Opening the PANDORA-BOX: Planning and Executing Timelines in a Training Environment

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Abstract

This paper introduces a novel use of timeline-based planning as the core element within a dynamic training environment designed for crisis managers. Training for crisis decision makers at the strategic level poses a number of challenges that range from the necessity to foster creative decision making to the need for the creation of engaging and realistic scenarios in support of experiential learning. This article describes our efforts to build an end-to-end system, called the PANDORA-BOX, that helps the trainer to populate and deliver a continuous 4-5 hours training session encompassing exercises that encourage a group of decision makers to achieve joint decisions. Specifically the emphasis is given to (a) the timeline-based representation as the core component for creating training sessions and unifying different concepts of the PANDORA domain; (b) the combination of planning and execution functionalities required to maintain and dynamically adapt a "lesson plan" on the basis of both trainee-trainer interaction and individual behaviors and performance; (c) the importance of keeping the trainer in close control of the activity loop.

Introduction

When a major incident or catastrophic event occurs, it is often human behavior alone that determines the speed and efficacy of the crisis response management arrangements. Indeed, all too often, shortcomings in the response to the emergency do not stem from ignorance of procedures but from difficulties inherent within the challenge presented when operating in traumatic circumstances, particularly when additional unexpected consequences arise. Effective crisis management is a key requirement to prevent an emergency from becoming a disaster. In recent years, poor management in response to an emergency has often resulted in critical situations becoming far worse. Furthermore, crisis events appear to occur more and more frequently and public expectation for an effective and immediate response grows at a similar pace. Thus managers, especially senior managers, have to cope almost routinely with crisis decision situations, given that we are now leaving in a "risk society" (Beck 1992). In these critical circumstances, there is a tremendous necessity to have effective leadership in place. Nevertheless, the ambiguity, urgency and high risk associated with crisis situations posits some constraint on the leadership capabilities. For example, given the need for an almost immediate and of course effective response to a crisis, there is little time to acquire and process effectively all the information that decision makers would wish to have available to them. As a consequence, they are required to assess information and make critical decisions under tremendous psychological stress and physical demands (Klann 2003; Leonard 2004), often caused by the difficulty of operating in a context where losses, including both human lives and critical resources, continue to rise until such time as the response can get ahead of the developing crisis.

Within this context training plays a crucial role in preparing crisis managers. Specifically, training for strategic decision making has to foster the leaders' ability to anticipate the possible consequences of poor decisions and to construct creative solutions to problems. In this light, experiential learning plays a crucial role. A great amount of investment is being devoted to the development of training procedures to increase the capability of crisis managers to deal with emergency situations. Two main modalities are mainly used: (a) the table top exercise (a group discussion guided by a simulated disaster); (b) a real world simulation exercise (field tests replicating emergency situations). Table top exercises are generally low cost and can be easily and frequently organized, but they cannot recreate the real atmosphere, in terms of stress, confusion and pressure. On the other hand, crisis managers trained through simulation exercises in the field can be very effective and can gain valuable skills, but such simulations are very expensive in both time and resources and cannot be easily and quickly organized.

The PANDORA project[1] aims to bridge the gap between tabletop exercises and real world simulation exercises by providing a near-real training environment at affordable costs. PANDORA's goal is to simulate all the dynamic elements contained within an entire disaster scenario within a training room setting that emulates an engaging, true-life environment. The system will be capable of presenting different evolving crisis scenarios, customized to meet specific and specified training needs according to the knowledge and experience levels among the participating students. A key aspect in PANDORA is the ability to create realistic consequence responses to the decisions taken by trainees thus reproducing realistic situations and facilitating the development of a comprehensive range of decision making skills. Additionally, the idea underpinning PANDORA is to take ac-

[1] http://www.pandoraproject.eu/

count of human behaviors and individual personalities in order to plan training sessions that recognize individual traits and training needs.

We have produced a first version of the whole system architecture, called the PANDORA-BOX, that fully demonstrates the feasibility of our approach. Central to the PANDORA system is an original use of the timeline-based planning (Muscettola 1994) to model a rich and unconventional domain. Specifically, planning is used (1) to compute diversified crisis scenarios corresponding to alternative training paths to foster creative decision-making, (2) to model and maintain trainees' behavioral patterns according to which training can be personalized, (3) to support mixed-initiative interaction between the trainer and the automated learning environment relying on a high level of abstraction for the internal representation.

