A framework for web-based dissemination of models and lessons learned from emergency-response exercises and operations

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Abstract: Emerging web-based technologies enable information sharing within and among rescue agencies and organisations. This development can facilitate education, training and development through effective distribution of documentation, models and lessons learned from training exercises and rescue operations. We discuss central aspects of this enterprise such as the need for domain-specific data models, methodologies for detailed exercise documentation, and the design of presentation and visualisation tools. Based on this investigation we present a framework that supports modelling, documentation and visualisation of rescue operations for web-based distribution. We briefly describe the implementation of the components of the framework. Finally, we discuss how to apply the methodology and framework to training of first responders and university-level education of emergency managers and officials.

Keywords: Modelling; visualisation; web publication; lessons learned; information dissemination; training; education; emergency management and response.

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1 Introduction

Our society's ability to reduce risks of emergencies, to respond to them, and to mitigate their effects depends on its capacity to establish and maintain adequate national and international infrastructures for emergency management and response. Examples of such infrastructures are command-and-control organisations, communication networks, response teams, and programs for training and education. Effective exchange of information about plans, procedures, operations, exercises and lessons learned among agencies and organisations is critical to ensure that the services provided are of high quality. This exchange requires an information infrastructure that can support activities and groups of users throughout the emergency management and response community. However, there remain many issues concerning both the requirements and the implementation of such a framework that require further investigation.

New web-based technologies for the internet enable novel ways of disseminating knowledge and lessons learned to individuals, groups and organisations. However, it is vitally important that we introduce these technologies in a methodologically sound way. For instance, we have to ensure that data is authentic, traceable, and up to date before we publish it on a website. There are also several issues regarding who owns the data and who is responsible for keeping data valid and complete. Real-time command and control imposes time constraints, which may or may not render these technologies inadequate for supporting command and control of real operations.

In this paper we examine the requirements of a framework capable of supporting dissemination of information about emergency response operations and exercises conducted. We demonstrate how systematic data collection, modelling, information compilation, and publication of documents, models, existing plans, and lessons learned can facilitate emergency planning, development of operating procedures and tactics, training, and education. Because an information infrastructure has to support such diverse activities, there are many different groups of users, for example policy makers, commanders, managers, and first-responders. These user groups have their own information requirements, which makes it necessary to provide the same basic data in many formats to support customised views. In the paper we elaborate on user-centred information representation and visualisation and introduce domain-specific data models as a means of capturing specific user needs.

The rest of this paper is organised in the following way. In the next section we discuss the general problems of disseminating information from emergency response operations and exercises in a heterogeneous community. We then describe the purpose and audience of our proposed framework and outline its principal design. Finally, we investigate three applications and show how they benefit from the information framework.

2 Information management problem

A recent report published by the US National Academy Press [1] deals with the topic of informational technology research for crisis management. The report emphasises that all phases of emergency management – that is, planning, mitigation, response and recovery – are information and communication-intensive efforts which impose heavy demands on information technologies. For example, the 'instant bureaucracies' that must form and cooperate to manage a given crisis typically over-burden existing communication systems. The amount of information, which could be useful in managing the crisis, is typically too much for managers and incident commanders to process and utilise to good effect. New ways are needed to simplify and consolidate information so that it is really useful in managing resources and effectively communicating among agencies.

The various organisations that are set up in our countries to serve and protect our society are based at separate geographical locations and have different resources available depending on factors such as population density, geographical conditions and the possible presence of dangerous facilities or plants. However, the organisations share a need for training and require the ability to learn from previous incidents and rescue operations. Several individuals and organisations collect data during a rescue operation. But the information has different formats and is reported to different destinations. To support data collection and information sharing it is necessary to provide the actors with relevant methods and tools. In this way it is possible to enter the information in a format that fulfils both the requirements of the local organisation and makes it available to the members of the common information network.

On all organisational levels there is a need for communicating new findings and observations in order to increase the knowledge and experience throughout the emergency community. Examples of this type of information are rescue plans that have proven to be successful in particular situations, efficient use of new equipment, and tactical lessons learned in situations previously not encountered. In addition, it is important to make it possible for other than the participants in large-scale emergency exercises to take advantage of the concluding findings and the lessons learned.

