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CONVERSATION ASSISTED LEARNING: THE SAVANT 3 DIALOG MODULE

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Summary

The SAVANT 3 system has been designed to help engineering students of Telecom Paris learn new concepts by themselves. The original feature of this system lies in its dialog module which tries to sustain "natural" conversations with the student. The two main objectives pursued are acceptability (by the student) and simplicity (for the author). The imitation of mechanisms occurring in spontaneous conversation allowed us to approach these two goals.

1 A SAVANT 3 DIALOG

Let us consider the following two excerpts which illustrate the kind of interaction that can occur between student and machine. The student had just received some definitions about filters, and had to speak about the suspension of her/his own car.

excerpt 1

S3- If you consider your suspension as a filter, what kind of filter is it?
St- *high-pass*
S3- It's surprising, if we consider that the system is transparent at very low frequencies!
St- *It is not transparent at low frequencies*
S3- So now you consider that the car doesn't follow the smooth variations in the level of the road!
St- . . .

The student's answer ("high-pass") cannot be considered as correct. However the machine is able to argue instead of merely refusing the answer. In excerpt 2 we see that a possibly correct answer is not simply accepted, but must be well-argued, this time by the student.

excerpt 2

S3- If you consider your suspension as a filter, what kind of filter is it?
St- *it's a band-pass filter*

S3- I presume your suspension is not completely satisfactory...
St- *no*
S3- And then...
St- *My shocks are worn out*
S3- Maybe your suspension may enter into resonance
St- *yes*
S3- okay

Two points are worth noting here. First the central role played by logical argumentation. As will be illustrated below, teaching concepts cannot be limited to the display of definitions or to simple exercises. The second point here is that the author has not to bother about the linking of replies. Both excerpts were conducted by SAVANT 3 using the same knowledge base (and many other conversations may have occurred with different students) and this knowledge is very limited on every topic (less than 4 kO text here). Argumentation appears thus as pedagogically useful, and technically implementable and efficient, as we will see. But we will first comment on the natural aspect of argumentation, which makes us hope that such dialogs will be well accepted by students.

2 THE NATURAL CONVERSATION PARADIGM

The idea of copying the logic of spontaneous conversation comes from the observation that concepts may be learned when conversing with friends (i.e. people with equal status). Let us consider the following real excerpt (original in French):

excerpt 3

A1- Now, getting older, I can swim long-distance, but when it comes to sprinting...
B1- *Normal.*
A2- I do better in long-distance than before. Crazy, isn't it ?
B2- *Normal. Normal. But it's normal. One acquires more endurance while loosing resistance . Getting older.*
C1- What's the difference ?
. . . .

During the remainder of the conversation A and C learn from B the difference between resistance and endurance. What is of crucial interest here for our purpose is to notice that the new concept is not mentioned out of context, but in the very specific frame of a logical problem. A2 formulates a paradox:

∀ Person; ∀ Sport_discipline;
older(Person) ==> not better_in(Person,Sport_discipline)
∃ A; ∃ Long_distance_swimming;

older(A) & better_in(A,Long_distance_swimming)

These two logical formulas are contradictory, and this is the paradox. The first formula belongs to the implicit context, and the second one is expressed through A1 and A2. We can express the effect of B2 on the implicit context in the following way:

∀Person; ∀Sport_discipline;
[older(Person) & not endurance(Sport_discipline)] ==>
not better_in(Person,Sport_discipline)

A's paradox no longer applies. We could have expressed this of course differently, but anyway we could not bypass the logical nature of the exchange and the presence of the logical paradox. The SAVANT 3 dialog module takes advantage of this observation.

3 MOTIVATING THE STUDENT WITH PARADOXES

As shown in (Dessalles 1985, 1990b) spontaneous conversations start in a very specific way: either with an improbable fact, or an (un)desirable fact, or a paradox. That is why SAVANT 3 tries to do the same (actually only paradoxes have been exploited until now). In excerpt 1 for instance, SAVANT 3 could establish a paradox by its second reply: a high-pass filter cannot be transparent at very low frequencies! The hope underlying this way of initiating dialogs is that the student perceives the paradox and is thus motivated to correct it, either because of the uncomfortable feeling about an inconsistency in her/his own knowledge, or because of the pleasure found in providing a solution to the machine's own puzzle (actually SAVANT 3 is able to feign surprise when a paradox is only partially verified). Finding out a paradox to be amazed at is not a problem for SAVANT 3 since its knowledge is structured as a set of paradoxes. If we think of logical knowledge as expressed by disjunctive clauses:

. . . .
T ==> (p_1 or not p_2 or not p_3 or p_4)
. . . .

then it is equivalent, but much more natural from a conversational point of view, to represent this knowledge as a set of paradoxical clauses:

. . . .
(not p_1 & p_2 & p_3 & not p_4) ==> **F**
. . . .

(here **T** and **F** stand for an ever true and an ever false proposition respectively). For instance in excerpts 1 and 2, SAVANT 3 relies on knowledge containing the following paradox:

(suspension_is_a_high_pass_filter & suspension_transparent_low_frequencies) ==> **F**

This representation of knowledge permits us to easily describe the strategy followed by SAVANT 3.

4 THE SAVANT 3 DIALOG MANAGEMENT

In its current implementation, SAVANT 3 has a straightforward form of behavior. In order to form its first utterance, and after each student's reply, it looks for an unbroken paradoxical clause, i.e. a clause having all its terms either true or unknown. The program works in an open world, and the truth value of most terms are deduced from the student's replies. If, at a given stage, a paradoxical clause appears saturated (all its terms being known as true), then SAVANT 3 utters a protest and the student is invited to change one of the terms forming the paradox, first in an open way, and finally, if necessary, in a closed choice (the student always has the possibility of having the last word and of expressing her/his disagreement with the author).

