

# Dynamic Selection of Learning Situations in Virtual Environment

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**Abstract:** In a lot of industrial contexts, workers may encounter novel situations which have never occurred in their training. Yet, such situations must be handled successfully to prevent high-cost consequences. Such consequences might be human casualties (in high-risk domains), material damages (in manufacturing domains) or productivity loss (in high performance industry). To address this lack in their training, virtual environments for training should provide a large spectrum of learning situations. The difficulty lies in generating these situations dynamically according to the learners profile while they have a total freedom of interaction in the virtual environment. To address this issue, we propose to generate activities by operationalising the Zone of Proximal Development in a multidimensional space. The filling of this space will be updated dynamically based on user interactions.

## 1 INTRODUCTION

Nowadays' working contexts are getting more and more complex, they are composed of a wide range of situations. Training is a major issue in industry for different reasons. It prevents accident in domain where security is critical (high-risk industry, nannies training), it fosters productivity in high-performance industry (aeronautic assembly, submarine maintenance), it also prevents manufacturing defect where customer satisfaction is a key point. Most commonly, in a professional environment, operative attends a short training before getting on the site. They lack of experience and each new situation is difficult to handle because it is a whole new one. It is widely accepted that experience is the most important way to develop professional skills in these domains. By encountering various situations, apprentices may consolidate their knowledge and build their own effective mental representations of the task processing. Moreover, it is accepted that situated learning can offer an efficient learning framework. As such training is expensive and requires the material to be requisitionned, virtual environment for training have been proven to be a good solution to provide learning in complex situations (Amokrane and Lourdeaux, 2009).

By simulating the work context, these environments deliver a wide range of real situations. However, providing content is not enough to ensure an efficient learning. The content must be adapted to the

learner's profile and historic : what has been learned? What needs to be learned next? Which errors are most commonly made? Besides, the content answering these questions must be provided in an engaging way. Our goal is to generate pedagogical content adapted to the learner level and presented through a story in which the learner will feel involved. The content proposed must enable learners to meet many and varied kind of situations and keep their motivation at a high level. To fulfill this requirement, we propose to dynamically generate relevant learning situations with regard of the learner's trace and learning objectives. A relevant learning situation is a set of states of the world that will test a subset of skills and knowledge in a efficient and engaging way. As our works fits in the situated learning theory, we considered that each learner builds his own mental representation in disregard of an elicitation of knowledge and skills. Thus, it makes it difficult to control knowledge acquisition. Another issue is to ensure that the generated content is relevant, which means it fulfills both pedagogical and narrative requirements. This also raised the underlying question about the balance between narrative and motivational factors and pedagogical needs.

SELDON, standing for ScEnario and Learning situations adaptation through Dynamic OrchestrationN, aim to generate and control scenario within a virtual environment. As part of the SELDON model, we propose the TAILOR model to generate a *canvas* which is a sequence of constraints on the state of the world, called situations, that should be met or prevented to

facilitate knowledge learning and skills acquisition. The canvas is then used by the other part of SELDON, a scenario planner, DIRECTOR (Barot et al., 2013) to constrain the simulation. This paper presents our contribution on activities selection based on belief about learner's aptitudes and pedagogical needs. In section 2 we present how our contribution positions in relation to different approaches on adaptive scenarisation. Then, we introduce the overall process of situation constraints generation and present a detailed method of selection of the constraints depending on pedagogical needs in section 3. Section 4 shows an illustration of this selection through the case of nannies training. Then we will present the perspectives we foresee to extend this work and conclude over the whole contribution.

## 2 RELATED WORKS

Adaptive scenarisation is the process of reacting to user's actions to provide content fitted to their need. In videogames, it might be used to adjust difficulty according to player's level without using typical discrete mode such as "Easy", "Hard", etc. With adaptive features, players are always in the *flow* (Csikszentmihalyi, 1991): the difficulty remains high enough to propose a suitable challenge, yet, players can overcome it so that they do not get bored or frustrated. Such a concept might be used to adapt difficulty in a training session so that learners keep a high level of motivation. The system can propose activities that are always difficult enough to challenge the learner but always manageable to prevent frustration and loss of motivation. Our objective is twofold: providing adapted content (1) and presenting this content in such a manner it does not cut the user from the flow and, moreover, motivate him (2).

