Goal-based Generation of Motivational Expressions in a Learning Environment[1]

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Abstract

In a tutorial setting, we often hear expressions such as "The method we are about to discuss will help you solve ... " or "Let us consider a subject which demands some more practice," which are issued by a tutor to motivate a student to attend to forthcoming discourse. In this paper we model the meaning of these expressions in terms of their anticipated influence on the status of a listener's goals, and use these predictions to produce motivational expressions and embed them in computer generated discourse. In particular, we have recognized relations which are instrumental in determining a listener's motivational requirements in a hierarchical problem-solving domain. These ideas have been incorporated into a system called FIGMENT which generates commentaries on the solution of algebraic equations.

I. Introduction

In a tutorial setting a student is constantly exposed to *Technical Utterances* in the form of explanations, definitions, descriptions and problems to be solved. Intelligent Tutoring Systems (Clancey 1979, Genesereth 1978, Sleeman and Brown 1982) and text generation systems (McKeown 1985, Appelt 1982, Mann and Moore 1982) have addressed the problem of determining the type of technical utterance to be presented and the information it should contain. However, in discourse produced by a human tutor we also notice the presence of expressions such as "however," "this technique demands some more practice," "as I said before" and "next," which are not part of the subject matter (Farnes 1973, Hallyday and Hassan 1976, Longacre 1976, Hoey 1979, Winter 1968). These expressions, denoted *Meta-Technical Utterances* (MTUs), carry important information which assists the listener in assimilating the knowledge being transferred (Zukerman 1986, Zukerman and Pearl 1986).

In this paper we focus on one type of MTUs, namely *Motivational MTUs*, which are used to motivate a student to perform prescribed tasks such as attending to forthcoming discourse and solving given problems. We attempt to gain insight into the mechanisms used by peo-

ple to generate these MTUs by building and implementing a generative model of their meaning. This model has been incorporated into an Intelligent Tutoring System called FIGMENT, enabling it to produce a variety of Motivational MTUs. For instance:

1. "We shall now consider a topic, namely quadratic equations, which we have not seen for a while" — This motivation is issued to prompt a student to practice a topic which he may be forgetting.

2. "This alternative serves to introduce the very important and interesting method of factoring out common factors" — A tutor uses this motivation to awaken interest in a new item of knowledge.

3. "This type of equation has been practiced a lot, but it still demands some more practice" — This motivation is generated to encourage a, probably tired, student to continue practicing a subject in which he lacks proficiency.

In the following section we present a goal-based taxonomy of Motivational MTUs. Then we examine the mechanism used by FIGMENT to generate them.

II. Goal-Based Taxonomy of Motivational MTUs

During the learning process a student is expected to exhibit the goal of *mastering the subject matter*. In addition, a typical student usually has a host of other goals, such as: *achievement goals* (passing a test, getting a good job), *social goals* (earning the respect of his peers, gaining the approval of the teacher), *enjoyment goals* (remaining interested and amused during lectures, being able to rest), etc (see Schank and Riesbeck 1981).

At any point in time, a goal is either non-existent or it can exhibit varying degrees of activity. A goal is non-existent if the entities involved are not represented in the listener's memory. For example, a person who has never heard of university cannot have a goal of studying there. A goal may become active due to the occurrence of an external event, e.g., if we find out there is a new movie featuring our favourite actor, our goal of seeing it becomes active; or by gradual build-up over a period of time, e.g., if a student has been studying for quite a while, his enjoyment goal of being able to rest is strengthened. The level of activity of a goal may decrease over a period of time if it was not reactivated and competing goals became active. In addition, a goal may become inactive if the listener believes that it has been

accomplished.

The level of activity of a goal also depends on the status of goals *enabled* by it, where the goal-enablement relationship is defined as follows: goal G_1 enables goal G_2 if the listener believes that the fulfillment of G_1 increases the probability of attaining G_2. Thus, if G_1 enables G_2 and G_2 is active, then G_1 is active as well. For example, if the listener has an active goal of *getting a good job*, and he believes that knowing how to program will help him get such a job, then the goal of *knowing how to program* is active too.

