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Research on virtual human in ergonomic simulation

Hou Honglun *, Sun Shouqian, Pan Yunhe

College of Computer Science, Zhejiang University, Hangzhou, Zhejiang 310027, PR China

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Abstract

The virtual product development is the unified process of product design, evaluation and validation. Ergonomics analysis is the important step for product validation in the process, and the virtual human is key to the computer-aided product ergonomics. In this paper, ergonomics simulation system is studied based on some elements of ergonomics analysis and assessment. An ergonomics virtual human is built, which is a unified framework made up of biomechanics/physiology-based model, anthropometrical model, posture and motion model, task model, human reactions and decision-making model and human factor analysis model. The framework is applied to virtual prototyping and virtual product development.

Keywords: Virtual human; Anthropometrics; Ergonomic simulation; Virtual prototyping; Virtual product development

1. Introduction

Since 1940s, human capability and limits have been studied, but their importance has not been recognized until 1980s. Recently, the development of product design impulses the research on relations between human, machine and environment. It brings ergonomics to a practicable stage, especially in rehabilitation aids design (Beitler, Harwin, & Mahoney, 1996), aerospace product design (Bennett, 1996) and workplace task ergonomics analysis (Rajan, Kadiresan, & Jeffrey, 1999). With the development of supercomputing, computer graphics, virtual reality and high performance graphics system, the research on ergonomics is extended to virtual environment design platform that is based on 3D-graphics, interactive, physics-based model, and provides real-time simulation and evaluation (Arzi, 1997). In virtual assembly (Rajan et al., 1999), pipeline design (de Sa & Zachmann, 1999), virtual training (Stuering & Schumann, 1999), verification of maintenance processes and others, it has been applied and incorporated in the framework of virtual prototype development. As a key step of product life cycle, it is very important for ergonomics simulation to shortcut test/development cycles, lower development costs, improved quality and enhance safety (Bennett, 1996; Weyrich & Drews, 1999).

* Corresponding author.
E-mail address: houhl@cs.zju.edu.cn (H. Honglun).

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2. Current research

There are 20 years for research on human model. The new techniques, such as virtual reality, and high performance graphics computing, accelerate some applications in computer animation, film special effects, and military simulation.

General human model is very difficult to be applied to ergonomics simulation. At present a model has not been available to ergonomics simulation perfectly. Peabody structure is a better human structure representation method (Peabody Object Representation). Hierarchical object representation is convenient for motion and interactive control of human animation (Badler, Phillips, & Webber, 1993; Boulic & Mas, 1996). Skeleton-based biomechanical model is applicable to static strength analysis, not to dynamic analysis (Chiffin, 1997), and sometimes it is not consistent with real human being because of non-precise model structure (Park, Park, & Kim, 1999). Inverted kinematics model is improved for posture prediction. Not combining with Skeleton-muscle model, strength analysis of motion is difficult (Wang, 1999). Since there are some methods of anthropometrical measure and anthropometrical dataset (Seitz & Bubb; Wang, Wang, & Yeh, 1999), it is possible to construct an anthropometrical model. In ergonomics research, analysis index model has been built independently, but has not been combined to form compositive human model available to human dynamic simulation.

Above all, human model is based on individual subject, object–model interaction is difficult, task authoring and analysis is intercrossed, model is not precise enough. The physical characteristic does not correspond to real human being. Demographic statistical characteristics of anthropometrical model are not synthesized perfectly to avail ergonomics analysis and evaluation. All need some supported techniques, such as database and data-warehousing.

In the next part, the human model is classified for ergonomic simulation, some improvement being done. The human model based on individual subject is put into a framework of ergonomics and is built to avail simulations. In Part 4, as a case, this model is applied to office safety design, and a platform is built for ergonomic simulation.

3. Ergonomic virtual human model

Ergonomic virtual human model is the basic element in ergonomic simulation. Its structure is to be applicable to model operation, animation, ergonomic performance analysis and evaluation.

The virtual human model which has real human characteristics is operated by visualizing, interacting as an avatar in virtual environment, not only in pipeline ergonomic simulation of CIMS, but in product ergonomic analysis. Based on its walking, carrying, lifting and joint limits the avatar's ergonomic performance is analyzed, such as safe posture, lifting and energy expenditure index, time standard, static strength index, joint range of motion, reach and accessibility, visual perspective and others. Ergonomic simulations being put into product life cycle, some problems of interface are evaluated in advance. The product design fault in assembly and maintaining process is found out. It will cut off time and cost in prototype making.

Next, the avatar is to be analyzed from different ergonomic characteristics, and improved according to the suggestions of ergonomic simulation. A framework is to be built to combine individual model.

3.1. Human structure model based on biomechanics/physiology

Human structure model is an integrated module, which is a model based on biomechanics/physiology. It includes human structure model, perception model, and posture and movements model.

3.1.1. Human structure model

Human structure model includes skeleton structure, outline measurement, joint relations and joint limits, which is an articulated geometric objects representation model (Fig. 1).

In the figure, geometric segment is combined by joint that drills through the attachment points. Each geometric segment is a combining part that is made up with segment and profile surface (polyhedron or polygon grid). Each attachment point has a coordinate relative to segment, and there is one attachment point at least on the segment. So we can get a relationship between geometric objects representation model and virtual human model. That is, segment-skeleton, profile surface-anthropometrical measurement, joint-arthrosis and