Real-time Support for Exercise Managers' Situation Assessment and Decision Making

Rita Kovordanyi
Linköping University
rita.kovordanyi@liu.se

Jelle Pelfrene
Space Applications Solutions
jelle.pelfrene@spaceapplications.com

Amy Rankin
Linköping University
amy.rankin@liu.se

Rudolf Schreiner
Object Security
ras@objectsecurity.com

Johan Jenvald
VSL Systems
johan.jenvald@vsl.se

Magnus Morin
VSL Systems
magnus.morin@vsl.se

Henrik Eriksson
Linköping University
henrik.eriksson@liu.se

ABSTRACT

Exercise managers and instructors have a particularly challenging task in monitoring and controlling on-going exercises, which may involve multiple response teams and organizations in highly complex and continuously evolving crisis situations. Managers and instructors must handle potentially incomplete and conflicting field-observation data and make decisions in real-time in order to control the flow of the exercise and to keep it in line with the training objectives. In simulation-based exercises, managers and instructors have access to a rich set of real-time data, with an increased potential to closely monitor the trainees' actions, and to keep the exercise on track. To assist exercise managers and instructors, data about the on-going exercise can be filtered, aggregated and refined by real-time decision-support systems. We have developed a model and a prototype decision-support system, using stream-based reasoning to assist exercise managers and instructors in real-time. The approach takes advantage of topic maps for ontological representation and a complex-event processing engine for analyzing the data stream from a virtual-reality simulator for crisis-management training. Aggregated data is presented both on-screen, in Twitter, and in the form of topic maps.

Keywords

Crisis management, decision making, stream-based reasoning, complex-event processing, semantic event processing, ontologies, topic maps

INTRODUCTION

Efficient crisis management requires adequate training for the emergency responders. Frequent training is vital for continuous coaching of new recruits and for maintaining a high level of expertise of experienced rescue workers. Because large-scale live exercises involving multiple organizations are costly and time-consuming, simulation-based exercises are often used as a complement. The work described in this paper is part of the on-going FP7-funded EU-project CRISIS, where we are developing a virtual-reality-based system for crisis-management training (http://idc.mdx.ac.uk/projects/crisis/). The CRISIS approach is innovative in the sense that the simulated exercises are realistic not only in terms of the trainees' visual experience, but also when it comes to the variability and unpredictability of events that could occur during the training exercise. Real-world crisis events can unfold in unexpected ways, and this unpredictability and uncertainty is expressed in the CRISIS system using the Variable Uncertainty Framework (VUF), which comes into play both during exercise planning and during the running of the exercise by controlling the activation and timing of various inject events (Barnett, Wong, Westley, Adderley, & Smith, 2011).

Exercise managers and instructors play a key role in crisis-management training. In addition to planning and preparing the exercise, they must compile, interpret and assess the pedagogical relevance of events that have occurred during the exercise as a preparation for after-action review (AAR), where the trainees' performance is evaluated and discussed. During the running of an exercise, the exercise managers and instructors must coordinate external role players and initiate injects—additional, smaller crisis events—to control the level of difficulty and the pace of the exercise.

For simulation-based exercises with multiple participants, the vast amounts of data make it inherently complex to monitor the evolving situation and the trainees' use of the simulator with respect to the training goals. The uncertainty and unpredictability of crisis events, also captured in the simulator-based exercises used in the CRISIS project, introduces an extra level of difficulty for managers and instructors when trying to monitor and control the unfolding of the exercise. Here, the quality of the team performance depends both on the complex interaction of various response actions, and on the current level of difficulty of the exercise and the injects that have been introduced into the simulation.

One way to alleviate the information load of exercise managers and instructors is to filter and aggregate the inflow of data through Complex Event Processing (CEP). In this technique, event patterns, such as "Triager X has put a red triage tag on victim Y *and* victim Y has a heart rate over 120 beats per minute", are matched against the sequence of events in one or several data streams to determine the presence of this particular pattern. When a particular pattern is detected, some of the data can be forwarded to an output stream and/or new information can be compiled on the basis of the detected data; for example, "Victim Y has been correctly triaged". CEP is especially useful for high-performance correlation, aggregation and filtering of events, based on simple event attributes like position or specific actions. CEP is, however, not very well suited for higher-level semantic analysis of events.