In a learning environment, a student is required to perform different tasks such as paying attention, studying and solving given problems. We recognize the following relationships between tasks and goals:

● Task T *enables* goal G if the listener believes that by performing T he will increase the probability of achieving G. The proverb "practice makes perfect" illustrates this relationship; and

● Goal G *immediately follows* task T, if T enables G and the completion of T ensures the immediate attainment of G. For instance, the goal *room is clean* immediately follows the task *cleaning room*.

We define a student to be motivated to perform a task T, if there exists a goal G such that G is active and T enables G.

If a student does not exhibit a goal for which both conditions are satisfied, a tutor will try to remedy this situation by producing a Motivational MTU. A *Task-based* Motivational MTU establishes an enablement relationship between a task and an already active goal, whereas a *Goal-based* Motivational MTU activates an inactive or non-existent goal.

A. Task Based Motivation

When a given task entails a considerable amount of time and effort, the enablement relationship between this task and a student's active goal may weaken, causing the student to become discouraged. In this case, a task-based Motivational MTU is usually generated. For instance:

"If you study for your exam you'll do well."
    task   enabled goal

B. Goal Based Motivation

Quite often, a listener is aware of the enablement relationship between a task and a goal. In this case, the speaker assumes that a listener's lack of motivation stems from the absence of an active goal, and generates a goal-based Motivational MTU.

In the following subsections we shall consider three types of goal based motivations: Direct, Indirect and Enablement.

1. Direct Goal Activation

A presently inactive goal may be directly activated by stating the degree of attainment of this goal or lack thereof. The following types of Motivational MTUs are commonly used to directly activate a student's goal of mastering the subject matter:

Knowledge Rectification — Occasionally, a student believes that he masters a particular information item even though his knowledge is imperfect. In this case, his goal of mastering the subject matter can be directly activated by stating or implying the error of his ways. For instance, "There is a better way to do this" or "I don't think I made myself clear";

Knowledge Preservation — If a certain item of information has not been encountered for some time, a student's skill may have deteriorated. In this case, he could be motivated to pay attention to this item by means of a *knowledge preservation* Motivational MTU such as "This equation enables us to practice a technique, **which we have not encountered for a while**"; and

Knowledge Incrementation — If a particular topic has been practiced recently, we can safely assume that the expertise of a student will only increase with additional practice. In this case, if the performance of the student leaves something to be desired, a tutor can use a *knowledge incrementation* motivation like the following: "Let us continue with the following type of equation, **which demands some more practice**."

2. Indirect Goal Activation

A non-existent or inactive goal of mastering a given item of knowledge may be indirectly activated by highlighting its positive attributes, and thereby arousing the listener's curiosity. The following Motivational MTU illustrates this type of goal activation: "Let us examine a **very important and interesting technique**."

3. Enablement Goal Activation

An inactive or non-existent goal may be activated by communicating to the listener that this goal enables another, already active, goal. For instance, if a listener exhibits the goal of going to the movies, the goal of completing the homework can be activated in the following manner: "If your homework isn't finished you can't go to the movies." The same effect can be obtained by directly referring to a task which is immediately followed by the goal to be activated. In our example, the task in question would be to *do the homework*.

We divide the Motivational MTUs which activate the goal of mastering the subject matter by enablement, into two subclasses based on the expected usage of the mastered knowledge:

Application — The acquired knowledge is directly applied in order to attain an enabled goal. Examples are: "You can use this technique **to beat your friends at tic-tac-toe**" and "A more efficient way to solve this equation is by ... " [*enabled goal*: solve problem in area of interest]. This type of motivation is often combined with a knowledge rectification motivation which directly activates the enabled goal; and

Precondition — The acquired knowledge is not directly used, but is considered an obstacle that needs to be overcome prior to the attainment of an enabled goal. The precondition may either be fictitious or factual.

