The Use of Analogies in Human Tutoring Dialogues

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Abstract

This paper discusses the use of analogies in human tutoring dialogues. Our long-term goal is to implement analogies in the CIRCSIM-Tutor system, an intelligent tutoring system that carries on a natural language dialogue with the student. We need to analyze human tutoring strategies that make use of analogies and the language that supports these strategies, so that our system can propose analogies to students and follow them up appropriately. The system needs to be capable of recognizing student misunderstandings and remedying them. All this will require the use of a computational model of analogy, which may eventually allow our system to recognize analogies proposed by students as well.

Introduction

It is well known that human instructors use analogies to explain new concepts to students (Goldblum 2001; Holyoak and Thagard 1995; Holyoak, Gentner, and Kokinov 2001). We decided that it was time to add analogies to the dialogue generated by our intelligent tutoring system, CIRCSIM-Tutor (Michael et al. to appear). There has been a recent spurt of interest in cognitive models of analogies (Gentner 1998, Holyoak, Gentner, and Kokinov 2001), which provide new computational tools for this enterprise. We have chosen the MAC/FAC model of Forbus and Gentner as the basis of our attempt to generate analogies, because it seems to fit the analogies that we have found in human tutoring sessions closely (Forbus, Gentner, and Law 1995, Gentner and Markman 1997). When we began to study human tutoring sessions carefully, we found that students propose analogies as well. MAC/FAC has the additional advantage that it might allow us to recognize student analogies some day.

Several authors of ITS have discussed the importance of supplying analogies to deepen student understanding of the material, but they have depended on template generation to
implement their ideas. Woolf (1984) argues for the importance of analogy as a tutoring strategy in the Meno system, but her natural language generation was entirely template driven. Winkels and Breuker (1990) discuss a shell that can be "filled in" with domain knowledge for the task at hand, including the generation of analogies, but their discourse planner also uses a template style of generation. Neither of these papers discusses how to follow up on an analogy if the student does not respond as hoped. Nor do they discuss how tutors explain the application of their analogies in a way that increases learning and decreases the likelihood of misconceptions (Feltovich, Spiro, and Coulson 1989). We believe that template-based generation cannot support these activities adequately and that they require schema-based generation.

In this paper we give a brief description Gentner's work and the MAC/FAC model. We show how it applies to the analysis of human tutoring sessions, formulate some of the schemas that we have observed, and show how they can be used in generation within the CIRCSIM-Tutor framework.

MAC/FAC

MAC/FAC (Many Are Called/Few Are Chosen) functions as a two step process (Forbus, Gentner, and Law 1995, Gentner and Markman 1997). The first part of the two-stage process, the MAC stage, is designed to be "cheap and inefficient." Memory is comprised of structural representations of current knowledge. "Content vectors" are constructed for each one of these structural representations and for the target. Many items are retrieved, but only the best one and ones within 10% of the best are outputted and used for the input of stage two. The MAC phase scans working memory, in a parallel fashion, seeking vectors that are similar to the target's vectors, and utilizes the predicate calculus to compute the dot products between content vectors for the base and the target. Stage two is the FAC stage. It utilizes a structure-mapping engine (SME) that takes its input from MAC. It does the structure-mapping described in Gentner (1983) between the target and the base and selects the best mapping and all those within 10% of it. Our goal is to use MAC/FAC when simulating the human use of analogy in CIRCSIM-Tutor.

Analogies in Human Tutoring Sessions

It is known that human instructors use analogies to explain new concepts to students (Holyoak and Thagard 1995; Goldblum 2001; Holyoak, Gentner, and Kokinov 2001). In order to evaluate the use of analogies in human tutoring, we analyzed a number of sessions conducted by two experts, Joel Michael and Allen Rovick, Professors of Physiology at Rush Medical College. The topic was the baroreceptor reflex that controls blood pressure in the cardiovascular system. The human sessions were marked

up, by hand, using an annotation language based on SGML and described in "Annotation of Tutorial Goals for Natural Language Generation" (Kim et al. 2002). Complete transcripts of the sessions are available by request. The sessions were conducted face-to-face (and then transcribed) and keyboard-to-keyboard using the software program called CDS, or Computer Dialogue System, which allows each person—student and tutor—to type one at a time (Li et al. 1992). We use two examples to illustrate some important points about analogies in human tutoring sessions.

