A Framework for Developing a Collaborative Training Environment for Crisis Management

Y. Arafa, C. Boldyreff, M. Dastbaz, H. Liu
School of Computing, IT and Engineering
University of East London
London, UK
{y,arafa;c.boldyreff,m.dastbaz.h.liu}@uel.ac.uk

***Abstract*— This paper describes the technical framework of a near real-life training environment for learning activities suitable for training in crisis scenarios. The context in focus here is to make provision for a learning environment that requires the training of collaborative, as well as independent, decision making among strategic crisis managers in potential crisis situations. Modelling the training scenarios takes into consideration both the pragmatic nature of responding to crisis, as well as the human-behavioural factors involved in dealing with situations of chaos and uncertainty. This work is part of ongoing research on the Pandora[1] project, which aims to provide a near-real training environment at affordable cost.**

Keywords-Technical Framework for Crisis Management Training, Human Factors in Crisis Training, 3D Training Interface, Adaptive Training Scenarios.

I. INTRODUCTION

There is increasing recognition for the need to train managers in non-technical skills such as control and decision making for crisis management needed in national emergencies, high-reliability industries, as well as in industrial workplaces [2,4,10,11]. Crisis management is a major issue in preventing emergency situations from turning into disasters. In recent years, mismanagement of emergencies has often created critical situations. When a catastrophic event occurs, it is human behaviour and often human behaviour alone that determines the speed and efficacy of the crisis management interventions. Frequently, untimely and ineffective responses are not due to a lack of knowledge of procedures, but to the inability to operate in contexts where frequent, potentially catastrophic events are occurring [1,7].

Training plays an important function in the preparation of the crisis manager. Currently, there are two main modalities for such training: table-top and real-world simulation exercises. Table-top exercises are low cost and can be easily and frequently organised. However, they cannot create a believable atmosphere of, for example, stress and confusion that is prevailing in real-life situations and is crucial to the training of timely and effective decision making. On the other hand, crisis managers trained through simulation exercises in the field can be very effective, but these are considerably more expensive, require specialist equipment and are difficult to organise on site.

Pandora aims to provide a framework to bridge the gap between table-top exercises and real-world simulation exercises, providing a near-real training environment at affordable cost. Pandora is developing an enabling technology to simulate believable dynamic elements of an entire disaster environment by emulating a complete crisis room using realistic 3D visuals and audio to engender a truly immersive, chaotic and stressful environment.

II. HUMAN FACTORS IN CRISIS MANAGEMENT

Pandora focuses on the affective state of the crises manager, because the knowledge of human behaviour, in all phases of emergency management, is crucial to the development of effective emergency policies, plans and training programs. For many years, business continuity planners worked under a simple assumption that when a disaster strikes, people will follow plans and procedures. Psychologists and other behavioural scientists have found that this idea fails to consider the often surprising behaviour of individuals during emergencies [4,7].

Traditional business continuity plans do not adequately take into account the forces of human behaviour, especially when scenarios include extreme fear, harmful behaviour and require survival responses. Strategy planners often wrongly assumed that an organisation's emergency plans will be automatically accepted, understood and acted upon by all. The principles of human psychology suggest that the behaviour of individuals and groups is shaped more by numerous intangible factors than by official or executive demand [1].

For these reasons the Pandora system is including mechanisms to maintain affective profiles of trainee crisis managers and to create believable immersive environments that aim to engender affective reactions as crisis scenarios unfold. Such affective interaction should help improve the decision making agility of novice decision makers in terms of their ability to identify and assess cues, handle negative information, and make decisions from a number of decision action options. In addition, since the scenarios and the feedback given to trainees are underpinned by Rules of

[1] Project FP7-ICT-2007-1- 225387. Co-funded by the European Commission under the mixed call on ICT and Security.

Engagement, Pandora should help in training and facilitate practice in interpreting Rules of Engagement.

III. A COLLABORATIVE LEARNING ENVIRONMENT

The underpinning Pandora system, as depicted in Figure 1, is composed of four components: the top three are intended as architectural sub-systems, implementing the corresponding high-level functionalities, whereas the remainder represent the type of environment where those functionalities are applied.

