

UNDERSTANDING COMPLEX SITUATIONS*

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Natural language texts often refer to complex situations. Many of these situations involve relationships between people's goals. In order to build a program that understands texts, it is necessary to give the program knowledge about goal relationships and the situations to which they give rise. This knowledge constitutes a theory of planning about real world situations. We have incorporated this theory of planning into a program called PAM (Plan Applier Mechanism). As a result we now have a natural language processing system that can comprehend many complicated dramatic situations.

1. INTRODUCTION

A number of recent attempts have been made to address the problem of inference proliferation in natural language text understanding (for example, see Cullingford (1978) and Charniak (1978)). The thrust of this research has been to use knowledge to guide the inference process. By equipping an understander with knowledge of the particular situation referred to in the text, the understander makes those inferences which are the most plausible without generating many spurious or irrelevant ones.

The drawback of this approach is that a natural language understander cannot be expected to have familiarity with every situation it is going to encounter. A human reader can understand many natural language texts that contain some novel elements in them. To build a natural language understanding system that is capable of understanding such text, a more general inferential capability is needed.

1.1 PAM

PAM (Plan Applier Mechanism) is a program that

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uses knowledge about people's intentions to understand situations that do not necessarily conform to stereotypical sequences of events. PAM applies knowledge about plans and goals to find explanations for the events in a text. That is, PAM explains a character's actions by inferring the plan that the action is a part of, and inferring the goal that the plan is aimed at achieving. Once a character's motivation has been determined, PAM uses this inference to help interpret subsequent events.

1.2 A Problem

The intentional knowledge originally given to PAM is based on the plan representation scheme of Schank and Abelson (1977). This scheme includes a number of important goals that a character could use to achieve a goal. PAM organizes its knowledge about these entities so that it could infer a character's intentions while reading a story.

While this idea worked well for understanding simple stories, most interesting story situations do not conform to this notion of planning. Real stories tend to be about dramatic situations in which some difficulty is presented for a character. Usually, this difficulty involves a situation in which numerous goals are present at once. These goals can interact in complicated ways, and knowledge about the nature of the goal relationships is needed to understand each character's behavior.

We have been able to formalize some of the knowledge about goal relationships needed for story understanding. By supplying PAM with this knowledge, the program is now able to understand and answer questions about many complicated stories that are beyond its former capacity, as well as the capacity of other natural language processing systems.

The goal relationships that appear to play a central role in story situations are the following:

- (1) Goal subsumption - A way of planning for recurring goals.
- (2) Goal conflict - An inimicable relationship between simultaneous goals of the same character.
- (3) Goal competition - An inimicable relationship between simultaneous goals of different characters.
- (4) Goal concord - A mutually advantageous relationship between simultaneous goals of different characters.

Goal subsumption is discussed in detail in Wilensky (1978b), and will only be touched on here. Instead, we shall be concerned with goal conflict and competition. A more detailed analysis of these relationships, as well as an analysis of goal concord, is found in Wilensky (1978a).

2. GOAL SUBSUMPTION

Goal subsumption is a form of planning in which a character plans in anticipation of having a set of goals, rather than in reaction to each individual goal. For example, consider the following story:

- (1) John got a job in another town. He asked Fred if he would sell him his car.

Instead of having a single goal, here John has a goal that is likely to recur repeatedly. Since having a job gives rise to the goal of being at work each day, it is possible to plan for these recurring goals at once rather than dealing with each one as it arises. John's plan to purchase a car makes it easier to achieve each of these goals since he would no longer have to obtain possession of a vehicle on each occasion.

Goal subsumption is composed of the following components:

- (1) A set of anticipated goals.
- (2) Plans for each goal, each plan sharing a common precondition.
- (3) A state that meets this precondition and

endures over a period of time during which the goals are expected to arise (called a goal subsumption state).

2.1 Goal Subsumption Situations

Goal subsumption is a useful concept in story understanding because there are a number of frequently occurring story situations based on it. The most important of these situations occurs when a functioning goal subsumption state is abruptly terminated, and is called Goal Subsumption Termination. The following is an example of a story PAM can process that involves such a situation.

PAM Example:

INPUT: JOHN AND MARY WERE HAPPILY MARRIED.
THEN ONE DAY, JOHN WAS KILLED IN A CAR
ACCIDENT. MARY HAD TO FIND A JOB.

Question:

INPUT: WHY DID MARY NEED EMPLOYMENT?

RESPONSE: JOHN DIED AND SO SHE NEEDED A SOURCE
OF INCOME.

