Pedagogical Negotiation in AMPLIA Environment

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Abstract. AMPLIA is an Intelligent Learning Multi-Agent Environment. It is designed to support training of diagnostic reasoning and modeling of domains with complex and uncertain knowledge. AMPLIA focuses on the medical area, where learner's modeling tasks will consist of creating a Bayesian network for a problem the system will present. A pedagogic negotiation process (managed by an intelligent *Mediator* Agent) will treat the differences of topology and probability distribution between the model the learner built and the one built-in in the system. That negotiation process occurs between the agents that represent the expert knowledge domain and the agent that represents the learner knowledge. The possibility of using Bayesian networks to create knowledge representation allows the learner to visualize his/her ideas organization, create and test hypothesis.

1 Introduction

AMPLIA is a computer multi-agent environment intended for teaching and learning over the web. Our proposal is to model this multi-agent intelligent learning environment using the pedagogical negotiation ideas described in this work.

Negotiation that occur in a teaching-learning process, or simply *pedagogical negotiation*, cannot be considered an economic process. By definition there is not an exchange of economic goods in any pedagogical negotiation process. Taking this into account, we may then think that the several negotiation mechanisms, derived from Games Theory and Market Theory [13], should not to be useful for this kind of negotiation. However, considering that these mechanisms were generalized to work with more abstract versions than economic values, such as utilities and preferences, we can verify the applicability of them, checking if the notions of preference or utility can be used in a process of pedagogical negotiation.

Thus, the pedagogical negotiation process could be defined like this:

Pedagogical negotiation aims at **solving conflicts** that may happen among agents involved in a teaching-learning process, exclusively using **pedagogical-like strategies** for conflicts solving.

For a real application, this definition is still incomplete because it don't specify the kind of agents that take part in a teaching-learning process, what is the result expected, what conflicts may arise and, finally, what pedagogical strategies should be adopted to solve these conflicts.

2 Pedagogical Negotiation

The first step is to understand which is the pedagogical negotiation role within a teaching-learning process. To do this we need to understand clearly which are the final objectives of this process are and how negotiation may help to reach them.

In traditional negotiation processes, based on the Economic Theory, the result of some negotiation process is the maximization of gains expected by the agents in negotiation. That is, we expect to find a solution that maximizes gains of agents in relation to all possibilities of solutions to the current negotiation. Gains are measured through a *utility function* known by the agents, that is, a function that they know how to calculate. The problem lies exactly on the presupposition that an agent knows how to determine the utility in a given situation, as well as in situations derived from its actions[13].

This does not happen in a teaching and learning process. That is, it is difficult to realize how a student (or an agent that represent it) has all his/her preferences defined, both current and future, in a teaching process.

The same is valid for the teacher (or artificial agents responsible for teaching). Simply, it is not reasonable to presuppose that the teacher has total knowledge on all situations that may happen in a teaching-learning process. Occasionally, students present results that, even if they are not in accordance with the teacher's expectations, they are perfectly acceptable in terms of teaching objectives intended (sometimes these solutions are even better than standard solutions).

Back to the initial problem, we observe that results of a pedagogical negotiation should be related to the final objectives of teaching-learning process, as well as the concept of preference or utility for an agent is not enough to characterize results expected in the pedagogical negotiation.

As a solution for these problems, we adopted some simplifying presuppositions, based on the common sense, with which we expect to contribute to elicit this issue a little bit more.

A primarily presupposition is not to approach the teaching-learning process directly as a *knowledge transference* process. Characterizing the process in this way implies to consider the need for solving classical epistemological issues that do not have concrete answers: what is knowledge? How could it be transferred to another person? How to measure a person's knowledge? To this claim we add the discourse of pedagogical models supported in the Piaget's genetic epistemology [10], where the subject builds knowledge through the subject-object interaction. According to Becker

[1], "constructivism means: the idea that nothing is ready, finished and that, specifically, knowledge is not given, in any moment as something finished".

