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LEXICAL USAGE IN THE TUTORING SCHEMATA OF CIRCSIM-TUTOR: ANALYSIS OF VARIABLE REFERENCES AND DISCOURSE MARKERS*

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ABSTRACT

CIRCSIM-Tutor, which attempts to imitate human dialogue, generates comprehensible but stilted conversation. We believe that by doing a better job of lexical selection, we can generate more natural, fluent dialogue. This paper develops a new method of lexical analysis that allows the researcher to visualize lexical research, which is not only useful in the CIRCSIM-Tutor domain, but also applicable to other schema-based text generation systems. We present lexical rules for variable references and discourse markers that can be used to improve the dialogue generated by our computer tutor.

INTRODUCTION

CIRCSIM-Tutor is an intelligent tutoring system that uses natural language dialogue. It makes statements and asks questions in English and the student responds in kind. In this paper we explore some of the lexical choices CIRCSIM-Tutor can make to produce more natural, fluent dialogue. We are particularly interested in choices that are affected by the structure of the tutorial plans. To this end we have examined human-tutorial dialogues teaching the same topics as the computer tutor. We marked up the tutorial structure in these dialogues, then tabulated instances of pronoun and discourse marker usage within the tutorial contexts in which they occur. From this analysis we derived rules that we can use in the computer tutor.

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THE CIRCSIM-TUTOR CONTEXT

CIRCSIM-Tutor tutors medical students on the baroreceptor reflex in the domain of cardiovascular physiology. The baroreceptor reflex attempts to regulate the blood pressure in the human body after a perturbation. The student is presented with a hypothetical perturbation and then is asked to predict the qualitative changes in seven physiological variables at three stages. The tutorial dialogues largely consist of segments devoted to single variables and their relationships with other variables. The tutor introduces a variable for discussion, and the tutor and the student discuss it until the student produces a correct prediction.

One of the important research resources in the CIRCSIM-Tutor project is a set of fifty transcripts of keyboard-to-keyboard tutorial dialogues carried out by professors of physiology and their students. These transcripts consist of more than 5000 dialogue turns. Most of the previous research in this project is based on the study and analysis of those transcripts. Freedman [1996] and Kim et al. [1998a, 1998b] analyzed these transcripts and came up with a structured description of the observed tutorial dialogue, which is the basis of tutorial and discourse planing in the computer tutor.

In the computer tutor, the ultimate result of tutorial dialogue planning is a sequence of informing and eliciting dialogue acts, for example, an acknowledgement of the student's answer followed by some additional information followed by the introduction by a new topic followed by a question [Freedman 1996]. In version 2 of CIRCSIM-Tutor the sentences are generated and output one at a time. Version 3 has a turn planner that produces much more coherent turns.