The adaptation can be made at different levels of granularity. A first approach is to have a *global adaptation*: a whole scenario has been written (Marion, 2010) or generated (Niehaus et al., 2011) and the outcomes of the events were scripted beforehand. This approach allows the building of a scaffolding scenario which present many advantages:

- *Pedagogical Coherence*: the scenario ensures a progressive learning through the session, assistance can be given easily at relevant key points;
- *Narrative Involvement*: it is therefore possible to unfold the event as a story which will involve the learner.

A main drawback is the lack of reactivity of the system. As the whole session has been planned, the sys-

tem cannot reorient the scenario to adapt to the very current learner's state. The only way to cope with it is to foresee each possible path which can represent a huge amount of work. An opposite approach is to provide *reactive adaptation* by controlling the outcomes of learner's actions. It enables:

- *Dynamic Adaptation*: the system triggers outcomes of learner's actions and provides assistances depending on pedagogical needs.

For example, in the application V3S (Barot et al., ), the triggering of a hazardous matter leak is computed in real-time by HERA (Amokrane and Lourdeaux, ), an intelligent tutoring system, according to a learner's model.

The simulation where the adaptation takes place can be run with opposite approaches: the *controlled approaches* versus the *emergent approaches*.

The *controlled approach* aims to provide a very efficient learning by orchestrating each part of the simulation: state of the objects, virtual character's behaviours, possibilities of action the learner, etc. It permits:

- *Pedagogical Control*: each element of the simulation serves the scenario and pedagogical needs.

This approach which is used in the Generic Virtual Training (Gerbaud et al., 2008) helps building pedagogically efficient scenarios but disables the possibility to encounter unintended - though relevant - situations. Moreover, such an approach demands an exhaustive modeling of the world functioning which handicaps the evolutivity of the system. The whole modeling has to be reconsidered to avoid incoherence each time an author adds new contents. Any attempt to interfere with the simulation can cause incoherence for the learner: virtual characters become unpredictable, states of objects changes with no coherent reason. As a result, there is no way to explain *a posteriori* the unfolding of events. These explanations are critical for the learner to understand causes and consequences of events and actions and they can be provided at the end of the session or reviewed by a teacher.

By a clever modelling of small behaviors of the world, *emergent approaches* allow new situations to arise (Shawver, 1997). It also enables:

- *Freedom of Action*: learners are not framed by the task they are supposed to do, they can experiment and discover the outcomes of their actions;
- *Autonomous Virtual Characters*: as they are not being controlled by a supervisor, virtual characters maintain their autonomy and their behaviours remain coherent throughout the simulation run.

The issue with emergent approaches is the lack of pedagogical control. The simulation runs itself according to initial parameters and there is no way to orchestrate the events to adapt the simulation to the current learner’s state. Each of these approaches has attractive features but none of them fulfills our requirements as explained below.

### 3 PROPOSITION

#### 3.1 Approach

Our work aims to provide a relevant adaptation at different level of granularity. At the lowest level, adaptation should modulate the consequences of the actions of the learner, this means an even set of events might have different outcomes depending of the expertise of the learner. Then, the adaptation must work on a middle level basis by producing complex sequences of events leading to a specific learning in a session. Finally, skills development requires a learner to follow a path of different learning situations during different learning sessions, the adaptation should also provide information about the path to follow between different sessions. For this purpose, we will try to adopt a balanced approach which is both *global* and *local*.

