Integration of Emergency Management Information Systems: Towards a Common Reference Model

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1 Introduction

The goal of this paper is to propose to the international Emergency Management community a framework for carrying out a coordinated effort of standardization of information systems used in the process of managing emergencies. *Integration* of emergency-related *information* of different sources will be the crucial factor in the near and longer-term future in achieving effective, coordinated management of a major crisis. The authors demonstrate why integration of information is indeed such an important issue in Emergency Management. They then go on to analyze the integration issues specifically related to Emergency Management. A correlation is then drawn between EM Integration and "classical" integration issues in information systems. Based on available integration technology addressing these issues, the authors then present a proposal for a common Emergency Management Integration Reference Model (EMIRM) which defines the services and tools necessary to achieve integration of Emergency Management information systems. The advantage of developing such a Reference Model is believed to be a significant contribution to attaining standardization in support for Emergency Management.

2 The role of information in Emergency Management

When emergencies occur they are generally tackled on the *ad-hoc* basis of experts exercising relevant knowledge *in situ*. Expert knowledge is usually enhanced in this complex task by pre-established procedures which contribute valuable "structure" to a chaotic situation. Nevertheless, the very nature of emergency procedures would make unlikely the use of fully automated operational emergency procedures. Indeed, emergency procedures can only be of limited help since they are predefined i.e., static, while no two emergencies are precisely the same. That is why the decision-maker, in charge of an emergency situation, in fact relies on the provision of up-to-date *information* related to the various aspects of the emergency in order to effectively tackle it. The importance of information in Emergency Management was demonstrated at a recent panel discussion [1], where experienced state emergency managers expressed the opinion that coupling Geographic Information Systems (GIS) and mobile means of communication will constitute the most significant enhancement to their practice. "Establish a modern communications and information resources management system" has indeed been one of the recommendations of the National Academy of Public Administration in recent survey carried out on behalf of the U.S. Congress and FEMA on the future of Emergency Management in the U.S.A [2].

3 Integration of information in Emergency Management

The result of successful integration is the perception, by the user, of coherence and consistency between the different elements of information at his dis-

posal for carrying out a given task. Integration is of interest to decision-makers in Emergency Management since it reduces the overwhelming complexity of the situation at hand by creating logical, operational links between otherwise disparate elements.

Thus, for example, it is useful to know during an emergency both the meteorological conditions on-site as well as the situation of traffic on nearby roads. Yet, it is of infinitely greater use to decision-makers to be able to localize on screen the occurrence of heavy rain *shown in direct relation* to the highway adjacent to the site of the emergency at hand.

4 The need for integration in Emergency Management

Integration in the case of Emergency Management should create for the user a single, unified working environment within which s/he can carry out all relevant activities.

Emergency Management integration therefore addresses several related user needs:

- Integration of **information** from various sources, of heterogeneous formats and conveying different levels of meaning in order to provide the decision-maker with a comprehensive and coherent view of the emergency situation.

- Integration of, and cooperation between different computer-based **tools** used to deal with various aspects of Emergency Management e.g., evacuation, message exchange, simulation.

- Integration of the different aspects making up the **working environment** of the emergency manager into a single, unified command and control console e.g., telephone, computer, fax.

- Integration between the different tasks, carried out by a variety of actors, making up the overall complex **process** of managing an emergency e.g., abatement, evacuation, communication.

5 Information system issues of Emergency Management Integration

The above-mentioned, specific integration needs of emergency managers can in fact be addressed through the use of "classic" *integration techniques* commonly utilized in the development of complex information systems,respectively: **data, control, presentation,** and *process* integration.

Let us therefore consider further some of the specific needs of Emergency Management in terms of information system integration.

Data integration

- During an emergency there is a need to use in a tightly cooperative manner data which is integrated *exclusively* at the time of emergency e.g., information about traffic, hospital capacity and meteorological conditions. This impromptu nature of integration is virtually a "guarantee" that data will not integrate smoothly (recently updated formats, new limits on values etc.)

- Many sources of data, useful in an emergency, are confidential to some extent. Total owner control over information should therefore be guaranteed when making such data available to other systems.

- Many sources of data are set up with only a single software tool to exploit them in mind. Other software systems may thus find these data inflexible to exploit. A mechanism is therefore needed which enables the sharing of data through existing, independent tools.

- Very little, if any time is available to effectively set up data sharing from the moment an emergency is declared to the moment integrated data are expected to be made available. Data-sharing mechanisms must therefore be flexible enough to allow such *ad hoc* operations.

- Since different sources of data are the property of different organizations, they are almost inevitably physically distributed. Significant support for data distribution should be provided.

