [MN93], which considers the postures of the upper limbs, trunk, and the neck. The results are mapped directly to the corresponding body parts, e.g. forearm, by color-coding. Consequently, a planner can immediately realize whether a posture of the virtual human is ergonomic or not. However, using color maps should always be done with respect to the human visual system. A further disadvantage is a lack of a proper visualization of several influencing factor. These factors, like the frequency of an action or the weight of an object (which the DHM has to carry) should be shown during a workload. An approach to solve this problem could be an intervention in the simulation process [WRF*11] or breakdown in event sequences [WGP*11]. All of these analyses use multiple windows to visualize their results. However, this can distract the user from the actual data because of a limited receptivity [PW06].

3.1. Conclusions

The survey, carried out by Mühlstedt [Müh12], yielded that most of the ergonomists very often use visual analysis functions and, moreover, rate them as fundamental for the ergonomic design process. We have shown some examples of the state of the art of visualization in ergonomics tools. Although the variety of visual metaphors is quite broad, the used approaches seem very simplistic and in many cases not human centered enough to facilitate an optimal process by ergonomists. In an extended version of the paper, we will analyze the visual paradigms of the market leader systems in deep and investigate their shortcomings. Furthermore, we will show how these problems can circumvented and propose new directions for visualization in industrial ergonomics.

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