NDLtutor: An Automated Conversational Agent to Facilitate Metacognitive Skills in Fully-Negotiated OLMs

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Abstract. In this paper we discuss the findings related to our research on the paradigm of Negotiation-Driven Learning (NDL). Fully-negotiated OLMs have employed different negotiation mechanisms to support learner learning and reflection. In NDL research we are trying to combine and extend the best practices of previous OLMs to enhance the role of negotiations and promote cognitive and metacognitive learning in the context of fully-negotiated OLMs. This paper describes the findings of our research and introduces the NDLtutor, which is the realization of the NDL paradigm.

Keywords: Metacognition · Negotiation-Driven Learning · Interest-Based Negotiation · Affect · Behavior · Motivation · Natural-language dialogue · Self-reflection

1 Introduction

We have been working on the paradigm of Negotiation-Driven Learning (NDL) to enhance the role of negotiation in fully-negotiated Open Learner Models (OLMs) [1]. In fully-negotiated OLMs, learners have the ability to change their belief base which can be different from the belief of the system about their knowledge level [2, 3]. Such differences (conflicts) serve as the basis of a dialogue between the learner and the system where both of the parties collaboratively construct and maintain the Learner Model (LM). This strategy has shown to promote learning gains as well as enhance metacognitive skills in the learner [2]. OLMs have deployed different negotiation mechanisms to discuss the LM with the learner [2, 3, 5, 6]. In our research on NDL, we are trying to maximize the utility of this negotiation mechanism by adopting and extending previous best practices into a single system.

NDLtutor is a concretization of the NDL paradigm [1], where we seek to elevate the role of negotiation as a tool to promote learning gains both in the sphere of cognitive and metacognitive skills. NDL follows the notion that learning is maximized by spontaneous participation. When a learner is challenged by the system about the change they made in their belief base, they are inherently driven to defend this change. It is basic human psychology that humans become stronger advocates of their beliefs once they

are challenged, and are intrinsically motivated to defend their belief [4]. NDL aims at exploiting this opportunity created by the occurrence of a conflict to involve an intrinsically motivated learner in a deep learning dialogue which not only discusses the domain knowledge but also encourages them to assess the discussion to promote self-reflection. To this effect, NDLtutor is being developed to advance the current state of the art of dialogue capabilities that provide the learner with the tools and support to interact with the system in a naturalistic environment.

In this paper we introduce the NDLtutor, report the work we have done previously and discuss the results of our work in the light of future directions. The rest of the paper is organized as follows; the next section provides the background of our study. Next we present Negotiation-Driven Learning along with the outline of the architecture and implementation of NDLtutor. The next section provides the result and discussion about the evaluation followed by the concluding remarks.

2 Related Work

Early fully-negotiated OLMs explored different forms of the negotiation methods (menu selection and conceptual graphs) to provide the learner with the opportunity to interact with the system [3, 5]. However, it was noted that the negotiation methods used by these OLMs were not very flexible or naturalistic. To overcome this chatbots were used to provide a more naturalistic interface for negotiation [6].

Automated conversational agents have been shown to successfully engage learners and promote learning gains [7]. One of the main reasons that human tutors are more effective is hypothesized to be their use of natural language dialogue. Allowing the learner to interact with the system in natural language requires that the system is able to understand the learner's input. To deal with the complexities of natural language, different Natural Language Processing (NLP) techniques have been employed by ITSs with varying success [12].

Another important factor in the success of human tutors is their ability to interact with the learner according to their mental state [8, 9]. If a learner is in some sub-optimal state, they need to be supported to an optimal state for increased learning.

Metacognition has been recognized as a trait of effective learners and therefore much work has been done in the field of OLMs to continuously promote these skills in learners [10]. In current OLMs self-reflection is mostly implicitly implied by the externalization of the LM and the changes the learner makes to it.