For this purpose, CEP can be combined with rule-based reasoning and an ontology of background knowledge, which describes how the world is structured and how things work. These combined approaches are often referred to as Semantic Event Processing, SEP, or, in the semantic web-community, simply streaming (Della Valle, Ceri, van Harmelen, & Fensel, 2009). Similarly to CEP, SEP works on event streams, but trades performance to allow processing of events at a higher level of abstraction and semantics, taking into account background information.

Below, we outline the information and support need of exercise managers and instructors, and describe a prototype implementation of the Decision Support System (DSS). We conclude with results, discussion and conclusions.

INFORMATION AND SUPPORT NEED OF EXERCISE MANAGEMENT

Human decision making is far from optimal (Arnott, 2006). In order to get an overview of the kind of support that might be beneficial during emergency-response training in the CRISIS system, we conducted a semi-structured interview with subject-matter experts with extensive experience of planning, running, and debriefing live emergency-response exercises. In addition to this, material from end-user interviews conducted in connection with the elicitation of functional requirements for the CRISIS system revealed a wish for passive, low-key decision support.

Interviews with subject-matter experts and emergency-response organizations suggest that it would be useful if the decision support system displayed phases of the exercise that have been successfully completed. It should be easy to see if the exercise progresses according to the exercise manager's plans and when certain milestones are reached. Since the information load on the exercise managers are already quite high, it is important that the output display is not cluttered up. The support system should use a few simple colors, for example, displaying checklist items marked green, yellow and red for completed, some deviation, and possible failure by the trained response teams.

An additional suggestion was that the system could make an initial selection among the raw data, and in this way act as an intermediate layer between the raw data and the human analyst. If there are observers in the exercise, they can also help to promote (highlight) data: "This is interesting". The promotion and demotion of various pieces of information, done automatically based on expressed preference and manually by observers, is crucial to manage information flow during the exercise and is also an important part of preparation for AAR. A decision-support system could contribute to this work, by identifying important information. However, it is essential that the information is then approved and can be demoted by the human analyst.

REAL-TIME SITUATION ASSESSMENT AND DECISION SUPPORT

We have implemented a prototype of the DSS to assess the feasibility of the chosen approach and to find the combination of tools and techniques that can achieve the expected functionality. The present system for real-time situation assessment and decision support comprises three main modules (Figure 1, middle four components): 1. The real-time module running a network of Esper-statements, 2. The central knowledge base for decision support and knowledge management, consisting of a Topic Maps system, and 3. The knowledge-based module running Drools rules. The interface between the central knowledge base and the other two modules is implemented in TMAPI. This interface allows for both reading and modification of the central topic map.

Raw data is received in real-time from the simulation environment (CRISIS ISE), and in batch from the Exercise log, a database of logged simulation data (upper and lower leftmost components in Figure 1). Exercise instructors can use the decision support in two ways (two rightmost processes in Figure 1): During the running of the exercise and during After-Action Review (AAR). Note that exercise management can affect events in the simulation environment during the running of the exercise (feedback connection at top of Figure 1).