To utilise the information that exists in the different rescue organisations today we need to understand relations, responsibilities and capabilities of different actors in the field. Based on this understanding we can analyse the current situation and make a map of the status of the participating organisations and their maturity when it comes to managing the information related to their rescue activities. To be successful in this effort, we need an information strategy and a clear goal for the activities that are carried out at different organisational levels. When an organisation in the rescue community takes on new systems and procedures, the information strategy and the models available from the policymakers should support the development work and at the same time make the resulting system compatible with the overall information network. In this work it is very important to realise that adhering to strategy is not an extra burden, but a key to get more value from the infrastructure investment.

3 Purpose and audience

Before introducing new procedures or systems in an organisation it is important to investigate the purpose of the introduction and to analyse potential benefits as well as expected costs. Some of the purposes with the introduction of methods and technology presented in this paper are to:

- Publish policy documents, instructions and regulations.
- Report incidents and results to authorities and agencies.
- Plan emergency operations for various potential scenarios.
- Train rescue personnel at different organisational levels.
- Analyse conditions and trends in previous operations to identify systematic problems in tactics, techniques, and procedures to be able to inform other members in the rescue community.
- Support research of the field of emergency management and response.

In another part of the investigation we analyse the consequences of new procedures and systems to identify the potential audience. This audience typically consists of users and personnel who will benefit from the new methods and tools. In our case we have identified the following audience:

- *Policy makers.* The new technology makes it possible for policymakers to reach the rescue community with short notice and to regularly send or publish new information that affects various rescue organisations. One example is that the US Federal Emergency Management Agency (FEMA) publishes the courseware of different rescue training courses on the internet so that the course material can be used as a resource for education and training at the local level.
- *Commanders.* Training can be facilitated by preparing the personnel for live exercises with information and lessons learned from similar exercises and operations in the rescue community. The rescue commander can select appropriate information and distribute it among the members of his own organisation.
- *Planners*. Planners can keep their plans up to date by retrieving new findings from the rescue community. For example by analysing the results from various exercises that have been conducted with detailed data collection.
- *First responder.* First responders can increase their safety by conducting after-action reviews after critical incidents and by reviewing after-action review reports from other members of the rescue community.

4 Information framework

A framework for dissemination of information originating from exercises and real operations has to meet several requirements, some of which may be in conflict. When we arbitrate between conflicting design goals, we have to constantly keep the overall objective in mind: *to make diverse types of information available by providing mechanisms for publishing it and accessing it in a distributed environment*. This goal is the most important one because the main purpose of the framework is to promote learning and improvement by critical reflection on past experiences through information sharing in the rescue community.

Figure 1a shows the hierarchical structure of a hypothetical rescue organisation. To be effective and comprehensible the structure of the information framework has to reflect the structure of the information exchange in the rescue community as indicated in Figure 1b. When the information needs changes, the framework has to be able to adapt accordingly. A design based on the static hierarchical arrangement of units, as depicted in Figure 1a, is too inflexible. Conversely, the topology of the communication network conveying the information only rarely reflects the logical structure of the information flow (see Figure 1c). Moreover, the communications routes in a web-based information system change dynamically and are hard to predict.

Advances in science and technology will provide new, rich sources of information that can be included in the information-processing network. At the same time, novel ways of combining existing and future information sources will be invented. Consequently, the framework has to be flexible enough to accommodate a variety of information sources and information users. Moreover, information users typically combine information from different sources to form new pieces of aggregated information. When they make this new information available they become information sources, too. Thus, the roles of source and user may change depending on the context.

4.1 Generic information processor

We define the concept of a *generic information processor* (GIP) as the basic entity of the framework. Every information source and information user can be modelled as a GIP. Figure 2 shows a graphica representation of a GIP. A GIP defines one or more *document types* representing the data formats it is able to generate and publish. The document types can either be standard or custom-defined. A GIP has a unique name, which is used to identify it and locate the information it publishes. Additionally, a GIP defines zero or more *virtual archives* that describe the input information the GIP requires to generate its output documents. In fact, a virtual archive is merely a catalogue of references to documents published by other GIPs. A GIP can act both as an information source and an information user depending on whether it imports data by defining any virtual archives. The internal working of a GIP is hidden from the world; A GIP is only defined by its name, the documents it publishes and the virtual archives it has.

