Representing knowledge in a Reflective Tutorial Dialogue System for Historical Text Comprehension

Maria Grigoriadou¹, Grammatiki Tsaganou¹ and Theodora Cavoura²

¹University of Athens, Dept. of Informatics and Telecommunications, GR-15784, Athens, Greece, e-mails: {gregor, gram}@di.uoa.gr
²University of Thessaly, Dept. of Education, Argonafton & Filellinon strs, GR-38221, Volos, Greece, e-mail: theokav@pre.uth.gr

Abstract
The Dialogue-based Reflective Learning System for Historical Text Comprehension consists of two parts: (1) the Diagnosis and (2) the Reflective Tutorial Dialogue. In this paper we present the knowledge representation in the dialogue generator module of the Reflective Tutorial Dialogue System (ReTuDiS), which is based on the Theory of Inquiry Teaching. The dialogue generator uses dialogue strategies, tactics and plans to generate the appropriate reflective learning dialogue for the learner according to his learner model. The dialogue generator is activated by the diagnostic results, plans the appropriate sequence of dialogue-parts using the dialogue-parts library and constructs the tutorial dialogue. Based on this prototype knowledge representation the system promotes learners’ reflection to accomplish the learning goals and helps learners to be aware of their reasoning and leads them towards a scientific thought. Moreover in this paper we present the comments of experts concerning the tutorial dialogue during an experiment.

Key-words: knowledge representation, planning, dialogue processing, reasoning with actions and change

1. Introduction

Tutorial dialogue has many positive characteristics for promoting learning. It provides learners with a learning environment appropriate for the accomplishment of learning goals. It affords the tutor the opportunity to tailor instruction to the needs of the learner. Advanced computer learning environments require open learner models, which promote reflection, in order to help learners overcome their learning difficulties [2] [3]. Reflective tutorial dialogue between the learner and the system about the learner’s own beliefs can make a learner model open [9] [13]. Interactive open learner modeling involves human learners in learning dialogues to improve learning through promoting and facilitating reflection.

Towards this direction, the dialogue management, the dialogue strategies and the dialogue tactics, which mainly formulate the dialogue framework, aim at the promotion of reflection in learning [7] [17] [19] [20]. The Theory of Inquiry Teaching is prescribed as a theory for the use of discovery and inquiry approach in learning [5]. Many of its strategies are intended more to develop higher thought processes than to develop content-specific knowledge. Questions provide the focus and direction for the instruction through reflective tutorial dialogue. Through dialogue the learner
defends his views to the system by collaborating, discussing and arguing the system’s assessment of his knowledge and beliefs [1].

Recently, approaches involve learners in negotiating dialogues, which encourage them in inspection. Other approaches explore guidance mechanisms to support interaction with artificial agents [19]. Knowledge is represented in StyLe-OLM using conceptual graphs [6]. In ATLAS-ANDES reusable components and tools for natural language dialogue are used [6]. In ScoT a dialogue manager handles mixed-initiative conversational tutorial dialogue [17]. Systems, which support mixed-initiative dialogue in case-based reasoning [11], modular dialogue planning and management [7] [19], have been explored.

Our system is a dialogue-based reflective learning system, which models dialogue concerning historical text comprehension [14] [15] grounded on the Theory of Inquiry Teaching. The dialogue generator module generates tutorial dialogue, which promotes and facilitates reflection in the domain of comprehension of historical text.

In section 2, we present the diagnosis part of the Dialogue-based Reflective Learning System for Historical Text Comprehension. In section 3, we describe the Theory of Inquiry Teaching and its tactics. In section 4, we concentrate on the knowledge representation in the Reflective Tutorial Dialogue part and especially on the dialogue generator module. We present how the Theory’s strategies and tactics are adopted by the system and how appropriate tutorial dialogue is generated using the dialogue-parts library. Moreover in this section, the four stages interactive dialogue between the learner and the system and how the dialogue engages the learners to reflect on their own strategies in each of the stages are displayed. In section 5, formative evaluation and results are discussed. In section 6, we conclude and give our future perspectives.

2. The Diagnosis of Historical Text Comprehension

2.1 Models of Historical Text Comprehension

Comprehension of text is a special kind of the complex and interactive process of cognition [1]. The reader utilises certain fundamental cognitive categories for establishing and organising the meaning of the text. During comprehension of historical text the reader attributes meanings to causal connections between occurrences [4]. In the level of comprehension as a cognitive task, the learner composes a representation of the historical text, which contains the cognitive categories: event, state and action. For the interpretation of the learner’s cognitive processes we trace in their discourse their arguments, which reveal the recognition or not of the three cognitive categories.