3 Negotiation-Driven Learning

As mentioned earlier, this paper provides new insights to our previous work where we introduced our paradigm of Negotiation-Driven Learning (NDL) [1]. NDL aims to maximize learning participation by providing adequate support to the learners that allows them to interact with the system in a natural language environment. The basic philosophy of NDL is to engage a learner according to their mental state and to ensure that they remain in an optimal learning state. From previous work on modeling of affect

and motivation, we have selected 6 states, 3 affective states (*Confusion, Frustration, Engagement*) and 3 behavioral states (*Confidence, Interest, Motivation*) to be used in NDL through a comprehensive Wizard of Oz experiment [1].

3.1 The NDLtutor

NDLtutor provides a natural language interface to the learner to interact with the system. NDLtutor is different from its counterparts [3, 5, 6] in that it uses the *approximate* affective and motivational states of a learner to control the flow of the dialogue. To accomplish this we employed Interest-Based Negotiations (IBN) [11] as its negotiation strategy. Figure 1 shows the architecture of the NDLtutor.
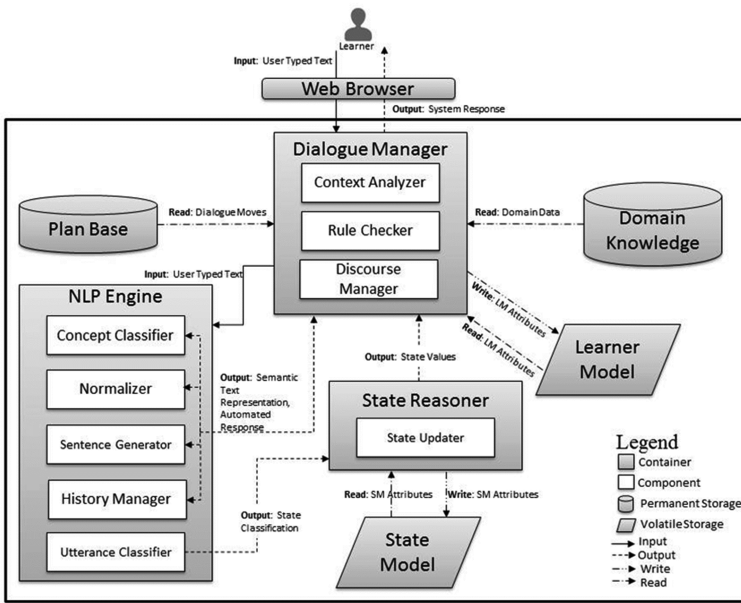

Fig. 1. NDL architecture adopted from [1]

3.2 Dialogue Design

One of the biggest challenges in the design of the NDLtutor was the dialogue management capability of the system. To design a dialogue management system, we needed to understand the dynamics of the possible learner interactions with our system. We conducted a Wizard of Oz study (WoZ) to create a basic classification of the learner input. Complete details of this experiment can be found in our previous work [1]. The data collected from the experiment allowed us to generate three main libraries; *User_Utterance_Library, System_Utterance_Library* and *Rules_Library*.

3.3 Implementation

The backend of the NDLtutor has been implemented using PHP and MySQL whereas the frontend (user interface) has been designed using HTML5 and jQuery. The backend database consists of:

- *Domain Knowledge:* The domain knowledge is stored as plain text which is divided into topics and sub-topics. Each topic has 2 sets of questions; (1) *Multiple-Choice Questions* (MCQs) to assess the learner's performance (2) *Domain Discussion Questions* (DDQs) that are used to discuss the topic with the learner during the conflict resolution phase.
- *State Model:* The state model is stored as a list of attributes (states).
- *Learner Model:* The learner model is an overlay of learner's knowledge upon the domain.
- *Plan Base:* Consists of the dialogue moves that have been identified to work during a specific scenario to improve the system's response time.
- *The Reflection Log:* The database also stores the learner's responses during the reflection phase and this act as a self-assessment log for the learner to review at any time.

