

Intelligent Virtual Environments for Training: A Tutoring Approach

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Abstract. Scaffolding is proposed as a tutoring approach for Intelligent Virtual Environments for Training. We have used the Activity Theory as a framework to define activities and related tasks to be executed as part of a plan, as proposed in a Team Training Strategy designed by the authors. The strategy is briefly described, and a scaffolding approach is proposed for the Pedagogical Virtual Agent that will integrate the team in the execution stage.

1 Introduction

In the scope of the teamwork, there is a growing understanding of the principles behind effective team training [1]: empirical studies are beginning to tease out the skills that make teams effective (e.g. task skills vs. team skills), the best type of feedback (e.g. outcome vs. process), the best source of feedback (e.g. instructor vs. team mate), the best goal structure (e.g. individual activities vs. group activities). On the other hand, the interaction achieved through software tools has been researched from different perspectives, such as: the learning promoted through human groups attempting to learn something together [2], the activity generated in the shared working space [3], the dialog type shared using intelligent environments [4], and

others. For Barros in [5], technology is interesting as far as it has potential to create, to favor, or to enrich interpersonal contexts of learning.

A Collaborative Virtual Environment (CVE) is a computer-based, distributed, virtual space or set of places; in a CVE people can meet and interact with others, with agents or with virtual objects [6]. CVEs—specially, Intelligent Virtual Environments for Training (IVETs)—can be used to train one or more students in the execution of a certain task, particularly in situations in which training in the real environments is either impossible or undesirable because it is costly or dangerous. The intelligence in the IVETs usually falls on a component named Pedagogical Virtual Agent (PVA) [7].

In the Decoroso Crespo Laboratory, in line with own interest on computer science applied to education and training, we have proposed a Team Training Strategy (TTS)—briefly described in section 2—which promotes collaborative learning skills as well as knowledge and skills in a procedurally oriented domain. The learning goals are organized in tasks, using the Activity Theory (AT)—briefly introduced in section 3—as a framework. The TTS will be conducted with the assistance of an IVET in each one of the stages. Regarding the team training principles above mentioned, in this approach: the type of feedback is centered in the process; the team mate (PVA) is in charge of the task skills tutoring; and we use group activities—cooperative activities—for organizing the goal structure

In this paper, we will focus on the third stage of the TTS. The section 4 describes the activities and the IVET proposed for assisting the team during the execution stage. In the section 5, the tutoring approach proposed for the PVA is described in detail. Finally, the conclusions and ongoing work of this proposal are presented in the last section.

2 The Team Training Strategy

The strategy consists of five interrelated stages in which the human team to be trained follows an iterative process of self-assessment about the execution of a plan to perform a proposed task (see fig. 1).

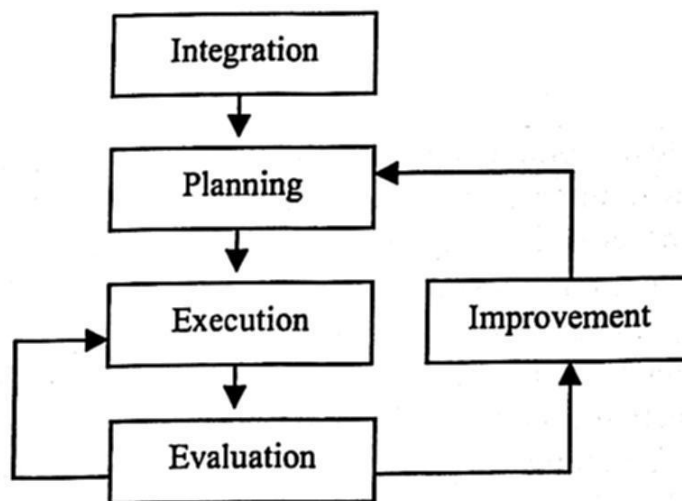


Fig. 1. The Team Training Strategy (TTS)

The *Integration* stage has the purpose of integrating the human team (using a CVE), as well as providing the apprentices (assisted by a Human Tutor) with a first mental schema of the plan to be executed for a predefined task. In the following stage (*Planning*) the team members, in a collaborative virtual meeting, co-construct an execution plan for the task (using a planning tool). In the third stage (*Execution*), the team uses an IVET to execute the planned activities according to their assigned roles; in this environment a PVA plays a team leader role to assist the trainees. In the fourth stage (*Evaluation*), the team members will have to evaluate their previous execution and must identify both individual and group errors with the purpose of avoiding them in a future execution stage. Finally, in the last stage (*Improvement*) the team members, in a virtual meeting, co-construct a new plan for the task using as a baseline the experience acquired during the iterative execution and evaluation of the initial plan.

