A TEAM OF AGENTS FOR THE DIALOGUE ENGINE

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This paper generalize preliminary results obtained in the Internet Delivered Agent Supported Text (IDAST) project being conducted at the Center for Electronic Studying, University of Oregon and at the Dialogue Systems Laboratory, Odessa State Academy of Refrigeration (Ukraine.) Three main topics are discussed: Internet delivered agent supported text documents ideas; dialogue behavior as an environment of knowledge interchange and its ability to maintain the process of logical inference; and, a domain-independent agent-based architecture for a dialogue engine.

INTRODUCTION

The foundation of our theoretical speculations is the supposition that the formation of new knowledge is always found in dialogue. Dialogue behavior can be seen in the forms of:

- a "conversation with myself," where both partners of the dialogue are the same person;
- "discussions" where two persons with the same level of knowledge and ignorance within a certain domain during the dialogue progressively learn more about something mentioned within the domain;
- "knowledge transmission" where during the dialogue knowledge is transmitted from one partner to another.

The cognitive processes enumerated above presuppose the existence of two goal oriented and interacting intelligent partners that are forming a joint cognitive system. Hence the following (often discussed) properties of Intelligent Tutoring Systems (ITS) such as:

- the step-by -step transmission/acquisition of new knowledge;
- accumulation of information of factual knowledge of the student;
- logical inferences regarding the student's cognitive state and knowledge level;
- curriculum management; etc.,

We consider these different aspects of the same phenomenon: dialogue behavior. The Dialogue Engine, described below, is a part of proposed computer environment called the Dialogue Operating Environment intended for the creation, storage, and interpretation of dialogue behavior scenarios. We believe that focusing on dialogue behavior will provide a relatively simple and fast Dialogue Engine that can integrate the functions of a number of architectural components of an ITS such as the: user interface, inference engine, student model, and a curriculum manager.

1. INTERNET DELIVERED AGENT SUPPORTED TEXT DOCUMENTS

All students face challenges as they construct meaning from text. These challenges can derive from encounters with text that is beyond the range of the student's reading skills, or far outside the range of their background experience. Students might be missing or misunderstand key concepts, or be unfamiliar with a technical vocabulary. Students might be reading text written in, what is for them, a foreign language. Still other challenges confront students with disabilities such as dyslexia, hearing impairments or blindness. Students might have limited or inadequate support and guidance in understanding, manipulating, studying, and applying text-based information to the real-world tasks of school and work. Any or all of these can prevent students from understanding text, learning from it, and applying what they read to other tasks.

We propose to help students meet these challenges such as these by creating a new electronic reading and learning environment with three critical characteristics. First, the "plain text" of these electronic documents will be infused with a set of user controlled, "supporting resources" designed to promote comprehension and learning. These resources could include definitions, explanations, alternative presentations, multimedia illustrations and simulations, supplementary or background information, linguistic translations, and tools to enable text retrieval and manipulation. From our research, we know that these types of supporting resources provide readers with alternative pathways to comprehension (e.g., Anderson-Inman & Horney, in press; Horney & Anderson-Inman,1995). Students access these resources through links embedded in the text.

Second, the reading skills, needs, and comprehension of readers will be monitored and evaluated by an agent-based Intelligent Tutoring System and further, that this system can provide specific guidance and instruction to readers on both the content of the document and the skills needed to read the document effectively.

Third, this combination of electronic text, embedded resources and intelligent tutoring system should be delivered to readers via the Internet so they are widely distributed, universally accessible, modifiable, and maintainable.

We call documents which with these specifications Internet Delivered Agent Supported Text (IDAST). We see a variety of tasks for agent-based Intelligent Tutoring System within IDAST documents:

- To monitor and report in detail on reader activities within the document. These reports are critical for the activities of other agents, and are also useful for teachers and for the readers themselves.
- To analyze transcripts of reader activities and construct profiles of characteristic reader behaviors.
- To modify and customize the document and the reading environment to better meet reader needs and expectations.

- To evaluate reader comprehension and make appropriate recommendations it readers and teachers for improving comprehension.

2. STRUCTURAL ELEMENTS OF DIALOGUE BEHAVIOR

This section describes main abstract concepts of dialogue behavior which are invariant to the domain of application of the dialogue scenario method.