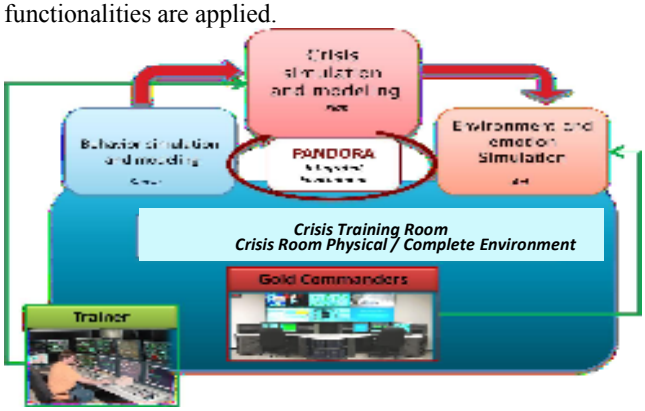

Figure 1. Pandora System Overview

Interaction assumes two types of actors: the Gold commanders, which are a group of individuals from different agencies undertaking training; and the Trainer, who activates the exercise and monitors the progress of actions and environment during a training session. One of the main achievements of the Pandora system is the provision of retroaction, which allows the trainer and trainees (through their decisions) to modify the scenario at runtime.

A. *Behaviour Simulation and Modelling*

In order to enhance the believability and realism of training sessions and to simulate real aspects of a crisis situation, it is necessary to take into account the trainees' behaviour and how their emotional/psychological profile can influence the decision making process during a simulated crisis.

The Pandora environment maintains an account of the behavioural status of crises managers and reacts accordingly. It also models different levels of abstraction so to make possible its use in diverse crisis situations. The environment is, however, not totally automated but is populated by several actors, among which a simulation director and some extras (Non Playable Characters -NPCs) participating to de-structured simulations with third parties.

The Behavioural Simulation and Modelling functionality has three main goals: 1) to select, model and monitor the relevant human factors or psychological variables that can have an influence on the decision making; 2) to develop a model able to represent trainee's actual behaviour/profile; and 3) to propose (plan) high level personalised training goals and user interactions to the crisis planner.

In particular the trainee model takes into account both psycho-physiological parameters, (e.g., heart beat rate, personality traits, self-efficacy, etc.), and pedagogical parameters, such as training methods. According to the particular trainee's status, this component decides personalised training paths with customised difficulty levels and challenges.

Training sessions are personalised by maintaining an affective profile of trainees and activating useful training activities according to the reconstructed mental context of trainees; a model of training strategies; and a set of user classifications. Classes of users are represented defining a set of so-called user "stereotypes" elicited from an analysis of domain knowledge [8,9]. They are aimed at creating a structure that allows personalisation of the user model for the training phase. Information on individuals is obtained by setting up a pre-evaluation protocol for each crisis manager that enters a training session.

B. *Crisis Simulation and Modelling*

Crisis Planning and Modelling is the key functionality of the overall Pandora system, as it creates the simulated network of events driving the entire training session. The objective of this functionality is twofold: on the one hand it must offer a knowledge base (static information) that shall be able to contain all the information relevant for the system, for example, the crisis procedure for managing crisis situations, information about the available resources, information about crisis events and their relations in terms of cause-effect and so forth; on the other hand it shall be able to elaborate a model that describes the joint effect of the static information, the action of the trainees, the adjustments of the trainer and the behavioural model and information.

An intelligent Crisis Planner is defined such that it receives as input a symbolic model of how a crisis can be simulated (what can happen during a crisis, how and when, according to which cause-effect relationships) and the high level characteristic of the training session from the Behavioural Planner and instantiates the contents of the crisis scenario that will be enacted by the Simulator in the Crisis Training Room.

C. *Environment and Emotion Simulation*

The Environment and emotion simulation functionality aims to render the sequence of events that comes from Crisis Planning and Modelling. Rendering these events is undertaken with the objective of engaging and involving trainees in the simulated scenario, for example, it is important to simulate situations of information overload and related stress, together with the pressure in making decisions. Therefore, the Pandora system aims to play out events in a way such that certain emotions will be transferred to the trainees. Accordingly, the functionality of this component includes the following:

Emotion simulation, which has two objectives: the first is to provide a tool that can select and customise environment content in the form of video, image or text that must be provided to the trainees to represent a range of emotional states; and the other is to provide information regarding NPCs that need to be simulated inside the system

and customise their behaviour according to trainer input and the evolving scenario.

