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ARIEL: AN APROACH TO UNDERSTANDING ANALOGIES IN ARGUMENTS

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ARIEL:

An Approach to Understanding Analogies in Arguments

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by

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To my parents, Jean and Les August,

who taught me perseverance,

and to my husband, Phillip,

and my daughters,

Elizabeth, Julianne, and Laura,

who persevered along with me.

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ABSTRACT OF THE DISSERTATION

ARIEL:
An Approach to Understanding Analogies in Arguments

by

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Analogical reasoning is an important component of natural language understanding. Humans are faced daily with the task of recognizing and understanding analogies embedded in arguments. Yet the problem of understanding analogies in natural language text and, in particular, the problem of understanding arguments which rely on analogy to make a point have not been studied.

We present an approach to developing a computational model of the process of understanding and reasoning about analogies in editorials. In our model, knowledge of the role analogy plays in arguments is coupled with knowledge about the logical structure of arguments to facilitate recognition of the analogy and understanding of the argument, and to guide the formation of a relevant conclusion. Domain-independent knowledge about the structure of beliefs and arguments is combined with domain knowledge in order to identify the reasoning behind an argument in the source domain. This line of reasoning is then "replayed" in the target domain in order to infer a target argument.

This approach has been implemented in ARIEL, a computer program which is able to understand editorials in which an author argues a point by analogy. ARIEL is able to detect the presence of the analogy in the text whether or not lexical clues have been used by the author to explicitly indicate its presence. Likewise, ARIEL is able to understand an argument-by-analogy whether or not the argument is explicitly completed by the author. By capturing the line of reasoning underlying an argument in a source domain, and coupling this underlying structure with domain knowledge, ARIEL is able to follow the example established in the source domain and generate an analogous argument in the target domain. The system is able to infer a plausible conclusion to an incomplete argument-by-analogy, even when a rich correspondence mapping between the analogs has not been provided in the text.

Chapter 1

Introduction

As natural language interfaces to intelligent systems become more widely used and more sophisticated, the range of language handled will need to be broadened to avoid restricting users to relatively simple and straightforward expressions. One type of expression that provides a very rich medium for communication is analogy. We often encounter analogies in editorials, which constitute one-sided arguments. In these texts, surface similarity between the corresponding arguments often does not exist. In addition, the author of an editorial, particularly a short letter-to-the-editor that one finds in weekly news magazines, will leave many details for the reader to infer. Thus, a rich correspondence mapping between source and target analogs is not available in the editorial. The reader can fall back on domain knowledge to understand the analogy, but unless this particular analogy has been encountered before, the result can easily be a fruitless search through a maze of domain knowledge, in hope of remembering something that will allow the reader to make sense of the editorial. However, by using knowledge regarding the general structure of arguments, the reader can identify a rough outline of what the author is inferring, and use this rough outline to retrieve the missing piece from domain knowledge.

In conveying an argument by analogy, an author will present a proposition in one domain, and support it with evidence from a different domain. The reader must be able to 1) recognize that an analogy is being used, 2) be able to follow and formulate an argument, 3) identify what is similar in the two domains, 4) explicitly complete the analogy if the author has not done so, and 5) understand why the analogy was used.

Developing a computer program that is capable of reasoning about beliefs when analogies are used to support those beliefs requires integrating natural language understanding, argumentation, and analogical reasoning. In the past, language processing systems have been developed for in-depth understanding of natural language text (Dyer83) (Aren86) and for reasoning about beliefs in arguments (Alva89) (Flow82) (Cohe87). Other Artificial Intelligence (AI) systems have been developed for retrieving analogous instances of events, and using those similar events to suggest a course of action to be taken to achieve a particular goal (Kolo87b) (Shin88a) (Shin88b) (Thag90) (Wins78). Still other AI systems have concentrated on using analogical reasoning in problem-solving tasks (Carb83a) (Carb83b) (Gent83) (Falk89) (Holy89). However, the problem of understanding analogies in natural language text, and in particular, the problem of understanding arguments which rely on analogy to make a point have not been studied. In addition, while important issues in analogical reasoning have been addressed in these systems, in each of these it is assumed that the user of the system will identify any input to the system as belonging to the source, target, or abstract component of the analogy[1]. In reality, however, humans are faced daily with the task of recognizing and understanding analogies embedded in arguments. First, a reader must notice that the presenter is using analogy to convey an idea. Then he or she proceeds to analyze the analogy into its source, target, and abstract components and to make any necessary inferences without further guidance. The reader gleans the point of the analogy, and understands how the analogy is being used to convey the idea.

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1 An analogy consists of a familiar or "source" component and an unfamiliar or "target" component. Each of these components is an "analog." The abstract component is a representation of the similarity which exists between the source and target analogs.

The goal of this research is to identify the knowledge and processes needed to support the ability to understand an argument-by-analogy. We have developed ARIEL[2] (Augu90) (Augu91a) (Augu91b) as a computational model of the process of recognizing, understanding and reasoning about analogies in editorials. This model integrates argumentation and analogical reasoning components into a natural language understanding system. Our model of argumentation enables the understander to capture and exploit the reasoning behind an argument. We have also incorporated into this model a theory of how analogy is used in editorials. By combining knowledge of argument structure, domain knowledge, and knowledge of the role analogy plays in editorials, our model is able to complete implicit arguments-by-analogy, and identify the point that the author is trying to make. It accepts as input the text of an editorial in which the author argues a point by analogy. From the input, ARIEL builds a conceptual representation (Norm75) (Scha75) (Rume76) of the argument, complete with the inferences that a human would need to make in order to understand the analogy in the argument. ARIEL can detect, understand, and complete analogies even in the absence of a rich correspondence mapping between the source and target analogs, and regardless of whether lexical clues are available to guide understanding of the argument or the analogy. As output, ARIEL produces the conclusion which it has drawn from the editorial. Our model draws upon and extends previous work (Augu85a) (Augu85b) (Augu85c), which demonstrated how textual clues and conceptual similarity can be exploited to detect the presence of an analogy in an editorial, and pointed out the necessity for including in the representation a direct correspondence mapping between the source and target analogs.

Our work differs from previous work in reasoning about beliefs by focusing on the use of analogy in arguments. Moreover, it differs from previous work in analogical reasoning by addressing the issues of detecting the presence of the analogy, and identifying the source and target components of the input. Analogical transfer in our theory relies on understanding why a particular analogy exists, and why the source argument has its particular structure, in addition to considering the explicit structure of the source analog and the correspondence mapping developed between the source and target analogs. Other systems depend upon structural and mapping information alone to complete the transfer.

1.1. The Process of Understanding the Analogy in an Editorial

Editorial understanding provides the context for our model of analogical reasoning. A natural language context allows us to address aspects of analogical reasoning, such as analogy recognition, not presented by the other domains, e.g., modeling physical systems (Falk86). Argumentation was chosen because conveying beliefs is an essential part of communication, and analogy is often used to illustrate or explain one's beliefs.

Consider the following editorial:

HIGH-TECH-1

> *Some people are against computer-aided manufacturing because CAM eliminates people's jobs. However, the automobile industry did the same thing to people in the horse carriage industry. Yet consumer demand for autos was strong enough that eventually more jobs were created in the auto industry than*

---

2 *A*nalogical *R*easoning *I*n *E*ditorial *L*etters

were lost in the horse carriage industry. In the end, the economy benefitted by the introduction of the new technology.

In response to HIGH-TECH-1, ARIEL produces the conclusion:

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THE MANUFACTURE OF CAM-PRODUCED GOODS IS GOOD
BECAUSE CONSUMER-DEMAND FOR CAM-PRODUCED GOODS WILL
HAVE THE RESULT THAT JOBS WILL BE CREATED IN THE
MANUFACTURE OF CAM-PRODUCED GOODS.
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The author of HIGH-TECH-1 is arguing that the introduction of computer technology will eventually improve the economy by increasing the number of positions available in the job market. This point is never explicitly made in the text. Instead, it is argued by analogy to a similar situation resulting from the introduction of the automobile. Informal protocols indicate that readers, asked the point of the editorial, will respond that *CAM will eventually create more new, CAM-related jobs than will be lost due to its introduction.*

Drawing this conclusion requires inferring some information not explicitly given in the text. This leads us to ask how the reader recognizes the presence of the analogy, and how the reader relates details of the source analog (the introduction of the automobile industry) to corresponding details of the target analog (introduction of CAM). What enables the reader to follow the argument in the editorial? How does the reader infer the missing or implicit details? How does the reader come to understand the general point of the editorial? This understanding proceeds as follows in HIGH-TECH-1:

Recognizing the analogy: The author starts off with a discussion of computer-aided manufacturing and the short term effects on the job market of its introduction. The author then mentions the auto industry and the horse carriage industry, which on the surface have no relation to CAM and the job market. To understand the phrase *...did the same thing...* the reader infers that the relationship between the automobile industry and the horse carriage industry is similar to the relationship between CAM and the job market. Making this inference causes the reader to view each as an instance of technology introduction causing job loss, and to note that these two instances are being compared. Thus, recognition of conceptual similarities can enable recognition of the presence of the analogy in the editorial. In addition, the reader must understand how this analogy fits into the editorial as a whole. This latter point is particularly important when no lexical clue is used to introduce the analogy in the text.

Recognizing the structure of the underlying argument: How do the pieces of the argument fit together? In HIGH-TECH-1, the author made the point that some people believe that CAM is bad, because it caused job loss. If two events or objects are similar in some respects, we can infer that they will be similar in other respects, as well. That is, we have analogous beliefs about analogous concepts. If two events are similar, we can infer that our value judgments about each will be similar as well. So, if CAM and the auto industry are similar, then if people think CAM is bad, then they would also have to think that the introduction of the auto industry must have been bad, since both had similar short term consequences. In HIGH-TECH-1, this reasoning is carried a step further. It is argued that the introduction of automobiles actually bolstered the economy in the long run, and was therefore a good thing. The reader recognizes this as a contradiction to the belief that the introduction of the automobile industry was bad.

Completing the details of the analogy: As HIGH-TECH-1 ends, the reader is expecting a similar contradiction regarding CAM. However, such a conclusion is not supplied in the editorial. By analogy, the reader infers that CAM will have similar good effects, and therefore will also turn out to be a good thing.

Drawing an appropriate conclusion from the editorial: The author's point here is that eventually the introduction of CAM technology will improve the economy, a point made only implicitly by the author. The reader's ability to complete the analogy as well as her ability to recognize the focus of attention in the editorial enables her to draw an appropriate conclusion from the editorial.

1.2. Issues Involved in Understanding Analogies in Arguments

Succeeding at the task of understanding analogies in editorials raises issues central to artificial intelligence in general: representation, reasoning, and recognition. In particular, this task requires:

1. Having enough lexical and domain knowledge to understand the points being made by the author,
2. Being able to follow an argument and formulate an argument, and
3. Being able to reason by analogy.

The focus of this research is on item 3, the mechanics of analogical reasoning in a natural language processing context. Let us consider how each of these is relevant to this research and examine some closely related work which has been done in the past.

1.2.1. Natural Language Understanding

Understanding a natural language, such as English, French, or Russian, requires not only a large amount of lexical knowledge, but a vast amount of general world knowledge as well. In addition, it also requires one to understand the role played by expectations which are generated by the topic being communicated and the context in which it is communicated. Consider the first sentence of HIGH-TECH-1:

Some people are against computer-aided manufacturing because CAM eliminates people's jobs.

A human reader knows what people, CAM, and jobs are. She knows that "against" can have multiple meanings: being against a physical object usually means that one is next to that object, whereas being against an event usually means that one does not approve of that event. The reader uses knowledge derived from surrounding text to disambiguate the meaning of against in this context. Domain knowledge of manufacturing, assembly lines, and the goals and plans associated with making profits enables the reader to understand that CAM technology can do a job better and faster than a person, thereby displacing people from assembly line jobs. By using these knowledge sources, the reader is able to understand that the first sentence means that some people are opposed to the introduction of CAM technology, because it replaces with automated machines people who work on assembly lines, causing unemployment for the former assembly line workers.

Previous work in developing natural language processing systems has shown how world knowledge and expectations generated by both the text itself and the context in which it is used are essential components of understanding natural language. BORIS (Dyer83) and PHRAN (Aren86) are examples of these systems. Neither BORIS nor PHRAN is designed to recognize or understanding analogies in natural language text.

The BORIS system (Dyer83) took an integrated approach to the problem of achieving an in-depth understanding of natural language, multiple-sentence texts. BORIS stressed the importance of exploiting the semantic content of the text, and demonstrated how the analysis of the text into conceptual primitives and identifying the higher level knowledge structures within the representation could proceed simultaneously. BORIS worked under the assumption that the meaning of an utterance could be computed from the meaning of its constituents by the use of general rules. Associated with each lexical entry was not only the meaning associated with the word, but also control information specifying, for example, where in the text the controller needed to check for other words and concepts. The control information for the processor was included as part of the meaning of various words. This diffused control information among the lexical entries. As a result, it was very difficult to incorporate new words into the system, or modify the meaning of existing lexical entries.

PHRAN, or PHRasal Analyzer (Aren86) presents a slightly different approach to natural language understanding. PHRAN stores information about the words of the language as well as information about more complex language constructs in the form of linguistic pattern-semantic concept pairs. Information about the meaning of a phrase is stored as a phrase, not disbursed among the lexical entries of the words comprising the phrase as in BORIS. PHRAN separates knowledge about language, kept in the pattern-concept pairs, from processing strategies, which are embedded in the code of the understanding mechanism. Thus, it is very easy to add additional phrases into the lexicon. PHRAN was designed to provide a natural language interface to the UC (UNIX Consultant) system (Wile82). UC is not able to relate the concepts from one sentence to those from another, and build an overall representation of all of the input it receives, although the system is able to handle some reference across sentence boundaries. As a result, it is not able to handle multi-sentence texts, such as editorials, and has no analogical reasoning component.

Natural language understanding in ARIEL is based upon PHRAN's phrasal parser. Because we want ARIEL's understanding to proceed in an integrated manner, we have also borrowed from BORIS to enable our parser to handle multi-sentential texts and to be able to generate expectations related to following arguments in the text. In addition, ARIEL is able to develop correspondence mapping between source and target analogs while understanding proceeds.

ARIEL is currently designed to generate an English equivalent of the representation of the conclusion it draws from the text read. This generation ability is based upon PHRAN's phrasal generator, with only minor modifications.

1.2.2. Argumentation

As HIGH-TECH-1 begins, the author states that the use of computers causes people to lose jobs. How is this statement identified as a belief? The reader's familiarity with the structure of arguments enables her to view the statement as a claim that computers are bad because they eliminate jobs.

The reader's knowledge of the strategies used to support and attack beliefs enable her to understand when the author attempts to disprove the initial claim about computers. Lexical clues in the text of the letter help her in this task. For example, *however* and *yet* in HIGH-TECH-1 signal the reader to expect the subsequent thought to contrast with a previous one.

This knowledge of argument strategies again comes into play in the final sentence of HIGH-TECH-1, when the reader draws upon her knowledge of the relationship between the job market and the economy and their impact on individuals to understand how and why the economy improved after the manufacture of automobiles began. She uses this information to understand the argument that automobile manufacturing was actually good, because it led to the creation of more new jobs.

The point of HIGH-TECH-1 is that the introduction of CAM technology will eventually benefit the economy. Since this point is not made explicitly in the editorial, the reader can grasp this idea only if she can 1) follow the author's argument that the automobile industry caused similar problems for people making horse carriages, then 2) generate the author's implied argument that CAM will have the same positive results that were seen when the auto was introduced.

An editorial expresses the opinions or beliefs of its author. As such, it is like a one-sided persuasive argument. A belief is stated, then either supported or attacked. After reading an editorial, the reader expects to know what the author believes, and why she believes it. To understand an editorial, the reader must be able to identify the beliefs, supports, and attacks mentioned or alluded to by the author. He or she must be able to tie these parts together to form a cohesive argument. This requires a basic idea of how arguments usually proceed, and the ability to generate arguments as needed to complete the author's thoughts. Research into computational models most closely related to ARIEL has dealt with adversary arguments (Flow82), editorial understanding (Alva89), the use of clue words in understanding arguments (Cohe87), and the creation and evaluation arguments (McGu85). It is interesting to note that none of these systems but the last has any ability to understand or generate arguments by analogy, and, in the case of (Cohe87), the natural language understanding component is limited to a parser which translates the input into logical statements and relies only upon syntactic information to tie together the pieces of the argument found in the input. And although (McGu85) does address argumentation by analogy, this work does not provide any mechanism for completing arguments by analogy.

(Flow82) deals with adversary arguments between two people. It identifies the basic tasks important to understanding an argument, and proposes an argument graph to represent the propositions and argument relations developed during the history of an argument. In ABDUL/ILANA, all rules are tied to specific types of events, such as military attacks, and are not domain independent. The arguments handled by ABDUL/ILANA are over the interpretation of the facts, slanted by the sympathies of each arguer.

ARIEL draws upon the model of argumentation developed by Flowers et al. However, our approach differs in two significant ways. First, ARIEL's knowledge of argumentation is domain independent. Our system relies upon domain knowledge to understand and infer value judgments about events, and to instantiate argument rules. Secondly, the focus in ARIEL is to understand the argument being presented by the author as impartially as possible, rather than to interpret facts in light of the sympathies of each arguer.

In OpEd (Alva89), editorial understanding is viewed as a process of recognizing and instantiating relatively large knowledge structures called Argument Units which are used to organize support and attack relationships in arguments. AUs convey implicit beliefs and are often cued by specific linguistic expressions. AUs are very useful when the editorial being processed is an instantiation of an existing argument unit. However, OpEd's AU-based understanding is not able to follow an editorial that follows a novel line of reasoning. ARIEL uses more the primitive constructs of argument rules and attack strategies to understand and capture the lines of reasoning in editorials, rather than relying on the larger and more comprehensive argument units. This lends a malleability to ARIEL which is essential to transforming arguments across domains and completing arguments by analogy.

(Cohe87) discusses a system whose top-level goal is to convince the hearer of some point of view. Cohen argues that clue words are necessary to understand one way arguments. While clue words are helpful in understanding arguments, we argue that the same arguments presented without clue words should be understood equally well. We demonstrate this by relying upon domain knowledge, context, and expectations related to argument understanding to follow arguments and to attribute justification for propositions.

McGuigan's MAGAC system (McGu85) simulates how people create and evaluate arguments. McGuigan breaks arguments into three categories: argument by analogy, in which conclusions are made about a target concept based upon a source concept at the same level of generality as the target concept; categorical argument, in which inferences about a concept are made based upon general knowledge related to the category into which the concept falls; and causal argument, in which causal knowledge is inferred based upon general knowledge. McGuigan's work supports the approach taken in ARIEL. However, ARIEL extends beyond MAGAC. First, it incorporates a natural language component into the system and exploits the semantic information in the text as well as additional world knowledge to augment the understanding process. Secondly, ARIEL's understanding of categorical and causal arguments goes beyond that in MAGAC by considering not only general knowledge, but also an analogous source concept as well when making inferences related to a target concept. Third, instead of focusing on creation and evaluation of arguments, ARIEL focuses on comprehension of arguments, and is able to complete an argument by analogy.

1.2.3. Analogical Reasoning

Analogical reasoning is the process of describing or reasoning about one object or domain in terms of another, similar one. Analogy is often used to explain the unfamiliar in terms of the familiar. The familiar domain is often referred to as the source analog, and the unfamiliar domain as the target analog. An essential part of the analogy is the correspondence mapping between the similar points in the source and target domains, which is often called the ground for the analogy.

Analogical reasoning is usually broken into four tasks:

1. retrieval
2. mapping
3. transference
4. learning

In editorial understanding, the reader is not required to retrieve an analog from long term memory, an issue frequently addressed in research into reasoning by analogy. Instead, in this task the reader must recognize that an analogy has been introduced in the text, and sort the information in the text into source and target analogs. Retrieval from short term memory is needed to piece together the components of the analogy provided in the editorial. Mapping and transference are also needed. Once all has been said and done, the reader must be able to identify the point being made by the author, or draw an appropriate conclusion from the editorial. However, the problem of what information should be transferred to long term memory, or "learned", is not addressed here. The aspects of analogical reasoning, then, which are relevant to this research are:

1. recognition
2. retrieval
3. mapping
4. transference
5. identification of the point of the analogy

In addition to addressing these aspects of analogical reasoning, we must also explore the relationship between analogy and the argumentation techniques used in editorials.

1.2.3.1. Analogy Recognition

Before understanding *how* the analogy is used in the editorial, the reader must realize that an analogy *is in* the editorial. What prompts the reader to notice that an analogy is being used? Is there an "analogy recognizer" constantly active? Or is analogy recognition triggered by something else? The approach taken in ARIEL is the latter. Analogy recognition is triggered either by lexical clues specifically drawing the reader's attention to the presence of the analogy, as shown in (Augu85a) (Augu85b) (Augu85c), or by the reader's expectations related to reading editorial text (Augu90) (Augu91b).

Let us look at how a reader recognizes the presence of the analogy in HIGH-TECH-1. The letter begins with a discussion of the computer industry. This is suddenly contrasted with a discussion of the automobile industry. Yet the reader is able to identify that at an abstract, conceptual level the topic underlying the discussion has not changed. By reference to *...the same thing...*, the author has directed the reader to the similarity between the two topics.

Knowledge of argument structure can also prompt a reader to notice the presence of the analogy. Knowing that a piece of text is an editorial, a reader will expect the author to support or attack each proposition presented. These supports and/or attacks can be made directly, or by analogy. Thus, these expectations can prompt the reader to recognize the presence of the analogy in the editorial, even when lexical clues indicating its presence are lacking.

Most computational models of analogical reasoning focus on identifying and retrieving a source analog from which to make inferences about a target analog, and therefore do not address the problem of detecting that analogy exists in the input to the model. Winston's work on understanding similes (Wins78) and Hobbs' work on understanding metaphors (Hobb81) (Hobb83a) (Hobb83b) are two notable exceptions. McGuigan does not address the issue of recognizing that an analogy is present in the input in discussing MAGAC (McGu85).

(Wins78) describes a system which learns by interpreting similes presented by a teacher. When presented with a simile such as "Robbie is like a fox", Winston's system identifies Robbie as the target and fox as the source by the order in which they are specified. Given the simile, the system would then endeavor to transfer properties of foxes onto Robbie, which was previously identified by the teacher as a robot. The focus of Winston's work was to create frames containing information relating to the source object, and chose from among those frames the ones containing information most appropriately transferred to the target object, based upon general knowledge and specific knowledge available about the target. This system does not handle more complex input, and therefore does not address the issue of recognizing analogy in text.

Hobbs' DIANA system (Hobb81) (Hobb83a) (Hobb83b) understands textual metaphors such as "Mary is graceful, but John is an elephant." A syntactic analysis of a metaphor such as this produces a set of predicate calculus formulas which are given to DIANA as input. Hobbs proposes that relevant inferences can be determined by employing the same means used to disambiguate other lexical expressions. The idea that metaphor understanding is integrated into natural language understanding is similar to the approach which we take. However, since DIANA does not accept as input a natural language text, but rather a *representation* of a natural language text, and does not identify the analogy underlying the metaphor, DIANA does not address the issue of recognizing the presence of the analogy in the text.

1.2.3.2. Analog Retrieval

While our tasks does not require searching long term memory for a source analog, understanding an argument-by-analogy does require a search of short term memory for a possible argument-by-analogy, when the analogy is not explicitly introduced in the text. This is needed when lexical clues are not provided in the text to introduce the analogy and guide the flow of the argument. HIGH-TECH-3 provides an example of this:

HIGH-TECH-3

> *Some people are against CAM because CAM eliminates jobs. The automobile industry caused people in the horse carriage industry to lose jobs. Consumer demand for autos was strong enough that more jobs were created in the automobile industry than were lost in the horse carriage industry. The economy benefitted by the introduction of the new technology.*

The initial belief is stated, as before, but the understander is not prompted to form an analogy between CAM and the auto industry until the end of the text is reached, and the expectation for a contrast to the initial belief remains. One technique for attacking is to introduce an analogous belief, and directly attack that. So ARIEL needs some technique for retrieving analogous concepts from short term memory.

Constraints on search and inference are essential components of analogical reasoning. Those observed in our system are similar in many respects to those employed in ACME (Holy89), ARCS (Thag90), and SME (Falk89). In ARIEL, these constraints are used not only for mapping, as in ACME and SME, and retrieval, as in ARCS, but also for inferring the missing pieces of the target analog from domain knowledge.

1.2.3.3. Mapping of Source and Target Analogs

In order to answer questions such as "What is being compared in HIGH-TECH-1?" an understander must have some representation of the correspondence mapping between the source and target analogs. How is this mapping directed? If one were to attempt to compare all features of the source analog to those in the target analog, one would surely find many points of dissimilarity. If one were to map only objects, then in HIGH-TECH-1 we would only have the CAM-automobile industry and assembly line jobs-horse carriage industry jobs mappings. The relations that hold within the analogs must be mapped as well. This mapping is essential to understanding the text, and takes place during comprehension, rather than being performed only after the entire text has been understood. In editorial understanding, the main point of the editorial constrains the linking associated with the analogy. Only those links required to support the goals of the editorial need to be made. In ARIEL, the expected structure of the argument and the propositions themselves provide pragmatic constraints on the mapping process. The comparisons explicitly made by the author, as well as those inferred during understanding are captured in the correspondence mapping developed between the analogs, to the extent that the mapping meets the constraints of semantic similarity and structural consistency.

The literature reflects several views on correspondence mapping between source and target analogs. SME (Gent83) (Falk89) (Skor87), requires identity of predicates at all levels of abstraction and develops different correspondence mappings directly between source and target depending upon the type of analogy sought. Other models (Wins80) (Wins82) (Carb83a) propose that only an indirect mapping exists between source and target, i.e., both are instances of a more general concept. Others, such as (Shin88a) and (Shin88b) incorporate mapping only directly between source and target. In our model, direct correspondence is mapped only at major points, and no agreement of predicates is required at minor points. We observe the same constraints on mapping as described in (Holy89) and (Thag90), and demonstrate how these constraints are manifested in the domain of argument-by-analogy.

1.2.3.4. Transference

In order to complete an analogy, it is essential for the reader to transfer information across domains. This raises two questions: *What needs to be transferred?* and *How is the transfer completed?* In problem solving by analogy, it is the *solution* which is transferred. In metaphor and simile understanding (Wins78) (Hobb81) (Hobb83a) (Hobb83b) only the information relevant to the context established by the non-metaphoric or source words is transferred. In editorial understanding, the decision to transfer information is prompted not only by the context established by the source domain, but also by the expectations which arise during the course of understanding and following an argument.

Once it has been decided what information needs to be transferred from the source to the target domain, some mechanism is needed to complete this transfer. A replication of the relationships which hold in the source knowledge structure in the target domain will not supply context-dependent details related to the features of the target analog. Many existing systems overcome this by relying upon the existence of a rich correspondence mapping between the source and target analogs to supply relevant, domain-dependent details, for example (Shin88a) (Shin88b) (Wins80) (Wins82). However, our earlier attempts at analogical transfer in JULIP (Augu85a) pointed out that in editorial understanding a rich correspondence mapping is unlikely to be supplied by the author. Thus, some other mechanism is needed to supply domain-dependent detail during transfer. One possibility is to exploit domain knowledge, and try to figure out what the relevant details would be, given the corresponding details from the source analog, if they exist. An alternate approach, and the one adopted in ARIEL, is to recognize that an analog has been chosen for the purpose of solving some goal, and to use that goal to guide the search for relevant domain-dependent details in the target knowledge base. This approach is proposed in (Holy85). In ARIEL, we use the underlying argument structure in the source domain to guide the transference of the source argument into an analogous target argument.

It is interesting to note that in other computational models of analogical reasoning, including (Wins78) and (Hobb81) (Hobb83a) (Hobb83b), the roles of source and target are never exchanged during understanding or problem solving. However, as seen in the example of HIGH-TECH-1 above, understanding analogies in arguments often requires a reader to transfer information back and forth across the domains or contexts, in order to make the inferences implied by the author. Thus, in ARIEL source and target are not fixed; information can be transferred as needed to facilitate understanding. As mentioned above, ARIEL employs the constraints of semantic similarity, pragmatic centrality, and structural consistency in mapping inferences.

1.2.3.5. Identification of the Point of an Argument-by-Analogy

In arguing a point, an author can argue directly, or chose to set aside the domain of the original point and argue indirectly, in another domain that is similar to the first. The analogy formed in this indirect argument supports the transfer of information across the domains.

A reader of HIGH-TECH-1 will conclude that the author thinks the introduction of computer technology will benefit the economy in the long run. Why doesn't the reader simply conclude instead that the introduction of CAM technology is a lot like the introduction of the automobile industry? A reader must be able to recognize the focus of attention of the author in order to draw the conclusion intended by the author.

Once the reader of HIGH-TECH-1 has followed the argument in the domain of the automobile industry, she must transfer that argument back to the domain of the computer industry. She can do this by applying the same line of reasoning applied in the case of automobile manufacturing, and inferring that since the use of computers will also lead to the creation of more new jobs, the introduction of computers in manufacturing must be good.

Why do people use analogies to support their beliefs? Analogy can be used as a sort of shorthand notation for conveying information that the author assumes the reader has about one domain, and that the author wants the reader to transfer to a new domain. Analogy can also acts as a vehicle to convey information which is not clearly expressed more directly, perhaps because it involves concepts which are difficult to explain. The inferences associated with the analogy can be made explicitly by the author, with the author drawing a detailed correspondence between source and target analogs, and explicitly declaring the conclusion to be drawn from the argument. This is seen in the following excerpt:

BALANCING FREEDOMS

> *[...] Consider three familiar situations that have much in common: screening of air passengers and their baggage, police roadblocks to catch drunken drivers and random urine testing for illegal drugs. In each of these circumstances, large numbers of innocent people are searched in order to catch a few who are guilty. [...]*
>
> *"Balancing Freedoms"*
> *Los Angeles Times*
> *Part II, page 4/ Thursday, September 25, 1986*

In other instances, the inferences can be left implicit by the author, in which case the reader herself must do the work of drawing the correspondence between source and target, perhaps gleaning the point of the argument by inference as well. This is seen in HIGH-TECH-1.

What is different about parsing editorial text in which points are argued by analogy, rather than being argued directly? Clearly, all the issues relevant to parsing any text -- disambiguation, domain knowledge, integration of semantic and syntactic knowledge -- come into play. In addition, the representation of the argument must also be considered. Also, the parser must deal with representing the analogy itself, and must incorporate knowledge about deciding to which domain a phrase belongs, and how to transfer information from one analog to the other.

Computational models of problem solving by analogy seek to translate the solution to a source problem into an analogous solution to a target problem (Falk89) (Shin88a) (Shin88b) (Carb83a). The output of these systems is the solution to the problem, as in (Shin88a) (Shin88b), or a completed representation of the input (Wins78) (Hobb81) (Hobb83a) (Hobb83b). These systems have no understanding about why certain facts were supplied, or what is significant about the analogy.

In editorial understanding, the reader must be able to recognize the focus of the author's attention in order to draw meaningful conclusions from the editorial. Expectations regarding the general structure of arguments serve to focus the reader's conclusion to the argument. In addition, we have identified three ways in which analogies are used in editorials. These are related to the transfer of information from the generalization formed from the analogy, as well as to the transfer of information between the source and target analogs that is both static, or time-invariant, and diachronic, related to how things change over time (Holy85). Recognizing these categories of analogy use facilitates drawing analogy-related conclusions to editorials.

Previous computational models of argumentation, such as (Flow82), (Alva89), and (Cohe87), did not address the issue of how analogy is used in argumentation. Alvarado only goes so far as to state that analogy can be used to support beliefs. The only work related to the role of analogy in arguments is (McGu85), as noted above, and JULIP (Augu85a) (Augu85b) (Augu85c). With JULIP, we showed how knowledge of argumentation facilitates the recognition and understanding of the analogy presented in an editorial text. However, neither of these directly addressed the issue of how analogy is used in arguments. Without such a model, the ability to automate understanding of editorial texts will be limited to processing those editorials in which the authors argue points directly. Analogies are frequently used in editorials regarding value judgments about various events. This research has identified a method for coupling theories of correspondence mapping and analogical transfer with expectations about the structure of arguments in order to complete an argument-by-analogy. In addition, this research has identified three ways in which people use analogies in editorials, and shows how recognizing these uses enables a reader to follow the reasoning in the editorial, and draw an analogy-related conclusion to the editorial.

1.3. Other Issues

Other interesting aspects of understanding analogies in natural language text which are beyond the scope of this research include:

1. deciding whether the analogy is a good one.
2. deciding whether the reader agrees with the point of the editorial.
3. identifying the author's opinion (perhaps this falls out from drawing the conclusion, but it is not our focus).
4. looking at how a reader's beliefs affect understanding.[3]
5. learning from the analogy.

These topics require research beyond our goals of comprehending the author's message in the editorial.

1.4. Motivation -- Why Is ARIEL Relevant?

This work addresses the problem of analogical reasoning in the domain of editorial letters. The ubiquitous nature of analogy dictates that a successful computational model of editorial understanding needs to incorporate the ability to recognize and understand analogies, complete implicit arguments by analogy, and draw appropriate conclusions from the analogy used in the editorial. Such a model would be useful, for example, in a system which identifies the political beliefs of the author of an editorial. We have previously pointed out ARIEL's relevance to natural language understanding in general. The theory embodied in ARIEL can be applied to other areas as well.

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3 (Reev88), (Reev89a), and (Reev91) discuss this topic.

1.4.1. Problem Solving

The ability to solve novel problems is an essential component of an intelligent system. Problem solving by analogy is a very valuable tool. The use of analogy in problem solving involves applying the solution from one problem to another, similar problem. This typically involves finding a related, previously solved problem, and modifying the solution to the previous problem to solve the current problem. It requires the ability to identify a related problem, as well a both domain knowledge and abstract knowledge problem-solving knowledge. The theory embodied in ARIEL can be used to support problem-solving by analogy.

1.4.2. Expert System Interfaces

An editorial is basically a one-way argument in which a person tries to persuade others to accept a particular belief, or tries to justify her reasons for making a particular decision, or choosing a particular course of action. Expert systems of the future will be expected to have this same ability. They will need to be able to explain their reasoning. They must be able to tailor their explanations to the user and the user's knowledge, creatively utilizing their own knowledge to explain or justify the new or unknown in terms of the old or known. Thus, expert system interfaces of the future will need belief models and the ability to argue. And since people so often draw upon analogy to convey ideas, the expert system interface will need to be able to recognize, understand, and produce arguments by analogy, in addition to being able to handle more direct forms of communication.

1.4.3. Legal Reasoning

Legal reasoning systems usually focus on retrieving an analogous case (Ashl87), rather than on understanding why a given case is analogous. The constraints on mapping used in ARIEL would be relevant in that domain, as well.

Legal reasoning systems do not consider the context in which one case would be useful for supporting another, nor do they include an abstract model of legal reasoning, although some work is being done in this area (McCa91). Techniques for incorporating context and an abstract model of reasoning can be derived from ARIEL for use in the legal reasoning domain.

1.4.4. Advertising

A recent ad for the version of LISP marketed by Franz Inc. is entitled "Loose Lisps Sink Chips" and is accompanied by an integrated circuit board in the shape of a ship sinking into the ocean. The thrust of the ad is that one's Lisp must be suited to one's chip in order to avoid processing disasters. In the ad, a ship is compared to a chip, the ship's cargo to a version of Lisp, and a port to a computer. There are several advantages of using this analogy. It helps the reader (1) identify or visualize the problem of a poorly designed Lisp implementation, (2) understand the value of a well designed implementation, and (2) appreciate the ease of loading a new Lisp implementation into one's current computing environment.

1.4.5. Teaching

People have difficulty explaining how they know things, or directly conveying the heuristics used to make judgments or accomplish tasks. Analogy is an effective tool for implicitly conveying information.

1.4.6. Expert/Computer Knowledge Transfer

Transferring expertise from a human expert to a computer or expert system is a difficult task. Having a computer learn directly from its experience in a particular domain is even more difficult, if learning of abstract concepts and symbolic information is necessary, instead of limiting the system to adapting based upon statistical evidence alone. A computational model of analogical reasoning would support this knowledge transfer process.

1.5. Outline of the Dissertation

This chapter has identified the issues to be addressed in developing a computational model of the process of understanding and reasoning about analogies in editorials. Textual clues, conceptual similarity, and expectations arising from editorial understanding are exploited in ARIEL to recognize the presence of an analogy in an editorial. Performing analogical transforms in our model relies upon identifying the reasoning underlying the argument in the source domain, and using this reasoning to complete an analogous argument in a target domain. An understanding of the role that analogy plays in arguments makes it possible to make inferences that are not available to a reader without this information.

The remainder of this dissertation is divided into three parts. In the first part, Chapter 2 discusses ARIEL's techniques for understanding, representing, and formulating arguments, and Chapter 3 describes the implementation of these techniques. The next part begins in Chapter 4 with a presentation of analogical reasoning as expressed in ARIEL. Chapter 5 shows how analogical transforms can be performed even in the absence of a rich correspondence mapping. Chapter 6 concludes this section with a discussion of the role analogy plays in arguments. The final part of the dissertation begins in Chapter 7, where the design of ARIEL is introduced, and understanding with various forms of input is demonstrated. Conclusions are presented in Chapter 8. The appendices include traces of ARIEL processing various texts, a survey of related work, a glossary of terms used in the dissertation, and a list of related publications.

Chapter 2

Reasoning About Arguments:

Identifying the Underlying Line of Reasoning

An editorial expresses the opinions or beliefs of its author. As such, it is like a one-sided persuasive argument. A belief is stated, then either supported or attacked. After reading an editorial, the reader expects to know what the author believes, and why she believes it. To understand an editorial, the reader must be able to identify the beliefs, supports, and attacks that are mentioned or alluded to by the author. The reader must be able to tie these parts together to form a cohesive argument. This requires the reader to have a basic idea of how arguments usually proceed, and to have the ability to generate arguments as needed to complete the author's thoughts.

The ARIEL approach to completing analogies relies on the ability to identify the structure underlying the source argument, and the ability to construct a similar argument in the target domain. The structure of arguments is captured in our model by a set of domain-independent roles that are frequently used in argument that center around the achievement and thwarting of goals.

Here we present our representation for arguments, identify the basic components of an argument, and propose a basic set of domain-independent rules for reasoning about arguments. In ARIEL, the underlying reasoning used in a belief or argument is captured by *argument rules* and *attack strategies*. These form the skeleton of the argument, or the glue that holds together the proposition and justification pieces. These rules and strategies come into play when ARIEL must complete an argument either directly, within the same domain, or indirectly, by analogy to an argument in another domain. Thus, if the context of an argument has given rise to the expectation that a belief will be attacked, and an explicit attack is not provided in the text, ARIEL must identify the argument rule underlying the proposition, as well as a relevant attack strategy.

2.1. Representing Arguments

Understanding an editorial or any form of argument requires an understanding of the basic components of arguments, and an understanding how these components are put together to form a complete argument. As understanding of an editorial argument proceeds in our model, a conceptual representation of the argument is developed in memory. The argument consists of a set of beliefs. In our model, a belief consists primarily of:

> a *proposition,* or *belief object*, and
> a *justification* for the belief.

A *proposition* consists of:

> an *event* about which a person has an opinion, and
> a *value judgment* about that event.

An *argument* is composed of one or more beliefs which either support or attack one another.

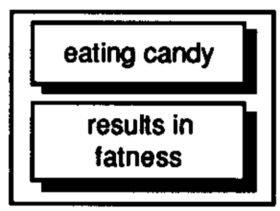
We represent the arguments in a text by maintaining a graph whose main building blocks are propositions, justifications for those propositions, and reasons why the justifications support the propositions. Given some event or sequence of events, and a model of a person, we can infer a value judgment held by the person about the event or event sequence. Consider, for example, the argument:

CANDY

Eating candy is bad, because eating candy will make you fat.

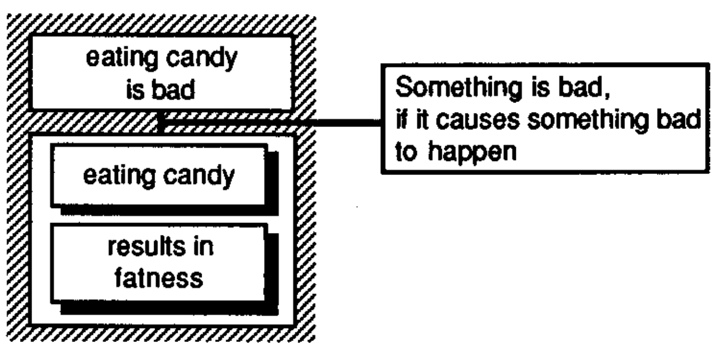
The event here is *eating candy*, and the proposition is that *eating candy is bad*. We represent this graphically as[4]:

The justification for this proposition is that *eating candy makes a person fat*, which we represent as:



In our representation, we refer to this as a causal structure. The outer box represents the entire causal structure, the top box its antecedent, and the bottom box its consequent.

The justification makes sense because underlying it is the idea that it is undesirable to be fat, so, since eating candy makes you fat, eating candy is bad. We refer to this underlying reason as an argument rule. We graph this belief as follows:



The shaded area behind the proposition and justification represents the belief containing these components. This relationship can be represented in general as:

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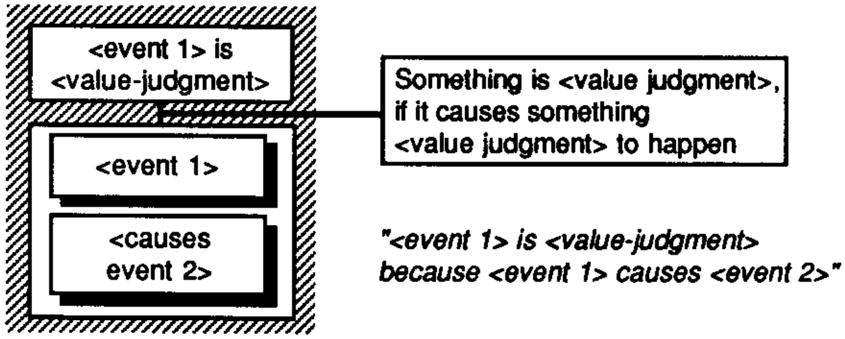
[4] The internal representation used by ARIEL is a frame-based (Mins75) or slot-filler notation. A graphical representation is used here to convey the general structure of the beliefs.