A *fictitious precondition* exists only in the mind of the speaker and the listener. It is expressed by Motivational MTUs such as "**You can't watch TV** unless you do your homework" [*enabled goal*: enjoyment] and "**I would like you to** solve the following equation"

[*enabled goal*: social - gain the teacher's approval]. This type of motivation is usually generated as a last resort, and its effectiveness depends on the speaker's authority.

A *factual precondition* represents a situation which takes place in real life. It is expressed by means of Motivational MTUs such as "If you don't know quadratic equations you won't do well in your final" [*enabled goal*: achievement (pass exams)] and "Firefighters also need to know how to read" [*enabled goal*: achievement (get a desired job)].

III.   Generating a Motivational MTU

In an interactive environment characterized by a tutor's active participation, a student is usually presented with various rather short tasks such as solving a few exercises or listening to an explanation. Thus, in general, he is aware of the enablement relationship between a task and the goal of mastering a given item of knowledge, and an anticipated lack of motivation can be attributed to the absence or inactivity of this goal. This situation calls for the generation of a goal-based Motivational MTU.

An effective human tutor ascertains the need for a Motivational MTU by using some models of cognitive processes triggered in a student upon encountering a technical utterance. These models represent a teacher's perception of the learning habits of a typical student. FIGMENT uses a similar strategy to determine whether a Motivational MTU is required. It predicts whether a student is motivated to perform a task, by consulting a simplified model of the effect of the state of the discourse on the status of the student's goal of mastering the subject matter (see figure 1). If, according to this model, the goal in question is either non-existent or inactive, the system concludes that the student is unmotivated, and records a requirement for a Motivational MTU.
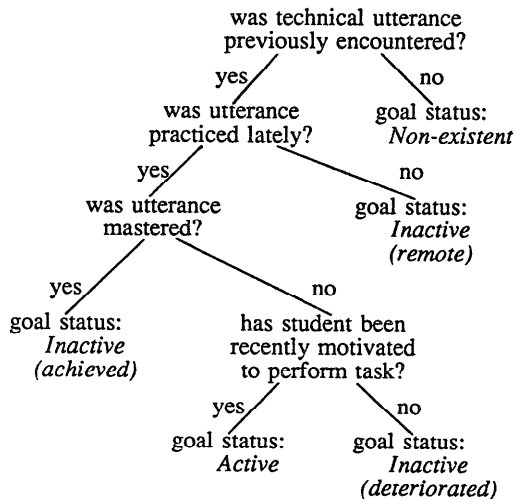
was technical utterance
previously encountered?

yes / \ no

was utterance   goal status:
practiced lately?   *Non-existent*

yes /   \ no

was utterance   goal status:
mastered?   *Inactive
                        (remote)*

yes /   \ no

goal status: has student been
Inactive   recently motivated
(achieved)   to perform task?

yes /   \ no

goal status: goal status:
Active   *Inactive
                        (deteriorated)*

**Figure 1:   Process for Predicting the Status
of the Goal of Mastering the Subject Matter**

According to this model, a tutor considers a student's goal of mastering an unknown item of knowledge to be non-existent. The goal of mastering an item of knowledge which a student believes has already been mastered, is presumed to be inactive. The goal of mastering a heavily practiced item for which a student has not been recently motivated deteriorates, eventually becoming inactive, i.e., it is superseded by enjoyment goals. Finally, the goal of mastering an item of knowledge which hasn't been seen for some time is inactive due to its remoteness, i.e., the goal of mastering a different item of knowledge has probably taken precedence.

The questions in the decision nodes of the procedure depicted in figure 1 are answered by applying procedures which take into consideration the state of the discourse and a student's talent, diligence and knowledge status.

After the status of the goal of mastering the subject matter has been ascertained, FIGMENT selects a Motivational MTU, by applying the following directives, and taking into account the student's attributes as well as rhetorical considerations:

A non-existent goal may be activated by means of an indirect goal activation and/or an application-enablement goal activation. For example, the Motivational MTU "Let us now consider a **rather important** technique, **which enables us to solve some equations of higher degree**" combines both types of activations.

