COMPUTER-ASSISTED COMPARISON OF ANALYSIS AND TEST RESULTS IN TRANSPORTATION EXPERIMENTS*

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SUMMARY

As a part of its ongoing research efforts, Sandia National Laboratories' Transportation Surety Center investigates the integrity of various containment methods for hazardous materials transport, subject to anomalous structural and thermal events such as free-fall impacts, collisions, and fires in both open and confined areas.

Since it is not possible to conduct field experiments for every set of possible conditions under which an actual transportation accident might occur, accurate modeling methods must be developed which will yield reliable simulations of the effects of accident events under various scenarios. This requires computer software which is capable of assimilating and processing data from experiments performed as benchmarks, as well as data obtained from numerical models that simulate the experiment. Software tools which can present all of these results in a meaningful and useful way to the analyst are a critical aspect of this process.

The intent of the data visualization effort in the Transportation Surety Center is twofold. First, improved data visualization provides an environment that enhances the interpretation of the results of simulations of structural and thermal accident events. Improved interpretation, in turn, increases the accuracy and reduces turn-around time of the simulation. In addition, the increased efficiency that results from improved data visualization methods translates into reduced product development costs, and contributes to the goal of a seamless mechanical product/data exchange.

Second, effective data visualization improves client communications. The traditional method of communicating the results of an analysis to a customer in the form of reports and view graphs is becoming obsolete at an accelerating pace. Visualization methods allow the analyst to provide results to the customer in high-fidelity digital form, and subsequently as still frames or animations on a computer terminal or videotape. Computer animations are an excellent method for demonstrating the results of a dynamic simulation event to a client. The purpose of this work is to provide software resources on a long term basis, and to ensure that the data visualization capabilities of the Center keep pace with advancing technology. This will provide leverage for its modeling and analysis abilities in a rapidly evolving hardware/software environment.

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DEVELOPMENTS IN REAL-TIME DATA PROCESSING

In early 1997, a new version of the MIDAS-based data acquisition and post-processing software was completed for use in the reduction of data from structural and thermal experiments. This program, known by its acronym KAPP (Ludwigsen, 1995; Ammerman, 1995), contains a number of improvements over the previous version, as well as several functional enhancements to the ability of the program to present test data in real time for quality assurance purposes.

A major enhancement to KAPP was the inclusion of support for time-synchronized digital video as a standard data type. Utilizing an onboard PARALLAX® video card, VHS video shot during a field experiment can be digitized and recorded on disk alongside the data from the experiment itself, then replayed and synchronized in time for viewing with standard KAPP analysis and display features. This creates a valuable synergism between analysis and test data, and can be an important tool in refining analytical models for forecasting purposes.

The ability to exchange video data in digital format is an important part of any visualization capability. Video media provide a permanent record both for further analysis and for archives. To this end, the University of California's EECS MPEG digital movie player was ported and customized for use on the Center's Hewlett Packard 755 desktop visualization workstation, and successfully tested there using a copy of a SeaRAM ship collision simulation.

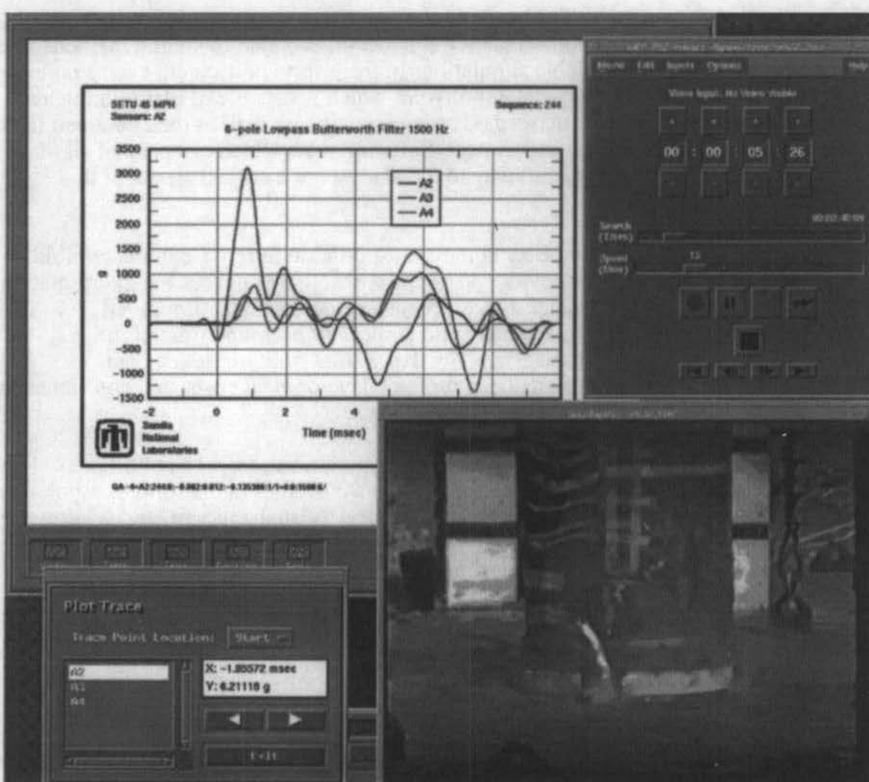

Figure 1. User interface for time-synchronized digital video and test results. Note data at upper left and video display of experiment at lower right.