PAM infers that John's death terminates a subsumption state for Mary, and that she may seek to replace it. Since traditional marriage subsumes certain economic goals that can also be subsumed by having a job, PAM infers that this is the reason behind Mary's goal. This explanation is accessed and given as the answer to the question above.

3. GOAL CONFLICT

Consider the following situations:

- (2) John wanted to go bowling with his friends, but he had promised Mary he would take her out to dinner that evening.
- (3) John wanted to live in San Francisco, but he also wanted to live near his relatives in Kansas.
- (4) John wanted to go to the football game, but it was raining outside.

In each of these stories, a character has a number of goals that interfere with one another. Such a situation is called a goal conflict. To understand a story involving a goal conflict, a story understander must be capable of detecting the presence of the conflict, and of using knowledge about the types of situations to which goal conflict may give rise. For example, suppose story (2) were

continued as follows:

John decided to go bowling anyway. When he got home, Mary told John she was going to divorce him.

To understand that Mary wanted to divorce John because he had neglected her, a reader must infer that John didn't take her out to dinner. This inference is based on the fact that John's goal of taking Mary out was in conflict with another goal, and that this goal was pursued. When two goals are in conflict, and one of them is pursued, a reader can infer that the other has been abandoned. This knowledge about goal conflict is required to find an explanation for Mary's behavior.

3.1 Types of Goal Conflict

A classification of goal conflicts is needed to organize knowledge for both goal conflict detection as well as for understanding the situations to which goal conflicts give rise. We have found the following taxonomy of goal conflicts to be useful:

Goal Conflict Classification

- (1) Goal conflicts based on resource limitations.
- (2) Goal conflicts based on mutually exclusive states.
- (3) Goal conflicts based on generating preservation goals.

Each of these classes is now described.

3.1.1 Resource Limitations

Goal conflicts based on limited resources can come about in a number of ways, depending upon the nature of the resource involved. Two important categories of resource limitations are found to exist:

- (a) Shortages based on time limitations
- (b) Shortages based on consumable resource limitations.

Due to a conflict based on a shortage of the consumable resource paper, we cannot afford a description of that kind of conflict here. We will discuss time limitations instead.

3.1.1.1 Time

Consider the following story:

- (5) John wanted to watch the football game, but he had a paper due the next day. John watched the football game. John failed Civics.

Story (5) is an instance of a goal conflict based on a shortage of time. In order for goals to conflict due to time resources, the plans for the goals must have some time restrictions on them; the amount of time available to the planner must be less than that needed for the successful execution of the plans, and the planner must be incapable of carrying out the plans simultaneously. For example, John must synchronize his plan of watching the football game with the game's broadcast; he must initiate his plan of writing a paper sufficiently before its deadline, and he is probably incapable of executing both plans at once because they each demand his attention.

Thus a goal conflict based on a limitation of time resources really also involves a limitation of a functional object or of a person's abilities. However, the text of a story does not usually make all these limitations explicit. Instead, a reader must infer the conflict from hints in the text. Time-based goal conflicts are hinted at by one of the following occurrences in the text of the story:

- (1) A statement of a deadline.
- (2) A statement of a limitation of a functional object.
- (3) A statement of a limitation of a person's abilities.
- (4) An explicit statement of a time shortage.

When one of these statements occurs in a story, the reader can infer that a time shortage exists. For example, story (5) above contains an explicit statement of a deadline. Thus the reader infers the goal conflict from the statement that John's paper was due at a certain time.

This inference can be made in PAM with the following rule:

Rule T1:

If

a character has two or more goals,
and

the story specifies that the plan for one of the goals must be initiated, completed, or occurring at or before a particular point in time,

then

infer that a goal conflict based on a shortage of time exists among that character's goals.

Hints (2), (3) and (4) are applicable to the following stories, respectively:

- (6) John wanted to simmer two dishes on his camp stove, but the stove had only one burner.
- (7) John had to write a paper for a course, and read a book for an exam, but John was a very slow reader.
- (8) John wanted to visit both Fred and Bill, but he didn't have enough time to see them both.

The rules needed to infer the conflict hinted at in each of these examples can be formulated similarly to rule T1 above.

When a reader sees one of these hints, the reader infers that a goal conflict is present. Of course, these are only hints, and the inference may be incorrect. For example, consider the following story:

- (9) John wanted to chat with Mary, but his train left in two days.