The remainder of this paper covers: presentation of the main challenge surrounding the training of decision makers at the strategic level; the general building blocks of the learning environment and the issues arising from the creation of an immersive training experience. A software architecture for the PANDORA-BOX is introduced and the role of a timeline-based representation as the core component for creating training sessions is underscored. Finally, a combination of planning and execution functionalities that allows for the maintenance and adaptation of a "lesson plan" to enable trainer-trainee interaction is described.

Training for crisis decision makers

When referring to planning connected to crisis management during emergency situations, we have in mind the intervention plans for those people that go directly to the operational level of response, see (Wilkins et al. 2008). In reality there are distinctly different levels of decision making all of which are relevant in any crisis situation. The success of crisis management often depends not only on the ability to apply well established procedures, but also on the effectiveness of high-level strategic choices. The ability of decision makers to anticipate the possible consequences of their actions (decisions) by means of flexible and forward-looking reasoning is also crucial to an effective response to a crisis. Figure 1 summarizes the three different levels corresponding to different roles of crisis decision makers:

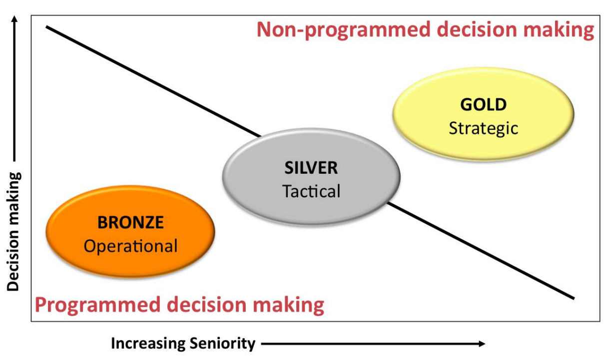

Figure 1: *Different decision makers in crisis management.*

- At the **operational level** we have the operational or **bronze level commanders**, people operating within the detailed area of a crisis situation that perform practical activities and actions, the results of which are monitored and communicated to higher levels;
- At the **tactical or silver level** decision makers that are located close to but not within affected areas of the crisis are responsible for translating high level strategic decisions into actions by allocating tasks and resources down to the bronze level. At this level the anticipated results from the various allocated tasks are monitored and assessed for effectiveness.
- The **strategic or gold level** commanders identify the key issues of a critical situation and prioritize required activity from a detached and sufficiently high level of abstraction. Strategies for resolving the crisis are also decided and are then communicated to the lower levels for their detailed specification and implementation.

The choices at the strategic level are particularly important and critical for the success of the overall crisis response and specifically for devising strategies to contain and correct the developing situation by anticipating future consequences with decisions that try to avoid escalating of the crisis situation.

Also depicted in Figure 1 are the different roles of crisis managers corresponding to the different decision-making levels. Specifically, at the strategic level, decision making is mainly unstructured and not describable in terms of programmed or fixed procedures, being mainly related to the novelty and unpredictability of a catastrophic event. Taken in this view, it is therefore assessed to be non-programmed decision making effort unlike the silver and bronze levels that will respond to higher level tasking and direction in a disciplined and procedural manner.

Most of the state-of-the-art training support systems and simulators are aimed at the operational or tactical levels. PANDORA however is specifically targeted towards strategic level decision makers thus presenting difficult challenges at both modeling and computational levels. Additional challenges arise from the need to foster quick decision making in stressful conditions and the need to encourage creative thinking to devise workable strategies to deal with uncommon situations.

Among the main objectives for gold commanders during a crisis are: protection of human life and, as far as possible, property; alleviation of suffering; support for the continuity of everyday activity; the restoration of disrupted services at the earliest opportunity; upholding the rule of law and the democratic process. The speed with which recovery strategies are identified to contain and resolve the crisis also has a great influence on the scale of loss of whatever nature. For this reason the strategic decision maker has to develop an ability to quickly react and decide to promote the overall goal of obtaining a rapid return to normality.

In this light, training plays a fundamental role. At the strategic level, training aims to teach decision-makers to focus on the possible consequences of their actions. It also teaches the value of integrating and testing the compatibility of plans and the need to work in collaboration with other organizations and between different nations, to promote continuity of efforts and to have a well-defined focus.

