UTILIZING REMOTE SENSED DATA IN A QUICK RESPONSE SYSTEM

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ABSTRACT:

We propose to optimize the use of new computer power, observational data systems, and telecommunication capabilities to extract and utilize remote sensed data available from a variety of means. This optimization is crucial in the sense that extracted both meteorological and surface characteristics datasets will be crucial for the use in an emergency response system. We will combine real-time remote sensing systems, existing remote sensing databases, conventional weather observational databases, and GIS together to provide necessary high spatial and temporal data sets necessary for an emergency response system to mitigate against hazardous material releases into the atmosphere. In this article, we give an overall design and also discuss potential issues for developing such a system.

The GIS system will be used to provide access to the geographic information, to support GIS-based computing, and to display the results. Remote sensing databases will be used to provide local area terrain and man-made configuration information such as building shapes. Real-time remote sensing mission is needed for updated information after a massive deconstructive event and for related data assimilation. The distributed online weather data information system will be used to retrieve current and predicted weather parameters. The weather information and the local area geographic information may then be used to feed the selected fast atmospheric transport and dispersion model. The information will be accessed through the Internet following a system-wide specific protocol or open protocols such as those specified by OGC. The system will invoke the model run and convert the model results into GIS compatible format for displaying and for further computation. The final results will be displayed by a GIS/WebGIS based interface, tailored to particular user/agencies.

1. INTRODUCTION

The potential for the release into the atmosphere of hazardous materials (such as Chemical, Biological, Radiological, and Nuclear, CBRN) is an increasing problem in this technological age. Hazardous releases can occur due to industrial accidents such as that occurred in Bhopal, India in 1984, the Chernobyl nuclear disaster that occurred in Ukraine in 1986, etc. More recently, modern military conflicts and terrorist activities are occurring with increasing regularity in urban settings such as the events of September 11th in New York City. This is a cause for concern because the exposure of large populations to military and terrorist activities presents the possibility of mass casualties when weapons of mass destruction are used.

In recent years, complex computer models for the simulation of real world systems are used pervasively in scientific research, and there are increasing demands for these models to support policy- and decision-making. As decision and policy makers come to rely increasingly on estimates and simulations produced by these models, in areas of emergency hazard prediction of Chemical, Biological, Nuclear, and Radiological (CBNR) agents, the need for high temporal and spatial resolution data for the state of atmosphere and the surface characteristic data sets is increasingly becoming crucial for the complex computer models.

The ability to obtain realistic runs from such complex computer models (such as mesoscale meteorological and transport and dispersion models) relies on our understanding of the coupled Earth atmosphere/ocean/land-surface system, which in turn depends on both the collection of data available from a variety of means including remote sensing and on the effective assembly of these datasets into a coherent global picture of the relevant problems.

We propose to optimize the use of new computer power, observational data systems, and telecommunication capabilities to extract and utilize remote sensed data available from a variety of means. This optimization is crucial in the sense that extracted both meteorological and surface characteristics datasets will be crucial for use in both mesoscale meteorological (e.g., data assimilation, adaptive observation initialization strategy) and atmospheric transport and dispersion models (e.g., diagnostic use of the data).

To deliver data and information quickly to decision makers, a quick response system is needed to collect and fuse the necessary data, invoke prediction models, and display the results. Suppose that there is a hazardous gas release in a given location or a massive explosion involving chemical materials. The quick response system should collect information including local area surface configuration such as buildings, terrain, even trees and rivers and nearby weather conditions such as temperature, wind, relative humidity, etc., and should make the data available for feeding into a transport and dispersion prediction model. After the model run, the system should collect population and road information and run an evacuation simulation to determine the optimal evacuation plan. All the results such as the hazardous areas and suggested route for people to escape should be displayed in almost real time and quickly distributed to affected people in efficient and effective ways.

The components for building a rapid response system exist in diverse communities already. For example, a Geographic Information System (GIS), which stores, manages, and computes spatial data, is a popular tool in both academic community and industry. This tool could be used to access and hold databases for local terrain, building information and for population and road information. The GIS client interface is very familiar to government employees and decision makers handling spatial data.