The proposition with its justification and support constitute an argument consisting of a single belief.

2.2. The Reasoning behind a Belief: Argument Rules

Underlying each belief is an abstract argument rule which indicates why a particular justification can be used to support a proposition. Consider, for example[5]:

BISON-1

People are against eliminating the existing, diseased bison population of Wood Buffalo National Park, because eliminating the animals would further reduce the population of an endangered species.

This can be interpreted as a belief that people are opposed to destroying the bison, because destroying the bison would lead to a failure of the goal of preserving an endangered species. Underlying BISON-1 is the rule that *Something is bad if it thwarts a goal.*

More complex supports are also found. Consider:

BALANCING-FREEDOMS-2[6]

While it is an invasion of privacy to screen passengers and luggage at the airport, it makes air travel safer.

The reasoning here is that screening is good, because, although it thwarts one's goal of preserving privacy, it achieves the goal of preserving life.

We have identified a set of basic argument rules that can be used to follow arguments involving beliefs about the achievement and thwarting of goals. These argument rules are represented in ARIEL in abstract form, in order to keep them domain independent. The

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[5] The *Bison* texts are based upon the article "Kill Bison Herd?" in the *Los Angeles Times*, 20 March 1990, Pt. 1.

[6] This text is based upon the "Balancing Freedoms" editorial that appeared in the Los Angeles Times, 25 September 1986, Pt. II, p.4.

argument rule associated with a proposition is identified by matching the structure of the belief containing the proposition against the known argument rules. This set currently includes the rules shown in Figure 2-1.

Argument Rule 1:	X is bad if X leads to Y and Y is bad.
Argument Rule 2:	X is good if X leads to Y and Y is good.
Argument Rule 3:	X is bad if X thwarts a goal.
Argument Rule 4:	X is good if X achieves a goal.
Argument Rule 5:	X is bad if X achieves a low-level goal Y but thwarts a high-level goal Z.
Argument Rule 6:	X is good if X thwarts a low-level goal Y but achieves a high-level goal Z.

Figure 2-1. Argument rules.

To identify the rule of argument relating a justification to a proposition, ARIEL translates between a domain-dependent representation of a belief and a domain-independent argument rule. For example, BISON-1 is represented as a belief in which a negative value judgment has been expressed about a destruction event because that event causes the failure of a preserve-endangered-species goal. We can restate this as:

> *Killing the bison is bad, because killing the bison thwarts the preserve-endangered-species goal.*

ARIEL compares this against its set of known argument rules. The negative value judgment, together with the thwarting of the goal, causes ARIEL to infer that the argument rule:

> *X is bad, if X thwarts a goal.*

has been used in this instance.

2.3. The Reasoning behind an Argument: Attack Strategies

An argument is attacked by attacking one of the components of the argument: the proposition, the justification, or the support (Flow82). To understand how a subsequent piece of information is related to the argument, we use argument rules plus knowledge of how arguments are attacked, or attack strategies. An argument can be attacked directly, as is the case when BISON-2 follows BISON-1:

BISON-2

> *However, if these animals are not destroyed, then the last remaining healthy and genetically pure herd of wood bison will be contaminated.*

That is, destroying the bison will achieve the goal of preserving the species in the long run. Underlying BISON-2 is the rule that *Something is good if it achieves a goal.* The strategy used to attack the belief justified by B-1 can be characterized as: *If something is bad because it thwarts a goal, then argue that it is actually good by showing that it also achieves a goal which is more important than the one being thwarted.* Thus, attack strategies are rules used to attack beliefs.

We have identified a basic set of strategies that are commonly used to attack beliefs which revolve around the achievement and thwarting of goals. Attack strategies in ARIEL are organized by the argument rule being attacked. That is, associated with each argument rule is one or more strategies for attacking a belief which relies upon that rule. These strategies, like argument rules, are stored in abstract form, to retain domain independence. The attack strategies currently in use are shown in Figure 2-2.

The problem of identifying an attack strategy falls into two categories: 1) identifying the strategy which an author employs, and 2) identifying an appropriate attack strategy to apply in the case that an attack is expected, but not explicitly provided.

To identify the attack strategy which an author has employed, case 1) above, the argument rule underlying the belief that is the focus of attention is first identified. Then the strategies associated with that rule are compared against the conceptual representation of the attack supplied by the author, using a scheme similar to the one for identifying the argument rule. Table 2-1 indicated which attack strategy (AS) is associated with each argument rule (AR). The strongest strategy appears first, followed by weaker strategies.

The BISON-1/BISON-2 example above is an instance of case 1. Figure 2-3 depicts the conceptual representation of BISON-1 and BISON-2, before the relationship between them is identified. The attack strategy associated with the argument rule underlying BISON-1 is AS-3. BISON-2 satisfies the criterion that the goal being achieved be higher than the goal being thwarted. Thus, BISON-2 can be instantiated as an attack on BISON-1, as shown in Figure 2-4. The appropriate proposition can then be inferred, and a new belief can be constructed, as shown in Figure 2-5.

When an attack is expected, but not explicitly provided, an appropriate attack strategy must be identified (case 2 above). In this case, the argument rule underlying the belief that is the focus of attention is identified, as in 1), and the related attack strategies are retrieved. These strategies are applied to the relevant belief in an effort to find a concept which constitutes a plausible completion to the argument in the given context. If a hypothesized attack is not contradicted by other information in the text, or by domain knowledge, the attacking concept is instantiated, and linked to the belief in an attack relationship. If a hypothesized attack is contradicted, another strategy is tried. Because the goal is to hypothesize a plausible completion, no effort is made to generate all hypothetically plausible completions in order to select the best possible.

Attack Strategy 1: If X is bad because X leads to Y and Y is bad,
Then attack by showing that
X is good because it also leads to Z and Z is good.

Attack Strategy 2: If X is good because X leads to Y and Y is good,
Then attack by showing that
X is bad because it also leads to Z and Z is bad.

Attack Strategy 3: If X is bad because X thwarts a goal Y,
Then attack by showing that
X is good because, although it thwarts goal Y,
it also achieves goal Z,
and Z is a higher-level goal than Y.

Attack Strategy 4: If X is good because X achieves a goal Y,
Then attack by showing that
X is bad because, although it achieves goal Y,
it also thwarts goal Z,
and Z is a higher-level goal .

Attack Strategy 5: If X is bad because X achieves a goal W
but thwarts goal Y, and Y is a high-level goal than W,
Then attack by showing that
X is good, because although it thwarts goal Y,
it also achieves goal Z
and Z is a higher-level goal than Y.

Attack Strategy 6: If X is good because X thwarts a goal W
but achieves goal Y,
and Y is a higher-level goal than W,
Then attack by showing that
X is bad, because, although it achieves goal Y,
it also thwarts goal Z
and Z is a higher-level goal than Y.

Figure 2-2. Attack strategies.

Table 2-1. Attack strategies indexed by argument rule.

Argument Rule	Relevant Attack Strategies
AR-1	AS-1
AR-2	AS-2
AR-3	AS-3, AS-1
AR-4	AS-4, AS-2
AR-5	AS-5, AS-3, AS-1
AR-6	AS-6, AS-4, AS-2

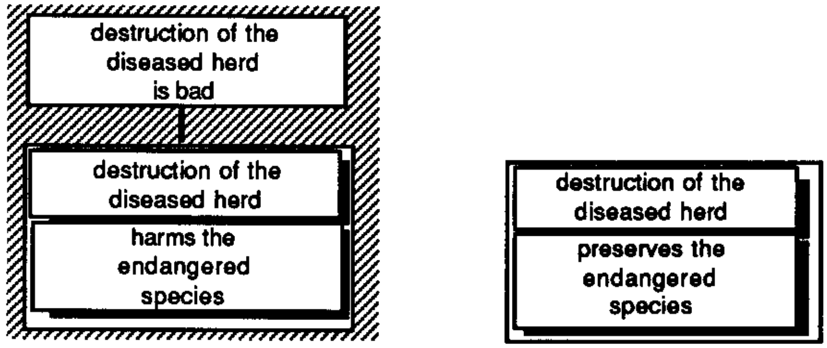


Figure 2-3. Graphical representation of BISON-2 and BISON-1.

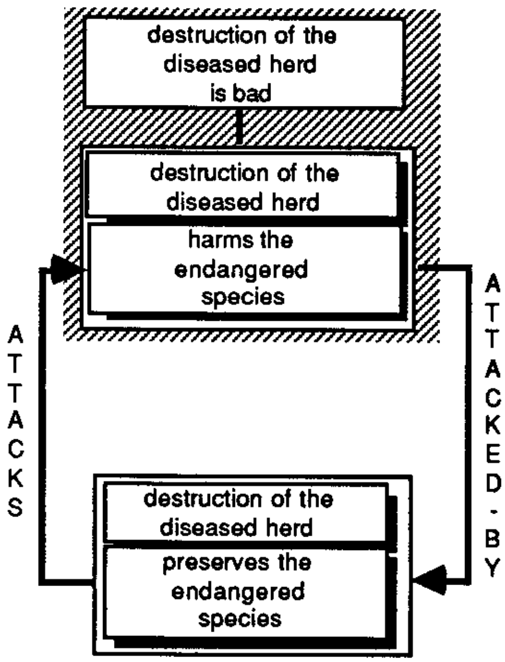


Figure 2-4. BISON-2 attacks BISON-1.

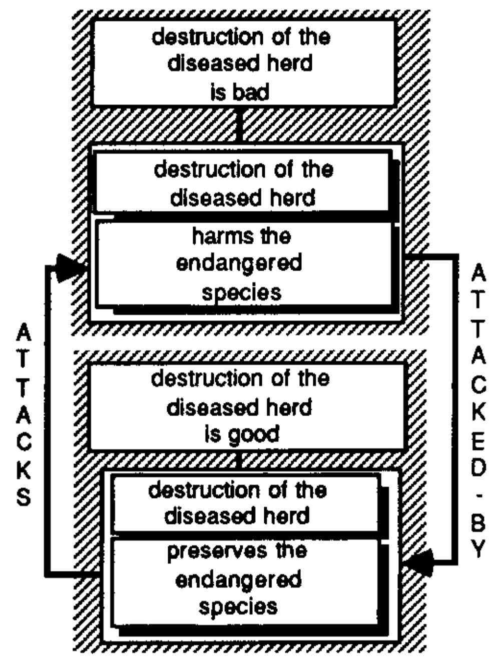


Figure 2-5. BISON-1/BISON-2 completed.

2.4. Rules and Strategies Provide Flexibility

A significant property of our argument rules and attack strategies is that they are used both for argument comprehension, that is, for translating the editorial into a conceptual representation, and also for reasoning about the argument after all of the text has been read, that is, to generate an argument or part of an argument to explicitly represent what the author has implied. Another significant property of our argument rules and attack strategies is that they are basically described at an abstract level, and are therefore domain independent. We rely upon domain-specific bodies of knowledge to instantiate arguments and recognize components of arguments. Therefore, the argument rules and attack strategies presented here can be used to reason about arguments in any domain. It is only within a particular domain, and within a particular context within that domain that value judgments such as "X is good" have any meaning, since value judgments are relative, and not absolute values.

ARIEL's sets of argument rules and attack strategies revolve around the achievement and thwarting of goals. They are not intended to represent a complete set of possible rules and strategies, but rather to identify the kinds of information that is needed to follow and represent arguments. Our sets can easily be augmented to include strategies for supporting propositions. They can also easily be augmented to support understanding and reasoning about other types of arguments. Another interesting extension to this work would be to learn frequently encountered argument patterns, and retain them in structures similar to Argument Units (Alva89).

ARIEL uses this knowledge of argument rules and attack strategies both to understand and to follow arguments, and to formulate arguments as needed to fulfill expectations generated during understanding. When an author chooses to attack an argument indirectly, using an analogy to convey her opinions, ARIEL can use this knowledge of argument rules and attack strategies to identify the reasoning underlying an argument, and transform an argument in the source domain into an analogous argument in the target domain.

2.5. Summary

Our model for understanding arguments constructs a graph containing beliefs connected in support and attack relationships. The basic building blocks of these beliefs are propositions and justifications for the propositions. Domain-independent argument rules and attack strategies capture the line of reasoning underlying the beliefs and arguments. This representation of argument structure provides ARIEL with the ability to formulate arguments, which is a key component in the process of completing arguments-by-analogy. The next issue to be addressed is the incorporation of this knowledge into the general understanding mechanism.

Chapter 3

Understanding Arguments

The previous chapter presented the building blocks for representing arguments and reasoning about them. This chapter illustrates how this knowledge is made an integral part of natural language understanding, and identifies the mechanisms employed to recognize and follow the flow of argument in the text.

In order to be robust enough to understand arguments across domains, the structure of beliefs and arguments must be captured in abstract, domain-independent patterns. In making the transition from the text to these domain-independent patterns, domains-specific knowledge and patterns are used to understand and represent text at the domain level. Higher-level or more abstract patterns are then recognized in the lower-level patterns.

The basic understanding mechanism in ARIEL is a phrasal parser. Lexical entries consist of concept-pattern pairs. A pattern is matched against the text, and the corresponding concept is instantiated. The pattern can be a word or sequence of words, or a concept or sequence of concepts, or a combination of words and concepts. The concepts range from low-level concepts, such as *body-part*, to high-level concepts, such as *belief*. The parser maintains a parse tree, and adds each new node as the right-most branch of the root.

We have seen how arguments are represented in ARIEL. Now let us examine how ARIEL goes about understanding the arguments it encounters.

3.1. Abstract Pattern-Concept Pairs Capture the Structure of Arguments

The overall structure of the argument is represented in ARIEL as a sequence of concepts in the phrasal parsing lexicon. This is used to represent the "external shape" of an argument. Recall, for example:

BISON-1

> *People are against eliminating the existing, diseased bison population of Wood Buffalo National Park, because eliminating the animals would further reduce the population of an endangered species.*

The phrase *eliminating the existing, diseased bison population of Wood Buffalo National Park* is eventually classified by the parser as a <destruction-event>, and *eliminating the animals* as the same <event>. This <event> is interpreted as having the consequence that it will *reduce the population of an endangered species*, which is eventually mapped to a failure of a preserve-endangered-species goal. This leads to the classification of the subordinate clause of this sentence as a <causal-structure>[7]. Subsequently, the input is found to match the high-level pattern:

---

[7] The emphasis in our work is on augmenting a natural language understanding system with the ability to reason by analogy, rather than developing the basic understanding mechanism; thus, we are not making any claims about the basic phrasal parsing mechanism employed.

```
<human> <aux-verb> against <event> because <causal structure>
```

which is associated with the semantic construct:

```
(belief 'name 'to be against
        'actor <human>
        'b-object (b-object 'event <event>
                            'value-judgment 'negative)
        'justification <causal-structure>)
```

that is, a belief that people are opposed to destroying the bison, because destroying the bison would lead to a failure of the goal of preserving an endangered species.

Because this pattern is in abstract form, it can match against concepts stemming from other domains, as well. Recall the first sentence of HIGH-TECH-1:

Some people are against computer-aided manufacturing because CAM eliminates people's jobs...

As understanding progresses, text matches against the lexical entries as shown in Figure 3-1. Subsequently, the input is found to match the high-level pattern shown above (Figure 3-2). Figures 3-3 and 3-4 display the equivalent information for BISON-1.

By using abstract patterns reflecting beliefs, ARIEL can capture the structure of arguments in many domains. The domain-specific entries can be added to the lexicon to enable the system to understand texts from other domains, but without affecting the recognition or processing of these abstract patterns.

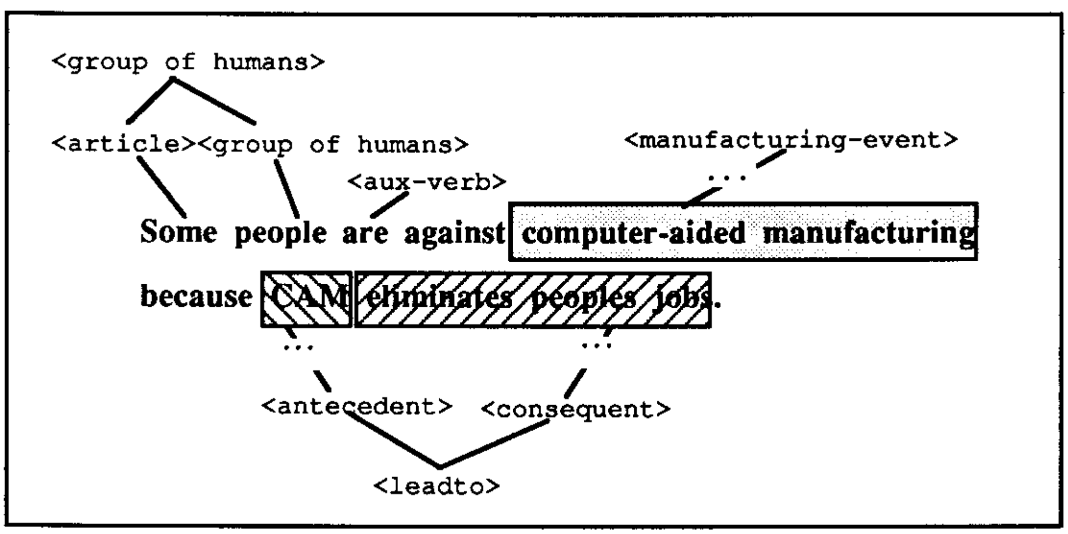


Figure 3-1. HIGH-TECH-1, sentence 1, matched against lexical entries.

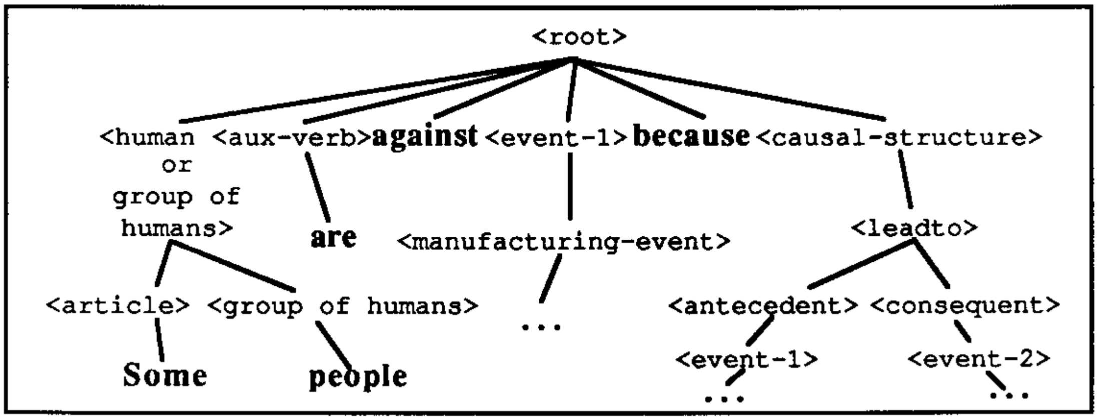


Figure 3-2. Parse tree for HIGH-TECH-1, sentence 1.

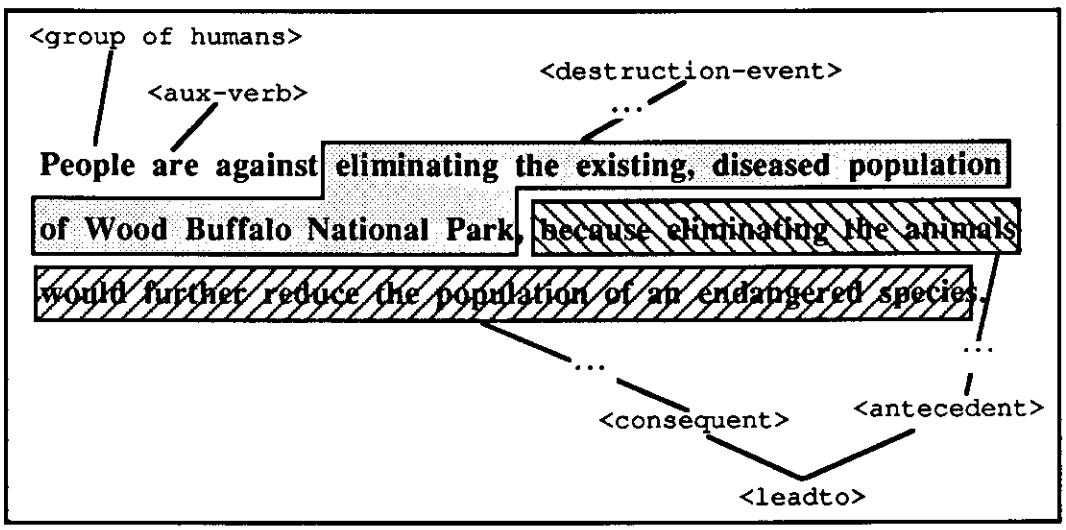


Figure 3-3. BISON-1 matched against lexical entries.

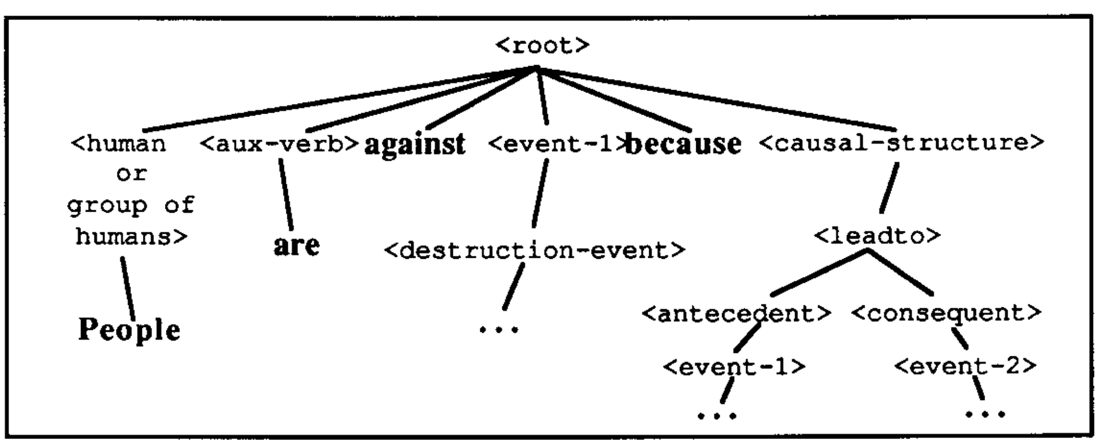


Figure 3-4. Parse tree for BISON-1.

3.2. Argument Structure-Related Expectations Facilitate Understanding

Effective communications often follow a standard form referred to as the *PREP* or *OREO* formula: Make a *P*oint, give a *R*eason, cite an *E*xample, make the *P*oint again, or State an *O*pinion, provide a *R*eason, give an *E*xample, restate the *O*pinion. This structure is exploited in ARIEL, and is the source for three important assumptions. First, when a proposition is encountered, a justification for the proposition is expected. Second, it is assumed that the first proposition in the argument is the focal point of the argument. Third, each belief is expected to be related via attack or support links to the other beliefs encountered. When a belief is encountered, a support for or an attack on that belief is sought. These expectations are represented in two ways: implicitly, in procedures associated with lexical entries, and explicitly, in argument-related expectation demons.

In addition to the linguistic pattern-semantic concept pair, lexical entries can contain a *parse test* and a *parse procedure*. If a linguistic pattern is tentatively matched, the parse test is run; the semantic concept is instantiated only if the test is successful. Once the concept has been instantiated, the parse procedure is run to perform any additional processing associated with matching the lexical entry. Argument-related expectations can be expressed in both the test and procedure parts of the lexical entry.

3.2.1. Understanding with Lexical Clues

Authors often use clue words or phrases, such as "however", "yet", or "on the other hand", to facilitate the flow of ideas in an argument. Consider, for example, the following:

PAPAL-WINDOW

> *Paul Conrad suggests [...] that Pope John Paul II, in firing Father Charles Curran of Catholic University of America, has shut the windows of the Catholic Church opened up by Pope John XXIII. Yet it is hardly clear that John XXIII wanted to open windows in order to throw out the Ten Commandments. [...]*
>
> *"Papal Window"*
> *Kevin G. Long*
> *Milwaukee, Wisconsin*
> *Los Angeles Times*
> *Part II, page 4/ Tuesday, September 16, 1986*

Lexical clues related to argumentation can be exploited in conjunction with the model's knowledge of argument structure to cause the model to anticipate that a particular proposition will be attacked. These phrases are often used to introduce a contrast to a concept previously encountered in the text. This is handled with two types of lexical entries. In the first, the parse test of the procedure initiates a search for a previous belief contradicted by the current concept. If located, the match on the entry succeeds, and a relevant belief is instantiated, based on the current concept. In the second type of lexical entry, the parse procedure places on the agenda an expectation for a contrast to the previous concept. When a phrase beginning with "however" is matched, a demon to search for a contrasting concept is placed on the expectation agenda, as shown in the following lexical entry:

```
linguistic pattern:
            however <causal-structure>
semantic concept:
            <causal-structure>
```

```
parse test: Is there a previous analogous concept which
            might subsequently be contrasted by this
            concept?
parse proc: Add to the expectation agenda an expectation
            for a contrast to that previous belief.
```

The steps for processing this expectation are as follows:

```
find-direct-contradiction-to belief

Does a belief which constitutes an attack on belief
already exist in memory?

If so, identify the attack strategy employed and
note the attack relationship.

Otherwise, identify the argument rule underlying
belief, retrieve a relevant attack strategy, and
apply it to belief, using existing structures in
short term memory to instantiate the attack, before
creating new ones.

If the result contradicts domain knowledge, or the
application of the strategy is unsuccessful, try
another instantiation, or another relevant
strategy.
```

When this expectation is executed, if the concept to which a contradiction is expected is a belief, this demon will check whether an attack on the justification of that belief already exists. If one does, the demon is killed. Otherwise, a search for a contrasting concept ensues.

Recall BISON-2 from Chapter 2:

BISON-2

> *However, if these animals are not destroyed, then the last remaining healthy and genetically pure herd of wood bison will be contaminated.*

When this text is encountered, and the destruction of the herd leading to long-term preservation of the species is interpreted as a causal structure, BISON-2 matches the `however <causal-structure>` pattern. In the BISON-1/BISON-2 context, when this phrase is identified, the demon *expect-contrast-to* BISON-2 is placed on the expectation agenda. When this demon is processed, it is discovered that BISON-2 contrasts with BISON-1:

> *B-1: If the animals are destroyed, the population will be reduced in the short run.*
>
> *B-2: If the animals are destroyed, the population will be preserved in the long run.*

Since B-1 is part of a belief, two things happen. First, B-2 is interpreted as an attack on that belief. Links are generated between the justification of B-1 and the justification of B-2, indicating that the latter is an attack on the justification of the former. Secondly, B-2 is made the justification for a new belief; because B-2 contradicts B-1, and the value-judgment associated with B-1 is negative, the value-judgment associated with B-2 is positive.

3.2.2. Understanding without Lexical Clues

Although argument-related clue words are often present in arguments, they are not always available. ARIEL relies on domain knowledge, context, and expectations related to argument understanding to follow arguments and to attribute justification for propositions. Expectation demons are associated with lexical entries in which the semantic concept to be instantiated is a belief, but no lexical clues exist in the linguistic pattern to be matched. An instance of this type of lexical entry is:

```
linguistic pattern:
            <human> <aux-verb> against <event>
            because <causal-structure>

semantic concept:
            (belief 'leB4-con1
                  'name 'to-be-against
                  'actor <human>
                  'b-object (b-object 'leB4-con2
                              'event <event>
                              'v-judge 'negative)
                  'justification <causal-structure>)

parse proc: Add to the agenda the expectation for a
            contrast to this belief.
```

When BISON-1 is encountered, the demon *expect-contrast-to BISON-1* is placed on the expectation agenda. Thus, if BISON-2 did not begin "However...", ARIEL would still be able to produce a representation of the ensuing argument similar to the one it produces in the case where the lexical clue is employed. This can lead to the duplication of expectations during understanding. Our system allows all occurrences of the expectation to be added to the agenda. The expectations are processed in a LIFO manner. When an expectation picked from the agenda has not yet been satisfied, an attempt is made to satisfy the expectation. If successful, the expectation is "killed" and removed from the agenda; otherwise, it is left on the agenda, and the next expectation is considered. If the selected expectation has already been satisfied, it is simply killed and removed from the agenda. Thus, a check for duplicate expectations is not deemed to be necessary.

3.2.3. Using Expectations to Link Beliefs

Whenever ARIEL encounters a phrase in the text that maps to a *belief* concept, an effort is made to relate that belief to other beliefs encountered during understanding. The *parse test* can seek out a contrasting belief in short term memory (STM). This would happen in the case that something in the text, such as a clue word, indicates that the contrast might have already been encountered. If a contrasting concept is found, the belief can be instantiated, and the appropriate attack or support relationships can be added to the representation. An example of this type of argument-related lexical entry is as follows:

```
linguistic pattern: yet <causal-structure>

semantic concept:
            (belief 'le39rev-con1
                  'b-object (b-object 'le39rev-con2)
                  'justification <causal-structure>)

parse test: Does <causal-structure> contradict a belief
            already encountered?

parse proc: Complete b-object for this new belief, based
            upon the b-object for the contrasting belief,
            and link the contrasting beliefs.
```

If the contrasting concept is not found, the match to this lexical entry fails, and another lexical entry is tried.

3.3 Summary

Abstract pattern-semantic concept pairs and expectations about the structure of arguments are needed to capture the structure of arguments. The most significant expectations are that each proposition will be justified, that the first belief encountered will be the focal point of the argument, and that each belief will constitute either an attack on or a support for another belief in the argument. These abstract patterns and expectations apply to multiple domains. The abstract patterns can be mapped to lower-level patterns from many domains, providing a robust understanding mechanism.

Chapter 4

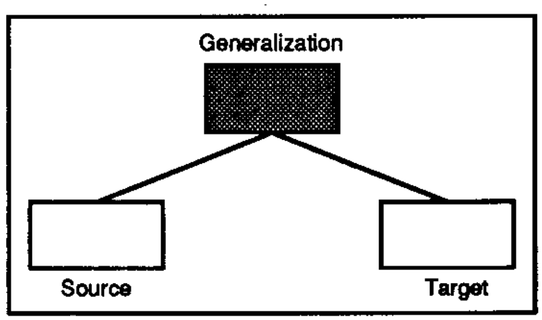
Arguing by Analogy: How Analogies are Used in Arguments

Understanding an editorial often requires a reader to follow an argument by analogy. In arguing by analogy in an editorial letter, the author of a letter presents a point in one domain, then proceeds to argue the point in another, analogous domain. The author might or might not repeat the same argument strategy in the original domain. If the author does not, the reader must. This requires the reader to transform the author's argument across domains. The reader must be able to: 1) recognize that an analogy is being used, 2) follow and formulate an argument, 3) identify what is similar in the two domains, 4) explicitly complete the analogy if the author has not done so, and 5) understand why the analogy was employed, in the sense of drawing an appropriate conclusion from the editorial.

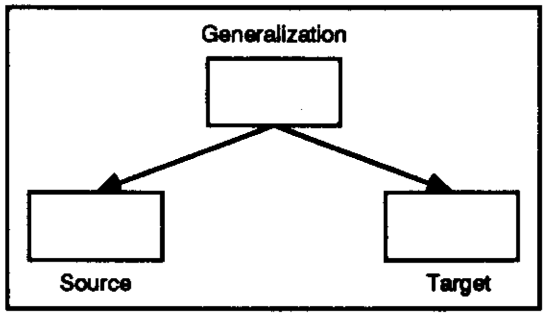
In the previous chapters we presented our model of argumentation, and showed how argument understanding proceeds with this model (item 2 above). In this chapter we will first look at analogy in general, then examine the role analogy plays in editorials, and the inferences that can be made from an editorial based on the role analogy plays in it (item 5). In Chapter 5 we will explore analogy recognition (item 1), as well as the process of identifying similarities, which is required by the mapping and retrieval tasks (item 3), and which lies at the core of representing analogies. Chapter 6 discusses the way analogical transforms are performed by ARIEL (item 4).

4.1. The Structure of Analogy

To understand how analogies are used in arguments, we must first examine how analogies are used in general. The basic idea behind analogical reasoning is that if we can show that a pair of events or objects are similar, we can make inferences about one member of the pair (the target analog) based upon inferences which we already know hold true about the other (the source analog). In arguing by analogy, the set of inferences which can be made include value judgments about the event or object. In our model, each analog consists of an argument, as described in Chapter 2. The analogs share a conceptualization. That is, each can be seen as a specific instance of a more general structure. Thus, the analogy has three main components: the generalization, the source analog, and the target analog. An analogy is formed to show that the analogs share a conceptualization at some more abstract level:

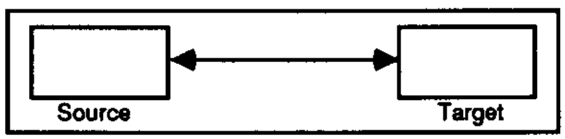


Both analogs can inherit knowledge from that structure, in which case the information flow is from the general instance to the specific:



This case can also be viewed as a flow of information from a specific instance to a general instance to a second specific instance; that is, information flows indirectly between the source and target.

The existence of some features which are shared by the analogs implies that additional shared features exist. These shared features form the basis for a correspondence mapping between the analogs. This mapping allows information to flow directly between the source and target analogs:



Dealing with analogy required identifying what aspect of the analogy itself needs to be represented, and deciding how should it be represented. One possible view is that the analogy exists on its own, as a separate entity. This would imply that the analogy exists outside of the context in which it occurs. Another possible view is that the analogy exists only in the links between analogous features of the objects being compared, implying that the analogy exists only as a relationship between two concepts. The approach to representing analogies which is promoted in ARIEL is that the analogy exists as a relationship between concepts *in a particular context*. The ability to generalize is essential in the reasoning process, but any generalization recognized during understanding is not explicitly represented as part of the analogy.

4.2. The Role of Analogy Editorials

People argue constantly, and frequently employ analogies in the process. We see evidence of this in editorials. What do people gain by relying on analogy? People use analogy in editorials for one or more of the following reasons:

1. To argue for consistent value judgments about similar events.
2. To infer that two events are similar instances of a more general structure.
3. To infer that similar events will have similar consequences.

Figure 4-1 gives a very general view of the way analogies are used in arguments. The numbers on the links in the figure refer to the categories of analogy use. The CT designation indicates that the link is a part of the correspondence mapping between the source and target analogs. In a given editorial, all of these links might be present. These links give rise to expectations about the structure of the argument-by-analogy, and guide the reader in making an relevant inferences about the analogy and the argument.

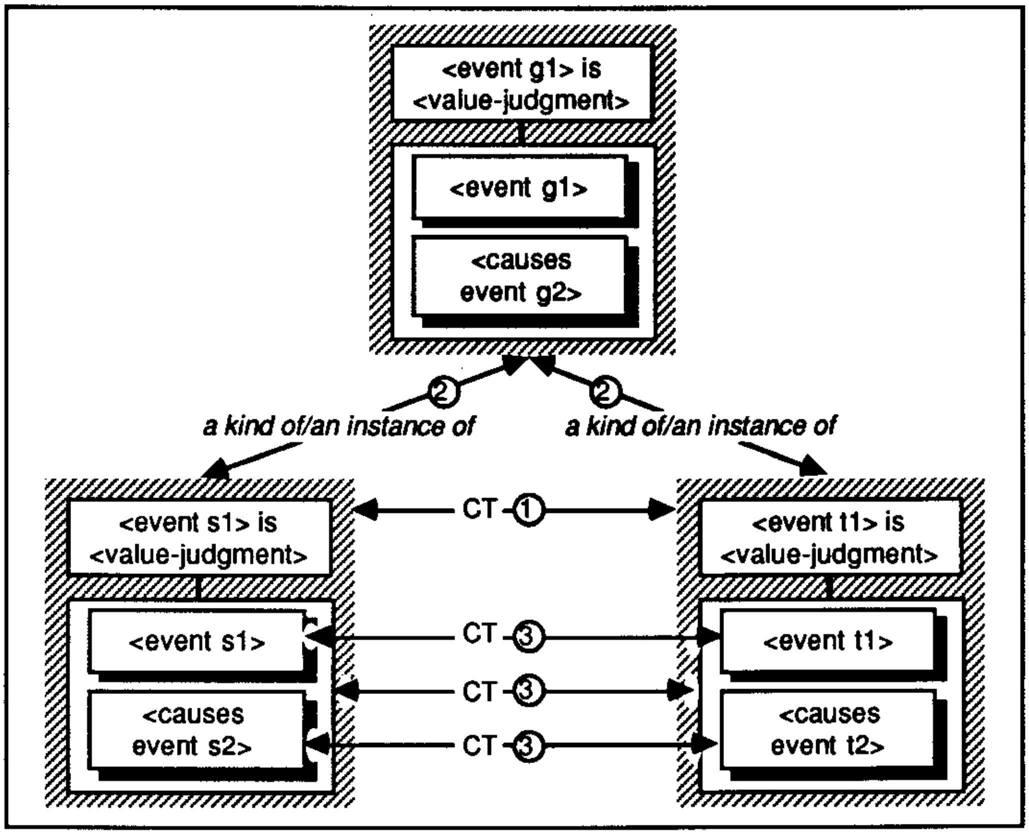


Figure 4-1. General diagram of the use of analogies in arguments.

Associated with each of these uses of analogy in an argument is a particular chain of reasoning. We have characterized these as *CONSISTENT VALUE JUDGMENTS*, *JOIN THE CLUB*, and *SIMILAR CONSEQUENCES*. This list does not exhaust the possible uses of analogy. The uses mentioned here are related to direct (*CONSISTENT VALUE JUDGMENTS* and *SIMILAR CONSEQUENCES*) vs. indirect (*JOIN THE CLUB*) mapping in an analogy, and to the kinds of inferences frequently made in arguing a point by analogy. *CONSISTENT VALUE JUDGMENTS* and *SIMILAR CONSEQUENCES* can be viewed as specific instances of a more general category for analogy use: *If two events, objects, or concepts are similar in some respects, they are probably similar in other respects as well.* We differentiate these two categories to emphasize or reflect how analogy is used in editorials.

4.2.1. Consistent Value Judgments

An author can employ an analogy in an argument in order to justify a certain value judgment, that is,

> *CONSISTENT VALUE JUDGMENTS: If we consider two events to be analogous, we should have the same value judgment about each.*

Analogy is used this way in ILLEGAL-DRUGS:

ILLEGAL-DRUGS

> *Instead of addressing the major sicknesses of our society, we grandstand against drugs. Trying to convince anyone who has taken drugs without negative consequences that they are universally bad falls on deaf ears, and rightfully so.*
>
> *The main problem with drugs is their illegality, not their chemical reactions. [...]*
>
> *The tobacco and alcohol producers are not hunted down as killers and destroyers. Nor should be the users or producers of drugs, which differ only in that they are illegal. [...]*
>
> *"The Main Problem With Drugs Is Their Illegality"*
> *Michael Hubbs, Northridge*
> *Los Angeles Times*
> *Part II, page 2/ Saturday, September 20, 1986*

CONSISTENT VALUE JUDGMENTS is employed both to attack a negative value judgment as well as to attack a positive value judgment. In this editorial, the author compares illegal drugs to tobacco and alcohol, on the basis that all three are harmful to health. He makes three major inferences: 1) if one considers illegal drug use to be bad because it leads to poor health, then one should also consider tobacco and alcohol bad as well, since they also lead to poor health; 2) if tobacco and alcohol production and distribution are acceptable, although they have harmful effects on health, then drug use should also be acceptable; and 3) it is the fact that use of illegal drugs forces one to associate with criminal elements that makes drugs bad, not the harmful effects that drugs have on people. The author of ILLEGAL-DRUGS has accepted the standard proposition that drugs are bad, but has substituted a different justification for this proposition.

Recognizing *CONSISTENT VALUE JUDGMENTS* in ILLEGAL-DRUGS enables the reader to make the following inference:

> *CONSISTENT VALUE JUDGMENTS:*
> *If drugs are illegal because they cause illness, then alcohol and tobacco should also be illegal.*
> *If production and distribution of alcohol and tobacco are legal, although they endanger health,*
> *then production and distribution of drugs should also be legal.*

These inferences are not mentioned explicitly in the editorial. They can be inferred only by recognizing the analogy, and understanding how it is being utilized. A similar inference is encountered during understanding of the first two sentences of HIGH-TECH-1, when the comparison is made between the current introduction of CAM technology and the introduction of the automobile industry in past years:

HIGH-TECH-1 (sentences 1-2)

> *Some people are against computer-aided manufacturing because CAM eliminates people's jobs. However, the automobile industry did the same thing to people in the horse carriage industry...*

Recognizing *CONSISTENT VALUE JUDGMENTS* in HIGH-TECH-1 enables the reader to make the inference:

> *CONSISTENT VALUE JUDGMENTS:*
> *If CAM is bad because it causes job loss, then the introduction of the automobile industry was also bad.*

In Figure 4-2, ① identifies the link formed as a result of the inference related to *CONSISTENT VALUE JUDGMENTS*. In this case, a link is formed between the two beliefs containing the analogous value judgments.

