INFORMATION INTEGRATION FOR EMERGENCY MANAGEMENT AND ENGINEERING

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ABSTRACT

Emergency Management and Engineering require the integrated analysis of widely disparate information. By the very nature of many "emergencies" it is not always possible to predetermine the essential information required or its location and access requirements. Relevant information usually spans a wide variety of data types. Much of this information resides in and is maintained by a number of independent agencies. Many potentially useful analysis tools (e.g., GIS, remote sensing analysis, surface and sub surface flow models) require access to large data sets of context dependent data. Unfortunately, much of the potentially useful data is fragmented between agencies, inconsistent, underutilized and often inaccessible; this has been called "information grid lock". Much potentially useful information is not available unless there is a substantial investment of expertise and time in data acquisition and inventorying. While some agencies and organizations have attempted to remedy this problem by developing useful specific data inventories and checklists, that can be used on stand alone computer systems, there is a requirement for an integrated information system containing: static and dynamic information, rule and knowledge bases and decision support and analysis tools. This paper proposes an approach to and issues associated with developing a emergency management shared information resource based on networked resources accessed through information "access agents" at local and remote sites.

INTRODUCTION

Managing and planning for major emergencies involve important environmental, business, social and governance issues that require integrated analysis of extensive disparate information. Many of the issues may have contradictory attributes. While it is possible that one major event may be the primary danger, it is usual that many important associated (i.e., secondary) risks must be identified, analyzed and managed. It is even conceivable that, over time, a secondary risk might emerge as a more significant danger than the original event. The potential impact of most emergencies can be measured only by careful consideration of many aspects of the specific area(s) under threat. Without computational support, the management and engineering related to emergencies would be intractable. The diversity of aspects and their dynamic and spatially specific nature clearly indicate that it is a significant challenge to develop a self contained system that can have sufficient information resources and capabilities to be ready for use with all emergencies. An approach that facilitates information sharing is essential for success in emergency management and engineering.

THE INFORMATION CONTEXT

Since major emergencies cut across many aspects of human and biotic activity, most line agencies of federal, provincial (i.e., state), and local government are involved along with effected citizens, community groups and business. A broad base of information is consulted even for "routine" emergencies. Table 1 shows an example of the general classes of location and event specific information that may be required (see Newkirk, 1993, for a more detailed list).

Assembly and use of appropriate information is complicated by the fact that there is often significant overlap between responsibilities of the agencies and various levels of government. Many of the agencies concerned have extensive relevant information and standards that could be applied. Since spatial representation is critical to environmental problem solving (Parks, 1993), this requires the use of detailed spatial data stored in various agency geographic information (GIS) or remote sensing systems. These

Table 1: Example General Classes of Location Specific Information

- environmental attributes (physical)
- environmental attributes (living communities)
- environmental processes
- social attributes (eg., distribution of populations by type)
- social facilities (eg., evacuation receptor capabilities, hospitals)
- agricultural attributes
- distribution of infrastructure
- infrastructure capacity and condition
- chemical processes (i.e., possible outputs of the emergency)
- chemical remediation procedures
- mandated notice and response procedures

files can be very large. For example, one remotely sensed image can require 10^9 bytes of data storage (Goodchild, 1993). But, emergency management and engineering systems need to process more than raw data sets. Processed data, event logs (with spatial descriptive information), parameters, knowledge bases and rule sets, threshold data, etc., must be included. Clearly, the emergency problem space could be characterized as *potentially "data rich"*. This has led various parties to suggest that a major standards definition initiative is required. One approach to system development has been to acquire, in advance, data from many agencies and store it as a large data base on a large "server" type emergency information system computer. Some software developers and local authorities are pursuing this approach. However there are several draw backs -- including: system vulnerability and legal liability.

System Vulnerability

The concentration of main emergency information files on one system implies that it is expected that the system will be available and easily used whenever an emergency condition exists. A major emergency may lead to the loss of the computer's site integrity and functionality. The large volume of data stored on site would make it hard to relocate such a computer in emergency conditions -- yet, this would be required if it was the only main repository for detailed local area data. While it is possible to counter this by developing redundant systems with full copies of the large data bases, this is not practical financially and would be very difficult to manage.