Figure 1 Three views of the structure of a rescue organisation: (a) the organisation chart defining the hierarchical relationship between units; (b) the information flow for a particular purpose in a rescue organisation; and (c) the structure of the communication network conveying the information packages

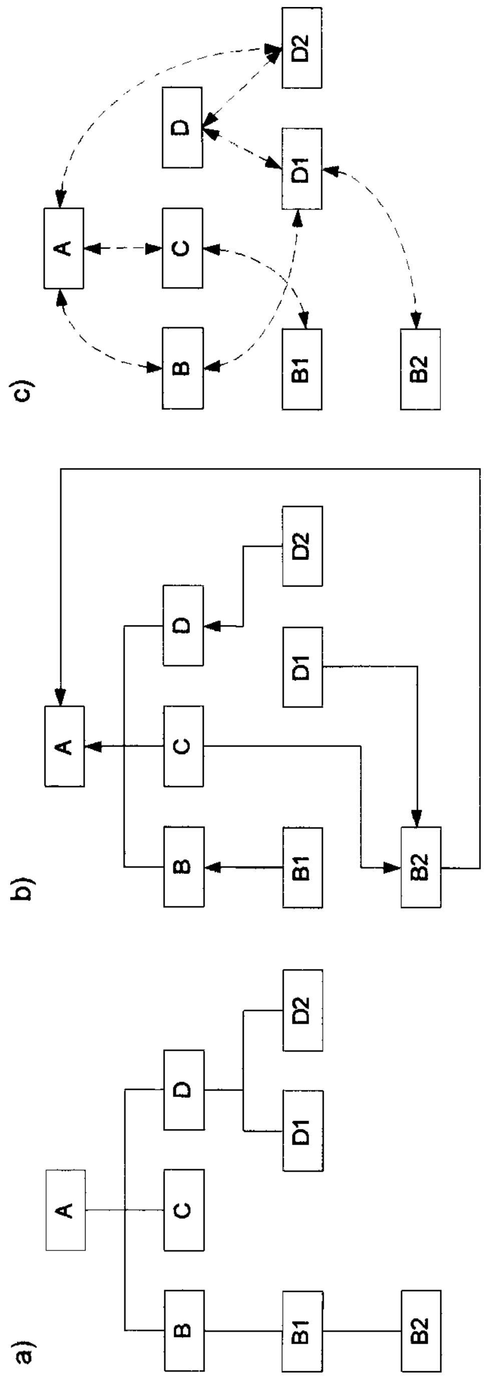
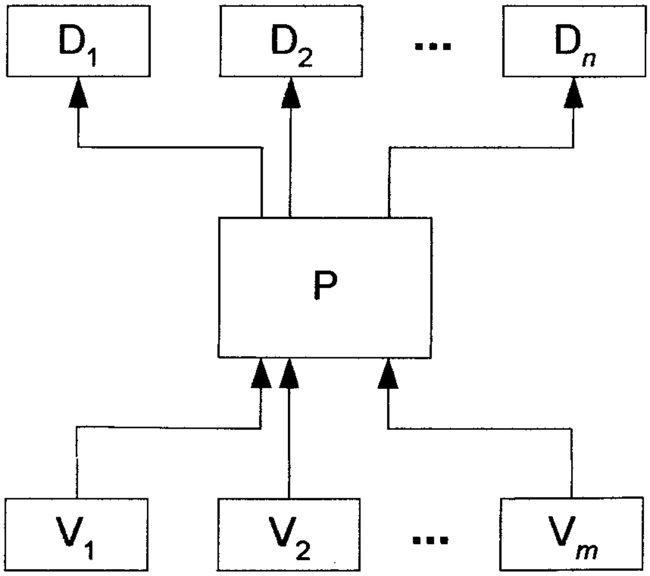
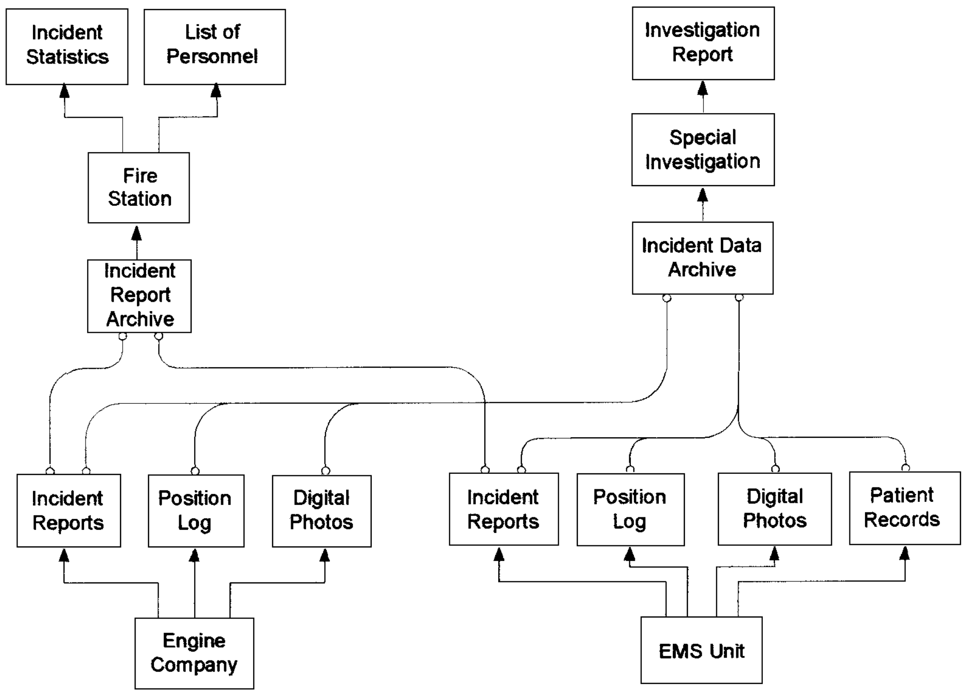


