Training-Based Evolutionary Multimedia Prototyping

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Abstract

The Port of Rotterdam is one of the largest cargo and container ports in the world, with a hazard area of over 600 square kilometers that affects about one million people. The port authority's emergency management training center is responsible for the training of more than 5000 field and command personnel, pertaining to five units: fire brigades, police, ambulance services, chemical advise, and port authority. Special consideration is given to the training of the Command Incident Place (CIP), which consists of the commanders of these five units, plus a commander and press officer. The CIP members must make joint decisions on how to respond to large and complex emergencies. A typical training session involves more than 20 trainers for only seven trainees, where scenario descriptions and communication is done by conventional means such as fax machines and telephones. The port authority's goal is to capitalize on advanced information and communication technologies to reduce human and material resources for such training sessions. To achieve this, we have developed a training-based evolutionary multimedia prototyping methodology. We present this methodology, along with a description of the four multimedia systems that we developed and their empirical evaluation in real training sessions. The results of our study have been used to provide the port of Rotterdam with practical guidelines regarding how to proceed with designing more efficient training sessions. The most important finding was that an integrated system performs best for the trainees and that this goal should not be compromised by technological considerations. The paper ends with an overview of how to further expand the system and cross-cultural considerations to generalize the system for other ports.

1. Introduction

The port of Rotterdam in the Netherlands is one of the largest worldwide cargo and container ports. Many processing facilities and storage sites for hazardous materials are located within the port's perimeter, such as storage places for ammonia, chlorine, liquefied natural gas, and propylene. The port area, which falls within the hazard area of the activities in the port, is about 600 square kilometers and contains about one million people.

The emergency response organization of the port of Rotterdam has developed a Regional Operational Base-Plan (ROB) to protect the physical and social health of the people living within and close to the port area. ROB is a product of industry, civil protection, and the port authority. ROB knows two major decision-making authorities, the Command Incident Place (CIP) and the Regional Operational Team (RegOT). The CIP consists of the commanders of the fire brigades, police, ambulance services, hazardous materials specialists, port authority, and a press representative. The organization's meeting facility consists of a mobile and specially equipped vehicle, which gets placed near the incident site. The head of CIP is a fire brigade commander.

The decision-making process for emergency management is defined in the Coordinated Regional Incident-Management Procedure (CRIP). CRIP is activated for incidents involving (1) hazardous materials, (2) large-scale technical emergency response, or (3) any other incident, where at least one of the CIP members calls for a coordinated response to an incident.

CRIP has four coordination alarm levels, which exceed the routine alarm level. The activation of the four CRIP levels is determined by the severity and extent of the incident. The operational and administrative units that get activated at the four CRIP levels are shown in figure 1.

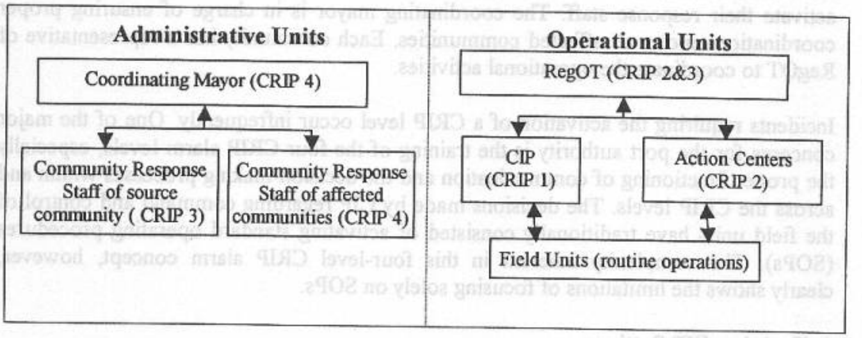

Figure 1: Activation of Coordinated Regional Incident-Management Procedures (CRIP) 1-4.