Besides, learners should have a total freedom and the system must react as it would in reality to help them to develop skills from their mistakes. Technical, organisational and human systems are getting more and more complex in working context. An exhaustive explicitation of each possible scenarios beforehand would result in a combinatorial explosion. To adress the growing complexity of such systems, we chose to model them through an emergent approach. However, as our purpose is to provide an efficient situated learning, we must ensure that relevant assistances are provided to learners as they would be provided in a working context. Moreover, we need to orchestrate dynamically the course of the training to adapt to current learner state. This can only be achieved by controlling the flow of events to some extent. We need to adopt an *emergent* approach to model the world but we want to provide pedagogical *control* over it.

To be able to have both global and local adaption with pedagogical control over an emergent simulation, we propose to orient dynamically the simulation towards specific situations which are consistant with the current state of the world, without breaking the coherence of neither object states nor the behaviour of virtual characters. This is the purpose of SELDON, standing for ScEnario and Learning situation adaptation through Dynamic OrchestrationN), which is a part

of the HUMANS platform described below.

#### 3.2 HUMANS Framework

The HUman Models-based Artificial eNvironments Software platform is dedicated to the simulation of virtual environments within complex domains where human factors are critical. HUMANS platform allows high cognitive virtual characters and learners to coexist in a simulation.

HUMANS uses three models which were designed to be informed by domain experts (ergonomists, didacticians, etc.):

- **DOMAIN** (figure 1) describes the world in a static way, the object, physical or abstract, that exists in the world and the relations between them through an ontology. It also includes a dynamic description: possible actions, the behaviours these actions trigger and events that might occur through rules;

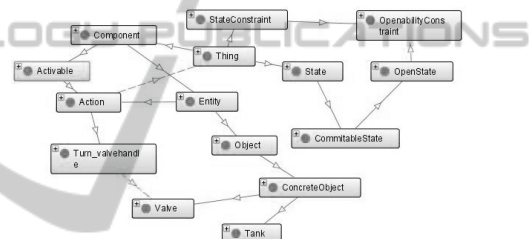


Figure 1: Part of an ontological representation of DOMAIN.

- **ACTIVITY** (figure 2) uses a hierarchical representation of the task to describe the activity as observed on a real site and not as depicted in procedures and protocols. The basic tasks are the actions referenced in DOMAIN;

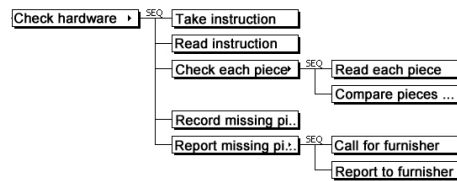


Figure 2: Hierarchical representation of ACTIVITY.

- **CAUSALITY** (figure 3) expresses pertinent causal chains occurring in the environment through a direct acyclic graph. It might describe causal chains of risks (when informed through a risk analysis) or errors induction (which can be generated using an error model generation);

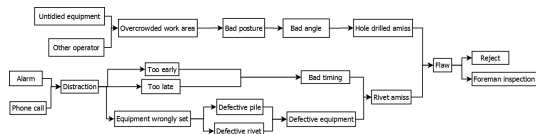


Figure 3: Graph representation of CAUSALITY.

These models manipulate common entities and each unit (Entity in DOMAIN, Task in ACTIVITY and Event in CAUSALITY) can be tagged to specify something to which a unit is related (skills, risks, performance criteria.etc.). TAILOR is the first of two parts constituting SELDON. It produces constraints for the second part, DIRECTOR whose role is to apply this constraints.

### 3.3 General Overview

As shown in Figure 4, the TAILOR model of constraints generation is divided in three parts: diagnosis, pedagogical selection, narrative framing.

The first part updates a dynamic model based on the Zone Of Proximal Development to establish a diagnosis of learner's capacities.

Second part computes this model to determine a set of situation constraints that fulfill pedagogical needs along with metrics on these situations. They describe if situations should be avoided or should be met. Situation constraints describe states of the world which should bring learners to discover/develop/use specific skills and knowledge. One of these situation constraints defines a goal situation toward the simulation should be leading. This situation is not the end of the scenario but merely one of its key points.

In a third part, key points are then framed into common narrative patterns to generate a story and modulate the dramatic tension. The canvas is the succession of situations constraints build upon time. The description of the metrics and of the narrative framing is beyond the scope of this paper.