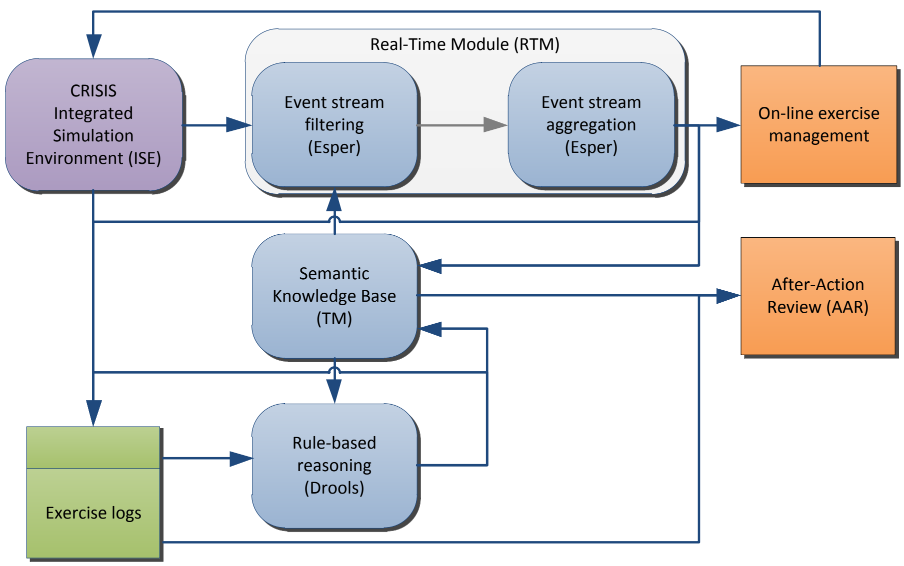

Figure 1. The real-time situation assessment and decision support system (middle components) depicted within the context of the CRISIS system (leftmost components) and user modes (rightmost processes). The three main modules of the decision support system (DSS) are: Real-Time Module, Semantic Knowledge Base and Rule-Based Reasoning.

The DSS currently utilizes a number of libraries: Ontopia for managing topic map data, TMAPI for seamless access to ontological and other forms of background knowledge, Drools for rule-based inference, Esper for real-time filtering of information streams, Log4J for handling textual communication with the user, JFreeChart for plotting aggregated data and Twitter4J for presenting aggregated information in real-time through Twitter.

Use case

We are currently running the DSS on a reference scenario set at Reykjavik airport. This scenario begins with an airplane crash, which results in a number of casualties as well as surviving victims, who has to be triaged (tagged as uninjured, lightly or seriously injured, or dead). As the scenario unfolds, additional victims emerge from the airplane fuselage, which increases the difficulty level of the exercise. In addition, the health state of a few of the victims deteriorates over time, which means that they have to be re-triaged.

The instructors' task in this case is to monitor the progress of the exercise, by for example, keeping an eye on the number of correctly and incorrectly triaged victims. The instructors also have to be prepared to intervene if the trainees' actions jeopardize the training goals and the general progress of the exercise. For example, in one of our field studies, the instructors found it necessary to intervene when they saw that the trainees had decided to "close off" the emergency room at a local hospital, letting it exclusively accept crisis victims. The exercise was paused and the trainees were debriefed on the inappropriateness of such a decision. Such a response action by the trainees would, of course, also be flagged for later reference and be brought up to discussion during AAR.

Data aggregation and refinement

The events that are input to the RTM have a spatio-temporal extent and encode information about what happens at each time step in the virtual environment, for example, that medic X has triaged victim Y as being seriously injured. This type of information is filtered and subsequently aggregated into a running count of the number of correctly and incorrectly triaged victims.

The aggregated information is used in two ways. First, the new information is added to the semantic background knowledge of the DSS. Second, it is presented on a mobile platform using Twitter messages with the possibility to attach maps, images, and summarizing plots (Figure 2 a), as well as on a computer screen (Figure 3). Information is currently presented at multiple levels of abstraction, conveying both the summarized, aggregated information, and the underlying events. Multiple levels of abstraction are needed, as aggregate information could, for example, hide interesting details needed during AAR, such as the individual triager's identity. Also, in this way, the human analyst can confirm or reject the way that the data has been aggregated by the DSS.

As we use Topic Maps for representing background knowledge (Pinchuk, Aked, De Orus, Dessin, De Weerdt, Focant, & Fontaine, 2007), we can utilize the close mapping between the association concept in Topic Maps and sentence structure to support answering questions in natural language using the topic map as a knowledge base (Mikhailian, Dalmas, & Pinchuk, 2009). This is intended as a user-friendly interface to complement the basic full-text search of the exercise log. An avenue that is being explored is converting questions posed by the user to live-running queries useful for decision support.

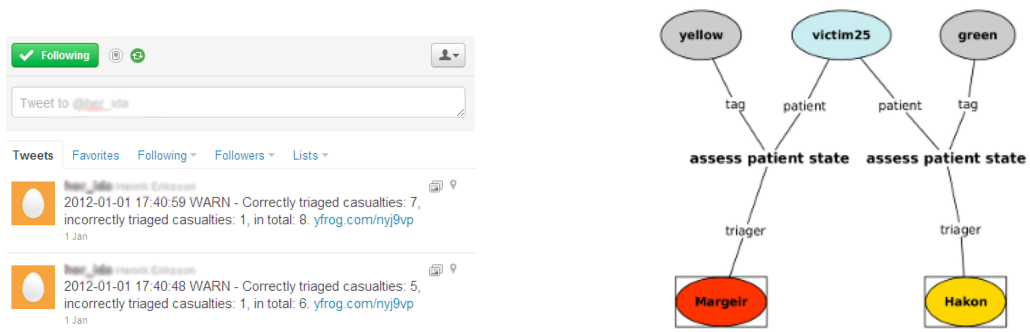

Figure 2. a. Twitter messages indicating the number of correct triages made at a given point in time. b. Answer to the natural language question: "Which triager assessed victim25"