First, we must explain that we consider dialogue behavior to be a discrete or step-by-step phenomena. We consider a step to be a "behaviorist molecule" of a dialogue scenario and assume that all scenarios can be created from a finite number of steps. During each step an elementary cycle of partners' knowledge interchange is completed.

2.1 ACTIVE AND PASSIVE PARTNERS

The knowledge interchange within a step presupposes the asymmetry of partners. This means that one of the partners initiates the knowledge interchange and that the second partner responds. Let the partner-initiator of knowledge interchange be called an Active partner and answering partner be called a Passive partner.

The Passive partner is logically dependent on the Active partner. Passive partners are not free in their answers but must return to the Active partner a relevant chunk of knowledge. This is because, in the opposite case, the logic of the dialogue is disturbed and the dialogue process is transformed into two independent monologues.

2.2 Q AND A KNOWLEDGE CHUNKS

Within a dialogue step, the Active and Passive partners transmitted to each other chunks of declarative knowledge. A chunk of declarative knowledge which Active partner is transmitted to the Passive partner has logical structure of a question. A chunk of knowledge that Passive partner returns to the Active partner has the logical structure of an answer. We use the term "logical structure" to allow for cases where questions and/or answers have nonverbal representations.

Let knowledge chunks that have the logical structure of questions and answers be called Q and A-chunk respectively. Results obtained in the Theory of Logic and Answers (Belnap & Steel, 1976) allow us to state that a Q-chunk carries two types of information:

- a fragment of declarative knowledge from which all answers can be formed called the Subject of the question, and
- a specification of the desired answer called the Prerequisite of the question.

The Subject is the "raw material" for the answer. The Passive partner, while generating the answer, does not use all the accessible declarative knowledge ,but only this fragment. The Prerequisite determines what part of the Subject should be in the answer. Consequently, the general logical structure of Q and A-chunks are as follows:

$$\text{Q-chunk} = P,S$$

$$\text{A-chunk} = S$$

Where S , P are the Subject and the Prerequisite of the question respectively.

We will consider that the Subject has a set of slots that hold semantically relative elements and that the Prerequisite is an encoded specification of the answer:

$$\text{Q-chunk} = P,\{Si\}\ \ i=1\ .\ .\ n$$

Where: $\{Si\}\ \ i=1\ .\ .\ n$ set of the Subject slots.

The A-chunk subsequently is a subset of the Subject slots:

$$\text{A-chunk} = \{Si\}\ \ i=1\ .\ .\ m;\quad m<n$$

Let consider two simple verbal examples illustrating the concepts of Subject and Prerequisite.

1. What prime numbers are between ten and twenty?
2. Give an example of prime number between ten and twenty?

Both questions have the same Subject: {11,13,17,19} and but different Prerequisites. The Prerequisite in the first question defines a single answer: "Between ten and twenty there are the following prime numbers: 11,13,17,19." The Prerequisite in the second question defines several answers: "An example of prime number between ten and twenty is: 11"; "An example of prime number between ten and twenty is: 13" and so on.

Every Q-chunk therefore can bear a set of possible A-chunks:

$$\text{A-set} = \{\text{A-chunk}i\}\ \ i=1\ .\ .\ k$$

The Active partner according to his/her goal plans to receive and recognize a more restricted answer than the A-set, set of answers. Let this set be call the Recognizable set of answers, or RA-set. RA-set unites answers that Active partners need at the current step in

accordance to their method. All other answers can be classified as non-recognizable.

The Subject and Prerequisite structure of the Q-chunk given above allow us to discuss the problem of the verbal and nonverbal representation of information within a question. Clearly, at least Subject slots can be represented graphically. As for the Prerequisite, an explanation might have to have a verbal representation, either textual or sound.

To summarize our speculations. We can conclude that the logical structure of each dialogue step is described by means of the following elements:

- step's name,
- Q-chunk's name,
- RA-set,
- set of pointers on next steps for RA-set, and
- next step name for non-recognizable answers.

3. DIALOGUE BEHAVIOR AND REASONING

Dialogue behavior presupposes two levels of reasoning:

- Reasoning within dialogue step; and
- Reasoning that are modeled by a sequence of dialogue steps.