Environment simulation, which aims to create a realistic and emotional engaging environment for the trainee. The following elements are used to realise this environment: graphical rendering of scenarios and of NPCs, as well as the appropriate devices necessary to display information in the form of video, maps, images, emails, phone calls, radio play out and so on, to the trainee.

D. The Crisis Training Room

The Crisis room is the "place" where a training exercise is conducted. Typically, it is comprised of a selection of audio-visual components and appropriate displays, communication and data delivery channels that are relevant to a training scenario.

Pandora has identified three use cases for the potential deployment of the room in order to maximise trainee benefit within the boundaries of physical setup and requirement considerations where training is to be conducted:

1) Single Site Training:

Training is delivered to group of trainees at the same time and at the same location. The group is called together by the trainer and trainee members are working around a table in a dedicated room where the system is installed, at a national or international training facility. This dedicated room has been set up with sensors, devices, tools and monitors that are fixed and not portable.

In the room each scenario instantiation is initiated by the trainer, who turns on the biometric sensors and sets the objectives of the exercise by defining the mission, the initial scenario, rescue resources available, and so on. In addition, the trainer prepares the system to be used by the group.

In addition to sensors, the room is setup with Multi-Screen Display - MSD consoles enabling trainees to receive multi-channelled information on a number of consoles reporting a range of happenings and events through multimedia representations (texts, sound, pictures, graphs, animations, videos). Such events include: actors' intervention, specific requests, third party impacts, and much more. Typically, the crisis room consoles look as follows:

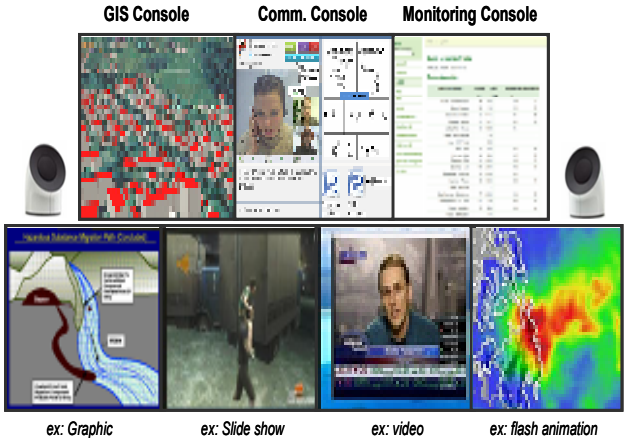

Figure 2. Typical Setup for Multi-Screen Display Console.

2) Deployed Training:

This use case differs from the previous in that it does not use a dedicated room and is located, for example, at an institutional building of a Gold Commander taking part in a training session (Civil Protection Centre, MIC, etc.). Once again, the system can be used by one or more trainees at the same time, which meet in a standard meeting room that has been properly equipped for the training session. For this use case the necessary equipment are portable and are transported on site for the purpose of training.

3) Distributed Training:

Here, training is delivered via the web, which means a dedicated room is not present and replaced by a virtual room in which the trainees can log in remotely and engage in training exercise scenarios. Again, the system can be used by one or more trainees at the same time.

A 3D distributed virtual environment (DVE) is being developed in order to set up this use case. The DVE provides a flexible training environment where trainees can participate in the training from anywhere. The DVE simulates a 3D virtual crisis room similar to that of the physical room described above and is capable of incorporating the same communication and data delivery channels that are relevant to a training scenario as shown in Figure3.

Here, participating trainees will each control an avatar, within the DVE, using their keyboard, mouse and/or micro-phone. Trainees collaborate with each other by in-world typing, speaking or emailing as needed and appropriate for the scenario at hand within the overall exercise.

The DVE itself does not generate events or storylines unless users make responses to world events. It is a frontend to the Pandora system, which controls its storylines. Specific crisis events within an overall crisis scenario are generated over time by the Pandora components and passed to the DVE for rendering through avatar actions, in-world text popups, streaming videos, maps, PowerPoint slides, etc. Trainees can respond to these events inside of the virtual world by typing or choosing one of the other options the system provides.

Figure 3. In-world Slide Show, Streaming Video, and Map Application.

The prototype DVE is developed using OpenSim [5], an open-source server platform for hosting virtual worlds. Upon receiving event requests from components, the DVE server generates a timeline XML file using native manipulating scripts, which are based on LSL (Linden Scripting Langue) [3] and OSSL (OpenSim Script Language) [6].