4 Evaluation of NDLtutor's Performance

We have planned a number of experiments to test the feasibility and applicability of our system. For the purpose of this paper, the evaluation was focused on investigating the following:

- The dialogue management capabilities of NDLtutor. (Quality of dialogues, Meaningful dialogues, Utility of the affective and behavioral selected states, Appropriate Feedback)
- Whether the inclusion of a reflective dialogue phase was beneficial for the learners?

4.1 Method

The participants for this evaluation were 20 students from the undergraduate Software Engineering program at Bahria University Islamabad, Pakistan. A pre-experiment test was conducted to generate an ad-doc LM for each participant. The average interaction time was 15.6 min. Post-experiment survey and interviews were conducted to get user feedback on the system.

4.2 Results and Discussion

As mentioned earlier, for this cycle of evaluation, we focused on the user's perceptions of the dialogue management capabilities of our system as well as the inclusion of a reflective dialogue as a means to promote self-reflection.

The dialogue management capabilities of the NDLtutor – The use of selected affective and behavioral states allowed the dialogues to progress smoothly, which suggests that the state selection together with the state-based dialogue management was appropriate to control the flow of dialogues. There were a total of 257 user utterances recorded. Out of these, 114 were domain-dependent, while the remaining 143 were domain-independent utterances. From the 143 domain-independent utterances, 129 (90.2 %) user utterances were successfully matched with the User_Utterance_Library while 14 (9.7 %) domain-independent user utterances could not be classified by our scheme.

Whether the inclusion of a reflective dialogue phase was beneficial for the learners – the answer to this question was retrieved from 3 sources:

- *The interaction logs of the reflection phase:* the interaction logs were analyzed to see learner's responses during the reflection phase. The students were able to identify their knowledge gaps by comparing their initial answers to their final answers. This comparison allowed them to reflect upon their initial understanding and how it evolved during the course of the discussion.
- *Post-experiment survey:* the survey results in Table 1 showed that majority of the students were receptive of the reflective dialogue phase introduced in NDLtutor.

Table 1. Post-experiment survey

	<Strongly agree…………Strongly disagree>					Mean
	(5)	(4)	(3)	(2)	(1)	
Do you think discussing a topic with the chatbot was a good way of justifying your proficiency in that topic?	16	3	1	0	0	4.75
Do you think discussing a topic with the chatbot helped you improve your understanding?	13	4	2	1	0	4.45
Was the chatbot able to correctly understand what you wanted to say?	16	2	0	1	1	4.55
Were the system's reactions to your inputs valid?	14	4	1	0	1	4.5
Did the chatbot make the negotiation process easy?	14	2	3	1	0	4.45
Did the use of off-topic discussion/ small talk make dialogue feel realistic/natural?	4	7	6	2	1	3.61
Did you find the reflection dialogue beneficial?	16	1	3	0	0	4.65
Would you be interested to use a similar system in the future as a study resource?	18	1	1	0	0	4.85

- *Post-experiment interviews:* students who were engaged in the reflective dialogue with the system were later interviewed to get their complete opinion about the system.

The students were very receptive of the reflection phase and found it to be very helpful in reviewing the dialogue and supporting self-reflection.

The analysis of the reflection phase showed that the participants did engage in self-reflection, however the role of the NDLtutor in this phase still needs further consideration. An observation made during the analysis of logs was that the less knowledgeable participants *gamed* the system by using the answers provided by the NDLtutor during domain discussion phase to generate their summarized answer. This allowed them to achieve high answer and concept coverage scores for their final answers. Such observations need to be further investigated and will be part of the future work.

5   Concluding Remarks

This paper presents the work we have done on our research on Negotiation-Driven Learning. By combining previous best practices, our work so far has produced very promising results. We understand the main reason for having such high rate of acceptance from the participants was partly because the survey was only focused on the dialogue management capabilities of the system. There are other major perspectives such as learning gains, managing high performing students etc. that this evaluation did not take into account. Including these perspectives will definitely affect the outcome of the evaluation study.

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