But most of the time no paradoxical clause is saturated and the program chooses an unbroken one (actually it chooses the clause with the highest percentage of known terms). If only one term remains unknown, it utters feigned surprise, giving the student some opportunity to "win" by invalidating the last term. For instance if p_1, p_2 and p_3 are known to be true in the following clause:

$$(p_1 \ \& \ p_2 \ \& \ p_3 \ \& \ p_4) \ ==> \ \mathbf{F}$$

and if p_4 is still unknown, then SAVANT 3 pretends to believe that the paradox

$$(p_1 \ \& \ p_2 \ \& \ p_3) \ ==> \ \mathbf{F}$$

exists in its knowledge and is saturated, and the student may then utter something like (not p_4), as in the following excerpt where filtering pulses plays the role of p_4.

excerpt 4

. . .
S3- How do you propose to eliminate ISI ?
St- *[ ]*
S3- Can we, for instance, change the pulse shape ?
St- *yes*
S3- But you change the transmitter parameters !
St- *no, we can filter the pulses just ahead of the receiver*
S3- OK.

In short, SAVANT 3 continuously attempts to trap the student in a paradox, trying another one if the current paradox becomes invalidated. But since the same strategy has been observed in natural conversation, we hope that the student will not experience it as a kind of chase, but will simply perceive the machine's replies as

relevant.
This simple mechanism allows SAVANT 3 to sustain different conversations with different students. But does it need a big logical knowledge base like operational expert systems?

5 THE TRANSPOSITION CHALLENGE

Most ICAL systems are not fully operational because developing two courses in unrelated topics represents almost twice the work necessary for one course. This is the transposition problem, which we kept in mind at each stage of SAVANT 3's development. Let us list the types of contingent knowledge SAVANT 3 needs:

- wording of all predicates
- logical formulas (expressed in paradoxical clauses)
- pat sentences or questions associated with each predicate
- keyword combinations for predicate detection in student's answers

The crucial point here is that this knowledge may remain local. Since no change of subject will be tolerated, either by the student or the machine, as long as any potential paradox remains, the machine can behave properly using only the small amount of relevant knowledge: typically less than 20 rules for a given subject.
The great advantage of this modular organization of knowledge is to reduce the authoring time drastically. This time grows linearly with the surface covered by the competence of the system (and not exponentially as it would with overall knowledge), since it is much easier to guarantee consistency, non-redundancy and completeness for 15 rules than for 500.
We are currently developing an authoring system with which an author will be able to construct the logical knowledge on each subject through a dialog with the machine, without being her/himself a specialist in logic.

6 IS SAVANT 3 AN I.T.S. ?

For many authors an Intelligent Tutoring System must include a student modeling device. In (Self, 1988) for instance we can read: "it is the student model component which gives ICAI research its distinctive flavour". But SAVANT 3 does not care about the overall knowledge of the student, nor does it take into account her/his previous behavior when working with the program. It does not try to establish any psychological or cognitive profile. So how can SAVANT 3 claim a label like ITS or ICAL-system?
It's very surprising to notice that among the 18 systems mentioned in (Self, 1988) as using a student's model, all but perhaps one are designed to teach skills, i.e. procedural knowledge. The same can be said of (Vassileva, 1990). The exception is the well known WHY system designed by Stevens and Collins which is more concerned with factual and conceptual knowledge teaching. In WHY we find a rule aiming at entrapping the student in a contradiction if (s)he agrees with an

overgeneralized rule induced by the system from her/his last answer (Collins, 1976). This is not far from SAVANT 3's strategy.

SAVANT 3 was designed as a Knowledge Communication System (Wenger, 1987), and is devoted to the teaching of conceptual knowledge, since concepts constitute the major part of what our students are supposed to learn in their curriculum. It was argued in (Dessalles, 1990a) that concept and skill learning are essentially distinct processes, and that concepts have to go through a logical negotiation before being properly acquired. This explains why logical argumentation, and not student modeling, appeared to be the first priority in our context.

7 EXPERIMENTING WITH SAVANT 3

SAVANT 3 is a complete system with narrative presentations (including SAVANT 2 videodisc sequences), hypertext (the SAVANT 1 encyclopedia), and simulations. The first complete course: "Second Order Systems" was distributed to Telecom Paris Students in 1989, but it contained only three dialogs. For two of them, the machine could play its role correctly and many students engaged into a well-balanced and enriching conversation. The third dialog encountered less success, since the machine was unable to understand more than half of the student's utterances. The reason for this lies in the size of the logical context. The unsuccessful dialog began with the question: "What do you think of the comfort of the suspension, in your car?", and the students answered using analogies, names of specific car models, or even slang! The first conclusion is that we must restrict the dialogs to technical subjects for which the logical context is limited and can be anticipated. Since this experiment, the SAVANT 3 dialog module has been improved but not yet used by students.

8 PERSPECTIVES

When leaving a paradox which has been invalidated and trying to validate another one, SAVANT 3 takes no care of transitions. The student may experience the reply displayed by the system as as an abrupt topic change, even if the subjects remain highly related. SAVANT 3 is indeed always able to justify the relevance of its utterances by displaying other terms of the current paradox and by feigning surprise. But this is perhaps not sufficient, and we can think up ways of synthesizing transitions.

Conversational logic is not so simple as presented above. As we have said, it involves two modalities which are Improbability and Undesirability (cf. (Dessalles, 1990b)). SAVANT 3 will improve by taking these modalities into account and also with a better reply interpretation. A great deal of effort will be devoted to the development of the authoring system. We will also explore the possibility of detecting predicates, and not mere propositions, in the student's replies, since the SAVANT 3 dialog module is able to handle knowledge expressed in first order logic.

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