The level of members interaction is expected to keep on growing while the team makes progress through the strategy stages (see fig. 2) and the iterative process followed by the team will trigger mechanisms that will generate a shared mental model between its members, enhancing the collaborative learning and allowing a better group performance during teamwork.

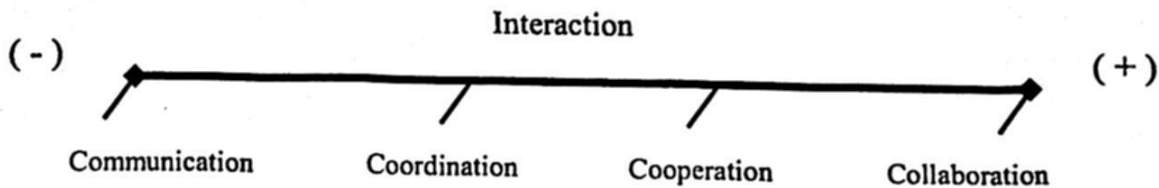


Fig. 2. Degree of Interaction

The potential domains for the application of the TTS are the control and maintenance of industrial or nuclear plants, operation and maintenance of industrial equipment, coordinated manipulation of vehicles and, especially, human rescue teams for disaster situations. The strategy orients the trainee to acquire simultaneously: knowledge, skills, and attitudes, in the three domains of learning promoted by training (cognitive, psychomotor, and relational/social).

3 Activity Theory

Jonassen & Rohrer-Murphy, in [8], consider that the AT has its roots in the classical German philosophy of Kant and Hegel, which emphasized both the historical development of ideas and the active and constructive role of humans.

AT states that all human activities are mediated by culturally created signs or tools; through external interactions with these signs the inner mental state of the person is transformed, the knowledge is interiorized [9]. Kuutti in [10] explains that the activity is the basic unit of the model proposed by Leont'ev, he presents a hierarchy of three levels in which the activity is at the upper level, the actions at the middle level, and the operations at the lower level.

Initially, the development of the AT tried to explain individual activities, however, most of the human activities are collective. Thus, Engeström [11] extends the model to consider collective activities; according to this new model, an activity is decomposed into one or more tasks (actions), has an objective, and is developed by a subject (individual or group) using a tool (physical or abstract tool) according to the rules of the community in which the activity is performed.

AT provides a powerful framework for studying and understanding human activities. In a CVE for training, AT can be used to think of how to support the training activities being transformed into automated operations, and to think of how the work objective is divided among the different learners and how to best support the associated actions. We propose in this paper an "activity set" to define the different activities available in the CVE for the trainee; each element belonging to the activity set allows the access to a related "action set", which has all the actions regarding to an activity, each one properly represented by a Learning Object.

4 The IVET for the Execution Stage in the TTS

At the *Execution* stage, the group members should achieve the previously described goal, executing the planned activities according to their assigned roles. To perform the task, the team will use an IVET which recreates a scenario in which the apprentices must carry out sequential or concurrent activities, according to the established plan.

In order to assist the team during this stage, we propose to include a PVA playing the role of team leader. It may communicate with the apprentices or make them suggestions during the execution of their activities, if necessary. The PVA will offer its help to the team, giving preference to critical activities for the task success. Fig. 3 shows a team member's view in an IVET prototype during a training session.

