A Multimedia Approach to the Efficient Implementation and Use of Emergency Plans

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Personnel safety is a crucial aspect of organizing and managing public transportation. Accordingly, personnel safety has a strong legal component because any form of public service involves an often large corpus of local and national regulations concerning safety. Organizations and companies offering such services are legally bound by these safety regulations, and their actions during an emergency are measured by how closely they follow existing regulations. To demonstrate compliance with regulations and guide appropriate reaction to emergencies, public transportation organizations are required to devise and maintain an emergency plan. The plan serves both as a legal document and a manual that describes procedures for dealing with emergencies. Every organization offering a public service must provide an emergency plan, which must be submitted to and approved by the corresponding authorities. It contains information about the kind and location of available safety equipment (such as emergency exits and fire barriers) and the detailed procedures to follow in a number of eventualities (for example, a fire in a subway tunnel, crashes, and equipment malfunctions).

The emergency plan is generally a complex document integrating all the information needed to preserve human lives in emergency situations. For instance, in a large building, the plan would contain maps clearly highlighting every emergency exit as well as all safety equipment, such as fire extinguishers. It would also explain how to route people at each floor to the corresponding emergency exits and in which order, the alternative routes to take in case some are blocked, dangerous spots to avoid in the building, entry points for rescue workers, and so on. In other cases, such as subway systems or airports, the emergency plan is far more complex, involving many people and many different possible threats and eventualities.

Responses to emergencies are normally coordinated from a centralized location where safety managers use the emergency plan as a decision-making guide. Trained personnel should, of course, be familiar with the plan and most emergency procedures, but in many cases, a task's sheer complexity requires that personnel take the time to read the emergency plan to follow its instructions step by step.

Because of the complexity of emergency procedures, the stressful situations during which they're executed, and the large margin for exceptional events, the emergency plan must be meticulously designed so that safety managers can quickly find needed information. Regardless of the complex procedures it describes and the trying situations where it would be used, the plan's success is always measured by how effective the evacuation is. Thus, safety-conscious organizations continually try to improve their emergency procedures and the way they present them in the emergency plan. Even so, most emergency plans remain as plain-text documents. Integrating incoming information during an emergency and correlating this information with the plan's procedures is a manual task for many safety managers. The danger is that the emergency plan can quickly become a bottleneck during the very emergency for which it describes procedures to resolve it.

We've faced this problem in the context of improving and optimizing the plain-text emergency plan for the subway system of Valencia, Spain, a mid-sized city.[1] Our solution was to turn the emergency plan into a multimedia software system that integrates text, audio, video, 3D

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models, and animations for handling emergencies in underground metropolitan transportation. In a first stage, we replaced the printed, sequentially ordered plan by a hypermedia, multimedia document that allows context-sensitive and adaptive browsing of its contents. Consequently, finding and correlating information in the plan during an emergency has become much more efficient, resulting in remarkably improved response time to emergencies.

In a second stage, we enriched the plan's multimedia content to facilitate interpretation and understanding under stressful situations. Our goal was to reduce textual content and replace it with workflow-like graphical descriptions of the procedures; that is, at any step in the hypermedia navigation, users have available all the information they need to make the decision. These context-aware graphical descriptions are linked to 3D maps of the subway system. For instance, we've shown evacuation paths superimposed over maps and accompanied them with video streams showing the evacuation route. We've also added 3D animations that give a much more direct, improved view of the infrastructures, safety equipment, and building structure. This information greatly facilitates guiding people through the evacuation routes and gives safety managers a more precise idea of where the emergency is developing.

Metro Valencia's plan

Metro Valencia is the public company that manages the railway transportation in the Valencia metropolitan area. In 1998, the Metro Valencia Safety Office began developing a system to improve its emergency plan. The Hypermedia Emergency Plan has been operational since June 2000 at the Metro Valencia's Traffic Control Office.[2] Before the Hypermedia Emergency Plan was developed—which is installed in a special-purpose server and accessible by 21-inch touch screen—emergency personnel were forced to consult the text-based emergency plan containing more than 100 pages of procedures. The document also contained surface maps of all stations, tunnels, and surface railways, and detailed descriptions of associated safety equipment. As a result, it was difficult for the Traffic Control Office to handle different types of information simultaneously because they were located in different parts of the plan.