Thus, instead of focusing knowledge, the focus will be the teaching-learning process and the interactions and characters (agents) involved in it. Specifically, we will use the notion of confidence that an agent can have in relation to another (or in relation to itself) to analyze this process, aiming at maximizing this relationship as the process evolves.

For that end, we will adopt the notion of confidence based on the expectation of future behavior of an agent in relation to another (or to itself). The idea is that the "expectation of future behavior" may be evaluated or judged more precisely than the perception of "how much this agent knows on the theme". For example, considering the classic student-teacher scenario, instead of defining a formal test as a "knowledge evaluation", it would be reinterpreted as a formal mechanism of "checking how much the student fulfils the teacher's expectations, in a certain situation".

Considering the teacher-student learning scenario, a first step in the characterization of the teaching-learning process is to attribute distinct objectives for each one of the roles. From the point of view of knowledge transfer, the main objectives of a teacher are: to help the student to reach the right understanding of the topic proposed and to be sure that he/she really has reached that understanding. In a constructivist point of view, the teacher role is to mediate the interaction process - offering a rich environment and stimulating the student - in a way that he/she can explore and question facts, reflect on them and formulate hypotheses.

In both cases, certification can be translated through the confidence level that the teacher has on the student, when he/she is in known, and mainly new, situations, where knowledge assimilated and already set or new reasoning and hypotheses are required.

With relation to the teacher's role, as a mediator of the teaching and learning process, not only the relation of confidence between teacher and student should be considered but an inverse analysis is required, that is, the relation of confidence between student and teacher. Thus, there are two important characteristics to outline in the student's behavior:

- The student is confident on the teacher's appraisal capacities during the development of contents. This statement does not imply necessarily that the confidence level is complete, i.e., that the student should blindly trust the teacher. What is said is that there should be a reasonable level of confidence, and that it should be undertaken so that the teaching and learning process can be accomplished.
- Definition of what the student expects as a result of the teaching and learning process. The simplifying presuppositions is to undertake that the student expects to reach a level of knowledge that makes possible to understand and solve situations or problems within the area or discipline that is being studied. The point is not exactly what the student intends, but how we could have concrete evidences that this objective was reached. The explanation that seems more natural is that all the process the teacher uses to be sure that the student has reached the goals will also provide the student with a strengthening on his/her confidence.

Summing up, the teaching-learning process could be seen as a way of reducing (or eliminating) the initial asymmetry of the confidence relation between teacher and student and the topic studied, maximizing the confidence of all. Putting this into a scheme:

- Beginning of the teaching and learning process:

Professor:
(IP.1) High level of confidence in the capacity of appraising the topic approached.
(IP.2) Low level of confidence in the student's capacities to deal with this topic.

Student:
(IA.1) Low level of confidence in the capacity of appraising the topic approached
(IA.2) High level of confidence in the capacity of appraising the topic approached.

- End (expected) of the teaching and learning process:

Professor:
(FP.1) High level of confidence in the capacity of appraising the topic approached
(FP.2) High level of confidence in the capacity of appraising the topic approached.

Student:
(FA.1) High level of confidence in the capacity of appraising the topic approached.
(FA.2) High level of confidence in the capacity of appraising the topic approached.

Conditions **(IP.1)** and **(FP.1)**, as well as **(IA.2)** and **(FA.2)** should not change, being only bases for an adequate beginning, development and end of the process. The effective result of the process would be the increase in the confidence level of the teacher in the student: **(IP.2)** for **(FP.2)**, and of the student in himself/herself: **(IA.1)** for **(FA.1)**.

2.1 Formalising these objectives

There are several ways of analyzing the confidence among agents, and it is possible to characterize several important aspects of this notion. According to Castelfranchi & Falconi [3], trust relations among agents depend on mental states and, therefore, only agents with mental attitudes (beliefs, desires, intentions, etc.) can trust one another. In our work, we will assume a weaker notion of trust turned towards an expectation of future actions of an agent, similar to the confidence notion defined by Fischer & Ghidini [5]. Their notion of confidence is based on a modal logic of beliefs and abilities, which is intuitive according to the idea that we trust somebody when we know how this person will behave in certain situations.