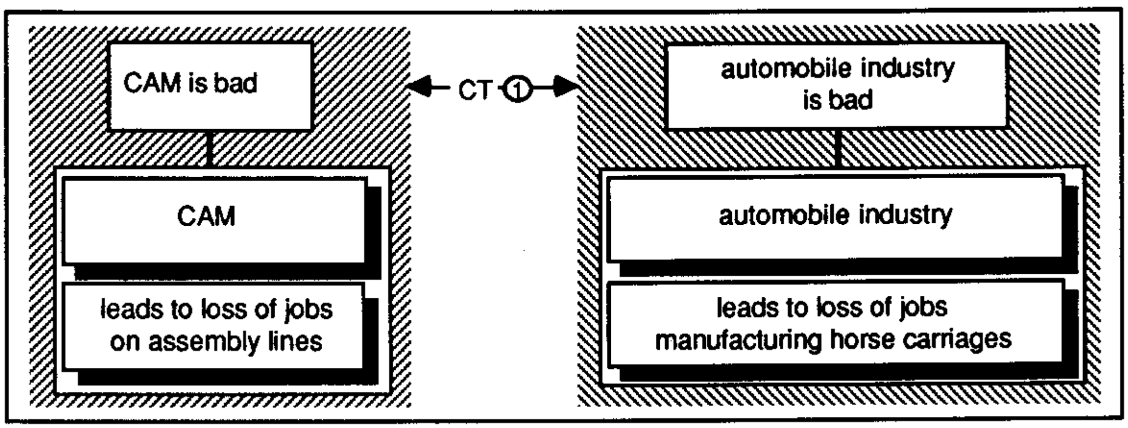


Figure 4-2. *CONSISTENT VALUE JUDGMENTS* in HIGH-TECH-1.

As in the case of ILLEGAL-DRUGS, this inference can only be made by understanding the role that the analogy plays in the argument. Thus, *CONSISTENT VALUE JUDGMENTS* provides a framework for following the author's reasoning.

4.2.2. Join the Club

Sometimes an author's point is that one event is actually the same as another apparently unrelated event. By showing that both are actually specific instances of a more general event, the author can transfer to the former the value judgments already held about the latter. The intent is to give a stronger, more general justification for the value judgment, that is,

> *JOIN THE CLUB: If two seemingly disparate events can be shown to be analogous instances of a more general structure, we can infer that the value judgment held about the more general structure applies to both events.*

The following letter contains an example of this technique:

LAUGHABLE

I enjoyed the April 4 feature on minority car dealers in the Southland, "Making Inroads in the Southland."

To the black car dealership owner who said that when he is standing on the lot with one of his white salespeople, a vendor or customer invariably will address the salesperson as the one with authority, I would like to say, "Join the crowd."

I own a restaurant in Bakersfield and have found it amusing that invariably when I have been standing with my male managers, customers and vendors always talk to them when they want someone with authority. [...]

I have encountered this prejudice/stereotyping many, many times on the job and still - after 16 years there - am correcting people who introduce me as the restaurant owner's wife. After a 60-hour work week, I find that description laughable.

Margaret Lemucchi, Bakersfield
Los Angeles Times
Letters, Part IV, page 3/Sunday, May 8, 1988

Here the author is claiming that the experience of a black owner of a car dealership is similar to her experience as that of a female restaurant owner. Both are instances of prejudice and stereotyping, and thus any beliefs about prejudice and stereotyping are inherited by both experiences. LAUGHABLE is diagrammed in Figure 4-3.

Recognizing *JOIN THE CLUB* in LAUGHABLE enables the reader to infer:

JOIN THE CLUB:
Given a black man and a white man standing at a car dealership, assuming that the white man is in charge is just as much an instance of stereotyping and prejudice as, given a man and a woman behind the counter in a restaurant, assuming that the man is in charge, and, as such, both are equally bad.

The categorization of both incidents as instances of discrimination is mentioned in LAUGHABLE. However, the inference that these two incidents are comparable, as captured in link ①, would not be made without knowledge of analogical reasoning.

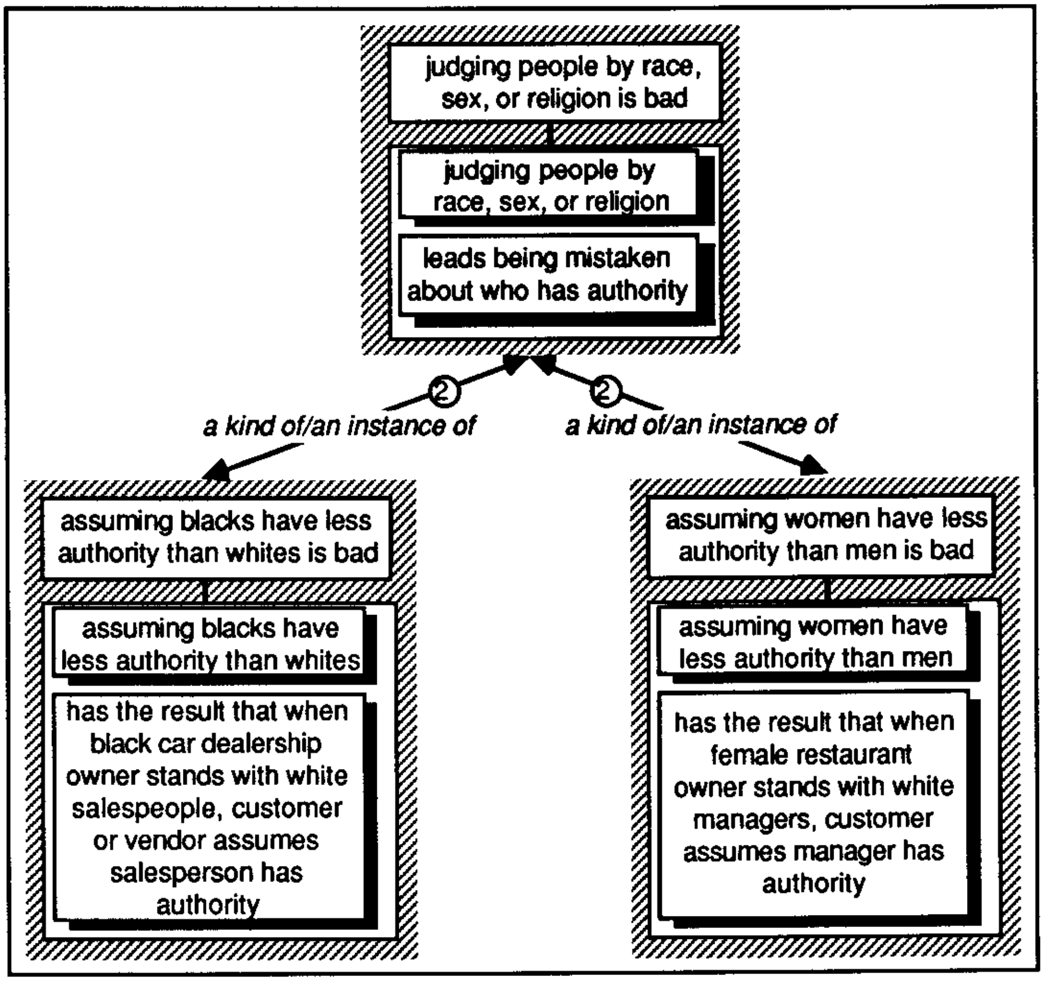


Figure 4-3. Diagram of LAUGHABLE.

4.2.3. Similar Consequences

An author can employ an analogy in an argument to predict the outcome of an event in the source domain, that is,

> *SIMILAR CONSEQUENCES: If two events are analogous, we can expect them to have the same results.*

An example of this line of reasoning is seen in REVOLUTION:

REVOLUTION

> *The Soviets are doing the same thing in Lebanon that they did in Vietnam. By supplying the Syrians and Druze with weapons, the U.S.S.R. is fostering internal feuds and abetting the downfall of Lebanon. In the end, the Soviets will not have lost one soldier, but they will have a stranglehold on the area.*
>
> *Robert Christison, Aberdeen, Scotland*
> *TIME*
> *October 1983*

Here the author is arguing that Soviet involvement in Lebanon will have the same consequences that Soviet involvement in Vietnam had. The author also implicitly employs *CONSISTENT VALUE JUDGMENTS* to argue against the Soviets' involvement in Lebanon. Figure 4-4 depicts the structure of the analogy in REVOLUTION. *SIMILAR CONSEQUENCES* results in links being created between the analogous events (*Soviets supply Syrians and Druze with weapons* and *Soviets supplied Viet Cong with weapons*), and their results (*Soviets foster feuds in Lebanon* and *Soviets fostered feuds in Vietnam*), and between the higher-level constructs containing these events (*supplying Syrians with weapons will foster feuds* and *Supplying Viet Cong with weapons fostered feuds*).

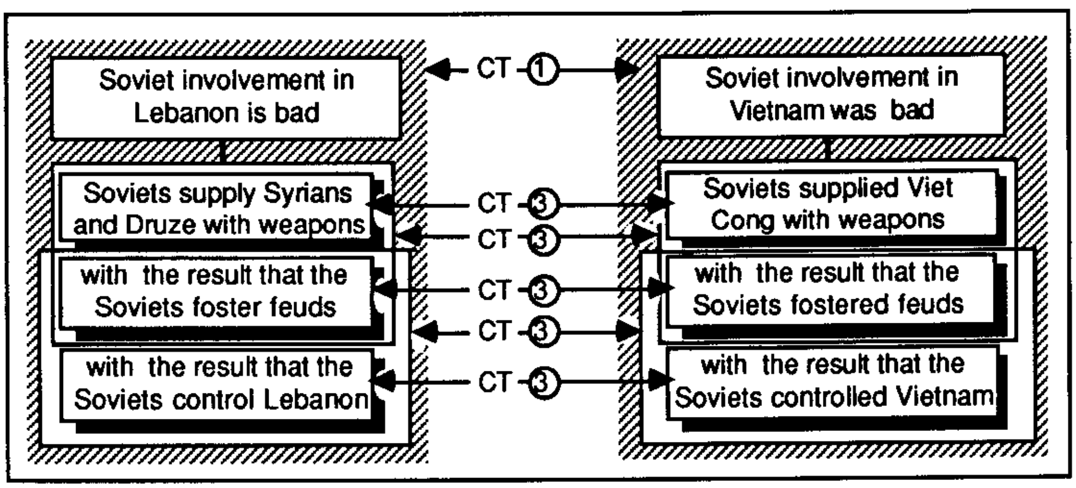


Figure 4-4. Diagram of REVOLUTION.

Recognizing these applications of analogy enables the reader to make the following inferences:

SIMILAR CONSEQUENCES:
If the Soviets foster internal feuds in Lebanon, they will gain control of Lebanon, just as they fostered internal feuds in Vietnam and gained control in Vietnam.

CONSISTENT VALUE JUDGMENTS:
Soviet involvement in Vietnam was bad, because it enabled the Soviets to gain control of Vietnam. Soviet involvement in Lebanon is bad, also, because it will enable the Soviets to gain control of Lebanon.

Similar inferences are made in final portion of HIGH-TECH-1, when an implicit comparison is made between the effects of the auto industry and the effects of CAM technology:

HIGH-TECH-1 (sentences 3-4)

> *... Yet consumer demand for autos was strong enough that more jobs were created in the automobile industry than were lost in the horse carriage industry. In the end, the economy benefitted by the introduction of the new technology.*

CONSISTENT VALUE JUDGMENTS is employed again as well, to argue for the introduction of CAM technology. The final portion of HIGH-TECH-1 is depicted in Figure 4-5.

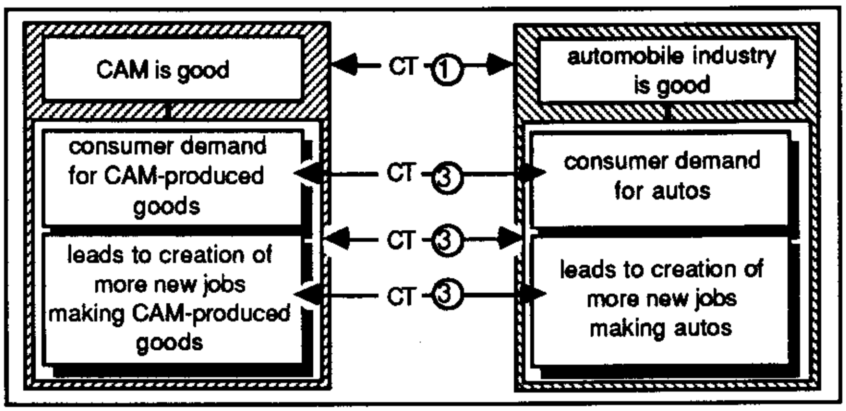


Figure 4-5. *SIMILAR CONSEQUENCES* and *CONSISTENT VALUE JUDGMENTS* in the final portion of HIGH-TECH-1.

Recognizing these applications of analogy enables the reader to make the following inferences:

SIMILAR CONSEQUENCES:
If the automobile industry created more jobs than were lost, then the introduction of CAM technology will also create more jobs than were lost.

CONSISTENT VALUE JUDGMENTS:
If the introduction of the automobile industry was beneficial, then CAM will also be beneficial.

Inferences related to *SIMILAR CONSEQUENCES* and *CONSISTENT VALUE JUDGMENTS* are not explicitly made in the texts of REVOLUTION and HIGH-TECH-1. They can only be made by incorporating an analogical reasoning component in the understanding mechanism.

4.3. Summary

The ability to understand analogies is an important part of understanding editorials. In our model, analogy exists as a relationship between concepts in a particular context. An understanding of the role analogy plays in arguments facilitates the process of making analogy-related inferences about an argument. Knowledge of this role gives rise to expectations about the structure of arguments-by-analogy, which, in turn, guide a reader through the process of understanding such arguments. In the next chapter we will look at these expectations, and see how they can be used to recognize the presence of analogy, and guide the development of a correspondence mapping between the source and target analogs.

Chapter 5

Recognizing and Mapping Analogies

Understanding an argument-by-analogy requires the reader to recognize the presence of the analogy in the argument, and to develop a correspondence mapping between similar components in the source and target analogs. Knowledge of the role analogy plays in argument facilitates this recognition process, and engenders the making of inferences during understanding.

Before any reasoning can be done regarding the analogy in an argument, the presence of the analogy in the argument must first be detected. Our model of analogy understanding accounts for both overt and covert introduction of analogies into the text. During understanding, lexical clues in the text, the similarity of concepts encountered, and a knowledge of the use of analogy in arguments cause the model to recognize the presence of an analogy in the editorial. These components must be integrated with one another to facilitate understanding. To clarify our discussion, in this chapter we will examine the use of lexical clues in the recognition process first, and then identify constraints that guide understanding. We complete the chapter by presenting criteria for identifying and mapping similarities between the analogs.

5.1. Exploiting Lexical Clues in Recognizing Analogies

Often analogies in arguments are introduced (overtly) via lexical clues. The author will use a phrase such as *X , Just as Y* or *Just as Y, X* as in:

LAUNDRY

> *[...] **Just as** mothers at home go through their children's pockets looking for bubble gum, candy bars or unspent lunch money, Budds' [jail laundry] crew goes through a similar procedure [looking for] knives, needles, syringes, and the like. [...]*
>
> *"White Wash"*
> *Los Angeles Times*
> *Part II, p.1/Sunday, November 6, 1988*

or X is like Y as in:

BISON-3

> *Destroying the diseased bison now living in the park and reintroducing the species from a healthy herd **is like** cutting off the finger to save the hand.*

or *X is doing the same thing as Y*, as in:

BISON-6

> *Some people are against destroying the diseased herd of bison at Wood Buffalo National Park, because destroying them would reduce the population of an endangered species. However, cutting off a diseased finger* ***does the same thing to*** *one's hand. Yet sometimes it is the only way to save the hand.*

In this way, the author explicitly draws the reader to compare events, objects, or other concepts. These explicit instances of introduction can be handled via lexical entries. Such entries incorporate the lexical clues into syntactic patterns and include any parsing demons needed to disambiguate a phrase having multiple interpretations. Let us examine one example of such a parsing demon.

When the phrase *X does the same thing to Y* is encountered, ARIEL searches memory for the most recent causal structure that can be transformed into a similar and plausible relationship between X and Y. To facilitate this search, concepts are indexed in memory by class, such as `<causal structure>` or `<belief>`.

In understanding BISON-6, the following causal structure[8] is produced as part of the representation generated for the first sentence:

```
(LEADTO  &LEADTO.11
    ANTE (DESTRUCTION  &DESTRUCTION.11
             DESTRUCTION-METHOD DESTROYING
             OBJECT  (HERD  &HERD.1
                        REF      DEFINITE
                        HEALTH   DISEASED
                        TYPE     BISON
                        LOCATION WOOD-BUFFALO-NATIONAL-PARK
                        SPECIES  (SPECIES  &SPECIES.1
                                     NAME    BISON
                                     STATUS  ENDANGERED))
             ANTE-OF  &LEADTO.11)
   CONSE  (GOAL  &GOAL.11
             TYPE   PRESERVATION
             OBJECT  (SPECIES  &SPECIES.1
                        NAME    BISON
                        STATUS  ENDANGERED)
             STATUS  FAILURE
             CONSE-OF  &LEADTO.11))
```

that is, destroying the herd leads to the failure of a preservation goal regarding the endangered species to which the bison belong. The clause *cutting off a diseased finger does the same thing to one's hand* matches the lexical entry:

```
<destruction> does the same thing to <thing>
```

---

8 Causal structures in ARIEL are currently represented as a `<leadto>` in which an antecedent (`<ante>`) event causes or results in a consequent (`<conse>`) event. The concept filling the `<ante>` slot of the `<leadto>` is given a pointer (`<ante-of>`) back to the concept of which it is the antecedent. The consequent is given a similar back-pointer.

where <destruction> is instantiated as:

```
(DESTRUCTION &DESTRUCTION.12
   DESTRUCTION-METHOD CUTTING-OFF
   OBJECT   (BODY-PART &BODY-PART.1
                HEALTH  DISEASED
                PART    FINGER
                PART-OF HAND))
```

and <thing> is instantiated as:

```
(BODY-PART &BODY-PART.2
   PART    HAND
   PART-OF ARM)
```

Memory search for a causal structure with an antecedent of type <destruction> begins, and &LEADTO.11 is identified. From this concept, the system hypothesizes that destroying the finger leads to the failure of a preservation goal regarding the hand of which the finger is a part. This does not conflict with domain knowledge, so a similar causal structure is instantiated:

```
(LEADTO  &LEADTO.12
      ANTE (DESTRUCTION  &DESTRUCTION.12
                DESTRUCTION-METHOD CUTTING-OFF
                OBJECT  (BODY-PART &BODY-PART.1
                             REF     INDEFINITE
                             HEALTH  DISEASED
                             PART    FINGER
                             PART-OF HAND)
                ANTE-OF  &LEADTO.12)
      CONSE  (GOAL  &GOAL.12
                 TYPE    PRESERVATION
                 OBJECT  (BODY-PART &BODY-PART.2
                             PART  HAND
                             PART-OF  ARM)
                 STATUS  FAILURE
                 CONSE-OF  &LEADTO.12))
```

5.2 Managing in the Absence of Lexical Clues

Just as often, there will be no lexical clues to trigger recognition of the presence of the analogy (covert introduction). Thus, the model must provide other means for noticing the analogy. The following editorial illustrates this problem:

A-LIKELY-STORY

Reagan wants the U.S. to aid the Contras in an effort to overthrow the legal government in Nicaragua. The U.S. fought to keep the Communists out of South Vietnam. All the U.S. achieved there was a lot of dead soldiers and a loss of honor.

[unknown]
October 19, 1989

In ARIEL, argument-related expectation demons, which anticipate and find contrasting concepts, fill this need. If a contrast to a belief is expected, but not explicitly encountered, ARIEL's knowledge of argumentation, as contained in these demons, tells it that the contrast might be by analogy. So, instead of searching directly for a contrasting concept, ARIEL searches for a concept analogous to the one to be contrasted, then looks for a contrast to that analogous concept. To do this, ARIEL needs to be able to retrieve analogous concepts from short term memory. This search must be directed in some way, to ensure that a plausible analog is located in a reasonable amount of time. Let us first consider constraints employed in this model, then examine the retrieval and mapping processes.

5.3. Constraining Search, Mapping, and Inference

Constraints on search and inference are essential components of analogical reasoning. Those observed in our system are similar in many respects to those employed in ACME (Holy89), ARCS (Thag90), and SME (Falk89). In ARIEL, these constraints are used not only for mapping, as in ACME and SME, and retrieval, as in ARCS, but also for inferring the missing pieces of the target analog from domain knowledge. Here we present those constraints using the terms as they are defined in (Holy89) and (Thag90). In the systems they describe, semantic similarity, pragmatic centrality, and structural consistency constrain retrieval of source analogs (ARCS), and guide appropriate mapping of analogous components (ACME).

The constraint of semantic similarity requires determining whether the predicates used in the representations of the two analogs are semantically similar. For example, a dog is semantically similar to a cat, since both are animals, and a hand is semantically similar to a foot, since both are body parts. The importance of semantic similarity is present in our system as well. ARIEL considers that this constraint is met if two objects are of the same class. In our scheme, a dog is represented as an animal of type dog, a cat as an animal of type cat, a hand as a body-part of type hand, and a foot as a body-part of type foot. ARIEL maps analogous components directly where semantic similarity exists. Concepts need to be semantically similar only at the highest level.

Pragmatic centrality is concerned with identifying those structures which are potentially important to a system's goals. In ARIEL, there are static pragmatic constraints, which guide understanding of arguments in general. There are also dynamic pragmatic constraints, which guide the retrieval and mapping of particular kinds of objects. For example, two beliefs can be considered analogous and linked together only if they share the same underlying argument rule (a pragmatic constraint), although they are semantically similar at the highest level. The justifications of the beliefs, and the component parts of the justifications, will be linked, as far as they are semantically similar and meet relevant pragmatic constraints. However, the propositions of the analogous beliefs are not mapped, since a correspondence mapping between propositions does not provide information needed by the system's analogical reasoning mechanism.

Early work on this project pointed to the need for using these pragmatic constraints, as well as structural consistency constraints, to guide making inferences by analogy, in addition to guiding retrieval and mapping processes. Structural consistency is said to exist if the objects in the potential analogs can be placed into correspondence so that relations among them also correspond. The constraints of structural consistency are seen as our system tries to disambiguate. Assume, for example, that a sentence of the form:

X is bad, because X causes Y and Y is bad

is given, and is followed by a sentence of the form:

However, X' did the same thing to Y'

ARIEL will look for a previous causal relationship between concepts that could be considered analogous to X' and Y', and where the causal relationship between those previous concepts is at least semantically similar to a corresponding and plausible relationship between X' and Y'. Thus, if a search of memory reveals that X and Y are semantically similar to X' and Y', respectively, and that the relationship between X and Y can be transformed into a plausible and semantically similar relationship between X' and Y', the understander will instantiate such a relationship between X' and Y' and at the same time form an analogous belief about this new relationship.

A case in point is HIGH-TECH-1, which we examined in Chapter 4. The automobile industry and CAM are both instances of manufacturing. ARIEL's domain knowledge enables it to infer that the jobs lost due to CAM were assembly line jobs (although the type of job lost is not important). This is interpreted as a goal failure involving jobs or occupations. *People in the horse carriage industry* is likewise interpreted as occupations involving that industry. The pieces of information available from the first two sentences of the HIGH-TECH-1 text are represented in Figure 5-1, and consist of the belief that CAM is bad, because it causes job loss, an instance of the automobile industry, and instance of jobs in the horse carriage industry, and the anticipation that an unknown relationship exists between the last two.

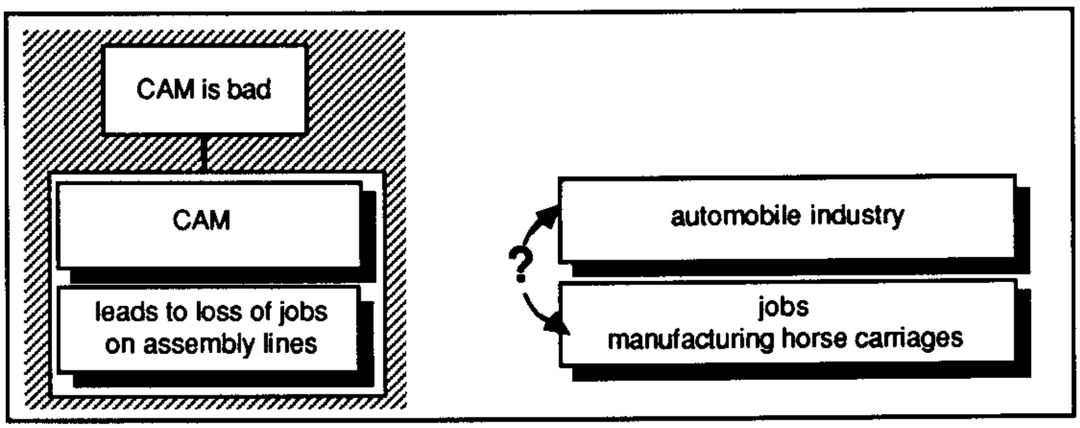


Figure 5-1. STM after the first two sentences of HIGH-TECH-1.

In searching memory for a plausible causal relationship between the auto industry and people in the horse carriage industry, the system determines that the auto industry is semantically similar to CAM, and retrieves the instance involving CAM as a tentative source analog. The next task is to determine whether the relationship of the instance of manufacturing causing job loss is plausible between the auto industry and horse-carriage related occupations. Such an inference does not conflict with ARIEL's domain knowledge. Therefore, such a relationship is inferred for the target analog. Since the CAM instance is part of a belief, ARIEL's system-level goals (static pragmatics) direct it to create an analogous belief about the auto industry. The completed representation of these two sentences is repeated in Figure 5-2, and includes the links between analogous components. The portions of the graph which represent knowledge explicitly mentioned in the text, are indicated by shading with bold diagonal lines.

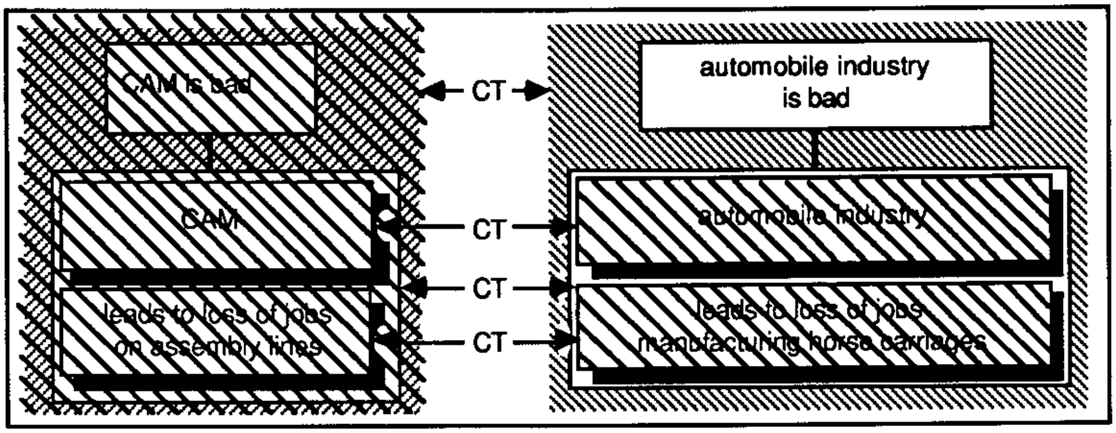


Figure 5-2. Completed representation of HIGH-TECH-1, sentences 1 and 2.

5.4. Identifying Similarities

In order for the expectation demon to search STM for a similar concept, ARIEL must have a mechanism for identifying what is similar between the analogs. Each concept in ARIEL is represented using a slot-filler notation. The majority of slots represent simple attributes of the concepts. For the most part, two concepts must have the same class to be accepted as being analogous. This is in keeping with the idea of matching only at high-level predicates, and not requiring matching at all levels of predicates. Of the 32 object classes we have defined, there are only four exceptions to the simple matching rule: beliefs, goals, groups, and causal structures:

1. A *belief* consists of a belief object, or b-object, containing an event and a value judgment about that event, and a justification for the belief. Underlying each belief is an argument rule explaining why the justification supports the belief object. Two beliefs are considered analogous only if they share the same underlying argument rule. Since the argument rules are domain independent, the classes of the events in the belief objects and the justifications in the beliefs need not meet the usual requirements for being considered analogous in order for the beliefs themselves to be accepted as analogous.

2. The main components of a *goal* are a goal object, or the thing to be achieved, and a status, which is "success" when the goal has been achieved, and "fail" when the goal has not been achieved. Two goals are considered analogous only if their objects are analogous and their goals have the same status.

3. *Groups* must be of the same type, such as human or physical object.

4. *Causal structures*, such as X leads to Y, where X is the antecedent and Y the consequent of the causal structure, must have analogous antecedents and consequents.

These four object classes are relatively high-level conceptual structures. The additional criteria for these classes are equivalent to a requirement that high-level conceptual structures be of the same subclass to be considered analogous.

5.5. Developing a Correspondence Mapping between Analogs

Once two concepts have been determined to be analogous, *compared-to* or CT links are established between them by the COMPARE-CONCEPTS function. This linking or mapping is implemented as a bidirectional pointer between the mapped concepts. For most object classes, the result is a single CT link between the concepts being compared. There are three exceptions:

1. When *causal structures* are recognized as being analogous, CT links are added between the analogous antecedents and between the analogous consequents.

2. When *beliefs* are recognized as being analogous, an attempt is made to add CT links between their justifications, even though the justifications are not directly compared when the determination is made that the beliefs are analogous.

3. When *goals* are recognized as being analogous, CT links are added between their objects.

Mapping of the analogous components of these high-level structures follows the same criteria as mapping other concepts. This additional linking is performed to facilitate reasoning about the analogies encountered.

During understanding, ARIEL creates a correspondence mapping between those components of the parallel arguments which the author of the editorial has explicitly identified as being analogous, or which the model has identified as being analogous in the course of understanding. Parsing demons associated with the matched lexical entries are used to develop the correspondence mapping when lexical clues are employed to introduce an analogy. Referring again to the BISON-6 example, when the "finger" analog is inferred based upon the "herd" causal structure, a correspondence mapping is established between the two causal structures, between the two destruction concepts which are the antecedents of the causal structures, and between the two goals, which are the consequents of the causal structures. Cutting off the finger (DESTRUCTION.12) is mapped to destroying the herd (DESTRUCTION.11), not preserving the hand (GOAL.12) is mapped to not preserving the herd (GOAL.12), and the cause-effect relation between cutting off the finger and not preserving the hand (LEADTO.12) is mapped to the cause-effect relation between destroying the herd and not preserving the species (LEADTO.11). The hand (BODY-PART.2) and the bison species (SPECIES.1), the objects of GOAL.12 and GOAL.11, respectively, are not directly mapped, since they have different object classes, although they do take on similar roles in the argument.

In addition to the explicit correspondence established by the author of the text, ARIEL relies upon the expectation demons to infer correspondence. These demons identify the rules and attack strategies underlying arguments. In searching for an indirect contrast, ARIEL identifies the underlying structure of the target argument, and references its abstract knowledge of argumentation to hypothesize, at an abstract level, a contrasting structure. It then searches STM for an instance of such a structure. When one is found, the COMPARE-CONCEPTS function is invoked to explicitly map the corresponding source and target components.

The roles of source and target remain fluid in our model, in the sense that the correspondence between components is bidirectional, and the flow of information can proceed in either direction. Direct correspondence is mapped only at major points, and no agreement of predicates is required at minor points.

5.6. Summary

Lexical clues can be exploited in recognizing analogies, when these clues are present in the text. In the absence of such clues, expectations related to the structure of arguments drives the recognition process, and facilitate the process of making inferences about these analogies. Inferences as well as mapping and retrieval are guided and constrained by considerations of semantic similarity, structural consistency, and pragmatic centrality. These same kinds of knowledge are essential to performing analogical transforms across domains, which we present next.

Chapter 6

Performing Analogical Transforms

In order to learn from an incomplete analogy, one must first infer the missing components of the analogy. Our model for completing arguments-by-analogy integrates domain-independent and domain-dependent knowledge. Expectations generated during understanding, abstract argument rules and attack strategies, and domain knowledge are all essential components in our model. By incorporating an understanding of the logical structure of the text, and domain knowledge, ARIEL complete analogies even in the absence of a rich correspondence mapping. Effective use of abstract knowledge about the structure of arguments is coupled with an example to guide a search through target domain knowledge and generate a plausible completion to an incomplete argument-by-analogy.

Although researchers have been looking at analogical reasoning for many years, little work has been done in the area of developing a model of analogical reasoning that can be used in conjunction with natural language understanding systems. Existing systems, such as (Thag85) (Holy89) (Kolo87a) (Shin88b) and others, rely heavily upon the availability of a rich correspondence mapping between the source and target analogs to formulate a target solution to a problem. Typically, any systems which have dealt with the problem of completing an analogy, such as (Wins78) (Hobb83a) (Hobb83b) (Shin88a) (Shin88b), have not incorporated any understanding of why each analog has the structure it has. Thus, these systems are not well suited to understanding analogies in editorials.

In this chapter we review approaches to analogical reasoning, and present our approach to generating a plausible completion to an incomplete argument-by-analogy. This approach uses knowledge of argumentation and an analysis of the source analog to guide a search through domain knowledge related to the target analog, in an effort to provide the missing components of the analogy. By implementing this approach in ARIEL (Augu90) (Augu91b), our system is able to detect the presence of an analogy in an editorial text, identify the source and target components, and develop a conceptual representation of the completed analogy in memory.

6.1. Related Work

Much of the recent work on analogical reasoning has centered around three approaches: Carbonell's work on derivational analogy (Carb85) (Carb86), case-based reasoning, and structure-mapping theory. These approaches, as well as related work on metaphor and simile understanding, have concentrated on general machine-learning methods, with little emphasis placed on incorporating the ability to actually reason about domain knowledge beyond that which is supplied in the input or retrieved solution. In ARIEL, an effort is made to integrate both a general reasoning mechanism and domain-specific heuristics.

Derivational analogy solves a problem by replaying the solution to a previous problem, modifying it as needed to form a solution to the current problem. The ARIEL approach is similar to derivational analogy in that an effort is made to replay a modified, previous solution to solve the current problem. In ARIEL, however, the previous solution is not explicitly represented; rather, it is represented implicitly in the analogous argument provided in the editorial text. Instead of storing and retrieving a previous solution, ARIEL "extracts" the previous solution from the information supplied in the text, based upon general knowledge of argumentation and domain knowledge.

This extracted "solution" plan is not a fixed, parameterized script that is instantiated to form a solution, the approach taken in case-based reasoning (CBR) (Kolo87a) (Syca88). Analyzing the given argument yields the domain-specific instantiations of argument rules (and attack strategies) that hold the elements of the argument together in a cohesive whole. These domain-specific rules and strategies in turn point back to domain-independent, or abstract rules and strategies. These abstract rules and strategies can be replayed, in the context of the current problem. This progression from (source) specific to abstract to (target) specific is similar in some respects to abstractional analogy (Shin88a). But in abstractional analogy, as in CBR, the abstract solution is parameterized, and accompanied by a correspondence mapping between the source and target analogs. This approach works well when a rich correspondence mapping is available. However, this is usually not the case in an editorial. This lack of explicit mapping must be compensated for. It can be compensated for in part by incorporating a body of domain knowledge into the model. This is not sufficient, however. The search through the domain knowledge must be guided or constrained, in order to find relevant details needed to complete the analogy. In ARIEL, not only are the relevant abstract rules and strategies available, the domain-specific rules and strategies and the original "source" plan are available as well. Thus, ARIEL departs from the abstractional analogy methods by allowing for a constrained and guided search through domain knowledge to identify relevant information that can be used to complete the target analogy.

The Structure Mapping Engine (Falk86) (Falk89) is a computer simulation of analogical processing based upon Gentner's structure mapping theory (Gent83). This theory is based upon the structure of inputs, and requires identity mapping at all levels of predicates. ARIEL, on the other hand, does not require this one-to-one correspondence mapping at all levels of predicate. First, an assumption is made, via Grice's maxim, that what the author is saying makes sense. ARIEL will map where possible, but does not enforce mapping at lower levels. ARIEL explicitly maps concepts only where: 1) the mapping is provided by the author, and 2) the mapping arises from the inferences made during understanding.

It is interesting to note that in other computational models of analogical reasoning, the roles of source and target are never exchanged during understanding or problem solving. However, understanding analogies in arguments often requires a reader to transfer information back and forth across the domains or contexts, in order to make the inferences implied by the author. Thus, in ARIEL source and target are not fixed; information can be transferred as needed to facilitate understanding.

6.2. Understanding An Argument by Analogy

Let us consider a another example of argument-by-analogy:

BAD-HABITS

If using marijuana is bad because using it has harmful psychological effects, then using alcohol is bad, too.

If one were to ask the reader of this brief text the question:

Why is using alcohol bad?

A plausible response would be:

USING ALCOHOL HAS HARMFUL PHYSICAL EFFECTS.

This is information not supplied in the original text. A reader might happen to come up with such an answer based solely upon the reader's knowledge about the effects of alcohol, without any sort of analogical transfer or understanding of the structure of arguments. But, in that case, the reader might just as easily respond that USING ALCOHOL CAN MAKE YOU LOSE YOUR INHIBITIONS, which is at least somewhat related to the ideas being presented in the text. Worse yet, the reader might respond that USING ALCOHOL MAKES YOU FEEL RELAXED, which would indicate that, in addition to not catching the author's point, the reader has little understanding of what "bad" means in this context.

An understanding of the structure of arguments enables the reader to identify *using marijuana has harmful psychological effects* as a justification for the proposition that *using marijuana is bad*, as well as to formulate a justification for the proposition that *using alcohol is bad*. An understanding of how analogies are used in arguments motivates the reader to look for clues to be used in justifying the latter proposition by seeking out the justification for the former proposition. And domain knowledge about alcohol and health provide information that the reader can use to form a plausible completion to the incomplete argument-by-analogy. In BAD-HABITS, marijuana is judged to be "bad", because it thwarts a person's goal of having good mental health. In our previous work, JULIP (Augu85b) (Augu85c) used expectations generated during understanding to motivate the understander to complete the analogy. The structure of the source argument was used to generate an analogous structure in the target domain. However, without information related to why the source argument had the details or values it had, it was difficult to supply analogous details for the target argument.

In contrast, ARIEL incorporates a closer coupling between knowledge of argumentation and domain knowledge (Augu90) (Augu91a) (Augu91b). As in our previous system, ARIEL generates expectations during understanding to prompt completion of the analogy. ARIEL differs from JULIP by also incorporating knowledge of the structure of arguments, which is used to constrain the search of the domain knowledge base in an effort to complete the analogy. We have also examined the issue of the use of analogies in arguments, and how this knowledge can focus the understander's attention and guide the drawing of appropriate conclusions.

6.3. Completing an Analogy

Let us look at how ARIEL makes the transition from a specific source argument, to an abstract argument structure, and back to a specific target argument. The input to our system is a brief editorial text, such as BAD-HABITS. ARIEL represents the text as an argument graph.

6.3.1. Generating Expectations for Missing Argument Components

Expectations for propositions and justifications are generated during understanding. These arise from lexical clues in the text as well as from ARIEL's knowledge of the structure of arguments. This knowledge includes such heuristics as expecting each proposition to be justified, and anticipating that the author of the editorial will either support or attack the initial point made in the editorial. As the text is read in, an argument graph is constructed. For example, when a proposition is encountered, a belief is instantiated, and an expectation for the justification of the proposition is generated. Thus, missing components of the graph are represented during understanding by expectations for those components. Given BAD-HABITS, ARIEL would develop the representation shown in Figure 6-1, and have the expectation that the proposition *using alcohol is bad* will be justified.

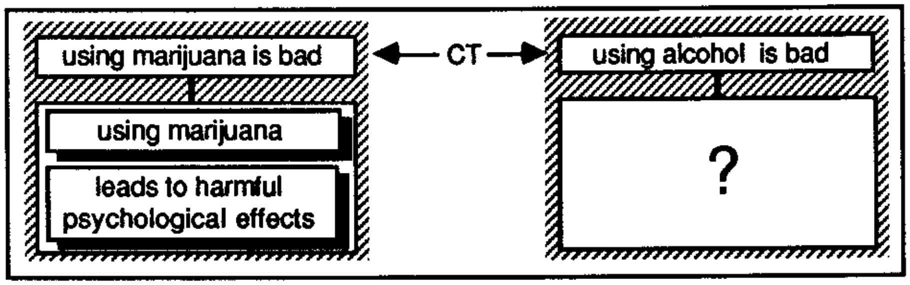


Figure 6-1. Incomplete argument graph of BAD-HABITS.

6.3.2. Extracting the Argument Structure from the Source Argument

ARIEL's knowledge of argumentation includes an understanding of how analogies are used in arguments. When a comparison is made between two beliefs, ARIEL infers that the justifications for the beliefs are being compared, as well. A source belief or argument is assumed to potentially contain the missing components of an analogous target belief or argument. The goal in our model is to identify the line of reasoning underlying the source argument, and replay that line of reasoning in the target domain. Therefore, before information can be transferred from source to target, ARIEL must analyze the source argument and identify the line of reasoning underlying it. That is, a general solution is extracted from a source analog, then used in guiding the completion of the target analog.

In BAD-HABITS, the belief that *using marijuana is bad* is viewed as a belief which is analogous to the belief that *using alcohol is bad.* ARIEL assumes that, potentially, the former contains a solution to the current problem of finding a justification for the latter.

Starting from the expectation that the proposition *using alcohol is bad* will be justified, ARIEL's understanding of how analogy is used in arguments prompts it to check whether the belief associated with the proposition is analogous to another belief. Correspondence mappings provided by the author and those made during understanding are explicitly represented. Thus, finding an analogous belief translates into traversing a link created between the belief about marijuana and the belief about alcohol during understanding. Once the analogous belief is located, ARIEL retrieves the justification for the analogous proposition. The proposition is matched against a set of domain-independent argument rules, and the abstract argument rule underlying the belief is identified. ARIEL interprets *has harmful psychological effects* as thwarting a preserve-mental-health goal. This, and the negative value judgment in the proposition, i.e., using marijuana is *bad*, cause ARIEL to infer that the argument rule

X is bad, because X thwarts a goal.

has been used in the belief regarding marijuana.