Without a Hypermedia Emergency Plan, emergency procedures are carried out manually. When an abnormal situation such as fire in a train occurs, the train driver must decide, depending on the magnitude of the emergency, whether to stop the train immediately or—significantly simplifying passenger evacuation—proceed to the nearest station. In either case the driver, upon becoming aware of the fire, must notify the safety manager at the Traffic Control Office of both the fire and the train's location. The safety manager initiates the emergency handling process according to the emergency plan.

First, the safety manager must quickly evaluate the situation before making the subsequent decisions: alert the staff in the station (where the passengers are headed) about the emergency; request the traffic controllers to stop train circulation in the affected subway line; and tell the installation managers to turn off the lines' electric power as soon as the train is stopped and passengers disembark.

The subsequent coordination process involves relaying appropriate instructions to the respective authorities for assuring that passengers safely evacuate. The train driver, for instance, is in charge of the passengers until the train arrives at the station. At that moment, the station manager on duty is responsible for the evacuation's second step. Other actions are also triggered by the safety manager according to the emergency plan, but we omit them for space reasons. The safety manager's task is complete only when passengers are safe and firefighters have the fire under control.

Handling all this information isn't easy. Stressful emergency situations can lead to undesired delays, resulting—in the worst cases—in the loss of lives. The advent of the Hypermedia Emergency Plan, however, has greatly streamlined the execution of emergency procedures. Currently, when an emergency occurs, the safety manager interacts with the hypermedia plan instead of the paper-based plan. From the information transmitted by the driver, the safety manager selects—from a computer screen menu—the type of emergency and the train location, and starts the coordination of the actors involved in the emergency resolution process. Once the emergency is identified, if the damaged train is en route to a station, a screen like the one in Figure 1 (next page) displays. There, a 3D model of the station gives a bird's eye view of every possible escape route. Under the model in Figure 1, three text frames contain the actions to be taken by the train driver and station staff (bottom center) and the safety manager (bottom left). When the safety manager selects an escape route, a 3D animation of the route displays at the bot-