Rule T1 says to infer that there is a goal conflict here, but this is probably not the case. Fortunately, most such situations are detectable with simple consistency checks. For example, in story (9), a consistency check would reveal that chatting usually takes much less time than is available, so that the presence of a conflict is unlikely. We shall not expand on consistency here because they are only of importance in unusual situations.

3.1.2. Mutually exclusive states

Goals often conflict because they require some states to exist that are inherently inconsistent. For example, consider the following stories:

- (10) John wanted to marry Mary. He also wanted to marry Sue.
- (11) John wanted to have a regular job. He also wanted to collect unemployment insurance.

Mutual exclusion is similar to Sacerdoti's 'double cross' conflict (Sacerdoti, 1977). A double cross occurs whenever "each of two conjunction purposes denies a precondition of the other". Mutual exclusion is somewhat different since it applies both to double cross situations and situations in which goal states are exclusive independent of particular plans. In addition, states can be either logically or socially exclusive. For example, being unemployed and having a job are logically impossible,

while being married to two different people at once is exclusive only according to the conventions of one's society.

3.1.3. Causing a preservation goal

Consider the following stories:

- (12) John wanted to go to the football game, but it was raining outside.
- (13) John wanted to take the night off, but he thought his boss would fire him.

In both cases, the conflict arises because execution of a plan for a goal would cause a character to have the goal of preventing something from happening. Thus a goal conflict can occur when the plan for a goal causes a character to have a preservation goal. In order to detect these conflicts, a reader must examine the plans likely to be used for each character's goals, and determine if the execution of that plan will invoke a preservation goal for that character.

3.2. Goal Conflict Situations

Goal conflicts give rise to interesting story situations. For example, consider the following situations:

- (14) John wanted to watch the football game, but he had a paper due the next day.
 - (a) That night, John watched the football game. John failed Civics.
 - (b) John called his teacher and asked if he could have an extension.
 - (c) John decided to record the football game on his Betamax.
 - (d) John's teacher informed him that the deadline for the paper had been postponed.

These stories are instances of the following types of goal conflict situations:

- (1) Goal abandonment - The character opts for one goal, abandoning the others. This is the case in story (14a).
- (2) Goal Conflict Resolution - The character can try to resolve the conflict, as in stories (14b) and (14c).
- (3) Spontaneous Goal Conflict Resolution - The conflict may be resolved by some event not initiated by the planner. Such an event occurs in story (14d).

PAM uses knowledge about the possible situations that might arise from a goal conflict to explain subsequent events. The following is an instance of a story PAM understands in this manner:

PAM Example:

INPUT: JOHN WANTED TO WATCH THE FOOTBALL GAME.
HE HAD A PAPER DUE THE NEXT DAY. JOHN
WATCHED THE FOOTBALL GAME. JOHN FAILED
CIVICS.

Question:

INPUT: WHY DID JOHN FAIL A COURSE?

RESPONSE: BECAUSE HE FAILED TO HAND IN AN
ASSIGNMENT.

PAM uses the presence of a deadline to infer a conflict. Since John pursues one of the goals, PAM infers this is a goal abandonment situation and infers the failure of John's other goal.

4. GOAL COMPETITION

Stories usually have more than one character. Goal competition arises when the fulfillment of one character's goal will interfere with the fulfillment of the goals of the other character.

Goals can compete with one another for reasons similar to those underlying goal conflict. However, the situations that can arise from goal competition are substantially different. Consider the following stories:

- (15) John told Mary he wanted to watch the football game. Mary said that she wanted to watch the Bolshoi ballet.
- (a) Mary put on channel 3. John got out the lawnmower.
 - (b) John got the old black and white TV out of the attic.
 - (c) Mary put on channel 3. John punched Mary in the mouth and put on the ball game.
 - (d) John told Mary he would take her out to the ballet if she would watch the football game with him.
 - (e) Mary put on channel 3. She found out that the ballet was postponed until later that day.

These stories are instances of the following types of goal competition situations:

- (1) Independent goal pursuit, in which each character pursues his goals without regard to the other characters. Story (15a) contains an instance of this situation.
- (2) Anti-planning, in which a character tries to interfere with another character's plan. Anti-planning occurs in examples (15c) and (15d).
- (3) Easing the competition, a situation where a character tries to undo an underlying cause of the competition. An example of

this is story (15b).

- (4) External competition removal, in which the goal competition is removed by some action not taken by one of the competitors, as in story (15e).