Legal Liability

Developing emergency plans and responding to emergencies leads to the selection of choices and the commitment of resources. This means that there could be exposure to legal liability if there is inadequate consideration of the necessary information while developing emergency management plans or determining remedial actions. For example, corporations, citizen groups, or municipalities could seek legal remedies if mandated actions were not considered, appropriate lead agency information was not consulted, or if some of the data was: incomplete, out of date, or at the wrong scale. Those attempting to develop a self contained emergency information system that contains its own archival storage of all possibly relevant information is faced with the challenge of avoiding data obsolescence and maintaining data set completeness. Failure to do this effectively opens the risk of legal liability. To avoid some of this liability, and manage information storage demands, it is best if an emergency management system obtain the required data sets *when required* by directly accessing the appropriate lead agency's data sets. Essentially, this can transfer much of the data accuracy and completeness liability to the lead agency that maintains the information.

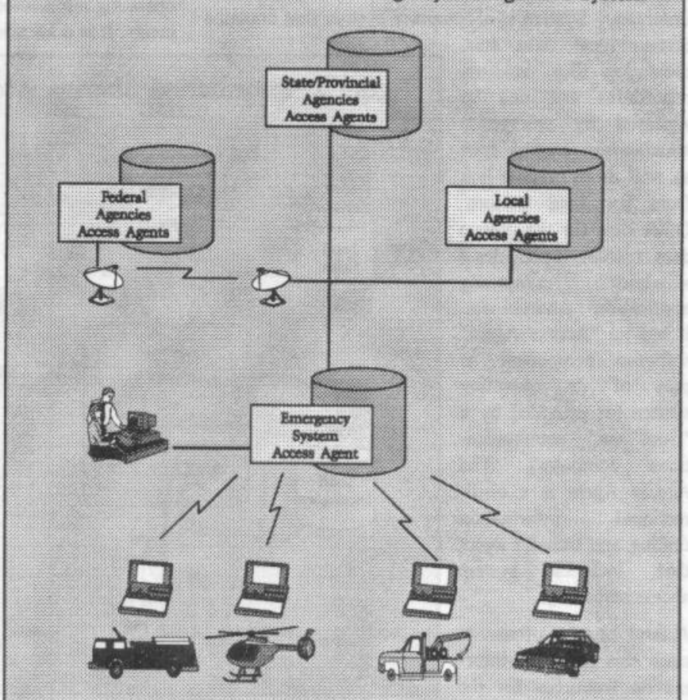
Difficulties in Data Access

Unfortunately, the largest portion of potentially useful public agency data is of no practical use in emergency management and engineering because it is not accessible. While some agencies have produced, for broad emergency community use, valuable reference data sets on disks and CD ROM (eg., a directory of chemicals that cross references: manufacturers, labeling, toxicity and recommended remedial management), these tend to be only current to the data set's specific release date and not specific to local areas. An agency using CD ROM data needs to develop management procedures to ensure that all of its CD ROM data is up to date. Important dynamic information files are beginning to be developed (eg., the Province of Ontario requires the transporters of hazardous chemicals to log manifests, transportation routes and schedules in a provincial data base) and access procedures have been established. On the other hand, for large volumes of area specific data, the actual information holdings are not published, data formats are not defined and access procedures have not been developed. Often, it is impossible even for departments within a government agency to gain access to an other department's information in the same agency. Surveys of government agencies at every level (federal, provincial (state), and local) usually reveal that information is often located at diverse sites, possibly in non machine readable format or on incompatible hardware platforms, perhaps stored in incompatible proprietary software systems, and usually very poorly indexed. It is not surprising that some hold out increasing hope that common data standards will overcome some of these difficulties and actually facilitate information exchange.

Many computing related standards already exist. For example, a large commercial GIS is subject to approximately 1,000 standards (Dangermond, 1993). In spite of these standards, it remains difficult to access GIS operations and results from external processes and systems. Existing standards have helped with the import and export of files in some selected standard formats; however, the main geographic information and GIS operations take place in proprietary internal structures (Oswald, 1993).