NWP (Numerical Weather Prediction) data are widely available through the Internet for the US. Such data will provide certain initial and boundary conditions for local weather models and dispersion models. Meso-scale weather models such as MM5 (The Fifth-Generation National Center for Atmospheric Research/Penn State Mesoscale Model) (NCAR, 1998) and RAMS (Regional Atmospheric Modeling System) (Pielke *et al.*, 1992) are already under extensive study and are widely used. Linked systems such as OMEGA (Operational Multiscale Environment model with Grid Adaptivity) (SAIC, 2002) and HPAC (Hazard Prediction and Assessment Capability) (DTRA, 2002) could be easily run to predict the motion of hazardous materials in atmosphere.

Remote sensing technology has been improving in the modern age. With LIDAR (LIght Detection And Ranging) and hyper-spectral instruments through space-borne and airborne platforms, one can get high spatial and spectral resolution information of the Earth surface. The information can be used to assess the damage of terrorist and other hazardous events and provide information for running prediction models for response planning.

Although the components exist for an integrated system, the development of such a system still needs to overcome a few hurdles. Some special issues need to be considered before building an effective and efficient system. In this paper, we describe the overall system architecture, the system components and data flows, and discuss some potential issues within such a system.

2. SYSTEM ARCHITECTURE

We propose to combine real-time remote sensing systems, existing remote sensing databases, conventional observational weather databases, and GIS together to be used in atmospheric transport and dispersion models, for emergency hazard prediction. Figure 1 shows a rough system architecture, which shows the major components and their relationships.

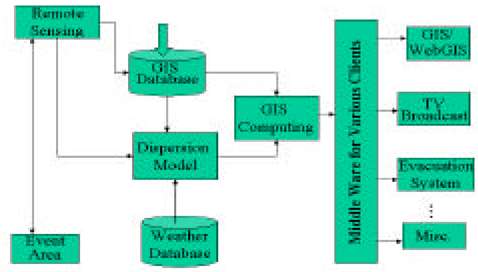

Figure 1. System diagram of a rapid response system

The most important component of the proposed architecture is the remote sensing. Remote sensing provides the necessary high temporal and spatial resolution data for the state of the atmosphere that is very crucial for model initialization, data assimilation, model evaluation & uncertainty studies, and diagnostic studies of atmospheric transport and dispersion. Remote sensing also provides the necessary high spatial resolution data for surface characteristics (such as soil moisture, soil temperature, SST, land use/land cover, etc.).

Real time remote sensing missions in the FIEOS era may become necessary for precise modeling and accurate data for decision-making. The goals of such missions include obtaining high resolution, real-time data for the areas of interest, producing parameter values that are needed but cannot be obtained from existing conventional databases. Moreover, the real time remote sensing would become necessary in certain situations with significant changes. For example, existing databases about buildings and local configurations may not be updated often, and massive explosions may damage buildings and change the local landscape dramatically, as occurred in New York City on September 11, 2001.

There are two major databases essential to the proposed system. One of them is the database for spatial data sets such as building configuration data in an urban area and population and road data. The initial building data may originate in a LIDAR remote sensing system. Road and population data may be held by government agencies. The spatial data may be stored in one system or may be distributed in various systems.

Another type of database is weather related databases. The databases may be distributed and updated periodically by data providers such as NCEP (National Centers for Environmental Prediction) for data like soil temperature, soil moisture, temperature, wind, etc. In addition to the model data, weather observation data can also be provided by such databases. It is expected that data sets from both the spatial databases for local information and the weather databases are enough for initializing and running models in normal situations. It is worth noting that the data sets from these databases may be different, both in format and in data volume.

Clearly, dispersion models will play a key role for a rapid response system, since they predict the motion of hazardous materials. The special requirement against general models for such a system is the overall efficiency. Another important feature of the required model is the spatial resolution.

Geographic Information System (GIS) has been widely used in commercial and academic communities and various government agencies. GIS can store, manage, and compute spatial data. In addition to spatial data management, there are two important features from GIS are essential for a complete rapid response system. One of them is to compute the evacuation plans based on the events and nearby road system. The other major use of GIS is for extensive data visualization.

