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Improving trainer decisions into a CVE for training applying ZPD concept

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Abstract: Assign the students the appropriate task associated with this own capabilities and knowledge, and form rights groups among team members are two main problems that a Pedagogical Agent –acting like a trainer- must solve into a Collaborative Virtual Environment for training. We use reusable learning objects design by contract to formulate a Student Knowledge Model and a student ZPD, concepts derived from Intelligent Tutorial Systems and Vygotsky's social theory, respectively. These models could help the trainer to improve its work facilitating information about the current student knowledge and the knowledge what s/he is ready to learn, then the student task assignation and the grouping into the team could be improving.

Key-Words: Collaborative Virtual Environments for Training, ZPD, Student Knowledge Model, and Reusable Object Learning by Contract.

1 Introduction

"A CVE is a computer-based, distributed, virtual space or set of places. In such places, people can meet and interact with others, with agents or with virtual objects. CVEs might vary in their representational richness from 3D graphical spaces, 2.5D and 2D environments, to text-based environments. Access to CVEs is by no means limited to desktop devices, but might well include mobile or wearable devices, public kiosks, etc."[1].

A CVE for training (CVET) can be used for training 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. In these environments "…the supervision of the learning process can be performed by human tutors or it can be performed by intelligent software tutors, also known as pedagogical agents… Those pedagogical agents, in turn, can be embodied and inhabit the virtual environment together with the students or they can be just a piece of software that interacts with the student via voice, text or a graphical user interface." [2].

In a CVET, the pedagogical agent (PA) plays the trainer role and the students are usually adults; anyway, if a lonely student wants to train, the PA can leave this trainer character and play a partner role.

In this scenario, the team collaborative work has additional and personal profits: doubts clarifications, to feel part of the enterprise, to know the partners, etc.

CVETs appear to sustain the constructivist theory of learning: supporting student exploration without instructing and prescribing activity, using case-based rather than predetermined sequences, giving the student the responsibility of what to learn (by selecting activities). Nevertheless, the trainer role played by the PA must guide the team along the training making task demonstrations, giving suggestions, proposing activities, applying assessments and others.

A CVET allows each team member to build his/her own training path in a collaborative way, and the PA applies an appropriate teaching strategy which avoids the danger of missing out some important learning or training sequences.

We can see that the information sharing process between team participants is very important for collaborative work and it has embedded the notion of communication into the CVET, so we need to clarify that by communication we do not understand just text or audio conversations; the agent's embodiment, the representation of students (avatars) and artefacts such as documents and tools within CVETs can facilitate it [1].

In a collaborative work, team member use verbal and no-verbal language to communicate themselves and make the assigned task together.

Based on Vygotsky's social theory[3], the associated concept of Zone of Proximal Development (ZPD) and the object learning design by contract proposal [4-6] we present a student knowledge model (SKM) and a ZPD model to apply into CVETs, which may improve training decisions relative to task assignment and team grouping.

These models are meant to work over the multi-agent architecture for intelligent VETs presented by De Antonio et ál [2] and all explanations about models are related to it; anyway, the models could be easily applied over other architectures.

2 RLO and RLO contracts

Learning objects (LOs) are "independent and self-standing units of learning content predisposed to reuse in multiple instructional contexts"[7].

A LO has non-functional requirements: *accessibility*, a LO should be tagged with metadata so that it can be stored and referenced; *reusability*, a LO can be used in different instructional contexts; and *interoperability*, the LO should be independent of both the delivery media and knowledge management systems [7].

The success in *reusability* of LOs is based "…on the rigorous separation of the LO and its use for instructional purposes"[7]. Designed in a high level of abstraction, a *reusable* learning object (RLO) can have functionality, independence from use and strong performative ability, making possible the RLOs association for instructional proposes.

Currently, the RLO concept is broadly used in virtual environments and e-learning contexts; we can define a RLO repository in the system which can be *accessed* by the agents that inhabit the environment and need some knowledge to do their work. The access is facilitated by a metadata mechanism described later.