One approach to decision making promotes the need for a creative decision making process to identify and construct potential courses of action in response to an identified developing situation. These possibilities are then filtered and reduced to a set of feasible options. The process is gradually refined until alternatives are decided between and a specific (best or least worse) course of action is to be chosen that will be adopted to achieve the identified strategic aim.

As mentioned earlier, two different delivery methods are currently used for training, the table top exercise and the real world simulation exercise. The PANDORA concept is to replicate the benefits of both of these methods by developing a system capable of guaranteeing the realism of the real world simulation and the practicality and affordability of table top exercises.

The PANDORA approach. Goal of the PANDORA project is to build an intelligent training environment able to deploy a spectrum of realistic simulations of crisis scenarios that: (1) reproduce the stressful factors of the real world crisis; (2) personalize the planned stimuli according to the assessed abilities of different trainees and (3) supports the dynamic adaptation of "lesson plans" during the training time-horizon.

The system design has followed a user-centered approach, based on a close cooperation with the training experts who have profoundly influenced the shaping of the system. Specifically, the Cabinet Office Emergency Planning College (EPC) has synthesized their experience, gained from training a wide range of senior decision makers combined with their pre-eminent expertise in emergency planning and crisis management. As the end user representative in the PANDORA consortium, EPC has contributed to identify the main requirements specification of the innovative training environment, and is influencing the design and implementation choices.

A number of general constraints have emerged during a first phase of user requirement analysis:

– *Support cooperative decision making*: it has become clear immediately how important it is to train gold commanders to take key decisions jointly in collaborative working conditions.

– *Training personalization*: the role of personalized teaching has been underscored even within a group decision making context.

– *Mixed-initiative interaction*: The need to have a tool that would empower the trainer to adapt and adjust the training session in real time run became apparent rather than relying upon a video-game type of immersive experience, hence the need to create a mixed-initiative environment in which the trainer is fully integrated in the "lesson loop".

Figure 2 shows the main architectural idea pursued within the project to obtain a system called the PANDORA-BOX whose current complete version was officially demonstrated in March 2011. The system comprises three environments: (a) a Trainer Support Framework allows the trainer to keep control of the training session and dynamically adjust the stimuli based on his/her experience; (b) distributed Trainee

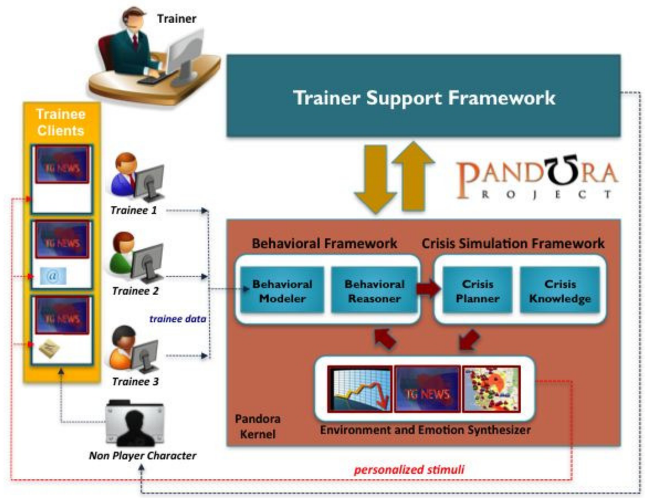

Figure 2: *The* PANDORA-BOX *general architecture*

Clients can access the PANDORA-BOX and receive both collective and individual stimuli during a lesson; (c) a PANDORA kernel which is the main engine that generates the "lesson plan", animates it in an engaging way and adjusts it on a continuous basis to keep pace with both the evolution of the specific group of people under training and their individual performance.

Specifically, a group of trainees, representative of the different agencies that would be involved in the resolution of a crisis (e.g., Civil Protection, Local Authorities, Health, Fire Rescue, Police, Transportation Agencies and so on) have access to the training system through their work station. If some of the representative authorities are not present they would be simulated by the PANDORA system through a Non Player Character (NPC), in which case, features and decisions are synthesized by the trainer via the system.