Figure 2 The generic information processor in the framework. Using *m* virtual archives $V_1,\ldots,V_m$, where $m \geq 0$, the processor P publishes documents of *n* different document types $D_1,\ldots,D_n$, where $n > 0$



Each GIP publishes information that is either generated by the GIP or collected from other GIPs and processed. Thus, the framework is based on the principle that every GIP will have to look up and retrieve the information it needs. The reason for this approach is that it makes it very easy to add new GIPs when the information requirements change. Figure 3 shows an example involving four GIPs. Three of them represent a fire station with two responding units. In this part of the model the information flow actually corresponds to the hierarchical organisation of the units. However, the fourth GIP illustrates the strength of the approach when it comes to modelling information flows across organisational structures. After a severe incident a special team is often formed to investigate the incident to establish its cause. In Figure 3 we see how the special investigation GIP is introduced. It defines a virtual archive that includes all relevant document types from the two responding units. The investigation GIP uses the information in the documents collected to create and publish the investigation report.

Figure 3 An example with four generic information processors (GIPs). At the bottom there are two GIPs representing a fire engine company and an emergency medical service (EMS) unit. These units are located at a fire station represented by another GIP. Both response units act as sources publishing incident reports, GPS position logs, and digital photographs. The EMS unit also publishes patient records. The fire station GIP collects incident reports in its incident report archive and publishes incident statistics. In addition it publishes a list of personnel assigned to the fire station. The fourth GIP represents a special investigation, for instance after a severe accident. This GIP collects all available data from the responding units to create and publish an investigation report



4.2 Document types as data models

Document types have a key role in the framework, as they are the means of distributing information about what data is available from a GIP and about the format used to store this data. Although document types define different data formats, they have some types of information in common – for instance, a unique type identifier making one document type distinguishable from another. Furthermore, all document types define information about who published the document and when it was created. Search programs can use optional keywords describing the contents of a document to collect information from a network of GIPs.

A document type may include any type of data in any format it would like to use. However, to enable information sharing the document type definition itself has to be in a well-defined format that is easily accessible across a heterogeneous network. So, while the format of data is arbitrary, the format of data definitions needs to be rigorously defined. In this way any custom-defined data models can be incorporated and distributed in the framework as long as the format of the data can be scrupulously defined as a document type.

