The development of a rich multimedia training environment for crisis management: using emotional affect to enhance learning

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PANDORA is an EU FP7-funded project developing a novel training and learning environment for Gold Commanders, individuals who carry executive responsibility for the services and facilities identified as strategically critical e.g. Police, Fire, in crisis management strategic planning situations. A key part of the work for this project is considering the emotional and behavioural state of the trainees, and the creation of more realistic, and thereby stressful, representations of multimedia information to impact on the decision-making of those trainees. Existing training models are predominantly paper-based, table-top exercises, which require an exercise of imagination on the part of the trainees to consider not only the various aspects of a crisis situation but also the impacts of interventions, and remediating actions in the event of the failure of an intervention. However, existing computing models and tools are focused on supporting tactical and operational activities in crisis management, not strategic. Therefore, the PANDORA system will provide a rich multimedia information environment, to provide trainees with the detailed information they require to develop strategic plans to deal with a crisis scenario, and will then provide information on the impacts of the implementation of those plans and provide the opportunity for the trainees to revise and remediate those plans. Since this activity is invariably multi-agency, the training environment must support group-based strategic planning activities and trainees will occupy specific roles within the crisis scenario. The system will also provide a range of non-playing characters (NPC) representing domain experts, high-level controllers (e.g. politicians, ministers), low-level controllers (tactical and operational commanders), and missing trainee roles, to ensure a fully populated scenario can be realised in each instantiation. Within the environment, the emotional and behavioural state of the trainees will be monitored, and interventions, in the form of environmental information controls and mechanisms impacting on the stress levels and decision-making capabilities of the trainees, will be used to personalise the training environment. This approach enables a richer and more realistic representation of the crisis scenario to be enacted, leading to better strategic plans and providing trainees with structured feedback on their performance under stress.

Keywords: affective computing; augmented reality simulations; affective impact in eLearning; timeline-based crisis scenarios; emotional markup

1. Introduction

It is often argued that learning under stress, for example in studying for exams or meeting deadlines for submission of coursework, focuses the mind and results in

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faster processing, storage and recall of information. While there is often debate about the retention of that information and the knowledge thereby gained, there can be no doubt that this model is frequently self-imposed by students. Additionally, decision-making in stressful situations can be impacted by the affect of elements of the situation on the emotional and behavioural makeup of the decision-maker. This paper discusses the work of the EU FP7 Project, PANDORA, and describes a system currently being developed which is designed to use emotional affect in order to impact decision-making and enhance learning. The application under development is designed to enhance and expand training exercises for Gold Commanders in crisis management. Gold Commanders are specifically engaged in the development of strategic plans to deal with a wide range of potential crisis situations that can arise in civil society. These crisis situations could be:

- Natural events, such as extreme weather, earthquake, landslides, etc.
- Transport events, such as plane, train or vehicle crashes.
- Service failures, such as electrical power plant failure, water supply failure, etc.
- Health crises, such as pandemics, epidemics, containment conditions.
- Technology failures, breakdown of automated control systems, central services.
- Policing and terrorism events.
- Some combination of some or all of the above.

In order to develop strategic plans to deal with such situations, individuals who carry executive responsibility for the services and facilities identified as strategically critical within these situations e.g. Police, Fire, Ambulance Service, Local Authorities, Health Service, are expected to work together. These individuals are identified as Gold Commanders, and their role is explicitly strategic. They are in overall control of the emergency. However, they will not generally be at the site of the emergency, but typically co-located in a control room. They will set the direction and propose solutions for the tactical (Silver) commanders to implement. Silver commanders will also typically not be physically present at the site of the emergency but give direction to operational commanders (Bronze) who are responsible for organising resources on the ground. In practice some Gold commanders may also have tactical or operational responsibility. Their objectives are to: save and protect life; relieve suffering; contain the emergency; provide the public with information; protect the health and safety of staff; safeguard the environment; protect property; maintain/restore critical services; maintain normal services appropriately; promote and facilitate self-help; facilitate the investigation/inquiry; facilitate community recovery and to evaluate and identify lessons learned.