2.2 The Learner Model of Historical Text Comprehension

The Diagnosis part of the system engages the learner in an activity which includes the reading comprehension of a historical text and answering question-pairs by using given alternative answers [14]. The learners’ answers are used for the diagnosis of the learners’ historical text comprehension. The historical text includes factors, which represent the 3 cognitive categories action, state and event. For every factor a question-pair, is submitted to the learner. The first question in the question-pair is related to the learner’s answer about the significance of this factor and is called
The second question is related to the learner’s justification concerning the position and is called justification. The learner has to use the given alternative answers, in order to express his position for certain historical issues and support it by selecting a justification. The alternative answers concerning position and justification are classified as scientific, towards-scientific or non-scientific. Figure 1 depicts a historical text concerning 5 different factors of the outbreak of French Revolution. In the historical text, one factor represents the cognitive category event, one the cognitive category state and three the cognitive category action. For example, question-pair 1, alternative answers a1 and b3 are non-scientific, a2, b1 and b4 are towards-scientific, whereas a3 and b2 are scientific.

For every question-pair the combination of the learner’s position and the corresponding justification constitute the learner’s argument. An argument is defined as complete when both position and justification are scientific. Otherwise the argument is non-complete. The expert defines the different degrees of argument completeness. The argument completeness, which is associated with the recognition or not of an instance of a cognitive category, is used as a vehicle to reveal the degree of the recognition or not of the corresponding cognitive category.

Table 1 demonstrates all possible combinations of position-justification pairs and the corresponding argument completeness. Possible values of argument completeness are: complete, almost complete, intermediate, nearly incomplete and incomplete. The learners’ cognitive profiles of Historical Text Comprehension are formulated taking into account the number of his arguments with high degree of argument completeness. The cognitive profile expresses the degree of recognition of the cognitive categories. Possible values of cognitive profiles are: very low, low, nearly low, below intermediate, above intermediate, nearly high, high and very high.
The Diagnosis system infers the argument completeness for all the learner’s arguments. Using the technique of Fuzzy-Case Based Reasoning the system handles case adaptation by exploiting the similarity values between the arguments’ completeness and infers the learner’s cognitive profile [16]. This technique integrates the right balance between the hard to acquire expert knowledge and the more easily acquired knowledge in the form of cases [18].

<table>
<thead>
<tr>
<th>position</th>
<th>justification</th>
<th>argument completeness</th>
</tr>
</thead>
<tbody>
<tr>
<td>scientific</td>
<td>scientific</td>
<td>complete</td>
</tr>
<tr>
<td>towards scientific</td>
<td>scientific</td>
<td>almost complete</td>
</tr>
<tr>
<td>non-scientific</td>
<td>scientific</td>
<td>intermediate</td>
</tr>
<tr>
<td>scientific</td>
<td>non-scientific</td>
<td>nearly incomplete</td>
</tr>
<tr>
<td>scientific</td>
<td>towards-scientific</td>
<td></td>
</tr>
<tr>
<td>towards-scientific</td>
<td>towards-scientific</td>
<td></td>
</tr>
<tr>
<td>non-scientific</td>
<td>towards-scientific</td>
<td></td>
</tr>
<tr>
<td>towards-scientific</td>
<td>non-scientific</td>
<td>incomplete</td>
</tr>
<tr>
<td>non-scientific</td>
<td>non-scientific</td>
<td></td>
</tr>
</tbody>
</table>

### 3 Theory of Inquiry Teaching

The Theory of Inquiry Teaching is a theory for the use of discovery approach [5]. Learners formulate hypotheses (discover generalities) based on observation of varied cases (examples), to force greater depth of processing of the new knowledge. Another feature is the use of an inquiry approach. Questions provide the focus and direction for the instruction, presumably to improve motivation. Inquiry teachers have two overall goals:
- to teach deep understanding of a particular domain so that students can make novel predictions about the domain.
- to teach students to think scientifically so that they can learn to construct general rules and theories in their own, and be able to test them out.

The dialogue tries to encompass both these goals of inquiry teaching. General tactics inquiry teachers use to accomplish these goals are:

1. **Selecting Positive and Negative Exemplars:** pick paradigm cases where the values of all the relevant factors are consistent with a particular value of a dependent variable. For example, “the heavy winter of 1989” or an earthquake, are accidental events which happen without human interference. On the other hand, the King’s convergence of the General Classes happens after the King’s interference.

