

Introducing quantitative analysis methods into virtual environments for real-time and continuous ergonomic evaluations

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Abstract

This paper presents our work on methods to link virtual environments (VE) and quantitative ergonomic analysis tools in real time for occupational ergonomic studies. We pursued two distinct approaches: (a) create methods to integrate the VE with commercially available ergonomic analysis tools for a synergistic use of functionalities and capabilities; (b) create a built-in ergonomic analysis module in the VE. The first approach provides the use of established, off-the-shelf tools integrated with the VE to create a hybrid application. This integration is performed through the use of APIs provided by the software vendor and existing Internet and communications technologies. The commercial ergonomics tool and the VE run concurrently and integrate their capabilities. The second approach provides the capability to do ergonomic evaluations in a self-contained VE application. In this method, the required ergonomics calculations are built into the VE. Each approach has its own distinct advantages. The use of a commercially available ergonomics tool integrated with a VE provides significant more capability and should be used where detailed and complex ergonomics evaluations are required. However, the process of integration in this approach is more difficult and time consuming. The self-contained VE application is more suited for simple ergonomic evaluations or in cases where the ergonomics algorithms are readily accessible and easily implemented. The two integration strategies are methodically explained and demonstrated using case studies conducted with industry partners. This integrated capability facilitates integration of ergonomic issues early in the design and planning phases of workplace layouts. It provides functionality beyond the capabilities of current commercial off-the-shelf (COTS) solutions. In addition, it contributes to a new trend in the integration of different technology fields for synergistic use in industry.

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1. Introduction and motivation

In the past, workplace ergonomic considerations have often been reactive, time-consuming, incomplete, sporadic, and difficult. Ergonomic experts who were consulted after problems occurred in the workplace examined data from injuries that had been observed and reported. There are now emerging technologies supporting simulation-based engineering to address this in a proactive manner. These allow the workplaces and the tasks to be simulated even before the facilities are physically in place.

In recent times, virtual reality has emerged as one such technology attaining maturity and gaining acceptance in industry [1]. Application of this technology spans health-care,

national security, design and manufacturing [2], education, and training [3]. One natural application domain of these immersive technologies is in ergonomic studies such as reach, visibility, and visual inspection through the use of CAD models in immersive environments. However, most of the virtual environments used for ergonomic evaluations only allow for subjective and qualitative evaluations based on verbal/written participant and observer feedback of comfort and effectiveness.

At present various commercial systems are available for ergonomic analysis of human posture and workplace design. However, these methods provide primarily static analysis of the task at hand, i.e. one can *create a static “snapshot”* of the posture or situation to be evaluated and then perform an analysis using the tool.

In the work presented in this paper, we synergize the ergonomic modeling and setup capability of a virtual environment with ergonomic analysis tools and methods to

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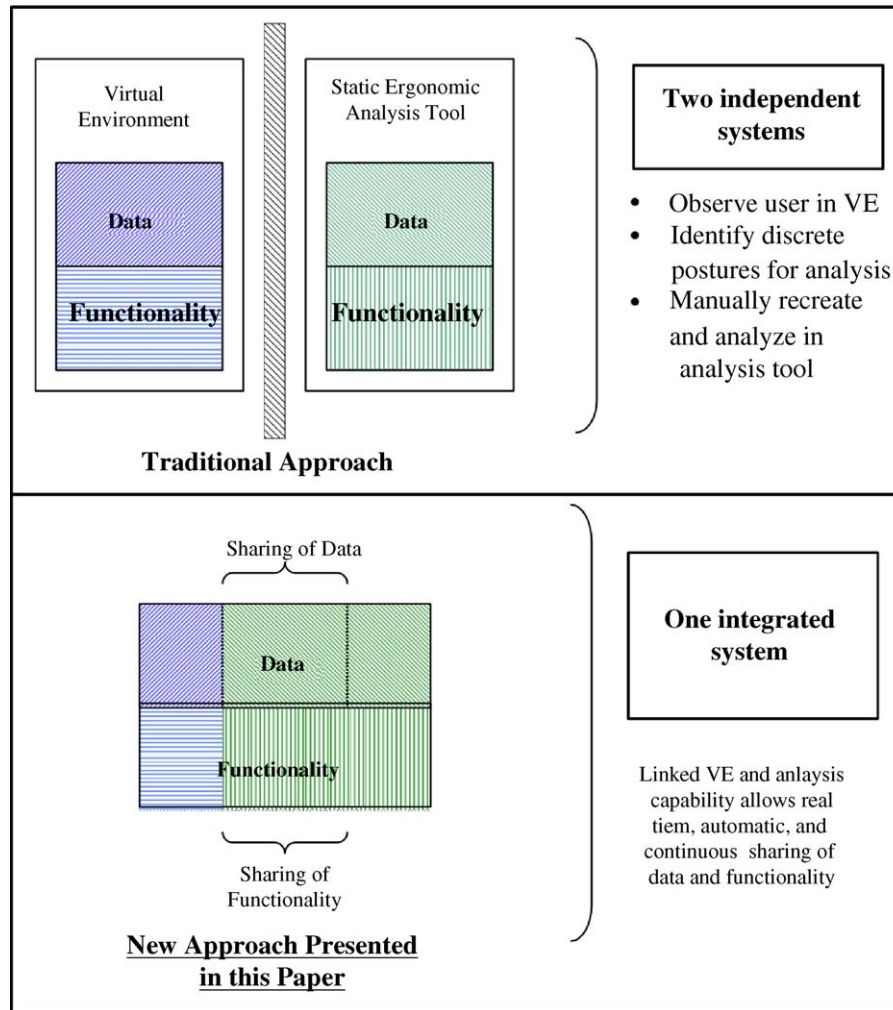


Fig. 1. Comparison of traditional approach to approach presented in this paper.

allow a more rigorous analysis of the underlying ergonomic aspects during the simulation in the immersive environment (Fig. 1). The key contribution of this is that it provides a monitoring system that analyzes the entire process continuously, in real-time, as the participant goes thru the motions required by the task and is able to automatically flag postures that are not ergonomically recommendable. This presents a very effective approach to take the evaluation capabilities of VEs to the next level.

Thus, the key questions to be answered through this research were: can linking an immersive system with quantitative ergonomic analysis functionality create a continuous ergonomics monitoring tool? How can we formulate an integration system to accomplish this by linking the VE (which is dynamic in nature) with a commercial package (that performs static posture analysis); what is the necessary data streaming that is necessary in both directions? What is the methodology required to create a simple ergonomic analysis capability within a VE?

We would like to emphasize that the focus of this study was not to actually perform a detailed ergonomic analysis and provide recommendations but to create the integrated

technology and verify that it had the potential to be useful for industrial ergonomics studies. As always, it can be argued that in some cases an expert ergonomist can make good recommendations with just a paper and pencil, without the need for this kind of relatively expensive environments. But the creation of this synergistic tool is justified since it is one more resource that would be appropriate and useful in more complex situations.

2. Related work

The importance of applying ergonomics to workplace design is illustrated by the Injuries, Illnesses, and Fatalities (IIF) program of the U.S. Department of Labor, Bureau of Labor Statistics [4]. According to the report there were 5.2 million occupational injuries and illnesses among U.S. workers and approximately 5.7 of every 100 workers experienced a job-related injury or illness. Workplace related injuries and illnesses increase workers' compensation and retraining costs, absenteeism, and faulty products. Many research studies have shown the positive effects of applying ergonomics principles in workplace design [5]. Riley et al. [6] describe a study to

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