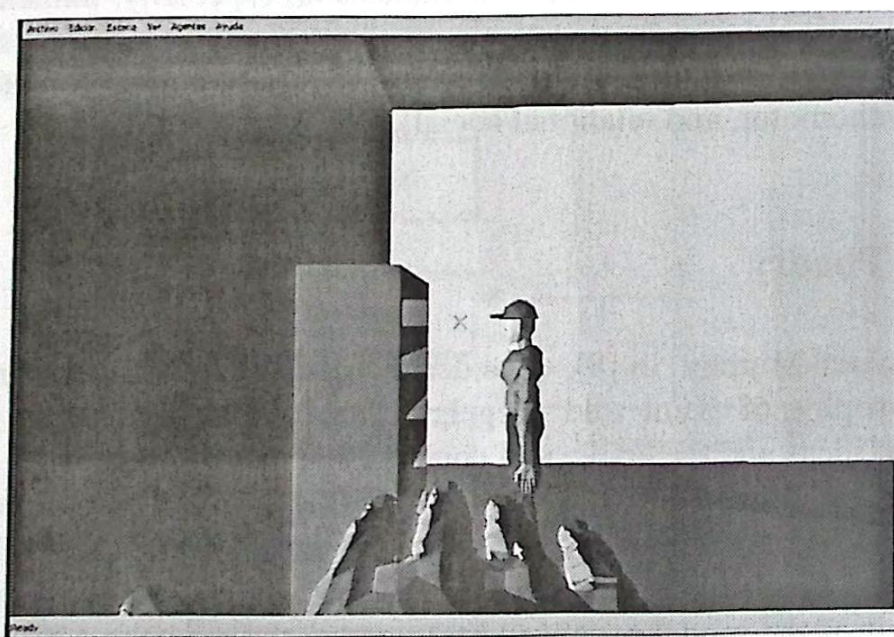


Fig. 3. A trainee view in an IVET prototype

Our development is based on MAEVIF [12], a Software Architecture aimed to develop IVETs. This architecture has been devised to be open and flexible, and basically it's composed by two subsystems: one dealing with the graphical visualization of the virtual environments and the interaction with the learners; and the other being a multi-agent system designed to provide "intelligence" to the tutoring system. For the development of the specific IVET proposed for the execution phase, the MAEVIF architecture is being adjusted extending the multi-agent system with a mechanism to model the group (Group Modeling Agent), inexistent in the original structure of MAEVIF.

Furthermore, the incorporation of a PVA as a team member requires to model it appropriately in order to provide it with behaviors similar to the ones expected in a human partner or in a human tutor. With this aim we have chosen to design and build our PVA according to a multilayered agent architecture named COGNITIVA [13], which allows the PVA to produce and manage reactive, deliberative and social behaviors influenced by personal characteristics and emotions.

5 The Scaffolding Approach for PVAs in IVETs

A scaffold is a temporary structure that physically supports workers while they complete jobs that would otherwise be impossible; when the work has finished, the scaffold is removed. The instructional scaffolding metaphor is used to describe a teaching strategy and some kinds of supports offered to the trainees in their interaction with teachers, tutors and partners when they are in a learning activity, focusing on the effective intervention of an "advanced partner".

According to Vygotsky [14], the zone in which the student can solve problems with external help (because s/he is ready to capture new contents) is called Zone of Proximal Development (ZPD), and is formally defined like the distance between the actual development level (determined by the student grade of independent problem solving) and the possible development level (determined by the student grade of problem solving with advanced help).

The scaffolding metaphor is attractive for IVETs because it focuses the attention at the trainer role in the apprenticeship process, and makes emphasis in each trainee individually. Scaffolding can be applied as a tutoring approach for PVAs in IVETs according to the steps described in the following subsections.

5.1 Activity Selection

In order to apply scaffolding successfully in the IVET it is necessary to classify the activities and actions. Firstly, we can consider the activity set which contains the different activities available in the IVET for the trainees (1); secondly, each element belonging to the activity set allows access to a related "action set", containing all the actions possibly related to an activity, each one properly represented by a Reusable Learning Object (RLO) (2).

$$\text{Activity set} = \{\text{Act}_1, \text{Act}_2, \dots, \text{Act}_n\}, \text{ where } n > 0 \quad (1)$$

$$\text{Action set}_i = \{\text{RLO}_{i1}, \text{RLO}_{i2}, \dots, \text{RLO}_{ij}\}, \quad (2)$$

where $i, j > 0$ and "i" refers to the activity "i"