The training of Gold commanders to prepare them to manage a crisis is very important and is currently typically undertaken in two ways:

(1) Through the use of table-top exercises: These are low cost, paper-based exercises, with some limited audio-visual input, undertaken by groups of Gold commanders representing different emergency services etc. led by an expert trainer. These events take place in a dedicated training environment or in a standard meeting room at a Gold Commander venue, as required. The expert trainer provides guidance to the Gold commanders on the case study

being used, tries to provide an intensive time constrained activity to simulate the pressure of a real crisis and provides feedback to the Gold commanders after the event. This type of training exercise can be easily organised and is cheap to run but it lacks the authentic feel of a real crisis which would place the Gold commanders under extreme pressure to make rapid and effective decisions.

(2) Real-world simulations: These train Gold commanders in the field through the use of simulation exercises. These are very effective; however they are also extremely expensive, time consuming to set up and require specialist equipment etc.

The purpose of these types of training events is to:

- Develop the collaborative skills of the trainees in formulating strategic responses across a number of organisations and events.
- Develop the strategic thinking of the trainees in considering the implications of their decisions and the effects on other services.
- Develop the responsive skills of trainees in formulating alternative strategies and remediating actions in the event of the failure of a strategic response.
- Determine the strategic planning ability, decision-making capability, flexibility and capability under pressure of the trainees.
- Develop skills to deal with the media, which are inevitably required in the event of a crisis.

However, as outlined above, the typical table-top training model that is used has severe limitations in achieving these goals and is almost entirely dependent on the ability of the trainer to engage and motivate the trainees, and to assess their performance subjectively in the training event.

When a crisis occurs, human behaviour and preparedness is critical to the delivery of an effective solution and therefore training needs to be as realistic as possible. It is important to be able to simulate the information overload and related stress, together with the pressure in making decisions. PANDORA therefore aims to bridge the gap between the low cost, table-top exercises and the expensive real-world simulations by providing an on-line e-learning environment in which the group and the trainer can participate in a realistic, dynamically changing, time sensitive, immersive crisis simulation exercise, that allows trainees to practice their decision making and negotiation skills within a realistic, stress-controlled environment (see Figure 1).

2. Background on affective and emotional computing

One of the key features of the training system developed for PANDORA is that it should provide an environment that engages the trainees on an emotional level. Ideally the trainees should experience emotions of a similar nature and intensity to those that they might experience when dealing with a real emergency. To this end their emotional state will be monitored and manipulated during the training in a variety of ways. This aspect of PANDORA is based on research into models of emotion, decision-making and learning.

Figure 1. The virtual training environment.

Research in neuroscience and psychology shows a strong connection between cognition and emotion. Cognition plays an important role in creating emotions. Emotions, in turn, cause a wide range of effects on attention, perception and cognitive processes involved in decision making, problem-solving and learning. Often the word affect is used instead of emotion and indicates that a wider range of factors than those classically considered as emotions are involved.

A special issue on "Affective modelling and adaptation" of the User Modelling and User-Adapted Interaction Journal focuses on some issues that are relevant to PANDORA. In the introduction, affective computing is described as having four areas of interest. The first area is the analysis of affective states and the relationship between affection and cognition, such as learning. Second is the automatic recognition of affective states e.g. through facial expression or physiological measurements. The third area is the adaptation of a system in response to the affective state of the person. The fourth aspect of affective computing concerns the design of avatars able to exhibit affective states. The second of these areas is considered the most difficult i.e. the ability to precisely and accurately recognise the affective state of a person. Most of the work reported relates to tutoring systems and modelling affective states of learners (Carberry and de Rosis 2008). Forbes-Riley et al. (2008) demonstrate how frustration and uncertainty influence learning and show that adding affective state to learning models increases the level of accuracy of the model. D'Mello et al. (2008) study the relationship between affect and features of interaction (such as the number of words in a student's response, response time etc.) and show that affect can be recognised by these. They consider a wider range of states than Forbes-Riley et al. (2008). McQuiggan, Mott, and Lester (2008) try to identify the level of student self-efficacy and confidence. The initial results of this study show that physiological response may be a predictor of self-efficacy. The work of Porayska-Pomsta, Mavrikis, and Pain (2008) derives a set of rules to adapt interactions with learners to their affective state. Yannakakis, Hallam, and Lund (2008) consider ways to estimate the level of engagement in games in order to adjust the virtual environment to the preferences of children.