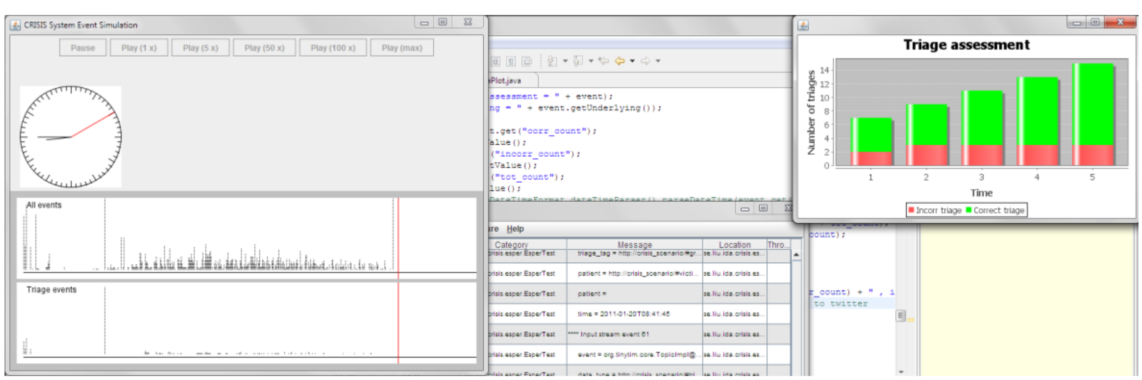

Figure 3. Screenshot showing the control panel with a time line, the textual output produced, and visual plot showing correct and incorrect triages.

An example will illustrate the concept. Suppose that during the preparation of the AAR session, the analyst asks the question "Which triager assessed victim25?", and gets a graphical representation as explanation (**Fel! Hittar inte referenskälla.** b). This picture highlights the two responders Margeir and Hakon and also shows that they made conflicting assessments of the health state of victim25. Besides showing the relevant first responders in a graph, the user interface can also expose when each triage action took place and trigger a replay of the specific scene. The reviewer can also browse the semantic logs to investigate hypotheses, such as whether the victim's condition actually changed over time, or whether a mistake was made and if this might be related to the stress level of the triagers.

DISCUSSION

For live exercises there is a limit to what can be automated in terms of real-time data collection, which affects the quality of decision support. For example, today it might not be technically and financially feasible to instrument every participant, vehicle and device with a system for transmitting sensor and position data in real time. However, it is possible for simulators, such as the CRISIS system, to produce a rich set of real-time events that a complex-event processing system can use already during the running of the exercise.

A real-time decision support system can aid the exercise manager in two major ways. Firstly, during the exercise, such a system can assure the manager that the exercise is proceeding according to plan, and that the training objectives are covered, or diagnose the opposite. Secondly, the system can suggest and support exploration of interesting topics for the AAR. Both uses will require tuning of the system in order to find relevant aspects of the data presented to the exercise manager. Real-time support requires some form of complex event processing (or other dynamic reasoning) while after-action analysis can be done in retrospect using a conventional decision-support system. An interesting question is whether it is possible to provide both real-time support and after-action analysis using the same system.

CONCLUSIONS

We believe that complex and semantic event processing are useful techniques for developing real-time support for training managers, especially for simulation-based exercises. Real-time decision support systems can provide exercise managers with alerts for specific conditions during the exercise, such as the correctness, timing and outcome of activities. Although the data availability in live exercises is a limiting factor, simulator-based exercises provide a data-rich environment where complex event processing can filter and aggregate relevant information. A specific challenge is the acquisition of background knowledge for the decision-support rule base. In our continued work we will explore suitable interaction modes for the exercise managers, and further develop the decision-support rule base and evaluate the resulting system.

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