A goal which is inactive due to its remoteness may be activated by means of a direct knowledge preservation motivation, e.g., "Let us go over a technique **which we haven't seen for a while**." This type of Motivational MTU may be accompanied by an indirect goal activation or an application-enablement goal activation, if the goal's activity level is extremely low, i.e., the student no longer recalls the reason for studying the subject under consideration. In this case, FIGMENT may produce a Motivational MTU like the following: "Let us consider an **extremely important and useful technique, which we haven't practiced for quite some time**."

A goal whose inactivity stems from its deterioration may be activated either by means of a direct knowledge incrementation motivation or by a precondition enablement motivation. In general, the latter is used only if the former is inapplicable. Like the knowledge preservation motivation, a direct knowledge incrementation motivation may be accompanied by an indirect or application-enablement goal activation, yielding a Motivational MTU such as "The following method, **which**, as you probably recall, **enables us to solve many problems in mechanics, demands some more practice**." A factual precondition-enablement goal activation is preferred to a fictitious one, which is generated as a last resort. Notice, however, that due to the nature of the interaction between an automated Tutoring System and a student, the only applicable fictitious precondition motivation is one which enables a social goal. For instance, "**I would like you to** solve one more equation."

Finally, a goal which the student believes has been attained, can either be reactivated by negating this belief, or, should this be unsuitable, by means of a fictitious enablement motivation. The following direct knowledge rectification MTU illustrates the former: "Can you think of another way to solve this equation?"

1. Motivation Relations in a Hierarchical Problem-Solving Domain

In a hierarchical problem-solving domain the subject matter is typically composed of a sequence of problems interleaved with declarative knowledge. Each problem belongs to a particular topic, and is usually accompanied by one or more solution alternatives. Each alternative contains a sequence of rules. In this case, a student's motivation to attend to a particular piece of information not only depends on the level of activity of his goal of mastering this information, but also on the status of the goal of mastering other items of knowledge in the hierarchy. This dependency is expressed by means of the following relations (see figure 2):

Inheritance — The goal of mastering a topic or equation is transmitted to the solution alternatives. For example, if a student has acquired the goal of solving a given problem, this goal shall remain active until the problem is solved, motivating the student to attend to various solution attempts. Similarly, lack of interest in a given equation is propagated to its solution alternatives.

Upwards propagation — The goal of mastering a rule or an equation can be used to motivate a listener to attend to higher levels in the hierarchy. Unlike the previous relationship, this type of propagation applies only to active goals. For instance, FIGMENT activates the goal of mastering the substitution method, and propagates it upwards to motivate the student to attend to a given equation, by means of the following indirect Motivational MTU: "The following equation **enables us to introduce the very important method of substitution.**" This motivation, in turn, may be inherited by other alternatives, by affixing the following text to this MTU: "But first, let us consider other ways to solve this equation, **for comparison purposes.**" A knowledge preservation or incrementation motivation may be propagated upwards, if it is shared by all the solution alternatives, yielding a sentence such as: "This equation enables us to practice a couple of methods, **which we have not seen for a while.**"
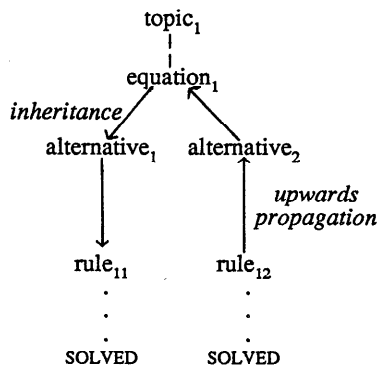
topic$_1$
|
equation$_1$
inheritance / ↖
alternative$_1$ alternative$_2$
| ↑
↓   _upwards propagation_
rule$_{11}$ rule$_{12}$
.   .
.   .
.   .
SOLVED   SOLVED

Figure 2: Motivation Relations in a Problem-Solving Hierarchy

FIGMENT determines whether a student needs to be motivated to attend to a commentary on an algebraic equation, by applying the goal-status determination process presented in figure 1 first to the root of the problem-solving hierarchy, namely the topic, and then to the equation. Next, it uses the inheritance relation to ascertain whether the student is motivated to attend to each solution alternative, and applies the goal-status determination process to a typical sequence of rules in each of the alternatives for which the student is unmotivated. Finally, if the goal of mastering the given equation or the typical sequence of rules in all the alternatives is active, the upwards propagation relation is used to cancel the motivational requirements recorded for their ancestors.