Before we go on, some comments should be made, comparing modeling outlined above for the teaching and learning process and the formal notion of confidence defined in the work by Fischer & Ghidini [5], which is given in the formula $Bi \Diamond j \varphi$. In this formal expression, there is not space for a "level of confidence", or the agent i believes that j will eventually make φ, or not. A possible approach to deal formally with this incongruous feature is to undertake this kind of belief, everything or nothing, and try to structure the belief object, formula φ, splitting it into sub-formulas $\varphi 1$, $\varphi 2$,

..., φn logically related to φ, in a way that φ1, φ2, ..., φn necessarily imply φ. Another way would be to deal with probabilities linked to a logic formula explicitly, using, for example, the PROB(φ) operator, defined in the work [11] by Rao & Georgeff, which attributes a probability PROB(φ) = α that the formula φ is true in a certain possible world.

In the present work, the last approach will be used having in mind the notorious drawbacks of defining a generic method of structuring some formula in terms of its most important components (a problem similar to the knowledge structuring). For example, supposing a scenario composed of an agent **p** professor, an agent **a** student and a proposition φ, that states the answer to be required. When facing a questioning on the theme being studied, we have that propositions **(IP.2)** and **(FP.2)** may be formalized as:

(IP.2) $B_p\, PROB(\Diamond_a\, \varphi) = \alpha$
(FP.2) $B_p\, PROB(\Diamond_a\, \varphi) = \beta$

Where $\alpha \leq \beta$. Coefficients α and β are probabilities used to indicate the confidence level or expectation that the student a eventually hits the answers asked in φ (or that he/she states the entire proposition φ complete, which is the same). In the beginning of the teaching-learning process, the teacher has a low expectation α that the student gives the correct answer. After this process, the expectation should increase to a new coefficient β. It is important to highlight that, from the formal point of view, effects of negotiation in a teaching-learning process can bring two kinds of changes in the formulas given above: they may both change the logic proposition φ related to the topic approached or change the final expectation β (or even the α initial value) of this process.

2.2 The role of pedagogical negotiation

The basic idea of the pedagogical negotiation role is that, although the teaching-learning process can be considered a process of "equalizing" confidence levels, we can not presuppose that it has a linear, monotonic and continually increasing behavior, that is, we can not warrant that this process will increase a certain confidence level step-by-step (linear), without interruptions (monotonic) or drawbacks (continually increasing) until it reaches the required level. It is possible that there are evaluation conflicts between teacher and student, and so it is needed to begin the pedagogical negotiation process so to, as much as possible, solve the conflict through argumentation mechanisms, with the aim of strengthening the confidence relation between teacher and student. That is, the expected result of a pedagogical negotiation process is the increase of the confidence level among agents that are interacting in this negotiation.

Another important aspect in the definition of a pedagogical negotiation mechanism is the definition of which teaching and learning strategy should be used. This is a topic that involves essentially the decision of which teaching and learning strategy

school the system will adopt (behavioral, instructional, constructivist, socio-historical or another one).

Schools that adopt an interactionist approach present important advantages in modeling multi-agent systems once such approach does not only concerns defining which kind of subjects (agents) take part in a teaching and learning process, but also to explain the features of this process, through interactions that happen among agents. Both cognitive constructivism, based on Piaget's works, and the approach based on Vygotski's social interaction are considered interactionist schools [8,9]. The present work undertakes the constructivist approach, which is being introduced into AMPLIA system [14], where the student will have an active role in the learning process and the teacher will be the mediator and motivator of this process, proposing reflection strategies in problems solving. Within this context, the main pedagogical strategies adopted are positive strategies turned towards the student's motivation and not only negative strategies that identify student's "mistakes" and "problems".