2. **Selecting Counterexamples.** If a student forms a hypothesis that is not completely true, the teacher will often select a case that satisfies the student’s hypothesis but violates the hypothesized prediction. For example, the learner considers the “living conditions of the 3rd class before 1789” as the most important reason. The tutor’s counterexample can be: “Whenever the living conditions of people are bad do we have a revolution?”

3. **Generating Hypothetical Cases:** generate hypothetical cases in order to force students to reason about situations that are hard to reproduce naturally.

4. **Forming Hypotheses:** try to make students predict how a dependent variable varies with one or more independent variables or factors. The tutor generates the hypothesis that “if the heavy winter of 1789 did not have happened, would the outbreak of the French Revolution have happened?” in order to make the learner to reason about it.

5. **Testing Hypotheses.** Once the student has formulated a hypothesis, the teacher wants the student to figure out how to test the hypothesis.
6. Tracing Consequences to a Contradiction. Tutors often trace the implications of a student's answer to a contradiction with some other belief the student holds.

In running an inquiry dialogue with students, teachers maintain an agenda of goals and sub-goals that is continuously updated throughout the dialogue with questions. As students answer the initial questions, they reveal misconceptions and holes in their knowledge that in turn generate sub-goals for the teacher to diagnose and correct.

The application of the theory outlined to construct tutorial dialogue about a historical text comprehension concerning the outbreak of the French Revolution is summarized in the following objectives. The learners must be able:
- to recognize the 3 cognitive categories
- to appraise a factor in the historical text that corresponds to the cognitive category action as the most important reason than state or event.
- to meet reflective activities and construct coherent arguments, which means without contradictions between position and its justification.


The heart of the ReTuDiS is the dialogue generator, which adopts the Theory of Inquiry Teaching to generate the appropriate tutorial dialogue for the learner using the library of dialogue-parts (Figure 2). Knowledge is represented in dialogue generator by: the learner models' base, the dialogue strategies, the dialogue tactics the dialogue plans and the dialogue parts library.

![Figure 2: Architecture of the Dialogue Generator Module](image)

Knowledge concerning the learner's behavior is represented in the learner model as characterizations of positions, justifications and arguments. The dialogue generator, based on a dialogue strategy, activates the appropriate for the learner dialogue tactics and dynamically constructs the dialogue plan. The individualized reflective tutorial dialogue is generated using dialogue-parts from the dialogue-parts library. The dialogue-parts are reusable components appropriate to the learner's learning difficulties, as they appear according to his learner model. The system has at its disposal a library of dialogue-parts, each of which is designed to remedy a particular learning difficulty. In order to generate the appropriate dialogue in response to the learner feedback, the system first analyzes the student's essays to assess, which are the contradictions within the student's arguments. In our design, dialogue-part is seen as a component in the library of dialogue-parts, which can be reused.
4.1 Learner models’ base

The learner model consists a record in the learner models’ base and includes: the learner’s answers to the question-pairs, the characterizations of his answers, the characterizations of the learner’s arguments, the cognitive profile, the profile descriptor, information data about the participation of the learner to the reflective dialogue and about the behavior of the learner during the reflective dialogue.

4.2 Dialogue Strategies

Tutorial strategies are methods for constructing an initial plan for reflective dialogue. ReTuDiS is designed to allow for reflecting tutoring. In order to construct an initial overall tutoring plan, the system uses information in an annotated record of the learner's performance in a comprehension activity concerning a historical text. The initial tutoring plan can be dynamically revised during the tutorial dialogue. ReTuDiS presently has two main strategies for taking instructional decisions and construct the initial tutorial plan.

The tutor informs the learner about how many of the problems were resolved and gives a brief appraisal of the learner's performance. The tutor then selects exemplar problems where the learner's performance was especially poor, which means that there are contradictions within the learner's arguments. For example the learner's position is scientific but his justification is non-scientific. The tutor has at his disposal two strategies to choose from:

- **Strategy 1:** the system selects the factor, which the learner considers as the most important of all the others (for the outbreak of the outbreak of French Revolution). This consideration characterizes learner’s attitude towards comprehension of the world of history and denotes his learning difficulties. In case this is not in accordance with the system the dialogue begins the discussion about this factor.
- **Strategy 2:** the system sorts the learner’s argument characterizations in a list according to decreasing degree of argument completeness. Tutorial dialogue begins with discussion about the factor for which the learner seems to face the less learning difficulties. The system generates the sequence of dialogue-parts for this factor. Then the system prepares the next dialogue-part based on the results of the previous dialogue-part.

In this work strategy 2 is followed.