An important aspect of affective computing concerns the design of avatars able to exhibit affective states. The design and implementation of computational emotion models is needed in order to support this. Marsella and Gratch (2009) have carried out research aimed at building a stable computational model of emotions based on appraisal theory. Figure 2 illustrates the relationship they see as existing between appraisal, emotion, coping and cognitive processes and illustrates the key sources of emotional dynamics.

The EMA model has been empirically assessed for three particular types of coping strategies: Wishful Thinking, Resignation and Distancing (Marsella and Gratch 2009). Marsella, Gratch and Petta (2010) propose an analysis of the role and utility of computational models of emotions. Psychological theories of emotions are typically formalised with a high level of abstraction through not very formalised natural language. This implies a high level of abstraction and a lack of detail and rigour. In contrast, computational models require a greater degree of precision since the theory must be implemented through a computational model. In this light computational models lead to the identification of underlying assumptions and complexity that are usually hidden and that need to be managed. Computational models can then be seen as a way to substantiate theories as well as a framework for their construction.

3. Description of PANDORA work to-date

3.1. Modes of delivery

The PANDORA crisis training room, which is where training is conducted, is designed to work in three different modes. These are:

(1) Single site training – this is where the training takes place in a physical room where the trainees and the trainer are co-located. The trainees sit around the table in the same way as they would have done for the paper-based table-top

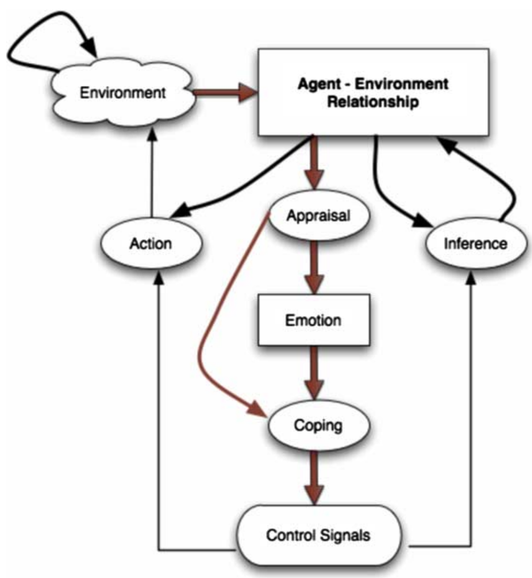

Figure 2. Theoretical assumptions of the relationship between appraisal, emotion, coping and cognition, and the sources of dynamics (Marsella and Gratch 2009).

exercise; however, with PANDORA, a range of consoles are used to provide multimedia information using sound, pictures, maps, animations, videos etc. for example, to simulate receiving information about the crisis such as a news broadcast. Biometric sensors are also used to gather physiological information about the trainees to assist in an analysis of their stress levels etc. The trainer is able to configure the scenario to e.g. set up NPC to role play an emergency service not represented within the group of trainees; subject matter experts; represent higher control (HICON) such as Government ministers – these individuals would be above the level of Gold Commanders and have the authority to demand actions or constrain resources, and can impose their decisions on the crisis team and the scenario; lower control (LOCON) – these individuals represent the lower levels of command within the crisis team and can provide valuable feedback on the tactical level realisation of the strategy being developed by the Gold Commanders.