3.1 REASONING WITHIN DIALOGUE STEP

Reasoning within a dialogue step falls into three phases:

- Active partner reasoning while preparing the question and before obtaining the answer;
- Passive partner reasoning while preparing the answer;
- Active partner reasoning after obtaining the answer.

The logical dependence of the Passive partner on the Active can be controlled by Active partner's goal-oriented design of Q-chunk structural elements. The Active partner can consider a question, as "psychological sensor" placed into the Passive partner's mind with the aim of obtaining the needed knowledge chunk. Knowledge fragment where "psychological sensor" is placed is defined by the Subject of the question and by how the Prerequisite specifies (and therefore restricts) the information which is transmitted into the answer.

A simplified view of the reasoning of the Active partner while preparing the question is as follows: "To continue the current dialogue method (it might be the process of problem solving or the process of teaching or the process of reasoning or the process of speculation), I need a chunk of knowledge from my partner. My guess is that needed chunk of knowledge is in the Subject. My partner can prepare that chunk of knowledge from the given

Subject within the limits that are determined by the Prerequisite."

Passive partner reasoning while preparing the answer is the logic of extracting or selection. Passive partner is forming the answer from the Subject with accordance to the Prerequisite limits by means of extracting or selecting an answer.

After obtaining the answer, the Active partner should decide what A-chunk he/she has to "induce" in Passive partner by means of the next question to continue the current dialogue method. Hence, after obtaining the answer, the Active partner should prepare/choose next step according to the dialogue method logic.

3.2 .MULTI-STEP DIALOGUE REASONING

Let the knowledge base, which stores a dialogue behavior description in the form of a set of steps' descriptions be called the Dialogue Knowledge Base (DiKB.) The DiKB stores procedural knowledge of the Active partner's method. A multi-step dialogue process causes two knowledge streams (coming from the opposite directions) to be combined with logical inference. Combination of dialogue and reasoning processes is not new idea. Messier Dillenbourg (Dillenbourg, 1996) give an example of dialogue where simultaneous with knowledge interchange, partners have realized a reasoning process. Therefore, from the logical inference point of view, the DiKB can be considered as a finite collection of the Active partner's hypothesis regarding the Passive partner's knowledge. Each hypothesis is equal to a certain chain of steps within DiKB and can be described by means of an equal production rule.

Hence, the dialogue process can be considered as a permanent process of proving a sequence of the Active partner's hypothesis about the Passive partner's knowledge, and therefore as a process of evaluating the Passive partner's knowledge by means of a deductive process of logical inference.

4. MULTI-AGENT ARCHITECTURE OF A DIALOGUE ENGINE

This section contains a brief description of a multi-agent architecture for a Dialogue Engine which is able to interpret a stored dialogue behavior, and which can be considered as a part of mentioned above Dialogue Operating Environment.

We understand the concepts of "agent" in the sense offered by Marvin Minsky (Minsky, 1988), as any part or process of the mind that, by itself, is simple enough to understand - even though the interactions among team of such agents may produce phenomena that are much harder to understand. We describe a Dialogue Operating Environment, which can generate and interpret intelligent behavior, by means of cooperative behavior of a team of non-intelligent agents.

Thus, each agent ,at every dialogue step, demonstrates a specific behavior, which is defined by its internal structure and state of the Dialogue Engine's internal and external world. The

world external to the Dialogue Engine is the knowledge of the opposite dialogue partner and world internal to the Dialogue Engine is the "frozen" dialogue behavior mainly stored in DiKB.

The proposed Dialogue Engine is designed to process any step and behavior of each agent from the team, as defined by the dialogue process logic, but not the "logic" of the domain of dialogue method application. All peculiarities of the domain are stored in the internal world descriptions. Agents act asynchronously, extremely sequentially, and cyclically to transmit their activity from one to another.

Thus the combination of dialogue and inference processes is attained not by means of parallel and simultaneous work of a few agents, but included in dialogue behavior scenario and is depicted in DiKB structure.

Figure 1 depicts Dialogue Engine structure of four agents:

- Presentation agent (Pr-agent);
- Perceptional agent (Per-agent);
- Analyzing agent (An-agent); and
- Step agent (S-agent).