6.3.3. Applying the Argument Rule to the Target Proposition

Once the argument rule underlying the source belief has been identified, ARIEL proceeds to apply that rule to the target proposition. The transform routine takes as input an argument rule, a proposition to be justified, and the source justification which is to be used as an example in instantiating the target justification.

For our example, the next step is for ARIEL to form a justification for the proposition *using alcohol is bad.* The inputs to the transform routine in this case are shown in Figure 6-2.

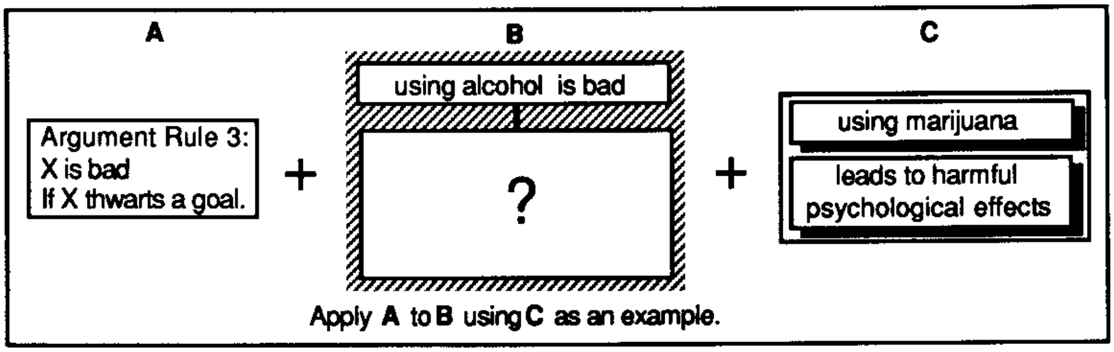
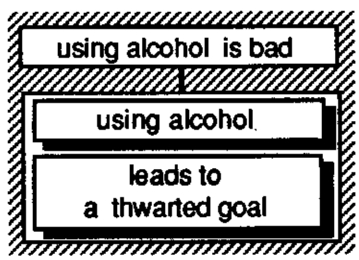


Figure 6-2. Inputs to analogical transform routine for BAD-HABITS.

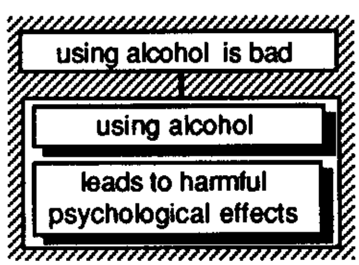
Based upon the argument rule used, the transform routine infers that the target justification will be a causal structure. The event from the proposition, i.e. *using alcohol*, is made the antecedent of this causal structure.

The next task is to identify the consequence of alcohol use. The argument rule employed in BAD-HABITS indicates that the consequence will involve the thwarting of a goal. The consequent of the causal structure could be left in this general state, e.g.,



However, this 1) does not take advantage of domain knowledge or the source analog, and 2) is not a very interesting inference, since it is so general in nature. This approach would be similar to that used by Winston (Wins78) in which a conclusion to an analogy was formed by finding in the concept hierarchy a common ancestor of the two concepts being compared.

Another possibility is to infer that the same goal is thwarted by using alcohol as is thwarted by using marijuana, e.g.,



This consequent is plausible. However, this approach to completing the analogy does not always work. For example, if the argument were

> *If smoking cigarettes is bad, because it causes addiction to nicotine, then drinking alcohol is bad, too.*

one would not want to infer that drinking alcohol causes addiction to nicotine.

A third possibility is to look to domain knowledge for a goal that is thwarted by using alcohol. By using the source example as a guide to constrain the search through the target domain, the symmetry of the analogy can be preserved where possible. The goal is to complete the analogy with as much domain-specific information as possible, with the level of detail used in the source analog matched where possible, but not exceeded.

Assume that the domain knowledge about the effects of alcohol is that represented informally in Figure 6-3. The proposition focuses the search toward negative effects. This eliminates ① and ⑦. The argument rule can be used to constrain the search to negative effects that involve the thwarting of goals, eliminating ⑧. The source analog example further constrains the search. The goal of preserving mental health is an instance of preserving health in general. In the marijuana belief, the goal being thwarted is a preserve-health goal. Domain knowledge about the effects of alcohol use is searched for a preserve-health goal being thwarted. "Has harmful physical effects", i.e., thwarts preserve-physical health, is found. The "thwarts preserve-physical health" goal is instantiated as the consequent, and the causal structure is made the justification for the proposition *using alcohol is bad*. The justifications are analogous, and, because each involves a causal structure, the antecedents and consequents are linked as well. This results in the completed analogy represented in Figure 6-4.

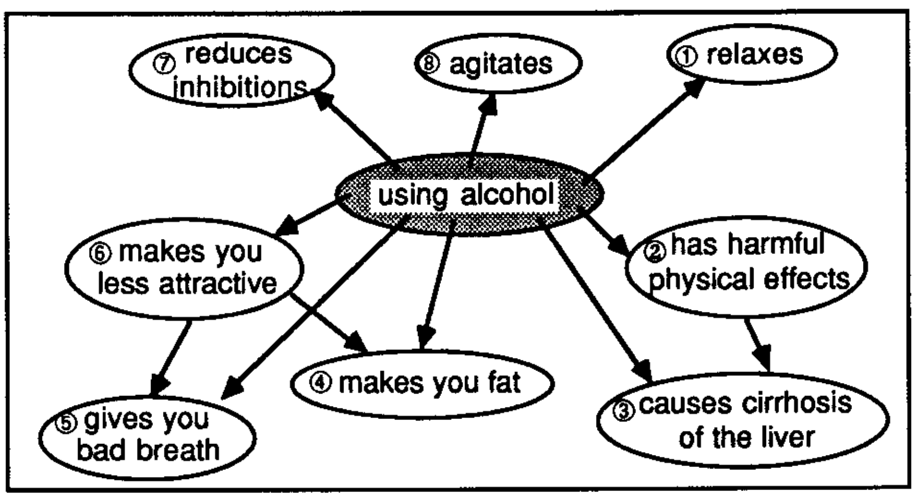


Figure 6-3. Domain knowledge about the effects of alcohol consumption.

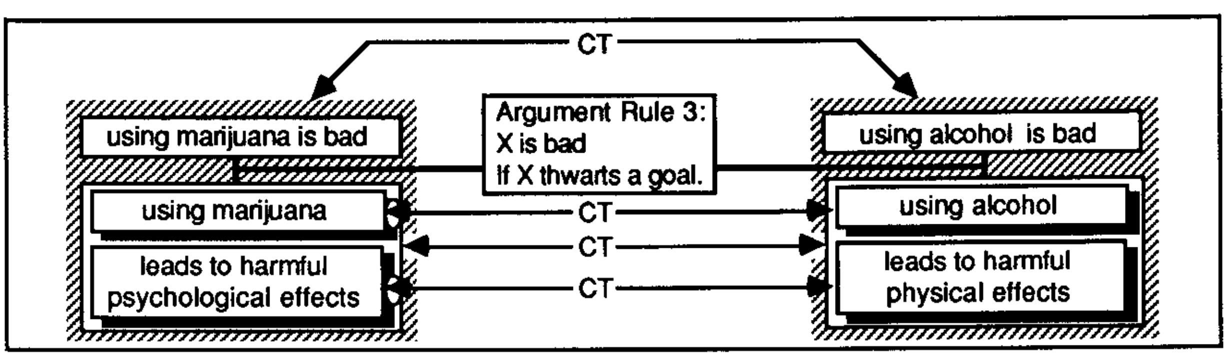


Figure 6-4. Completed argument graph of BAD-HABITS.

6.4. Finding a Contrast-by-Analogy

A key component to ARIEL's argument-related expectation demons is the ability to either find or infer a contradiction to an existing belief. ARIEL currently handles the case where a *contradiction* to the initial belief is made. The case where the belief is supported would be handled in a similar fashion, with the exception that a support relationship, rather than an attack relationship, would be sought. One case which must be handled is that in which the initial belief is already marked as being analogous to a second belief, and that belief, in turn, had already been marked as having been attacked by a third belief. The general structure of this type of argument is shown in Figure 6-5.

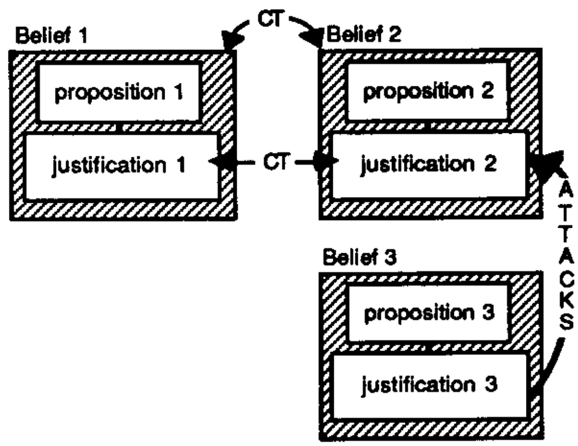


Figure 6-5. General diagram of an incomplete argument-by-analogy.

In this case, ARIEL retrieves both the attack strategy employed, and the attacking third belief, and uses these to form an analogous attack, encompassed by a fourth belief, on the initial belief. The general structure of the completed argument is shown in Figure 6-6.

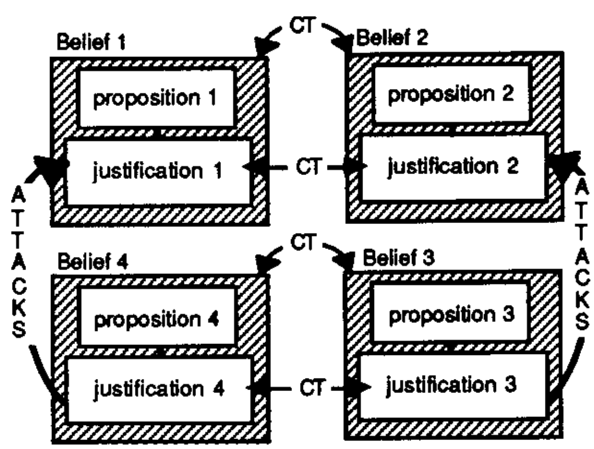


Figure 6-6. General diagram of a complete argument-by-analogy.

The contrast between B-1 and B-2 in Chapter 3 is to identify, because the same event leads to contrasting consequences. However, when an analogy is used in an argument, the contrast is not as easy to identify. Consider the following:

BISON-4

> *Stacy Tessaro of Agriculture Canada wants to destroy the bison herd of Canada's Wood Buffalo National Park, because the animals are diseased. A person diagnosed with diabetes is diseased. This person is allowed to live.*

After reading the first sentence of BISON-4, ARIEL's expectation agenda will contain a demon which expects a contrast to the idea that destroying the bison is good, because they are diseased. However, the subsequent text does not directly satisfy this expectation. At this point, ARIEL's knowledge of the use of analogy in arguments is invoked. If a direct contrast is not found, the expectation demon seeks to find another concept in STM which is similar to the concept to which a contrast is anticipated. At the heart of this expectation is the ability to either find or infer a contradiction to an existing belief. The search for a contrast is performed by the FIND-CONTRADICTION-TO function.[9] This function handles the case in which a belief, Belief A, is already marked as being analogous to another belief, Belief B, which in turn is marked as having been attacked by a third belief, Belief C. In this case, ARIEL retrieves both the attack strategy employed, and the attacking belief C, and uses these to form an analogous attack, encompassed by Belief D, on belief A. FIND-CONTRADICTION-TO also handles the case in which the components of an attack by analogy exist in memory, but are not yet tied together, as well as the case in which a directly contrasting belief already exists in memory, but is not yet recognized as such. The function proceeds as follows:

`find-contradiction-to` *belief*

```
Does a belief which constitutes an attack on belief already
   exist in memory?

If so, identify the attack strategy employed and note the
   attack relationship.

If not, is belief already considered analogous to another
   belief, whose justification has been attacked by something
   else?

If so, retrieve the strategy used, and apply it to belief,
   using existing memory structures to instantiate the attack
   before creating new ones.  If the result contradicts domain
   knowledge or the application is unsuccessful, try another
   relevant strategy.

If not, does an analogous belief exist in memory, and has its
   justification been attacked?  If so, retrieve the strategy
   used, and proceed as above.

If not, does an analogous justification exist in memory, and
   has it been attacked?  If so, retrieve the strategy used,
   and proceed as above.
```

---

9 Our system currently handles the case where a contradiction to the initial belief is made. The case where the belief is supported would be handled in a similar fashion, with the exception that a support relationship would be sought, rather an attack relationship.

```
Otherwise, identify the argument rule underlying belief,
   retrieve a relevant attack strategy, and proceed as above.
```

The ability to either find or infer a contradiction to an existing belief is a key component to ARIEL's argument-related expectations. The function FIND-CONTRADICTION-TO gives our system flexibility in regard to the format of the input it is able to handle.

6.5. Completing an Argument-by-Analogy

BISON-6 presents an implicit argument against destroying the diseased bison, a point never explicitly made in the text. It illustrates the need for ARIEL to be able to complete an argument-by-analogy. The text, as read into the system, is as follows:

BISON-6

*some people are against destroying the diseased herd-of-bison-at-wood-buffalo-national-park because destroying them would reduce the-population-of-an-endangered-species *period* however cutting-off a diseased finger does-the-same-thing-to one*s hand *period* yet sometimes cutting-off the finger is-the-only-way-to save-the-hand *period**

As noted above, when the second sentence of BISON-6 has been read, ARIEL has drawn an analogy between the belief that destroying the herd is bad, and the belief that destroying the finger is bad. A graphical representation of this analogy is shown in Figure 6-7. As the remainder of the text is read, the system forms an attacking belief that *destroying the finger is good, because it leads to preservation of the hand in the long run*. The process used to form this belief was described in section 2.3 above. The resulting graph is shown in Figure 6-8. At this point, all of the text has been read. In addition to the graph of the three beliefs built up to this point in short term memory, there is on the agenda an expectation for a contrast to the initial belief, that destroying the herd is bad.

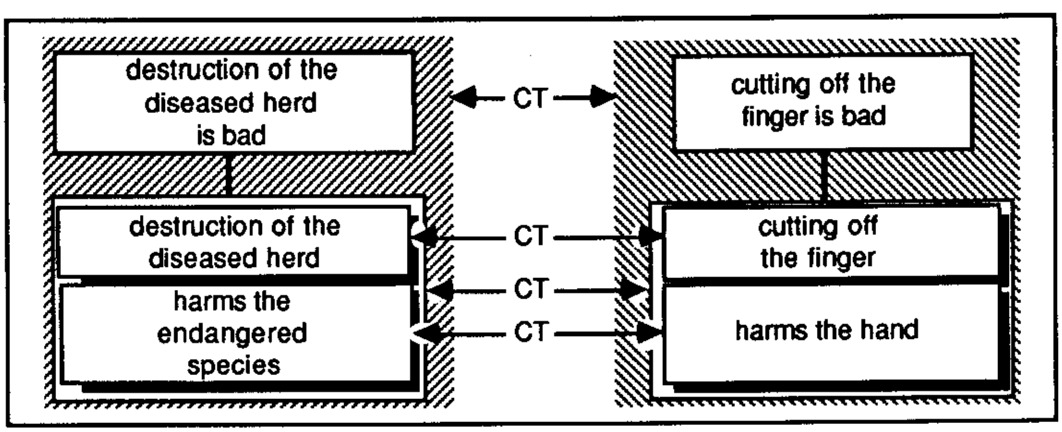


Figure 6-7. Graph of the first two sentences of BISON-6.

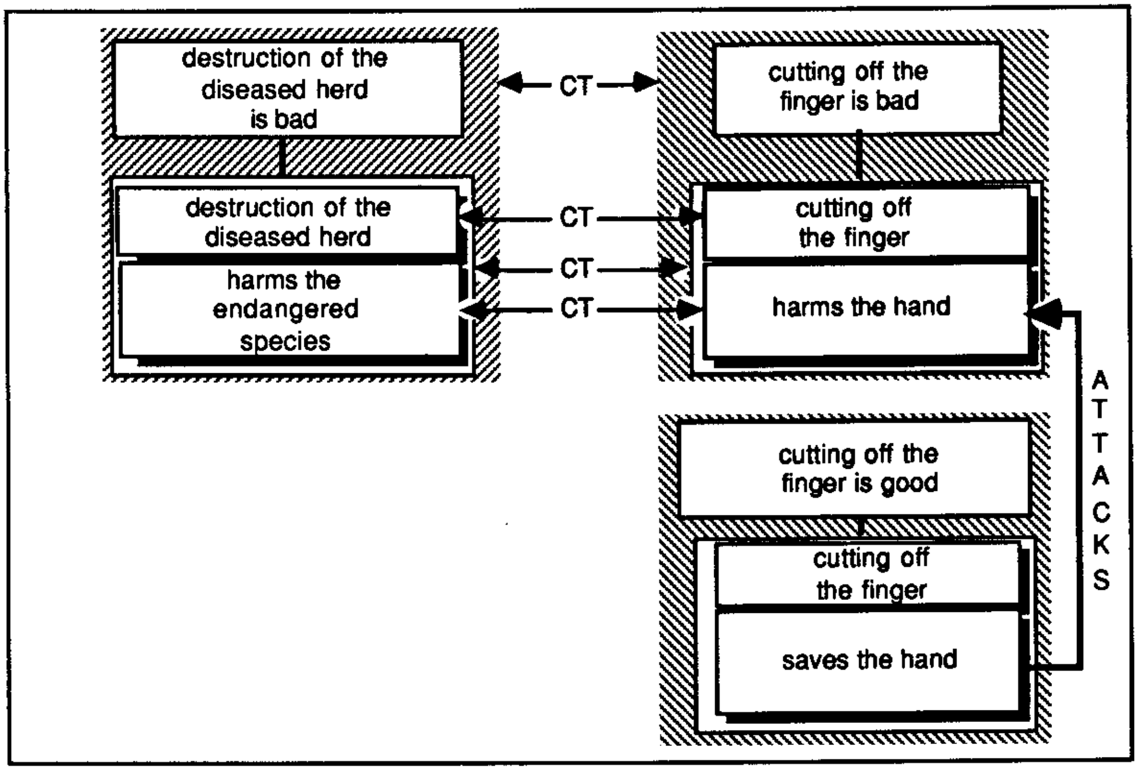


Figure 6-8. Graph of the first three sentences of BISON-6.

Since this belief has not yet been attacked, memory is searched for an analogous belief which has been attacked. It finds the belief that *cutting off the finger is bad*, and retrieves the attacking concept, *cutting off the finger saves the hand.* It then identifies the attack strategy employed, attack strategy 4, in this case. The existence of this attack leads ARIEL to infer that the initial belief, *destroying the herd is bad,* has been attacked by analogy. The problem at this point is to form an attacking belief that *destroying the herd is good,* because it will achieve a higher-level goal than the one being thwarted. The belief will be formed by using the attack strategy retrieved and basing the justification for this new belief on the analogous justification, *cutting off the finger saves the hand.* This justification is viewed as an instance of DESTROY-PART-TO-PRESERVE-WHOLE. At this point, the system needs to transform this into an analogous causal structure regarding the bison. Relying on domain knowledge, ARIEL reasons that, as a finger is part of the hand, the herd of bison is part of the endangered bison species. It forms a causal structure reflecting that *destroying this diseased herd will preserve the endangered species.* As the new, contrasting belief is formed, this causal structure is included as the justification of the belief. The attack relationship between the initial belief and this newly formed belief is noted. The argument is now complete, and ARIEL translates the concept built as a result of processing the expectation:

```
(DESTROYING THE DISEASED ENDANGERED BISON AT WOOD-
BUFFALO-NATIONAL-PARK IS GOOD BECAUSE DESTROYING
THE DISEASED ENDANGERED BISON AT WOOD-BUFFALO-
NATIONAL-PARK WILL HAVE THE RESULT THAT THE
ENDANGERED BISON WILL BE PRESERVED)
```

A graphic representation of the completed argument is shown in Figure 6-9. As seen in this series of diagrams, the mapping of the analogous components of BISON-6 are represented via bidirectional "CT" or compared-to links. Our system's bidirectional flow of information between domains of the analogy is seen in this example. As ARIEL recognizes that an analogy is being drawn between destruction of the diseased herd and amputation of the finger, it forms a belief regarding finger amputation that is analogous to the one stated regarding destruction of the diseased herd, i.e., it is bad. As ARIEL recognizes *saving the hand* as an attack and generates the belief that the amputation is good in the long run, the flow is reversed, and knowledge of argumentation then causes the system to infer an analogous belief in the other direction, producing the goal belief that destroying the diseased herd will be good in the long run.

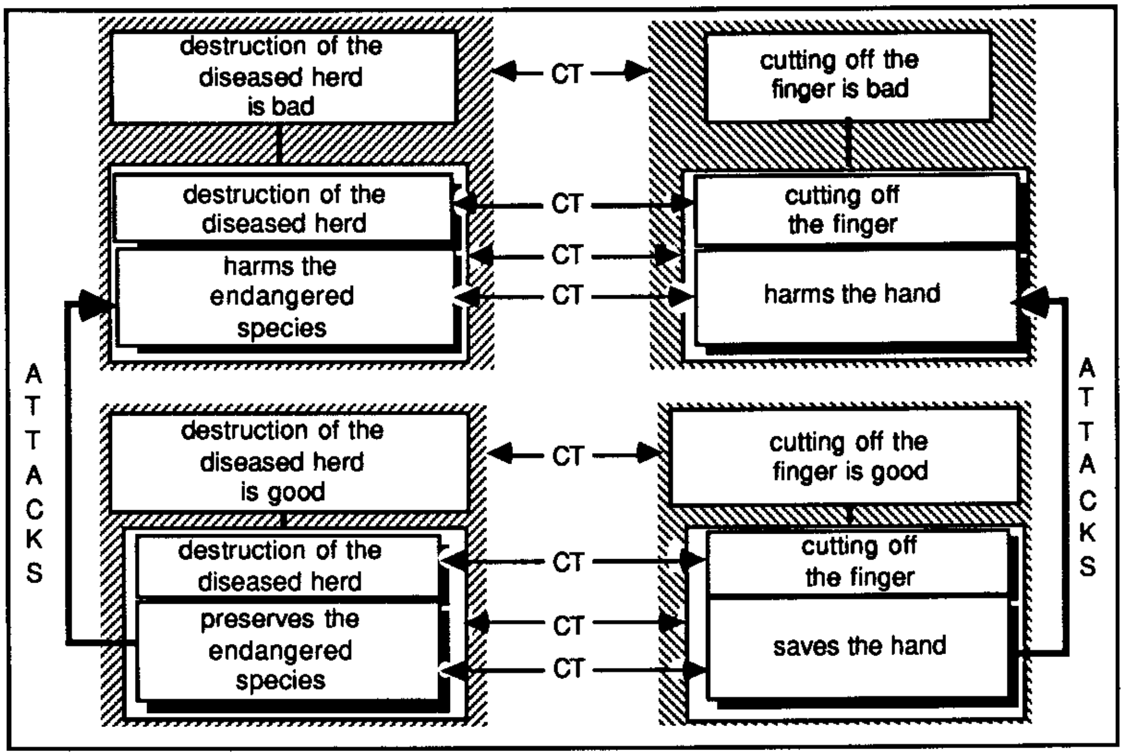


Figure 6-9. Graphical representation of completed BISON-6 argument.

6.6. Summary

When completing an argument-by-analogy, if the proposition in the source analog has been attacked, the attack strategy employed in the source is retrieved, and applied to the target argument. Since the attack strategy is in a domain-independent form, domain knowledge is required to instantiate the attack in the target domain. Domain details are supplied first from the correspondence mapping which exists between the source and target analogs. However, this source of information alone is often not sufficient to provide domain-specific details in the attacking proposition and justification being formed. Additional domain-specific detail is supplied in two ways. First, the high-level predicates in the source attack are employed as clues as to how the details should be instantiated. Secondly, domain information is consulted directly for appropriate details.

If the proposition in the source analog has not been attacked, an alternate strategy is followed. The argument rule associated with the proposition to be attacked is retrieved, and the attack strategies associated with that argument rule are identified. An instantiation of one of the strategies is hypothesized to be true, and an attempt is made to verify the hypothesis. This verification can take place either by determining that the instantiation matches the input, or by determining that the hypothesis does not contradict domain knowledge.

This approach combines the use of the correspondence mapping as well as domain search in order to complete an argument by analogy. The domain search is guided and constrained both by the example found in the source analog and abstract knowledge of argumentation in the form of domain-independent argument rules and attack strategies. Analogical reasoning proceeds both directly between the analogs, through the use of the correspondence mapping, and indirectly, via common, abstract argument rules and attack strategies.

Chapter 7

Integrating Analogical Reasoning in a Natural Language Understander

As mentioned earlier, succeeding at the task of understanding analogies in editorials requires:

1. Having enough lexical and domain knowledge to understand the points being made by the author,
2. Being able to follow an argument and formulate an argument, and
3. Being able to reason by analogy.

Item 1 is a requisite in any natural language understanding system. However, basic parsing mechanisms are not sufficient for processing the multi-sentence arguments found in editorials. If lexical clues are always used to indicate the presence of an argument and guide the flow of the argument, and authors always made each point explicitly, then lexical entries could be developed for understanding arguments (item 2 above). Yet, authors often make points implicitly. To understand an author's point, a reader often has to hypothesize a plausible conclusion to the explicit argument. Information about the component parts of arguments, as well as about the rules used to put the components together must be made available to the understander. These cannot be captured in lexical entries alone. Therefore, the basic parsing mechanism must be augmented with a body of knowledge related to argumentation.

The focus of this research has been on item 3 above, the mechanics of analogical reasoning in a natural language processing context. This entails being able to: 1) recognize that an analogy is being used, 2) form a mapping between the corresponding components of the source and target analogs, and 3) complete an analogy. As with arguments, if lexical clues are always used to introduce analogies, and if the associated correspondence mapping is always made explicit by the author, then lexical entries could be developed to provide 1) and 2). Typically, though, lexical clues and, especially, explicit mappings are not provided. And 3) cannot be handled via lexical entries at all, except in the case of analogies used so frequently that they have become figures of speech. Therefore, an additional component capable of handling all three abilities must be built on top of the basic parsing mechanism already augmented with knowledge of argumentation.

In this chapter we present the design methodology used to implement our system, and demonstrate understanding with various forms of input. An analysis of the differences in processing these sample texts is presented. A complete trace of the program running on each of the texts is found in Appendix A.

7.1. The Design of ARIEL

ARIEL is built on top of general phrasal parsing and generation mechanisms which provide the ability to understand and generate simple, single-sentence texts. We have modified these tools to support the development of a cohesive, complete representation of the concepts contained in multi-sentence editorial texts. This has required us to add declarative knowledge about the structure of arguments, procedural knowledge needed to process expectations related to the structure of arguments, and procedural knowledge needed to perform the analogical transforms required to complete an argument-by-analogy.

The basic understanding mechanism in ARIEL is a phrasal parser. As words are read in by the parser, they are matched against a set of lexical entries. The lexicon consists of linguistic patterns mapped to semantic concepts, and low-level semantic concepts mapped to higher-level concepts. The parser builds a parse tree as it reads in the words of the text. The leaves of the tree contain the words read from the input; successively higher levels of the tree represent successively higher levels of concepts. The conceptual representation can be viewed and modified independently of the parse tree. Modifications to the concepts in the parse tree do not affect the structure of the parse tree itself.

The parse tree is maintained in short term memory (STM). In addition to typical parsing demons, which perform tasks such as adding modifiers to concepts representing objects, attached to some of the lexical entries are expectation demons related to the structure of arguments. These demons can generate relationships between concepts associated with the nodes of the parse tree. They are placed in STM on an expectation agenda, which tracks the expectations generated during understanding. The parsing demons are examined with every parser cycle. If an expectation has been filled, that demon is removed from the agenda. If it has not been filled and there is more text to process, the demon is left on the agenda. Otherwise, it is removed and executed. Argument-related expectation demons are cycled through only after the entire editorial text has been read, in order to avoid making inferences that are explicitly stated later in the text. In processing one of these expectations, ARIEL attempts to hypothesize the missing component of the argument by relying upon the information explicitly provided in the text, and domain knowledge, and knowledge of the structure of arguments. When the entire text has been read, and all demons have been executed, ARIEL generates an English equivalent of the representation in STM of the conclusion it draws from the text read.

Figure 7-1 identifies the components of ARIEL. ARIEL is built on top of Rhapsody (Turn87), which includes a phrasal parser modelled after PHRAN (Aren86). Information about the words of the language as well as information about more complex language constructs is stored in the form of linguistic pattern-semantic concept pairs. These pairs are contained in the *parsing lexicon* and referenced by the *phrasal parser*. *Parsing demons* associated with lexical entries are used to perform tasks such as adding modifiers to concepts in STM, and testing whether a particular phrase matches the input. To the basic parsing ability provided by Rhapsody we have added the ability to handle multi-sentence texts. More importantly, we have added the ability not only to understand and follow arguments-by-analogy, but also to complete simple implicit arguments, and to complete implicit arguments-by-analogy. These last two abilities require a facility for formulating both straightforward arguments and indirect arguments-by-analogy. In our model, knowledge of argumentation is contained in *argument rules*, *attack strategies*, and *expectation demons*, as well as in the parsing lexicon. Knowledge of analogical reasoning is closely coupled with knowledge of argumentation, and is contained primarily in the expectation demons, as well as in the parsing demons.

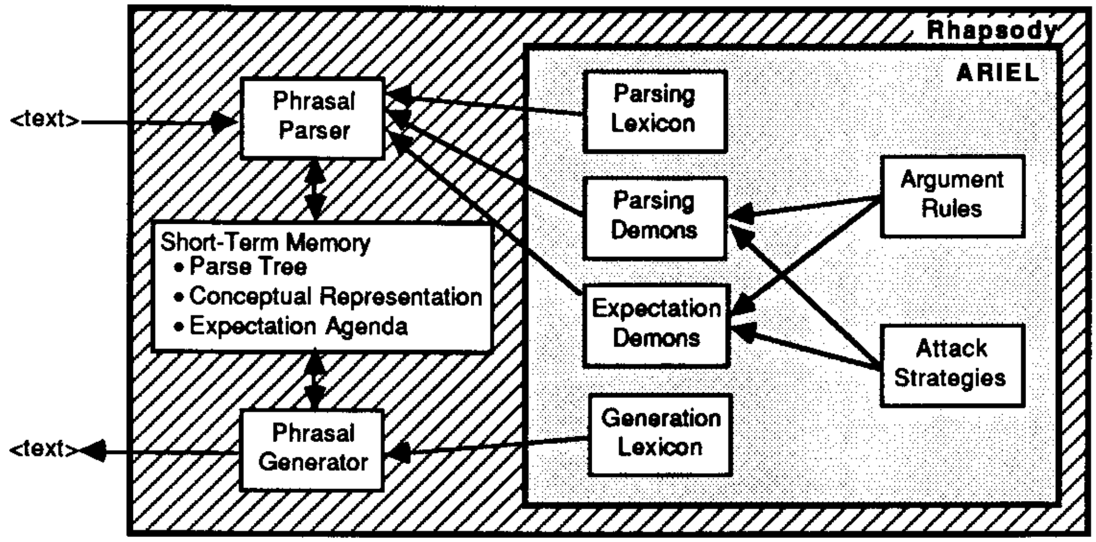


Figure 7-1. The components of ARIEL.

ARIEL uses RHAP (Reev89b), the Rhapsody phrasal generator, to generate output. This recursive descent generator is based upon PHRAN's phrasal generator, with only minor modifications. The *generation lexicon* used by the *phrasal generator* contains pattern-concept pairs similar to those used by the parser. The generator forms linguistic structures from corresponding semantic concepts.

7.2. Challenges to the System

When ARIEL was first completed, it was able to understand HIGH-TECH-1. In this text, the argument-by-analogy is incomplete, and both the analogy and the argument are indicated by the presence of lexical clues. We subsequently challenged the system by providing a wider range of texts for understanding. A subset of these texts focused on the same subject, but different components were missing from each argument. One text (HIGH-TECH-2) lacked lexical clues related to the presence of the analogy. Another (HIGH-TECH-3) lacked both lexical clues related to the presence of the analogy and lexical clues facilitating the flow of the argument. Both HIGH-TECH-2 and HIGH-TECH-3 contained incomplete arguments. The last text in this set (HIGH-TECH-4) included analogy- and argument-related lexical clues, as well as an explicitly completed argument. Our goal in testing these texts was to ensure that ARIEL would produce similar conceptual representations for each text, regardless of whether the argument was made explicitly or implicitly, or whether it included lexical clues relating to the structure of the argument or the presence of the analogy. ARIEL was also tested on an additional text (BISON-6) having a similar argument structure, but different domain, to determine the generality of the reasoning mechanisms incorporated into the model.

In analyzing the results of the first set of tests, we found that ARIEL was able to generate similar representations for all but one of the HIGH-TECH texts. The only difference in the exception (HIGH-TECH-4) was that the justification for the concluding belief was slightly different than that generated for the other texts, due to the additional information provided in the text. In general, we found that our system generated plausible completions to the arguments even when it encountered words in the text that it did not recognize as being in the lexicon. It would simply skip over the unknown words or phrases, and try to draw a conclusion based upon what it did understand. We also found that ARIEL had no difficulty understanding the argument from the alternate bison domain, once it was given the lexical entries and small amount of domain knowledge needed to handle the additional words.

Our challenges to the system did point out a need for more clearly defined procedures for deciding whether two concepts were analogous. We also needed to refine procedures for mapping analogous components of concepts, and for constructing and locating contrasting concepts in STM. In addition, it became evident that the generation of additional argument-related expectations was required. Subsequent changes to the system to enable it to understand these texts has resulted in a more refined model, and a more robust system. The resulting system has been presented in the previous chapters.

By examining the processing performed in understanding each of these texts, we can identify the significance of the differences among the texts, and demonstrate the robustness of the model.

7.3. Understanding the HIGH-TECH Texts

The HIGH-TECH texts are variations on HIGH-TECH-1, introduced in Chapter 1. We repeat it here to facilitate contrasting it with the remaining HIGH-TECH texts:

HIGH-TECH-1

> *Some people are against CAM because CAM eliminates jobs. However the automobile industry did the same thing to people in the horse carriage industry. Yet consumer demand for autos was strong enough that more jobs were created in the automobile industry than were lost in the horse carriage industry. In the end, the economy benefitted by the introduction of the new technology.*

In this text the author states a belief, then proceeds to attack the belief via an analogy. As discussed in Chapter 1, the point of HIGH-TECH is that CAM is actually good, because it, too, will lead to more new jobs. When ARIEL has understood the HIGH-TECH argument, it completes in memory a conceptual representation of the argument, which is depicted graphically in Figure 7-2. This representation captures the correspondence inferred between the beliefs in the source and target analogs and between the justifications for these beliefs, as well as capturing the inferred attack relationship between the beliefs within each analog.

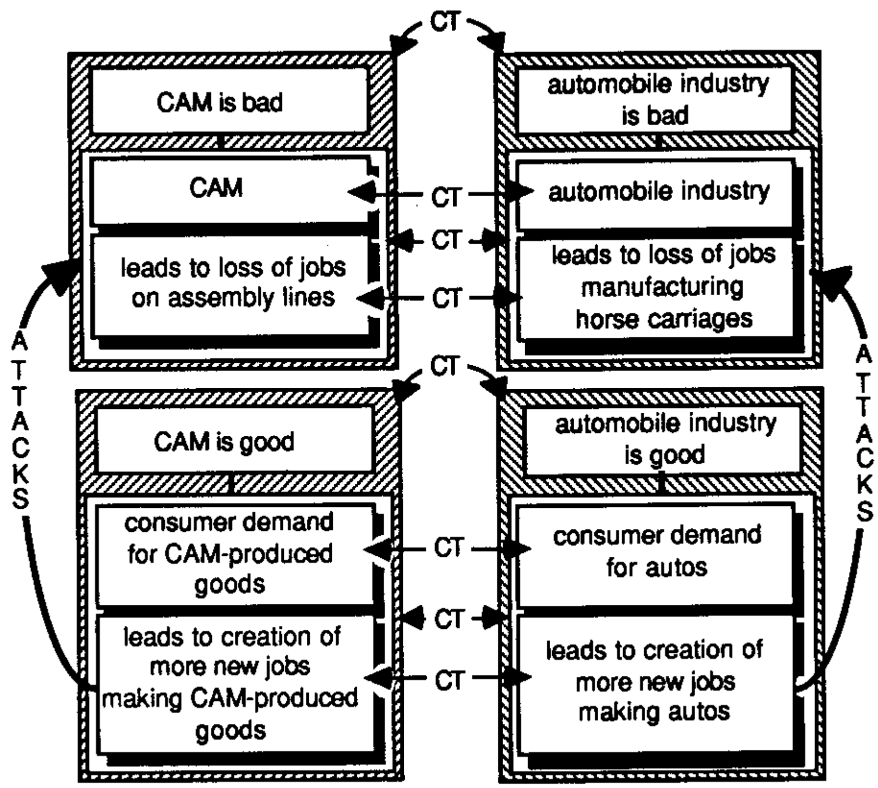


Figure 7-2. A graphical representation of HIGH-TECH.

7.3.1. HIGH-TECH-1

In HIGH-TECH-1, the author states a belief, then proceeds to attack the belief indirectly via an analogy, leaving it to the reader to form an analogous, direct attack on the original belief. The text contains the explicit lexical clue *did the same thing to* introducing the presence of the analogy in the text, as well as the explicit lexical clues *however*, *yet*, and *in the end* facilitating the flow of the argument. These clues alone were sufficient to prompt ARIEL to recognize the analogy, and complete the argument, drawing the conclusion that CAM is actually good, because it, too, will lead to more new jobs.

Disambiguating the phrase *did the same thing to* in the HIGH-TECH texts causes a flow of information from the CAM domain (the source analog) to the auto industry domain (the target analog). Completing the implicit argument, however, causes a reversal of this flow, with the auto industry domain becoming the source analog and the CAM domain becoming the target analog. Direct correspondence is mapped only at major points in our system, and no agreement of predicates is required at minor points.

The word *however* used in HIGH-TECH-1 indicates that a contrast to the preceding concept will be introduced. The second sentence matches tentatively with the linguistic pattern `however <causal-structure>`. This prompts ARIEL to locate a previously encountered concept in memory that contrasts with the current concept. `<causal-structure>` can contrast either directly or indirectly with the earlier concept. Processing associated with this lexical entry follows one of two paths. If `<causal-structure>` is already known to be analogous to another concept, as indicated by the presence of a compared-to or CT link between `<causal-structure>` and the other concept, the assumption is made that `<causal-structure>` itself is not a direct contrast, but will lead to an indirect contrast. That is, it is assumed that the contrast will be by analogy: a contrast to <causal-structure> will be introduced later, and that contrast will indirectly contrast with the concept preceding "however".

On the other hand, if a CT link does not exist between <causal-structure> and another concept, an attempt is made to find an analogous concept. If such an analogy can be formed, an indirect contrast can still be assumed, as above. In either case, a demon to search for a contrast to the preceding concept is placed on the expectation agenda.

As seen above, in HIGH-TECH-1 this <causal-structure> matches to the relationship between the auto industry and job loss in the horse carriage industry. This is known to be analogous to the causal relationship between CAM and loss of assembly line jobs. So an indirect contrast is assumed, and an expectation for a contrast to the preceding concept (the belief that CAM is bad) is placed on the expectation agenda.

The word *yet* in the third sentence creates the expectation that a contrast to the preceding concept will be introduced. The third sentence matches tentatively with the linguistic pattern `yet <causal-structure>`, prompting the system to perform another search for a previously encountered concept in memory that contrasts with the current concept. The direct contrast between the increase in jobs in the auto industry and the loss of jobs manufacturing horse carriages is recognized, satisfying the expectation, and a contrasting belief (that the auto industry is good) is instantiated.

The fourth sentence serves to reinforce the previously made point, and has the result that a second justification (that the economy benefitted by the manufacture of autos) is added to the belief that the auto industry is good.

When ARIEL has read all of the text of HIGH-TECH-1, it has built in memory the representation depicted in Figure 7-3, and has the expectation that the initial belief will be contrasted. The inferences which have been made up to this point are indicated in italics, and include the CT and attack links.

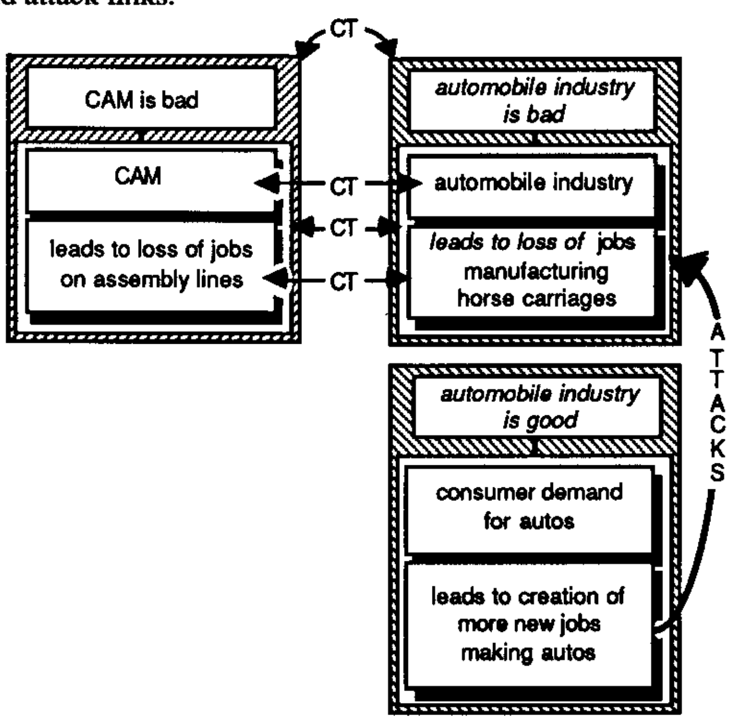


Figure 7-3. Representation of HIGH-TECH-1 after reading text.

