# Express Risk Assessment through Web Access to Simulation Data

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## Abstract

*A prototype of an express risk assessment system is proposed and implemented as a combination of a distributed simulator and a web interface. A case of aerosol dispersion in an urban environment is investigated. Fast response of the system is achieved by replacing complex 3D simulations with information retrieval from aerosol dispersion database. The database is created by extensive simulations of different aerosol dispersion scenarios. Cluster or grid computing environments are most suitable for these type of simulations. The reduction of system response from a few days to several seconds can be achieved compared to real-time 3D simulations.*

**Keywords:** 3D Modeling and Simulation, Risk Assessment, Web Interfaces, Cluster Computing, Information Retrieval

## 1. Background and Methodology

Simulation of aerosol spreading in urban environments requires large computing resources and many hours if not days of computations to achieve accurate predictions. This time and resources may not be available in an emergency situation, and other means of express risk analysis may be appropriate.

Utilizing a commercial computing grid, it is possible to run simulations of multiple dispersion situations on parallel systems in order to quickly develop data sets for a wide range of scenarios.

With this data, one can design a web-based application that allows the user to select a location from which a contaminant has been released and obtain accurate results in less time than it would take to run the simulation. In this way, not only can the issue of accurate dispersion scenario simulations be addressed accurately and quickly, it would also allow emergency first responders to immediately access this information via a laptop computer and a wireless internet connection from close proximity to the actual contaminant release location.

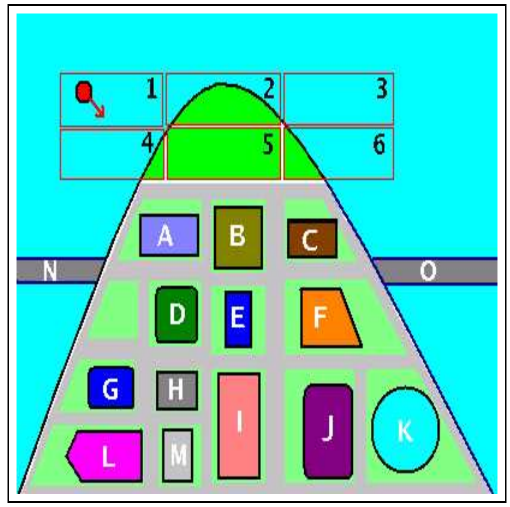


**Figure 1. Aerosol dispersion in a city: 1..6 - available aerosol release data; A-O - affected objects.**

In this study the issues discussed have been addressed and implemented in a prototype risk assessment system. The system consists of a simulator and front-end interface. The simulator incorporates a physically based model of aerosol transport and is executed on high-performance computing facilities, such as computer clusters or grid environments. It collects the data of possible aerosol release scenarios. The front-end interface runs as a web-based application and retrieves the data for particular scenarios and their outcomes.

The outcomes of 3D simulations are usually given as three dimensional time dependent probability density functions of aerosol distribution. From a practical perspective the important question is to what degree each particular object in the city landscape, such as a building or a bridge is affected.

Figure 1 shows a generic city map where different objects are marked by letters (A,B,C...). The results of aerosol simulations are kept in a remote database of hit counts on all objects, corresponding to all possible release scenarios. Since the whole database is too large to be transfered over the network at once, the data are split into chunks, or *datasets*, corresponding to limited areas, marked by numbered squares (1,2,...) in Fig. 1. The size of each data set is selected so as to minimize the time of data Transfer, as well as to provide a representative set of release scenarios in a given location (see Sec.2). For each a particular scenario to be investigated, the corresponding data set is retrieved, including all of the scenarios from the local area. Thus, multiple scenarios from the same location can be investigated without the need of subsequent data transfers.

Data corresponding to each release scenario contain the degree of fallout on every object in the domain of interest (i.e. downtown area). In this format the size of the data set is much smaller than it would be if three-dimensional probability density functions were used.

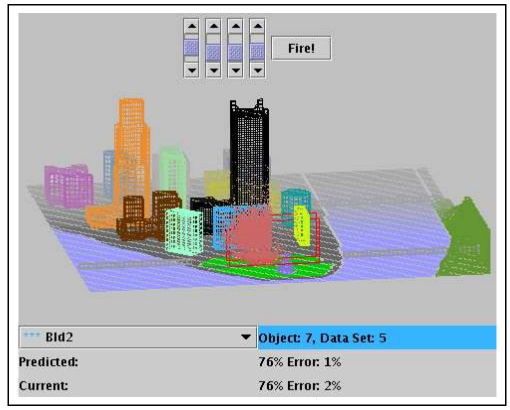


**Figure 2. Web interface to simulate aerosol release in a city**

## 2. Results and Discussion

The prototype of the risk assessment system was developed where the physical simulator, running on the cluster, is constantly updating the database of aerosol dispersion scenarios, and the web-based query system can quickly retrieve the data on each particular scenario from the database.

A generic city landscape based upon the Pittsburgh downtown area was constructed using the voxel-based 3D graphics system [1]. The landscape was populated with characteristic features like rivers, hills, bridges, park area, pavements and buildings (Fig.1). To examine all possible scenarios of aerosol release, the injection of airborne particles was simulated at each grid node and for different possible wind scenarios. In this study we kept the wind strength constant, while varying its angular direction between 0 and $360^o$. with a total number of $N_a = 36$ aerosol release scenarios for each node, which corresponds to 36 wind directions spanning the circle of $360^o$. For the aerosol transport a simple particle convection model was used, augmented with the random walk model to account for the effect of turbulent dispersion.

The simulator of aerosol transport and dispersion was implemented in C++ language and executed on a Beowulf cluster with 1GB, 1GHz computing nodes. The computation of one particle trajectory with our scheme in a given landscape took on the average $\tau = 4.5 \times 10^{-5}\ sec$. Even with the simplifying assumptions used, simulating all the scenarios with one aerosol release point for each node of the domain and for each wind direction will take an estimated $10^7$ scenarios. Considering that the accuracy of the simulations is determined by the number of particles release, a $10\%$ accuracy would require computing about $10^5$ particles trajectories for each scenario. Computing all the required trajectories for all the scenarios may take several years of simulations on a single computing node, which can be reduced to about a month for a cluster or days for a grid computing environment.

In the present study we used $N_s = 12$ sub-domains for possible aerosol release locations, with each sub domain containing $N_i = 1000$ aerosol release locations. In parallel simulations one sub-domain was assigned per computing node. The hit count data for each sub-domain were split between several files, each corresponding to one object in the domain. With the number of objects $N_o = 20$ in this particular case, this resulted in $N_s N_o = 240$ files, which were compressed with a standard gzip compressor and stored on a remote server.

To demonstrate the viability of this method a prototype web interface was developed, which enabled us to test different scenarios of aerosol release (**mulphys.com/sim**). The interface is written in Java language and provides a 3D representation of a city landscape with the possibility of navigating through the landscape, arbitrary positioning of the aerosol source, and setting wind direction (Fig.2). The applet also performs a real time simulation of aerosol propagation and dispersion for a limited number of particles.

When tested on a 1GB 1HG workstation with 100MB Internet connection the speed of retrieval of each dataset was on the average 15 times faster than the execution of the simulation for $10^4$ particles. Considering that the retrieved data set consisted of 1000 realizations, it leads to a much greater speedup if multiple local scenarios need to be analyzed.

## References

[1] A. Smirnov, H. Zhang, A. Burt, and I. Celik. Fuel-cell simulator interface. *Journal of Power Sources*, 138/1-2:187–193, 2004.