NISTIR 6242

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Book of Abstracts
November 2-5, 1998

Kellie Ann Beall, Editor

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Gaithersburg, Maryland 20899

NIST

United States Department of Commerce
Technology Administration
National Institute of Standards and Technology

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Matching Fires and Simulations

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Introduction

This paper describes a prototype system for matching a building-specific fire simulation database with information from real fire sensors situated within the building. One use of this would be as an aid to fire-fighting efforts. The system could be used to provide responding fire fighters with fire visualizations based on real time fire predictions from Computational Fluid Dynamics (CFD) fire models. This would be a major improvement over the current situation which depends on simplistic annunciator panels to illustrate the location of detectors that have operated, but which give little indication of the fire growth rate or future fire spread.

Others have discussed the use of computer fire models for real-time fire prediction [1]. However, it has been assumed that only zone models could be used for this purpose. Unfortunately, zone models do not give adequate spatial information to assist fire fighters in truly understanding a fire's spread and growth rate. The use of a CFD code can solve this problem. However there are two major problems using CFD codes for this purpose. The first is the significant amount of time and skill necessary to prepare a CFD simulation. This is something that is not available at a fire scene. Second are the lengthy run times of such models and the difficulty in interpreting model results. In the researcher's office, this problem is resolved through the use of fast computers, or "weekend" long runs. The results are then evaluated using sophisticated computer graphics software, sometimes running on dedicated hardware platforms.

This project investigates the use of previously generated and stored computer simulations in aiding manual fire suppression. Such simulations might be prepared months or even years in advance of a fire incident. The resulting data could then be stored in a simple to access database. During a fire, this database could be compared against real-time fire sensor information to determine which of the previously modeled fires best match the one occurring in real-time. The results could then be displayed in a simple format to aid arriving fire fighters in determining the fire's progression and future spread.

This paper discusses the problem of matching real-time sensor information with CFD results stored in a database.

Database Matching

Fire models based on CFD codes generate large volumes of data. This is because a continuum is divided into a grid of thousands of cells. Each cell is treated as an individual control volume where principles of conservation of mass, energy and momentum are applied. The result of such a simulation is cell property predictions of variables such as temperature and pressure and resulting flow fields.

For our purposes, cell properties needed to match real-time sensor measurements must be stored. In addition, one might also store pre-drawn computer visualizations of the simulated fires as animations or static images. In either case, one needs to store the information necessary to display the history and future for the simulated fire(s) which are sufficiently similar to the real-time sensor data. Obviously, these requirements place huge data storage demands on the problem. Concurrent with the storage issue is the retrieval and matching of the data with the active sensor information in the short time allowed (real time).

Matching actual sensor data, which is a continuously evolving sequence of locations and activation times (or location/time/temperature read-outs, depending on the sensor type), and CFD simulation output is complicated. It involves first the computation of a virtual sensor history for the simulation and then a calculation of a distance metric between the actual and simulated sequences. It is a difficult problem due to many factors:

1. There are only a finite number of simulated fires that can be stored for a particular building, and thus all possible scenarios will not be included.
2. Two very similar fires can have significant differences in the order in which sensors activate, due to building and sensor layout.
3. Sensors which have obstructions between them can have very distinct relationships from those with no obstructions (i.e., spatial position is not the only factor).
4. It is possible for sensors to fail.
5. Two fires can have identical ordering of sensor activation, but have different growth rates, leading to significant differences in timing.

In our matching algorithm, we first attempt to match on the order of sensor activation, and then by time between sensor activations. We compute a spatio-temporal distance between the real (incomplete) sensor sequence and all of the entries in the database [2]. The distance can consider all active sensors equally, or weigh later activations as more significant than earlier ones. As each new real sensor activation occurs, the metric must be recalculated. Simulations which match all active sensors of the real sequence but have additional active sensors (i.e., a larger fire than the actual one) have their scores penalized based on the number of and distance to these additional activated sensors.

If this procedure fails to identify a simulation of sufficient similarity to the real fire, we examine a number of different alternatives. In **substitution**, we identify sensors that are physically near those which have activated and swap one or more, followed by a recomputation of the metric. In **reordering**, we check to see if two activated sensors have approximately the same activation time and, if so, try swapping their order. Finally, in **elimination**, we assume one or more sensors have failed and remove them from consideration in computing the metric.

The result of this algorithm is an ordered set of simulations that approximately match the actual building fire to date. One or more of these simulations can then be visualized at the time fire fighters arrive to provide additional information in the development of a safe and effective suppression strategy. Visualization methods we have developed and evaluated are presented in another paper. As our ability to model fires becomes more and more accurate, we expect this approach to aiding fire suppression activities will become more effective.

References

[1] Plumb, O. A., and Richards, R. F., "Development of Economical Video Based Fire Detection and Location System," NIST Grantee presentation, Washington State University, 1994.

[2] Dyreson, C. E., and Snodgrass, R. T., "Valid-Time Indeterminacy," Proceedings of the International Conference on Data Engineering, pp. 335-343, 1993.