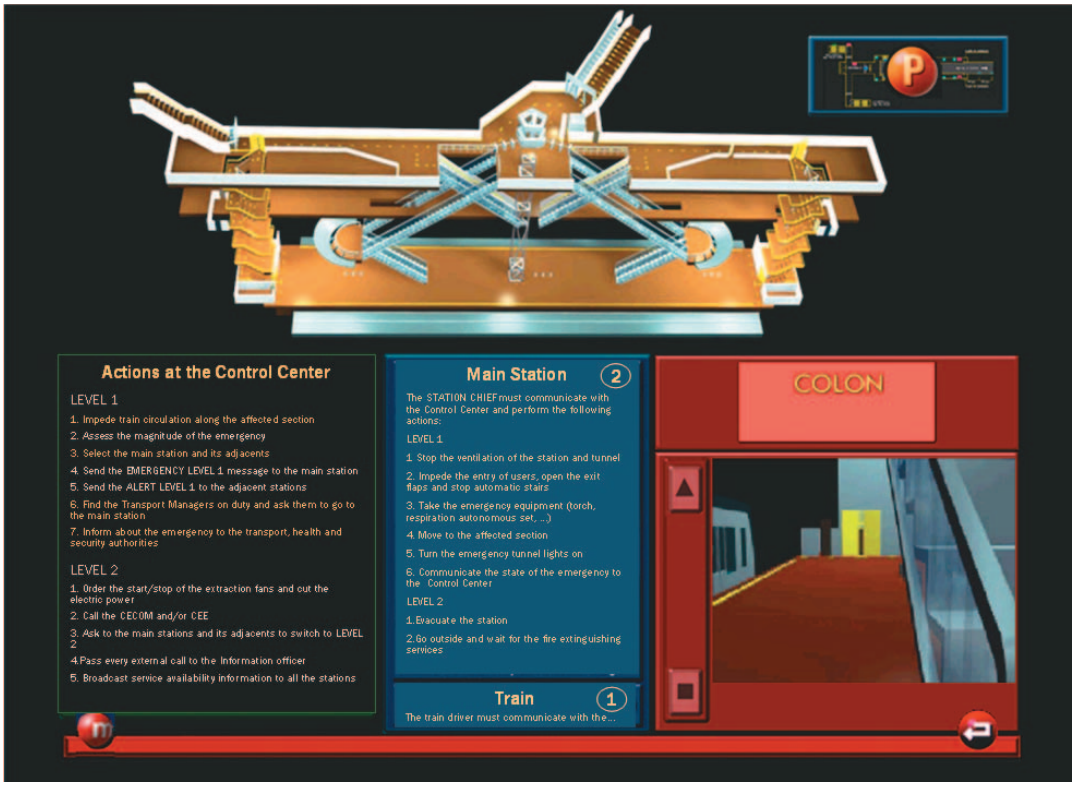

Figure 1. Screen shot of the Hypermedia Emergency Plan for directing passenger evacuation in a subway station.

tom right of the screen. The information that was located in different sections of the paper-based emergency plan is now integrated on one screen, which saves crucial time previously spent flipping pages and thumbing through different parts of the plan document.

Other types of multimedia information appear in other contexts. For instance, surface station maps show that the safety installations (see Figure 2) are reachable through the icon at the top right of Figure 1. If the driver stops the train before arriving at the station, videos of tunnels and street maps are available to help the safety manager precisely locate the train and guide firefighters to the nearest tunnel entry, as Figure 3 (on p. 110) shows. Having all this information at hand simultaneously while using a paper-based emergency plan was impossible.

Lessons learned

Emergency management is entering a new era marked by the use of information technology to streamline incident resolution processes. In this article, we've shown how multimedia technology can play a crucial role in helping to manage emergency situations. Specifically, we transformed the emergency plan of a public transportation company into a multimedia software environment that combines information from different sources to produce an accurate and easily understandable description of emergency procedures. Thanks to this approach, and according to the drill exercises performed in the Metro Valencia staff training program, both the response time during emergencies and number of human errors made when following the plan's complex procedures have been significantly reduced.

Our solution is applicable to other public service organizations like hotels, stadiums, theaters, and even whole cities in case of natural disasters. Although every situation is different, and many specific details must be taken into account, systems supporting emergency management (what we call *safety-oriented systems*, or SOSs) must fulfill two basic requirements. First, they must provide multimedia storage and delivery. Second, they must support advanced, workflow-like navigation of the available information. By combining multimedia and workflow technologies, the system facilitates access to all necessary information in the appropriate order by enacting the workflow processes that describe the emergency procedures.

Based on our experience gathered from the Valencia project, we've identified a number of issues that need attention and further research before SOSs are widely used:

- *Process*. The resolution of an emergency is the execution of a process, the specification of which includes the participants, the time-ordered actions they must perform, the information consumed and generated by each action, and so on. The process must be amenable to exceptions and can't impose a strict execution order but leave the emergency manager with enough leeway to adapt as the situation evolves. Recent proposals in this area and with close ties to Web services—such as the Business Process Execution Language for Web Services specification (http://www-106.ibm.com/developerworks/webservices/library/ws-bpel/) and Business Process Modeling Language (http://www.bpmi.org/bpml.esp)—can be advantageous to developers for standardizing and even normalizing the description of these procedures.

- *Presentation*. Participants will perceive the emergency resolution process in different ways since they consult different information pieces—such as maps and pictures—to perform their activities. The system information, therefore, must be amenable to different presentation modes that selectively emphasize whatever information is more relevant at a given moment. Efficient handling and coordination of such views will be crucial in letting several emergency managers interact with the system simultaneously from different locations.