In processing the expectation, the system finds that the belief that CAM is bad is analogous to the (hypothetical) belief that the auto industry was bad. This belief, in turn, has been attacked by showing that, although jobs were lost by the introduction of the technology, jobs were also gained. The underlying strategy employed can be stated as:

```
If X is bad because it thwarts a goal Y,
then attack by showing that X is good,
because although it thwarts goal Y,
it also achieves goal Z
and Z is a higher-level goal than Y.
```

Using this strategy, together with the justification of the attacking belief, as the source analog, ARIEL instantiates a similar attack on the belief that CAM is bad, and completes the argument as shown above in Figure 7-2. The details of this process are similar to those presented in Chapter 6 with regard to BISON-6. ARIEL then generates the following conclusion:

```
(THE MANUFACTURE OF CAM-PRODUCED GOODS IS GOOD
BECAUSE CONSUMER-DEMAND-FOR CAM-PRODUCED GOODS WILL
HAVE THE RESULT THAT JOBS WILL BE CREATED IN THE
MANUFACTURE OF CAM-PRODUCED GOODS)
```

This is an English version of the belief it formed in response to the expectation for a contrast to the initial belief in the text.

7.3.2. HIGH-TECH-2

HIGH-TECH-2 is similar in most respects to HIGH-TECH-1:

HIGH-TECH-2

Some people are against CAM because CAM eliminates jobs. However, the automobile industry caused people in the horse carriage industry to lose jobs. Yet consumer demand for autos was strong enough that more jobs were created in the automobile industry than were lost in the horse carriage industry. In the end, the economy benefitted by the introduction of the new technology.

HIGH-TECH-2 differs in that the explicit introduction of the analogy is not provided. In its place, the causal relationship between the auto industry and jobs in the horse carriage industry is explicitly stated. The absence of lexical clues introducing the analogy in the text forces ARIEL to rely solely upon its knowledge of how analogies are used in arguments in order to recognize the presence of the analogy in the editorial. This knowledge is manifested in the parse tests associated with argument-related lexical entries, and in the argument-related expectation demons.

The second sentence of HIGH-TECH-2 again matches tentatively to the pattern `however <causal-structure>`. This time the `<causal-structure>` is not known to be analogous to another concept, so an attempt is made to find an analogous concept. A direct contrast is not found, and the `<causal-structure>` relating the auto industry to job loss is not marked as being analogous. ARIEL therefore hypothesizes that the contrast will be indirect, and commences to search memory for a concept analogous to the current `<causal-structure>`. It determines that the causal relationship between CAM and loss of assembly line jobs is analogous to the current `<causal-structure>`, and develops a correspondence mapping between the two concepts. As with HIGH-TECH-1, an expectation for a contrast to the preceding concept (the belief that CAM is bad) is placed on the expectation agenda. The processing of the remaining two sentences proceeds as for the previous text.

After the text of HIGH-TECH-2 has been read, memory contains the same information as shown in Figure 7-3, the only difference being that the relationship between the auto industry and people in the horse carriage industry was supplied explicitly in the text, rather than being inferred. The process for completing the argument is the same as that for HIGH-TECH-1. ARIEL then generates the following conclusion:

```
(THE MANUFACTURE OF CAM-PRODUCED GOODS IS GOOD
BECAUSE CONSUMER-DEMAND-FOR CAM-PRODUCED GOODS WILL
HAVE THE RESULT THAT JOBS WILL BE CREATED IN THE
MANUFACTURE OF CAM-PRODUCED GOODS)
```

which matches that produced in response to HIGH-TECH-1, as expected.

7.3.3. HIGH-TECH-3

The text of HIGH-TECH-3 has neither a lexical clue introducing the analogy, nor lexical clues guiding the flow of the argument:

HIGH-TECH-3

Some people are against CAM because CAM eliminates jobs. The automobile industry caused people in the horse carriage industry to lose jobs. Consumer demand for autos was strong enough that more jobs were created in the automobile industry than were lost in the horse carriage industry. The economy benefitted by the introduction of the new technology.

Yet the information conveyed is basically the same as in HIGH-TECH-1 and HIGH-TECH-2. Contents of STM after reading the text are shown in Figure 7-4.

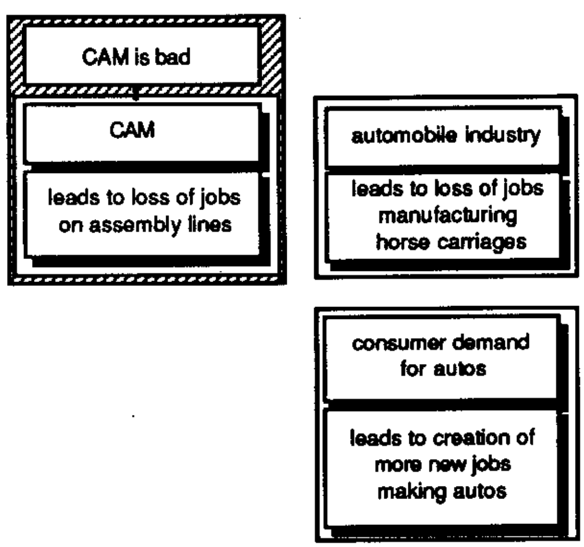


Figure 7-4. Representation of HIGH-TECH-3 after reading text.

In this case, very few inferences have been made. ARIEL handles this case by relying solely upon the expectation demon generated in understanding the first sentence of HIGH-TECH-3 to enable it to identify the indirect contrast, and complete the analogy. Since the initial belief has not been noted as being analogous to any other, an attempt is made to locate an analogous belief in memory. When this search fails, the system checks whether there is a concept which could be considered analogous to the justification of the initial belief. Once an analogous concept is found, it is CT linked to the concept which is the justification of the initial belief. When a CT link is formed between two concepts, and one is the justification for a belief, an analogous belief is inferred about the other concept, and those beliefs, in turn, are CT linked. At this point ARIEL seeks an attack on this newly formed belief, by analyzing the underlying structure of the new belief and hypothesizing a strategy for attacking that belief. (See Augu90 for a description of this process.) It finds a concept which fills this need, notes the attack relationship, and formulates another belief around the attack. At this point, memory contains the information that it contained after reading HIGH-TECH-1, as shown in Figure 7-4, and processing from this point on continues as before.

7.3.4. HIGH-TECH-4

The final member of this set is HIGH-TECH-4:

HIGH-TECH-4

Some people are against CAM because CAM eliminates jobs. However the automobile industry did the same thing to people in the horse carriage industry. Yet consumer demand for autos was strong enough that more jobs were created in the automobile industry than were lost in the horse carriage industry. In the end, the economy benefitted by the introduction of the new technology. Likewise, consumer demand for CAM-produced goods eventually will be strong enough that more jobs will be created in other areas than will be lost on the assembly line. In the end the economy will benefit by the introduction of CAM technology.

HIGH-TECH-4 provides the most information of the HIGH-TECH set, and contains complete arguments in both domains. When the text has been read, memory contains the information shown in Figure 7-5, plus the expectation of a contrast to the initial belief (that CAM is bad). The word *likewise* in HIGH-TECH-4 prompts ARIEL to recognize the analogy in the latter half of the text, and infer the fourth belief, that CAM is good. When the first expectation demon is taken from the agenda, this fourth belief is recognized as constituting an attack on the first belief, and the attack is noted. The second demon is then killed when it is removed from the agenda, because the expectation has now been filled.

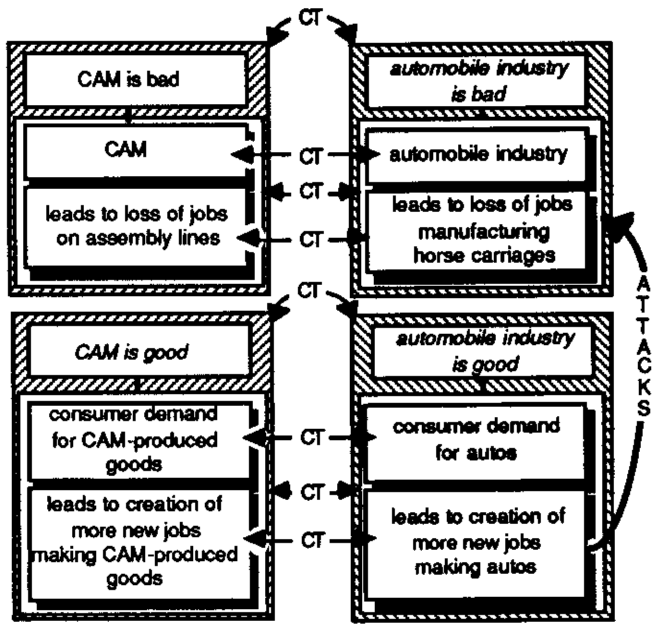


Figure 7-5. Representation of HIGH-TECH-4 after reading text.

The conclusion formed to HIGH-TECH-4 is slightly different than the one reported for the other HIGH-TECH texts:

```
(THE MANUFACTURE OF CAM-PRODUCED GOODS IS GOOD
BECAUSE CONSUMER-DEMAND-FOR CAM-PRODUCED GOODS WILL
HAVE THE RESULT THAT THE ECONOMY WILL BENEFIT BY
COMPUTER-AIDED MANUFACTURING AND CONSUMER-DEMAND-
FOR CAM-PRODUCED GOODS WILL HAVE THE RESULT THAT
THE ECONOMY WILL IMPROVE AS JOBS ARE SHIFTED
BETWEEN OCCUPATIONS)
```

This difference reflects the fact that the author explicitly completed the argument in the HIGH-TECH-4 text.

With the more varied input, including texts in which the argument-by-analogy was explicitly completed, FIND-CONTRADICTION-TO was obliged to also handle the case in which the components of an attack by analogy existed in memory, but were not yet tied together, as well as the case in which a directly contrasting belief already existed in memory, but was not yet recognized as such. The revised function appeared above in Chapter 6.

This augmentation of FIND-CONTRADICTION-TO led to a change in the construction of analogous beliefs. In our original model, when an analogous belief was formed and the justification for the belief was a causal structure, the antecedent of the causal structure was established as the event of the belief's belief object. That is, if the justification for a belief were "X causes Y", the belief object would be assumed to be "X is good/bad." However, when an attacking belief was formed, the new belief object's event was assigned the value of event of the attacked belief's belief object; the new value judgment was given the value opposite the value judgment. Thus, given a belief that "X is good", the attacking belief would be that "X is bad." A conflict arose in the following case:

Given:

W, X, Y, and Z, which are analogous to W', X', Y', and Z' respectively,
belief P: X is bad because X causes Y, and Y is bad,
belief Q: X is good, because W, which involves X, causes Z, and Z is good,

and the argument:

One might think P, but actually Q,

ARIEL would form:

belief P', analogous to P, as:
X' is bad because X' causes Y', and Y' is bad,
belief Q', analogous to Q, as:
W' is good, because W', which involves X', causes Z', and Z' is good,

but:

belief Q'', attacking P', as:
X' is good, because W', which involves X', causes Z', and Z' is good.

If STM contained P, Q, P', and Q', ARIEL would overlook Q' when searching for a belief contradicting P', since the event of the belief Q' (W') does not match that of P' (X'). When given a text containing an explicitly completed argument, the system was unable to recognize the existing analogous belief, and, instead of simply developing the appropriate CT and attack links, instantiated a new belief, which contradicted the original belief. This occurred during initial testing of HIGH-TECH-4, shown above. The justification for an attacking belief is provided explicitly in this text. The lexical clue *likewise* prompts ARIEL to search for an analogous, previously encountered concept. Once located, the system checks whether the analogous concept is part of a belief. If so, it forms an analogous belief around the concept following *likewise*, using *consumer demand for CAM-produced goods* as the belief object, under the old scheme. When the expectation for a contrast to the first belief is removed from the agenda and processed, the system looks for a belief having the same belief object, but a different value judgment, i.e., the proposition to be contradicted is *CAM is bad*, and its contradiction is *CAM is good*. As a result, the explicitly-stated belief regarding CAM-produced goods is overlooked as an existing contrast, and a new belief, using the same justification but the proposition *CAM is good* is formed. ARIEL was able to generate a the new, analogous belief based upon the input, but the belief that was formed did not directly attack the original belief. While this was a perfectly valid belief to conclude, it did not satisfy the expectation generated during understanding.

As a result of this problem, we developed the following heuristic for forming analogous beliefs:

```
form analogous belief

If the event of the source belief's proposition is CT linked to
   another event in the target analog, obtain the event for the
   target belief's proposition by traversing the CT link.
```

```
Otherwise, establish the antecedent of the causal structure in
   the target belief's justification as the event of the target
   belief's proposition.
```

Under this new scheme, Q' and Q" would be the same in most cases, enabling ARIEL to more easily identify an existing, contrasting belief.

7.4. Understanding the BISON-6 Text

In order to determine the robustness of ARIEL, we gave it a new text as input that had the same structure as HIGH-TECH-1, but was on a different subject:

BISON-6

> *Some people are against destroying the diseased herd of bison at Wood Buffalo National Park, because destroying them would reduce the population of an endangered species. However, cutting of a diseased finger does the same thing to one's hand. Yet sometimes it is the only way to save the hand.*

The processing of BISON-6 was discussed in detail in Chapter 6, and closely parallels that of HIGH-TECH-1. In order to understand BISON-6, a number of concepts had to be added to ARIEL's knowledge base, such as `<finger>`, `<body-part>`, and `<species>`. In addition, some low-level lexical entries had to be created, such as cutting off `<body-part>`. But, most significantly, at the highest level, the semantic patterns which were matched for each of the BISON-6 sentences:

```
<human> <aux-verb> against <event> because <causal-structure>.
However <leadto>
Yet <leadto>.
```

were the same as those used for the HIGH-TECH texts. Thus, at an abstract level, ARIEL appears to provide a robust model for reasoning about analogies in arguments of the type considered in this work.

7.5. Summary

We have illustrated our approach to understanding arguments-by-analogy by having ARIEL process a variety of prototypical editorials. These texts have been selected to demonstrate 1) understanding both with and without lexical clues related to the analogy and/or argument, 2) understanding when an argument-by-analogy has not been completed by an author, 3) understanding when an argument-by-analogy has been explicitly completed, and 4) understanding in different domains. A subset of the chosen texts focuses on the same domain or subject, with different components missing from each argument. Other editorials contain similarly-structured arguments on different subjects. These texts were included to develop and illustrate the domain-independent aspects of our approach. Adapting the system to enable it to understand this variety of texts has resulted in a more refined model, and a more robust system.

Chapter 8

Accomplishments and Future Work

The ability to comprehend arguments-by-analogy is an essential component of a robust natural language understanding system. It requires the integration of natural language understanding capability with knowledge of argumentation and analogical reasoning, as well as domain knowledge. The goal of this research was to identify the knowledge and processes needed to understand an editorial in which an author argues a point by analogy. The emphasis has been on the ability to complete an incomplete argument-by-analogy.

We have presented a model for an approach to understanding analogies in the arguments of editorial letters that integrates both domain-independent and domain-dependent knowledge. The components of our approach are fourfold. First, the presence of the analogy in the text must be detected. Secondly, the structure of the underlying argument must be identified. Thirdly, the implicitly stated details of the analogy must be inferred. Fourthly, a relevant conclusion must be drawn from the editorial.

In the ARIEL model, detection of the analogy is accomplished by exploiting lexical clues indicating its presence, when such clues are available. In their absence, knowledge of the way analogy is typically used in argumentation gives rise to the anticipation, and subsequent recognition, of its presence. Thus ARIEL is able to detect the presence of analogy whether or not lexical clues explicitly introduce it.

An argument in our model is composed of a set of beliefs which support and attack one another. A belief consists of a value judgment about an event, and a justification for that value judgment. Key to reasoning about beliefs in ARIEL is the ability to identify the underlying structure of the beliefs and arguments encountered. Domain-independent argument rules capture the structure of beliefs, while domain-independent attack strategies are employed to represent the structure of arguments.

Our use of these rules and strategies, coupled with domain knowledge, enables ARIEL to make relevant inferences about incomplete arguments. By using these rules and strategies, we can capture the reasoning behind an argument in a source domain, and replay that abstract reasoning pattern in a target domain, to generate plausible inferences in an incomplete argument-by-analogy. The use of argument rules and attack strategies in ARIEL is also essential for formulating an attack on a belief when an attack is made only implicitly. Without this knowledge of argumentation, ARIEL would not be able to formulate attacks when analogous instances are not readily available, or when an insufficient amount of detail has been provided about both source and target domains.

Expectations about argument structure and about the role analogy plays in arguments are integrated into the recognition, reasoning, and inference mechanisms. Satisfying these expectations enables ARIEL to form relevant conclusions about the arguments it encounters.

In this chapter we will describe the status of ARIEL, and outline future work.

8.1 Status

We have developed the computer program ARIEL which integrates a natural language understanding capability with knowledge of argumentation and analogical reasoning. This system is able to detect the presence of an analogy in an editorial text. Our system is able not only to understand a complete argument-by-analogy, but also to form a plausible completion to an incompletely stated argument-by-analogy. By incorporating an understanding of the logical structure of the text, and domain knowledge, ARIEL can understand and complete analogies even in the absence of a rich correspondence mapping, and regardless of whether lexical clues are available to guide understanding.

Our system demonstrates how effective use of abstract knowledge of argument structure can be coupled with an example to guide a search through target domain knowledge and generate a plausible completion to an incomplete argument-by-analogy. This integration of the phrasal parser, knowledge of argumentation, and knowledge of analogical reasoning enable ARIEL to understand arguments-by-analogy, and identify the point that the author of the argument is trying to make.

We have illustrated our approach to understanding arguments-by-analogy by having ARIEL process a variety of prototypical editorials from two domains. These texts have been selected to demonstrate 1) understanding both with and without lexical clues related to the analogy and/or argument, 2) understanding when an argument-by-analogy has not been completed by an author, 3) understanding when an argument-by-analogy has been explicitly completed, and 4) understanding in different domains. A subset of the chosen texts focuses on the same domain or subject, with different components missing from each argument. Our goal in processing these editorials was to ensure that ARIEL would produce the same conceptual representation for each text, regardless of whether the argument was made explicitly or implicitly, or whether it included lexical clues relating to the structure of the argument or the presence of the analogy. An additional editorial contains a similarly-structured argument on a different topic. This text was included to develop and illustrate the domain-independent aspects of our approach. Analysis of our results indicate that the general reasoning mechanism in ARIEL is robust enough to handle a variety of texts, once low-level lexical entries are added to handle new words.

ARIEL is written in Common Lisp and runs on a Macintosh Plus with 4 megabytes of memory. We have defined 32 classes of objects, 53 phrases for the parsing lexicon, and 19 phrases for the generation lexicon. ARIEL encompasses approximately 1,500 lines of code by itself, in addition to the code embodied in Rhapsody (Turn87) and its phrasal parser and phrasal generator (Reev89b).

8.2 Future Work

Avenues for future work exist in each of the three components integrated into ARIEL, that is, analogical reasoning, natural language understanding, and argumentation.

8.2.1. Enhancing Analogical Reasoning

One area of interest for further research involves enhancing the analogical reasoning component. ARIEL currently handles texts in which both source and target concepts are at the same level of abstraction. We would like to examine the problem of recognizing and reasoning about analogies in which the analogs are at different levels of abstraction.

We have identified three ways in which analogy is typically used in editorials. Two of these (*CONSISTENT VALUE JUDGMENTS* and *SIMILAR CONSEQUENCES*) are captured in the links developed between source and target analogs in our model. The third (*JOIN THE CLUB*) is not used in either the HIGH-TECH texts nor in BISON-6. Capturing this category of analogy use would require representing analogy in abstract form, or as a generalization, which ARIEL currently does not do. Coupling knowledge of each of these categories more closely into the ARIEL model would enhance the system's ability to draw analogy-related conclusions from editorials encountered.

8.2.2. Learning By Analogy

An important part of analogical reasoning is the issue of learning by analogy. In our research, we have restricted our dealings with this issue to the matter of forming a relevant conclusion to an argument-by-analogy. Another interesting question related to learning is whether relationships denoting analogy between concepts (i.e., the *compared-to* links) be retained in long term memory. If these links are retained in the representation of the concepts, then the analogy would possibly be taken out of context in which it occurred. However, retaining these links would facilitate understanding the next time the analogy is encountered.

A related issue concerns what information about the analogy should be saved in long term memory, and how it should be recorded. It might prove useful to retain the analogy-related conclusions, mentioned in 8.2.1 above, if the goal in learning is to learn general problem-solving strategies. On the other hand, if the goal of the system is to learn about a particular domain, such as a particular individuals political beliefs, then this information might not prove to be useful.

8.2.3. Augmenting the Lexicon

The processing components in our system are sufficiently flexible and modular to support understanding of a much broader range of texts than currently supported. A natural extension to this work lies in extending the lexicon and domain knowledge needed to processes texts drawing upon a wider vocabulary. In this same vein, the lexicon should be augmented to recognize more of the typical lexical clues relating both to analogy (e.g., *X is like Y* and *X just as Y*), and to argumentation (e.g., *On the other hand, Instead of doing X, we should be doing Y*).

From a generation point of view, another area for further development is the enhancement of the generation mechanism to convert a conceptual representation of a completed argument-by-analogy into an easily understood text that conveys the use of analogy in the argument.

8.2.4. Extending Knowledge of Argumentation

ARIEL's sets of argument rules and attack strategies revolve around the achievement and thwarting of goals. They are not intended to represent a complete set of possible rules and strategies, but rather to identify the kinds of information that is needed to follow and represent arguments. A logical extension to our work is to augment ARIEL's knowledge of argumentation with strategies for supporting propositions, and with knowledge needed to support understanding and reasoning about other types of arguments. For example, the text of ILLEGAL-DRUGS in Chapter 4 is currently too complex for ARIEL to handle, in part because the system does not support attack by counter-example, as seen in this editorial. In the current system, justifications of beliefs are all assumed to be causal in nature. It would be interesting to explore what other kinds of justifications exist, and extend the model to consider other types of support.

8.2.5. Learning Argument Techniques

In the future we would like to address the problem of learning unknown argument rules, and recognizing and retaining frequently-encountered argument patterns. If the structure underlying an argument cannot be found among the known argument rules, our system would then be able to formulate a new rule reflecting the structure and add it tentatively to the rule set.

8.3 Summary

The goal of this research was to develop an approach to understanding analogies in arguments. We have achieved this goal by developing ARIEL, a computer program which is able to understand editorials in which an author argues a point by analogy. ARIEL is able to detect the presence of the analogy in the text whether or not lexical clues have been used by the author to explicitly indicate its presence. Likewise, ARIEL is able to understand an argument-by-analogy whether or not the argument is explicitly completed by the author. By capturing the line of reasoning underlying an argument in a source domain, and coupling this underlying structure with domain knowledge, ARIEL is able to follow the example established in the source domain and generate an analogous argument in the target domain. The system is able to infer a plausible conclusion to an incomplete argument-by-analogy, even when a rich correspondence mapping between the analogs has not been provided in the text.

The focus of this research has been restricted to analogical reasoning in editorials. Yet it has application in other areas. A similar use of abstract knowledge can facilitate finding a solution to a problem or supplying missing details to a specific case in other domains, such as menu planning. The ability to recognize, understand and produce arguments by analogy will enhance an expert system's explanation capability.

The widespread use of analogy in human communication and problem solving underscores the need for advances in computational models of analogical reasoning. By identifying the knowledge and processes needed to understand arguments-by-analogy, we have made a contribution to meeting this need.

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Appendix A

Traces

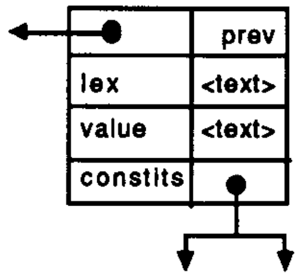
ARIEL is a computer program which models comprehension of editorials containing analogies. ARIEL's memory contains domain knowledge as well as knowledge about analogical reasoning and argumentation. Using the phrasal parser in Rhapsody (Turn87), ARIEL reads a prototypical editorial letter, recognizes the presence of an analogy in the text, identifies the source and target components, and develops a conceptual representation (Norm75) (Scha75) (Scha77) (Rume76) of the completed analogy in memory. ARIEL maintains a history of the argument structure during understanding. Using this history and domain knowledge, ARIEL is able to to transform an argument in a source domain into an analogous argument in a target domain. Thus, ARIEL is able to complete an implicit argument by analogy, and identify the point that the author of the editorial is trying to make. Using the RHAP phrasal generator (Reev89b), ARIEL generates an English equivalent of the conclusion it draws from the letter.

A.1. How ARIEL Parses

ARIEL's lexicon consists of pattern:concept pairs. The phrasal parser in Rhapsody reads input strings one at a time. It compares the input to the pattern portion of the pattern:concept pairs of ARIEL's lexicon. Lexical entries in Rhapsody's phrasal parser have the following format:

```
(phrase:define '<name>
               <comment>
               <pattern>
               <concept>
               <parse-test>
               <gen-test>
               <parse-proc>
               <gen-proc> )

        name -- unique identifier for this lexical entry

     comment -- text to identify the meaning of the phrase

     pattern -- the pattern to be matched

     concept -- the concept to be instantiated

  parse-test -- lambda to run to determine whether the phrase
                is applicable for generation

  parse-proc -- procedure to run after the pattern has
                matched during parsing

    gen-proc -- procedure to run after the concept has
                matched during generation
```

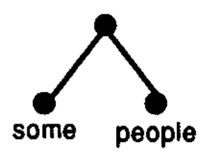
As ARIEL reads each word, the parser adds a new node as the right-most branch of the root. This node has the structure:



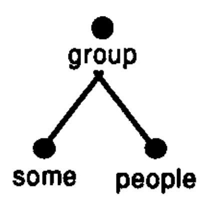
The new node's value is set to the current word, and it gets a pointer back to the most recently created node. The new node then becomes the root of the parse tree. Next, the parser checks whether there is a lexical entry for the word. If no entry is found, the parser goes on to read the next word in the sentence, and repeats the process. If an entry is found, a new node is added to the tree to represent the phrase.

For example, after reading "some" ARIEL has

in memory. After reading "people", it has:



in memory. Next, it checks whether the resulting tree matches any other pattern in memory. It matches the phrase "<article> <group>", which is paired with the concept for group modified by a referent, and adds this concept to the root of the tree:



This process of "read a word, look for matching pattern, add to the tree, look for other phrase matches, modify tree, read a word" continues until all of the words of the text have been processed.

The following five sections contain an annotated trace of ARIEL processing BISON-6, followed by annotated traces of ARIEL processing each of the HIGH-TECH texts.

A.2. BISON-6 Annotated Trace

The following is an annotated trace of ARIEL processing BISON-6, shown below. ARIEL is invoked with a command `(pparse-<text>)` to process a particular text. The amount of tracing detail that is displayed decreases as the we proceed further along in the trace.

```
> (pparse-ht1)

BISON-6:
Some people are against destroying the diseased
herd-of-bison-at-wood-buffalo-national-park
because destroying them would reduce
the-population-of-an-endangered-species *period*
however cutting-off a diseased finger
does-the-same-thing-to one*s hand *period*
yet sometimes cutting-off the finger
is-the-only-way-to save-the-hand *period*
```

A.2.1. Sentence 1

ARIEL begins with the first sentence of BISON-6:

> ***Some people are against destroying the diseased herd-of-bison-at-wood-buffalo-national-park because destroying them would reduce the-population of an endangered species...***

```
---------------------------------
Processing word: SOME
---------------------------------
Trying phrase #{LE1}

Found Phrase: #{LE1}
-----> some <-----

Created Concept:
(ARTICLE &ARTICLE.10
   TYPE INDEFINITE)

Trying phrase #{LEB12}
Trying phrase #{LEH31}
---------------------------------
Processing word: PEOPLE
---------------------------------
Trying phrase #{LEB12}
Trying phrase #{LEH31}
Trying phrase #{LE3}

Found Phrase: #{LE3}
-----> people <-----

Created Concept:
(GROUP &GROUP.10
   NAME PEOPLE
   TYPE #{HUMAN})

Found Phrase: #{LEB12}
-----> <article> <thing> <-----
```

```
Created Concept:
(GROUP &GROUP.10
   REF  INDEFINITE
   NAME PEOPLE
   TYPE #{HUMAN})
--------------------------------
Processing word: ARE
--------------------------------
Found Phrase: #{LE4}
-----> are <-----

Created Concept:
(AUX-VERB &AUX-VERB.6
   NAME   TO-BE
   TENSE  PRESENT
   NUMBER PLURAL)
--------------------------------
Processing word: AGAINST
--------------------------------
--------------------------------
Processing word: DESTROYING
--------------------------------
--------------------------------
Processing word: THE
--------------------------------
Found Phrase: #{LE23}
-----> the <-----

Created Concept:
(ARTICLE &ARTICLE.11
   TYPE DEFINITE)
--------------------------------
Processing word: DISEASED
--------------------------------
--------------------------------
Processing word: HERD-OF-BISON-AT-WOOD-BUFFALO-
NATIONAL-PARK
--------------------------------
Found Phrase: #{LEB20}
-----> herd of bison at Wood Buffalo National Park <-----

Created Concept:
(HERD &HERD.1
   TYPE     BISON
   LOCATION WOOD-BUFFALO-NATIONAL-PARK
   SPECIES  &SPECIES.1)

Found Phrase: #{LEB15}
-----> diseased <thing> <-----

Created Concept:
(HERD &HERD.1
   HEALTH   DISEASED
   TYPE     BISON
   LOCATION WOOD-BUFFALO-NATIONAL-PARK
   SPECIES  &SPECIES.1)
```

```
Found Phrase: #{LEB12}
-----> <article> <thing> <-----

Created Concept:
(HERD &HERD.1
   REF      DEFINITE
   HEALTH   DISEASED
   TYPE     BISON
   LOCATION WOOD-BUFFALO-NATIONAL-PARK
   SPECIES  &SPECIES.1)

Found Phrase: #{LEB1B}
-----> destroying <something> <-----

Created Concept:
(DESTRUCTION &DESTRUCTION.1
   DESTRUCTION-METHOD DESTROYING
   OBJECT             &HERD.1)
---------------------------------
Processing word: BECAUSE...DESTROYING...THEM
---------------------------------
Found Phrase: #{LEB21}
-----> them <-----

Created Concept:
(HERD &HERD.1
   REF      DEFINITE
   HEALTH   DISEASED
   TYPE     BISON
   LOCATION WOOD-BUFFALO-NATIONAL-PARK
   SPECIES  &SPECIES.1)

Found Phrase: #{LEB1B}
-----> destroying <something> <-----

Created Concept:
(DESTRUCTION &DESTRUCTION.2
   DESTRUCTION-METHOD DESTROYING
   OBJECT             &HERD.1)
---------------------------------
Processing word: WOULD...REDUCE...
    THE-POPULATION-OF-AN-ENDANGERED-SPECIES
---------------------------------
Found Phrase: #{LEB2}
-----> the population of an endangered species <-----

Created Concept:
(SPECIES &SPECIES.2
   STATUS ENDANGERED)

Found Phrase: #{LEB3}
-----> <destruction> would reduce <species> <-----

Created Concept:
(GOAL &GOAL.11
   OBJECT      &SPECIES.2
   STATUS      FAILURE)
```

```
------------------------------
Noting that #{GOAL.11}
Is the consequent of #{LEADTO.11}
------------------------------
------------------------------
Noting that #{DESTRUCTION.2}
Is the antecedent of #{LEADTO.11}
------------------------------
Created Concept:
(LEADTO &LEADTO.11
   ANTE  &DESTRUCTION.2
   CONSE &GOAL.11)
---------------------------------
Processing word: *PERIOD*
---------------------------------
Found Phrase: #{LEB4}
-----> <human> <aux-verb> against <event>
            because <causal-structure>. <-----
------------------------------
Noting that #{LEADTO.11}
Is the justification of #{BELIEF.5}
------------------------------
------------------------------
Noting expectation: EXPECT-CONTRAST-TO #{BELIEF.5}
------------------------------
Created Concept:
(BELIEF &BELIEF.5
   NAME          TO-BE-AGAINST
   ACTOR         &GROUP.10
   B-OBJECT      &B-OBJECT.5
   JUSTIFICATION &LEADTO.11)
```

This belief can be represented graphically as shown in Figure A-1.

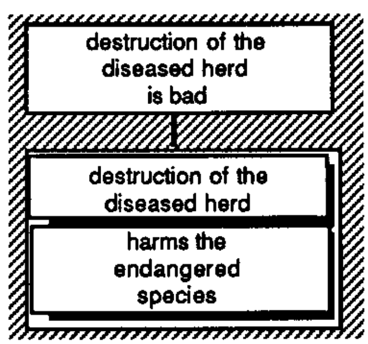


Figure A-1. Diagram of memory after parse of BISON-6 sentence 1.

A.2.2. Sentence 2

ARIEL continues with the second sentence of BISON-6:

> ***...however cutting-off a diseased finger does-the-same-thing-to one*s hand *period* ...***

```
---------------------------------
Processing word: HOWEVER
---------------------------------
```

HOWEVER indicates that the following concept will contrast with the previous one.

```
---------------------------------
Processing word: CUTTING-OFF...A
---------------------------------
Found Phrase: #{LEB17}
-----> a <-----

Created Concept:
(ARTICLE &ARTICLE.12
   TYPE INDEFINITE)
---------------------------------
Processing word: DISEASED...FINGER
---------------------------------
Found Phrase: #{LEB16}
-----> finger <-----

Created Concept:
(BODY-PART &BODY-PART.1
   PART    FINGER
   PART-OF HAND)

Found Phrase: #{LEB15}
-----> diseased <thing> <-----

Created Concept:
(BODY-PART &BODY-PART.1
   HEALTH  DISEASED
   PART    FINGER
   PART-OF HAND)

Found Phrase: #{LEB12}
-----> <article> <thing> <-----

Created Concept:
(BODY-PART &BODY-PART.1
   REF     INDEFINITE
   HEALTH  DISEASED
   PART    FINGER
   PART-OF HAND)

Found Phrase: #{LEB5}
-----> cutting off <body-part> <-----

Created Concept:
(DESTRUCTION &DESTRUCTION.3
   DESTRUCTION-METHOD CUTTING-OFF
   OBJECT             &BODY-PART.1)
---------------------------------
Processing word: DOES-THE-SAME-THING-TO...ONE*S...HAND
---------------------------------
Found Phrase: #{LEB6}
-----> one's hand <-----
```

```
Created Concept:
(BODY-PART &BODY-PART.2
   PART    HAND
   PART-OF ARM)

Trying phrase #{LEB7}
LEB7 pattern: <destruction> does the same thing to <thing>
```

ARIEL is trying to identify amputating a finger does to the hand. Domain knowledge includes possible consequences of a destructive act, including the thwarting of a goal. The system searches STM for a recent causal structure in which an instance of destruction thwarted a goal. This search is facilitated by the fact that ARIEL categorizes concepts as they are instantiated. Thus, recent causal structures can be searched by traversing the list of causal structures encountered up to this point.

```
------------------------------
Checking for a similar recent event
In which destruction thwarted a goal...
------------------------------
Found Phrase: #{LEB7}
-----> <destruction> does the same thing to <thing> <-----
```

ARIEL has made a match with this phrase by finding the instance of destroying the herd (#DESTRUCTION.2) resulting in a reduction in the population of the endangered species (#GOAL.11), which together form #LEADTO.11. This verifies ARIEL's hypothesis that the relationship between "damaging the finger" and "a hand" is that the former impairs the hand. ARIEL instantiates a causal relationship (#LEADTO.12) between destroying the diseased finger (#DESTRUCTION.3) and the thwarting of the goal to have a healthy hand (#LEADTO.2) which reflects this. Note that ARIEL is not forming #LEADTO.12 merely by copying the structure #LEADTO.11. Rather, ARIEL has made a hypothesis about the relationship, verified that hypothesis, and made the instantiation based upon its domain knowledge. Since #LEADTO.11 was used to verify the relationship #LEADTO.12, ARIEL forms an analogy between these two structures. The analogy is represented by comparison links mapping #LEADTO.11 to #LEADTO.12, and mapping the antecedent and consequent of #LEADTO.11 to the antecedent and consequent of #LEADTO.12, respectively. ARIEL has concluded that the following things are being compared:

1. Destruction of the herd is being compared to the destruction of the finger.

2. Damage to the endangered species is being compared to damage to the hand.

3. Destruction of the herd thwarting the goal of preserving the species is being compared to destruction of the finger thwarting the goal of preserving the hand.

The objects of the two goals, #SPECIES.2 and #BODY-PART.2, are not mapped, because they are not semantically similar, even though the goals of which they are a part can be mapped within the constraints of structural similarity.

```
------------------------------
... Similar event found.
Drawing an analogy between the events
#{LEADTO.12} and #{LEADTO.11}
------------------------------
------------------------------
Comparing the concept: #{LEADTO.12}
With the concept: #{LEADTO.11}
------------------------------
(LEADTO &LEADTO.12
   COMPARED-TO &LEADTO.11
   ANTE        &DESTRUCTION.3
   CONSE       &GOAL.12)

(LEADTO &LEADTO.11
   COMPARED-TO      &LEADTO.12
   JUSTIFICATION-OF &BELIEF.5
   ANTE             &DESTRUCTION.2
   CONSE            &GOAL.11)
------------------------------
Comparing the concept: #{DESTRUCTION.3}
With the concept: #{DESTRUCTION.2}
------------------------------
(DESTRUCTION &DESTRUCTION.3
   COMPARED-TO        &DESTRUCTION.2
   ANTE-OF            &LEADTO.12
   DESTRUCTION-METHOD CUTTING-OFF
   OBJECT             &BODY-PART.1)

(DESTRUCTION &DESTRUCTION.2
   COMPARED-TO        &DESTRUCTION.3
   ANTE-OF            &LEADTO.11
   DESTRUCTION-METHOD DESTROYING
   OBJECT             &HERD.1)
------------------------------
Comparing the concept: #{GOAL.12}
With the concept: #{GOAL.11}
------------------------------
(GOAL &GOAL.12
   COMPARED-TO &GOAL.11
   CONSE-OF    &LEADTO.12
   OBJECT      &BODY-PART.2
   STATUS      FAILURE)

(GOAL &GOAL.11
   COMPARED-TO &GOAL.12
   CONSE-OF    &LEADTO.11
   OBJECT      &SPECIES.2
   STATUS      FAILURE)

Created Concept:
(LEADTO &LEADTO.12
   COMPARED-TO &LEADTO.11
   ANTE        &DESTRUCTION.3
   CONSE       &GOAL.12)
```

```
------------------------------
[leH35 PARSE-TEST]
Testing phrase:  However <leadto>...
Is <leadto> analogous to a similar event,
and is that event the justification of a belief?
------------------------------
------------------------------
HOWEVER indicates that the following concept
Will contrast with the previous one,
Or that it will lead to a contrast
With the previous concept.
------------------------------
------------------------------
Looking for the previous concept to which
A contrast will be introduced
------------------------------
------------------------------
#{LEADTO.12} is compared to: #{LEADTO.11}
------------------------------
------------------------------
Checking whether #{LEADTO.11}
Is part of a belief...
------------------------------
------------------------------
Checking whether #{LEADTO.11}
Is the justification for the belief: #{BELIEF.5}...
------------------------------
------------------------------
#{LEADTO.11} is the justification
For the belief: #{BELIEF.5}
------------------------------
------------------------------
Previous concept found: #{BELIEF.5}
------------------------------
Found Phrase: #{LEH35}
-----> However <leadto> <-----
------------------------------
Noting expectation: EXPECT-CONTRAST-TO #{BELIEF.5}
------------------------------
------------------------------
Inferring that: #{BELIEF.5}
Is analogous to: #{BELIEF.6}
------------------------------
------------------------------
Comparing the concept: #{BELIEF.5}
With the concept: #{BELIEF.6}
------------------------------
(BELIEF &BELIEF.5
   COMPARED-TO   &BELIEF.6
   NAME          TO-BE-AGAINST
   ACTOR         &GROUP.10
   B-OBJECT      &B-OBJECT.5
   JUSTIFICATION &LEADTO.11)
```

```
(BELIEF &BELIEF.6
   ACTOR         #{HUMAN}
   B-OBJECT      &B-OBJECT.6
   JUSTIFICATION &LEADTO.12
   COMPARED-TO   &BELIEF.5)
------------------------------
Comparing the concept: #{LEADTO.11}
With the concept: #{LEADTO.12}
------------------------------
(LEADTO &LEADTO.11
   COMPARED-TO      &LEADTO.12
   JUSTIFICATION-OF &BELIEF.5
   ANTE             &DESTRUCTION.2
   CONSE            &GOAL.11)

(LEADTO &LEADTO.12
   JUSTIFICATION-OF &BELIEF.6
   COMPARED-TO      &LEADTO.11
   ANTE             &DESTRUCTION.3
   CONSE            &GOAL.12)
------------------------------
Comparing the concept: #{DESTRUCTION.2}
With the concept: #{DESTRUCTION.3}
------------------------------
(DESTRUCTION &DESTRUCTION.2
   COMPARED-TO        &DESTRUCTION.3
   ANTE-OF            &LEADTO.11
   DESTRUCTION-METHOD DESTROYING
   OBJECT             &HERD.1)

(DESTRUCTION &DESTRUCTION.3
   COMPARED-TO        &DESTRUCTION.2
   ANTE-OF            &LEADTO.12
   DESTRUCTION-METHOD CUTTING-OFF
   OBJECT             &BODY-PART.1)
------------------------------
Comparing the concept: #{GOAL.11}
With the concept: #{GOAL.12}
------------------------------
(GOAL &GOAL.11
   COMPARED-TO &GOAL.12
   CONSE-OF    &LEADTO.11
   OBJECT      &SPECIES.2
   STATUS      FAILURE)

(GOAL &GOAL.12
   COMPARED-TO &GOAL.11
   CONSE-OF    &LEADTO.12
   OBJECT      &BODY-PART.2
   STATUS      FAILURE)
------------------------------
Inferring name of new belief: TO-BE-AGAINST
From analogous belief
------------------------------
```

```
------------------------------
Inferring event of the new belief object
#{DESTRUCTION.3}
From antecedent of the current causal structure
#{LEADTO.12}
------------------------------
------------------------------
Inferring value judgment
Of the new belief object is: NEGATIVE
From analogous belief's belief-object
------------------------------
Created Concept:
(BELIEF &BELIEF.6
   ACTOR          #{HUMAN}
   B-OBJECT       &B-OBJECT.6
   JUSTIFICATION &LEADTO.12
   NAME           TO-BE-AGAINST
   COMPARED-TO    &BELIEF.5)
---------------------------------
Processing word: *PERIOD*
---------------------------------
```

The contents of memory after sentence 2 are shown in Figure A-2.