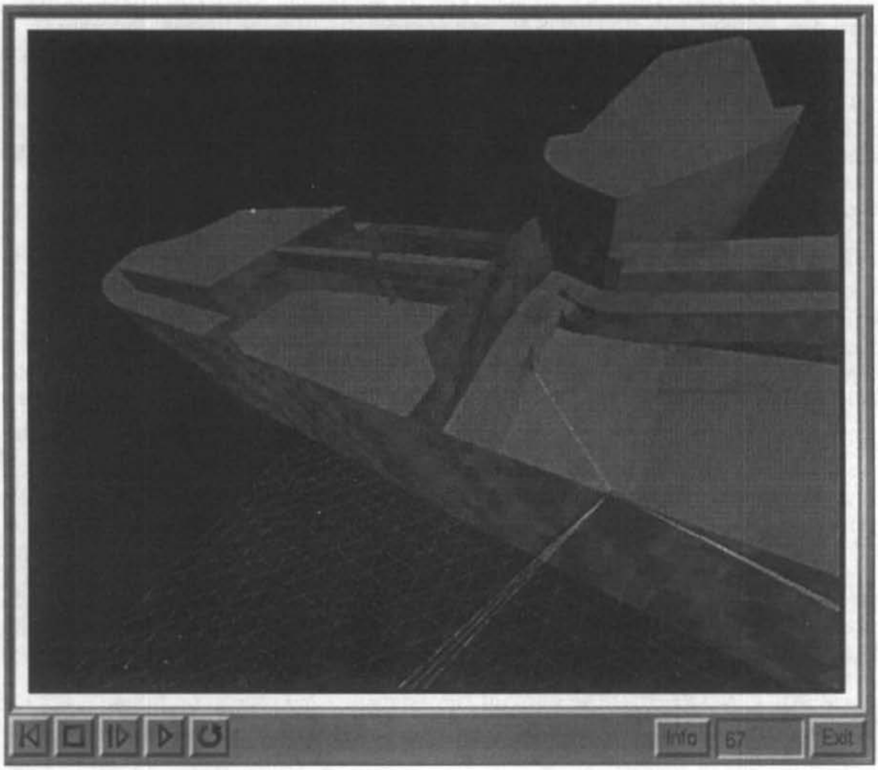

Figure 2. Snapshot from MPEG digital movie of SEARAM collision simulation.

REAL-TIME VIDEO CAPTURE FACILITY

In addition, software which permits images from the HP-UX workstation monitor to be digitally recorded and transcribed to JPEG digital format was written and tested. This function allows an analyst literally to record digital movies from the computer screen, a capability which is not currently supported by licensed commercial software currently in use on this computer. The JPEG/JFIF digital format allows the digital movie to be read and replayed using digital compression/decompression hardware (PowerVideo®) and software (VideoStream®) supplied by PARALLAX GRAPHICS, INC., Santa Clara, California, which can then be transcribed directly to VHS videotape.

DEVELOPMENTS IN DATA EXCHANGE CAPABILITIES

A new application was designed, developed, and tested for use on HP-UX platforms running version 9.x of that operating system in support of KAPP/MIDAS-related data reduction activities. The new application, called MIDAS_X, is capable of reading finite-element model (FEM) data in Sandia's EXODUS II format (Mills-Curran, et. al.,1988) and extracting specific nodal and element variable information which is then transformed to a MIDAS-compatible format. This permits model data stored in EXODUS format to be interpreted by the KAPP system and analyzed alongside actual test data acquired in the field by MIDAS. This greatly enhances the analyst's ability to correlate both types of data, and to refine the FEM models accordingly.

In addition, a software program was developed for use in converting CFD/CFX format thermal data into Sandia's EXODUS II finite element data storage format. Program CFX_trans accepts CFX 4.x data in either binary or ASCII, and translates it into an EXODUS II database which can be read by any software system which accepts the EXODUS format. The output EXODUS II data is consistent with the description of that data format as set out in Sandia Document SAND92-2137 (Schoof, 1994). The CFX format accepted by CFX_trans is consistent with the data format described in the CFX3D 4.x User's Manual (October 1995). This allows visualization of thermal data to be performed in the same way as visualization of structural and test data.

DEVELOPMENTS IN HIGH-PERFORMANCE GRAPHICS COMPUTING

High performance graphical visualtization is conducted on the Transportation Surety Center's SGI Reality Engine® II computer. This computer is running IRIX® 6.2 operating system, with 27 gigabytes of high-density fast-wide differential SCSI disk space. Analog and digital video support for the RE II is accomplished with SGI's Sirius Video peripheral controller and the SIRIUS® video board on the SGI chassis. Analog input and output have been successfully tested using IRIX®-based interfaces to these functions. Digital support is enhanced by the migration of the previously described UC/EECS MPEG digital video player to this platform, and by the use of DuPont's shareware ImageMagick, a digital image editing library.