CRIP 1 is the lowest coordination alarm level and involves activating CIP. The port authority, fire brigades, police, hazardous materials specialists, ambulance services, and press work together in a multidisciplinary team with the fire brigade chief as the head of the team. The focus of CRIP 1 is to coordinate and manage the response activities of the units in the field. The incident will be purely local and it can be handled by the services provided by the CIP members. Information dissemination is carried out by CIP's press officer. CRIP 1 usually does not involve any measuring of hazardous releases, except at the actual incident site. If release measures outside the incident site are necessary, then CRIP 2 gets activated.

CRIP 2 must be activated if the incident has an impact for the surrounding; it involves the limited start-up of RegOT. Emergency response is done on-site through CIP but also through action centers. Both CIP and the action centers coordinate the field units and report to RegOT. RegOT is located at the regional fire brigade; the members of RegOT are commanders of fire brigade, police, hazardous materials experts, ambulance, and port authority. RegOT reports to the administrative units, which have not been activated yet in full during CRIP 2.

CRIP 3 is activated if the incident calls for emergency response activities at the community level, where a full-scale RegOT gets activated. The response staff of the community where the incident originates (the source community) is activated and the operational activities are put on full alert. The population is alarmed through sirens and the local radio station can be requested to act as the official information provider for the population.

CRIP 4, the highest alarm coordination level, is activated if the effects of a disaster cross the boarders of the source community. In this case, all the affected communities activate their response staff. The coordinating mayor is in charge of ensuring proper coordination among all affected communities. Each community has a representative of RegOT to coordinate the operational activities.

Incidents requiring the activation of a CRIP level occur infrequently. One of the major concerns for the port authority is the training of the four CRIP alarm levels, especially the proper functioning of communication and the decision-making processes within and across the CRIP levels. The decisions made by CIP regarding command and control of the field units have traditionally consisted of activating standard operating procedures (SOPs). The complexity inherent in this four-level CRIP alarm concept, however, clearly shows the limitations of focusing solely on SOPs.

2. Training CIP Settings

The training sessions involved in this research refer to the annual training of CIP, which consists of the commanders of fire brigades, port authority, ambulance services, police, chemical advise, a press officer, a commander of CIP. The CIP crisis management team consists, therefore, of seven members; Figure 2 shows of picture of one of the CIP sessions.

Figure 2: Command Incident Place (CIP) session in action.

A current traditional one-day CIP training session involves 21 trainees (three CIP teams) and 45 trainers taking on the roles of lower and higher control. All information is transferred via phone, fax machines, or written on paper. The disadvantage of the current situation is that too many human and material resources are needed with respect to the number of trainees. Writing all the scenarios and events on paper and using phones and fax machines to communicate the messages to the participants is very inefficient. Moreover, the preparation time required is very long and replication of exercise scenarios is not easy to accomplish.

The port authority would therefore like to go over to a system with only 10 trainers, where all information is transferred and processed by computer systems. Multimedia technologies should be used for a clearer and more realistic introduction to the scenario. The advantage of such an approach would be that fewer human and material resources would be necessary and all the communication could be easily printed as standard output. Most importantly, preparation time would be reduced and scenarios would be much easier to reproduce. The use of the Internet could also be considered as a viable alternative for the near future.

The port authority is currently investigating alternative methods to support communication and decision processes for all four CRIP alarm levels. In this vein, the port authority has acquired various advanced communications and information technologies, including a group decision support facility (GDSF) with corresponding software, a multimedia authoring tool to design exercise scenarios, a large flat panel for digital video conferencing, and several digital cameras to record incident scenarios and to monitor the exercises.

Supporting a group of experts in making real-time decisions entails two components: (1) the (multimedia) technology, and (2) the decision logic that helps the experts to reason and to make decisions. Early research on real-time decision support for hazardous operations was done in 1992, where Beroggi and Wallace [1998] developed a decision logic and integrated it into a multimedia system technology, to support an individual, centralized decision-maker The application case was the transport of hazardous materials.

The concept of real-time decision support with multimedia technology was generalized in 1994 and called Operational Risk Management (ORM), and a reasoning logic was developed to support an individual, centralized decision-maker [Beroggi and Wallace, 1998].