- Geographic data are by far the most requested type of information during an emergency [3]. Yet almost every single GIS product has its own propriety data management system. Several bodies are working on the standardization of GIS data-exchange [4]). A recognized, international GIS-data standard is therefore needed.

Control integration

- Emergency managers are, in the current situation, mostly using as decision support various stand-alone software tools developed by different vendors with no *a priori* intention in mind of co-operating with other systems. It is necessary to provide support for cooperation between systems at the software tool level on a variety of hardware and system-level software platforms.

Presentation integration

- Emergency management deals with very complex situations whence a profusion of information to be communicated to decision-makers. Presentation must therefore act at once as an integrator and as a filter, integrating only the most pertinent information and avoiding accumulation of integrated yet, at the same time, unexploitable information.

- During an emergency the decision-maker is literally flooded with information. It is therefore crucial that every bit of information presented to him/her is visually presented together with related information in a manner whereby the simultaneous presentation of different bits of information enhances their meaning for the user.

Process integration

- Emergency management is characterized by rigorous, pre-established procedures which define precise roles for people at different levels of the hierarchy whereas actions on-site are taken by *de facto*-autonomous agents in an order dictated to a great extent by the evolution of the emergency.

- Procedures are necessarily devised per *type* of emergency while each single emergency has its own very important discrepancies from the general "rule" or "order of events". Thus many of the most effective actions during an emergency are taken on the basis of intuition alone without reference to procedures and in a manner which may be difficult to structure.

It is therefore necessary to provide Emergency Management support which implements existing plans of action while leaving them flexible enough to take into account the effect of related events as they occur.

- Many actors with different skills and responsibilities are involved in managing an emergency. Moreover, the emergency is the first occasion for most of them to collaborate in an operational manner. There is therefore a need to provide Emergency Management support which is highly adaptable to the structure of the organization tackling the emergency.

We can thus characterize the need for integration of information necessary for Emergency Management decision support as:

- bringing together very heterogeneous, independent system elements,

- requiring short delay for its deployment,

- addressing a naturally unstructured work process,

- requiring a unified approach for the presentation of its results.

6 A common Reference Model as a means for achieving integration

Having demonstrated the need for integration of information related to the different aspects of Emergency Management we now need to propose a pragmatic approach for actually achieving it. The proposed approach consists of defining *a common Reference Model for Integrated Emergency Management - EMIRM*. The EMIRM defines:

- The information services which should be proposed to emergency managers.

- How these services are *used* in a cooperative manner i.e., what are the expected, standard exchanges between these services.

- How do these services cooperate on a *system level* to achieve a level of service satisfactory to the user.

These aspects are defined on a functional level which can then be implemented in any of several possible manners, on different platforms.

The EMIRM is *not* a description of a single system and its graphical representation (see figure 1) in no way constitutes a system architecture. The EMIRM should be considered on a *functional level*. To simplify, the EMIRM can be viewed as an elaborate, standard checklist which enumerates useful Emergency Management services and functions while describing how they can be used in a cooperative manner within an integrated information system. The cooperation between tools is defined from both a user and systems point of view. The EMIRM therefore provides:

- Principles, *at the functional level*, for developing Emergency Management information systems.

- Guidelines for evaluating existing systems according to the same criteria.

How should the EMIRM be used?

The EMIRM can be used in several manners:

- **Tool developers/vendors** can evaluate how the value of their specific Emergency Management tools can be enhanced through its utilisation in relation with tools and services addressing other aspects of Emergency Management.

- **Application developers** can examine whether their system addresses all the relevant issues required for achieving integration and how it is positioned in relation to other possible functions not yet provided by their system.

- **End users** (emergency managers) can obtain a wide, global view of possible services and functions and use the EMIRM to evaluate proposed tools and systems.

Most important is the fact that the EMIRM allows the important actors in Emergency Management system development i.e., emergency managers, tool vendors and system developers *to share a detailed, common basis for their cooperation.*

The rationale for the EMIRM

The authors believe the EMIRM can constitute a significant contribution to Emergency Management for the following reasons:

- Members of the Emergency Management community are greatly preoccupied with standardization of software and data used during emergencies. Their goal is to create significant synergy between the the skills and means of all actors involved. The EMIRM seeks to define a standard "Universe of Discourse" in the domain of Emergency Management i.e., allow different systems and their users to define the cooperation between themselves based on a common set of concepts and references. The "universe of Discourse" approach has been developed for and successfully used in other application domains (e.g., information system development as demonstrated in the European Software Factory project).

- A similar Reference-Model approach has proved very successful in other fields of engineering (e.g., [5], [6]) in even less favorable conditions i.e., a market where several established, conflicting commercial product offers are vying for a share.