Hyperspectral imaging is an emerging, enabling technology -- useful to both DoD and civil organizations in areas including: remote sensing of chemical and biological agents to combat terrorism; locating mobile rocket launchers, detecting fuel leaks at our nation's pipeline systems, discriminating missiles by plume spectra, controlling urban development, detecting narcotic-related agents; and detecting pollution sources. Hyperspectral and other modern imaging systems such as radar and laser systems are becoming increasingly available to perform quantitative measurements that will yield information not available from more conventional sources. Unique literal and non-literal measurements made with these systems from ground, airborne, and spaceborne platforms can help with many applications. However, for this capability to be exploitable, it is essential that a well-populated spectral library information system exists and be accessible in a user-friendly way by the user of this technology. This will also require the development of faster processing algorithms, better search methods, improved spectral matching techniques, data fusion, availability of digital elevation data, and cost-effective data handling and management structures, all of which need to be addressed. Modern ground, airborne and spaceborne modern systems are currently demonstrating that the very high efficiencies and extreme flexibility of these sensors provide a powerful measurement technology.

3. POTENTIAL ISSUES FOR A QUICK RESPONSE SYSTEM

Although the components exist today, to build a real-time operational rapid response system needs to overcome several hurdles. The problems include data interoperabilities among different components, real-time data acquiring for data assimilation, and information dissemination.

3.1 Data Interoperability

The data interoperability is a major issue for an integrated system. Consider what data are needed for such a system, remote sensing data, spatial data from a spatial database or a GIS system, weather data from observations and numerical weather prediction, and potential social-economic data such as census data and transportation data. All data from remote sensing are originally in imagery formats containing some measurements of radiations. The imagery data must be converted into geophysical values in a format suitable for numerical weather and dispersion models. This conversion may be relatively simple since one only needs to transfer the data from one raster format into another raster format. Of course, there many remote sensing algorithms are involved in the conversion processes.

The conversion from spatial data into data suitable for numerical models may be more difficult. Generally speaking, most spatial data are vector data. In other words, the data model for describing spatial data and the data model for the data used in numerical weather and dispersion models are different. Therefore, the data conversion is not simply storage format conversion but data model conversion. More computation is needed in addition to the regular format transformation for such a case.

The conversion between vector data and raster data needs to be two-way. The output from numerical models may be in some standard formats in the numerical weather prediction communities, such as GRIB (Dey, 1998) or IEEE float numbers (Hollasch, 2001). To use such numerical results for further spatial analysis, one need to convert the raster data back into vector data. This process is not straightforward as simple data format conversion. Some feature extraction algorithms are needed for this task. For examples, one may clearly see the areas over which the hazardous material concentration is in certain ranges. But to run the evacuation model, one must convert the data into vector data that is understandable by the GIS system and related software.

One potential solution to the data interoperability problem is to use standard data transport protocols for all data passing. OGC (Open GIS Consortium) has developed several implementation specifications for building distributed computing platforms. For example, OGC's OpenGIS Grid Coverages Implementation Specification defines the implementation standard for grid data (OGC, 2001). However, in the weather and dispersion model communities, although standard data formats exist, they are defined at the file basis. To use the data directly to an online operation system based on distributed data sets, certain processings such as subsetting are necessary.

3.2 Data Assimilation Requirement For Future Intelligent Satellites And Remote Sensing

The most important requirement of a rapid response system is the speed of achieving current information. To achieve this goal, real-time data are needed to run the weather and dispersion models as well as evacuation models. For instance, explosions may destroy bridges or some key roads for traffic. The new route information must be used to run the evacuation models. Moreover, the massive damage from explosions may change the landscape near event locations. Original information from the database must be modified to have an accurate dispersion model run. The changes may occur over relatively large areas so that new measurements by human at local stations become impossible. Remote sensing technology would be very helpful in providing real-time information in such situations.

The requirement for such remote sensing cannot be satisfied by today's capability in satellite platforms and spaceborne instruments. One of the most important requirements is the spatial resolution, which should be less than one meter. Since the hazardous events may occur anywhere at anytime, remote-sensing instruments should be deployed over the event areas quickly. Moreover, the weather and dispersion model results could be significantly improved if observation data are applied in the simulation process. This requires high temporal resolution of the platforms. Geo-stationary satellites can easily satisfy the temporal requirements but may be difficult to satisfy the spatial resolution requirement. For both spatial and temporal coverage and resolutions, airborne remote sensing may be more practical.