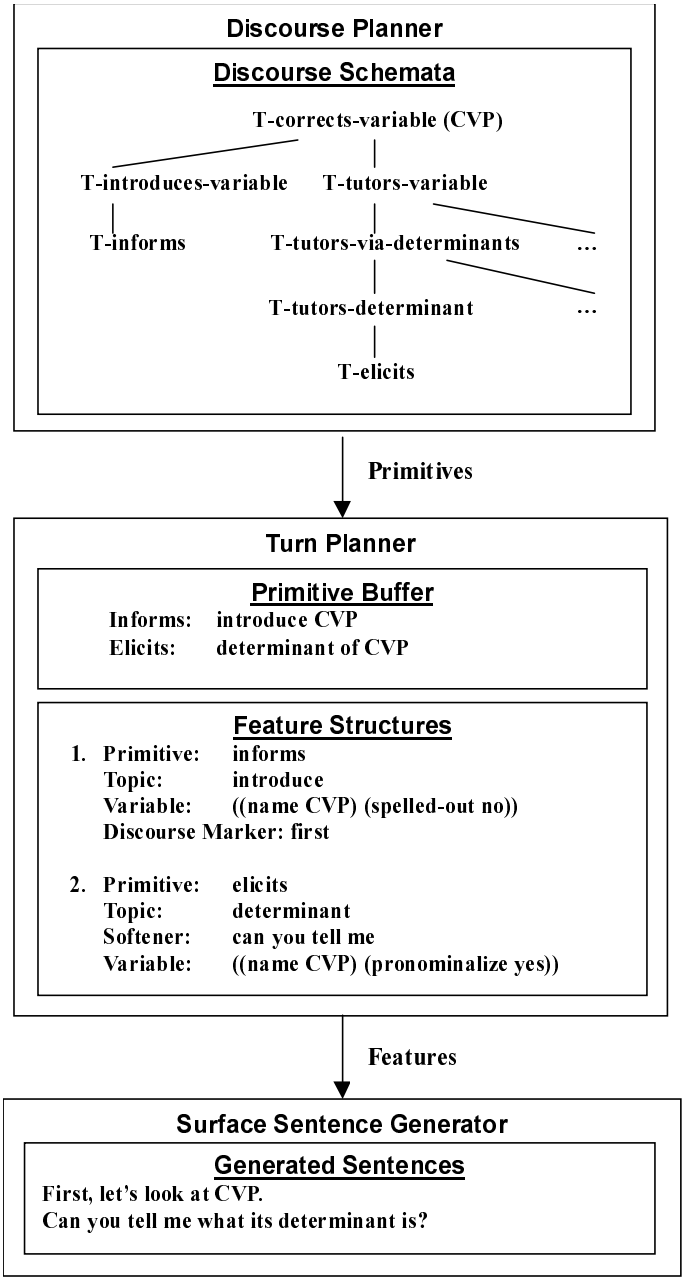

Figure 1. Generating a Tutorial Turn

The turn planner collects all the tutorial primitives within a turn from the discourse planner and selects the related lexical items. It then passes these features to the surface sentence generator for sentence generation. This process is illustrated in Figure 1 [Yang et al. 2000]. The purpose of this paper is to describe the lexical selection inside the turn planner.

PREVIOUS RELATED RESEARCH

Several methods have been proposed for investigating lexical selection in the local discourse context. We have chosen to explore lexical issues in contextual discourse by marking up the corpus of tutoring transcripts. By investigating the relationship between reference and segmentation, Passonneau [1994] designed a protocol for coding discourse referential noun phrases and their antecedents. Other researchers such as [Nakatani et al. 1995], [Allen and Core 1997] and [Nakatani and Traum 1998] also provide methods for annotating discourse issues.

Another useful way of dealing with lexical issues is applying global discourse structure such as the history list. Based on the history list we can explore anaphoric reference, ellipsis, VP anaphora, etc.

This research is mostly motivated by Passonneau's protocol, especially for the problem of finding the inference relationship between different discourse segments. Another useful idea comes from [Allen and Core 1997], the draft of DAMSL, which uses a backward looking function to capture how the current utterance relates to its antecedent. We are analyzing the semantic relationships among the tutoring schemata to look at the special phenomena of lexical usage in the CIRCSIM-Tutor domain.

METHOD OF ANALYSIS

Some previous studies of our keyboard-to-keyboard transcripts have concentrated on the syntactic structure [Seu et al. 1991], or the pedagogical goals [Freedman 1996 and Kim et al. 1998a]. Based on the theories of [Freedman 1996], Kim et al. [1998b] marked up a portion of the transcripts which include more than 270 turns, producing a set of hierarchical tutoring schemata which are now used as plan operators in CIRCSIM-Tutor V3.0.

HIERARCHICAL TUTORING SCHEMATA

To be compatible with the representation of our new method of lexical analysis, the original tutoring schemata of CIRCSIM-Tutor [Kim et al. 1998b] are tabulated as shown in Table 1. The abstract level schema named **T-tutors-procedure** is used for teaching each predefined perturbation. Each perturbation is then divided into three stages; the schemata for these stages are designated **T-tutors-stage**. In each stage, the tutor carries on a remedial dialogue about any wrong prediction the student has made. The schemata at this level are named **T-corrects-variable**. The tutoring of each variable can be further expanded to several alternative methods, which are named **T-does-neural-DLR**, **T-tutors-via-determinants**, etc. Again, each method consists of one or more topics, which are

designated **T-tutors-mechanism**, **T-tutors-DR-info**, etc., and each topic consists of primitive dialogue acts, which are designated as **T-elicits** or **T-informs**.

