Application of Agent Negotiation in Supporting Constructive Learning

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Abstract: This study presents a novel model that integrates agent negotiation into constructive learning for enhancing interaction efficiency between learner and instructor and promoting learning motivation. A constraint-based agent negotiation mechanism is employed to support a web-based learning environment in which instructor can perceive learners' feedback and receive suggestion about pedagogical strategies. Experimental results suggested that the proposed methodology was able to improve learning effectiveness and learners also believed that the system enhanced their learning motivation and increased the flexibility of course learning.

Key–Words: Intelligent systems in education, autonomous agents, constructive learning, agent negotiation, fuzzy constraints.

1 Introduction

Learning is an active and constructive process of recognition in which learners construct knowledge from physical experiences and interaction. Effective interaction methods, thus, could play a crucial role in the success of a web-based learning [11]. Especially, the learners and instructors often bring different ideas and perspectives during a learning process, and these cognitive differences can be explored to enhance the communications between instructors and learners. Thus, a learning environment supporting effective interaction is important mainly because the learners can articulate their understanding and participate more actively in learning activities and the instructors can then adjust their teaching strategy accordingly.

In a web-based learning environment, inconsistency among ideas, concepts, or statements among the learners and instructors might be negotiated to reach a consensus. Negotiation is an interactive process that includes competition and collaboration. It enables instructors to realize learners' needs and reach common consensuses in pedagogical strategy to promote learning effectiveness. For autonomous, interaction and flexibility, agent negotiation can play an important role in supporting constructive learning [7]. Thus, the main idea of this study is to develop a framework that integrates agent negotiation to enhance the learner-instructor interaction in a constructive learning environment. The framework is designed with a consideration of constructivism into a negotiation process to support learning. In addition, the proposed methodology employs a fuzzy constraint-based agent negotiation mechanism to support effective interaction and to assist all participants to achieve their expectation.

The remainder of this paper is organized as follows. Section 2 presents a concept of modeling e-Learning as agent negotiation. Section 3 describes constructive learning with negotiation along with a computational model that is utilized to illustrate the process of agent negotiation. Section 4 provides experimental results and evaluation of the questionnaire followed by some concluding remarks in Section 5.

2 e-Learning as Agent Negotiation

e-Learning has been defined as the use of Internet technologies to deliver a broad array of solutions that enhance knowledge and performance of learning [16]. Instructors and learners generally spend more time on a e-Learning course due to various course materials and flexible learning environment. Increases on learner participation and interaction are evident as the course progresses. Instructors are also more concerned about the level of participation and interaction with learners in a e-Learning environment [11]. Interaction can be viewed as a function of learners' participation, instructional activities, and social collaboration [3]. Garrison and Moore define all forms of education as essentially interactions between content, learners, and instructors [5]. Figure 1 shows a conceptual view of learning activities involved in these interactions.

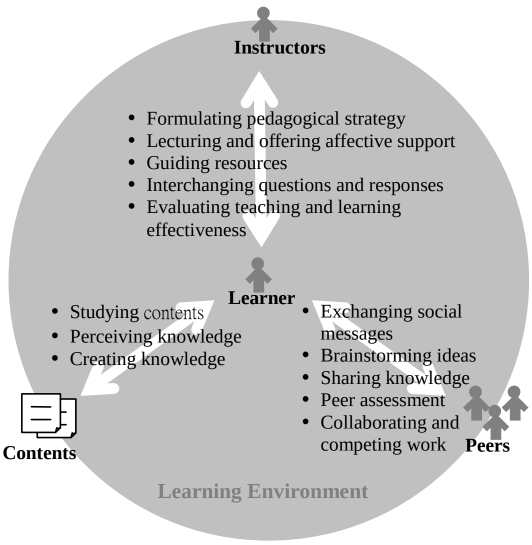

Figure 1: Types of interaction in a learning environment

In Figure 1, learners participate in many ways such as seeing and hearing, reflecting, acting, reasoning, discussing and memorizing. Learner-content interaction is a process in which the learners examine, consider, and process the course contents. Each learner also has to construct knowledge through a process of personally assimilating information into previously existed cognitive structures. It is interacting with contents that results in these changes in the learner's understanding [12]. Thus, the interaction between learner and contents may include studying contents, perceiving knowledge, and creating knowledge.