- The baseline technology necessary to implement such an approach is already mature, with some components based on accepted industry standards. Distribution is addressed by OSF/DCE and OMG CORBA both of which are implemented by Commercial Off The Shelf (COTS) products. Message-based architectures are being standardized by industry leaders participating in the the CASE Communique group[5].

- This approach facilitates agreement and standardization on the conceptual level, while reckoning with the market-pull towards multiple-vendor offers. Some degree of integration is thus immediately supported which would not otherwise be possible if addressed exclusively at the implementation level.

7 The paradigm of the EMIRM

Although the EMIRM (see figure 1) can form the basis for many different implementations it is nevertheless based on several principles which clearly orient its underlying system paradigm:

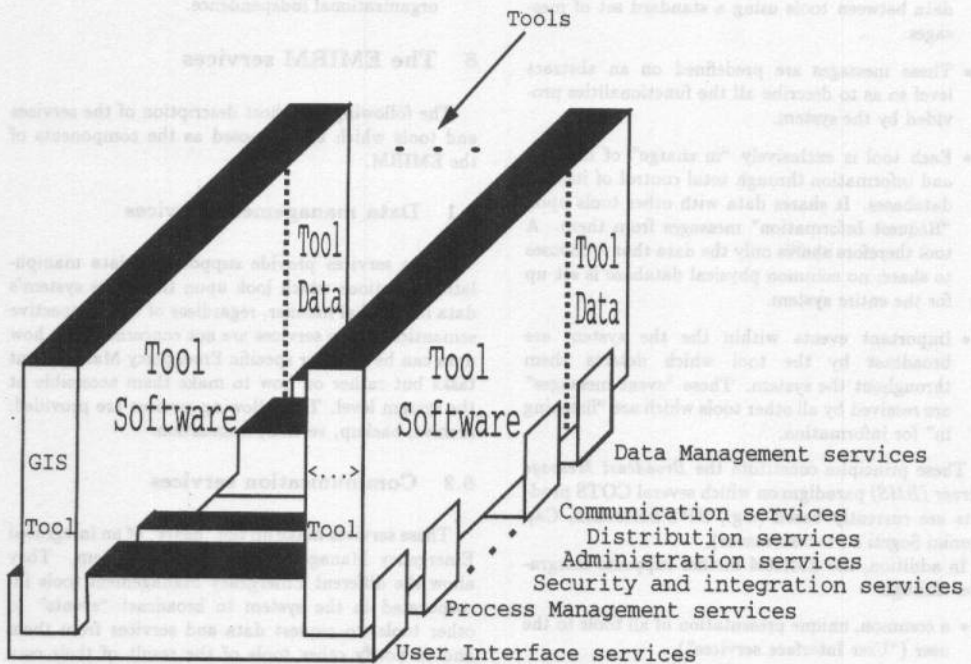- Each Emergency Management information system consists of

Figure 1: The Services and Tools of the EMIRM

- *software tools* which provide "visible", end-user functions.

- standardized *system-level services* which provide "invisible glue" i.e., integration between the above tools.

- Integration is achieved through the exchange of data between tools using a standard set of messages.

- These messages are predefined on an abstract level so as to describe all the functionalities provided by the system.

- Each tool is exclusively "in charge" of its data and information through total control of its own databases. It shares data with other tools upon "Request Information" messages from them. A tool therefore shares only the data that it chooses to share; no common physical database is set up for the entire system.

- Important events within the the system are broadcast by the tool which detects them throughout the system. These "event messages" are received by all other tools which are "listening in" for information.

These principles constitute the *Broadcast Message Server (BMS)* paradigm on which several COTS products are currently based (e.g., HP's Softbench, Cap Gemini Sogeti's ProcessWeaver).

In addition, the EMIRM further supports integration through

- a common, unique presentation of all tools to the user ("User Interface services"),

- the operational use of Emergency Management procedures and processes in order to place each tool in the most appropriate context of utilization.

This approach is a promising one since it addresses several realities of Emergency Management information systems:

- The approach is, by definition, incremental. Any "external" tool can be made to exchange messages with the "tools" and "services" through the addition of a standard BMS software layer to the existing software.

- No database, common to all tools, is set up. Such common databases are very difficult to develop and even more difficult to maintain and update.

- The tools,, *and their different users*, retain total control over their data. Their participation in an integrated system in no way jeopardizes their organizational independence.

8   The EMIRM services

The following is a short description of the services and tools which are proposed as the components of the EMIRM.