PRESENTATION OF LEXICAL USAGE FOR VISUALIZATION

This research begins by visualizing the hierarchical tutoring schemata as tables and then maps the lexical items of interest onto those tables according to their original positions in the schemata. Table 2 shows an example from one human tutoring session involving the physiological variable TPR.

In Table 2, we have used typography to indicate the lexical features that interest us. The variable "TPR" is marked, along with the anaphoric references to it. The discourse markers "so" and "now" are marked as well.

The purpose of this tabular form is to gather together all the instances of these phenomena, showing the contexts in which they occur. We look at two types of context: the surrounding text and the position within the tutorial dialogue schema. Ultimately we want to find rules governing when CIRCSIM-Tutor can generate these phenomena in its own tutorial dialogue.

RESULTS AND DISCUSSION

Using the method explained previously, we developed lexical rules for variable references and discourse makers.

LEXICAL RULES FOR VARIABLE REFERENCES

One phenomenon we want to describe is the realization of references to physiological variables: as the name itself (e.g., "Total Peripheral Resistance, the standard abbreviation TPR"), as a pronoun (e.g., "it"), or as a definite description (e.g., "the last variable you predicted").

There are several contexts in which explicitly naming the variable is always permissible.

1) When introducing a variable prior to tutoring it (**T-introduces-variable**).

2) Within the first topic of teaching that variable.

3) Within the last topic, when the tutor is eliciting the correct answer after tutoring.

Here is an attested example illustrating all these rules.

Ex: T: Ok, let's get to your question about *TPR* then. (**T-introducing variable**) How is *TPR* controlled? (**first topic**)
S: …
T: Now what do you say about *TPR*? (**final topic**)
S: zero.
T: Right.

Table 1. The Tutoring Schemata

<table>
<tr><td colspan="6">T-tutors-procedure</td></tr>
<tr><td colspan="5">T-tutors-stage</td><td rowspan="4">…</td></tr>
<tr><td>T-introduces-stage</td><td colspan="3">T-corrects-variable</td><td>T-concludes-stage</td></tr>
<tr><td rowspan="3">T-informs</td><td>T-introduces-variable</td><td colspan="2">T-tutors-variable</td><td rowspan="3">T-informs</td></tr>
<tr><td>T-informs</td><td colspan="2">T-does-neural-DLR</td></tr>
<tr><td></td><td>T-tutors-mechanism
T-elicits</td><td>…</td></tr>
</table>

Table 2. Example of Tutoring TPR

<table>
<tr><td rowspan="5"></td><td colspan="4">T-corrects-variable var=TPR</td></tr>
<tr><td>T-introduces-variable</td><td colspan="3">T-tutors-variable</td></tr>
<tr><td rowspan="3">T-informs</td><td colspan="3">T-does-neural-DLR</td></tr>
<tr><td>T-tutors-mechanism</td><td>T-tutors-DR-info</td><td>T-tutors-value</td></tr>
<tr><td>T-elicits</td><td>T-informs</td><td>T-elicits</td></tr>
<tr><td>K12</td><td>T: ***Now*** how about **TPR**?
S: …</td><td>T: By what mechanism will **it** increase?
S: …</td><td>…</td><td>T: ***So*** what do you think about **TPR *now***?
S: …</td></tr>
</table>

Pronominalization of variable names can occur as in ordinary English text. For example, in the first topic after a variable is introduced, a pronoun frequently occurs even though the name itself is acceptable.

Ex: T: Now how about *TPR*? (**introducing variable**)
T: By what mechanism will *it* increase? (**first topic**)
S: …

There are some contexts where use of the pronoun seems to be prohibited. The last topic in the tutoring of variable, where the answer is elicited is such a context. The tutor will use the name of the variable or a definite description but rarely a pronoun.

Ex: T: Can you tell me how TPR is controlled?
S: …
T: And the predictions that you are making are for the period before any neural changes take place.
T: So what about *TPR*? (**last topic**)
S: …

A similar case occurs when a variable is introduced for tutoring, a simple, bare, pronoun will not be used even if the variable was just previously mentioned.