The trainee's activity set will contain a limited number of activities according to what the trainee is expected to do in his/her role. We will use the syntax proposed in the Design by Contract Method [15], sketched as follows:

```

rlo <URI>
    require
        precondition 1
        ...
    ensure
        postcondition 1
        ...

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5.2 Construction of the SKM and ZPD

When the trainee starts his/her training activity the PVA will have to define correctly the Zone of Proximal Development (ZPD) and the Student Knowledge Model (SKM) associated to him/her. We define a RLO repository in the system which can be accessed by the PVA. All RLOs are accessible to the PVA by their associated metadata. The best procedure to solve a problem, the SKM and the ZPD will be constructed using these associated RLO metadata. The PVA uses the repository to build the trainee's SKM and to suggest activities to him. The SKM is defined as a set of components, where each component makes reference to a RLO completed by the trainee (3).

$$\text{SKM} = \{\text{RLO}_1^k, \text{RLO}_2^k, \dots, \text{RLO}_l^k\} \text{ where } l \geq 0 \quad (3)$$

The PVA constructs the trainee's ZPD based on the SKM; the process starts by looking in the RLO repository for the RLOs that can be satisfied in all (or almost all) of their preconditions with the post-conditions of the RLOs that belong to the SKM. Then we can construct the trainee's ZPD as a RLO set, where each element will reference a specific RLO the trainee is ready to learn with partner's help (4). Finally, the PVA is able to know what the trainee is ready to learn chooses the proper activities, and suggest the trainee to practice those which he/she needs to reinforce.

$$\text{ZPD} = \{\text{RLO}_1^D, \text{RLO}_2^D, \dots, \text{RLO}_p^D\} \text{ where } p \geq 0 \quad (4)$$

5.3 Action Demonstration

Once one activity has been selected, the PVA can execute a complete action demonstration, giving explanations and repeating it any times the trainee needs. The PVA shows the trainee how to perform the activity in a step-by-step way, using available resources like the verbalization of the problem solving plan. On the other hand, the scaffolding proposed fully solves the problem just at the beginning of the training, and then offers partial solutions to the problem or gives cues when the trainee needs it.

A way to implement this approach in an IVET is allowing the full activity demonstration at the beginning, but limiting afterwards the demonstration to the action currently performed.

5.4 Skill Imitation and Action Assessment

This step provides the training experience to the trainee; here s/he has the opportunity to execute the actions by him/herself. All the time the trainee is executing the activity, the PVA is assessing his/her performance, ready to give scaffoldings if these are needed (repeated failures, too long time without actions, etc.). The amount and types of scaffoldings offered could change depending on the trainee's performance; for example, the PVA can: provide advices, explanations or suggestions inviting him/her to do something; give her/him cues or ideas, etc. The PVA can remove the scaffoldings allowing the trainee to perform the action by him/herself, whenever it considers it appropriate.

An activity is finished when the trainee can execute it correctly without any help; this can occur at any moment during the training and the IVE gives each trainee the possibility to train any times s/he needs.

5.5 Trainee ZDP and SKM Updating

The PVA must apply a continuous assessment over the learner's actions and it's in charge of updating continuously the ZPD and SKM of the trainee with their successes or failures. Using these previously defined structures, the PVA can check which actions the trainee could execute (or complete) comparing the RLOs belonging to the ZPD to the RLOs associated with each defined action. In the same way, comparing the SKM to each action set, the PVA is able to know which actions have been learnt and determine which activities are complete, which ones are incomplete, and which ones have not been trained at all. To suggest an action to execute, the PVA will prefer the ones related to the activity in course; anyway, if the trainee decides to change the activity or the action, the PVA has the mechanism to offer adequate alternatives.

5.6 End of the Training

The trainee will be invited to review a summary about his/her work session when s/he decides to end the training (s/he can review previous sessions if s/he wants to). Presenting the trainee an overview about their training performance is a powerful way to meet the goal of having the trainee in charge of their own progress; in this way s/he can engage her/himself in an active training perspective, processing the information in a deeper level of understanding and being able to recognise what s/he does not know yet.

5.7 Applying the Model

Virtual Reality Technology is especially valuable in domains where real life training is impossible, very expensive or where students can experience some risky situations [16], such a maintenance or control of Nuclear Power Plants (NPP). Méndez et al. have described in [17] two applications for training in NPPs, MAEVIF and PRVIR, which help the trainee to learn how to perform physical, procedural task, such as the procedure for entrance in a radioactivity controlled area.

Even if the trainee has freedom to walk around the environment and select the activity and the actions to do, each action has a very well defined number of steps to be followed, with a clear sequence of RLOs. Let's consider, for example, some activities, actions and roles defined in a NPP which allow us to illustrate the proposed structures:

NPP Activities:

(access_NPP, access_radioactivity_area, operate_machine1,)

Related Actions:

Access_NPP_Actions=(identification_process, access_individual_box,
put_on_working_suit, put_on_security_shoes)

Access_radioactivity_area_Actions = (put_on_security_gloves,
put_on_security_mask, hold_tool)

...

Related Roles:

Role<learner-operator>

Require

 Lrn.type=operator

Ensure

 Lrn.knows(Access_NPP)

 Lrn.knows(access_radioactivity_area)

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Lrn.knows(operate_machine1)
...

Role<learner-maintenance>
Require
    Lrn.type=maintenance
    Lrn.knows(Access_NPP)
    Lrn.knows(access_radioactivity_area)
    Lrn.knows(operate_machine1)
    ...

Ensure
    Lrn.knows(machine_maintenance)

Role<learner-supervisor>
Require
    Lrn.type=supervisor
    Lrn.knows=machine_maintenance

Ensure
    Lrn.knows=performance_supervision
    
```

