FireGrid: Integrated emergency response and fire safety engineering for the future built environment

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Introduction

Analyses of disasters such as the Piper Alpha explosion, the World Trade Centre collapse and the fires at Kings Cross and the Mont Blanc tunnel have revealed many mistaken decisions, such as that which sent 300 fire-fighters to their deaths in the World Trade Centre. Many of these mistakes have been attributed to a lack of information about the conditions within the fire and the imminent consequences of the event.

E-Science offers an opportunity to significantly improve the intervention in fire emergencies. CFD and FE techniques are now sufficiently advanced to accurately model the spread of a fire and its effects on structures. Planning-based command and control (C/C) systems are already used in evacuation planning. Together they allow the generation of evacuation scenarios in anticipation of future fires. These are sufficient to guide better building design. We call this the "Design mode" of FireGrid. The same technologies will also support training of emergency response teams.

In FireGrid's "Emergency Response" mode, parallelisation and on-demand Grids will allow simulations to run faster than real time. Sensors and wireless networks will obtain data in real time which will be used to guide and accelerate simulations. Data from simulations and sensors will be input to the real-time planner. The same wireless networks will enable the C/C system to direct the first line of defences – alarms, sprinklers, fans, and similar devices. Finally, human responders – fire-fighters – will have much more information to guide their response.

The FireGrid Consortium is working on a mixture of research projects to make this vision a reality. This paper describes the research challenges and our approach to solving them.

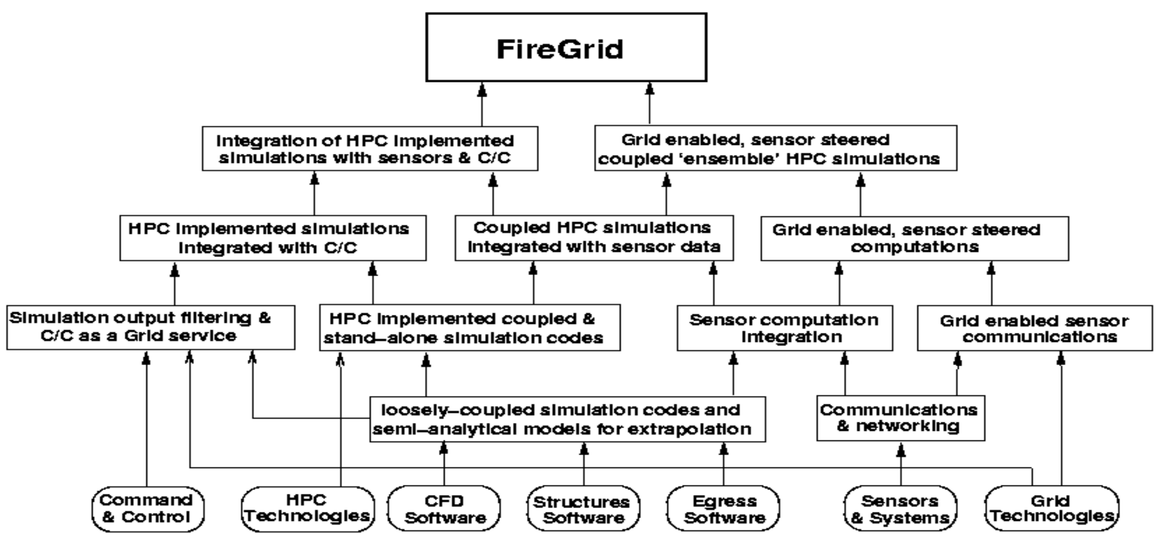

Figure 1: Integration of FireGrid technologies

FireGrid technologies

The figure shows how the contributing technologies will be integrated. We plan a series of pairwise experiments that gradually develop the full system, with detailed evaluations at each stage. Every stage will generate new research challenges, results & papers. Some of these experiments are already underway, funded as individual research projects.

HPC

FireGrid integrates several existing modelling packages. These will be enabled as Grid components. Where necessary, OpenMP will be used to parallelise sequential codes. All these components will be loosely coupled to model all aspects of a fire scenario.

For the emergency response mode, these components will have to simulate the fire in super-real-time. This will require performance tuning and optimisation.

A further research topic is to make efficient use of sensor data to steer and accelerate simulations. One technique is to run simulations in parallel, discarding those that do not match the sensor input and replacing them with new simulations.

Command and Control

FireGrid C/C technologies will further develop the I-X collaborative process management, planning and workflow enactment system.. This provides a framework for collaborative agents, both humans and systems.

In design mode, this will generate and store a multiplicity of potential emergency response scenarios. In emergency response mode, it will be a bridge between Grid services and emergency responders. I-X already provides an operational area map and 3D-view front-ends. The research challenge is to use I-X to steer the fire simulations, show the utility of simulation results to decide intervention, provide an impact assessment of emerging situation reports, react to issues and events, and plan communication, delegation and dynamic repair.

Sensors

A typical FireGrid scenario could involve 10,000 sensors. Different types of sensors (e.g. smoke, CO, temperature, etc) yield different types and ranges of information. Data rates from individual sensors will be modest, typically updates on a 0.1-1s interval with a few kilobits per sensor.

The reliability and durability of the sensors in a fire is key to the success of this work and will require investigation. The survivability of a sensor implies some form of shielding from the environment which will have implications for the sensitivity of the sensors and for the communications technology. The likelihood of sensors being destroyed suggests that the communications network will have to self-organize without prior knowledge of the network topology. Topics to be investigated using a range of existing linked cluster ad-hoc routing algorithms for wireless-based sensor networks will be the need to adapt to propagation conditions, node destruction and failure.

A research challenge is to identify key events from the large amount of sensor data. We plan to run data mining and other codes on processors close to the sensors to detect subtle changes in the environment. The system will also analyse the multiple sensor inputs and compare them to typical fire "signatures," thus authenticating the data and avoiding false alarms.

Grid

Grid technologies are the glue that will connect the various components and make FireGrid a reality. The emergency response scenario requires remote access to high performance systems, with appropriate workflow management. It demands priority scheduling on these systems, displacing any mundane work currently executing. This requires new workload schedulers and policies. An important function of the Grid will be to allow escalation of the computer resources involved as the event increases in magnitude.

The sensor input must be routed to the simulations and the data filters must be updated in response. The system also requires remote access to distributed databases of model input data. All of these will be co-ordinated by the grid-enabled C/C system, which will also allow the participation of remote experts to give advice.

Evaluation

The initial pairwise experiments will use appropriate evaluation techniques. For the full-scale integration, we will use the facilities of the Fire Training College to instrument and burn a mock-up of a real building. This will test the whole system under realistic conditions. We will compare the sensor information against the predictions of the software, evaluate the reliability of the sensor network and the performance of the C/C system, and hold a de-brief meeting with fire staff.

Summary

FireGrid is researching the development and integration of modelling, sensors, Grid, HPC, and C/C technologies. It will stimulate further research, in new safety systems and strategies, in new sensor technologies, in improved modelling techniques and in Grid technologies and operation.

By integrating previously uncoupled tools, FireGrid will allow true performance-based design for the built environment. It will introduce a new emergency response paradigm, using scenarios planned and stored in advance in conjunction with super-real-time simulation. Deployment of FireGrid will reduce costs and save lives.