(2) Deployed training – this is essentially the same as for the single site training; however it is not delivered in a dedicated room, but elsewhere, for example at the site of one of the Gold commanders taking part in the training. The PANDORA system, equipment and setup must therefore be portable to enable this delivery mode to be realised.

(3) Distributed training – in this mode, as shown in Figure 3, the physical room is replaced by a virtual room and trainees participate through a web-based interface. The 3D virtual room contains NPC. As with the other two modes these fulfil any key emergency service roles that are missing from the trainees. Each trainee is represented by their own avatar. It provides the same multimedia channels as the physical room to provide the trainees with information on the unfolding crisis with which they have to deal.

3.2. PANDORA architecture

The underpinning architecture of the system is the same for all three deployment modes and is made up of several key components which are described below:

- The Crisis Module Framework – This provides an event network to model a crisis scenario against a timeline, supporting the management of the training

Figure 3. In-world slide show, streaming video and map application.

process including the introduction of decision points for trainees incorporated into events within the crisis scenario. Event network planning and mapping to timelines is managed through a knowledge-based approach, utilising rules stored in the Crisis Knowledge Base.

- The Behavioural Framework – This considers the behaviour of trainees, based on a pre-determined user model, and feedback from a variety of biometric sensors and the trainer during the training session. This component shows how a complete loop crisis-stimuli/trainee-reaction/PANDORA-behaviour-analysis can be implemented and shown to work in a training environment.
- The Trainer Support Framework – This allows the trainer to carry out three key functions:

    (1) The setup of a scenario for use with a particular group of trainees e.g. configuring an avatar to represent a missing trainee from one of the emergency services.
    (2) Customise a training session and dynamically update a scenario whilst it is being executed e.g. by compressing the timeline in which events occur and/or to interject additional events, in order to increase the stress levels of one of more of the trainees.
    (3) Record each run of the scenario so the trainer can review the training session after it has been completed with one or more trainees to reflect on the rationale for the decisions made and the alternative choices that could have been chosen during the simulation.

- The Emotion Engine – This is a middleware component within the PANDORA system, providing facilities for the development, configuration and introduction of NPC into the crisis scenario to interact with the trainees, and multimedia information assets, tagged for emotional affect. The NPC framework also permits the trainer to take control of an NPC to provide direct inputs, in specific events, to the trainees. The Affective Framework, which is a sub-component of the emotion engine, manages a repository of affectively tagged multimedia assets and uses inputs from the behavioural framework and local mashup rules to produce combinations of those assets to provide emotionally and behaviourally affective information to the trainees. The output of the Emotion Engine, generated through the Environment Framework Builder, is a rendering specification describing the environmental conditions, multimedia information assets and NPC to be generated in the training environment.
- The Emulated Crisis Room – in essence this is the trainee environment, since the rendering of the information generated from the other components is realised within this component.
- Integration of the above components is managed through a middleware model that has been developed for the project, and various test beds and test harnesses are also being constructed specifically to meet the needs of the PANDORA system.

3.3. Design for emotional affect

This section describes in more detail how the emotional affect is created by the PANDORA e-learning environment through both behavioural simulation and modelling, and the Emotion Engine.

The focus of the behavioural simulation and modelling functionality is to:

- Select, model and monitor the relevant human factors or psychological variables that can influence decision making.
- Develop a model able to represent trainees' actual behaviour/profile.
- Propose (plan) high-level personalised training goals and user interactions for the crisis planner.

The trainee model takes into account both psycho–physiological parameters e.g. heartbeat rate, personality traits, self-efficacy and pedagogical parameters like training methods. User profiles are developed by asking the trainees to take neuropsychological and psychological tests in advance of the training in order to assess factors such as self-efficacy, self-estimate, affective style, anxiety etc. The PANDORA system will then determine a personalised training path for each trainee, customised with difficulty levels and challenges.

