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Computers in Industry 56 (2005) 479–492
COMPUTERS IN INDUSTRY
www.elsevier.com/locate/compind

An online ergonomic evaluator for 3D product design

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Received 15 May 2004; received in revised form 4 January 2005; accepted 24 February 2005
Available online 21 April 2005

Abstract

This paper presents an online ergonomic evaluation system for 3D product development with car interior design as an example, which consists of a 3D viewer, a digital human model, an ergonomic engine, and the web-based GUI's. The digital human is constructed with a number of templates based on anthropometry database that represent various levels of body size and shape for the end-user. The interactions between the human and a product model are captured by the viewer, and thus, simulate the user operation of the product. According to the Chaffin's biomechanical model, the ergonomic engine then computes the physical loads of body joints with the captured information. The result enables online evaluation of the product design from the ergonomic aspects. It also serves as a base of interactive product customization. This research is the first study that realizes the web-based ergonomic evaluation for 3D car interior design with no needs of high-end CAD systems or complex VR environment. In this manner, the human factor issues can be effectively taken into account at the early design phase and the costs of ergonomic evaluation will be significantly reduced.

Keywords: Product design; Digital human model; 3D viewing; Ergonomics; CAD

1. Introduction

To satisfy the customer's needs is a critical issue for companies worldwide to survive in the global market. Customization (or personalization) is considered an effective means to achieve this imperative and should be conducted throughout a product lifecycle as possible. Hence, human-centered product design [1] has received much attention in both academia and industries. Like design for manufacturing (DFM) or design for assembly (DFA), ergonomic issues must also be taken into account at the early design stage. Important human factors, such as vision, reach of envelope, operation strength, and workloads determine to a large extent the product performance, and thus, need to be timely accessed during the product life cycle.

Recent progresses in information technologies provide many useful tools for accomplishing human-centric design. Among them, computer-aided software systems have assisted to enhance the efficiency of most activities in engineering design

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doi:10.1016/j.compind.2005.02.002

and manufacturing. Integration between heterogeneous software systems has also become feasible in the modern IT environment. On the other hand, since the early 1990s human behavior has been modeled in a digital form that enables full-scale ergonomic evaluation, both physically and psychologically, in a variety of industrial applications [2–4]. To incorporate a digital model that simulates human actions in the product design process has been recognized as highly effective in realizing human-centric product design. For instance, vehicle interior design is an engineering task that must cautiously consider ergonomic interactions between the design and the end-user. Equipments in a car should be properly arranged so that the driver can posture well and feel comfortable in driving. Assessments of car setting are usually very time-consuming and involve multidisciplinary team members such as engineer, designer, ergonomic expert, and test user. Complex facilities such as physical mock-up, virtual reality system, and CAD software are commonly employed in the assessment process. The development costs of these products are consequently increased.

A number of software tools [5–9] have been developed for ergonomic design of consumer products, machines, workplaces, and occupational devices. Most of them utilize full-scale CAD systems and/or high-end virtual reality environment for ergonomic estimation [10,11]. However, CAD or VR tools may not be always available to product designers or small/medium enterprises that cannot afford such costly tools. In addition, any ergonomic evaluation for consumer products should be conducted based on appropriate anthropometry data. It is not very likely that anthropometry databases and design tools are located in one software system within a company, and thus, the integration between them poses a serious problem. Finally, customers' inputs are highly valuable and most of the time necessary for ergonomic design. However, to obtain their opinions within an engineering context during the product design remains a challenging task. Very little research has addressed this issue.

This study develops a web-based light-weighted ergonomic evaluator for vehicle interior design. A digital human model is constructed based on Taiwan local anthropometry data that enables the user to query ergonomic information through a regular browser. The product model is simplified from its original 3D CAD representation, but still retains necessary information for the purpose of ergonomic evaluation. This system allows the 3D human to interact with the product model, thus mimicking the condition in which a person is sitting in the front seat and driving the vehicle. Given a posture, physical loads on the body joints of the digital human can be computed using the Chaffin's biomechanical model. In this manner, the user can interactively adjust the interior setting until a better design is obtained that gives a more comfortable posture explicitly for the user. This work demonstrates the feasibility of web-based ergocentric product design with no needs of CAD or VR systems. It provides both the designer and end-customer[1] an easy but effective solution for ergonomic evaluation of product development at the early design stage.

2. Research approaches

2.1. Digital human modeling

3D virtual humans have been used in many engineering and entertainment applications since the early 1990s. For example, interactive computer models have served as a substitute for "the real human" in the ergonomic evaluation for designs of vehicles, work areas, machine tools, occupational devices, etc. prior to the actual construction [12–14]. They successfully provide a real-time representation of human beings or other live participants embedded in virtual environment. In addition, the designer is able to collect customers' feedback based on a digital model that simulates human behaviors both physically and psychologically at the early concept design phase. In addition, such a digital human can carry useful information like body shapes, dimensions, motion constraints, and operation sequences in 3D space that must be taken into account in detailed design. Allowing the end-user, characterized by the digital human, to interact with the product model facilitates product personalization as the design process evolves.

[1] Both the professional designer and the general customer can use the proposed ergonomic evaluation system. There is no direct link between these two roles. "The user" can mean either one depending on the context in this paper.