- *Information management and retrieval*. Safety-oriented systems are complex systems, handling very different types of task-related multimedia information. Moreover, the information's relevance and validity can change as the emergency develops. Consequently, an SOS requires dynamic delivery of information.[3] We can fulfill such a requirement with current digital library technology, but many related issues concerning middleware, data caching, and data distribution must be improved.

- *Communication*. During an emergency, numerous communications take place. Reliable communication channels must support the voice interaction between participants involved in handling the emergency. Similarly, a significant amount of multimedia data must be transmitted, fast and reliably, to the different devices used. Here, research in ubiquitous computing will have a great impact in the interim. In particular, linking the system to sensor networks, and emergency workers' using mobile computing devices, will let the system obtain—and offer—a much more accurate picture of the situation than is possible today.

- *Collaboration*. Once an alarm has been activated either by sensors or human communication, experts in different fields can be called to e-meetings to analyze the situation, assess damages, identify potential risks, and advise managers in their decision making. After the emergency is resolved, experts can collaboratively assess the process and give safety managers insight for improving processes. A different type of collaboration is the interoperability between the SOS and other applications used in a given organization. A complete SOS must support a continuous improvement process; it's unacceptable for an emergency plan to become obsolete simply because it's difficult to update and change the system implementing it.

- *Intelligence*. Intelligence is the system's ability to generate valuable information from data collected from different sources. Sometimes these sources may be sensors, the data of which may be combined via information fusion techniques[4] to give the user consolidated information, rather than raw data, thereby saving time in critical moments.

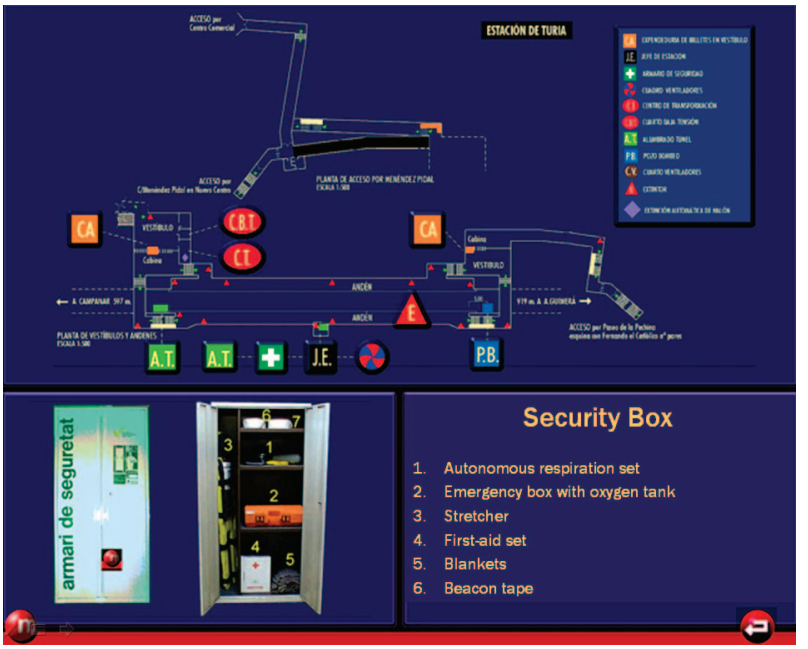

Figure 2. Surface map of a station and detail of safety equipment.

Figure 3. Selecting the evacuation path in a tunnel.

Conclusions

Safety-oriented systems are a significant and complex challenge because of the critical situations in which they're used and the restrictive requirements they must meet. Yet, the complexity of today's environments leaves no alternative to sophisticated computer-based solutions to support the management of emergency situations. From our experience with the Hypermedia Emergency Plan, and with the advent of many new technologies (such as mobile computing, wireless networks, Web services, and digital libraries), we're convinced that the time has come to tackle this challenge. It will require the concerted effort from many experts, but the rewards—in making our society a safer place—will make the effort worthwhile. **MM**

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