PANDORA must also have the ability to relate a user's emotional and psychological aspects within a computational user model that is able to recreate physical effects. The Emotion Engine has been designed with two components outlined as follows:

(1) An NPC Framework, which can provide representations ranging from simple text information through to full avatar representation (dependent on the mode of deployment of the system) and can represent emotion within those characters within the limitations of the media format used and the current state of the art in emotion representation.
(2) An Affective State Framework, which maintains a repository of multimedia assets related to the training scenario, tagged according to potential emotional affect and linked, where appropriate, to events in the scenario event network. This Framework can combine assets using mashup rules to create emotionally affective multimedia artefacts, subject to the requirements generated from the Behavioural Framework.

The emotional and behavioural condition of the trainees will be monitored in the Behavioural Framework, which will provide 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 will provide 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, adapted 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 the rapid selection of assets.

The key concept to consider in the development of multimedia information representations for the trainees is the affective impact that combinations of these assets may have. It is standard practice in film and TV design and production to utilise combinations of environmental outputs to generate affective conditions, often referred to as *ambience*. While in the PANDORA environment there will be no background music to create mood, it will be possible to use audio effects to reinforce outputs generated from a crisis situation. The use of video images combined with TV style voice-overs will permit differential levels of anxiety in the voice-over to be associated with the same images, permitting reuse to change the affective impact related to the same information, and a number of similar techniques may be applied to video and audio information. By using an XML-based tagging for multimedia assets, it becomes possible to use rule-based mechanisms to combine multimedia assets and create mashups to achieve a desired level of emotional affect within the environment. Information management techniques, such as overloading the media channels with multiple inputs, noisy media channels, missing and incomplete information, and media channel failures, can all also be used to impact the stress level of the trainees. Given that the system can identify the current emotional and behavioural level of the trainees, and for the purposes of the training event a target emotional level can be identified, then the Affective State Framework can be used to manage the information presentation to the trainees to impact on their emotional state on a trajectory towards the target level. The efficacy of affective impact of particular approaches will be determined from changes to the emotional and behavioural level of the trainees, determined by the Behavioural Framework. This information will be used to enable the system to learn and adapt the rules and techniques to provide more effective affective controls.

3.4. Summary of key PANDORA features

The PANDORA system addresses the shortcomings of the existing training model, enhances the range and scope of the training events and offers the potential for future development by:

- Offering a fully featured multimedia environment to provide information to the trainees, including audio, video, maps, texts, email, graphics and text.
- Developing a structured, timeline-based, sequence of events, crisis scenario model running in a computer-based simulation environment controlled by the trainer.
- Providing real-time operational inputs demonstrating strategic decision outcomes to trainees, asking them to dynamically revise strategic plans and decisions.
- Capturing trainee behaviour and emotional state, through the use of pre-event information capture, direct sensor inputs, self-reporting by trainees, and

trainer inputs, and using affective media effects and information presentation techniques to induce changes to those behavioural and emotional states.
- Providing a graphical virtual representation of the training environment to support on-line distributed training events.
- Providing virtual characters, in any form from textual through to full animation, to engage in the event, including replacements for missing trainees, to ensure that the full scenario enactment is supported in all training events.
- Providing the trainer with a full control system for the training event, including the ability to change events, add new events, expand and compress timelines, provide direct interventions into the scenario and increase or decrease the emotional stress applied to individual trainees.
- Maintaining a detailed log of the training event, to permit rerun of some or all events, modelling of individual trainee performance and capture of relevant and useful events as exemplars for future training.
- Maintaining configurable scenario models, knowledge, multimedia asset and databases to enable the system to build a wide range of crisis scenarios, to use as training events for those involved in crisis management at all levels.

4. Contribution to the EmotionML standard

Emotion Markup Language (EmotionML) is an XML-based language designed to represent emotion in a machine-readable manner. It is going through the W3C standards process and is currently at the 'Working Draft' stage (W3C 2010a). EmotionML is intended to be used as a plug-in language i.e. to be used in conjunction with other XML languages such as SMIL.

The main areas in which EmotionML is expected to be applied are:

(1) Annotation of data and media.
(2) Recognition of emotion expressed by people.
(3) Simulation of emotion by technological artefacts.