On the other hand, design by contract is a technique from object-oriented software engineering [8], that have been applied to the learning object design by contract [4-6], a formalization of learning object metadata which allows stating by contract "the conditions under which a learning object can be used and the outcomes that might be expected from its use" [4]. Originally created to be used on e-learning applications, we want to apply it in CVETs.

The formalization consists in specifying a formula in the form *{C}LO{O}[*θ*]* for each learning object, meaning: using the learning object LO in a learning context *C* – that includes a description of a specific learner profile – facilitates the acquisition of some kind of learning outcome *O* to a certain degree of credibility θ [4, 6].

The clauses use preconditions (*C*) and postconditions (*O*) that allow defining formal contracts to describe the behaviour of one RLO in the system.

The proposed syntax to write LOs by contract is [4, 5]:

rlo <URI>
    require
        precondition1
        precondition2
        ...
    ensure
        postcondition1
        ...

pre- and post-conditions are defined by assertions according to the syntax [4]:

[level] preconditionId.element <relationalOperator> requestedValue
postconditionId.element <relationalOperator> value [θ]

where *pre-* and *post-condition identifiers* match to the learner (lrn), or the learning context (ctx), or the system where the learning object is due to be executed (sys);

element maps to a LOM element entry [4, 5]; and *level* indicates the strength of the precondition (mandatory, recommended or optional) [4, 5].

3 Student and ZPD models in CVET

Vygotsky's social theory focuses on social interaction to extend the learner's cognitive process. The new knowledge is built (by the student) over his/her previous knowledge, always helped by an advanced partner who introduces available conceptual tools from society, and fades out the support at the time that the student makes the task better.

The application of the Vygotsky principles in a CVET requires having assistance of an advanced partner, role that could be played by the PA acting like a trainer or an advanced member of the team.

According to Vigotsky [3], 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 as the distance between the actual development level (determinate by the student independent grade of problem solving) and the possible development level (determinated by the student's grade of problem solving with advanced help [9, 10].

As a related works, Luckin & du Boulay [9] applied a Vygotskyan framework to build Ecolab, an interactive learning environment designed to help children to learn about alimentary chains; they crystallize the ZPD concept building a ZAA (zone of proximal adjustment, that represent an appropriate selection from the ZAA for the actual learner state). Ecolab is a well documented intelligent tutorial system, based on Vygotsky's theories.

By the other hand, Arroyo et ál [11] have built AnimalWatch, a computer-based tutor that provide individualized math instruction for children by using artificial intelligent techniques and ZPD concepts. Arroyo et ál affirm that AnimalWatch could select the amount of challenge and difficulty of problems to fit students' ZPD.

In the multi-agent architecture, the Student Modelling Agent working into the CVET must build an actualized student's knowledge model (SKM). The Tutoring Agent uses this model to make its tutoring decisions.

Now, we want to extend this process, adding a student's ZPD for each team member; that way the PA will know what kind of task the student is ready to learn and could suggest the appropriate one to each student, and could associate an advanced learner with a less advanced one to make the task. Therefore, the advanced student could reinforce his/her knowledge, internalizing it because of the knowledge communication process, and the less advanced learner can learn how to do it in a direct interaction with other team member.

In this new situation, the Student Modelling Agent will be in charge of the building of both the student model (SM) and the ZPD (see figure1). The SM should reflect student knowledge model (SKM) and other important personal information about the learner (motivation, historical behaviour,etc.). The ZPD is an extension of the SKM which shows us where the student can try to do a task –based in what s/he already knows- helped by the PA.