The ORM logic was extended in 1997 to the multi-expert setting, where many independent experts, at decentralized locations, need to be supported in making decisions [Beroggi and Wallace, 1998]. The multi-expert logic was applied in 1998 to a case dealing with managing a nuclear accident at Niagara Mohawk Nine Mile Point Nuclear Power Station Unit 2, in New York State, by developing a multimedia decision support system that supports all decision-makers in the case of an accident [Ikeda et al., 1998].

The focus of the work reported on in this paper is on the specification of the technology for multi-expert decision-making at the port of Rotterdam. The same training scenarios were used for the assessment of all four multimedia training systems reported on in this paper.

The scenario was derived from the Milford Harbor accident in 1994, and placed at a hypothetical location at the harbor of Rotterdam. The accident required the CIP officers to handle an escalating accident involving explosions and fire at a petroleum refinery. A CIP command and control center was staffed supported by seven laptop computers that were connected to a server. Each CIP officer was sitting in front of a computer. The training started after a brief introduction by the trainer regarding the purpose and objective of the multimedia-based training session. The training session consisted of two phases:

Phase 1, Assessment: Each CIP officer was given a multimedia description of the incident with specific information relating to his or her unit. The CIP officers could navigate through the information system for about 15 minutes. A set of questions was posed to them, which referred to how they evaluated the incident and what actions they would recommend to the field units.

Phase 2, Decision-Making: The CIP members had to share their information and their assessments of the situation and discuss possible actions. The commander led the discussion from his or her computing place or from in front of the flipchart. The decision-making phase was repeatedly interrupted by incoming messages about the developing incident. When the group had reached a joint decision, all CIP members answered the questions put to them on their own computers, and submitted their solutions to the trainers. The collection of all the individual solutions was used to make up the group solution.

The training session ended when all CIP officers had submitted their decisions. These decisions had to be submitted within a preestablished time limit. A short debriefing session followed, along with a questionnaire for the trainees to fill. The answers provided by the trainees were used to assess the different multimedia systems.

3. Evolutionary Multimedia Prototyping

The port authority is considering the acquisition of appropriate software systems that could become part of an advanced training concept. GroupSystems is a tool that allows team members to communicate, exchange information, and share information through a personal computer network. GroupSystems also supports the trainers in centralized dissemination and collection of data, and training results can easily be formatted in text form.

Multimedia authoring tools are an important class of software systems. Visualization and animation are vital elements to increase realism in emergency response training. Oracle Media Object (OMO) was used as the multimedia authoring environment to integrate animation, visualization, video, and voice. Beroggi and Wallace [1994] proposed a prototype decision support system in hypermedia for operational control of hazardous material shipments, and Ikeda et al. [1999, 2000] proposed a system to support multi-group emergency management with multimedia. The drawback of multimedia systems is that they are rather complex to use for developing user-specific applications.

Another class of important software systems refers to commercial off-the-shelf systems that are suited for developing presentations, such as PowerPoint, spread-sheets, data-base system, word processors, and all environments for developing web-pages, such as FrontPage. The disadvantage of these systems is that they have limited data input and output capabilities.

All these systems differ with respect to their technological flexibility and difficulty to develop user-specific applications. The more flexible a system, the more difficult it is to develop the desired application.

The port authority's goal is to have a system at its disposal which combines communication and visualization, and which is flexible and easy to use for tailoring the application to different training sessions. Such a system should provide enough flexibility for trainers to develop new training sessions, to combine past training sessions, and to add any sort of animation, video, and sound to make the training sessions as realistic as possible.

The port authority holds an annual series of four training days; a past year's session could be used to develop and test multimedia technologies. Instead of trying immediately to design the best possible system, a training-based evolutionary multimedia prototyping (TEMP) approach was chosen. The concept of TEMP is to start with the best possible design based on the objective of the training, and an educated guess about how trainees would react to computer-supported training sessions.

The technological experience gained with this first system, and the assessment of the system by the trainees, can be used to adjust the system, possibly by including other software tools. Improvements regarding the technological aspects and the user-friendliness of the system were made after each of the four training sessions. The head trainer of the port authority was closely involved in the TEMP development process, since he will be in charge of using the system after the research has been completed.