The typical GIP retrieves information in the form of documents from one or more GIPs, processes the information in some way, and publishes the results as another document. By prescribing that source information should be preserved when information is aggregated, we enable tracking of the various sources used to build an aggregated document. This ability to trace aggregated information back to its original sources is particularly useful for checking the motivations for subjective conclusions.

4.3 Organisational issues

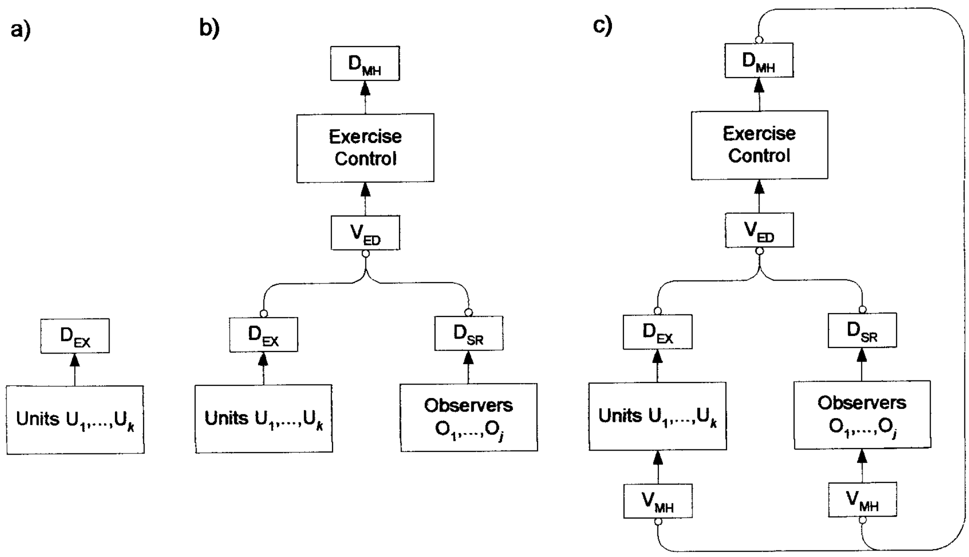
So far we have concentrated on modelling the flow of information as illustrated in Figure 1b in a general way using GIPs. Even though the framework presented stresses the distributed nature of the data exchange among cooperating units, the traditional hierarchical organisation of these units is important as well. As indicated in Figure 1a, it provides the necessary structure for defining responsibilities, to enforce standards, and to prescribe what minimal set of document types subordinate units are required to publish. Also, it provides a backbone for administrating common information services required in the framework such as dictionaries and access control mechanisms. Two directory services are required in the framework: a *dictionary of document types* and a *dictionary of GIPs*. The dictionary of document types can enumerate the types defined, whereas the dictionary of GIPs allows us to query for GIPs that support a particular document type.

4.4 Implementation notes

Although a detailed description of the implementation of the information framework is beyond the scope of this paper, we shall make some notes concerning implementation strategies. Clearly, the advent of the World Wide Web and the associated technology support the development of distributed applications for the internet and for proprietary intranets. Much of the information published by various GIPs will be accessible using a standard browser. As a result framework issues such as access control, user authentication and data security can be handled using standard solutions available today.

A key to successful information management is the ability to describe the information available in a strict way. From an implementation point of view these descriptions have to be available across the network irrespective of the type of platform or browser being used by different users. The *Extended Mark-up Language* (XML) provides a text-based format that allows publishers to describe the information precisely while still allowing standard tools to browse, search, store and process that information [2]. The origin of XML is SGML (Standard Generalised Mark-up Language), which is a meta-language for creating new languages in order to describe any kind of information [3]. Most contemporary web browsers support XML, which makes it a candidate for describing and representing information in the rescue domain.