For learner-instructor interaction, instructors perceive their interaction with learners in lecturing, asking questions, responding, supporting, sharing and clarifying concepts [6]. The role of the instructor in learner-instructor interaction is to guide resources and to offer affective support (welcome, encourage, show empathy, role model support-giving) [2]. The interaction between learner and instructor consists in formulating pedagogical strategy, lecturing, offering affective support, guiding resources, interchanging questions and responses, evaluating teaching and learning effectiveness.

Peers interact with learners through social, brainstorming communication, collaboration, and sharing [14]. According to some studies [1][20], learner-peers interaction, such as exchanging social message, sharing information, collaborating and competing work, peer assessment, and brainstorming ideas, has been demonstrated the usefulness in promoting learners' understanding and stimulating critical thinking.

While we have presented the pervasiveness of interaction, then how to support these interaction effectively? Especially, all participants bring different ideas and perspectives. That is, in a e-Learning environment, inconsistency and conflicts among ideas, concepts, or statements exist during the interaction between learners, contents, instructors, and peers. In order to deal with conflicts, some form of agent negotiation mechanism might be an appropriate method to resolve these cognitive differences and reach a consensus [7].

To that end, the effectiveness of integrating agent negotiation into peer assessment has been studied [8]. In that study, peers evaluate the portfolios submitted by learner and negotiate different marks to reach an agreement through an intermediate assessment agent. Learner can then reflect on the evaluation that has been agreed upon and think more objectively to incorporate peers' assessment, and thereby improve their learning effectiveness. In what follows, we focus on instructor-to-learner interaction to enhance the effectiveness of teaching and learning.

3 Integrating Agent Negotiation into Constructive Learning

3.1 Methodology

Constructive learning is a kind of inspiring instruction that an instructor is just a mentor to assist learners to learn and learners can decide their learning methods by themselves [19]. However, in conventional approach, an instructor often employs identical pedagogical strategies to the learners and expects that every learner can achieve the same pedagogical objectives. In fact, learners possess different learning abilities, attitudes, beliefs, and experiences that result in different constructive patterns of knowledge and effectiveness. Therefore, learners often hope that the instructor can tailor his or her pedagogical strategies such as teaching approach, contents, requirements and assessments to their individual interest and background. In order to reach an agreement of recognition, learners may attempt to negotiate a pedagogical strategy with instructor and the agreement should enable the learners to improve the motivation and effectiveness of learning.

To reach an agreement of recognition between instructor and learners, the mechanism of agent negotiation is integrated into a learning environment. It is necessary for learners to construct qualitative models that are essential for a deep structural understanding of their own field [10]. Social constructivism acknowledges that learning is a social activity in which learners are involved in constructing consensual meaning through discussions and negotiations. During these discussions, learners can identify and articulate their own views, exchange ideas, reorganize their own views and negotiate shared meanings [15]. Therefore, an ideal learning system should consider learners' experiences and views. In our study, to enhance the flexibility and effectiveness in teaching and learning, the mechanism of agent negotiation that combines with constructivism is integrated into a e-learning environment and the framework is shown in Figure 2.

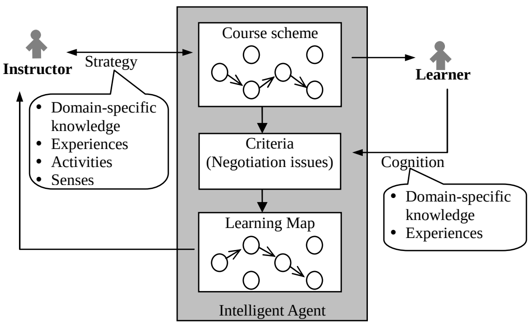

Figure 2: The framework of integrating agent negotiation into constructive learning.