The various participants in the training session are characterized by different aspects, both in relation to the components closely linked to their role and responsibility, and for the particular "affective states" they may exhibit during the training experience in response to the presented stimuli. Therefore, each trainee, by interacting with the system, feeds personal data to the PANDORA-BOX, which gathers this information to build a *user model* (Behavioral Model shown at Figure 2). Based on this model, the system synthesizes a personalized training path that meets the specific needs and status of each trainee (Behavioral Planner). The output of this process is passed to a second module (the Crisis Planner), which on the basis of the Behavioral Module's indications, as well as the knowledge of the chosen guiding training scenario, synthesizes a sequence of stimuli appropriate for both the group (information shared among all trainees) and the individual trainees (information tailored to induce the "right level of stress" for different individuals).

The plan synthesized by the crisis planner is then given as input to the module called the Environment and Emotion Synthesizer which is responsible for an effective rendering of the training temporal plan. In practice this module adds an additional level of "realism" to the stimuli, by customizing the appropriate presentation mode (e.g., introducing background noise or other distraction during a phone call report) in order to achieve a high level of realism, stress and pressure. The use of advanced 3D scenario reproduction is also included and assessed in the project.

Overall the PANDORA-BOX supports the loop *trainer* → *training environment* → *trainee*, encouraging the customization and adaptation based on the users feedback as well as the inclusion of training goals and other inputs by the trainer.

We now turn to timeline-based planning technology within the PANDORA-BOX and describe how the planning technology has become the unifying element of the overall system.

The planning problem

The basic goal for the training environment is to create and dynamically adapt content for a four hour continuous training session. The pursued idea is to represent a session's content as a *plan* composed of different "messages" to be sent to trainees which have temporal features and causal relations among them. In PANDORA a lesson master plan is first synthesized starting from an abstract specification given by the Trainer. It is then, animated, expanded and updated during its execution, in response to new information gathered from the trainees and the decisions that they may make. Specifically, the lesson master plan contains time-tagged activities that trigger multimedia events presented presented to the trainees. A key aspect will be the reaction of trainees to lesson stimuli (e.g., the answer to a request to produce a joint decision on a specific critical point). "User reactions" internally represented in the plan trigger different evolutions of the current plan thus supporting dynamic adaptation.

The use of AI planning is quite natural for creating such a master plan. Previous work exists on the use of constraint reasoning for synthesizing multi-media presentations (e.g., (Jourdan, Layaida, and Roisin 1998)), and on the use of planning in story-telling (e.g., (Young 1999)), etc. The main "technological idea" we have pursued in PANDORA is to use timeline-based technology to represent and organize in time heterogeneous information, a choice that naturally matches some of the manipulations that were specifically required by the master plan representation within the project. In particular two aspects offered an interesting challenge for timeline based technology: (a) the idea of doing planning, execution, re-planning in a continuous cycle; (b) the possibility for modeling a completely different type of information with respect to the "usual" applicative domains in which timeline-based planning has been used (e.g., (Muscettola 1994; Jonsson et al. 2000; Cesta et al. 2011)).

A timeline-based problem representation. Figure 3 exemplifies the basic modeling features and introduces some terminology for the PANDORA domain modeling. The main data structure is the timeline which, in generic terms, is a function of time over a finite domain. For the purpose of this description we call "events" the values for a timeline. Events are represented with a predicate holding over a time interval and characterized by start and end time [2].

Events can be linked to each other through *relations* in order to reduce allowed values for their constituting parameters and thus decreasing allowed system behaviors. In general, relations can represent any logical combination of linear constraints among event parameters. According to the number of involved events, relations can be divided into unary, binary, and n-ary. For example, unary relations are used in the PANDORA-BOX to fix initial scenario event parameters by placing them in time. Given an event e, an example of unary relation can be $start\text{-}at\,(e, 15, 20)$ forcing the starting time of the event e to be constrained inside simulation time interval $[15, 20]$. Given two events e_0 and e_1, an example of binary relation can be $after\,(e_0, e_1, 100, 120)$, forcing the starting time of event e_1 constrained to be a minimum 100 and maximum 120 time units after ending the time of event e_0.