After ascertaining the status of the student's goal of mastering each item in the hierarchy, FIGMENT applies the directives presented above to the items which the student is unmotivated to study, in order to determine an adequate type of Motivational MTU for each of these items. These actions yield a structure containing suggestions for Motivational MTUs, such as the one presented in table 1 for the linearized hierarchy in figure 3.

TOPIC	_direct (knowledge preservation)_
EQUATION	_fictitious precondition enablement (social)_
ALTER- NATIVE$_1$	{rule$_{11}$ REMOVE PARENTHESES — _fictitious enablement (social)_} {rule$_{12}$ COLLECT TERMS — _direct (knowledge incrementation)_}
ALTER- NATIVE$_2$	{rule$_{21}$ SUBSTITUTE — _indirect (highlight attributes)_}

Table 1: Types of Suggested Motivational MTUs for Sample Input

According to this structure, a knowledge preservation motivation may be used to motivate a student to attend to the topic of quadratic equations, and the only motivation applicable to the equation is a fictitious social motivation. The typical sequence in the first alternative consists of two rules, which require a social and a knowledge incrementation MTU, respectively, and the typical sequence in the last alternative contains the substitution rule, for which an indirect goal activation is advised.

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TOPIC:      quadratic
EQUATION:   (x-3)² - 4(x-3) - 12 = 0

(ALTERNATIVE 1)
RULE:       remove-parentheses
RULE:       collect-terms
RESULT:     x² - 10x + 9 = 0
CONTINUE

(ALTERNATIVE 2)
RULE:       substitute (object y) (for x-3)
RESULT:     y² - 4y - 12 = 0
RULE:       solve-for (object y)
RESULT:     y=6 or y=-2
RULE:       substitute-back (object x-3) (for y)
RESULT:     x-3 = 6  or  x-3 = -2
RULE:       transfer-term
RESULT:     x=9 or x=1
FINISH
```

Figure 3: Sample Input to FIGMENT's Motivation Generation Component

FIGMENT completes the motivation generation process by selecting a subset of the suggested Motivational MTUs. The selection process takes into consideration inheritance and upwards propagation relations, and is guided by the principles of implying the least possible ignorance in the student and, at the same time, exhibiting knowledge about the situation at hand. Thus, FIGMENT will generally favour an application-enablement or indirect motivation over a direct knowledge-status related motivation, and prefer the latter to a precondition-enablement motivation. In addition, among direct motivations, preference is given to one that addresses the lowest possible information item in the hierarchy.

For the above presented structure, in most cases the system will highlight the attributes of the substitution method and propagate it upwards, producing a sentence such as "The following equation serves to introduce a very interesting technique, namely substitution." The first alternative then inherits this motivation, causing the following text to be appended "but first, let us consider another alternative for comparison purposes." In the rest of the cases, the system will generate a knowledge preservation Motivational MTU for the topic, yielding the following sentence: "Let us now consider the topic of quadratic equations, which we have not seen for some time." Notice that this Motivational MTU accounts only for the first solution alternative, and a separate motivation is produced for the second one, e.g., "Let us now consider another alternative. This approach enables us to introduce the technique of substitution, which is very interesting."

IV. Conclusions

In a learning environment a speaker produces motivational expressions based on his perception of the state of the discourse and the listener's attributes. This paper presents a motivation-generating mechanism which follows this paradigm and can be readily incorporated into an Intelligent Tutoring System. Specifically, the paper demonstrates the generation of motivational expressions by consulting a simplified model of the effect of the state of the discourse on the listener's goals. Motivational expressions produced in this manner not only encourage the listener to attend to forthcoming discourse, but enhance the credibility of an Intelligent Tutoring System.

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