All three of these areas are relevant to PANDORA, and so from the inception of the project, EmotionML was considered as a likely technology for use in its implementation.

Detailed consideration of how EmotionML could be used to implement aspects of PANDORA revealed several potential issues with the version 1.0 or the draft standard. Three of these are outlined below:

(1) EmotionML considers scales (e.g. for representing intensity of emotion) to be continuous, linear values. This may not be adequate to capture important information in PANDORA. In some cases scales may need to be logarithmic or take into account the notion of a 'tipping point'. In other cases it may be important to be able to represent discrete values.
(2) EmotionML allows for different vocabularies (e.g. for representing the category of emotion). The need for this is the lack of agreement amongst professionals, such as psychologists, about a single vocabulary. The problem of having a multiplicity of vocabularies, especially with none being specified as a default, is that of interoperability. As PANDORA moves beyond a pilot

project it is likely it will need to interact with external systems e.g. to use media originated and annotated externally and so interoperability will be important.

(3) EmotionML allows for emotions to be tagged with a timestamp. In PANDORA data received from monitoring the trainees' affective state will be received in a stream throughout training and it will be useful to be able to represent the identification of emotion as starting at a time offset within the session.

These issues and a description of planned use-cases for EmotionML in implementing PANDORA were discussed at a W3C EmotionML Workshop in October 2010 and will be taken into account when revising the draft standard (MacKinnon, Windall, and Bacon 2010; W3C 2010b).

5. Conclusion and future work

The PANDORA project will produce an advanced training system, targeted specifically at Gold commanders in crisis management scenarios. Since Gold commanders represent the strategic level of crisis planning, improving the training and thereby the efficacy of their strategic thinking and the design of their remediation plans will have a significant beneficial effect in the handling of a variety of different crisis. Better crisis management will have significant socio-economic impacts, in terms of reduced casualty rates, faster and more efficient remediation, reduced loss of working time, reduced loss of productivity and improved coordination of expensive resources. Additionally, since the project will provide different deployment models for the training scenarios, it becomes possible to train larger numbers both at strategic and tactical levels, utilising distributed virtualised representations of information, and thereby advance the training scenarios into fully immersive digital environments. Such an approach will enable the use of varied training scenarios that are too expensive for physical simulations to be realised in virtual form, thereby enabling training activities that are not currently practical. Again this will have significant socio-economic benefits, in the ability of crisis managers to develop more wide-ranging, complex and detailed strategies and remediating actions to deal with the ever-growing range of crises that they might be called on to manage. The use of the PANDORA system in different partner countries within Europe will also support the sharing of best practices in crisis management, scenario information and experiences, and will promote understanding of different response modes related to cultural, legal and social variations, which would be of particular importance when dealing with crises that cross national boundaries.

Whilst the PANDORA system is currently being developed for crisis management training, the e-learning architecture and component model is not specific to this particular situation and could be used for a variety of different training needs, since the key component is a scenario that can be modelled as a set of discrete events against a timeline. We can envisage a large number of different application areas ranging from business planning, through health and social care, to regional infrastructure planning, all of which could be modelled within the PANDORA system and then used for simulation and training purposes. In fact, if we consider that the PANDORA system offers a visualisation and simulation environment to support event network-based scenarios, we can consider its use for almost any timeline-based process. The benefits of the training environment, which include the modelling of the behaviour of trainees, the potential for customisation of the immediate training session by the trainer and the introduction of affective elements to impact the emotions and behaviours of the trainees, provide a range of facilities that could be utilised in different ways. Using the PANDORA approach to provide training for a variety of different sectors and scenarios would give Europe a significant lead in the use of visualisation and simulation technologies to provide learning experiences that would otherwise be too expensive, too dangerous or simply impracticable for the general workforce. The socio-economic and social impacts of the widespread use of high-quality simulation and visualisation in distributed virtual environments to provide realistic learning experiences would be extremely significant.

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