Examples

Example 1. An example of analogical use to explain new material appears in this face-to-face session. The student (st) makes an analogy by comparing the heart to a sink. This analogy does not meet Holyoak and Thagard's (1995) structure constraint—the sink is not distensible and the heart is. The tutor (tu) advises the student to pick a more suitable analogy.

F1-st-62-1: If I make an analogy of you try to fill a sink with water and you...
F1-tu-63-1: Try to fill a balloon with water, since that's what we're dealing with, a distensible object.
F1-st-64-1: OK.

The session continues with the tutor guiding the student to making the appropriate, or analogical, structure-mapping—process as described in Holyoak and Thagard (1995) and Gentner (1983)—between the balloon and the heart:

Structure (legs) for the balloon
- fill a balloon with water
- it will distend
- the pressure in the balloon increases as it distends

Structure (legs) for the heart
- fill the right atrium
- the right atrium will distend
- pressure will increase as it distends

Making a one-to-one mapping between the relationships present in the two scenarios provided the student with a familiar situation to "connect new knowledge to knowledge already possessed," thereby increasing understanding of the new knowledge (Goldblum 2001; Holyoak and Thagard 1995; Gentner 1983, 1998).

Example 2. An example of a tutor prompting the student to make an analogy appears in many keyboard-to-keyboard sessions. In the following example, the tutor has managed to get the student to make correct predictions for one neural variable and is prompting the student to make an analogy between it and other neurally controlled variables. After discussing how a neurally controlled variable (TPR) behaves in the DR period, the tutor requests that the student identify another neurally controlled variable. He then invites the student to infer from the analogy that the other variable will behave in the same manner during this time period. The student makes the correct inference.

K1-tu-30-2: What other variables are neurally controlled?
K1-st-31-1: CC, HR
K1-tu-32-1: Again correct.
K1-tu-32-2: Now we know that in this guy HR is under the control of the artificial pacemaker.
K1-tu-32-3: But what would happen toCC?
K1-st-33-1: CC 0
K1-tu-34-1: Right on!

Schemas for the Generation of Analogies

Once a topic has been chosen by the lesson planner, the system decides which schemas to use when developing the topic. Analogy schemas are used when the discourse planner decides to propose an analogy.

Tutor proposes an analogy
Tutor attempt to discover if analogy is understood
Tutor prompts student to make an inference to determine understanding
or Tutor asks for a relationship

This schema occurred in Example 2, line **K1-tu-32-3** above. The tutor is asking the student for an inference, resulting in a correct inference made by the student. This sequence happens most of the time and the tutor moves to the next topic. The tutor explains the analogy only when correcting student misunderstandings, as follows:

Decide to explain the analogy
Map the legs of the analogs
Map the relationships
Tutor prompts student to make an inference to determine understanding

The tutor questions the student or requests an inference to determine understanding. Expert tutors try to avoid explaining things. First, they ask questions; they give explanations only if the student still fails to understand. In the first example, the tutor recognizes an analogy proposed by the student as being inappropriate and proceeds to correct that misunderstanding. In other examples of analogies, tutors attempt to avoid inaccurate application of analogies resulting in the misconceptions

mentioned by Feltovich, Spiro, and Coulson (1989). The following schema provides corrections if necessary:

Recognize an analogy
- Map the legs of the analogs
- Map the relationships
- Determine student understanding
- Correct if necessary

Conclusion

Advances in the study of analogies and progress in discourse planning have provided a solid foundation to build an electronic tutoring system that uses natural language to model the human use of analogies in tutoring systems. This will involve trying to develop a methodology for implementing analogical thinking in CIRCSIM-Tutor using MAC/FAC. Our goals are to further study human sessions, analyze the human tutors' use of analogy, and model their behavior in CIRCSIM-Tutor. Computational issues that need to be addressed are when to provide an analogy and how to interpret student responses and correct misunderstandings.

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