Figure 4 A model of how exercise data are collected and processed to support training feedback. The picture shows: (a) a set of *k* units participating in training, each of which collects and publishes exercise data (D_{EX}); (b) a set of *j* observers supporting the exercise, each of which publishes structured reports (D_{SR}), together with an exercise control that collects exercise data and observations and publishes a mission history (D_{MH}); and (c) a feedback loop where the model of the exercise is accessed by both nits and observers to get feedback on the exercise



5 Applications

To demonstrate how the framework defined helps us to model the flow of information in rescue operations we provide a number of short examples. In the first example we use the framework to represent the information flow at a taskforce training exercise [4]. In this scenario a taskforce consisting of k units respond to an incident (see Figure 4a). We assume that the exercise is supported by an instrumentation system, such as MIND [5,6], that collects and visualises exercise data. In this example units and observers act as data sources, making exercise data and structured observation reports [7] available to the exercise control as shown in Figure 4b. The exercise control collects this data and compile it into a *mission history* [8], which is an executable model of the course of events of the exercise. The exercise control publishes the mission history as a document. By adding virtual archives to the GIPs representing units and observers the mission history is fed back to the exercise participants and observers to help them learn the lessons of the exercise (see Figure 4c).

Another application of the framework is to disseminate mission histories as a basis for evaluating common practice, standard operating procedures, regulations, and instructions. In Figure 5 we can see how this evaluation may lead to modifications of the regulations and how the current regulations and instructions are published as a document, which the rescue units can access.

Figure 5 A model of how exercise data can be used to evaluate the regulations and instructions in use. Mission histories (D_{MH}) from multiple exercises are used to evaluate the exercises with respect to regulations and instructions (D_{REG}). The result of the evaluation (D_{EVAL}) is used to modify regulations whenever necessary. The current set of regulations governs the activities of the rescue units, which access regulations and instructions through a virtual archive (V_{REG})

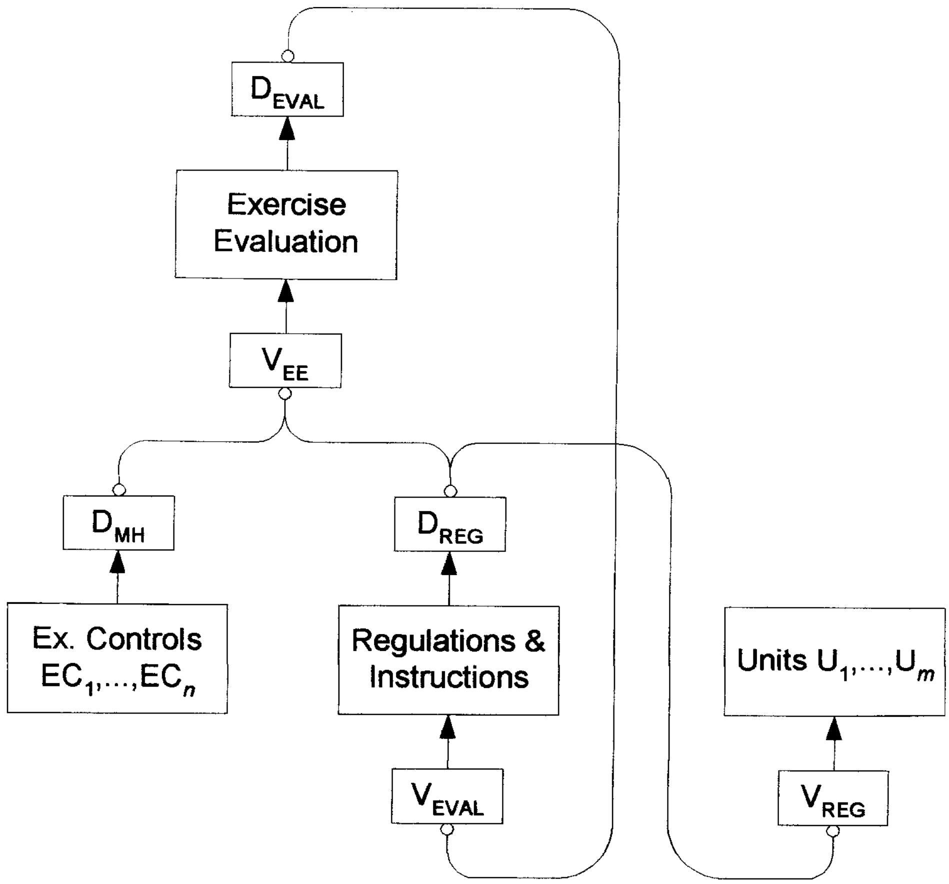
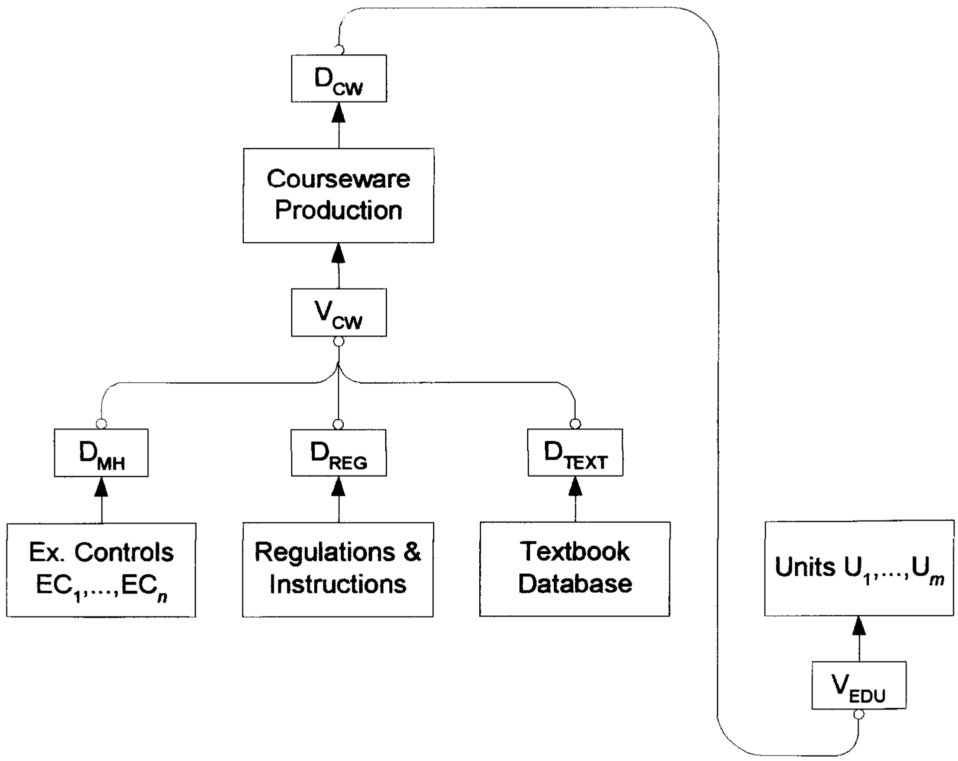