IV. THE PANDORA ENABLING TECHNOLOGY

The following sections describe the architecture underpinning the Pandora system. The main functionality of the Pandora architecture is depicted in Figure 4, and the functionality of the comprising components is described in the subsections to follow.

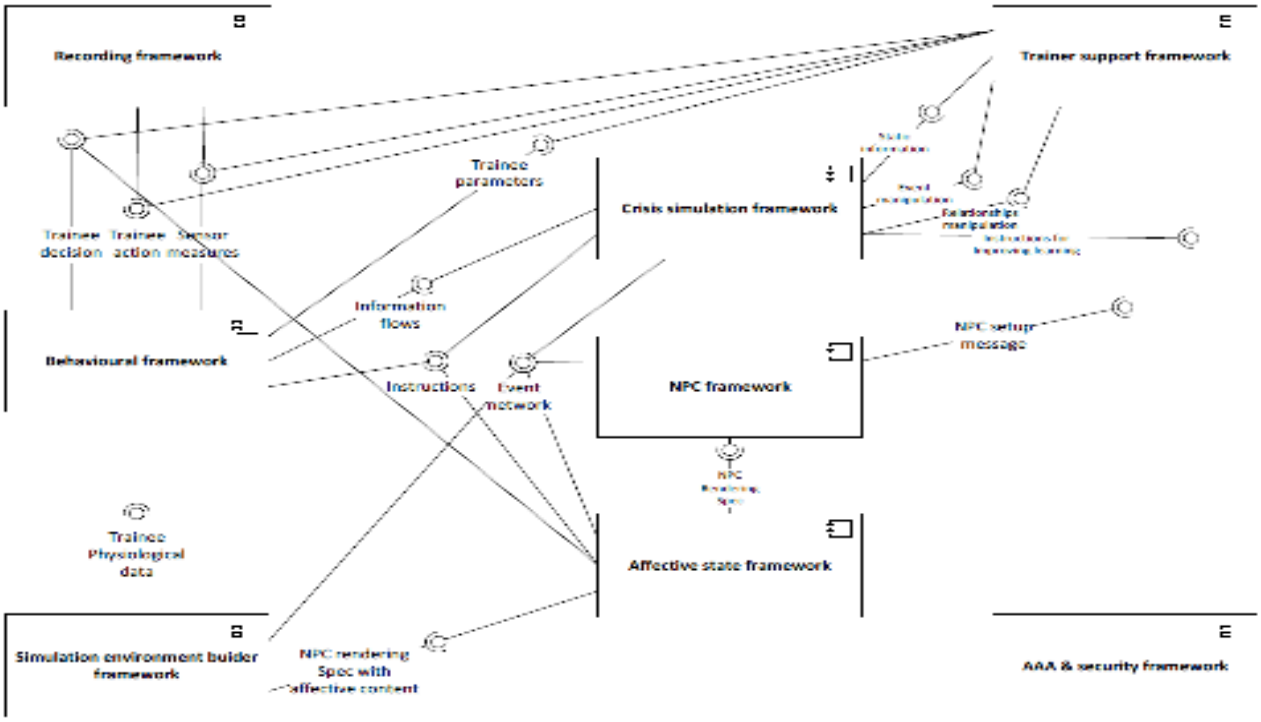

Figure 4:Pandora Functional Architecture.

A. *Behavioural Framework*

The Behavioural Framework works along side the Crisis Simulation Framework to orchestrate training sessions by reaching decisions on how to organise the content of a crisis simulation. The main functionality of this module includes the following:

Behavioural Profile Manager, which is related to the collection of the trainee profiles. This operation is performed upon first registration of the trainee into the system. The trainee is presented with some questionnaires aimed at setting some initial psychological data, which will be adjusted and updated throughout the training sessions.

The creation and maintenance of user models is done within this framework. Based on the assessment of the emotional factors that are considered relevant for the training at hand, different user profiles (we refer to the classical term of stereotypes [8,9] as a base to start with) are determined and used to classify user capabilities for the behavioural and crisis planners. User profiles are activated by using the neuropsychological and psychological tests to assessing levels of factors like self-efficacy, self-estimate, affective style, anxiety etc

The static or current features of the user (trainee) model is constantly kept updated during a training session by a real time monitoring of the trainee thanks to the continuous measure of neurophysiologic indexes (e.g. level anxiety, arousal, workload, etc.);

Behavioural Planner, which gets the information flow from the crisis simulation framework, as well as the trainee behaviour and the trainee profiles. It uses this information to generate a set of instructions on how to personalise the training environment to improving the training exercises according to the trainee status. It also maintains and updates the sensor trainee parameters, which are mentioned below (e.g., psycho-physiological trainee data and their evolution over time), for de-briefing purposes.