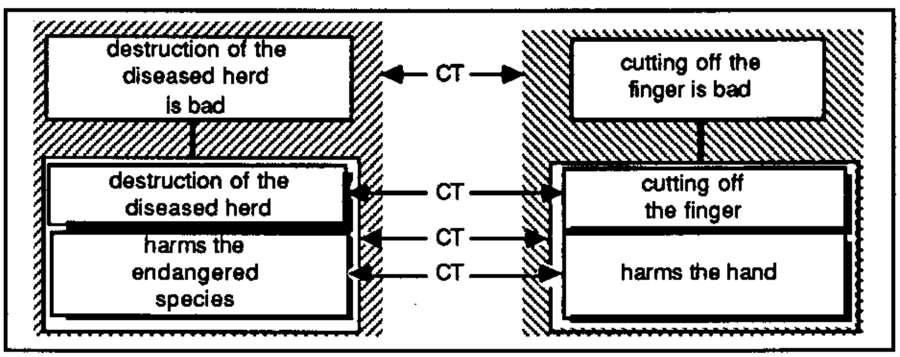


Figure A-2. Diagram after parse of BISON-6 sentence 2.

A.2.3. Sentence 3

ARIEL begins with the third sentence:

> ***...Yet sometines cutting-off the finger is-the-only-way-to save-the-hand *period****

```
---------------------------------
Processing word: YET...SOMETIMES...CUTTING-OFF...THE
---------------------------------
Found Phrase: #{LE23}
-----> the <-----

Created Concept:
(ARTICLE &ARTICLE.13
   TYPE DEFINITE)
```

```
---------------------------------
Processing word: FINGER
---------------------------------
Found Phrase: #{LEB16}
-----> finger <-----

Created Concept:
(BODY-PART &BODY-PART.3
   PART    FINGER
   PART-OF HAND)

Found Phrase: #{LEB12}
-----> <article> <thing> <-----

Created Concept:
(BODY-PART &BODY-PART.3
   REF     DEFINITE
   PART    FINGER
   PART-OF HAND)

Found Phrase: #{LEB5}
-----> cutting off <body-part> <-----

Created Concept:
(DESTRUCTION &DESTRUCTION.4
   DESTRUCTION-METHOD CUTTING-OFF
   OBJECT   &BODY-PART.3)
---------------------------------
Processing word: IS-THE-ONLY-WAY-TO...SAVE-THE-HAND
---------------------------------
Found Phrase: #{LEB9}
-----> save the hand <-----

Created Concept:
(GOAL &GOAL.13
   OBJECT &BODY-PART.4
   STATUS SUCCESS)

Found Phrase: #{LEB10}
-----> <destruction> is the only way to <goal> <-----

Created Concept:
(LEADTO &LEADTO.13
   ANTE  &DESTRUCTION.4
   CONSE &GOAL.13)

Found Phrase: #{LEB11}
-----> sometimes <leadto> <-----

Created Concept:
(LEADTO &LEADTO.13
   ANTE  &DESTRUCTION.4
   CONSE &GOAL.13)
---------------------------------
Processing word: *PERIOD*
---------------------------------
Trying phrase #{LE39REV}
```

```
------------------------------
[LE39rev PARSE-TEST]
Testing phrase:  Yet <leadto>.
Is there a preceding belief
Which is contradicted by <leadto>?
------------------------------
```

The word *YET* creates the expectation that the concept following it concept will contradict a previously stated belief. So ARIEL must check whether such a contradiction exists. It proceeds by checking whether cutting of the diseased finger achieving the goal of preserving the hand contradicts a previous belief. ARIEL starts with the most recent belief, then works back. Once a recent belief is found, the rule underlying the belief is either retrieved or derived and attached to the belief. Then ARIEL checks to see how such an argument can be attacked.

```
------------------------------
Looking for a belief contradicted by: #{LEADTO.13}
------------------------------
(LEADTO &LEADTO.13
   ANTE  &DESTRUCTION.4
   CONSE &GOAL.13)
------------------------------
Trying: #{BELIEF.6}
------------------------------
------------------------------
Checking whether: #{LEADTO.13} can attack #{BELIEF.6}
Using attack strategy: #{AS-1}
------------------------------
------------------------------
Attack Strategy 1:
    If X is bad because X causes Y and Y is bad,
    Then show that X causes Z and Z is good.
------------------------------
------------------------------
Checking whether #{DESTRUCTION.4}
Is similar to #{DESTRUCTION.3} (X)
------------------------------
------------------------------
Checking similarity of #{DESTRUCTION.3}
and #{DESTRUCTION.4}
------------------------------
(DESTRUCTION &DESTRUCTION.3
   COMPARED-TO        &DESTRUCTION.2
   ANTE-OF            &LEADTO.12
   DESTRUCTION-METHOD CUTTING-OFF
   OBJECT             &BODY-PART.1)

(DESTRUCTION &DESTRUCTION.4
   ANTE-OF            &LEADTO.13
   DESTRUCTION-METHOD CUTTING-OFF
   OBJECT             &BODY-PART.3)
------------------------------
Looking in slot: DESTRUCTION-METHOD
------------------------------
------------------------------
Looking in slot: OBJECT
------------------------------
```

```
------------------------------
Checking similarity of #{BODY-PART.1}
and #{BODY-PART.3}
------------------------------
(BODY-PART &BODY-PART.1
   REF     INDEFINITE
   HEALTH  DISEASED
   PART    FINGER
   PART-OF HAND)

(BODY-PART &BODY-PART.3
   REF     DEFINITE
   PART    FINGER
   PART-OF HAND)
------------------------------
Looking in slot: PART
------------------------------
------------------------------
Looking in slot: PART-OF
------------------------------
------------------------------
#{BODY-PART.1} and #{BODY-PART.3} are similar
------------------------------
------------------------------
#{DESTRUCTION.3} and #{DESTRUCTION.4} are similar
------------------------------
------------------------------
#{GOAL.13} involves preserving a body part.
Preserving a body part is good.
------------------------------
------------------------------
#{BELIEF.6} is contradicted via: #{AS-1}
------------------------------
```

This enables ARIEL to interpret sentence three of BISON-6 as a new belief which contradicts the previous belief that cutting off the diseased finger is bad:

```
Found Phrase: #{LE39REV}
-----> Yet <leadto>. <-----
------------------------------
Noting that #{LEADTO.13}
Is the justification of #{BELIEF.7}
------------------------------
------------------------------
Instantiating a new belief which
Contradicts the previous belief: #{BELIEF.6}
------------------------------
------------------------------
The event of the new belief object: #{DESTRUCTION.3}
Is the same as the event
Of the belief being contradicted.
------------------------------
------------------------------
The value judgment of the previous belief is: NEGATIVE
------------------------------
```

```
------------------------------
Inferring that the value judgment
Of the new belief is: POSITIVE
------------------------------
------------------------------
The justification of the new belief: #{LEADTO.13}
Contradicts the justification
Of the previous belief: #{LEADTO.12}
------------------------------
------------------------------
The new belief:
(BELIEF &BELIEF.7
   ACTOR         #{HUMAN}
   NAME          TO-BE-FOR
   B-OBJECT      &B-OBJECT.7
   JUSTIFICATION &LEADTO.13)
------------------------------
------------------------------
Noting that #{LEADTO.12}
Is being attacked by #{LEADTO.13}
------------------------------
Created Concept:
(BELIEF &BELIEF.7
   ACTOR         #{HUMAN}
   NAME          TO-BE-FOR
   B-OBJECT      &B-OBJECT.7
   JUSTIFICATION &LEADTO.13)

Processing Complete
Result of Parse:
#{BELIEF.5}
#{BELIEF.6}
#{BELIEF.7}
```

At this point, all of the text has been read in, and the argument graph shown in Figure A-3 has been built in memory. The argument is still incomplete, and an unresolved expectation for a contrast to the initial belief remains on the expectation agenda.

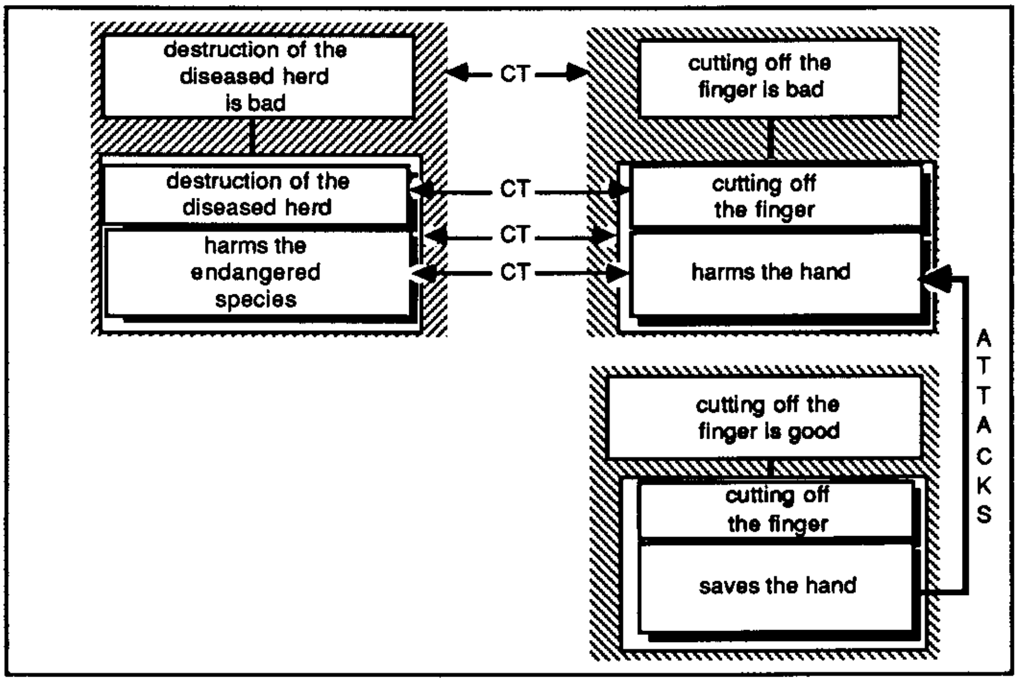


Figure A-3. Diagram of BISON-6 after all text has been read.

A.2.4. Completing the Argument

The expectations remaining on the agenda are now processed.

```
-----------------------------
Entering: EXPECT::EXPECT-RUN EXPECT-CONTRAST-TO #{BELIEF.5}
-----------------------------
```

To determine whether a belief has been attacked, ARIEL checks whether the justification for the belief has been attacked, either directly or by analogy.

```
-----------------------------
Contrast to: #{BELIEF.5} is expected...
-----------------------------
-----------------------------
#{BELIEF.5} is analogous to: #{BELIEF.6}
Whose justification: #{LEADTO.12}
Has been attacked by: #{LEADTO.13}
-----------------------------
-----------------------------
The justification of #{BELIEF.6}: #{LEADTO.12}
Has been attacked by: #{LEADTO.13}
Using the strategy: #{AS-1}
Thus, #{LEADTO.13} attacks #{BELIEF.5} by analogy.
-----------------------------
-----------------------------
Form an analogous attack on: #{BELIEF.5}
Using the strategy #{AS-1} and
Using #{LEADTO.13} as a source analog.
Check first for an existing attack.
-----------------------------
```

Since the attack is by analogy, in order to form an attack on #{BELIEF.5} ARIEL must identify the strategy underlying the argument in the source domain, and "replay" that strategy in the target domain. By examining the analogous belief #{BELIEF.6}, the attacking concept #{LEATO.13} is retrieved for analysis.

First, identify the underlying structure of the justification #{LEADTO.13}:

```
------------------------------
#{LEADTO.13} is an instance of:
DESTROY-PART-TO-PRESERVE-WHOLE
------------------------------
```

Next, to transfer the justification to the target domain, instantiate an instance of DESTROY-PART-TO-PRESERVE-WHOLE in the finger/hand domain as #{LEADTO.14}, making it the justification of the target belief #{BELIEF.8}, using as an example the source justification #{LEADTO.13}:

```
------------------------------
[EXPECT::INSTANTIATE-REASON]
idea: DESTROY-PART-TO-PRESERVE-WHOLE
target: #{LEADTO.14}
bel: #{BELIEF.8} source: #{LEADTO.13}
------------------------------
------------------------------
Noting that #{DESTRUCTION.1}
Is the antecedent of #{LEADTO.14}
------------------------------
------------------------------
Noting that #{GOAL.14}
Is the consequent of #{LEADTO.14}
------------------------------
------------------------------
DESTROY-PART-TO-PRESERVE-WHOLE
Is being instantiated as: #{LEADTO.14}
------------------------------
```

Now, verify that the hypothesized justification does not contradict domain knowledge. The belief to be formed is that destroying the herd is good, if it leads to the preservation of the species in the long run. Verification entails making sure that preservation of the species in the long run is not considered a bad thing.

```
------------------------------
The hypothesized justification: #{LEADTO.14}
Is not contradicted
------------------------------
------------------------------
Verification criterion used: IS NOT BAD.
------------------------------
```

This does not contradict domain knowledge, so ARIEL assumes it is a plausible justification for the target belief. The new belief is instantiated, compared to the source belief, and linked to the previous belief in an attack relationship.

```
------------------------------
Instantiating a new belief which
Contradicts the previous belief: #{BELIEF.5}
------------------------------
------------------------------
The event of the new belief object: #{DESTRUCTION.1}
Is the same as the event
Of the belief being contradicted.
------------------------------
------------------------------
The value judgment of the previous belief is: NEGATIVE
------------------------------
------------------------------
Inferring that the value judgment
Of the new belief is: POSITIVE
------------------------------
------------------------------
The justification of the new belief: #{LEADTO.14}
Contradicts the justification
Of the previous belief: #{LEADTO.11}
------------------------------
------------------------------
The new belief:
(BELIEF &BELIEF.8
   JUSTIFICATION &LEADTO.14
   B-OBJECT      &B-OBJECT.8
   NAME          TO-BE-FOR
   ACTOR         &GROUP.10)
------------------------------
------------------------------
Comparing the concept: #{BELIEF.8}
With the concept: #{BELIEF.7}
------------------------------
(BELIEF &BELIEF.8
   COMPARED-TO   &BELIEF.7
   JUSTIFICATION &LEADTO.14
   B-OBJECT      &B-OBJECT.8
   NAME          TO-BE-FOR
   ACTOR         &GROUP.10)

(BELIEF &BELIEF.7
   COMPARED-TO   &BELIEF.8
   ACTOR         #{HUMAN}
   NAME          TO-BE-FOR
   B-OBJECT      &B-OBJECT.7
   JUSTIFICATION &LEADTO.13)
------------------------------
Noting that #{LEADTO.11}
Is being attacked by #{LEADTO.14}
------------------------------
------------------------------
Killing expectation: (EXPECT-CONTRAST-TO #{BELIEF.5})
------------------------------
```

The duplicate expectation for a contrast remains on the agenda. ARIEL recognizes that the expectation has been filled, and kills the expectation, leaving an empty agenda.

```
------------------------------
Entering: EXPECT::EXPECT-RUN EXPECT-CONTRAST-TO #{BELIEF.5}
------------------------------
------------------------------
Contrast to: #{BELIEF.5} is expected...
------------------------------
------------------------------
Contrast was already made.
The justification of: #{BELIEF.5}
Is attacked by: #{LEADTO.14}
------------------------------
------------------------------
Killing expectation: (EXPECT-CONTRAST-TO #{BELIEF.5})
------------------------------
```

The completed argument graph for BISON-6 is shown in Figure A-4.

The internal representations of the components of the belief are now displayed:

```
(BELIEF &BELIEF.8
   COMPARED-TO   &BELIEF.7
   JUSTIFICATION &LEADTO.14
   B-OBJECT      &B-OBJECT.8
   NAME          TO-BE-FOR
   ACTOR         &GROUP.10)

(B-OBJECT &B-OBJECT.8
   V-JUDGE POSITIVE
   EVENT   &DESTRUCTION.1)

(DESTRUCTION &DESTRUCTION.1
   COMPARED-TO          &DESTRUCTION.4
   ANTE-OF              &LEADTO.14
   DESTRUCTION-METHOD DESTROYING
   OBJECT               &HERD.1)
```

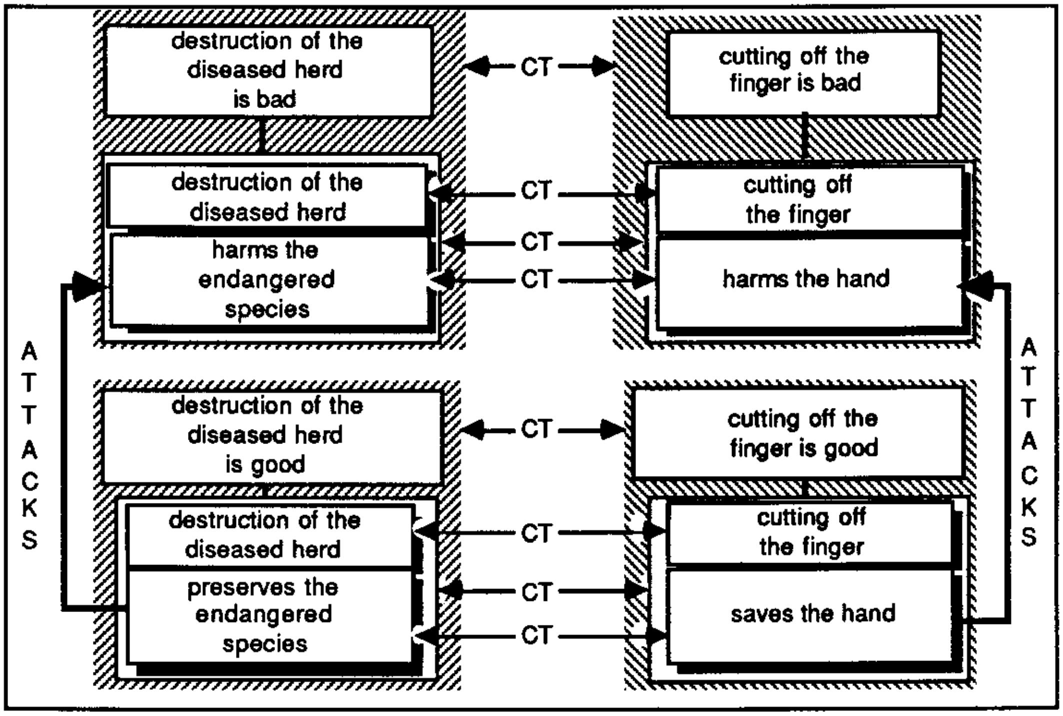


Figure A-4. The completed argument graph for BISON-6.

```
(LEADTO &LEADTO.14
   ATTACK-STRATEGY   (&AS-1 &BELIEF.5)
   ATTACKS            &LEADTO.11
   COMPARED-TO        &LEADTO.13
   JUSTIFICATION-OF   &BELIEF.8
   CONSE              &GOAL.14
   ANTE               &DESTRUCTION.1)

(DESTRUCTION &DESTRUCTION.1
   COMPARED-TO          &DESTRUCTION.4
   ANTE-OF              &LEADTO.14
   DESTRUCTION-METHOD DESTROYING
   OBJECT               &HERD.1)

(GOAL &GOAL.14
   COMPARED-TO &GOAL.13
   CONSE-OF    &LEADTO.14
   STATUS      SUCCESS
   OBJECT      &SPECIES.1)
```

A.2.5. Generating the Conclusion

The English version of the newly formed, concluding belief is then generated:

```
Generating:
#{BELIEF.8}
trying phrase #{GE1}
```

```
Applying phrase: #{GE1}
-----> <b-object> because <justification> <-----

Generating:
#{B-OBJECT.8}
trying phrase #{GE2}

Applying phrase: #{GE2}
-----> <event> is good <-----

Generating:
#{DESTRUCTION.1}
trying phrase #{GE3}

Applying phrase: #{GE3}
-----> destroying <object> <-----
---------------------------------
Generating word: DESTROYING
---------------------------------
Generating:
#{HERD.1}

Applying phrase: #{GE5}
-----> the <thing> at <location> <-----
---------------------------------
Generating word: THE
---------------------------------
-----------------------------------
Generating word: DISEASED
---------------------------------
Generating:
#{SPECIES.1}

Applying phrase: #{GE4}
-----> <species> <-----
---------------------------------
Generating word: ENDANGERED...BISON
---------------------------------
---------------------------------
Generating word: AT...WOOD-BUFFALO-NATIONAL-PARK
---------------------------------
---------------------------------
Generating word: IS...GOOD
---------------------------------
---------------------------------
Generating word: BECAUSE
---------------------------------
Generating:
#{LEADTO.14}

Applying phrase: #{GE6A}
-----> <event> will have the result that <event> <-----

Generating:
#{DESTRUCTION.1}

Applying phrase: #{GE3}
-----> destroying <object> <-----
```

```
---------------------------------
Generating word: DESTROYING
---------------------------------
Generating:
#{HERD.1}

Applying phrase: #{GE5}
-----> the <thing> at <location> <-----
---------------------------------
Generating word: THE...DISEASED
---------------------------------
Generating:
#{SPECIES.1}

Applying phrase: #{GE4}
-----> <species> <-----
---------------------------------
Generating word: ENDANGERED...BISON
---------------------------------
---------------------------------
Generating word: AT...WOOD-BUFFALO-NATIONAL-PARK
---------------------------------
---------------------------------
Generating word: WILL... HAVE...THE...RESULT...THAT
---------------------------------
Generating:
#{GOAL.14}

Applying phrase: #{GE19}
-----> the <species> will be preserved <-----
---------------------------------
Generating word: THE
---------------------------------
Generating:
#{SPECIES.1}

Applying phrase: #{GE4}
-----> <species> <-----
---------------------------------
Generating word: ENDANGERED...BISON
---------------------------------
---------------------------------
Generating word: WILL...BE...PRESERVED
---------------------------------

Processing Complete
(DESTROYING THE DISEASED ENDANGERED BISON AT WOOD-
BUFFALO-NATIONAL-PARK IS GOOD BECAUSE DESTROYING THE
DISEASED ENDANGERED BISON AT WOOD-BUFFALO-NATIONAL-
PARK WILL HAVE THE RESULT THAT THE ENDANGERED BISON
WILL BE PRESERVED)
```

A.2.6. Memory after Processing

The contents of short term memory is available for examination when processing has completed:

```
***** BELIEF OBJECT INSTANCES *****
(B-OBJECT &B-OBJECT.8
   V-JUDGE POSITIVE
   EVENT   &DESTRUCTION.1)
(B-OBJECT &B-OBJECT.7
   V-JUDGE POSITIVE
   EVENT   &DESTRUCTION.3)
(B-OBJECT &B-OBJECT.6
   V-JUDGE NEGATIVE
   EVENT   &DESTRUCTION.3)
(B-OBJECT &B-OBJECT.5
   EVENT   &DESTRUCTION.1
   V-JUDGE NEGATIVE)

***** BELIEF INSTANCES *****
(BELIEF &BELIEF.8
   COMPARED-TO   &BELIEF.7
   JUSTIFICATION &LEADTO.14
   B-OBJECT      &B-OBJECT.8
   NAME          TO-BE-FOR
   ACTOR         &GROUP.10)
(BELIEF &BELIEF.7
   COMPARED-TO   &BELIEF.8
   ACTOR         #{HUMAN}
   NAME          TO-BE-FOR
   B-OBJECT      &B-OBJECT.7
   JUSTIFICATION &LEADTO.13)
(BELIEF &BELIEF.6
   ACTOR         #{HUMAN}
   B-OBJECT      &B-OBJECT.6
   JUSTIFICATION &LEADTO.12
   NAME          TO-BE-AGAINST
   COMPARED-TO   &BELIEF.5)
(BELIEF &BELIEF.5
   COMPARED-TO   &BELIEF.6
   NAME          TO-BE-AGAINST
   ACTOR         &GROUP.10
   B-OBJECT      &B-OBJECT.5
   JUSTIFICATION &LEADTO.11)

***** BODY-PART INSTANCES *****
(BODY-PART &BODY-PART.4
   PART    HAND
   PART-OF ARM
   HEALTH  INTACT)
(BODY-PART &BODY-PART.3
   REF     DEFINITE
   PART    FINGER
   PART-OF HAND)
(BODY-PART &BODY-PART.2
   PART    HAND
   PART-OF ARM)
(BODY-PART &BODY-PART.1
   REF     INDEFINITE
   HEALTH  DISEASED
   PART    FINGER
   PART-OF HAND)
```

```
***** DESTRUCTION INSTANCES *****
(DESTRUCTION &DESTRUCTION.4
   COMPARED-TO          &DESTRUCTION.1
   ANTE-OF              &LEADTO.13
   DESTRUCTION-METHOD CUTTING-OFF
   OBJECT               &BODY-PART.3)
(DESTRUCTION &DESTRUCTION.3
   COMPARED-TO          &DESTRUCTION.2
   ANTE-OF              &LEADTO.12
   DESTRUCTION-METHOD CUTTING-OFF
   OBJECT               &BODY-PART.1)
(DESTRUCTION &DESTRUCTION.2
   COMPARED-TO          &DESTRUCTION.3
   ANTE-OF              &LEADTO.11
   DESTRUCTION-METHOD DESTROYING
   OBJECT               &HERD.1)
(DESTRUCTION &DESTRUCTION.1
   COMPARED-TO          &DESTRUCTION.4
   ANTE-OF              &LEADTO.14
   DESTRUCTION-METHOD DESTROYING
   OBJECT               &HERD.1)

***** GOAL INSTANCES *****
(GOAL &GOAL.14
   COMPARED-TO &GOAL.13
   CONSE-OF    &LEADTO.14
   STATUS      SUCCESS
   OBJECT      &SPECIES.1)
(GOAL &GOAL.13
   COMPARED-TO &GOAL.14
   CONSE-OF    &LEADTO.13
   OBJECT      &BODY-PART.4
   STATUS      SUCCESS)
(GOAL &GOAL.12
   COMPARED-TO &GOAL.11
   CONSE-OF    &LEADTO.12
   OBJECT      &BODY-PART.2
   STATUS      FAILURE)
(GOAL &GOAL.11
   COMPARED-TO &GOAL.12
   CONSE-OF    &LEADTO.11
   OBJECT      &SPECIES.2
   STATUS      FAILURE)

***** GROUP INSTANCES *****
(GROUP &GROUP.10
   REF  INDEFINITE
   NAME PEOPLE
   TYPE #{HUMAN})

***** HERD INSTANCES *****
(HERD &HERD.1
   REF      DEFINITE
   HEALTH   DISEASED
   TYPE     BISON
   LOCATION WOOD-BUFFALO-NATIONAL-PARK
   SPECIES  &SPECIES.1)
```

```
***** LEADTO INSTANCES *****
(LEADTO &LEADTO.14
   ATTACK-STRATEGY  (&AS-1 &BELIEF.5)
   ATTACKS          &LEADTO.11
   COMPARED-TO      &LEADTO.13
   JUSTIFICATION-OF &BELIEF.8
   CONSE            &GOAL.14
   ANTE             &DESTRUCTION.1)
(LEADTO &LEADTO.13
   COMPARED-TO      &LEADTO.14
   ATTACKS          &LEADTO.12
   JUSTIFICATION-OF &BELIEF.7
   ATTACK-STRATEGY  (&AS-1 &BELIEF.6)
   ANTE             &DESTRUCTION.4
   CONSE            &GOAL.13)
(LEADTO &LEADTO.12
   ATTACKED-BY      &LEADTO.13
   JUSTIFICATION-OF &BELIEF.6
   COMPARED-TO      &LEADTO.11
   ANTE             &DESTRUCTION.3
   CONSE            &GOAL.12)
(LEADTO &LEADTO.11
   ATTACKED-BY      &LEADTO.14
   COMPARED-TO      &LEADTO.12
   JUSTIFICATION-OF &BELIEF.5
   ANTE             &DESTRUCTION.2
   CONSE            &GOAL.11)

***** SPECIES INSTANCES *****
(SPECIES &SPECIES.2
   STATUS ENDANGERED)
(SPECIES &SPECIES.1
   NAME   BISON
   STATUS ENDANGERED)
```