In this framework, instructor is free to construct course scheme based on his or her domain-specific knowledge, expectation and cognition for learners. Through agent negotiation, instructor is able to dynamically realign teaching strategy to learners' response. When learners get the course activities, they use criteria to evaluate pedagogical strategy and provide a feedback to instructor. In agent negotiation, agents that represent learners choose a pedagogical strategy from feasible alternatives in accordance with the instructor's knowledge and beliefs about learners' intention and are responsible for offering their feedback about the course and their preference. During the negotiation of pedagogical strategy, agents may switch to another pedagogical approach with different preference level by a concession strategy.

3.2 Negotiation Process and Computational Model

Various negotiation mechanisms have been explored from game theory [17], Bayesian [18], evolutionary computation [13], to fuzzy constraint-based approach [9]. Among them, fuzzy constraints can serve as a natural means of modeling an agent's requirements involving imprecision and human concept over single issues or combinations of multiple issues. They are also appropriate for modeling trade-off between different issues, and capturing the process by which an agent relaxes its constraints to reach a partially satisfactory deal. Therefore, the core computational model in this study focuses on using fuzzy constraints to represent personal interests and applies negotiation strategies in making concessions between different possible values for negotiation issues.

In what follows, we describe how to infer the process of agent negotiation relies on fuzzy constraints in supporting constructive learning. Following Figures 2, the negotiation process and its computational model are described as follows.

Providing Course Schema

- S is a set of course units designed by the instructor, S_i is a course unit in S and t is the number of course units.

Initially, the instructor provides a sequence of course units $S_1, .., S_t$ and requests every learner to start with the same unit S_1. After studying the initial unit, learners evaluate the course unit to reflect their learning effectiveness.

Evaluating Course Materials

Instructors and learners define their own fuzzy membership functions to evaluate the effectiveness of learning. These fuzzy membership functions for evaluation criteria are regarded as fuzzy constraints.

- $\mathbf{C}^p$ is a distributed fuzzy constraint network that represents an agent $\mathfrak{R}_p$.
- $\Pi_{\mathbf{C}^p}$ is the intent of a distributed fuzzy constraint network $\mathbf{C}^p$ and represents the set of all potential agreements for agent $\mathfrak{R}_p$. $\Pi_{\mathbf{C}^p}$ is defined as

$$\Pi_{\mathbf{C}^p} = \bar{C}_1^p(T_1) \cap \cdots \cap \bar{C}_m^p(T_m) \qquad (1)$$

where , m is the number of constraints and $C_j^p(T_j) \in \mathbf{C}^p$, T_j is a subtuple of X and $\bar{C}_j^p(T_j)$ is its cylindrical extension in the space X. X is a tuple of n negotiation issues $X_1, \ldots, X_n$.

Progressing Negotiation

The process of negotiation is a series of determining how agents evaluate and generate alternatives from a possible designated space. $\mathfrak{T}(\mathfrak{R},_{\alpha_i}\Pi_{\mathbf{C}^p})$ denotes to find a final agreement for all agents in $\mathfrak{R}$ from ${}_{\alpha_i}\Pi_{\mathbf{C}^p}$. If $\mathfrak{T}(\mathfrak{R},_{\alpha_i}\Pi_{\mathbf{C}^p})$ holds, the negotiation is complete and terminates; otherwise, agents lower the threshold of acceptability and repeatedly apply $\mathfrak{T}(\mathfrak{R},_{\alpha_i}\Pi_{\mathbf{C}^p})$ to achieve an agreement.

- $\mu_{\Pi_{\mathbf{C}^p}}(u)$ is the overall degree of satisfaction reached with a solution u.

$$\mu_{\Pi_{\mathbf{C}^p}} = \min_{q=1,\ldots,n}(\mu_{C_q^p}(u)) \quad (2)$$

where $\mu_{C_q^p}(u)$ is the degree of satisfaction for agent $\mathfrak{R}_p$ and issue q.

