A High-Quality High-Fidelity Visualization of the September 11 Attack on the World Trade Center

Paul Rosen, Voicu Popescu, Christoph Hoffmann, and Ayhan Irfanoglu

Abstract—In this application paper we describe the efforts of a multi-disciplinary team towards producing a visualization of the September 11 Attack on the North Tower of New York's World Trade Center. The visualization was designed to meet two requirements. First, the visualization had to depict the impact with high fidelity, by closely following the laws of physics. Second, the visualization had to be eloquent to a non-expert user. This was achieved by first designing and computing a finite element analysis (FEA) simulation of the impact between the aircraft and the top 20 stories of the building, and then by visualizing the FEA results with a state-of-the-art commercial animation system. The visualization was enabled by an automatic translator that converts the simulation data into an animation system 3D scene. We built upon a previously developed translator. The translator was substantially extended to enable and control visualization of fire and of disintegrating elements, to better scale with the number of nodes and number of states, to handle beam elements with complex profiles, and to handle smoothed particle hydrodynamics liquid representation. The resulting translator is a powerful automatic and scalable tool for high-quality visualization of FEA results.

Index Terms—I.3.4 Three-Dimensional Graphics and Realism, I.3.8 Applications.

1 Introduction

VISUALIZATION has long been recognized by experts in a variety of domains as an indispensable tool. Visualization systems are typically developed in collaboration with domain experts and achieve—automatically or with user guidance—the detection and isolation of relevant data subsets, which are then converted into salient visual representations. The rules of this conversion and the resulting visualization language are well familiar to the domain experts, for whom it facilitates broad-band assimilation of information. However, this same visualization language can be cryptic to anyone outside the narrow circle of domain experts.

This is a serious limitation when the interest in the visualization transcends a single domain, as is the case, for example, for computer simulations. Simulation codes and computing hardware are now sufficiently powerful to enable high-fidelity simulations that track in detail complex interactions in large scenes. Results of such simulations are often of great interest to a group of users with heterogeneous expertise, yet the visualization modules of simulation systems typically cater only to the experts who designed the simulation.

This application paper describes the collaborative efforts of visualization and civil engineering researchers to produce a simulation of the September 11, 2001 Attack on New York's World Trade Center. The interest in such a simulation transcends civil engineering and includes emergency response, defense, and the society in general.

- P. Rosen is with the Computer Science Department, Purdue University, West-Lafayette, IN 47907. Email: rosen@cs.purdue.edu.
- V. Popescu is with the Computer Science Department, Purdue University, West-Lafayette, IN 47907. Email: popescu@cs.purdue.edu.
- C. Hoffmann is with the Computer Science Department, Purdue University, West-Lafayette, IN 47907. Email: cmh@cs.purdue.edu.
- A. Irfanoglu is with the Civil Engineering Department, Purdue University, West-Lafayette, IN 47907. Email: ayhan@ecn.purdue.edu.

Therefore we pursued two major goals. On the one hand the simulation had to follow the laws of physics as closely as possible. On the other hand, the simulation results had to be presented through a visualization that is eloquent to users outside of civil engineering. The goals of simulation fidelity and of broad accessibility to the simulation results through visualization are somewhat contradictory and are rarely pursued in combination.

Employing state-of-the-art numerical simulation code has the advantage of a high degree of confidence in the fidelity of the physical simulation, but suffers from the disadvantage of lower fidelity visualization provided by post-processing modules that are one or several steps behind the state-of-the-art in general purpose visualization. Employing a state-of-the-art animation system on the other hand enables high-quality visualization but there is little confidence that the rendered imagery faithfully depicts the actual events. We combine the advantages and avoid the disadvantages of both approaches by computing the simulation in a state-of-the-art commercial simulation system and by visualizing the results using a state-of-the-art commercial animation system.

We generated finite element models of the Boeing 767 and of the top 20 stories of the North Tower of the World Trade Center (WTC-I) consisting of beam, shell, smoothed particle hydrodynamics (SPH), and solid elements. The finite element models were used to compute an FEA simulation of the impact using LS-DYNA [1]. The simulation tracked the impact over one second of real time. Simulation results were saved for 400 output time steps, thus every 2.5ms. The simulation results were imported into 3ds Max [2] where, relying on state-of-the-art geometry, material, light, and visual effects editors a high-quality visualization of the simulation results was produced (see Figures 2-7 and accompanying video).