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A fast parametric deformation mechanism for virtual reality applications

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Abstract

Virtual reality technologies have been adopted in a wide variety of applications for its interactive ability and realistic senses. Despite early implementations regard VR only as a medium for lively animation; a practical VR work must deliver precise deformation on virtual objects based on real-time interactions. The exact ability is especially important for users who utilize VR to do collaborative design, for it will greatly reduce the amount of on-line computations on operating substance-based interactions, and consequently facilitates the collaboration. Therefore, this research will employ neural networks to memorize the deformation behavior of solid objects, and then perform instant and accurate deformations in the virtual environment. The proposed method also allows design variations for parametric features, and uses feature parameters as variable switches to adjust the deformation mechanism. There are three steps in the method: (1) For a sample object, generate force-induced deformations using the finite-element method; (2) memorize the surface displacements with artificial neural networks; and (3) convert the parametric deformation matrices into Behavioral Modules for the virtual reality engine. In the implementations, ANSYS is used to generate model deformations, and MATLAB is used to perform neural training. Finally, a virtual environment is built using Virtools where customized Building Blocks are created to present interactive deformation behavior. Experiments were carried out on an Intel XEON workstation with nVIDIA Quadro4 750GL display device. Sample workparts are tested to examine the ability of the method. The results show that both training accuracy and real-time capability are more than satisfactory.

Keywords: Emulated deformation; Virtual reality; Collaborative design; Parametric design; Neural networks

1. Introduction

For engineers who practice component design, it is desirable to visualize the performance and the analysis of the design process throughout the development cycle. In this case, an attributed model representation, which requires minimal on-line process to generate vivid animations and rational behavior, is usually prefer-

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able. Therefore, more users have turned to virtual reality for possible solutions (Calderon & Cavazza, 2003). On the other hand, advances in the information network technology have encouraged collaborative works on product development. Multiple users may practice concurrent design on the same part with networks apart. The common ground that the discrete systems share will be the geometry and attributes of the design. However, rival design packages often have technical difficulties on data compatibility, particularly when sharing data of common interest. Performing real-time and interactive simulations on a VR platform may be a practical approach to exchange instantaneous design intentions (Fröst & Warren, 2000). This paper uses neural networks to memorize material behavior and then generate real-time deformations upon force interactions on a VR platform. The proposed method also allows instant design variations on parametric features, and uses feature parameters as variable switches to control the deformation mechanism.

Virtual reality has been used extensively for applications such as engineering, medicine, military, education, commercial, and entertainment. An engineering process may refer to the rational interactions between the virtual entities and the users to deliver a sense of immersive and to activate subsequent activities (Mujber, Szecsi, & Hashmi, 2005). A medical task may utilize the realistic feedback from the virtual environment to induce sensible practices from a professional user (Chanthasopeephan, Desai, & Lau, 2004). A military operation may incorporate emulated situations with strategic consultations in a virtual environment and generates simulations for tactical exercises or vice versa (Sherman & Craig, 2003). An educator may embed implicit knowledge in an interactive teaching material for the learners to explore (Lu, Pan, Lin, Zhang, & Shi, 2005; Pan, Zhu, Hu, Lun, & Zhou, 2005). A commercial demonstration may present comprehensible features of a virtual merchant with versatile interface to promote its functionality (Virtools Web Site; Keckeisen, Stoev, Feurer, & Straβer, 2003). A VR-based entertainment unit may interact users with equivalent or augmented human senses to vitalize their imaginations (Zyda, 2005).

For the above VR applications, a realistic computer-rendered animation with real-time interactive capability is a basic function. Specific and advanced functions, depending on the implementation, may strengthen individual applications. However, incorporating advanced functions and interactions could largely expand the computational load, making new functions a heavy burden. Still, creating an emulated reality in the digital space to provide real-time and realistic interactions is the ultimate goal for the development of VR technologies. The degree of factualness, including speed response and precision of the virtual behavior, from implementing the technologies will then become the criterion of measurement.

Among the advanced VR functions, emulated physical and mechanical properties for virtual objects are the most principal and practical characteristics, in addition to the appearance, that an interactive system should possess. (Gudukbay, Ozguc, & Tokad, 1997; Kang & Kak, 1996; Marek & Maret, 1997) These advanced functions will greatly extend the usefulness of virtual reality, especially in engineering and medical applications, where accuracy is of major concern. Certain applications in the manufacturing or production simulations may also employ a realistic VR interaction to realize and to synchronize the physical as well as logical compatibilities among the facilities (Mujber et al., 2005). A precise and reliable feedback of physical attributes from the virtual-substantial interactions will be of great help when planning schedules automatically in the digital space.

For those components that need assemble during fabrication, deformations of any magnitude may exist and may influence product functionality. For those components that have potential interactions with the surrounding objects, force-induced deformations can be excessive and should be simulated along the design process. Most designers will implement parametric design on product features, for features are the conceptual and/or physical connections among the components, and design variations of the components are sometimes trivial but related. All variations and their behavioral influences should be presented geometrically and graphically to the collaborative workers in real-time. However, such amount of computation cannot be performed by current deformation mechanisms. Methods such as mass-spring method (MSM), finite-element method (FEM), or boundary-element method (BEM) alone are inadequate to accomplish partial or entire procedure for the collaborative works.

The mass-spring method simulates solid substance with dimensionally comprehended spatial nodes and connecting springs among them. A spring is a symbolic mechanism that represents and re-creates the substantial properties. The method embeds emulated material properties in the springs of the model representation, and propagates the influence of the interacting forces through the springs to get overall deformations.