We present in the following subsection a model for selecting a goal situation according to a uncertain learner's model.

### 3.4 Description of the Pedagogical Process

#### 3.4.1 Input Data

The dynamic mechanism of selection of activities underlying TAILOR lies on both inputs from the learner and the teacher.

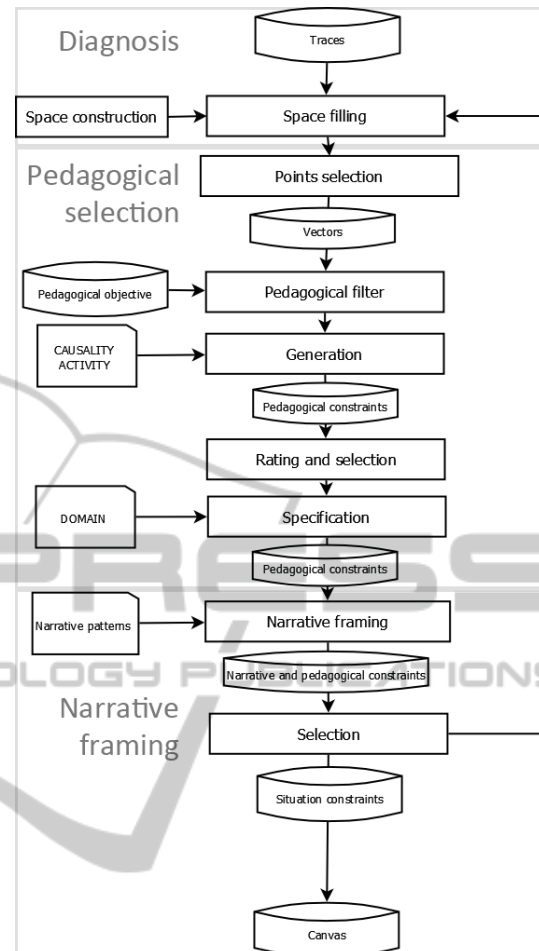


Figure 4: General Overview.

- *Learner's Inputs*: each session of training the learner follows is recorded through a trace based on HERA model (Amokrane and Lourdeaux, ). As the model is based on activity analysis, traces identify *previous situations encountered, errors, causes and consequences, risk produced*. Traces are also enriched with activity traces of virtual characters as well as the tracking of causal chains within the environment;
- *Teacher's Inputs*: the teacher can influence the simulation beforehand at different levels: he can select *situations* which should be encounter during the session in the CAUSALITY model, *task* to be performed in ACTIVITY model and *performance criteria* to favour.

#### 3.4.2 Diagnosis

On this purpose, the first matter is to establish and maintain a diagnosis of learner's current level of



knowledge. As seen in (Brusilovsky and Millán, 2007), most systems use an elicitation of knowledge, of the influences they have between each other and of the events which are clues of learning.

Actually, we fit our work in the paradigm of situated learning, it would be paradoxical to build a model of skills and knowledge acquisition. Moreover, we want to produce a progressive learning individualized to each learner. Vygotsky proposes the model of Zone Proximal of Development (ZPD) (Vygotsky, 1978) in which a student can develop skills inside its comfort zone and enlarge it by the help of the teacher. We think the ZPD can be used in a more general learning context than education and that the teacher, which is responsible of the scaffolding, might be played by virtual scaffolding and by an intelligent scenarisation of events. To operationalize this approach, we choose to deal with a belief the system has in the capabilities of a learner to handle a certain type of situation depicted by constraints. They might include a set of skills, performance criteria, tasks, errors, etc., which are informed by pedagogical experts of the domain within the models presented in 3.2. These constraints "mold" a space where each situation is reported with a belief on whether the learner handled it successfully or unsuccessfully. This space is constructed so that two points in space are representative of semantically close situations in the simulation. Beliefs are propagated around each point to estimate a belief on the capabilities of a learner to handle a situation matching another set of constraints semantically close. The Transferable Belief Model and the conjunctive rule of combination (CRC) described in (Smets and Kennes, 1994) are used to represent and update these beliefs.