4.3 Dialogue plans

In order to construct an initial overall tutoring dialogue plan (Table 3), the system uses information stored in the learner model concerning the learner’s performance in a comprehension activity about the historical text. The initial tutoring plan can be dynamically revised during the tutorial dialogue according to the learners’ responses to the dialogue.

<table>
<thead>
<tr>
<th>Table 3: Dialogue Plan</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1 System:</strong> Your answers concerning the ...(factor) indicate that you consider it as ...(comparison) for the French Revolution. Your argument is characterized ...(description). Do you want the system to... or to....? (selection)</td>
</tr>
<tr>
<td><strong>Learner:</strong> I'd like to ...(explanation)</td>
</tr>
<tr>
<td><strong>2 System:</strong> You asked the system to explain. Your answers concerning the ...(factor) consist of your</td>
</tr>
</tbody>
</table>
position and your justification. Your position is that the ...(factor) were...(comparison) for the French Revolution. This is a ...(description) position. Your justification for that position is that the ...(alternative answer). This is a ...(characterization) justification.

Your position about the ...(factor) is ...(contradiction) your justification. That is why your argument is characterized ...(description). What do you intend to do now?... or ... ...(intention)

Learner: I ...(selection) in my position that the ...(factor)...(comparison).

3 System: You ...(decision) in your position. Let consider that the ...(factor) as a reason for the French Revolution didn’t exist. Do you believe that the outbreak of the French revolution would have happened?

Learner: I believe that the outbreak of the French revolution would have ...(selection).

System: But the outbreak of the French revolution has happened. So, what is your logic conclusion?

Learner: The ...(factor)...(comparison)

4 System: Would you like to try to answer again?....(selection)

4.4 Dialogue-parts Library

The dialogue-parts are excerpts of clauses, which are provided by the expert in historical text comprehension. Dialogue-parts are used to construct a dialogue turn between learner and system. The dialogue-parts belong to various types, such as factors, comparisons, descriptions, explanations, intentions, selections, contradictions, suggestions, etc. and are retrieved from the library to fill the dialogue plan, which initialises the dialogue according to the learner model. The Dialogue-parts Library of Table 4, consists of dialogue-parts.

<table>
<thead>
<tr>
<th>Types of dialogue-parts</th>
<th>dialogue-parts</th>
</tr>
</thead>
<tbody>
<tr>
<td>factors</td>
<td>the living conditions of the 3rd class, the heavy winter of 1789, the financial development during the decade 1930-1940, the convergence of the general classes by the king bourgeoisie and 3rd class jointly claim for constitution</td>
</tr>
<tr>
<td>comparisons</td>
<td>the most important reason, important reason, less important reason</td>
</tr>
<tr>
<td>descriptions</td>
<td>scientific, towards-scientific, non-scientific, complete almost complete, intermediate, nearly incomplete, incomplete</td>
</tr>
<tr>
<td>explanations</td>
<td>explain, don’t explain</td>
</tr>
<tr>
<td>intentions</td>
<td>insist, don’t insist</td>
</tr>
<tr>
<td>selections</td>
<td>happened, not happened, yes indeed, no i don’t believe, yes i’d like, no i don’t like</td>
</tr>
<tr>
<td>contradictions</td>
<td>contradictory to, not contradictory to</td>
</tr>
</tbody>
</table>

4.5 Dialogue Tactics

The dialogue is generated in 4 stages each based on the appropriate dialogue tactics (Figure 3). A sequence of dialogue-parts, each based on the results of the previous stage, feeds the dialogue plan and constructs the dialogue.

STAGE 1: The system makes the learner aware of the general framework of the assessment results, that is whether the learner is correct or not and encourages him to take his first decision for participating in discussion. The dialogue-part S1D1 is generated by the system in case the learner wants the system to explain him the differences between his answers and the system concerning an argument. The dialogue-part S1D2 is generated in case the learner does not want the system to explain to him and the dialogue concerning this argument is terminated.
STAGE 2: The system uses qualitative criteria to indicate where the learner has contradiction between his position and his justification. The dialogue-parts S2D1 to S2D5 are generated by the system according to the different combinations of the learner’s responses, which correspond to different degrees of argument completeness and are related to one of the 5 factors in the historical text. When the dialogue-part S2D5 is generated the system responds appreciatively regarding the learner’s abilities and encourages him to return to stage 1 and continue with the next argument.

STAGE 3: The learner’s decision triggers the system to use the appropriate individualized tactics. The dialogue-part S3D1 is generated in case the learner insists in his answer and the S3D2 in case he does not insist, which means that he recognizes his contradiction and changes his reasoning.