Developers of emergency management face a number of formal and informal standards that help only partially with information requirements. Emergency management systems and applications must draw upon and interface with many subject areas where there are already partially developed formal and *de facto* standards. Agencies with potentially valuable data are mainly concerned with their own use of the data and are unlikely to make major changes to accommodate external needs. Even with an initiative by the Emergency Management and Engineering Society to begin the development of emergency system standards, it is likely the impact will be modest at best and will take some time to develop. The orderly development of emergency management systems requires a strategy to provide effective information access.

Figure 1: A Shared Information Emergency Management System



INFORMATION INTEGRATION FRAMEWORK

A computing framework that facilitates sharing of environmental information is under development at the University of Waterloo (Cowan et al., 1994a,b). Its fundamental goal is "to enable its users to locate, acquire, and process information relevant to a problem, and then present results in a meaningful fashion". It is a flexible infrastructure (independent of specific hardware and software platforms) to expedite acquisition and utilization of information by improving the connection between *Resources* and *Use*. The operational objective is to seek out and access data resources through a system of "trusted agents".

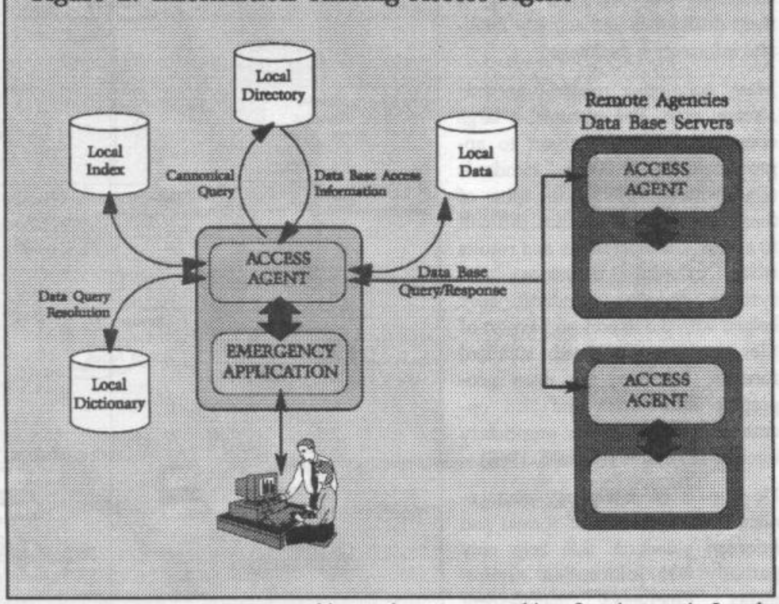
The fundamental principles of this approach can be used to extend earlier concepts of shared information computing (Newkirk and Banz, 1988) for emergency management and engineering systems. By using network interconnection between access agents located in a multitude of agencies and locations, emergency systems can gain access to the required current information without having to maintain a large local archival storage.

Figure 1 is a general representation of a proposed Emergency Management and Information System. The Emergency System is a computer system that contains certain local data sets, event log files, analysis procedures and can be accessed by emergency management central staff as well as by remote link from key field stations. Other than for the unique data it stores, it provides a standard computing application environment. It has an "Access Agent" software component as part of its operating system (or provided by a "front end" communications computer). The Access Agent is a bi-directional information finding and transfer agent that includes system access screening.

A large number of remote sites can serve as information resources for the Emergency System through their Access Agents using standard communication network services (possibly, satellite data communications will be used in major systems). Thus, Federal, State/Provincial and various local agencies can be accessed as required depending upon the nature of the emergency. The Access Agent is designed to be a standard component that is added to each of the systems willing to cooperate in information sharing.