For each point of this space, describing a type of situation, we have four values:

- h - Belief on the ability to handle this situation,
- d - Belief on the disability to handle this situation,
- i - Ignorance, either ability or disability
- c - Conflict between belief of ability and disability

With  $h + d + i + c = 1$

TAILOR parses traces produced by the trace-based system called MONITOR that exists within the HUMANS framework. Based on ACTIVITY and CAUSALITY models, MONITOR aims to record every action agents makes whether they are real learners or virtual characters. These actions are linked to task and high-level tasks in the activity hierarchy and are associated to a potentiality to trigger an error, a risk or affecting a performance criteria. Each trace is used as a source of information to update the beliefs

about a type of situation. New values are compute according to the application of the conjunctive rule of combination as shown in 1,2,3,4.

$$h_{new} = h_{cur} * h_{source} + i_{cur} * h_{source} + i_{source} * h_{cur} \quad (1)$$

$$d_{new} = d_{cur} * d_{source} + i_{cur} * d_{source} + i_{source} * d_{cur} \quad (2)$$

$$i_{new} = i_{cur} * i_{source} \quad (3)$$

$$c_{new} = 1 - h_{new} - d_{new} - i_{new} \quad (4)$$

Where  $h_{cur}, d_{cur}, i_{cur}$  are the current values,  $h_{source}, d_{source}, i_{source}$  are values provided by the trace and  $h_{new}, d_{new}, i_{new}, c_{new}$  are the updated values.

The association between beliefs and the multidimensional space described above draws our ZPD we call *zpd-space*.

### 3.5 Pedagogical Selection of Activities

As the learner progresses throughout activities and sessions, the space is filled with points and associated beliefs are updated.

TAILOR will then select a set of points in this space to generate a new situation. The difficulty lies in determining which points will produce an efficient learning. The selection is made based on the 4 values aforementioned using pedagogical rules.

- Points where belief has a high ignorance-value are not likely to be interesting;
- Points where belief has a high ability-value are not interesting to produce new learning, but they can be used in the beginning of the session to make the learner at ease;
- Points where belief has a high disability-value are interesting, because they are the proof of an error, a violation and more generally a misconception. Depending on specific pedagogical rules, the situation will be avoided or, on the contrary, a learning situation will be generate to break the misconception through an assistance;
- Points where belief has a high conflict-value are interesting. Mathematically, it means the different sources of information are contradictory. In our case, it means the learner is able to handle a situation in a specific context but a misconception prevent him from using the same skills in another context.

A set of pedagogical rules helps selecting relevant points according to these values and pedagogical objectives. After this filtering, TAILOR compute DOMAIN, ACTIVITY and CAUSALITY model to determine which events and which activities responds to these constraints.

Table 2: ZPD-space initialisation in nannies training simulator.