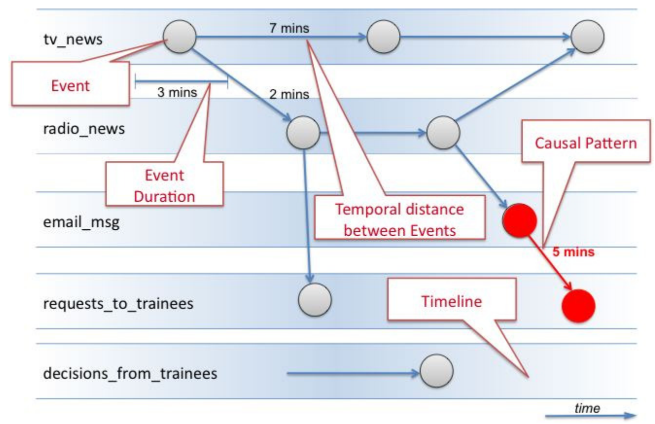

Figure 3: *The timeline-based plan data structure*

An "Event Network" is a hyper-graph having events as nodes and relations as hyper-edges. Through the concept of an Event Network, the whole timeline-based planning procedure can be reduced to the process of reaching a target Event Network, that meets the desired *goal* conditions, starting from an initial Event Network. In our case, goal conditions are characterized by high level scenario events representing the abstract blueprint for the master plan while the initial Event Network is, trivially, an empty Event Network.

In the example of Figure 3 we see an Event Network distributed over 5 timelines (three representing different media for giving "active" information about a situation (`tv_news`, `radio_news`, `email_msg`), and two more special to purpose, seeking trainee input and gathering such input (`request_to_trainees`, `decisions_from_trainees`) [3].

A further basic ingredient in timeline modeling are the

[2] Events here are equivalent to "tokens" in other timeline-based approaches (Muscettola 1994). The reason for re-naming them is to focus attention on the PANDORA main task, namely the generation of timeline values to be "rendered" as a specific multi-media *event* when presented to trainees. Even if the use of timelines in PANDORA is wider with respect to the pure generation of multi-media events, the name survived to facilitate communication internal to the project.

[3] As usually done in timeline-based planning, the sketchy Event Network shown in the figure is defined on top of a Temporal Constraint Network and included between a start-time and end-time of a temporal horizon.

so-called "Causal Patterns" (see an example in Figure 3). These are a way to express planning domain/causal rules in the current internal representation. Any given Event Network should be consistent with respect to the set of such specified causal patterns [4].

Patterns are defined through a logic implication $reference \rightarrow requirement$ where $reference$ is the event value that demands pattern application while $requirement$ is the "consequence" of the presence of the $reference$ value in the Event Network. Making use of a recursive definition, a requirement can be a target event value, representing a new value on the same or another timeline and a relationship between reference value and target values, a conjunction of requirements or a disjunction of requirements. Being relations, in the most general case, linear constraints, causal patterns allow great expressiveness that allows a PANDORA modeler to represent quite complex behaviors.

A planning domain is generically defined by creating a set of timelines and a set of Domain Causal Patterns. From this basic domain representation, receiving a set of goals a planner generates an event network to be executed.

Opening the PANDORA ... BOX

Having introduced the basic modeling features we now describe the use of reasoners that support PANDORA functionalities. Figure 4 shows the different modules that work around the Timeline-based Plan Representation which is the central data structure as always in this type of planning applications.

Trainer abstract plan. The initial driving role is given to the Trainer. Through his Support Framework the trainer can loads a specific "Scenario", an abstract plan sketch that works as a sequence of "lesson goals" and as a skeleton plan for the ground planner. The scenario is contained in a particular timeline that generates sub-goaling by interacting with the set of domain causal patterns. Scenarios have the double role of enabling the Trainer to reason on a high level of abstraction thus avoiding the details of the planning technology and to continuously influence the event network that actually implements the detailed lesson at ground level. Furthermore the Trainer is endowed with commands to introduce single steps in a scenario hence triggering dynamic plan adaptation. It is worth highlighting how the overall system aims to empower the trainer with a more effective means to train people. Indeed the suggested crisis stimuli as well as the behavioral analysis is offered to the trainer who can influence at any moment the training session in perfect line with a *mixed-initiative* style.

The Planner in Figure 4 works on the ground timeline representation to create the training storyboards, e.g., the set of connected "events" that are communicated to the trainees (e.g., a video news from the crisis setting, a phone call or e-mail from a field manager, and a set of temporal distances among events). Once the planner has achieved a fix-point given the abstract scenario goals from the Trainer and the Domain Causal Patterns, the responsibility is left to the Plan Dispatcher that step-by-step executes the plan by sending events to the Rendering Environment according to their progressive start times. Some of the events are requests for trainees to make decisions (see Figure 3), the result of which are fed back to the timeline representation as additional information for plan adaptation. In fact the Planner is able to reacts to trainees' strategic decisions, triggering consequent events to continue the training session.