4.1. Anti-planning

Anti-planning, or the process of countering one's opponent, is the most complex of these story situations. The following forms of anti-planning are distinguished:

- (1) Physical Elimination
- (2) Sabotage
- (3) Persuasion

The plans applicable to (1) and (3) are the general plans for overpowering someone and for persuading someone, which have been discussed elsewhere (see Schank and Abelson (1977) and Wilensky (1978)). Also, Bruce and Newman (1978) point out that story situations involving several characters often involve deception. In the scheme of things used here, deception is a variation of plans of persuasion in which some of the argument used by the persuader is known to the persuader to be false. These variations are called trick options. For example, a trick option in the BARGAIN plan may be to bargain away some object one does not possess; a trick option in the THREATEN plan is to bluff, or pretend that some object is a weapon that is not (e.g., a toy gun). PAM does not currently know about the trick options of any plan, however.

4.1.1. Sabotage

Consider the following story:

- (16) John and Bill both wanted to marry Mary. John began spreading nasty rumors about Bill.

John is using an anti-plan to stymie Bill's goal in order to maintain the possibility of fulfilling his own. This anti-plan is called UNDO-PRECONDITION. It involves pursuing a plan whose goal is to remove a precondition for someone else's plan. For example, in the story above, John employs the UNDO-PRECONDITION anti-plan against Bill by trying to get Mary to dislike Bill, since Bill's plan to get Mary to marry him probably requires that she be favorably disposed toward him.

The following is a computer example of PAM processing a story involving sabotage:

PAM example:

INPUT: JOHN WANTED TO WIN THE STOCKCAR RACE. BILL ALSO WANTED TO WIN THE STOCKCAR RACE. BEFORE THE RACE, JOHN CUT BILL'S IGNITION WIRE.

Question:

INPUT: WHY DID JOHN BREAK AN IGNITION WIRE?

RESPONSE: BECAUSE HE WAS TRYING TO PREVENT BILL FROM RACING.

Because John's goal and Bill's goal constitute mutually exclusive states, PAM infers the presence of goal competition. Since having a vehicle in good condition is a prerequisite for being in a race, PAM infers that John is using the UNDO-PRECONDITION plan to anti-plan against Bill.

4.1.2. Avoiding Danger

A special set of anti-planning rules is required for understanding goal competition situations based on generating a preservation goal. A particularly interesting subset of these situations occurs when a character may wish to execute a plan so as to avoid causing someone else to have a goal competitive with his. These are called anticipated preservation goal situations. For example, consider the following stories:

- (17) John wanted to get the treasure, but it was guarded by a huge dragon.
- (a) John tiptoed past the beast.
- (b) John threw a rock on the other side of the beast and then got the treasure when the dragon ran over to investigate the disturbance.
- (c) John poisoned the dragon's lunch.

Each of these stories demonstrates a plan that can be used to execute another plan without generating an anticipated preservation goal.

These plans are given the following names:

- (1) AVOID-DETECTION - executing a plan in such a way so as not to be detected by one's opponent. This is the case in story (17a).
- (2) DISTRACT - turning one's opponent's attention elsewhere. In story (17b), John executes a plan to divert the dragon's attention, after which John will presumably pursue his plan to get the treasure.
- (3) OVERPOWER - physically pre-empting one's opponent. John tries to reduce the dragon's physical abilities in story (17c) so that the execution of his plan for getting the treasure does not generate a preservation goal.

The following is a computer example of PAM understanding a story involving an anticipated preservation goal:

PAM example:

INPUT: JOHN WANTED TO GET THE TREASURE, BUT IT WAS GUARDED BY A DRAGON. JOHN WALKED OVER TO THE TREASURE QUIETLY.

Question:

INPUT: WHY DID JOHN SNEAK OVER TO THE TREASURE?

RESPONSE: BECAUSE HE WAS TRYING TO GET THE TREASURE AND HE WANTED TO PREVENT THE DRAGON FROM KNOWING WHERE HE WAS.

PAM infers two explanations for John's behavior. First, that he is executing a plan to get near the treasure, and second, that he was also using the AVOID-DETECTION anti-plan to prevent generating opposition from the dragon.

5. CONCLUSION

Stories are typically about interesting dramatic situations. Many such situations are based on interactions between goals. In order to build an understander that can comprehend stories about real world situations, it is necessary to have a theory of plans and goals that reflects the complexity of the real world. PAM uses such a theory to find explanations for characters' behavior. However, such knowledge should also be applicable to a broader range of AI problem areas. For example, problem solving requires a planner to consider situations in which a number of goals are present. The theory of goal relationships presented here should be useful for planning for and acting in these situations as well as for understanding them.

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