3 Teaching and Learning in AMPLIA

3.1 AMPLIA Environment

In AMPLIA environment, besides real students, there are the following artificial agents:

- *Learner* Agent (*LearnerAgent*), responsible for representing the student within the system, acting in favor of its interests. This agent undertakes the student's role in the setting that is being discussed up to now.
- *Expert* Agent (*DomainAgent*), responsible for representing the expert in the domain. This agent has the knowledge the student must study.
- *Mediator* Agent (*MediatorAgent*), responsible for mediating the teaching and learning process between the *Domain* agent and *Learner* agent. This is also the kind of agent that partially undertakes the teacher's role, within the scenario that has been being discussed.

In terms of pedagogical negotiation the *Learner* agent represents the student, gathering all concrete evidences about the status of its learning process, registering the self-confidence level declared and trying to infer its confidence with relation to other agents of the system.

Expert and *Mediator* agents share the teacher's role. The *Expert* agent incorporates the knowledge base on the theme to be studied and, therefore, it has the higher confidence level about the topic. The *Mediator* agent incorporates negotiation mechanisms needed to solve conflicts of this process, that is, teaching pedagogical strategies that can be used in pedagogical negotiation.

3.2 Constructivism in AMPLIA

The basic characteristics of the teaching and learning process of AMPLIA are:

- The teaching and learning process develops in a sequence of decision taking steps (different phases). Each of these phases corresponds to an interaction cycle between *Learner* and *Expert*, with the possible participation of the *Mediator* to help in conflicts solving.
- The student updates his knowledge after the analysis of arguments received during each decision making phase, aiming at basing and qualifying its decisions in the next phase. The *Learner* agent registers all actions the student carries out. These observations support the constructivist pedagogical orientation, where knowledge is built.

In AMPLIA, both the student and the *Expert* agent take part in the teaching and learning process.

Knowledge is assimilated and later accommodated through changes in pre-existent mental structures. The reflection about these changes origins new mental structures, that may undergo new accommodations and so on [2]. When the student analyses observations and suggestions (arguments) supplied by the *Mediator*, it updates its knowledge, aiming at improving its diagnostic model. The same may happen with the *Expert*, that is, starting from the presupposition that a case study may be modeled in different ways, the student may create a feasible model, although it is not identical to the *Expert* solution.

Interaction among the system agents is based on pedagogical strategies that, in AMPLIA, are of two kinds: affective and cognitive. These strategies make possible an intensive use of argumentation when presenting and clarifying situations, searching for a balance through mutual concessions from both *Learner* and *Expert* agents. In the next section we describe the dynamic of interaction among agents.

3.3 Dynamics of interaction among agents

In AMPLIA, the student expresses its argumentation through modeling of a Bayesian network. Bertil Rolf [12] states that the practice and teaching of reasoning and argumentation are proper for the use of schemas. We agree on the idea and, that is why the student's way of expressing him/herself happens through a graphic editor where arguments are formed by nodes and links among them. Rolf classifies three levels of software that can express arguments through graphic structures. This classification takes into account the calculus used. Belvedere system, for example, does not have any calculus, constituting the first level; Athenas and Reason!Able systems are in an intermediate level, having some numerical naming and rules for filtering the best arguments. AMPLIA is at the third level, where the system has an advanced mathematical theory, based on bayesian inference. Systems mentioned above, except AMPLIA, do not present a mediator in the learning process.

The negotiation process follows a protocol of interaction/conversation that is in a schema like the following:

(1) At the initial phase, the *Expert* agent presents a case study for the student. In this state, the *Learner* agent only take notes on the example and passes it to the student.

(2) At the second state, the student models the diagnostic hypothesis, starting from case studies made available by the *Expert* agent. Yet, in the second state, the student sends (through the *Learner* agent) his/her model to the *Expert* agent to be evaluated. This evaluation refers to the importance of each region of the model (trigger, essential, complementary, ...). This evaluation is not directly passed to the *Learner* agent, but sent to the *Mediator* agent.