Figure 6 illustrates how exercise models represented as mission histories can be included in courseware for distance education. This type of augmentation has the potential of making the courseware much more interesting for the course participants by adding a dimension of authenticity. In this way the framework can support education projects such as the FEMA's *Higher Education Project* and various web-based management courses at colleges and universities.

Figure 6 A model of distance education based on courseware combining textbook material (D_{TEXT}), regulations and instructions (D_{REG}), and illustrative examples from previous exercises (D_{MH}). Detailed models of exercises performed can provide an illustration of key points made in the text and give examples of successful and not so successful approaches to solving common problems



6 Conclusion

Information exchange between different organisations in the rescue community can greatly improve the way operations are carried out in response to serious incidents. Effective dissemination of incident reports and lessons learned form both real operations and exercises has a high priority in this work. A first step toward seamless information exchange can be to make information collected at computer-supported taskforce training exercises [4] available. By using the internet or a proprietary intranet we can disseminate detailed models of such exercises – and the lessons learned from analysing them – to a broad audience in the rescue community. However, the lack of a proper information infrastructure is a serious impediment to this development.

The framework presented in this paper is an attempt to overcome this obstacle by defining, in a very general way, the main mechanisms in web-based information exchange. The intention is to provide a foundation for analysing information needs and information flows based on user data. Furthermore, it can serve as a starting point for defining implementation strategies for multi-organisational information systems.

Cooperation across agencies and other organisations in the rescue community should be encouraged. It is not a matter of designing the ultimate information system for all branches of the rescue domain, but to increase the understanding of how information collected from different sources can be used for multiple purposes. Moreover, it is a question of how we can manage and distribute this information to make it available throughout the rescue community to make it a part the accumulated body of knowledge.

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