The Behavioural Planner is an intelligent module that supervises the behaviour of the intelligent simulation environment using knowledge of the cognitive processes that may influence the behaviour of the crisis manager. It is a cognitive system that during a training session enacts a closed interaction engagement with the trainee by deciding a set of stimuli trainees should receive by the simulation, monitoring the reactions and eventually adapting the goals of the training session dynamically according to these reactions.

Behavioural Recording Manager, which continuously observes the trainees' actions and behaviour. According to their performance, the framework might decide to ask the Crisis Simulation Framework to generate more or less stressful events or to raise or lower the difficulty level.

Action Input Manager, which collects the trainees' decisions and actions made within training sessions.

Sensor Input Manager, which collects the biometric sensor measures.

B. Crisis Simulation Framework

The crisis simulation framework is responsible for maintaining the Pandora system consistency. The main data structure of the Pandora system is modelled by means of an "event network", which maintains a representation in terms of events and relations among them. The event network provides interfaces for adding/removing events and relations between events as well as offering query services for events happening at a given time.

A Crisis Simulation Planner is responsible for adding events (and relations among events) to the event network, taking information from the knowledge base. These new events represent consequences of a certain event e. The planning process goes on until no event in the event network has consequences or all consequences of all events have been added to the event network.

Events are related to timelines, which are a particular data structure used to index events according to a thematic feature that the system has to monitor over time. A timeline, therefore, represents the set of events that happen in time for a particular modelled element. The set of timelines provide complete information of the current training session in terms of what's already happened (world events, user state and their chosen options) what is happening (again, world events, user state and their chosen options) and what will happen (user state and chosen options are not yet known so only world events information are provided).

C. Emotion Engine

The Emotion Engine interprets and filters instructions from the Crisis Simulation Framework, the Behavioural Framework, and the Trainer Support Framework, and provides rendering instructions to the Simulation Environment Builder Framework. It can be broken down in to two sub-components: The Affective State Framework and the NPC Framework.

1) Affective State Framework

The emotional and behavioural condition of trainees during the training event are monitored in the Behavioural Framework, which provides input to the Affective State Framework, primarily associated with determining the level of affective input to provide to the trainees, individually or as a group. This information can be pre-determined within the event network, dynamically created by the behavioural framework on an individual or group basis, or input directly by the trainer through that framework.

Within the Affective State Framework a local Multimedia Asset Store provides a repository for a wide variety of multimedia assets developed to support the scenarios. Each of these assets will be meta-tagged with an XML emotion mark-up language specification, developed specifically for Pandora, which will provide standard information on the type and nature of the asset, the media channels for which it is appropriate, the potential for combination with other multimedia assets, duration, etc. It will also indicate an affective level that the asset individually can be expected to engender in the trainees, based on an affective scale defined and categorised for the Pandora project. These assets can also be specifically tagged for use in specified events in training scenarios, to support rapid selection of assets.

2) NPC Framework

In Games terminology, a Non-Playable Character (NPC) can be defined as a sprite or game element that acts as an agent of the game, to facilitate game-play, and is not subject to independent player control or independent autonomous actions. Within Pandora, there are four types of NPCs that can be rendered within the simulation environment:

- HICON (Higher Control Strategic Agents) representing the most senior authority figures within a scenario, e.g. Government Ministers. Such individuals are above the level of Gold Commanders, have the authority to demand actions or constrain resources, and can impose their decisions on the crisis team and scenario.
- LOCON (Lower Control Tactical Agents) representing the lower levels of command within the crisis team who can provide valuable feedback on tactical level realisation of a strategy being developed by the Gold Commanders, as well as on-site reports of the situation, available resources, local constraints, etc.
- External Experts, representing specialists in particular areas of importance in given scenarios who can provide inputs through media interviews or information sites, or can be directly consulted by the trainees.
- Missing trainees, for each scenario a set of key players will be identified, and these must be represented so that all the elements of the scenario can be realised. Each of these players will also be modelled as an NPC, where their actions will be pre-determined in relation to the narrative of the scenario. In the event that a training event takes place in which one or more of the trainees are missing, the relevant NPC(s) can be configured to take their place and enable the event to take place.