Other capabilities include software from MUSE Technologies, Inc. which is in use in a number of locations at SNL for visual immersion and virtual reality applications on high-end graphics workstations, primarily Silicon Graphics platforms. A derivative application of this system, first designed by the Manufacturing Applications Center at SNL, was migrated to the TSC RE II and successfully tested there using several prototype EXODUS II datasets. This software allows an analyst to view an EXODUS-formatted dataset in stereographic 3-D space, and to use mouse and cursor controls to navigate the data volume as though he were traveling through it in a virtual aircraft. The capability has enormous potential for enhanced structural and thermal modeling and for quality assurance, as the user is able to interactively interrogate his data for the values of geometrical and physical parameters. The software will require some customization for use in the Transportation Surety Center, however, and this will be the subject of ongoing research and future software development efforts. Stereographic and virtual reality display capabilities are provided by several sets of Crystal Vision's Crystal Eyes® Eyewear and associated auxiliary equipment, which were installed and tested on the RE II concurrently with MUSE.

Table 1 summarizes the configuration of the TSC REII computer, as of 8/31/97.

Table 1
TSC SGI REII Configuration

Machine type	**Silicon Graphics RE II**
CPU	**Dual 150 Mhz R4400 IP19**
FPU	**R4000 FPC Rev 0.0**
Main memory	**256 mB**
Data Cache	**16 kB**
Secondary Cache	**1 mB**
EPC Serial ports	**4**
EPC Parallel Ports	**1**

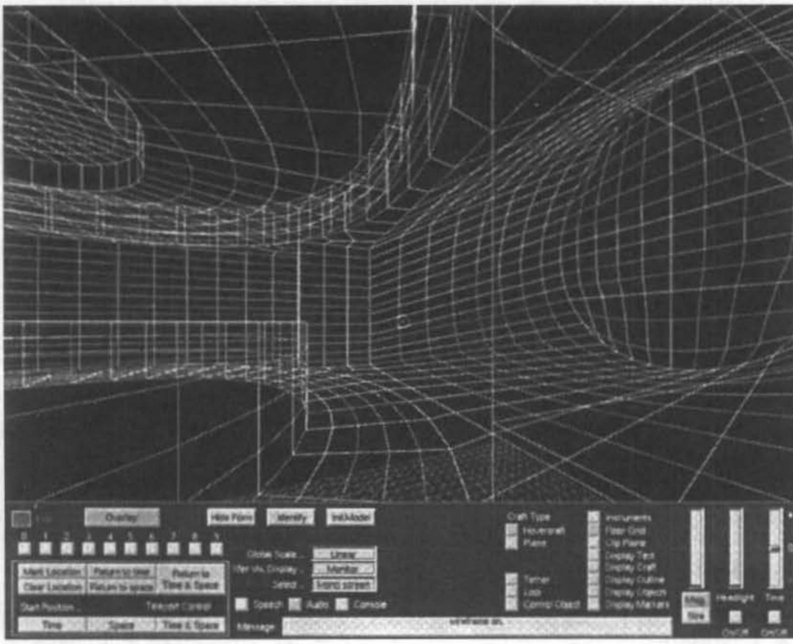

Figure 3. Navigating a 3-D mesh volume in virtual space.

Figure 3 contains a sample illustration of a MUSE-generated 3-D data volume viewed on the RE II. The system allows an analyst to navigate his model as though it were a virtual object, subject to interrogation by him for information such as the value of a finite element node or element variable, or of time-dependent structural deformations. Such information is frequently directly comparable with the data acquired from field experiments, which can then be used to refine the corresponding computer model, leading to greater reliability in response prediction in the design and modeling process.

With suitable eyewear, described previously in this report, images such as that in Figure 3 can be viewed by the analyst in stereoscopic 3-D.

CONCLUSIONS

The need for accurate and reliable modeling methods in the packaging and transportation of nuclear waste and other hazardous materials will accelerate in this era of post-Cold War nuclear safety engineering. Certification of transportation package designs will frequently require combinations of both analysis and field testing to ensure compliance. Evaluation of the data from either source will require continuously increasing computing-power in the form of both high-performance processing and data visualization tools.

Steps taken during the course of this project will help initiate methods that would allow a transportation analyst to interact with his data, searching for errors or inconsistencies in his own physical models or in data collected from a field experiment. His concomitant ability to make refinements to the data from such observations is a singularly significant milestone, because the observations must often be distilled from voluminous databases with sizes measured in the hundreds of megabytes.

Technologies which provide the analysts with tools such as these represent the forefront of environmental engineering advances during this century. They will almost certainly become indispensable tools in the next.

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Crystal Eyes® is a trademark of StereoGraphics, Inc.; San Rafael, California.

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