However, the cheap micro-satellite array technology would also be beneficial to the problem (Zheng *et al.,* 1999). Here, one can envisage a constellation of satellites providing wide coverage for different parts of the world. Such satellites could be quickly programmed by homeland security agencies to point their instruments to the areas affected. Constellations of satellites could also be built to provide different spectral coverage (e.g., IR vs. visible).

The requirement for remote sensing instruments depends on the specific problems. Suppose the hazardous release is an invisible gas, can we use remote sensing technology to identify it, to measure the spread area, or even to measure the concentration in real time to feed dispersion models for accurate prediction. The information certainly is very useful for a rapid response system. However, to achieve that, more advanced instruments such as those for hyperspectral measurement may be valuable. In other words, in addition to the high spatial and temporal resolutions, high spectral resolution is also required for the future use of remote sensing technology in homeland security applications.

3.3 Information Dissemination

During an emergency, how to distribute the critical information to those involved is a very important task. The information dissemination problem is related to the system design, especially the client design, of an integrated system. Suppose that we have the proposed integrated system, where to implement the final step, evacuation planning, and how to distribute the final information may depend on the client design.

The final client may be visualization result in GIS with other metadata. The evacuation notification and suggested routes could be sent to residents by traditional media such as TV broadcast or telephone calls operated as automatic "reverse 911" (Brown, 2002). A more promising way is, of course, through the Internet. Although it sounds unpractical to expect residents in that situation would check the Internet for messages, other people who get the information may pass the information back to people involved in the area. We have heard the story that cellular phone calls to people in the World Trade Centers helped them to know what happened and to allow them to escape as soon as possible. In an emergency situation, one more or less message may lead to life or death. Therefore, the final information should be distributed automatically through various media.

4. CONCLUSIONS

To build an operational rapid response system is not a trivial task. There are many issues that should be resolved before the system integration. The independent issues are considered in different communities, and it is expected that solutions will appear as time passes. Even with all solutions available, system integration needs extensive collaborations among experts in various fields.

It should be noted that there are already prototype systems for rapid response systems at a smaller scale (Brown, 2002). They are basically supported by commercial companies based on their core technology such as the ESRI Homeland Security Initiatives (ESRI, 2002). We believe that government agencies and academic organizations should play more important if not leading roles because such a system is really a multi-facet product that requires knowledge in multiple disciplines.

REFERENCES

Brown, Stuart F., 2002, "Building America's Anti-Terror Machine," Fortune Magazine, July 22, 2002.

Dey, Clifford H., 1998, "GRIB (Edition 1)," ftp://ncardata.ucar.edu/libraries/grib/gribdoc.pdf (accessed August 1, 2002)

DTRA (Defense Threat Reduction Agency), 2002, Hazard Prediction Assessment Capability (HPAC), http://www.dtra.mil/td/acecenter/td_hpac.html (accessed August 1, 2002)

ESRI, 2002, ESRI Homeland Security Initiatives," ArcNews, vol. 24, No. 2

Hollasch, S., 2001, "IEEE Standard 754 Floating Point Numbers," http://www.research.microsoft.com/~hollasch/cgindex/coding/ieeefloat.html

NCAR (National Center for Atmospheric Research), 1998, "MM5 HOME PAGE," http://www.mmm.ucar.edu/mm5/mm5-home.html (accessed August 1, 2002)

OGC, 2001, "OpenGIS Grid Coverages Implementation Specification," Revision 1.00, January 12, 2001 http://www.opengis.org/techno/specs/01-004.pdf (accessed August 1, 2002)

Pielke, R. A. and Coauthors, 1992, "A Comprehensive Meteorological Modeling System—RAMS," Meteor. Atmos. Phys., v49, pp69-91

SAIC (Science Applications International Corporation), 2002, "SAIC: Operational Multiscale Environment model with Grid Adaptivity (OMEGA): High Resolution Weather Forecasting" Operational Multiscale Environment model with Grid Adaptivity http://www.saic.com/omega/ (accessed August 1, 2002)

Zheng, Y., Gong Ke, T. Butlin, W. Sun, MN. Sweeting, 1999, "Tsinghua-1 Microsatellite-Demonstration of EO and Disaster Monitoring Network," Proceedings of the International Symposium on Digital Earth, Beijing, China, November 29--December 2, 1999.