Each NPC will be identified by a standard specification and configuration model, stored locally in the NPC Repository, which will allow the NPC to be rendered in a variety of multimedia forms, ranging from the simplest pure text representation through to fully rendered 3D avatars.

The NPC Repository Manager provides an interface for the input and manipulation of NPC specifications interactively, and direct import and export will be supported using a standard XML avatar description language, suitably extended to support Pandora requirements. This is not a runtime activity, but will be performed during system downtime, and is not therefore described in the Pandora use cases for the runtime system.

The NPC Customisation Engine receives input from the Crisis Simulation Framework, specifically from the Event Network, triggered by a trainee's action (either individual or group), a trainer's action, or a pre-determined event point in the narrative of the scenario. Such events can activate or de-

activate one or more available NPCs, provide NPC(s) with association(s) with activities related to the event, and provide information or action requests to one or more NPCs.

D. Simulation Environment Builder

The Simulation Environment Builder Framework creates a realistic and engaging interaction 3D environment around the trainees and is focused on the best way to render the simulation scenario to the trainees. This module should be able to transfer, during the simulation, certain emotions to the trainees, in particular information overload and related stress and the pressure in making decisions.

It uses the event network data coming from the Crisis Simulation Framework to decide what information should be displayed to the trainee, in terms of maps and the information on them and in terms of video/audio that must be played to trainees. The rendering of these two types of information is managed by the Maps rendering manager and from the Virtual Environment Animation Manager component respectively.

When a video/audio involves an NPC, an NPC Rendering Manager component is considered. It starts from the NPC rendering specification with affective content that comes from the Affective State Framework, and tries to animate the NPC and to recreate the required emotional affect.

Since the trainees' GUI is not only composed of different windows, but will also be displayed using different tools (video-wall, laptop PC) and can be different for each trainee, it is necessary to have an Information Rendering Manager to handle this required functionality. Finally, the Simulation Environment Builder Framework collects information to generate the trainee profile which is sent to the Behavioural Framework for the subsequent elaboration.

E. Recording Framework

The Recording Manager is responsible for the recording functionalities, which are concerned with the collection of trainee actions, decisions, and any available information that is related to these actions and decisions with trainee behaviour. This framework also collects the output coming from sensors. This data is stored in digital format and subsequently accessed and used by other frameworks within the Pandora system to dynamically change training storylines, and to use for de-briefing.

F. Trainer Support Framework

This is the system module responsible for managing the interaction with the trainer. A trainer is able to interact with the system in three different situations: 1) at the beginning, as the trainer needs to broadly define the training scenario and training goals; 2) during the simulation at runtime, the trainer needs to be able to drive the training session dynamically depending on how the team is progressing, to speed it up or slow it down, to add extra information, to stop the team going down a dead-end; and 3) at the end of the simulation, the trainer needs support in giving feedback to the trainees, based on their performance. It incorporates the following main components:

- A **GUI trainer manager**: which manages the graphical interface the trainer would use and interact with.
- A **learning strategies expert system**, which defines the best pedagogical methods that suit the particular training objectives. These objectives are defined by a trainer at the beginning of a training session, and are appropriate to the profile of the trainees.
- The **trainer runtime manipulation manager**, which allows a trainer to modify the course of events in a training session. This means, for example, being able to go forward and backward in terms of timing, to accelerate or decelerate the session according to the progress of each trainees. This component also allows trainers to alter the event flow of a training scenario in order to address specific learning needs that have not been achieved within the progress of a session as intended.
- The **trainer de-briefing support manager** supports a trainer during or at the end of a session by composing a report for debriefing. It receives information about trainee performance during the training session, in order to organise that information into a report to which the trainer can add his evaluation and comments.

V. CONCLUSION

The paper has described a technical framework for the development of near real-life training environments for collaborative learning activities. The key components and architecture of the system detailed here will help create an environment useful in the training of crisis management by facilitating a realistic and complete simulation that is time coherent to that of expected near real time in real-life situations; that reproduces the realistic emotional status; and that supports and facilitates the collaboration of crisis managers from different agencies in training scenarios.

ACKNOWLEDGMENT

This paper is a product of research and development by consortium members of the Pandora project. Pandora is co-funded by the European Commission under the mixed call on ICT and Security.

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