Figure 2 shows the proposed basic Access Agent architecture. Each agency's Access Agent contains the same functional components -- although each will contain different information depending upon the mission of the owning agency and its resources. *Local Data* consists of the sets of information held by the local system. *Local Data* is partitioned into the data that may be accessed remotely, and private information. The *Local Index* maintains information about the location and technical and functional specifications of local sharable files. A *Local Dictionary* is included to assist users and operating applications clarify their information requirements. It is a knowledge based subsystem that provides searching and pattern matching functions. A *Local Directory* provides to both external and internal users and applications information about data bases, rule bases and tools. Normally, sharable information is stored in a standard (i.e., canonical) form. If the data is available in canonical form, the *Local Directory* so

Figure 2: Information Sharing Access Agent



indicates; otherwise it provides the specification (defined by the information owner) of transformation functions or procedures that allow the information to be accessed in perhaps one of several canonical forms. This means that the data set owner need not reformat its data as long as it indicates how the data can be accessed.

When a running emergency application seeks information that is unavailable its local system, the Access Agent uses standard "request for information" polling in the distributed network. This may be a general request when the local Access Agent has no specific knowledge of possible sources, or the request may be directed to a specific agency's Access Agent by information obtained from the *Local Directory*. (In other words, the local directory and index services can be customized to speed up information searches.)

A key feature of each Access Agent is its role as a "trusted agent" (see Cowan et al., 1994a,b) that incorporates standards for access control (and, if appropriate, access charges). The trusted agent is simply a process that intervenes in all accesses to a database. Its protocol is defined by specification of the information sharing framework -- but the actual implementation of the trusted agent operation is the responsibility of the data provider since different agencies will wish to assign different levels of control.

Advantages

This approach does not predetermine a specific character of the resources in the data sharing framework. Nor does it specify operating systems, hardware platforms or application software. Data providers are encouraged to make information available without requiring them to complete major resource transformations. The framework is defined to deal with data sets, knowledge and rule bases, etc., as defined by any basic standard. Therefore it does not require a major new standards definition exercise. Willingness of agencies to cooperate should be maximized because the framework does not require participants to change their own standards or procedures. Since the approach is not hardware or software systems dependent, and since it encourages the holding of smaller local data archives, system portability and relocation prospects are enhanced. This reduces concerns of system vulnerability and legal liability.

A prototype framework for environmental spatial information is being implemented at the University of Waterloo, based on standard network protocols and in association with Federal, Provincial, and local municipality research partners. The development should have a large impact on the development of shared emergency management and engineering systems as well as environmental information systems generally.

REFERENCES

Cowan, D. D., T. R. Grove, C. I. Mayfield, R. T. Newkirk, and D. A. B. Swayne (1994a) "An Integrative Framework for Environmental Management and Research", *Proceedings of the Second International Conference/Workshop on Integrating Geographic Information Systems and Environmental Modeling, 1993*. In press.

Cowan, D.D., T. R. Grove, C. I. Mayfield, R. T. Newkirk, and D. A. B. Swayne (1994b) "Managing Environmental Data -- An Extension to the GIS Architecture", *Advances in Geographic Information Systems.* In press.

Dangermond, Jack (1993) "The Role of Software Vendors in Integrating GIS and Environmental Modeling", in Goodchild, M.F., B.O. Parks, and LT. Steyart (eds.) *Environmental Modeling with GIS.* Oxford University Press, pp. 51-56.

Goodchild, M. F. (1993) "The State of GIS for Environmental Problem Solving", in Goodchild, M.F., B.O. Parks, and LT. Steyart (eds.) *Environmental Modeling with GIS.* Oxford University Press, pp. 8-15.

Newkirk, R.T., and G. Banz (1988) "Application of Portable Microcomputers in Simulations for Emergency Evacuation Planning and Response", *Modeling and Simulation on Microcomputers.* Society for Computer Simulation International, San Diego, pp. 24-27

Newkirk, R. T. (1993) "Extending Geographic Information Systems for Risk Analysis and Management", *Journal of Contingencies and Crisis Management.* Vol.1, No. 4, Blackwell: Exeter, UK., pp. 203-206.

Oswald, Rolf (1993) "The Information Utility", Dr. Dobb's Journal. pp. 18-30.

Parks, B.O. (1993) "The Need for Integration", in Goodchild, M.F., B.O. Parks, and LT. Steyart (eds.) *Environmental Modeling with GIS.* Oxford University Press, pp. 31-34.