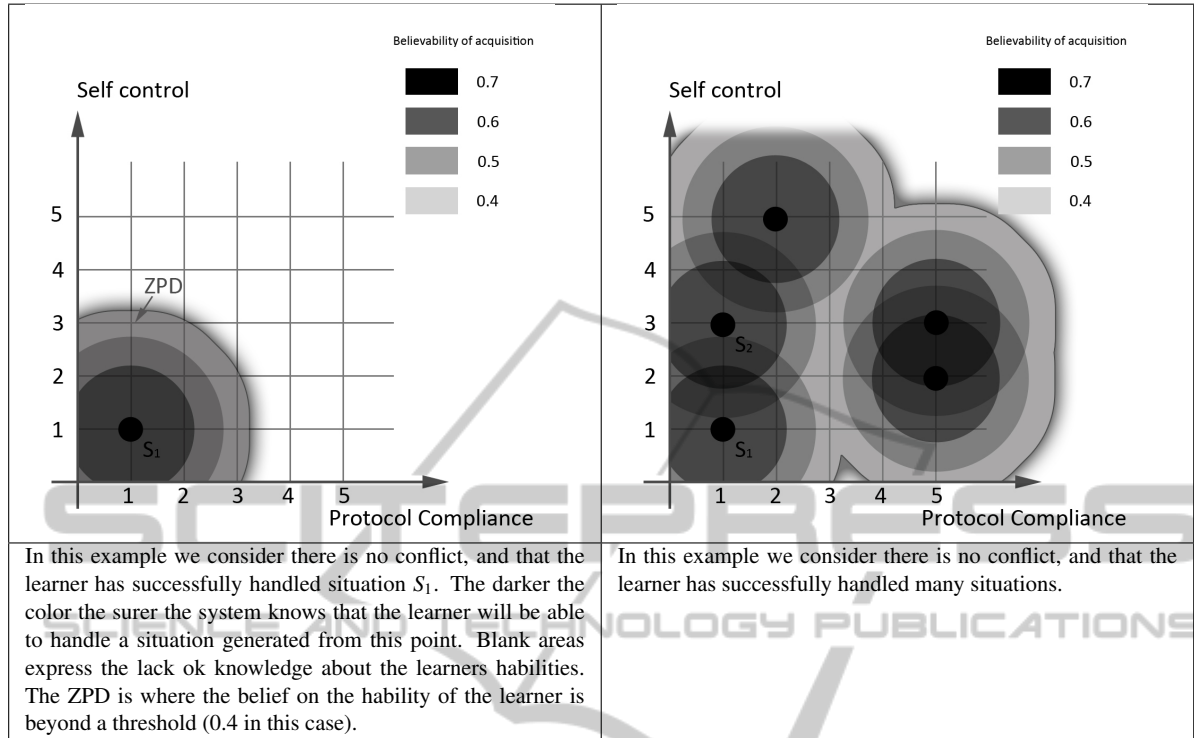


Table 1: Situations and desirability.

| Situation constraints | Desirability      |
|-----------------------|-------------------|
| $Sit_1$               | $D_1 \in [-1, 1]$ |
| ...                   | ...               |
| $Sit_n$               | $D_n \in [-1, 1]$ |
| $Sit_{Goal}$          | 1                 |

### 3.5.1 Output Data

At each iteration, TAILOR generates a set of *situation constraints* associated to a desirability which represent how desired this state of the world is (see Table 1). A negative value describe a situation that should be avoid. One situation is tagged as the goal situation. A situation is depicted by a subset of triple describing a specific state of the world using the formalism of DOMAIN.

## 4 EXAMPLE: NANNIES TRAINING SIMULATOR

We applied the model generation to a scenario of nannies training. The french organism for learning provided a large amount of didactic information for a previous work on the project SimADVf (figure 5).

The learner is the nanny and has to take care of two children: Marion, a six month-old baby and Jean, a five year-old boy. Each activity has various indicators about performance criteria. For instance, changing the nappies of a baby requires *Vigilance*, *Intervention planification* and *Protocol compliance*. Let us consider the case of a novice learner which has very little use of the training simulation. The skills space is drawn by performance criteria which values range from 0 to 5. There are eleven performance criteria which means a discrete space of  $6^{11}$  values e.g. more than 360 million types of situation. Fortunately, all combinations do not define a valid situation i.e. some points are pointless and the space is lacunar. For the sake of the demonstration and to facilitate the visibility, we shall consider only two performance criteria: *Self Control* and *Protocol Compliance*. The pedagogical objective is arbitrarily set to *Self Control*. Two examples are presented in Table 1 to Table 5 for a novice learner which has used the system once and for a more advanced learner.