STAGE 4: The system discusses and justifies itself and argues with the learner for his contradictions. The appropriate dialogue-parts S4D1, S4D2, S4D3 are generated in case the learner insists in position, in justification or in both respectively. The actions of the system have to be driven towards the aim of eliminating the contradiction. The elimination will only be possible when the learner himself removes the contradiction and so he is able to construct a more coherent argument. At the end, the system encourages the learner to try again to read the historical text and answer the questions so it can have a second chance to reassess the learner. So, the learner is involved in the diagnosis process and is expected to change his model.

4.6 Tutorial Dialogue

The following dialogue example illustrates the interaction concerning question-pair 1. The learner has given non-scientific position and scientific justification, which correspond to answers a1 and b2 of Figure 1 and result in an intermediate argument of the category state. ReTuDiS uses dialogue tactics to support tutorial interactions. For example, in turn 3, the tactics: selection of counterexamples and generation of hypothesis are used. The learner considers the “living conditions of the 3rd class before 1789” as the most important reason. The tutor’s counterexample can be “whenever the living conditions of people are bad do we have a revolution”? The tutor generates the hypothesis that: “if the heavy winter of 1989 did not have happened, would the outbreak of the French Revolution have happened”? in order to make the learner to reason about it.
Table 5: A 4 turns dialogue example concerning an argument

| System: | Your answers concerning the LIVING CONDITIONS indicate that you consider it as THE MOST IMPORTANT REASON for the French Revolution. Your argument is characterized INTERMEDIATE. Do you want the system to EXPLAIN or to CONTINUE? |
| Learner: | EXPLAIN |
| System: | You asked the system to explain. Your answers concerning the LIVING CONDITIONS consist of your position and your justification. Your position is that the LIVING CONDITIONS were THE MOST IMPORTANT REASON for the French Revolution. This is a NON-SCIENTIFIC position. Your justification for that position is that the LIVING CONDITIONS WERE THE SAME FOR MANY YEARS. This is a SCIENTIFIC justification. Your position about the LIVING CONDITIONS is CONTRADICTORY to your justification. That is why your argument is characterized INTERMEDIATE. What do you intend to do now? INSIST or NOT INSIST. |
| Learner: | I INSIST in my position that the LIVING CONDITIONS ARE THE MOST IMPORTANT REASON. |
| System: | You INSIST in your position. Let consider that the LIVING CONDITIONS as a reason for the French Revolution didn’t exist. Do you believe that the outbreak of the French revolution would have happened? |
| Learner: | I believe that the outbreak of the French revolution would have NOT HAPPENED. |
| System: | But the outbreak of the French revolution has happened. So, what is your logic conclusion? |
| Learner: | The LIVING CONDITIONS ARE NOT THE MOST IMPORTANT REASON |
| System: | Would you like to try to answer again? |

5. Formative evaluation

Formative evaluation was conducted as part of the development cycle of the system and with the participation of human experts and was used for further revisions, modifications and improvements [10] [12]. This evaluation focused on indicating problems with dialogue coherence, suitability of dialogue tactics and strategies appropriate for planning effective diagnostic dialogues. The participants were given an explanation about the aims of ReTuDiS and asked to explore a variety of potential situations envisaging the behaviour of a learner who would discuss his domain knowledge with the system. Their comments were recorded and an interview at the end clarified uncovered aspects.

In general, dialogue planning appeared suitable for organising dialogue that meets the requirements of dialogue-based interactive and reflective learning. The dialogue tactics in ReTuDiS were considered adequate in respect to maintaining the local focus of the dialogue. Few problems with the current implementation were identified, e.g. occasionally, repetitions of system’s statements and questions about already made claims occurred. A richer domain knowledge base could lead to higher chances for obtaining adequate dialogue tactics.

6. Conclusions and Future Plans

In this work we presented and evaluated knowledge representation of dialogue generation in ReTuDiS (implemented using Java). Based on the learner model the dialogue generator engages the learners in learning dialogues according to the appropriate dialogue strategies and tactics. The dialogue indicates the contradictions within the learner’s answers and discusses with the learner in order to help him eliminate his contradictions. The dialogue promotes learners’ reflection and helps them to be aware of their reasoning, to construct more coherent arguments and leads them towards scientific thought. The application perspectives of this dialogue-based
interactive and reflective learning environment aim at individualized learning in history, by activating the appropriate dialogue for a learner interactive dialogue with the system. There are educational benefits of the system for the students in changing their reasoning. The evaluation results are encouraging for the system’s educational impact on learners and for future work. In our future plans falls research concerning the application and evaluation of the diagnostic and learning interaction in classroom conditions.

References