Each action set is composed of several actions that the trainee has to perform to meet the activity goal. Each action in the IVET is described by one RLO, which describes the sequence and the tools used to correctly execute the action in the plant. The RLOs are stored in a repository; each RLO can be accessed through the contract associated metadata. Not forgetting that there are pre-requisites and post-conditions for each RLO, the Access_radioactivity_area_Actions have as pre-requisite the well-executed Access_NPP_Actions; in the same way, having correctly executed the Access_NPP_Actions gives the trainee the faculty of walking around the power plant installations.

As the trainee is working in the IVET, the PVA is conveying his successes and failures to the related agents, in order to update the individual associated Binnacle, SKM_set and ZPD_set. According to the previous example, let suppose the following trainee performance, recorded in its associated binnacle (see table 1).

As a consequence of the trainee's performance, some actualization of SKM_set and ZPD_set is done:

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SKM_set = (Access_NPP)
ZPD_set = (Access_radioactivity_area, ...)
    
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All over the trainee's learning activities, the PVA is tutoring the learner according to both the current strategy step and the trainee's performance and experience. These

are important factors to determine the kind of responses the PVA will offer (quantitative and qualitatively).

Table 1. The Trainee binnacle.

Trainee_ID	Date	RLOi-executed	Start-time	End-time	Success
xx1	2005-10-10	identification_process	14:45	15:05	True
xx1	2005-10-10	access_individual_box	15:20	15:35	False
xx1	2005-10-10	access_individual_box	15:35	15:45	True
xx1	2005-10-10	wear_working_suit	15:50	16:05	True
xx1	2005-10-10	wear_security_shoes	16:10	16:35	True
...					

6 Conclusions and Ongoing work

In this paper, Scaffolding as a Tutoring Approach for a PVA has been proposed in a TTS. The TTS has been designed taking as a framework the AT and considering instructional design aspects. Using the AT too, we have also proposed some useful structures, like the Student Knowledge Model, the Zone of Proximal Development and the activities and actions sets. Then, we have showed the advantages of using these structures in an IVE to formulate a Scaffolding Tutoring proposal for a PVA. The PVA have characteristics that allow increasing the computer's ability to engage and motivate trainees along their training process [18].

Once we have formulated and designed these structures, our current work is focused on the implementation of the CVE for Training (CVET) based on the TTS and its related Scaffolding Tutoring Approach, in order to check the viability/effectiveness of our proposal. As a first step of this development, we have already designed a software architecture for IVEs allowing the execution of the training practice using a virtual 3D environment. This virtual 3D environment will allow to carrying new experimentation with the TTS considering the lessons learnt in [19], and the proposed tutoring approach.

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