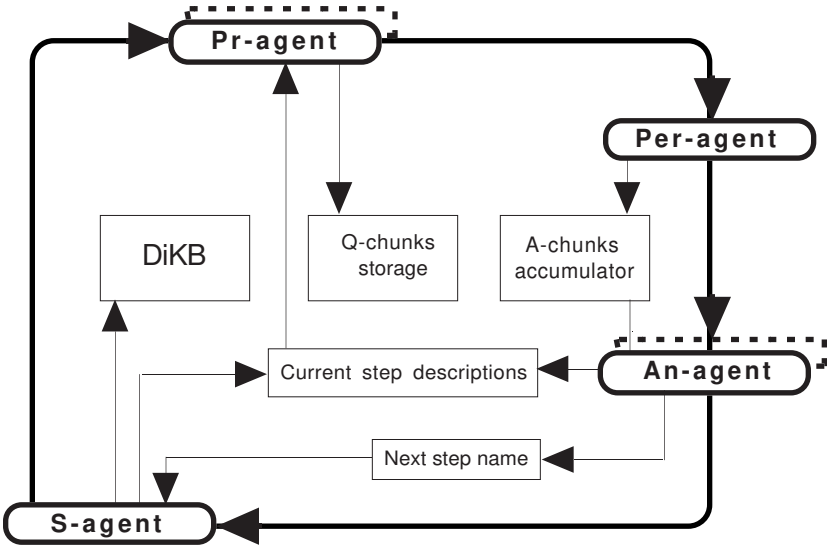

Figure 1. Agent-based architecture of Dialogue Engine.

The agents in Figure 1 are placed in cyclical order, which determine their activation. All components of the Dialogue Engine's internal world are placed inside the cycle.

Pr-agent behavior

The Pr-agent presents a Q-chunk to the Passive partner of the dialogue. In IDAST documents for instance, the Q-chunk can correspond to a question that is designed to obtaining facts in order to draw a conclusions about the degree of readers comprehension of the

document.

Pr-agent interaction with external and internal worlds: The interaction with external world is unidirectional, from the Pr-agent to the Passive partner. The interaction with internal world is as follows. From the memory unit that stores descriptions of the current step the Pr-agent reads the Q-chunk name and then reads all that is needed for the presentation of the Q-chunk's descriptions from the Q-chunks storage.

Per-agent behavior

The Per-agent perceives A-chunks from the Passive partner and accumulates them in the A-chunks accumulator. Thus, the A-chunks accumulator stores the dialogue behavior history and/or a dialogue behavior protocol.

Per-agent interaction with external and internal worlds: The interaction with external world is unidirectional, from the Passive partner to the Per-agent. The Passive partner's answers are perceived and encoded by a standard computer peripheral device. Interaction with internal world is as follows. The A-chunks are stores in an accumulator.

An-agent behavior

The An-agent recognizes a perceived A-chunk by means of a sequential comparison with RA-set elements and defines next step name.

An-agent interaction with external and internal worlds: The An-agent does not interact with external world. Its interaction with internal world is as follows. The An-agent reads an A-chunk from the accumulator and an RA-set from the memory unit that stores descriptions of current step. Then, the Defined name of the next step is placed into the memory of next step name.

S-agent behavior

The S-agent renews the current step descriptions. S-agent interaction with external and internal worlds: The S-agent does not interact with the external world. Its interaction with internal world is as follows. The S-agent reads the next step name from the memory and then its descriptions from the DiKB. the next step descriptions is placed to its memory.

The Dialogue Engine structure described above presupposes a certain standard of dialogue behavior scenario descriptions. For example, a Q-chunk can be assembled only from Dialogue Operating Environment objects. Next step names are defined uniquely after an A-chunk has been recognized and stored in the current step descriptions. Moreover, the Dialogue Engine can not calculate. To enhance mentioned standard we presuppose the ability of break the cycle on Figure 1 at two points: during Pr-agent functioning and during An-agent functioning. The necessity for cycle breaking plans in step descriptions. A cycle break causes control to be transferring to the procedure called Demon-procedure (on Figure 1 Demon-procedure are shown by means of the dotted lines.) Demon-procedures

service all additional to the standard dialogue method functions.

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