(3) At the third state, the *Mediator* agent based on the result of the *Expert* analysis and on the confidence level (declared by the student) supplied by the *Learner* agent, chooses the best pedagogic strategy, activating the tactics suitable to a particular situation.

(4) At the fourth state, the student evaluates the message received from the *Mediator* agent and tries to discuss the topics it considers important, by changing its model. At this stage, the student may also decide to give up the learning process (because he/she is not satisfied, for example.)

The negotiation process of AMPLIA happens around the dynamic choice of strategies. Parameters considered are linked to student's beliefs and to the evaluation the *Expert* agent carries out and to observations registered by the *Learner* agent.

In this negotiation process, both the student and the *Expert* agent has the possibility of giving up the interaction. However, the *Expert* agent only abandons the negotiation process when the student presents a solution, whose performance is equivalent or better than its model. The *Expert* agent may come to accept the student's modeling, although it does not correspond exactly to its model), that is, in case the arguments the student uses to solve the study case problem that was presented to him.

4. Conclusions

In intelligent teach and learning environments the pedagogical (or similar) agents takes different kind of roles accordingly to the implicit pedagogical proposal embedded in the environment. For example, the function of this type of agent can be to adapt the environment to the needs of the student, based on some kind of "student profile" that is composed by information provided by the student or inferred by the agent, as in Souto [15]. Pedagogical agents can also assume the role of "tutors" that, based on the observation of the student activity, show hints or make suggestions to the student, attempting to conduce his/her actions toward the solution of some problem. This is the role assumed by pedagogical agents in systems like ADELE [7], ANDES [6] or SE-Coach [4].

However, in AMPLIA system the proposal is that the pedagogical agent works like a mediator in the knowledge construction process, acting directly in the interaction between subject and object, through a "dialogical" relationship that can be called "negotiation". Negotiation, in this context, is directly linked to the pedagogical way of

how to make a student to develop his diagnostic reasoning, refining his/her learning ability

This negotiation process is different in several aspects of the negotiation systems based on Games Theory and Market Theories, because it deals with a negotiation with a pedagogical profile. We are interested on the development of autonomous agents able to help learning, and learning is based on the experience and incremental improvement of the agent's behavior. Pedagogical negotiation uses the *Mediator* agent to solve deadlocks that may happen in the interaction among *Expert* agent and the student (and its corresponding Learner agent). AMPLIA negotiation happens in levels of tolerance of deadlocks, and the *Mediator* agent is due to choose the tactics to be used. The negotiation process happens in decision rounds (cycles), whose cycle begins with the submission of the student model to an evaluation.

Negotiation rationale is the student's learning process itself. Starting from the presuppose that his/her capacity is absorbing all findings of a diagnostic modeling are affected by his/her own experience as a professional, the negotiation process intuitively makes possible, through argumentation, to modify beliefs of another agent.

Pedagogical negotiation is a process of conflicts solving that happen through agents participants in a teaching and learning process. Within the approach presented, this conflict happens exactly when the confidence is broken between agents. In practice, this is seen when an expected behavior or the performance of an agent with another is not carried out.

On the other hand, in a negotiation process we must consider the confronting space, where there are several possibilities for the solution of a deadlock. This happens during the modeling of a diagnostic hypothesis. That is, a diagnostic can be modeled through different ways (casual relation).

In practice, and according to the approach exposed, the final expected result of the negotiation is that student's expectations with relation to the teacher and professor with relation to the student are confirmed and, that, therefore, a high level of confidence is set in the capacities of each other.

Currently, the development of AMPLIA system is in the phase of implementation of *Mediator* and *Expert* agents and in the modeling of *Learner* agent. This work will result in a first prototype of the system that will be used, in the next step, to experiment, test and analyze the behavior of the system with real students.

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