The same incident was used for all four training session. The trainees were experienced commanders from different units, fire brigades, ambulance services, the police, the port authority, chemical advise, and a press officer. The four training sessions were part of their annual training. They were instructed that this year's sessions would be different and that they would have an exploratory character, even for the trainers. Each of the four systems was used for one CIP setting, and each CIP was staffed with seven or eight officers. As a result, we had a total of 30 officers using and assessing the multimedia-based concept of training sessions. The characteristics of the four systems were as follows.

System 1: OMO and GroupSystems. The assessment phase was accomplished using a multimedia system, designed in OMO. Although OMO gives all the required flexibility for using animation, video, text input, audio, etc., it also requires a considerable amount of programming knowledge on behalf of the trainer. The questions regarding the officers' decisions were sent and collected using GroupSystems. Using GroupSystems for such a trivial task is something of an overkill. The advantage of using GroupSystems lies certainly with the trainers who do not have to do any programming to obtain the results in a nicely formatted form as a text file. The trainees were told that they could switch between the two systems by hitting the Ctrl and Tab keys. This was necessary if they wanted to switch back and forth between the incident information and the questions about their decisions. The trainees stated that this switching back and forth between two systems was not only confusing, but an additional hurdle since they had to learn two different navigation principles. System 2 was therefore designed as an integrated system.

System 2: Integrated Multimedia. The information about the incident and the questions about their decisions were integrated into one system, developed in OMO. The subjects could navigate freely within the two sets of information using one navigation principle. The system was programmed to generate automatically formatted reports for the trainers so that they could debrief the trainees immediately following the sessions. Due to the flexibility of OMO's developing environment and the complexity of the programming code, the system had some minor problems, which had to be eliminated as part of designing the third system. Subjects seemed to be pleased with what the system allowed them to do, but they reacted sensitively to any conceptual and technical problems they found regarding the system.

System 3: Integrated Multimedia. The integrated multimedia system was improved in technical and conceptual terms. The trainees were presented with the most complete and integrated system, which had hardly any technical problems and only minor conceptual limitations. Despite the sophistication of this system, and the satisfaction expressed by the trainees, it would not be the system of choice for the trainers, since it involved advanced programming. The decision was therefore made to investigate a technically easier system for the trainers, at the cost of losing some conceptual understanding for the trainees.

System 4: PowerPoint and GroupSystems. The easiest technological solution for the trainers would be to use two off-the-shelf software systems, such as PowerPoint for the introduction of the incident and GroupSystems for the decision-making phase. However, the resulting increase of conceptual complexity for the trainees could not be compensated for by the reduction of technological complexity for the trainers. Only an integrated system seems to provide a satisfactory system for both trainers and trainees.

3. Analysis and Conclusions

The formal evaluation of the four training sessions was done using a questionnaire, which was designed based on principles developed by Moorman and Miner [1998], Bailey and Pearson [1983], and Davison [1997].

Table 1 shows the results of the questionnaire on a scale from 1 (worst) to 7 (best). It should be noted that S2 and S3 were the integrated systems, which implies that the assessments referred to both phases--incident introduction and decision-making. The assessments of S1 and S4 refer only to the incident introduction phase, since the decision making phase was accomplished using GroupSystems (see table 2). The numbers in the subsequent tables are the averages based on 30 officers.