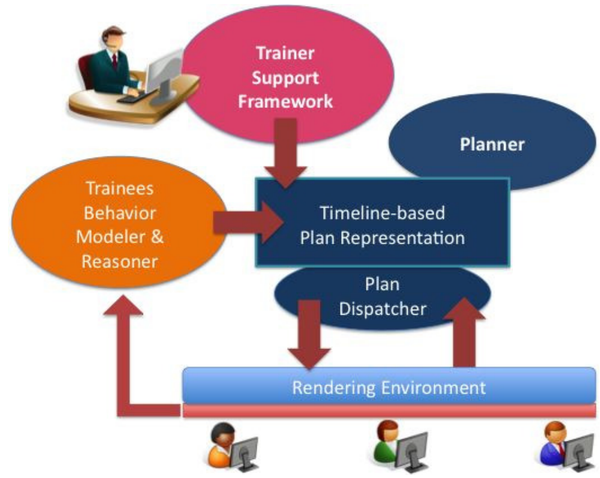

Figure 4: *A blow-up of the* PANDORA-BOX

A further path on the dynamic adaptation of the lesson plan is given by the personalization for each trainee which is fostered by the block named Trainees Behavior Modeler and Reasoner. Through this module psycho-physiological trainee features are modeled and updated during training and internally represented as timelines. Specifically a set of "relevant user variables" has been selected among those that influence human behavior under crisis and used to build a trainee model. The timeline-based approach also supports the dynamic update of the user model during the training session. Based on this model, the Behavioral Reasoner, synthesizes specific result timelines that are used as goals by the general planner, thus introducing a continuous loop of adaptation aimed at tailoring the intensity of stimuli to individual trainees.

Planning a lesson. Starting from scenario goal events and from the set of domain causal patterns, the planning process generates a target Event Network that is consistent with the given goals, ordering events in time through scheduling features and producing proper event consequences. Additionally, as described in previous section, new goals can be added during crisis simulation to represent (a) decisions taken by trainees, (b) inferences made by the behavioral reasoner, (c) new scenario steps added by the Trainer. The PANDORA planner is therefore able to replan in order to make its current Event Network to remain consistent with respect to the new dynamic input and with its consequences, namely, changing the current course of the simulated crisis.

[4] Causal Patters are defined within a domain description language, similar to *compatibilities* (Muscettola 1994) or *synchronizations* (Fratini, Pecora, and Cesta 2008), that allow to specify a pattern of mixed time/causal value relations involving PANDORA events.

In general, target event values are added to current Event Network producing new goals that require pattern application in order for them to be causally justified. It is worth noticing that disjunctions of requirements produce branches on the search tree guaranteeing varieties of presented scenarios. In particular, it may happen that some rule cannot be applied since it imposes too strict constraints resulting in an inconsistent Event Network. In such cases, a backjumping procedure allows to go back to the highest safe decision level. When the planning process succeeds, an Event Network consistent with given goals replaces current planner state. At present we are using a planner which is inspired by (Fratini, Pecora, and Cesta 2008) but is specifically tailored to PANDORA needs.

It is worth noting that because not all courses of action in a crisis can be predicted at scenario design time we have also endowed the Trainer with a service that allows to incrementally modify the ongoing scenario in order to adapt the simulation to unpredicted trainees' decisions. Alternatively, the trainer can manipulate ongoing crisis to bring back execution to a desired behavior having already predicted courses. This kind of scenario modifications are stored in a knowledge base providing capacity to expand and evolve the system training capabilities during its use.

The role of trainees modeling and personalization. The trainee's profile are built by considering relevant variables known to have an influence in decision making under stress (Cortellessa et al. 2011). An initial assessment is made through standardized psychological tests and physiological measurements made off-line, immediately before the training session begins and updated during the training session. We choose to model trainees variables, similarly to the lesson storyboard, hence using timelines, in order to maintain a unique representation system. Therefore, with a little overhead of terminology, we will call *event* any of the values on timelines.