Ex: T: Next and last?
S: TPR increases.
T: Ok, let's take a look at your predictions. Take *the last one* first. (**introducing variable**) Can you tell me how TPR is controlled?
S: …

In this example the variable TPR ends a prior discussion. Immediately afterward it is introduced for tutoring, by means of a definite description.

LEXICAL RULES FOR DISCOURSE MARKERS

In CIRCSIM-Tutor, the primitive dialogue acts of our tutorial schemata frequently correspond to individual utterances. Two adjacent tutorial utterances, however, are not necessarily closely related. For example, a sentence closing one topic can be followed by one opening the next topic. In order to produce fluent text, it is desirable to introduce discourse markers to show how sentences relate to the rest of the dialogue. Here we describe some rules we have observed for deciding what discourse markers to insert along with the contexts in which they occur.

Rule 1: "Now" can be used in **T-introduces-variable** to shift focus to a new idea. This is similar to behavior observed by Schiffrin [1987, p261]

Ex: T: *Now* let me ask you, are there any other of these variables that primarily under neural control? (**T-introduces-variable**)

Rule 2: "So" can be used to conclude **T-tutors-variable**, in the sense of marking results [Schiffrin 1987, Ch. 7].

Ex: T: *So* what about TPR? (**T-tutors-value**)

Rule 3: The first topic related to the first variable being tutored is marked with "first."

Ex: T: *First*, what parameter determines the value of RAP? (**The first topic related to the first variable**)

Rule 4: When tutoring using a contradiction, "but" often marks the **T-presents-contradiction** topic.

Ex: T: You predicted that it would go up (**T-presents-contradiction**)
…
T: *But* remember that we're dealing with the period before there can be any neural changes.

Rule 5: "Therefore" can mark the final topic of an excursion into a detailed explanation, a schema called **T-tutors-via-deeper-concepts**.

Ex: T: If I have a single blood vessel, what parameter most strongly determines its resistance to flow (**T-tutors-via-deeper-concepts**)
…
T: And physiologically, what determines the diameter of the blood vessels?
…
T: *Therefore*, what determines TPR?

CONCLUSION AND FUTURE WORK

This method works very well for selecting lexical phenomena that are closely related to the tutoring schemata, such as variable references and discourse markers. However, we still have other phenomena to explore. Among the lexical selections that interest us are:

1) Form of the tutor's acknowledgment of the student's answer, [Brandle, 1997]
2) Insertion of "softeners," politeness locutions such as "can you tell me" and "do you know" [Kim et al., 1998a],
3) Choice of verb phrases for qualitative change [Ramachandran, 1994]

Our studies indicated these choices are less explained by tutoring schemata, meaning we will have to find other criteria for deriving rules. We need more methods, such as user driven lexical choice [Ramachandran 1994] and machine learning and corpus-based statistical knowledge to complete this work. Ultimately, we want to improve our computer tutor to generate more natural and fluent dialogue. The following example is an illustration of our desired improvements.

Dialogue from the current CIRCSIM-Tutor:

T1: By what mechanism is Inotropic State controlled?
S2: nervous system
T3: Correct, Inotropic State is controlled by the nervous system. What is the value of Inotropic State in DR?
S4: decreased
T5: Nope, the value of Inotropic State is not decreased in DR. Remember. Inotropic state is neurally controlled. What is the value of Inotropic State in DR?
S6: not changed
T7: Correct, the value of Inotropic State is unchanged in DR. Please change the value of 'IS' in the prediction table.

The same dialogue after choosing better variable references, inserting softeners and discourse markers, and picking briefer acknowledgments:

T1: Can you tell me by what mechanism Inotropic State is controlled?
S2: nervous system
T3: Right. So, what is the value of IS in DR?
S4: decreased
T5: No, it is not decreased in DR. Remember, it is neurally controlled. Now, what is the value of IS in DR?
S6: not changed
T7: Very good. Please change the value of IS in the prediction table.

None of these changes affect the meaning of the dialogue, but in our opinion they do make it more natural.

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