A.3. HIGH-TECH-1 Trace

The processing of HIGH-TECH-1 is similar to that of BISON-6. The trace is shown without annotation. Some of the detail of the trace has been omitted for the sake of brevity.

```
> (pparse-ht1)

HIGH-TECH-1:
Some people are against CAM
because CAM eliminates jobs *period*
However the automobile-industry
did-the-same-thing-to people
in the horse-carriage-industry *period*
Yet consumer-demand-for autos was strong enough
that more jobs were created in the automobile-
industry than jobs were lost in the horse-
carriage-industry *period*
In-the-end the economy benefitted-by
the-introduction-of-the-new-technology *period*

--------------------------------
Processing word: SOME
--------------------------------
```

```
Found Phrase: #{LE1}
-----> some <-----

Created Concept:
(ARTICLE &ARTICLE.3
   TYPE INDEFINITE)
--------------------------------
Processing word: PEOPLE
--------------------------------
Found Phrase: #{LE3}
-----> people <-----

Created Concept:
(GROUP &GROUP.1
   NAME PEOPLE
   TYPE #{HUMAN})

Found Phrase: #{LEB12}
-----> <article> <thing> <-----

Created Concept:
(GROUP &GROUP.1
   REF  INDEFINITE
   NAME PEOPLE
   TYPE #{HUMAN})
--------------------------------
Processing word: ARE
--------------------------------
Found Phrase: #{LE4}
-----> are <-----

Created Concept:
(AUX-VERB &AUX-VERB.3
   NAME   TO-BE
   TENSE  PRESENT
   NUMBER PLURAL)
--------------------------------
Processing word: AGAINST...CAM
--------------------------------
Found Phrase: #{LE5REV}
-----> CAM <-----

Created Concept:
(MANUFACTURE &MANUFACTURE.1
   PRODUCTION-METHOD COMPUTER
   NAME              COMPUTER-INDUSTRY)
--------------------------------
Processing word: BECAUSE...CAM
--------------------------------
Found Phrase: #{LE5REV}
-----> CAM <-----

Created Concept:
(MANUFACTURE &MANUFACTURE.2
   PRODUCTION-METHOD COMPUTER
   NAME   COMPUTER-INDUSTRY)
```

```
---------------------------------
Processing word: ELIMINATES...JOBS
---------------------------------
Found Phrase: #{LE7}
-----> jobs <-----

Created Concept:
(OCCUPATION &OCCUPATION.1
   ACTOR &GROUP.2)

Found Phrase: #{LE8REV}
-----> <manufacture> eliminates <occupation> <-----

Created Concept:
(LEADTO &LEADTO.1
   ANTE  &MANUFACTURE.2
   CONSE &GOAL.1)
---------------------------------
Processing word: *PERIOD*
---------------------------------
Found Phrase: #{LEB4}
-----> <human> <aux-verb> against
           <event> because <causal-structure>. <-----
------------------------------
Noting that #{LEADTO.1}
Is the justification of #{BELIEF.1}
------------------------------
------------------------------
Noting expectation: EXPECT-CONTRAST-TO #{BELIEF.1}
------------------------------
Created Concept:
(BELIEF &BELIEF.1
   NAME          TO-BE-AGAINST
   ACTOR         &GROUP.1
   B-OBJECT      &B-OBJECT.1
   JUSTIFICATION &LEADTO.1)
---------------------------------
Processing word: HOWEVER...THE
---------------------------------
Found Phrase: #{LE23}
-----> the <-----

Created Concept:
(ARTICLE &ARTICLE.4
   TYPE DEFINITE)
---------------------------------
Processing word: AUTOMOBILE-INDUSTRY
---------------------------------
Found Phrase: #{LE20REV}
-----> automobile industry <-----

Created Concept:
(MANUFACTURE &MANUFACTURE.3
   PRODUCT &PHYS-OBJ.1
   NAME    AUTOMOBILE-INDUSTRY)

Found Phrase: #{LEB12}
-----> <article> <thing> <-----
```

```
Created Concept:
(MANUFACTURE &MANUFACTURE.3
   REF     DEFINITE
   PRODUCT &PHYS-OBJ.1
   NAME    AUTOMOBILE-INDUSTRY)
---------------------------------
Processing word: DID-THE-SAME-THING-TO...PEOPLE
---------------------------------
Found Phrase: #{LE3}
-----> people <-----

Created Concept:
(GROUP &GROUP.4
   NAME PEOPLE
   TYPE #{HUMAN})
---------------------------------
Processing word: IN...THE
---------------------------------
Found Phrase: #{LE23}
-----> the <-----

Created Concept:
(ARTICLE &ARTICLE.5
   TYPE DEFINITE)
---------------------------------
Processing word: HORSE-CARRIAGE-INDUSTRY
---------------------------------
Found Phrase: #{LE21}
-----> horse carriage industry <-----

Created Concept:
(MANUFACTURE &MANUFACTURE.4
   PRODUCT HORSE-CARRIAGE
   NAME    HORSE-CARRIAGE-INDUSTRY)

Found Phrase: #{LE22}
-----> <human> in <ref> <manufacture> <-----

Created Concept:
(OCCUPATION &OCCUPATION.2
   ACTOR   &GROUP.4
   REF     DEFINITE
   SETTING &MANUFACTURE.4)
------------------------------
Checking for a similar recent event
In which manufacturing caused job loss...
------------------------------
Found Phrase: #{LE26REV}
-----> <manufacture> did the same thing
              to <occupation> <-----
------------------------------
... Similar event found.
Drawing an analogy between the events
#{LEADTO.2} and #{LEADTO.1}
------------------------------
```

```
------------------------------
Comparing the concept: #{LEADTO.2}
With the concept: #{LEADTO.1}
------------------------------
Created Concept:
(LEADTO &LEADTO.2
   COMPARED-TO &LEADTO.1
   ANTE        &MANUFACTURE.3
   CONSE       &GOAL.2)
------------------------------
Testing phrase:  However <leadto>...
Is <leadto> analogous to a similar event,
and is that event the justification of a belief?
------------------------------
------------------------------
HOWEVER indicates that the following concept
Will contrast with the previous one,
Or that it will lead to a contrast
With the previous concept.
------------------------------
------------------------------
Looking for the previous concept to which
A contrast will be introduced
------------------------------
------------------------------
#{LEADTO.2} is compared to: #{LEADTO.1}
------------------------------
------------------------------
Checking whether #{LEADTO.1} is part of a belief...
------------------------------
------------------------------
Checking whether #{LEADTO.1}
Is the justification for the belief: #{BELIEF.1}...
------------------------------
------------------------------
#{LEADTO.1} is the justification
For the belief: #{BELIEF.1}
------------------------------
------------------------------
Previous concept found: #{BELIEF.1}
------------------------------
Found Phrase: #{LEH35}
-----> However <leadto> <-----
------------------------------
Noting that #{LEADTO.2}
Is the justification of #{BELIEF.2}
------------------------------
------------------------------
Noting expectation: EXPECT-CONTRAST-TO #{BELIEF.1}
------------------------------
------------------------------
Inferring that: #{BELIEF.1}
Is analogous to: #{BELIEF.2}
------------------------------
...
```

```
------------------------------
Inferring name of new belief: TO-BE-AGAINST
From analogous belief
------------------------------
------------------------------
Inferring event of the new belief object #{MANUFACTURE.3}
From antecedent of the current causal structure
#{LEADTO.2}
------------------------------
------------------------------
Inferring value judgment
Of the new belief object NEGATIVE
From analogous belief's belief-object
------------------------------
Created Concept:
(BELIEF &BELIEF.2
   ACTOR   #{HUMAN}
   B-OBJECT  &B-OBJECT.2
   JUSTIFICATION &LEADTO.2
   NAME  TO-BE-AGAINST
   COMPARED-TO  &BELIEF.1)
---------------------------------
Processing word: *PERIOD*...YET...
    CONSUMER-DEMAND-FOR... AUTOS
---------------------------------
Found Phrase: #{LE31A}
-----> autos <-----

Created Concept:
(PHYS-OBJ &PHYS-OBJ.2
   NAME    AUTOMOBILES
   TYPE     WORK-TOOL
   SCALE    (<NORM)
   PRODUCTION-METHOD ASSEMBLY-LINE)

Found Phrase: #{LE30}
-----> consumer demand for <phys-obj> <-----

Created Concept:
(WANT-COMMODITY &WANT-COMMODITY.1
   NAME   CONSUMER-DEMAND-FOR
   OBJECT &PHYS-OBJ.2)
---------------------------------
Processing word: WAS
---------------------------------
Found Phrase: #{LE32}
-----> was <-----

Created Concept:
(AUX-VERB &AUX-VERB.4
   NAME  TO-BE
   TENSE PAST)
---------------------------------
Processing word: STRONG...ENOUGH...THAT...MORE...JOBS
---------------------------------
Found Phrase: #{LE7}
-----> jobs <-----
```

```
Created Concept:
(OCCUPATION &OCCUPATION.3
   ACTOR &GROUP.6)
---------------------------------
Processing word: WERE...CREATED...IN...THE
---------------------------------
Found Phrase: #{LE23}
-----> the <-----

Created Concept:
(ARTICLE &ARTICLE.6
   TYPE DEFINITE)
---------------------------------
Processing word: AUTOMOBILE-INDUSTRY
---------------------------------
Found Phrase: #{LE20REV}
-----> automobile industry <-----

Created Concept:
(MANUFACTURE &MANUFACTURE.5
   PRODUCT &PHYS-OBJ.3
   NAME    AUTOMOBILE-INDUSTRY)

Found Phrase: #{LEB12}
-----> <article> <thing> <-----

Created Concept:
(MANUFACTURE &MANUFACTURE.5
   REF     DEFINITE
   PRODUCT &PHYS-OBJ.3
   NAME    AUTOMOBILE-INDUSTRY)

Found Phrase: #{LE35REV}
-----> <occupation> were created in <manufacture> <-----

Created Concept:
(GOAL &GOAL.3
   OBJECT &OCCUPATION.3
   STATUS SUCCESS)
---------------------------------
Processing word: THAN...JOBS
---------------------------------
Found Phrase: #{LE7}
-----> jobs <-----

Created Concept:
(OCCUPATION &OCCUPATION.4
   ACTOR &GROUP.7)
---------------------------------
Processing word: WERE...LOST...IN...THE
---------------------------------
Found Phrase: #{LE23}
-----> the <-----

Created Concept:
(ARTICLE &ARTICLE.7
   TYPE DEFINITE)
```

```
---------------------------------
Processing word: HORSE-CARRIAGE-INDUSTRY
---------------------------------
Found Phrase: #{LE21}
-----> horse carriage industry <-----

Created Concept:
(MANUFACTURE &MANUFACTURE.6
   PRODUCT HORSE-CARRIAGE
   NAME    HORSE-CARRIAGE-INDUSTRY)

Found Phrase: #{LEB12}
-----> <article> <thing> <-----

Created Concept:
(MANUFACTURE &MANUFACTURE.6
   REF     DEFINITE
   PRODUCT HORSE-CARRIAGE
   NAME    HORSE-CARRIAGE-INDUSTRY)

Found Phrase: #{LE36REV}
-----> <occupation> were lost in <manufacture> <-----

Created Concept:
(GOAL &GOAL.4
   OBJECT &OCCUPATION.4
   INSTR  &MANUFACTURE.6
   STATUS FAILURE)

Found Phrase: #{LE34REV}
-----> more <goal1> than <goal2> <-----

Created Concept:
(GOAL &GOAL.5
   NAME   IMPROVED-ECONOMY
   OBJECT &OCCUPATION.5
   INSTR  JOB-SHIFT
   FROM   &OCCUPATION.4
   TO     &OCCUPATION.3
   STATUS SUCCESS)

Found Phrase: #{LE33}
-----> <want-commodity> <aux-verb>
         strong enough that <goal> <-----
------------------------------
If consumer demand for a product
Increases the number of jobs available,
We can infer the implicit causal chain
That consumer demand for the product
Caused the product to be manufactured,
And the manufacturing of the product
Caused the increase in the number of jobs.
------------------------------
------------------------------
Inferring an implicit causal chain
------------------------------
```

```
------------------------------
Inferring that: #{WANT-COMMODITY.1}
Caused: #{MANUFACTURE.7}
------------------------------
------------------------------
Inferring that: #{MANUFACTURE.7}
Caused: #{GOAL.5}
------------------------------
Created Concept:
(LEADTO &LEADTO.3
   ANTE  &WANT-COMMODITY.1
   CONSE &GOAL.5)
---------------------------------
Processing word: *PERIOD*
---------------------------------
------------------------------
Testing phrase:  Yet <leadto>.
Is there a preceding belief which
Is  contradicted by <leadto>?
------------------------------
------------------------------
Looking for a belief contradicted by: #{LEADTO.3}
------------------------------
(LEADTO &LEADTO.3
   ANTE  &WANT-COMMODITY.1
   CONSE &GOAL.5)
------------------------------
Trying: #{BELIEF.2}
------------------------------
------------------------------
Checking whether: #{LEADTO.3}
Can attack #{BELIEF.2}
Using attack strategy: #{AS-1}
------------------------------
------------------------------
Attack Strategy 1:
    If X is bad because X causes Y and Y is bad,
    Then show that X causes Z and Z is good.
------------------------------
------------------------------
Checking whether #{WANT-COMMODITY.1}
Is similar to #{MANUFACTURE.3} (X)
------------------------------
------------------------------
Checking similarity of #{MANUFACTURE.3}
and #{WANT-COMMODITY.1}
------------------------------
...
------------------------------
#{WANT-COMMODITY.1} is not directly similar
to #{MANUFACTURE.3} (X)
------------------------------
------------------------------
Checking whether #{WANT-COMMODITY.1}
Causes something that
Is similar to #{MANUFACTURE.3} (X)
------------------------------
```

```
------------------------------
Checking similarity of #{MANUFACTURE.3}
and #{MANUFACTURE.7}
------------------------------
(MANUFACTURE &MANUFACTURE.3
   COMPARED-TO &MANUFACTURE.2
   ANTE-OF     &LEADTO.2
   REF         DEFINITE
   PRODUCT     &PHYS-OBJ.1
   NAME        AUTOMOBILE-INDUSTRY)

(MANUFACTURE &MANUFACTURE.7
   ANTE-OF   &LEADTO.5
   CONSE-OF  &LEADTO.4
   PRODUCT   &PHYS-OBJ.2)
------------------------------
Looking in slot: PRODUCTION-METHOD
------------------------------
------------------------------
Looking in slot: PRODUCT
------------------------------
------------------------------
Checking similarity of #{PHYS-OBJ.1}
and #{PHYS-OBJ.2}
------------------------------
(PHYS-OBJ &PHYS-OBJ.1
   NAME              AUTOMOBILES
   TYPE              WORK-TOOL
   SCALE             (<NORM)
   PRODUCTION-METHOD ASSEMBLY-LINE)

(PHYS-OBJ &PHYS-OBJ.2
   NAME              AUTOMOBILES
   TYPE              WORK-TOOL
   SCALE             (<NORM)
   PRODUCTION-METHOD ASSEMBLY-LINE)
------------------------------
Looking in slot: TYPE... SETTING...PRODUCTION-METHOD
------------------------------
------------------------------
#{PHYS-OBJ.1} and #{PHYS-OBJ.2} are similar
------------------------------
------------------------------
#{MANUFACTURE.3} and #{MANUFACTURE.7} are similar
------------------------------
------------------------------
#{GOAL.5} involves having jobs
Having jobs is good
------------------------------
------------------------------
#{BELIEF.2} is contradicted via: #{AS-1}
------------------------------
Found Phrase: #{LE39REV}
-----> Yet <leadto>. <-----
------------------------------
Noting that #{LEADTO.3}
Is the justification of #{BELIEF.3}
------------------------------
```

```
------------------------------
Instantiating a new belief which
Contradicts the previous belief: #{BELIEF.2}
------------------------------
------------------------------
The event of the new belief object: #{MANUFACTURE.3}
Is the same as the event
Of the belief being contradicted.
------------------------------
------------------------------
The value judgment of the previous belief is: NEGATIVE
------------------------------
------------------------------
Inferring that the value judgment
Of the new belief is: POSITIVE
------------------------------
------------------------------
The justification of the new belief: #{LEADTO.3}
Contradicts the justification
Of the previous belief: #{LEADTO.2}
------------------------------
------------------------------
The new belief:
(BELIEF &BELIEF.3
   ACTOR         #{HUMAN}
   NAME          TO-BE-FOR
   B-OBJECT      &B-OBJECT.3
   JUSTIFICATION &LEADTO.3)
------------------------------
------------------------------
Noting that #{LEADTO.2}
Is being attacked by #{LEADTO.3}
------------------------------
Created Concept:
(BELIEF &BELIEF.3
   ACTOR         #{HUMAN}
   NAME          TO-BE-FOR
   B-OBJECT      &B-OBJECT.3
   JUSTIFICATION &LEADTO.3)
---------------------------------
Processing word: IN-THE-END... THE
------------------------------
Found Phrase: #{LE23}
-----> the <-----

Created Concept:
(ARTICLE &ARTICLE.8
   TYPE DEFINITE)
---------------------------------
Processing word: ECONOMY
------------------------------
Found Phrase: #{LE41}
-----> economy <-----

Created Concept:
(ECONOMY &ECONOMY.1
   INSTITUTION UNITED-STATES
   RESOURCES   (GOODS AND SERVICES))
```

```
Found Phrase: #{LEB12}
-----> <article> <thing> <-----

Created Concept:
(ECONOMY &ECONOMY.1
   REF   DEFINITE
   INSTITUTION UNITED-STATES
   RESOURCES   (GOODS AND SERVICES))
---------------------------------
Processing word: BENEFITTED-BY...
    THE-INTRODUCTION-OF-THE-NEW-TECHNOLOGY
---------------------------------
Found Phrase: #{LE42}
-----> the-introduction-of-the-new-technology <-----

Created Concept:
(MANUFACTURE &MANUFACTURE.8
   PRODUCTION-METHOD NEW-TECHNOLOGY)

Found Phrase: #{LE43}
-----> <economy> benefitted-by <manufacture> <-----

Created Concept:
(GOAL &GOAL.6
   OBJECT &ECONOMY.1
   INSTR  &MANUFACTURE.8
   STATUS SUCCESS)
---------------------------------
Processing word: *PERIOD*
---------------------------------
Found Phrase: #{LE44REV}
-----> <belief>  In-the-end <goal>. <-----

Created Concept:
(BELIEF &BELIEF.3
   ACTOR         #{HUMAN}
   NAME          TO-BE-FOR
   B-OBJECT      &B-OBJECT.3
   JUSTIFICATION (&LEADTO.3 &LEADTO.6))

Processing Complete
Result of Parse
#{BELIEF.1}
#{BELIEF.2}
*PERIOD*
#{BELIEF.3}
------------------------------
Entering: EXPECT::EXPECT-RUN EXPECT-CONTRAST-TO #{BELIEF.1}
------------------------------
------------------------------
Contrast to: #{BELIEF.1} is expected...
------------------------------
------------------------------
#{BELIEF.1} is analogous to: #{BELIEF.2}
Whose justification: #{LEADTO.2}
Has been attacked by: #{LEADTO.3}
------------------------------
```

```
------------------------------
The justification of #{BELIEF.2}: #{LEADTO.2}
Has been attacked by: #{LEADTO.3}
Using the strategy: #{AS-1}
Thus, #{LEADTO.3} attacks #{BELIEF.1} by analogy.
------------------------------
------------------------------
Form an analogous attack on: #{BELIEF.1}
Using the strategy #{AS-1}
And using #{LEADTO.3} as a source analog.
Check first for an existing attack.
------------------------------
------------------------------
Entering: EXPECT::APPLY-STRATEGY
APPLY-ATTACK-STRATEGY-1 #{BELIEF.1}#{LEADTO.3}
------------------------------
------------------------------
[EXPECT::HYPOTHESIZE-AND-VERIFY-REASON]
source: #{LEADTO.3} target: #{LEADTO.7}
bel: #{BELIEF.4}  ver. criterion: IS-NOT-BAD
------------------------------
[EXPECT::TRANSFER-REASON]
source: #{LEADTO.3} target: #{LEADTO.7} bel: #{BELIEF.4}
------------------------------
------------------------------
[EXPECT::UNDERLYING-REASON] leadto: #{LEADTO.3}
------------------------------
------------------------------
#{LEADTO.3} is an instance of: WC-LEADS-TO-JOBS
------------------------------
------------------------------
[EXPECT::WC-LEADS-TO-JOBS?]
------------------------------
------------------------------
[EXPECT::INSTANTIATE-REASON]
idea: WC-LEADS-TO-JOBS
target: #{LEADTO.7} bel: #{BELIEF.4} source: #{LEADTO.3}
------------------------------
------------------------------
If consumer demand for a product
Increases the number of jobs available,
We can infer the implicit causal chain
That consumer demand for the product
Caused the product to be manufactured,
And the manufacturing of the product
Caused the increase in the number of jobs.
------------------------------
------------------------------
Inferring an implicit causal chain
------------------------------
------------------------------
Inferring that: #{WANT-COMMODITY.2}
Caused: #{MANUFACTURE.9}
------------------------------
------------------------------
Inferring that: #{MANUFACTURE.9}
Caused: #{GOAL.7}
------------------------------
```

```
------------------------------
WC-LEADS-TO-JOBS is being instantiated as: #{LEADTO.7}
------------------------------
------------------------------
[EXPECT::INSTANTIATE-REASON:WC-LEADS-TO-JOBS]
------------------------------
------------------------------
The hypothesized justification: #{LEADTO.7}
Is not contradicted
------------------------------
------------------------------
Verification criterion used: IS NOT BAD.
------------------------------
------------------------------
Comparing the concept: #{BELIEF.4}
With the concept: #{BELIEF.3}
------------------------------
------------------------------
Instantiating a new belief which
Contradicts the previous belief: #{BELIEF.1}
------------------------------
------------------------------
The event of the new belief object: #{MANUFACTURE.1}
Is the same as the event
Of the belief being contradicted.
------------------------------
------------------------------
The value judgment of the previous belief is: NEGATIVE
------------------------------
------------------------------
Inferring that the value judgment
Of the new belief is: POSITIVE
------------------------------
------------------------------
The justification of the new belief: #{LEADTO.7}
Contradicts the justification
Of the previous belief: #{LEADTO.1}
------------------------------
------------------------------
The new belief:
(BELIEF &BELIEF.4
   COMPARED-TO   &BELIEF.3
   JUSTIFICATION &LEADTO.7
   B-OBJECT      &B-OBJECT.4
   NAME          TO-BE-FOR
   ACTOR         &GROUP.1)
------------------------------
------------------------------
Noting that #{LEADTO.1}
Is being attacked by #{LEADTO.7}
------------------------------
------------------------------
Killing expectation: (EXPECT-CONTRAST-TO #{BELIEF.1})
------------------------------
------------------------------
Entering: EXPECT::EXPECT-RUN EXPECT-CONTRAST-TO #{BELIEF.1}
------------------------------
```

```
------------------------------
Contrast to: #{BELIEF.1} is expected...
------------------------------
------------------------------
Contrast was already made.
The justification of: #{BELIEF.1}
Is attacked by: #{LEADTO.7}
------------------------------
------------------------------
Killing expectation: (EXPECT-CONTRAST-TO #{BELIEF.1})
------------------------------
(BELIEF &BELIEF.4
   COMPARED-TO   &BELIEF.3
   JUSTIFICATION &LEADTO.7
   B-OBJECT      &B-OBJECT.4
   NAME          TO-BE-FOR
   ACTOR         &GROUP.1)

(B-OBJECT &B-OBJECT.4
   V-JUDGE POSITIVE
   EVENT   &MANUFACTURE.1)

(MANUFACTURE &MANUFACTURE.1
   PRODUCTION-METHOD COMPUTER
   NAME              COMPUTER-INDUSTRY)

(LEADTO &LEADTO.7
   ATTACK-STRATEGY  (&AS-1 &BELIEF.1)
   ATTACKS          &LEADTO.1
   JUSTIFICATION-OF &BELIEF.4
   CONSE            &GOAL.7
   ANTE             &WANT-COMMODITY.2)

(WANT-COMMODITY &WANT-COMMODITY.2
   ANTE-OF (&LEADTO.8 &LEADTO.7)
   OBJECT  &PHYS-OBJ.4)

(GOAL &GOAL.7
   CONSE-OF (&LEADTO.9 &LEADTO.7)
   STATUS   SUCCESS
   OBJECT   &OCCUPATION.6)

Generating:
#{BELIEF.4}
Applying phrase: #{GE1}
-----> <b-object> because <justification> <-----
Generating:
#{B-OBJECT.4}
Applying phrase: #{GE2}
-----> <event> is good <-----
Generating:
#{MANUFACTURE.1}
Applying phrase: #{GE18}
-----> the manufacture of CAM-produced goods <-----
---------------------------------
Generating word: THE...MANUFACTURE...OF...
    CAM-PRODUCED...GOODS
---------------------------------
```

```
--------------------------------
Generating word: IS...GOOD...BECAUSE
--------------------------------
Generating:
#{LEADTO.7}
Applying phrase: #{GE6A}
-----> <event> leads to <event> <-----
Generating:
#{WANT-COMMODITY.2}
Applying phrase: #{GE14A}
-----> consumer demand for <phys-obj> <-----
--------------------------------
Generating word: CONSUMER-DEMAND-FOR
--------------------------------
Generating:
#{PHYS-OBJ.4}
Applying phrase: #{GE15}
-----> CAM-produced goods <-----
--------------------------------
Generating word: CAM-PRODUCED... GOODS
--------------------------------
--------------------------------
Generating word:   WILL...HAVE...THE...RESULT...THAT
--------------------------------
Generating:
#{GOAL.7}
Applying phrase: #{GE16}
-----> jobs will be created in <manufacture> <-----
--------------------------------
Generating word: JOBS...WILL...BE...CREATED...IN
--------------------------------
Generating:
#{MANUFACTURE.1}
Applying phrase: #{GE18}
-----> the manufacture of CAM-produced goods <-----
--------------------------------
Generating word: THE...MANUFACTURE...OF...
    CAM-PRODUCED...GOODS
--------------------------------
Processing Complete
(THE MANUFACTURE OF CAM-PRODUCED GOODS IS GOOD
BECAUSE CONSUMER-DEMAND-FOR CAM-PRODUCED GOODS
WILL HAVE THE RESULT THAT JOBS WILL BE CREATED IN
THE MANUFACTURE  OF CAM-PRODUCED GOODS)

***** BELIEF OBJECT INSTANCES *****
(B-OBJECT &B-OBJECT.4
   V-JUDGE POSITIVE
   EVENT   &MANUFACTURE.1)
(B-OBJECT &B-OBJECT.3
   V-JUDGE POSITIVE
   EVENT   &MANUFACTURE.3)
(B-OBJECT &B-OBJECT.2
   V-JUDGE NEGATIVE
   EVENT   &MANUFACTURE.3)
(B-OBJECT &B-OBJECT.1
   EVENT   &MANUFACTURE.1
   V-JUDGE NEGATIVE)
```

```
***** BELIEF INSTANCES *****
(BELIEF &BELIEF.4
   COMPARED-TO    &BELIEF.3
   JUSTIFICATION &LEADTO.7
   B-OBJECT       &B-OBJECT.4
   NAME           TO-BE-FOR
   ACTOR          &GROUP.1)
(BELIEF &BELIEF.3
   COMPARED-TO    &BELIEF.4
   ACTOR          #{HUMAN}
   NAME           TO-BE-FOR
   B-OBJECT       &B-OBJECT.3
   JUSTIFICATION (&LEADTO.3 &LEADTO.6))
(BELIEF &BELIEF.2
   ACTOR          #{HUMAN}
   B-OBJECT       &B-OBJECT.2
   JUSTIFICATION &LEADTO.2
   NAME           TO-BE-AGAINST
   COMPARED-TO    &BELIEF.1)
(BELIEF &BELIEF.1
   COMPARED-TO    &BELIEF.2
   NAME           TO-BE-AGAINST
   ACTOR          &GROUP.1
   B-OBJECT       &B-OBJECT.1
   JUSTIFICATION &LEADTO.1)

***** ECONOMY INSTANCES *****
(ECONOMY &ECONOMY.1
   REF         DEFINITE
   INSTITUTION UNITED-STATES
   RESOURCES   (GOODS AND SERVICES))

***** GOAL INSTANCES *****
(GOAL &GOAL.7
   CONSE-OF (&LEADTO.9 &LEADTO.7)
   STATUS   SUCCESS
   OBJECT   &OCCUPATION.6)
(GOAL &GOAL.6
   CONSE-OF &LEADTO.6
   OBJECT   &ECONOMY.1
   INSTR    &MANUFACTURE.8
   STATUS   SUCCESS)
(GOAL &GOAL.5
   CONSE-OF (&LEADTO.5 &LEADTO.3)
   NAME     IMPROVED-ECONOMY
   OBJECT   &OCCUPATION.5
   INSTR    JOB-SHIFT
   FROM     &OCCUPATION.4
   TO       &OCCUPATION.3
   STATUS   SUCCESS)
(GOAL &GOAL.4
   OBJECT &OCCUPATION.4
   INSTR  &MANUFACTURE.6
   STATUS FAILURE)
(GOAL &GOAL.3
   OBJECT &OCCUPATION.3
   STATUS SUCCESS)
```

```
(GOAL &GOAL.2
   COMPARED-TO &GOAL.1
   CONSE-OF    &LEADTO.2
   ACTOR       &GROUP.5
   OBJECT      &OCCUPATION.2
   STATUS      FAILURE)
(GOAL &GOAL.1
   COMPARED-TO &GOAL.2
   CONSE-OF    &LEADTO.1
   ACTOR       &GROUP.3
   OBJECT      &OCCUPATION.1
   STATUS      FAILURE)

***** GROUP INSTANCES *****
(GROUP &GROUP.7
   TYPE #{HUMAN})
(GROUP &GROUP.6
   TYPE #{HUMAN})
(GROUP &GROUP.5
   TYPE #{HUMAN})
(GROUP &GROUP.4
   NAME PEOPLE
   TYPE #{HUMAN})
(GROUP &GROUP.3
   TYPE #{HUMAN})
(GROUP &GROUP.2
   TYPE #{HUMAN})
(GROUP &GROUP.1
   REF  INDEFINITE
   NAME PEOPLE
   TYPE #{HUMAN})

***** LEADTO INSTANCES *****
(LEADTO &LEADTO.9
   CONSE &GOAL.7
   ANTE  &MANUFACTURE.9)
(LEADTO &LEADTO.8
   CONSE &MANUFACTURE.9
   ANTE  &WANT-COMMODITY.2)
(LEADTO &LEADTO.7
   ATTACK-STRATEGY  (&AS-1 &BELIEF.1)
   ATTACKS          &LEADTO.1
   JUSTIFICATION-OF &BELIEF.4
   CONSE            &GOAL.7
   ANTE             &WANT-COMMODITY.2)
(LEADTO &LEADTO.6
   ANTE  &WANT-COMMODITY.1
   CONSE &GOAL.6)
(LEADTO &LEADTO.5
   CONSE &GOAL.5
   ANTE  &MANUFACTURE.7)
(LEADTO &LEADTO.4
   CONSE &MANUFACTURE.7
   ANTE  &WANT-COMMODITY.1)
```

```
(LEADTO &LEADTO.3
   ATTACKS            &LEADTO.2
   JUSTIFICATION-OF &BELIEF.3
   ATTACK-STRATEGY   (&AS-1 &BELIEF.2)
   ANTE               &WANT-COMMODITY.1
   CONSE              &GOAL.5)
(LEADTO &LEADTO.2
   ATTACKED-BY        &LEADTO.3
   JUSTIFICATION-OF &BELIEF.2
   COMPARED-TO        &LEADTO.1
   ANTE               &MANUFACTURE.3
   CONSE              &GOAL.2)
(LEADTO &LEADTO.1
   ATTACKED-BY        &LEADTO.7
   COMPARED-TO        &LEADTO.2
   JUSTIFICATION-OF &BELIEF.1
   ANTE               &MANUFACTURE.2
   CONSE              &GOAL.1)

***** MANUFACTURE INSTANCES *****
(MANUFACTURE &MANUFACTURE.9
   ANTE-OF  &LEADTO.9
   CONSE-OF &LEADTO.8
   PRODUCT  &PHYS-OBJ.4)
(MANUFACTURE &MANUFACTURE.8
   PRODUCTION-METHOD NEW-TECHNOLOGY)
(MANUFACTURE &MANUFACTURE.7
   ANTE-OF  &LEADTO.5
   CONSE-OF &LEADTO.4
   PRODUCT  &PHYS-OBJ.2)
(MANUFACTURE &MANUFACTURE.6
   REF     DEFINITE
   PRODUCT HORSE-CARRIAGE
   NAME    HORSE-CARRIAGE-INDUSTRY)
(MANUFACTURE &MANUFACTURE.5
   REF     DEFINITE
   PRODUCT &PHYS-OBJ.3
   NAME    AUTOMOBILE-INDUSTRY)
(MANUFACTURE &MANUFACTURE.4
   PRODUCT HORSE-CARRIAGE
   NAME    HORSE-CARRIAGE-INDUSTRY)
(MANUFACTURE &MANUFACTURE.3
   COMPARED-TO &MANUFACTURE.2
   ANTE-OF     &LEADTO.2
   REF         DEFINITE
   PRODUCT     &PHYS-OBJ.1
   NAME        AUTOMOBILE-INDUSTRY)
(MANUFACTURE &MANUFACTURE.2
   COMPARED-TO       &MANUFACTURE.3
   ANTE-OF           &LEADTO.1
   PRODUCTION-METHOD COMPUTER
   NAME              COMPUTER-INDUSTRY)
(MANUFACTURE &MANUFACTURE.1
   PRODUCTION-METHOD COMPUTER
   NAME              COMPUTER-INDUSTRY)
```

```
***** OCCUPATION INSTANCES *****
(OCCUPATION &OCCUPATION.6
   SETTING &MANUFACTURE.1)
(OCCUPATION &OCCUPATION.5)
(OCCUPATION &OCCUPATION.4
   SETTING &MANUFACTURE.6
   ACTOR   &GROUP.7)
(OCCUPATION &OCCUPATION.3
   SETTING &MANUFACTURE.5
   ACTOR   &GROUP.6)
(OCCUPATION &OCCUPATION.2
   ACTOR   &GROUP.4
   REF     DEFINITE
   SETTING &MANUFACTURE.4)
(OCCUPATION &OCCUPATION.1
   ACTOR &GROUP.2)

***** PHYSICAL OBJECT INSTANCES *****
(PHYS-OBJ &PHYS-OBJ.4
   PRODUCTION-METHOD COMPUTER)
(PHYS-OBJ &PHYS-OBJ.3
   NAME              AUTOMOBILES
   TYPE              WORK-TOOL
   SCALE             (<NORM)
   PRODUCTION-METHOD ASSEMBLY-LINE)
(PHYS-OBJ &PHYS-OBJ.2
   NAME              AUTOMOBILES
   TYPE              WORK-TOOL
   SCALE             (<NORM)
   PRODUCTION-METHOD ASSEMBLY-LINE)
(PHYS-OBJ &PHYS-OBJ.1
   NAME              AUTOMOBILES
   TYPE              WORK-TOOL
   SCALE             (<NORM)
   PRODUCTION-METHOD ASSEMBLY-LINE)

***** WANT COMMODITY INSTANCES *****
(WANT-COMMODITY &WANT-COMMODITY.2
   ANTE-OF (&LEADTO.8 &LEADTO.7)
   OBJECT  &PHYS-OBJ.4)
(WANT-COMMODITY &WANT-COMMODITY.1
   ANTE-OF (&LEADTO.6 &LEADTO.4 &LEADTO.3)
   NAME    CONSUMER-DEMAND-FOR
   OBJECT  &PHYS-OBJ.2)
```

A.4. HIGH-TECH-2 Trace

The processing of HIGH-TECH-2 is identical in many respects to that of HIGH-TECH-1. The primary difference is in the lack of the lexical clue introducing the presence of the analogy in the second sentence. Again, some of the detail of the trace has been omitted for the sake of brevity.

```
> (pparse-ht1)

HIGH-TECH-2:
Some people are against CAM
because CAM eliminates jobs *period*
```

```
However the automobile-industry caused people in the
horse-carriage-industryto-lose jobs *period*
Yet consumer-demand-for autos was strong enough
that more jobs were created in the automobile-
industry than jobs were lost in the horse-
carriage-industry *period*
In-the-end the economy benefitted-by
the-introduction-of-the-new-technology *period*
```

The processing of the first sentence of HIGH-TECH-2 is identical to the processing of the first sentence of HIGH-TECH-1, and is omitted here.

```
...
Created Concept:
(BELIEF &BELIEF.1
   NAME          TO-BE-AGAINST
   ACTOR         &GROUP.1
   B-OBJECT      &B-OBJECT.1
   JUSTIFICATION &LEADTO.1)
---------------------------------
Processing word: HOWEVER
---------------------------------
---------------------------------
Processing word: THE
---------------------------------
Found Phrase: #{LE23}
-----> the <-----

Created Concept:
(ARTICLE &ARTICLE.4
   TYPE DEFINITE)
---------------------------------
Processing word: AUTOMOBILE-INDUSTRY
---------------------------------
Found Phrase: #{LE20REV}
-----> automobile industry <-----

Created Concept:
(MANUFACTURE &MANUFACTURE.3
   PRODUCT &PHYS-OBJ.1
   NAME    AUTOMOBILE-INDUSTRY)

Found Phrase: #{LEB12}
-----> <article> <thing> <-----

Created Concept:
(MANUFACTURE &MANUFACTURE.3
   REF     DEFINITE
   PRODUCT &PHYS-OBJ.1
   NAME    AUTOMOBILE-INDUSTRY)
---------------------------------
Processing word: CAUSED...PEOPLE
---------------------------------
Found Phrase: #{LE3}
-----> people <-----
```

```
Created Concept:
(GROUP &GROUP.4
   NAME PEOPLE
   TYPE #{HUMAN})
---------------------------------
Processing word: IN...THE
---------------------------------
Found Phrase: #{LE23}
-----> the <-----

Created Concept:
(ARTICLE &ARTICLE.5
   TYPE DEFINITE)
---------------------------------
Processing word: HORSE-CARRIAGE-INDUSTRY
---------------------------------
Found Phrase: #{LE21}
-----> horse carriage industry <-----

Created Concept:
(MANUFACTURE &MANUFACTURE.4
   PRODUCT HORSE-CARRIAGE
   NAME    HORSE-CARRIAGE-INDUSTRY)

Found Phrase: #{LE22}
-----> <human> in <ref> <manufacture> <-----

Created Concept:
(OCCUPATION &OCCUPATION.2
   ACTOR   &GROUP.4
   REF     DEFINITE
   SETTING &MANUFACTURE.4)
---------------------------------
Processing word: TO-LOSE
---------------------------------
Found Phrase: #{LEY}
-----> to lose <-----

Created Concept:
(LOSE-VERB &LOSE-VERB.1
   NAME  TO-LOSE
   TENSE INFINITIVE)
---------------------------------
Processing word: JOBS
---------------------------------
Found Phrase: #{LE7}
-----> jobs <-----

Created Concept:
(OCCUPATION &OCCUPATION.3
   ACTOR &GROUP.5)

Found Phrase: #{LEH31}
-----> <occupation> <lose-verb> <occupation> <-----
------------------------------
Making the actor of the goal
The same as the actor of the occupation...
------------------------------
```

```
Created Concept:
(GOAL &GOAL.2
   OBJECT &OCCUPATION.2
   STATUS FAILURE)
---------------------------------
Processing word: *PERIOD*
---------------------------------
Found Phrase: #{LENEW3}
-----> <manufacture> caused <goal>. <-----

Created Concept:
(LEADTO &LEADTO.2
   ANTE  &MANUFACTURE.3
   CONSE &GOAL.2)
------------------------------
Testing phrase:  However <leadto>...
Is <leadto> analogous to a similar event,
and is that event the justification of a belief?
------------------------------
------------------------------
HOWEVER indicates that the following concept
Will contrast with the previous one,
Or that it will lead to a contrast
With the previous concept.
------------------------------
------------------------------
Looking for the previous concept to which
A contrast will be introduced
------------------------------
------------------------------
Looking for an instance compared to #{LEADTO.2}...
------------------------------
...
------------------------------
#{LEADTO.2} can be compared to: #{LEADTO.1}
------------------------------
------------------------------
Checking whether #{LEADTO.1} is part of a belief...
------------------------------
------------------------------
Checking whether #{LEADTO.1}
Is the justification for the belief: #{BELIEF.1}...
------------------------------
------------------------------
#{LEADTO.1} is the justification
For the belief: #{BELIEF.1}
------------------------------
------------------------------
Previous concept found: #{BELIEF.1}
------------------------------
Found Phrase: #{LEH35}
-----> However <leadto> <-----
------------------------------
Noting that #{LEADTO.2}
Is the justification of #{BELIEF.2}
------------------------------
```

```
------------------------------
Noting expectation: EXPECT-CONTRAST-TO #{BELIEF.1}
------------------------------
------------------------------
Inferring that: #{BELIEF.1}
Is analogous to: #{BELIEF.2}
------------------------------
------------------------------
Inferring name of new belief: TO-BE-AGAINST
From analogous belief
------------------------------
------------------------------
Inferring event of the new belief object #{MANUFACTURE.3}
From antecedent of the current causal structure
#{LEADTO.2}
------------------------------
------------------------------
Inferring value judgment
Of the new belief object NEGATIVE
From analogous belief's belief-object
------------------------------
Created Concept:
(BELIEF &BELIEF.2
   ACTOR         #{HUMAN}
   B-OBJECT      &B-OBJECT.2
   JUSTIFICATION &LEADTO.2
   NAME          TO-BE-AGAINST
   COMPARED-TO   &BELIEF.1)
---------------------------------
Processing word: YET...CONSUMER-DEMAND-FOR...AUTOS
---------------------------------
Found Phrase: #{LE31A}
-----> autos <-----

Created Concept:
(PHYS-OBJ &PHYS-OBJ.2
   NAME     AUTOMOBILES
   TYPE    WORK-TOOL
   SCALE    (<NORM)
   PRODUCTION-METHOD ASSEMBLY-LINE)

Found Phrase: #{LE30}
-----> consumer demand for <phys-obj> <-----

Created Concept:
(WANT-COMMODITY &WANT-COMMODITY.1
   NAME   CONSUMER-DEMAND-FOR
   OBJECT &PHYS-OBJ.2)
---------------------------------
Processing word: WAS
---------------------------------
Found Phrase: #{LE32}
-----> was <-----

Created Concept:
(AUX-VERB &AUX-VERB.4
   NAME  TO-BE
   TENSE PAST)
```

```
--------------------------------
Processing word: STRONG...ENOUGH...THAT...MORE...JOBS
--------------------------------
Found Phrase: #{LE7}
-----> jobs <-----

Created Concept:
(OCCUPATION &OCCUPATION.4
   ACTOR &GROUP.6)
--------------------------------
Processing word: WERE...CREATED...IN...THE
--------------------------------
Found Phrase: #{LE23}
-----> the <-----

Created Concept:
(ARTICLE &ARTICLE.6
   TYPE DEFINITE)
--------------------------------
Processing word: AUTOMOBILE-INDUSTRY
--------------------------------
Found Phrase: #{LE20REV}
-----> automobile industry <-----

Created Concept:
(MANUFACTURE &MANUFACTURE.5
   PRODUCT &PHYS-OBJ.3
   NAME    AUTOMOBILE-INDUSTRY)

Found Phrase: #{LEB12}
-----> <article> <thing> <-----

Created Concept:
(MANUFACTURE &MANUFACTURE.5
   REF     DEFINITE
   PRODUCT &PHYS-OBJ.3
   NAME    AUTOMOBILE-INDUSTRY)

Found Phrase: #{LE35REV}
-----> <occupation> were created in <manufacture> <-----

Created Concept:
(GOAL &GOAL.3
   OBJECT &OCCUPATION.4
   STATUS SUCCESS)
--------------------------------
Processing word: THAN...JOBS
--------------------------------
Found Phrase: #{LE7}
-----> jobs <-----

Created Concept:
(OCCUPATION &OCCUPATION.5
   ACTOR &GROUP.7)
--------------------------------
Processing word: WERE...LOST...IN...THE
--------------------------------
```

```
Found Phrase: #{LE23}
-----> the <-----

Created Concept:
(ARTICLE &ARTICLE.7
   TYPE DEFINITE)
---------------------------------
Processing word: HORSE-CARRIAGE-INDUSTRY
---------------------------------
Found Phrase: #{LE21}
-----> horse carriage industry <-----

Created Concept:
(MANUFACTURE &MANUFACTURE.6
   PRODUCT HORSE-CARRIAGE
   NAME    HORSE-CARRIAGE-INDUSTRY)

Found Phrase: #{LEB12}
-----> <article> <thing> <-----

Created Concept:
(MANUFACTURE &MANUFACTURE.6
   REF     DEFINITE
   PRODUCT HORSE-CARRIAGE
   NAME    HORSE-CARRIAGE-INDUSTRY)

Found Phrase: #{LE36REV}
-----> <occupation> were lost in <manufacture> <-----

Created Concept:
(GOAL &GOAL.4
   OBJECT &OCCUPATION.5
   INSTR  &MANUFACTURE.6
   STATUS FAILURE)

Found Phrase: #{LE34REV}
-----> more <goal1> than <goal2> <-----

Created Concept:
(GOAL &GOAL.5
   NAME   IMPROVED-ECONOMY
   OBJECT &OCCUPATION.6
   INSTR  JOB-SHIFT
   FROM   &OCCUPATION.5
   TO     &OCCUPATION.4
   STATUS SUCCESS)

Found Phrase: #{LE33}
-----> <want-commodity> <aux-verb>
          strong enough that <goal> <-----
```

```
------------------------------
If consumer demand for a product
Increases the number of jobs available,
We can infer the implicit causal chain
That consumer demand for the product
Caused the product to be manufactured,
And the manufacturing of the product
Caused the increase in the number of jobs.
------------------------------
------------------------------
Inferring an implicit causal chain
------------------------------
------------------------------
Inferring that: #{WANT-COMMODITY.1}
Caused: #{MANUFACTURE.7}
------------------------------
------------------------------
Inferring that: #{MANUFACTURE.7}
Caused: #{GOAL.5}
------------------------------
Created Concept:
(LEADTO &LEADTO.3
   ANTE  &WANT-COMMODITY.1
   CONSE &GOAL.5)
---------------------------------
Processing word: *PERIOD*
---------------------------------
------------------------------
Testing phrase:  Yet <leadto>.
Is there a preceding belief which
Is contradicted by <leadto>?
------------------------------
------------------------------
Looking for a belief contradicted by: #{LEADTO.3}
------------------------------
(LEADTO &LEADTO.3
   ANTE  &WANT-COMMODITY.1
   CONSE &GOAL.5)
------------------------------
Trying: #{BELIEF.2}
------------------------------
------------------------------
Checking whether: #{LEADTO.3}
Can attack #{BELIEF.2}
Using attack strategy: #{AS-1}
------------------------------
------------------------------
Attack Strategy 1:
    If X is bad because X causes Y and Y is bad,
    Then show that X causes Z and Z is good.
------------------------------
------------------------------
Checking whether #{WANT-COMMODITY.1}
Is similar to #{MANUFACTURE.3} (X)
------------------------------
```

```
------------------------------
Checking similarity of #{MANUFACTURE.3}
and #{WANT-COMMODITY.1}
------------------------------
------------------------------
#{WANT-COMMODITY.1} is not directly similar
to #{MANUFACTURE.3} (X)
------------------------------
------------------------------
Checking whether #{WANT-COMMODITY.1}
Causes something that
Is similar to #{MANUFACTURE.3} (X)
------------------------------
------------------------------
Checking similarity of #{MANUFACTURE.3}
and #{MANUFACTURE.7}
------------------------------
(MANUFACTURE &MANUFACTURE.3
   COMPARED-TO &MANUFACTURE.2
   ANTE-OF     &LEADTO.2
   REF         DEFINITE
   PRODUCT     &PHYS-OBJ.1
   NAME        AUTOMOBILE-INDUSTRY)

(MANUFACTURE &MANUFACTURE.7
   ANTE-OF  &LEADTO.5
   CONSE-OF &LEADTO.4
   PRODUCT  &PHYS-OBJ.2)
------------------------------
Looking in slot: PRODUCTION-METHOD...PRODUCT
------------------------------
------------------------------
Checking similarity of #{PHYS-OBJ.1}
and #{PHYS-OBJ.2}
------------------------------
(PHYS-OBJ &PHYS-OBJ.1
   NAME              AUTOMOBILES
   TYPE              WORK-TOOL
   SCALE             (<NORM)
   PRODUCTION-METHOD ASSEMBLY-LINE)

(PHYS-OBJ &PHYS-OBJ.2
   NAME              AUTOMOBILES
   TYPE              WORK-TOOL
   SCALE             (<NORM)
   PRODUCTION-METHOD ASSEMBLY-LINE)
------------------------------
Looking in slot: TYPE...SETTING...PRODUCTION-METHOD
------------------------------
------------------------------
#{PHYS-OBJ.1} and #{PHYS-OBJ.2} are similar
------------------------------
------------------------------
#{MANUFACTURE.3} and #{MANUFACTURE.7} are similar
------------------------------
```

```
------------------------------
#{GOAL.5} involves having jobs
Having jobs is good
------------------------------
------------------------------
#{BELIEF.2} is contradicted via: #{AS-1}
------------------------------
Found Phrase: #{LE39REV}
-----> Yet <leadto>. <-----
------------------------------
Noting that #{LEADTO.3}
Is the justification of #{BELIEF.3}
------------------------------
------------------------------
Instantiating a new belief which
Contradicts the previous belief: #{BELIEF.2}
------------------------------
------------------------------
The event of the new belief object: #{MANUFACTURE.3}
Is the same as the event
Of the belief being contradicted.
------------------------------
------------------------------
The value judgment of the previous belief is: NEGATIVE
------------------------------
------------------------------
Inferring that the value judgment
Of the new belief is: POSITIVE
------------------------------
------------------------------
The justification of the new belief: #{LEADTO.3}
Contradicts the justification
Of the previous belief: #{LEADTO.2}
------------------------------
------------------------------
The new belief:
(BELIEF &BELIEF.3
   ACTOR         #{HUMAN}
   NAME          TO-BE-FOR
   B-OBJECT      &B-OBJECT.3
   JUSTIFICATION &LEADTO.3)
------------------------------
------------------------------
Noting that #{LEADTO.2}
Is being attacked by #{LEADTO.3}
------------------------------
Created Concept:
(BELIEF &BELIEF.3
   ACTOR         #{HUMAN}
   NAME          TO-BE-FOR
   B-OBJECT      &B-OBJECT.3
   JUSTIFICATION &LEADTO.3)
---------------------------------
Processing word: IN-THE-END
---------------------------------
---------------------------------
Processing word: THE
---------------------------------
```

```
Found Phrase: #{LE23}
-----> the <-----

Created Concept:
(ARTICLE &ARTICLE.8
   TYPE DEFINITE)
---------------------------------
Processing word: ECONOMY
---------------------------------
Found Phrase: #{LE41}
-----> economy <-----

Created Concept:
(ECONOMY &ECONOMY.1
   INSTITUTION UNITED-STATES
   RESOURCES   (GOODS AND SERVICES))

Found Phrase: #{LEB12}
-----> <article> <thing> <-----

Created Concept:
(ECONOMY &ECONOMY.1
   REF         DEFINITE
   INSTITUTION UNITED-STATES
   RESOURCES   (GOODS AND SERVICES))
---------------------------------
Processing word: BENEFITTED-BY
---------------------------------
---------------------------------
Processing word: THE-INTRODUCTION-OF-THE-NEW-TECHNOLOGY
---------------------------------
Found Phrase: #{LE42}
-----> the-introduction-of-the-new-technology <-----

Created Concept:
(MANUFACTURE &MANUFACTURE.8
   PRODUCTION-METHOD NEW-TECHNOLOGY)

Found Phrase: #{LE43}
-----> <economy> benefitted-by <manufacture> <-----

Created Concept:
(GOAL &GOAL.6
   OBJECT &ECONOMY.1
   INSTR  &MANUFACTURE.8
   STATUS SUCCESS)
---------------------------------
Processing word: *PERIOD*
---------------------------------
Found Phrase: #{LE44REV}
-----> <belief>  In-the-end <goal>. <-----

Created Concept:
(BELIEF &BELIEF.3
   ACTOR         #{HUMAN}
   NAME          TO-BE-FOR
   B-OBJECT      &B-OBJECT.3
   JUSTIFICATION (&LEADTO.3 &LEADTO.6))
```

```
Processing Complete
Result of Parse
#{BELIEF.1}
#{BELIEF.2}
#{BELIEF.3}
------------------------------
Entering: EXPECT::EXPECT-RUN EXPECT-CONTRAST-TO #{BELIEF.1}
------------------------------
------------------------------
Contrast to: #{BELIEF.1} is expected...
------------------------------
------------------------------
#{BELIEF.1} is analogous to: #{BELIEF.2}
Whose justification: #{LEADTO.2}
Has been attacked by: #{LEADTO.3}
------------------------------
------------------------------
The justification of #{BELIEF.2}: #{LEADTO.2}
Has been attacked by: #{LEADTO.3}
Using the strategy: #{AS-1}
Thus, #{LEADTO.3} attacks #{BELIEF.1} by analogy.
------------------------------
------------------------------
Form an analogous attack on: #{BELIEF.1}
Using the strategy #{AS-1}
And using #{LEADTO.3} as a source analog.
Check first for an existing attack.
------------------------------
------------------------------
Entering: EXPECT::APPLY-STRATEGY
APPLY-ATTACK-STRATEGY-1 #{BELIEF.1}#{LEADTO.3}
------------------------------
------------------------------
[EXPECT::HYPOTHESIZE-AND-VERIFY-REASON]
source: #{LEADTO.3} target: #{LEADTO.7}
bel: #{BELIEF.4} ver. criterion: IS-NOT-BAD
------------------------------
------------------------------
[EXPECT::TRANSFER-REASON]
source: #{LEADTO.3} target: #{LEADTO.7} bel: #{BELIEF.4}
------------------------------
------------------------------
[EXPECT::UNDERLYING-REASON] leadto: #{LEADTO.3}
------------------------------
------------------------------
#{LEADTO.3} is an instance of: WC-LEADS-TO-JOBS
------------------------------
------------------------------
[EXPECT::WC-LEADS-TO-JOBS?]
------------------------------
------------------------------
[EXPECT::INSTANTIATE-REASON]
idea: WC-LEADS-TO-JOBS target: #{LEADTO.7}
bel:#{BELIEF.4} source: #{LEADTO.3}
------------------------------
```

```
------------------------------
If consumer demand for a product
Increases the number of jobs available,
We can infer the implicit causal chain
That consumer demand for the product
Caused the product to be manufactured,
And the manufacturing of the product
Caused the increase in the number of jobs.
------------------------------
------------------------------
Inferring an implicit causal chain
------------------------------
------------------------------
Inferring that: #{WANT-COMMODITY.2}
Caused: #{MANUFACTURE.9}
------------------------------
------------------------------
Inferring that: #{MANUFACTURE.9}
Caused: #{GOAL.7}
------------------------------
------------------------------
WC-LEADS-TO-JOBS is being instantiated as: #{LEADTO.7}
------------------------------
------------------------------
[EXPECT::INSTANTIATE-REASON:WC-LEADS-TO-JOBS]
------------------------------
------------------------------
The hypothesized justification: #{LEADTO.7}
Is not contradicted
------------------------------
------------------------------
Verification criterion used: IS NOT BAD.
------------------------------
------------------------------
Noting that #{LEADTO.7}
Is the justification of #{BELIEF.4}
------------------------------
...
------------------------------
Instantiating a new belief which
Contradicts the previous belief: #{BELIEF.1}
------------------------------
------------------------------
The event of the new belief object: #{MANUFACTURE.1}
Is the same as the event
Of the belief being contradicted.
------------------------------
------------------------------
The value judgment of the previous belief is: NEGATIVE
------------------------------
------------------------------
Inferring that the value judgment
Of the new belief is: POSITIVE
------------------------------
```

```
------------------------------
The justification of the new belief: #{LEADTO.7}
Contradicts the justification
Of the previous belief: #{LEADTO.1}
------------------------------
------------------------------
The new belief:
(BELIEF &BELIEF.4
   COMPARED-TO   &BELIEF.3
   JUSTIFICATION &LEADTO.7
   B-OBJECT      &B-OBJECT.4
   NAME          TO-BE-FOR
   ACTOR         &GROUP.1)
------------------------------
------------------------------
Noting that #{LEADTO.1}
Is being attacked by #{LEADTO.7}
------------------------------
------------------------------
Killing expectation: (EXPECT-CONTRAST-TO #{BELIEF.1})
------------------------------
------------------------------
Entering: EXPECT::EXPECT-RUN EXPECT-CONTRAST-TO #{BELIEF.1}
------------------------------
------------------------------
Contrast to: #{BELIEF.1} is expected...
------------------------------
------------------------------
Contrast was already made.
The justification of: #{BELIEF.1}
Is attacked by: #{LEADTO.7}
------------------------------
------------------------------
Killing expectation: (EXPECT-CONTRAST-TO #{BELIEF.1})
------------------------------
(BELIEF &BELIEF.4
   COMPARED-TO   &BELIEF.3
   JUSTIFICATION &LEADTO.7
   B-OBJECT      &B-OBJECT.4
   NAME          TO-BE-FOR
   ACTOR         &GROUP.1)

(B-OBJECT &B-OBJECT.4
   V-JUDGE POSITIVE
   EVENT   &MANUFACTURE.1)

(MANUFACTURE &MANUFACTURE.1
   PRODUCTION-METHOD COMPUTER
   NAME              COMPUTER-INDUSTRY)

(LEADTO &LEADTO.7
   ATTACK-STRATEGY  (&AS-1 &BELIEF.1)
   ATTACKS          &LEADTO.1
   JUSTIFICATION-OF &BELIEF.4
   CONSE            &GOAL.7
   ANTE             &WANT-COMMODITY.2)
```

```
(WANT-COMMODITY &WANT-COMMODITY.2
   ANTE-OF (&LEADTO.8 &LEADTO.7)
   OBJECT  &PHYS-OBJ.4)

(GOAL &GOAL.7
   CONSE-OF (&LEADTO.9 &LEADTO.7)
   STATUS   SUCCESS
   OBJECT   &OCCUPATION.7)
```