We demonstrate how lessons personalization is planned for through a simple example. Two trainee features that are relevant during training (Cortellessa et al. 2011) are:

– the *background experience*, the crisis leader' past experience in managing crisis situation. A short questionnaire assesses leaders socio-demographic information, their previous experiences with leading public health and safety crises and their level of success in doing it. This variable can be used also for tuning the right level of difficulty during the training exercise. We represent *background experience* through predicates of the form $background\text{-}experience\,(x)$ where x is an integer assuming values 0 for low experience, 1 for medium experience and 2 for high experience;

– the *self efficacy* defined by (Bandura 1986) as the people belief in their capabilities to perform a certain task successfully. It has been shown that this variable has influence on different aspects like the ability to manage stressful situations, performance as well as the probability to receive benefits from training programs. We represent the *self efficacy* through predicates of the form $self\text{-}efficacy\,(x)$ with x being an integer ranging from 0 to 10.

In order to explain how trainees are assigned to profiles during training, let us suppose that a trainee x answers to a self-efficacy question and that, consequently, an event representing its updated level of self-efficacy is added to his (or her) self-efficacy timeline. The causal patterns that is applied by the planner have a structure similar to the following:

$$x.self\text{-}efficacy \rightarrow \begin{cases} pro : x.profile \\ during\,(this, pro, [0, +\infty], [0, +\infty]) \end{cases}$$

This patterns assures that every time we have a self-efficacy update, an event, named pro locally to the rule, is added to $profile$ timeline of trainee x, new self-efficacy value must appear "during" pro (triggering event's starting point is constrained to be $[0, +\infty]$ before pro's starting point while pro's ending point is constrained to be $[0, +\infty]$ before triggering event's ending point). Once the event pro is added to current Event Network the solving procedure is called and requires itself a pattern application.

Let's assume now that the following requirements, representing trainee association to different profiles, are defined inside the Behavioral Modeler:

$$r_0 : (se.value = 0 \wedge be.value = 0 \wedge is.value = 0)$$

$$r_1 : (se.value = 1 \wedge be.value = 0 \wedge is.value = 1)$$

$$\ldots$$

These requirements basically state: if self-efficacy value is equal to 0 and background-experience is equal to 0 than induced-stress' $value$ parameter must be equal to 0; if self-efficacy value is equal to 1 and background-experience is equal to 0 than induced-stress' $value$ parameter must be equal to 1; etc.. Enacting such requirements the association of trainees to profiles can change. Profile information is than passed on to the Crisis Planner that updates values of other timelines associated to trainee x, for example, changing the amount of induced stress for the trainee x, using a pattern like:

$$x.profile \rightarrow \begin{cases} se : (?)\, x.self\text{-}efficacy \\ be : (?)\, x.backgroung\text{-}experience \\ is : x.induced\text{-}stress \\ contains\,(this, se, [0, +\infty], [0, +\infty]) \\ contains\,(this, be, [0, +\infty], [0, +\infty]) \\ equals\,(this, is) \\ r_0 \vee r_1 \vee \ldots \end{cases}$$

where the $(?)$ symbol forces target values se and be to "unify" with an already solved event in order to close the loop and interrupt the pattern application process for the event. Finally, induced stress pattern selects proper events from Crisis Knowledge Base and propose them to the trainee in order to generate an adequate stress level with the aim of maximizing the learning process.

Executing the lesson plan. Another important functionality of the PANDORA system, the more relevant for understanding the use of plans, is represented by the lesson plan execution. Simulation time t is maintained by execution module and increased of execution speed dt at each execution step. Each timeline transition that appears inside

Figure 5: *Screenshots of the current Trainer and Trainee Interfaces*

interval $[t, t + dt]$ is then dispatched to PANDORA rendering modules for creating the best effect for the target trainees. By maintaining information about current simulation time, the executor module is responsible for placing in time events that represent trainees' actions, adding proper relations, thus fostering re-planning features, or plan adaptation, in order to integrate actions' consequences inside current Event Network.

Additionally, the training process requires utilities for temporal navigation through the storyboard allowing execution speed adjustments as well as features for rewind and rerun. When going back in time, two different behaviors are provided by PANDORA-BOX:

- *default roll-back*, intended for debriefing purposes, that simply updates current simulation time t to desired target value keeping untouched actions taken by trainees;
- *heavy roll-back*, intended to revert to a crucial decision point at time t, removing each event representing trainees' choices at time $t' > t$, along with their consequences, in order to allow a different simulation course.