## 5 PERSPECTIVES AND FUTURE WORKS

Selection of activities is the first part of our work. To

Table 3: Situations generation.

|   |  |
|---|--|
|   |  |
| <p>In regard of the pedagogical objectives, which here emphasize on <i>Self Control</i>, the system selects points to privilege this performance criteria. The point <math>S_G(SC = 3, PC = 1)</math> is selected. By computing the ACTIVITY model, TAILOR determines tasks requiring a <math>(SC = 3, PC = 1)</math> set of skills. The task "Dealing with a capricious child" is an activity that fulfills this requirement. Its precondition is the occurrence of child in state "angry". TAILOR does not control virtual character inner state but the constraint will be used by DIRECTOR.</p> | <p>In regard of the pedagogical objectives, which here emphasize on <i>Self Control</i>, the system selects points to privilege this performance criteria. The point <math>S_G(SC = 5, PC = 5)</math> is selected, the system has a belief of 0.4 for the learner to handle this type of situation. By computing the ACTIVITY model, TAILOR determine the tasks requiring a <math>(SC = 5, PC = 5)</math> set of skills. The task "Caring an injured children in emergency situation" is an activity that fulfills this requirement. Its precondition is the occurrence of a major accident on a children. TAILOR parses CAUSALITY to determine potential sources of an accident. There are two possible causes:</p> <ul style="list-style-type: none"> <li>• a burn from hot tapwater which may occur when the tapwater is turned on hot;</li> <li>• a small fall down the staircase when the gate is open.</li> </ul> <p>By parsing the DOMAIN model, TAILOR determines that each of these situations can occur in current session: there is a tapwater and a staircase closed by a gate. As both situations are possible in current state of the world and in order to constraint the least possible the simulation, the output is reduced to "the occurrence of an accident". Metric considerations, that are not discussed in this paper, control the gravity of the event. Here, the gravity is relatively low. In CAUSALITY, an injury on a baby is tagged as a <i>grave</i> event.</p> |
| <pre>Situations Goal   Desirability:1   States:     (?child has-state ?angry)     (?angry has-level high)</pre>   | <pre>Situations Goal   Desirability:1   States:     (?child has-accident ?acc)     (?acc has-gravity major)  Situation1   Desirability:-1   States:     (?child has-accident ?acc)     (?acc has-gravity mortal)</pre>   |

Table 4: ZPD-space update and new activities selection.

|   |   |
|---|---|
|   |   |
| <p>The learner reacted well to the previously generated situation , the ZPD-space is updated. The point <math>S_G(SC = 4, PC = 3)</math> is now selected, the system has a belief of 0.4 for the learner to handle this type of situation. By computing the ACTIVITY model, TAILOR determines tasks requiring a <math>(SC = 4, PC = 3)</math> set of performance criteria. The task "Caring an injured children" is an activity that fulfills this requirements. Its precondition is the occurrence of a <i>minor</i> accident on a children. TAILOR parses CAUSALITY to determine potential sources of a minor accident. A cause of a minor accident is a child stumbling on an toy. It can occur when child is in state "excited" and the room is messy. By parsing the DOMAIN model, TAILOR determines that the situation can occurred in current session. The output is the child to be excited and a room to be messy.</p> | <p>In the trace providing by the learner tracking module a <i>deletion error</i> was detected: the learner did not performed a subtask of the high-level task "Caring a children in emergency situation". Indeed, the learner should have call emergency services or, at least the parents, to warn them and to ensure no further healing were to be done. The situation was not handled successfully, so the ZPD-space is updated with a belief on the inhability of the learner to handle a situation such as <math>(SC = 5, PC = 5)</math>. To correct this behavior, TAILOR computes CAUSALITY to determine which event are likely to learn the user the good practises. It occurred when parents are home, in a worried state to rebuke nannies for their misbehavior.</p> |
| <pre> Situations   Goal     Desirability:1     States:       (?child has-state excited)       (?room is-a room_object)       (?room has-state messy)    Situation1     Desirability:-1     States:       (?child has-accident ?acc)       (?acc has-gravity major)         </pre>   | <pre> Situations   Goal     Desirability:1     States:       (?parent at home)       (?parent has-state ?worried)       (?worried has-level ?high)         </pre>   |

provide adapted content is essential but to involve the learner, we need to use motivational factors. Modulating the dramatic tension is a possible solution. To create tension, a story must be built upon the events and the world depicted within the simulation. The aim is to provide a purpose to the training session by showing the virtual characters as story characters who can

be helpers or opponents, the events as plot points that will increase or decrease the tension. We plan to use narrative pattern, as described by (Campbell, 2008), (Propp, 1968) or (Greimas, 1966) to extends current pedagogical situations. The element described by the situations will be fitted with element from a pattern such as *location, helpers, opponents, goal,etc.* For



Table 5: End of training session.