Question		Ranks	Multimedia Component	S1 OMO	S2 OMO	S3 OMO	S4 PowerPoint
1		2,3,1,4	user-friendliness	5.71	5.43	5.71	4.86
2		3,2,1,4	difficulty of use	5.71	5.86	6.00	4.43
3		4,2,1,3	completeness of information	5.14	5.57	6.00	5.29
4		4,1,3,2	adequacy of information	4.57	5.43	5.00	5.43
5		4,3,1,2	general layout	6.29	5.29	5.86	5.57
6		4,3,1,2	difficulty of layout	5.86	5.86	5.86	5.86
7		3,4,1,2	confidence in system	5.14	4.86	5.57	5.29
8		4,3,1,2	relevance of information	4.71	5.14	5.57	5.29
9		4,2,1,3	clearness of information	5.43	5.29	5.71	5.43
10		1,3,4,2	comprehension of system	6.00	5.86	5.14	5.71
11		1,3,4,2	sufficiency of training	6.29	5.71	5.29	5.86
12		3,2,1,4	value of visual information	5.71	6.00	6.29	5.29
13		4,2,3,1	value of video	5.14	5.29	5.14	5.43
14		1,3,2,4	value of navigation tool	6.57	6.29	6.29	6.29
	sum	42,36,25,37	**average**	**5.60**	**5.56**	**5.67**	**5.43**

Table 1: Assessment of Multimedia Component for four systems (S1-S4).

Table 1 indicates that the fully integrated and improved multimedia system, S3, performs best over all four systems. Using the numeric values given in Table 1, we see that S3 is only slightly statistically significantly better than S4 (one-sided paired t-test, $p=0.08$). However, the sum of ranks over the 14 questions is 42 (S1), 36 (S2), 25 (S3), and 37 (S4), and S3 was assessed 9 out of 14 times to be the best system. Rank correlation for all fourteen questions is only 0.15, which indicates some inconsistencies regarding the overall ranking of the four systems.

The finding that S3 is the best system is certainly supported by the impression that we got from the sessions. The integrated system, S3, outperforms any other approach, and two off-the-shelf tools can perform poorly if they do not connect well.

Table 2 shows the average assessments provided by 15 officers for the two systems using GroupSystems for the decision-making phase. S1 is significantly better than S4. This result is not surprising, since we noticed that the combination of GroupSystems with OMO not only works better but it is also preferred to the combination of GroupSystems with PowerPoint. The conclusion to be drawn from this result is that the combination of two technically easy, but inflexible, systems is not advisable. OMO's flexibility could make up for some of the limitations of combining two different technologies, while PowerPoint could not.

GroupSystems	S1	S4
user-friendliness	6.29	5.43
ease of use	6.57	5.57
completeness of information	5.71	5.43
adequacy of information	5.57	5.57
layout	6.14	5.71
readability	6.43	5.57
usefulness	6.29	5.57
comprehension of system	6.57	5.57
difficulty of system	6.43	5.43
confidence in system	6.14	5.29
training	6.29	6.00
average	**6.22**	**5.56**

Table 2: Assessment of GroupSystems for four systems (S1-S4).

4. Conclusions

We have presented and applied a training-based evolutionary multimedia prototyping (TEMP) concept to investigate the possibility for the port authority of the port of Rotterdam using advanced information and communications technologies in its emergency response training sessions. Four systems were developed, where the first three systems were developed according to the TEMP concept, and the last system was an attempt to reduce technological complexity. The four systems had to benefit both trainers and trainees, where the trainers were mostly interested in a technologically easily adaptable technology, and the trainees wanted to have a conceptually easy system that allowed them to focus on the tasks and not on how to use the technology.

Our results showed that a fully integrated system is the best approach to pursue. Technological ease for the trainers is achieved at the cost of considerably increased conceptual complexity for the trainees. We would therefore not advise using a combination of two off-the-shelf systems if they cannot be perfectly integrated.

Using advanced information and communication technologies in an annual training of officers in a command and control CIP setting brings up some critical points that should be considered by the port authority.

- If the CIP members are trained using a "futuristic" multimedia system, what is the added value for their field operations?
- Should the operational CIP also be equipped with advanced intelligent multimedia technology?
- If the CIP members do well during the training, how does this translate for their capabilities during real incident situations?
- What would happen if the technology fails; should the CIP still be capable of going back to the old system?

Our future research in this field involves a cross-cultural comparison with a port in the United States. The four systems used in our research will be presented to the corresponding port authority. The officers in charge of training will be asked for their assessment, and their answers will be balanced against our experience gained during this research.

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