A further feature worth noting is that at the end of a training session the resulting completed plan contains all the information given to the class, as well as well as the trainee decisions to required questions, the simulated consequences of such decision and also the trainee's psycho-physiological state evolution. In general this is an annotated plan that can be used by the trainer during a debriefing phase to explain pros and cons of the trainees behavior during the lesson. The different roll-back functions could contribute to this phase to re-run stretch of the lesson for explanation purposes.

Current status

A first prototype of the complete system has been produced in early December 2010 while a first robust version of the PANDORA-BOX has been officially demoed on March 2011 to the EU project officers during the for mid-term project review. To give the reader an idea of the system at work this section describes first some aspect of the interactive environment that connects Trainer and Trainees and then presents a simple experimental table to show the time needed to the planner to synthesize event networks of different size.

The interactive environment. Figure 5 depicts some of the interaction features that have been implemented in the demonstrator. Specifically, we can distinguish between two types of interaction:

- *trainer-system interaction*, indicated as *Trainer View*, which is related to the functionalities available to the trainer to create a training session, monitor, edit it and interact dynamically with the class;
- *trainee-system interaction*, indicated as *Trainee View*, which is the interface through which the trainee can connect to the PANDORA-BOX, receive stimuli and make decisions about the critical situation.

Trainer View. After creating a *class*, the trainer can load a *Scenario*, and see it in tabular form with a series of important information such as the execution time of each goal event and who is the main recipient of information. It is worth highlighting how this representation reproduces the current way of working of the trainers and has been instrumental in establishing a dialogue with them, before proposing any kind of completely new solutions. Along with the scenario, the interface also contains information about available resources to resolve the crisis and the consequences of trainees' decisions, both represented through resource timelines and dynamically updated during the training. In parallel with the traditional tabular view, the trainer can inspect a more advanced view of the PANDORA module, that is the internal representation of both the Crisis and the Behavioral Framework (*Expert View*). As already said, all type of information within PANDORA is represented as a timeline and continually updated (see different colors for timelines related to the crisis and the user model in the Expert View). At this point, through the Execute button, the trainer can start the session. A series of additional commands also allows the trainer to dynamically add new stimuli, in perfect line with the mixed initiative interaction style.

Trainee View[5]. The Trainee interface contains three main blocks, in addition to a number of features related to communication of each trainee with the rest of the class and the trainer. The main building blocks are the following: *Background Documents*, which represents a set of information delivered off-line to the class in the form of maps, documents, reports, in order to create awareness about the upcoming exercise; *Dynamic information* that represents the information dynamically scheduled and sent to the trainee in the form of videos, maps, decision points etc.; *Main Communication Window*, which is devoted to display stimuli (possibly customized) to individual trainees or to the class.

The interaction environment has been critical in our dialogue with the end users and will be further refined on the one hand to satisfy user requirements on interaction, on the other to make the advanced features more useful for the trainer eventually filling the gap between the internal representation and users' expectation, with the aim of promoting their active involvement in the management of training.

Table 1: Average problem solving times in proportion to initial goal number.

goal #	avg. t (ms)	ev. #	var. #	constr. #
26	36	46	459	42
32	54	64	1459	92
76	296	186	2459	142
101	455	256	3459	192
126	979	326	4459	242
151	1511	396	5459	292
176	1903	466	6459	342
201	2864	536	7459	392
226	3793	606	8459	442
276	6241	746	10459	542

The planning time constants. In order to give an idea of the performance of the timeline-based internal engine we report here an initial scaling test. In particular we have generated a fixed training class of a single trainee plus four NPC players, leading to a total number of 84 timelines, and attempted to load several crisis scenarios of increasing complexity. Table 1 summarizes average scenario loading times showing initial imposed goals, planner solving times expressed in milliseconds, and events number resulting after planning process. Finally, last two columns show the number of involved variables and constraints among them in order to give an idea of underlying problem complexity.

Ongoing work is aimed at finding a smarter way to remove elements from an Event Network, at increasing overall performances through some preprocessing steps and at facilitating scenario editing in order to allow non-technical people to easy modify simulated crisis.

[5]The current Trainee interaction features have been implemented by our colleagues from XLAB.

Conclusions

This paper has described the year one demonstrator of the PANDORA project. Main goal of the paper is to give the reader a comprehensive idea of the use of planning technology in the PANDORA-BOX. We have seen how the representation with timelines is the core component of the crisis simulation, and that a continuous loop of planning, execution, plan adaptation is created to support personalized training with Trainer in the loop.

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