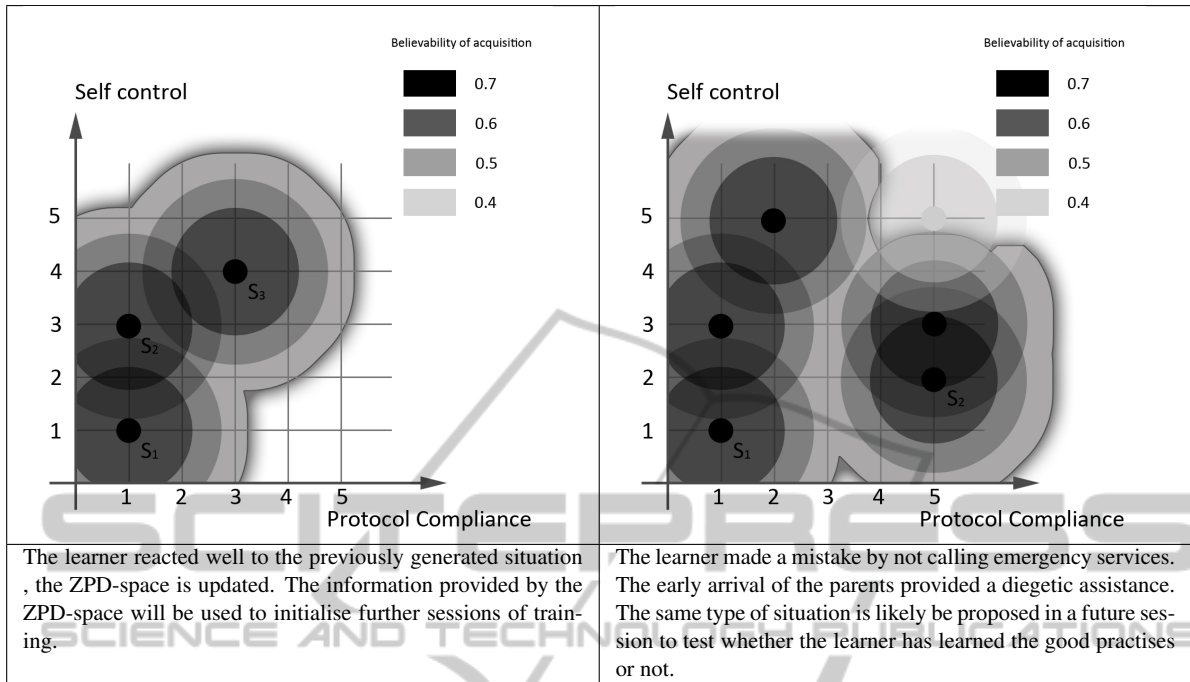


Figure 5: A screenshot of SimADVF - Nannies training simulator.

one pedagogical situation, many narrative configurations are possible. We will use a measure of the narrative utility based on earlier events in the simulation. The utility will maximize if it furthers the development of the story depicted in past events without disrupting the whole coherence.

## 6 CONCLUSIONS

We proposed in this paper a model to dynamically generate scenarios in a virtual environment regarding learner’s capacities. The process uses a phase of diagnosis which compute traces at the initialisation and in real time. It operationalizes the theory zone of proximal development through a multidimensionnal space of belief, updated at each task performed by the

learner within the virtual environment. Then the system computes current world state to determine which situation can take place to answer ZPD and pedagogical objectives requirements. We build a first prototype within the HUMANS platform working on the example of nanny training. Our future works will focus in the narratives consideration by framing the successive situations in a narrative pattern to relate a story.

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