8.1   Data management services

These services provide support for data manipulation functions which look upon the entire system's data in a global manner, regardless of their respective semantics. These services are not concerned with how data can be used for specific Emergency Management tasks but rather on how to make them accessible at the system level. The following services are provided: archive, backup, version, transaction.

8.2   Communication services

These services make up the "heart" of an integrated Emergency Management information system. They allow the different Emergency Management tools incorporated in the system to broadcast "events" to other tools, to request data and services from them and to notify other tools of the result of their own requests. The following services are provided: message handling, event notification, tool-interface management.

8.3   Process management services

These services provide support for using the different Emergency Management tools in accordance with a scheme which defines the Emergency Management life cycle. Indeed, the Emergency Management process can be defined in terms of tasks to be performed, actors performing them *and the software tools needed to carry out each of them*. The process management

services therefore provide the link between the organizational aspects of Emergency Management and the underlying technology enabling their utilization.

The following services are provided: process monitoring, process enactment, process scoping.

8.4   User Interface services

The user interface services provide common means for all Emergency Management tools to communicate with the user i.e., presenting the system's information to him/her through controlled dialog. These services thus allow the user to have a single, coherent perception of all the components in the system through display and input mechanisms common to all tools e.g., dragging objects between windows.

The following services are provided: dialog management, display management, user assistance, error message handling, internationalization.

8.5   Security services

These services provide support for the control of access to the system and the rights of different users to execute different operations through this access. The provided services are: operation control, tool enactment, authentification.

8.6   Administration services

These services provide support for the system managers (*not* the emergency managers) in the day-to-day monitoring of global system operation and performance. The following services are provided: system log, statistics, file and tool activation.

8.7   Distribution services

These services provide support for satisfying one of the major requirements made on emergency Management information systems: operation within a distributed working environment. Distribution implies that while users, tools and databases are located on remote sites they still need to cooperate within a close-knit organization. The following services are provided: location, network.

8.8   Emergency management tools

Although different Emergency Management information systems can be required to support very different sets of functionalities it is expected that all such systems will be requested to provide some level of support for certain reoccuring functions. For the need of the EMIRM it is assumed that each of these functions is implemented by a distinct software entity i.e., tool.

The following tools are provided: geographic functions, dialog management, emergency procedures management, risk assessment, evacuation management, training.

Of particular importance are the geographic functions. Indeed, these functions can in some cases form, on their own, the nucleus of a small-scale Emergency Management information system which satisfies many user requirements. Nowadays, these requirements can be satisfied all the more efficiently as many high-quality GIS COTS are currently available.

9   An implementation based on the EMIRM

The MEM*brain* project is currently the single most ambitious European project in the development of information technology for Emergency Management.

Within the project the EMIRM has been used during the preliminary phases in the aim of:

- clearly defining those emergency management tasks which stand most to benefit from the use of information technology,
- giving the different functions their respective priorities within the project's different applications,
- allowing a distributed, international tool development process given a the common reference framework.

The use of the EMIRM has had a clear influence on the MEM*brain* system architecture inasmuch as it is based on a specific integration paradigm i.e., broadcast messaging. Nevertheless, the project unites 9 partners in 6 different countries thereby making system heterogeneity a central issue to be reckoned with. The use of the EMIRM has allowed the different applications using MEM*brain* technologies to make divergent baseline choices in areas such as GIS, DBMS and User

Interface with minimal effect to the common development process and results.

Moreover, the use of of the EMIRM has made it possible for the MEM*brain* project to develop Emergency Management tools and services which are then included in applications based on different system platforms. Several of these applications incorporate legacy software and databases. Utilization of the EMIRM has allowed to upgrade the results of past investment for use in a state of the art environment.

10 The evolution of the EMIRM

The MEM*brain* experience has shown that the EMIRM can form the basis of an international effort aimed at opening Emergency Management information systems to each other and to the wide offer of information technologies currently available.

The authors are encouraged by the fact that similar efforts in other fields of information system integration have proven very successful over the past three years (Object Management Group, Open Software Foundation, Case Communique, European Computer Manufacturers Association).

In this perspective it would be necessary to set up a moderated, international working group bringing together Emergency Managers and technology providers. This group will:

- Widen the current scope of current service definitions. This activity has already been started by analysing each service through several complementary angles or "dimensions", each service description thereby consisting of an analysis of this service through this dimension. The following useful dimensions have been identified: conceptual, external, internal, related service, application, examples.

- Define, at a conceptual level, the Emergency Management Universe of Discourse including all the entities, operations, actors, their integration and their respective roles.

- Match the EMIRM with available tools and systems in order to establish an in-depth state-of-the-art.

These activities form a necessary condition to the acceptance of an Emergency Management standard further down the road.

Acknowledgements

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