- $\Psi_{\mathbf{C}^p}$ is an evaluation function that represents the aggregate satisfaction value of agent $\mathfrak{R}_p$ for the potential agreement in ${}_{\alpha_i}\Pi_{\mathbf{C}^p}$. α is a threshold value in the interval $[0, 1]$. The aggregate satisfaction value is the measure of human preference. Given an offer (or counteroffer) u, the aggregate satisfaction value of u for agent $\mathfrak{R}_p$ can be defined as

$$\Psi_{\mathbf{C}^p}(u) = \frac{1}{n}\sum_{q=1}^{n}(\mu_{C_q^p}(x_q)) \quad (3)$$

where $\mu_{C_q^p}(x_q)$ is the satisfaction degree of the constraint C_q^p.

- Given the latest offer v and an acceptable threshold α_i^q of agent p, the set of feasible proposals at the threshold α_i^p for the next offer of agent p can be defined as

$${}_{\alpha_i^p}\Gamma_u^p = \{v|(\mu_{C^p}(v) \geq \alpha_i^p) \wedge (\Psi^p(v) \leq \Psi^p(u))\} \quad (4)$$

- The task of offer generation by agent p is to make an expected proposal u^* from ${}_{\alpha_i^p}\Gamma_u^p$. If agent p faces no expected proposal u^* in ${}_{\alpha_i^p}\Gamma_u^p$, then agent p lowers the threshold of acceptability α_i^p to the next threshold α_{i+1}^p and creates new feasible proposals ${}_{\alpha_{i+1}^p}\Gamma_u^p$. The procedure of offer generation by agents will continue until the expected proposal u^* is generated or no more solution can be proposed. However, assuming that agent p proposes an offer u to another agent p' and p' subsequently proposes a counter-offer u' to agent p, agent p will accept the offer u' proposed by its opponent p' as an agreement if

$$(\mu_{C^p}(u') \geq \alpha_i^p) \wedge (\Psi^p(u') \geq \Psi^p(u)) \quad (5)$$

where α_i^p is the acceptable threshold of agent p.

- A rational agent will not propose a counter-offer that is worse than the offer proposed already by the opponent. Thus, assuming that the counter-offer u' is proposed by agent p' and the u^* is the next offer of agent p, a rational agent p would also accept the offer proposed by its opponent as an agreement if

$$(\mu_{C^p}(u') \geq \alpha_i^p) \wedge (\Psi^p(u') \geq \Psi^p(u^*)) \quad (6)$$

where α_i^p is the acceptable threshold of agent p.

- The $\mathfrak{T}(\mathfrak{R},_{\alpha_i}\Pi_{\mathbf{C}^p})$ will be found if all agents accept an offer according to (5)(6).

Applying Negotiation Strategy

Agents apply concession strategy to negotiate. Through offers generation and evaluation, if an agreement cannot be reached, the concession strategy will be adopted. Conversely, if an agreement is reached, the interests of the instructor and the learner are considered to produce the final results.

- In a concession strategy, agents generate new proposals to achieve a mutual satisfactory outcome by reducing their demands. ${}_{\alpha_q^p}\mathfrak{P}_u^p$ is a set of feasible concession proposals at the threshold α_q^p for agent p and it is defined as

$${}_{\alpha_q^p}\mathfrak{P}_u^p = \{v|(\mu_{C^p}(v) \geq \alpha_q^p) \wedge (\Psi^p(v) \leq \Psi^p(u) - r)\} \quad (7)$$

where r is the concession value.

The agent's concession value r may be determined from the agent's mental state and the opponent's responsive state. The proposed methodology uses the fixed concession strategy. An agent will translate its urgency into its concession value r. Thus, a greater urgency corresponds to the making of more concessions. While ${}_{\alpha_q^p}\mathfrak{P}_u^p$ is found, it is necessary to return to equation (2) to reach a final agreement for all agents.

Adjusting Pedagogical Activities

After an agreement has been reached, learner receives his or her learning map and then the system will provide the next course unit in S. If the course unit S_1 is beyond learners' comprehension, and then the system will automatically guide learners to learn other appropriate contents to enhance knowledge. Through the negotiation process, the instructor also can gradually perceive the learners' feedback and then reflect on the appropriateness of the learning sequence, adjust pedagogical activities. The instructor can thus provide more adaptive teaching based on learners' specific needs to enhance learning effectiveness.