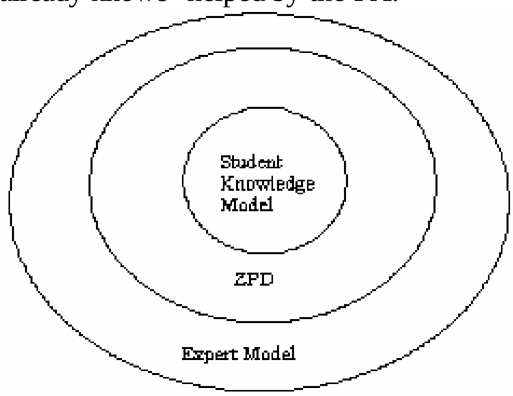

Fig. 1: ZPD context

We propose organizing the knowledge in learning objects designed by contract, easily accessible for the agents to build dynamically the student's ZPD and the student's knowledge model. In this form, these standard objects can be used to model different tasks easily, and the SKM and the ZPD can be actualized as many times as it is necessary.

4 Building the SKM and the ZPD's

There is a repository containing RLO's defined by such these contracts (see previous definition), then, the PA decides the training objective based on the outcomes the object is projected to produce (postconditions), the preconditions (i.e. prerequisites) required and the student's ZPD.

The Expert Agent accesses the repository to construct the best procedure to solve a problem, the procedure could be seen like a concatenated –by pre and post conditions- structure of RLO's:

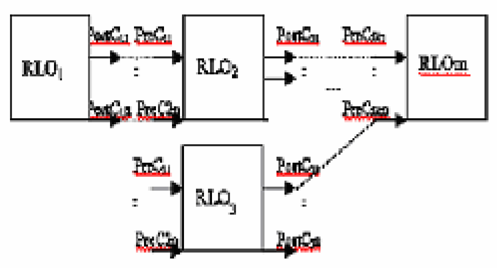

Fig. 2: The best procedure to solve a problem

Each precondition of RLOi must be satisfied with one (or more) postcondition of RLO_{i-1} (or RLO_{i-2}, etc.), except for the first one (initial state) and the last one (the desired outcomes).

All RLOs are accessible to CVET agents by the associated metadata, so the best procedure to solve a problem, the SKM and the ZPD will be constructed using this associated RLO metadata. The Student Modelling Agent will apply a diagnosis the first time the student uses the CVET if appropriate.

The repository will contain full RLOs, and each RLO can be accessed by the associated metadata. In this way, the best procedure to solve a problem, the SKM and the ZPD will be modelled having in consideration only the associated metadata to each RLO component.

When a learner is making a task, the PA (the trainer) must communicate the result (success or failure) to the Student Modelling Agent which will actualize the student binnacle, the SKM and the ZPD where appropriate.

If the learning objective is reached, the student has acquired a new skill or ability and his/her SKM must be actualized. This SKM is defined like a set of components, where each component makes reference to a RLO completed by the student:

$$\boxed{SKM = \{RLO_1, RLO_2, ..., RLO_k\}; \text{ where } k \geq 0} \quad (1)$$

Additionally, the Student Modelling Agent constructs the student's ZPD based on the student's SKM: the process starts 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 belongs to SKM. Then we can construct the student ZPD like a RLO metadata set, since each element will reference a specific RLO the student is ready to learn with a partner help:

$$\boxed{ZPD = \{RLO_1, RLO_2, ..., RLO_p\}; \text{ where } p \geq 0} \quad (2)$$

Now the trainer is able to know what the student is ready to learn and can assign the appropriate task. In this way, since there is a student binnacle, the trainer knows when an advanced partner needs reinforce a task and could form appropriate groups among team members.

Conclusion and future work

The SKM and ZPD models presented in this paper are useful and easy to implement mechanisms that allow the virtual trainer to improve both the task assignment to each student in the team and the grouping among team members.

In collaborative virtual environments communication is a main aspect, being it verbal or non-verbal, and the environment must support this activities. Working in an appropriate group (without strong differences in knowledge and abilities) is another factor that can be considered to facilitate team communication using the present proposal.

Avatars and PAs acting on CVETs extend the notion of computer-based applications for training: PA and students embodiments allow virtual social interaction, in this way the instruction strategies based on Vigotsky social theory can be applied in this simulated world.

We want to extend this work applying other principles of Vygotsky's social theory in CVETs, exploiting the virtual social capability that inhabitants of the environment have.

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