4 Experiment and Results

This experiment examined the usability and effectiveness of a computational model that emphasizes constructive learning and critical thinking. 73 college students learning a software certification course were selected as study subjects. These students were divided into the experimental group ($n_1 = 38$) and the control group ($n_2 = 35$). They were assigned to undergo a certification examination before the end of the course. The experimental group participated the learning activities using the proposed model, while the control group represented traditional ways of studying and reading for examination. The experimental process consisted of the following six steps.

Step1: Providing Course Scheme

The instructor constructed course schema according to his domain-specific knowledge and experiences. There were two parts (Part A and B) containing ten units (Unit A-1, A-2,... A-5 and B-1, B-2,... B-5) in this course. Each unit was assessed the appropriateness of various stages using fuzzy constraints. The control group followed the fixed course scheme (from A-3 to B-4) to study. The experimental group acted according to the following steps.

Step2: Evaluating Course Materials

Students first learned the course unit (A-3). After each student studied the course unit, he defined fuzzy constraints to evaluate the unit according to the learning perception.

Step3: Negotiating and Adjusting Pedagogical Activities

According to fuzzy constraints provided by the instructor and students, agents adopted the concession strategy to commence negotiating. When the negotiation reached an agreement, the system automatically provided the next appropriate unit for individual student. The negotiation mechanism assisted the instructor and each student to organize the learning maps. The statistical result presented that the average of course units provided to students to learn is 5.21 in the experimental group, while the number of course units is 2 for the control group. The results also indicate that most students in the experiment group considered themselves can not comprehend the first course unit. The system then assigned more course units to these students to enhance their learning achievement. Table 1 shows the relation between the number of course units and learning performance.

The correlation between the number of course units and learning performance is 0.705 ($p<0.01$). Thus, a positive correlation between the number of course units and learning performance is found. An increase in the score of the examination appeared to be associated with an increase in the number of course units.

Table 1: The learning performance for learning course units

	Number of course units							
	2	3	4	5	6	7	8	9
Average score	75.2	78.3	83.2	82.5	79.3	81.1	82.0	84.1

Step4: Analyzing Group Performance

The instructor then gave all students an examination related to software operation. Analytical results of t-test indicated that students who participated in constructive learning had acquired more knowledge than students who did not. Furthermore, quantitative scores also indicate that the learning performance in the experimental group is better than that in the control group.

The average of the experimental group is higher than that of the control group. A t-test analysis for performance indicates that the performance between the two groups was significant (Table 2).

Table 2: Performance analysis

Students	n	Mean	t-value	p-value
Experimental Group	38	80.23	1.91	0.012
Control Group	35	75.86		

Level of significance α =0.05

Step5: Evaluating Questionnaire Results

Following the experiment, students provided feedback via a questionnaire. A 5-point Likert scale was employed to grade responses. Questionnaire results indicate that students regarded the agent as a satisfactory approach for flexibly assessing courses, autonomously learning, and enhancing their learning performance. (Mean=4.08) Although some students considered it was complex, most students believed that the system helped them to reflect on and improve their learning activities. Additionally, students felt that by relying on fuzzy membership functions and agent negotiation, the assessment model was flexible and easy to use.

5 Conclusion

This study has proposed a concept of integrating agent negotiation in supporting constructive learning. It allows instructors and learners to negotiate the pedagogical methods and course activities during the learning process. Base on the experimental results, the proposed model has the following merits.

- The methodology assists learners to acquire more knowledge and improve learning performance through course evaluation and negotiation. The learners describe that constructive learning combined with agent negotiation can be an effective learning tool for developing thinking.
- The instructor can perceive learners' feedback and then reflect on the appropriateness of the learning sequence, adjust pedagogical activities. Most importantly, the instructor can provide more adaptive learning based on learners' specific needs to enhance learning motivation.
- Fuzzy constraint-based agent negotiation increases the flexibility of evaluation on learning effectiveness.
- The proposed system also provides higher degree of autonomy and convenience in that it eliminates time and location constraints and offers effective interaction and feedback.

Finally, although the proposed methodology has yielded promising results in promoting learning effectiveness, considerable work remains to be done, including further development of the methodology and a large-scale experiment in other learning scenarios.

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