The generation of the conclusion to HIGH-TECH-2 is identical to the generation of the conclusion to HIGH-TECH-1, and is omitted here.

```
***** BELIEF OBJECT INSTANCES *****
(B-OBJECT &B-OBJECT.4
   V-JUDGE POSITIVE
   EVENT   &MANUFACTURE.1)
(B-OBJECT &B-OBJECT.3
   V-JUDGE POSITIVE
   EVENT   &MANUFACTURE.3)
(B-OBJECT &B-OBJECT.2
   V-JUDGE NEGATIVE
   EVENT   &MANUFACTURE.3)
(B-OBJECT &B-OBJECT.1
   EVENT   &MANUFACTURE.1
   V-JUDGE NEGATIVE)

***** BELIEF INSTANCES *****
(BELIEF &BELIEF.4
   COMPARED-TO   &BELIEF.3
   JUSTIFICATION &LEADTO.7
   B-OBJECT      &B-OBJECT.4
   NAME          TO-BE-FOR
   ACTOR         &GROUP.1)
(BELIEF &BELIEF.3
   COMPARED-TO   &BELIEF.4
   ACTOR         #{HUMAN}
   NAME          TO-BE-FOR
   B-OBJECT      &B-OBJECT.3
   JUSTIFICATION (&LEADTO.3 &LEADTO.6))
(BELIEF &BELIEF.2
   ACTOR         #{HUMAN}
   B-OBJECT      &B-OBJECT.2
   JUSTIFICATION &LEADTO.2
   NAME          TO-BE-AGAINST
   COMPARED-TO   &BELIEF.1)
(BELIEF &BELIEF.1
   COMPARED-TO   &BELIEF.2
   NAME          TO-BE-AGAINST
   ACTOR         &GROUP.1
   B-OBJECT      &B-OBJECT.1
   JUSTIFICATION &LEADTO.1)

***** ECONOMY INSTANCES *****
(ECONOMY &ECONOMY.1
   REF         DEFINITE
   INSTITUTION UNITED-STATES
   RESOURCES   (GOODS AND SERVICES))
```

```
***** GOAL INSTANCES *****
(GOAL &GOAL.7
   CONSE-OF (&LEADTO.9 &LEADTO.7)
   STATUS   SUCCESS
   OBJECT   &OCCUPATION.7)
(GOAL &GOAL.6
   CONSE-OF &LEADTO.6
   OBJECT   &ECONOMY.1
   INSTR    &MANUFACTURE.8
   STATUS   SUCCESS)
(GOAL &GOAL.5
   CONSE-OF (&LEADTO.5 &LEADTO.3)
   NAME     IMPROVED-ECONOMY
   OBJECT   &OCCUPATION.6
   INSTR    JOB-SHIFT
   FROM     &OCCUPATION.5
   TO       &OCCUPATION.4
   STATUS   SUCCESS)
(GOAL &GOAL.4
   OBJECT &OCCUPATION.5
   INSTR  &MANUFACTURE.6
   STATUS FAILURE)
(GOAL &GOAL.3
   OBJECT &OCCUPATION.4
   STATUS SUCCESS)
(GOAL &GOAL.2
   COMPARED-TO &GOAL.1
   CONSE-OF    &LEADTO.2
   OBJECT      &OCCUPATION.2
   STATUS      FAILURE)
(GOAL &GOAL.1
   COMPARED-TO &GOAL.2
   CONSE-OF    &LEADTO.1
   ACTOR       &GROUP.3
   OBJECT      &OCCUPATION.1
   STATUS      FAILURE)

***** GROUP INSTANCES *****
(GROUP &GROUP.7
   TYPE #{HUMAN})
(GROUP &GROUP.6
   TYPE #{HUMAN})
(GROUP &GROUP.5
   TYPE #{HUMAN})
(GROUP &GROUP.4
   NAME PEOPLE
   TYPE #{HUMAN})
(GROUP &GROUP.3
   TYPE #{HUMAN})
(GROUP &GROUP.2
   TYPE #{HUMAN})
(GROUP &GROUP.1
   REF  INDEFINITE
   NAME PEOPLE
   TYPE #{HUMAN})
```

```
***** LEADTO INSTANCES *****
(LEADTO &LEADTO.9
   CONSE &GOAL.7
   ANTE  &MANUFACTURE.9)
(LEADTO &LEADTO.8
   CONSE &MANUFACTURE.9
   ANTE  &WANT-COMMODITY.2)
(LEADTO &LEADTO.7
   ATTACK-STRATEGY  (&AS-1 &BELIEF.1)
   ATTACKS   &LEADTO.1
   JUSTIFICATION-OF &BELIEF.4
   CONSE   &GOAL.7
   ANTE  &WANT-COMMODITY.2)
(LEADTO &LEADTO.6
   ANTE  &WANT-COMMODITY.1
   CONSE &GOAL.6)
(LEADTO &LEADTO.5
   CONSE &GOAL.5
   ANTE  &MANUFACTURE.7)
(LEADTO &LEADTO.4
   CONSE &MANUFACTURE.7
   ANTE  &WANT-COMMODITY.1)
(LEADTO &LEADTO.3
   ATTACKS  &LEADTO.2
   JUSTIFICATION-OF &BELIEF.3
   ATTACK-STRATEGY  (&AS-1 &BELIEF.2)
   ANTE   &WANT-COMMODITY.1
   CONSE   &GOAL.5)
(LEADTO &LEADTO.2
   ATTACKED-BY      &LEADTO.3
   COMPARED-TO      &LEADTO.1
   JUSTIFICATION-OF &BELIEF.2
   ANTE   &MANUFACTURE.3
   CONSE   &GOAL.2)
(LEADTO &LEADTO.1
   ATTACKED-BY   &LEADTO.7
   COMPARED-TO   &LEADTO.2
   JUSTIFICATION-OF &BELIEF.1
   ANTE  &MANUFACTURE.2
   CONSE   &GOAL.1)

***** MANUFACTURE INSTANCES *****
(MANUFACTURE &MANUFACTURE.9
   ANTE-OF  &LEADTO.9
   CONSE-OF &LEADTO.8
   PRODUCT  &PHYS-OBJ.4)
(MANUFACTURE &MANUFACTURE.8
   PRODUCTION-METHOD NEW-TECHNOLOGY)
(MANUFACTURE &MANUFACTURE.7
   ANTE-OF  &LEADTO.5
   CONSE-OF &LEADTO.4
   PRODUCT  &PHYS-OBJ.2)
(MANUFACTURE &MANUFACTURE.6
   REF     DEFINITE
   PRODUCT HORSE-CARRIAGE
   NAME    HORSE-CARRIAGE-INDUSTRY)
```

```
(MANUFACTURE &MANUFACTURE.5
   REF     DEFINITE
   PRODUCT &PHYS-OBJ.3
   NAME    AUTOMOBILE-INDUSTRY)
(MANUFACTURE &MANUFACTURE.4
   PRODUCT HORSE-CARRIAGE
   NAME    HORSE-CARRIAGE-INDUSTRY)
(MANUFACTURE &MANUFACTURE.3
   COMPARED-TO &MANUFACTURE.2
   ANTE-OF     &LEADTO.2
   REF         DEFINITE
   PRODUCT     &PHYS-OBJ.1
   NAME        AUTOMOBILE-INDUSTRY)
(MANUFACTURE &MANUFACTURE.2
   COMPARED-TO       &MANUFACTURE.3
   ANTE-OF           &LEADTO.1
   PRODUCTION-METHOD COMPUTER
   NAME              COMPUTER-INDUSTRY)
(MANUFACTURE &MANUFACTURE.1
   PRODUCTION-METHOD COMPUTER
   NAME              COMPUTER-INDUSTRY)

***** OCCUPATION INSTANCES *****
(OCCUPATION &OCCUPATION.7
   SETTING &MANUFACTURE.1)
(OCCUPATION &OCCUPATION.6)
(OCCUPATION &OCCUPATION.5
   SETTING &MANUFACTURE.6
   ACTOR   &GROUP.7)
(OCCUPATION &OCCUPATION.4
   SETTING &MANUFACTURE.5
   ACTOR   &GROUP.6)
(OCCUPATION &OCCUPATION.3
   ACTOR &GROUP.5)
(OCCUPATION &OCCUPATION.2
   ACTOR   &GROUP.4
   REF     DEFINITE
   SETTING &MANUFACTURE.4)
(OCCUPATION &OCCUPATION.1
   ACTOR &GROUP.2)

***** PHYSICAL OBJECT INSTANCES *****
(PHYS-OBJ &PHYS-OBJ.4
   PRODUCTION-METHOD COMPUTER)
(PHYS-OBJ &PHYS-OBJ.3
   NAME              AUTOMOBILES
   TYPE              WORK-TOOL
   SCALE             (<NORM)
   PRODUCTION-METHOD ASSEMBLY-LINE)
(PHYS-OBJ &PHYS-OBJ.2
   NAME              AUTOMOBILES
   TYPE              WORK-TOOL
   SCALE             (<NORM)
   PRODUCTION-METHOD ASSEMBLY-LINE)
```

```
(PHYS-OBJ &PHYS-OBJ.1
   NAME              AUTOMOBILES
   TYPE              WORK-TOOL
   SCALE             (<NORM)
   PRODUCTION-METHOD ASSEMBLY-LINE)

***** WANT COMMODITY INSTANCES *****
(WANT-COMMODITY &WANT-COMMODITY.2
   ANTE-OF (&LEADTO.8 &LEADTO.7)
   OBJECT  &PHYS-OBJ.4)
(WANT-COMMODITY &WANT-COMMODITY.1
   ANTE-OF (&LEADTO.6 &LEADTO.4 &LEADTO.3)
   NAME    CONSUMER-DEMAND-FOR
   OBJECT  &PHYS-OBJ.2)
```

A.5. HIGH-TECH-3 Trace

The processing of the first sentence of HIGH-TECH-3 is identical to that of HIGH-TECH-1 and HIGH-TECH-2. The second sentence lacks both the lexical clue introducing the presence of the analogy, and the lexical clues in the second and third sentences guiding the flow of the argument. As with HIGH-TECH-1 and HIGH-TECH-2, HIGH-TECH-3 contains an incomplete argument-by-analogy. Details of the trace has been omitted where possible for the sake of brevity.

```
> (pparse-ht1)

HIGH-TECH-3:
Some people are against CAM
because CAM eliminates jobs *period*
The automobile-industry caused people in the
horse-carriage-industry to-lose jobs *period*
Consumer-demand-for autos was strong enough
that more jobs were created in the
automobile-industry than jobs were lost in the
horse-carriage-industry *period*
The economy benefitted-by
the-introduction-of-the-new-technology *period*
```

The processing of the first sentence of HIGH-TECH-3 is identical to the processing of the first sentence of HIGH-TECH-1, and is omitted here.

```
...
---------------------------------
Processing word: THE
---------------------------------
Found Phrase: #{LE23}
-----> the <-----

Created Concept:
(ARTICLE &ARTICLE.10
   TYPE DEFINITE)
---------------------------------
Processing word: AUTOMOBILE-INDUSTRY
---------------------------------
Found Phrase: #{LE20REV}
-----> automobile industry <-----
```

```
Created Concept:
(MANUFACTURE &MANUFACTURE.12
   PRODUCT &PHYS-OBJ.5
   NAME    AUTOMOBILE-INDUSTRY)

Found Phrase: #{LEB12}
-----> <article> <thing> <-----

Created Concept:
(MANUFACTURE &MANUFACTURE.12
   REF     DEFINITE
   PRODUCT &PHYS-OBJ.5
   NAME    AUTOMOBILE-INDUSTRY)
---------------------------------
Processing word: CAUSED...PEOPLE
---------------------------------
Found Phrase: #{LE3}
-----> people <-----

Created Concept:
(GROUP &GROUP.11
   NAME PEOPLE
   TYPE #{HUMAN})
---------------------------------
Processing word: IN...THE
---------------------------------
Found Phrase: #{LE23}
-----> the <-----

Created Concept:
(ARTICLE &ARTICLE.11
   TYPE DEFINITE)
---------------------------------
Processing word: HORSE-CARRIAGE-INDUSTRY
---------------------------------
Found Phrase: #{LE21}
-----> horse carriage industry <-----

Created Concept:
(MANUFACTURE &MANUFACTURE.13
   PRODUCT HORSE-CARRIAGE
   NAME    HORSE-CARRIAGE-INDUSTRY)

Found Phrase: #{LE22}
-----> <human> in <ref> <manufacture> <-----

Created Concept:
(OCCUPATION &OCCUPATION.8
   ACTOR   &GROUP.11
   REF     DEFINITE
   SETTING &MANUFACTURE.13)
---------------------------------
Processing word: TO-LOSE
---------------------------------
Found Phrase: #{LEY}
-----> to lose <-----
```

```
Created Concept:
(LOSE-VERB &LOSE-VERB.1
   NAME  TO-LOSE
   TENSE INFINITIVE)
---------------------------------
Processing word: JOBS
---------------------------------
Found Phrase: #{LE7}
-----> jobs <-----

Created Concept:
(OCCUPATION &OCCUPATION.9
   ACTOR &GROUP.12)

Found Phrase: #{LEH31}
-----> <occupation> <lose-verb> <occupation> <-----
------------------------------
Making the actor of the goal
The same as the actor of the occupation...
------------------------------
Created Concept:
(GOAL &GOAL.9
   OBJECT &OCCUPATION.8
   STATUS FAILURE)
---------------------------------
Processing word: *PERIOD*
---------------------------------
Found Phrase: #{LENEW3}
-----> <manufacture> caused <goal>. <-----

Created Concept:
(LEADTO &LEADTO.11
   ANTE  &MANUFACTURE.12
   CONSE &GOAL.9)
---------------------------------
Processing word: CONSUMER-DEMAND-FOR...AUTOS
---------------------------------
Found Phrase: #{LE31A}
-----> autos <-----

Created Concept:
(PHYS-OBJ &PHYS-OBJ.6
   NAME                  AUTOMOBILES
   TYPE                  WORK-TOOL
   SCALE                 (<NORM)
   PRODUCTION-METHOD ASSEMBLY-LINE)

Found Phrase: #{LE30}
-----> consumer demand for <phys-obj> <-----

Created Concept:
(WANT-COMMODITY &WANT-COMMODITY.3
   NAME   CONSUMER-DEMAND-FOR
   OBJECT &PHYS-OBJ.6)
---------------------------------
Processing word: WAS
---------------------------------
```

```
Found Phrase: #{LE32}
-----> was <-----

Created Concept:
(AUX-VERB &AUX-VERB.6
   NAME  TO-BE
   TENSE PAST)
---------------------------------
Processing word: STRONG...ENOUGH...THAT...MORE...JOBS
---------------------------------
Found Phrase: #{LE7}
-----> jobs <-----

Created Concept:
(OCCUPATION &OCCUPATION.10
   ACTOR &GROUP.13)
---------------------------------
Processing word: WERE...CREATED...IN...THE
---------------------------------
Found Phrase: #{LE23}
-----> the <-----

Created Concept:
(ARTICLE &ARTICLE.12
   TYPE DEFINITE)
---------------------------------
Processing word: AUTOMOBILE-INDUSTRY
---------------------------------
Found Phrase: #{LE20REV}
-----> automobile industry <-----

Created Concept:
(MANUFACTURE &MANUFACTURE.14
   PRODUCT &PHYS-OBJ.7
   NAME    AUTOMOBILE-INDUSTRY)

Found Phrase: #{LEB12}
-----> <article> <thing> <-----

Created Concept:
(MANUFACTURE &MANUFACTURE.14
   REF     DEFINITE
   PRODUCT &PHYS-OBJ.7
   NAME    AUTOMOBILE-INDUSTRY)

Found Phrase: #{LE35REV}
-----> <occupation> were created in <manufacture> <-----

Created Concept:
(GOAL &GOAL.10
   OBJECT &OCCUPATION.10
   STATUS SUCCESS)
---------------------------------
Processing word: THAN...JOBS
---------------------------------
Found Phrase: #{LE7}
-----> jobs <-----
```

```
Created Concept:
(OCCUPATION &OCCUPATION.11
   ACTOR &GROUP.14)
---------------------------------
Processing word: WERE...LOST...IN...THE
---------------------------------
Found Phrase: #{LE23}
-----> the <-----

Created Concept:
(ARTICLE &ARTICLE.13
   TYPE DEFINITE)
---------------------------------
Processing word: HORSE-CARRIAGE-INDUSTRY
---------------------------------
Found Phrase: #{LE21}
-----> horse carriage industry <-----

Created Concept:
(MANUFACTURE &MANUFACTURE.15
   PRODUCT HORSE-CARRIAGE
   NAME    HORSE-CARRIAGE-INDUSTRY)

Found Phrase: #{LEB12}
-----> <article> <thing> <-----

Created Concept:
(MANUFACTURE &MANUFACTURE.15
   REF     DEFINITE
   PRODUCT HORSE-CARRIAGE
   NAME    HORSE-CARRIAGE-INDUSTRY)

Found Phrase: #{LE36REV}
-----> <occupation> were lost in <manufacture> <-----

Created Concept:
(GOAL &GOAL.11
   OBJECT &OCCUPATION.11
   INSTR  &MANUFACTURE.15
   STATUS FAILURE)

Found Phrase: #{LE34REV}
-----> more <goal1> than <goal2> <-----

Created Concept:
(GOAL &GOAL.12
   NAME   IMPROVED-ECONOMY
   OBJECT &OCCUPATION.12
   INSTR  JOB-SHIFT
   FROM   &OCCUPATION.11
   TO     &OCCUPATION.10
   STATUS SUCCESS)

Found Phrase: #{LE33}
-----> <want-commodity> <aux-verb>
         strong enough that <goal> <-----
```

```
------------------------------
If consumer demand for a product
Increases the number of jobs available,
We can infer the implicit causal chain
That consumer demand for the product
Caused the product to be manufactured,
And the manufacturing of the product
Caused the increase in the number of jobs.
------------------------------
------------------------------
Inferring an implicit causal chain
------------------------------
------------------------------
Inferring that: #{WANT-COMMODITY.3}
Caused: #{MANUFACTURE.16}
------------------------------
------------------------------
Inferring that: #{MANUFACTURE.16}
Caused: #{GOAL.12}
------------------------------
Created Concept:
(LEADTO &LEADTO.12
   ANTE  &WANT-COMMODITY.3
   CONSE &GOAL.12)
---------------------------------
Processing word: *PERIOD*
---------------------------------
Found Phrase: #{LEH32}
-----> <leadto>. <-----

Created Concept:
(LEADTO &LEADTO.12
   ANTE  &WANT-COMMODITY.3
   CONSE &GOAL.12)
---------------------------------
Processing word: THE
---------------------------------
Found Phrase: #{LE23}
-----> the <-----

Created Concept:
(ARTICLE &ARTICLE.14
   TYPE DEFINITE)
---------------------------------
Processing word: ECONOMY
---------------------------------
Found Phrase: #{LE41}
-----> economy <-----

Created Concept:
(ECONOMY &ECONOMY.2
   INSTITUTION UNITED-STATES
   RESOURCES   (GOODS AND SERVICES))

Found Phrase: #{LEB12}
-----> <article> <thing> <-----
```

```
Created Concept:
(ECONOMY &ECONOMY.2
   REF   DEFINITE
   INSTITUTION UNITED-STATES
   RESOURCES   (GOODS AND SERVICES))
---------------------------------
Processing word: BENEFITTED-BY...
    THE-INTRODUCTION-OF-THE-NEW-TECHNOLOGY
---------------------------------
Found Phrase: #{LE42}
-----> the-introduction-of-the-new-technology <-----

Created Concept:
(MANUFACTURE &MANUFACTURE.17
   PRODUCTION-METHOD NEW-TECHNOLOGY)

Found Phrase: #{LE43}
-----> <economy> benefitted-by <manufacture> <-----

Created Concept:
(GOAL &GOAL.13
   OBJECT &ECONOMY.2
   INSTR  &MANUFACTURE.17
   STATUS SUCCESS)
---------------------------------
Processing word: *PERIOD*
---------------------------------
Found Phrase: #{LEH33}
-----> <goal>. <-----

Created Concept:
(GOAL &GOAL.13
   OBJECT &ECONOMY.2
   INSTR  &MANUFACTURE.17
   STATUS SUCCESS)

Processing Complete
Result of Parse
#{BELIEF.5}
#{LEADTO.11}
#{LEADTO.12}
#{GOAL.13}
------------------------------
Entering: EXPECT::EXPECT-RUN EXPECT-CONTRAST-TO #{BELIEF.5}
------------------------------
------------------------------
Contrast to: #{BELIEF.5} is expected...
------------------------------
------------------------------
Checking whether #{LEADTO.10} and
#{LEADTO.14} are analogous...
------------------------------
(LEADTO &LEADTO.10
   JUSTIFICATION-OF &BELIEF.5
   ANTE             &MANUFACTURE.11
   CONSE            &GOAL.8)
```

```
(LEADTO &LEADTO.14
   CONSE &GOAL.12
   ANTE  &MANUFACTURE.16)
------------------------------
Checking whether #{MANUFACTURE.11} and
#{MANUFACTURE.16} are analogous...
------------------------------
(MANUFACTURE &MANUFACTURE.11
   ANTE-OF           &LEADTO.10
   PRODUCTION-METHOD COMPUTER
   NAME              COMPUTER-INDUSTRY)

(MANUFACTURE &MANUFACTURE.16
   ANTE-OF  &LEADTO.14
   CONSE-OF &LEADTO.13
   PRODUCT  &PHYS-OBJ.6)
------------------------------
Checking whether #{GOAL.8}
and #{GOAL.12} are analogous...
------------------------------
(GOAL &GOAL.8
   CONSE-OF &LEADTO.10
   ACTOR    &GROUP.10
   OBJECT   &OCCUPATION.7
   STATUS   FAILURE)

(GOAL &GOAL.12
   CONSE-OF (&LEADTO.14 &LEADTO.12)
   NAME     IMPROVED-ECONOMY
   OBJECT   &OCCUPATION.12
   INSTR    JOB-SHIFT
   FROM     &OCCUPATION.11
   TO       &OCCUPATION.10
   STATUS   SUCCESS)
------------------------------
Checking whether #{LEADTO.10}
and #{LEADTO.13} are analogous...
------------------------------
(LEADTO &LEADTO.10
   JUSTIFICATION-OF &BELIEF.5
   ANTE             &MANUFACTURE.11
   CONSE            &GOAL.8)

(LEADTO &LEADTO.13
   CONSE &MANUFACTURE.16
   ANTE  &WANT-COMMODITY.3)
------------------------------
Checking whether #{MANUFACTURE.11} and
#{WANT-COMMODITY.3} are analogous...
------------------------------
(MANUFACTURE &MANUFACTURE.11
   ANTE-OF           &LEADTO.10
   PRODUCTION-METHOD COMPUTER
   NAME              COMPUTER-INDUSTRY)
```

```
(WANT-COMMODITY &WANT-COMMODITY.3
   ANTE-OF (&LEADTO.13 &LEADTO.12)
   NAME    CONSUMER-DEMAND-FOR
   OBJECT  &PHYS-OBJ.6)
------------------------------
Checking whether #{LEADTO.10}
and #{LEADTO.12} are analogous...
------------------------------
(LEADTO &LEADTO.10
   JUSTIFICATION-OF &BELIEF.5
   ANTE             &MANUFACTURE.11
   CONSE            &GOAL.8)

(LEADTO &LEADTO.12
   ANTE  &WANT-COMMODITY.3
   CONSE &GOAL.12)
------------------------------
Checking whether #{MANUFACTURE.11} and
#{WANT-COMMODITY.3} are analogous...
------------------------------
(MANUFACTURE &MANUFACTURE.11
   ANTE-OF           &LEADTO.10
   PRODUCTION-METHOD COMPUTER
   NAME              COMPUTER-INDUSTRY)

(WANT-COMMODITY &WANT-COMMODITY.3
   ANTE-OF (&LEADTO.13 &LEADTO.12)
   NAME    CONSUMER-DEMAND-FOR
   OBJECT  &PHYS-OBJ.6)
------------------------------
Checking whether #{LEADTO.10}
and #{LEADTO.11} are analogous...
------------------------------
(LEADTO &LEADTO.10
   JUSTIFICATION-OF &BELIEF.5
   ANTE             &MANUFACTURE.11
   CONSE            &GOAL.8)

(LEADTO &LEADTO.11
   ANTE  &MANUFACTURE.12
   CONSE &GOAL.9)
------------------------------
Checking whether #{MANUFACTURE.11}
and #{MANUFACTURE.12} are analogous...
------------------------------
(MANUFACTURE &MANUFACTURE.11
   ANTE-OF           &LEADTO.10
   PRODUCTION-METHOD COMPUTER
   NAME              COMPUTER-INDUSTRY)

(MANUFACTURE &MANUFACTURE.12
   ANTE-OF &LEADTO.11
   REF     DEFINITE
   PRODUCT &PHYS-OBJ.5
   NAME    AUTOMOBILE-INDUSTRY)
```

```
------------------------------
Checking whether #{GOAL.8}
and #{GOAL.9} are analogous...
------------------------------
(GOAL &GOAL.8
   CONSE-OF &LEADTO.10
   ACTOR    &GROUP.10
   OBJECT   &OCCUPATION.7
   STATUS   FAILURE)

(GOAL &GOAL.9
   CONSE-OF &LEADTO.11
   OBJECT   &OCCUPATION.8
   STATUS   FAILURE)
------------------------------
Checking whether #{OCCUPATION.7} and
#{OCCUPATION.8} are analogous...
------------------------------
(OCCUPATION &OCCUPATION.7
   ACTOR &GROUP.9)

(OCCUPATION &OCCUPATION.8
   ACTOR   &GROUP.11
   REF     DEFINITE
   SETTING &MANUFACTURE.13)
------------------------------
Comparing the concept: #{GOAL.8}
With the concept: #{GOAL.9}
------------------------------
------------------------------
Comparing the concept: #{LEADTO.10}
With the concept: #{LEADTO.11}
------------------------------
------------------------------
Comparing the concept: #{MANUFACTURE.11}
With the concept: #{MANUFACTURE.12}
------------------------------
------------------------------
Comparing the concept: #{GOAL.8}
With the concept: #{GOAL.9}
------------------------------
------------------------------
Inferring a new belief
Analogous to the existing belief: #{BELIEF.5}
------------------------------
------------------------------
Inferring the name of new belief: TO-BE-AGAINST
From the analogous belief...
------------------------------
------------------------------
Inferring the justification
Of the new belief: #{LEADTO.11}
------------------------------
------------------------------
Noting that #{LEADTO.11}
Is the justification of #{BELIEF.6}
------------------------------
```

```
------------------------------
Inferring event of the new belief object:
#{MANUFACTURE.12}
From antecedent of the selected belief justification:
#{LEADTO.11}
------------------------------
------------------------------
Inferring value judgment
Of the new belief object: NEGATIVE
From analogous belief's belief-object.
------------------------------
------------------------------
Linking the analogous beliefs:
#{BELIEF.5} and #{BELIEF.6}
------------------------------
(BELIEF &BELIEF.5
   COMPARED-TO   &BELIEF.6
   NAME          TO-BE-AGAINST
   ACTOR         &GROUP.8
   B-OBJECT      &B-OBJECT.5
   JUSTIFICATION &LEADTO.10)

(BELIEF &BELIEF.6
   COMPARED-TO   &BELIEF.5
   B-OBJECT      &B-OBJECT.6
   JUSTIFICATION &LEADTO.11
   NAME          TO-BE-AGAINST)
------------------------------
Comparing the concept: #{LEADTO.10}
With the concept: #{LEADTO.11}
------------------------------
------------------------------
Comparing the concept: #{MANUFACTURE.11}
With the concept: #{MANUFACTURE.12}
------------------------------
------------------------------
Comparing the concept: #{GOAL.8}
With the concept: #{GOAL.9}
------------------------------
------------------------------
Concept: #{LEADTO.11} is a LEADTO
It has not been attacked.
------------------------------
------------------------------
Checking whether: #{LEADTO.11}
Can attack #{LEADTO.14}
Using attack strategy: #{AS-1}
------------------------------
------------------------------
Attack Strategy 1:
    If X is bad because X causes Y and Y is bad,
    Then show that X causes Z and Z is good.
------------------------------
------------------------------
Checking whether #{MANUFACTURE.12}
Is similar to #{MANUFACTURE.16} (X)
------------------------------
```

```
-----------------------------
Checking similarity of #{MANUFACTURE.16}
and #{MANUFACTURE.12}
-----------------------------
(MANUFACTURE &MANUFACTURE.16
   ANTE-OF  &LEADTO.14
   CONSE-OF &LEADTO.13
   PRODUCT  &PHYS-OBJ.6)

(MANUFACTURE &MANUFACTURE.12
   COMPARED-TO &MANUFACTURE.11
   ANTE-OF     &LEADTO.11
   REF         DEFINITE
   PRODUCT     &PHYS-OBJ.5
   NAME        AUTOMOBILE-INDUSTRY)
-----------------------------
Looking in slot: PRODUCTION-METHOD...PRODUCT
-----------------------------
-----------------------------
Checking similarity of #{PHYS-OBJ.6}
and #{PHYS-OBJ.5}
-----------------------------
(PHYS-OBJ &PHYS-OBJ.6
   NAME              AUTOMOBILES
   TYPE              WORK-TOOL
   SCALE             (<NORM)
   PRODUCTION-METHOD ASSEMBLY-LINE)

(PHYS-OBJ &PHYS-OBJ.5
   NAME              AUTOMOBILES
   TYPE              WORK-TOOL
   SCALE             (<NORM)
   PRODUCTION-METHOD ASSEMBLY-LINE)
-----------------------------
Looking in slot: TYPE...SETTING...PRODUCTION-METHOD
-----------------------------
-----------------------------
#{PHYS-OBJ.6} and #{PHYS-OBJ.5} are similar
-----------------------------
-----------------------------
#{MANUFACTURE.16} and #{MANUFACTURE.12} are similar
-----------------------------
-----------------------------
#{GOAL.9} involves loss of jobs
Losing jobs is bad
-----------------------------
-----------------------------
#{GOAL.12} involves having jobs
Having jobs is good
-----------------------------
-----------------------------
TEST-FOR-AS-1 passed
Using: #{LEADTO.11}and #{LEADTO.14}
-----------------------------
-----------------------------
Noting that #{LEADTO.11}
Is being attacked by #{LEADTO.14}
-----------------------------
```

```
------------------------------
A belief contrasting with #{BELIEF.6} is being formed.
------------------------------
------------------------------
Noting that #{LEADTO.14}
Is the justification of #{NEW-BELIEF}
------------------------------
------------------------------
Entering: EXPECT::APPLY-STRATEGY
APPLY-ATTACK-STRATEGY-1 #{BELIEF.5} #{LEADTO.14}
------------------------------
------------------------------
[EXPECT::HYPOTHESIZE-AND-VERIFY-REASON]
source: #{LEADTO.14} target: #{LEADTO.15}
bel: #{BELIEF.7} ver. criterion: IS-NOT-BAD
------------------------------
------------------------------
[EXPECT::TRANSFER-REASON]
source: #{LEADTO.14} target: #{LEADTO.15} bel: #{BELIEF.7}
------------------------------
------------------------------
[EXPECT::UNDERLYING-REASON] leadto: #{LEADTO.14}
------------------------------
------------------------------
#{LEADTO.14} is an instance of: MFG-LEADS-TO-JOBS
------------------------------
------------------------------
[EXPECT::MFG-LEADS-TO-JOBS?]
------------------------------
------------------------------
[EXPECT::INSTANTIATE-REASON]
idea: MFG-LEADS-TO-JOBS target: #{LEADTO.15}
bel: #{BELIEF.7} source: #{LEADTO.14}
------------------------------
------------------------------
MFG-LEADS-TO-JOBS is being instantiated as: #{LEADTO.15}
------------------------------
------------------------------
[EXPECT::INSTANTIATE-REASON:MFG-LEADS-TO-JOBS]
------------------------------
------------------------------
The hypothesized justification: #{LEADTO.15} is not
contradicted
------------------------------
------------------------------
Verification criterion used: IS NOT BAD.
------------------------------
------------------------------
Noting that #{LEADTO.15}
Is the justification of #{BELIEF.7}
------------------------------
------------------------------
Comparing the concept: #{BELIEF.7}
With the concept: #{NEW-BELIEF}
------------------------------
```

```
------------------------------
Comparing the concept: #{LEADTO.15}
With the concept: #{LEADTO.14}
------------------------------
------------------------------
Comparing the concept: #{MANUFACTURE.10}
With the concept: #{MANUFACTURE.16}
------------------------------
------------------------------
Comparing the concept: #{GOAL.14}
With the concept: #{GOAL.12}
------------------------------
------------------------------
Instantiating a new belief which
Contradicts the previous belief: #{BELIEF.5}
------------------------------
------------------------------
The event of the new belief object: #{MANUFACTURE.10}
Is the same as the event
Of the belief being contradicted.
------------------------------
------------------------------
The value judgment of the previous belief is: NEGATIVE
------------------------------
------------------------------
Inferring that the value judgment
Of the new belief is: POSITIVE
------------------------------
------------------------------
The justification of the new belief: #{LEADTO.15}
Contradicts the justification
Of the previous belief: #{LEADTO.10}
------------------------------
------------------------------
The new belief:
(BELIEF &BELIEF.7
   COMPARED-TO   &NEW-BELIEF
   JUSTIFICATION &LEADTO.15
   B-OBJECT      &B-OBJECT.7
   NAME          TO-BE-FOR
   ACTOR         &GROUP.8)
------------------------------
------------------------------
Noting that #{LEADTO.10}
Is being attacked by #{LEADTO.15}
------------------------------
------------------------------
Killing expectation: (EXPECT-CONTRAST-TO #{BELIEF.5})
------------------------------
(BELIEF &BELIEF.7
   COMPARED-TO   &NEW-BELIEF
   JUSTIFICATION &LEADTO.15
   B-OBJECT      &B-OBJECT.7
   NAME          TO-BE-FOR
   ACTOR         &GROUP.8)
```

```
(B-OBJECT &B-OBJECT.7
   V-JUDGE POSITIVE
   EVENT   &MANUFACTURE.10)

(MANUFACTURE &MANUFACTURE.10
   COMPARED-TO        &MANUFACTURE.16
   ANTE-OF            &LEADTO.15
   PRODUCTION-METHOD COMPUTER
   NAME               COMPUTER-INDUSTRY)

(LEADTO &LEADTO.15
   ATTACK-STRATEGY  (&AS-1 &BELIEF.5)
   ATTACKS          &LEADTO.10
   COMPARED-TO      &LEADTO.14
   JUSTIFICATION-OF &BELIEF.7
   CONSE            &GOAL.14
   ANTE             &MANUFACTURE.10)

(MANUFACTURE &MANUFACTURE.10
   COMPARED-TO        &MANUFACTURE.16
   ANTE-OF            &LEADTO.15
   PRODUCTION-METHOD COMPUTER
   NAME               COMPUTER-INDUSTRY)

(GOAL &GOAL.14
   COMPARED-TO &GOAL.12
   CONSE-OF    &LEADTO.15
   STATUS      SUCCESS
   OBJECT      &OCCUPATION.13)
```

The generation of the conclusion to HIGH-TECH-3 is similar to that of HIGH-TECH-1 and HIGH-TECH-2, and is omitted here.

```
***** BELIEF OBJECT INSTANCES *****
(B-OBJECT &B-OBJECT.7
   V-JUDGE POSITIVE
   EVENT   &MANUFACTURE.10)
(B-OBJECT &NEW-B-OBJECT
   V-JUDGE POSITIVE
   EVENT   &MANUFACTURE.16)
(B-OBJECT &B-OBJECT.6
   V-JUDGE NEGATIVE
   EVENT   &MANUFACTURE.12)
(B-OBJECT &B-OBJECT.5
   EVENT   &MANUFACTURE.10
   V-JUDGE NEGATIVE)

***** BELIEF INSTANCES *****
(BELIEF &BELIEF.7
   COMPARED-TO   &NEW-BELIEF
   JUSTIFICATION &LEADTO.15
   B-OBJECT      &B-OBJECT.7
   NAME          TO-BE-FOR
   ACTOR         &GROUP.8)
(BELIEF &NEW-BELIEF
   COMPARED-TO   &BELIEF.7
   B-OBJECT      &NEW-B-OBJECT
   JUSTIFICATION &LEADTO.14)
```

```
(BELIEF &BELIEF.6
   COMPARED-TO   &BELIEF.5
   B-OBJECT      &B-OBJECT.6
   JUSTIFICATION &LEADTO.11
   NAME          TO-BE-AGAINST)
(BELIEF &BELIEF.5
   COMPARED-TO   &BELIEF.6
   NAME          TO-BE-AGAINST
   ACTOR         &GROUP.8
   B-OBJECT      &B-OBJECT.5
   JUSTIFICATION &LEADTO.10)

***** ECONOMY INSTANCES *****
(ECONOMY &ECONOMY.2
   REF         DEFINITE
   INSTITUTION UNITED-STATES
   RESOURCES   (GOODS AND SERVICES))

***** GOAL INSTANCES *****
(GOAL &GOAL.14
   COMPARED-TO &GOAL.12
   CONSE-OF    &LEADTO.15
   STATUS      SUCCESS
   OBJECT      &OCCUPATION.13)
(GOAL &GOAL.13
   OBJECT &ECONOMY.2
   INSTR  &MANUFACTURE.17
   STATUS SUCCESS)
(GOAL &GOAL.12
   COMPARED-TO &GOAL.14
   CONSE-OF    (&LEADTO.14 &LEADTO.12)
   NAME        IMPROVED-ECONOMY
   OBJECT      &OCCUPATION.12
   INSTR       JOB-SHIFT
   FROM        &OCCUPATION.11
   TO          &OCCUPATION.10
   STATUS      SUCCESS)
(GOAL &GOAL.11
   OBJECT &OCCUPATION.11
   INSTR  &MANUFACTURE.15
   STATUS FAILURE)
(GOAL &GOAL.10
   OBJECT &OCCUPATION.10
   STATUS SUCCESS)
(GOAL &GOAL.9
   COMPARED-TO &GOAL.8
   CONSE-OF    &LEADTO.11
   OBJECT      &OCCUPATION.8
   STATUS      FAILURE)
(GOAL &GOAL.8
   COMPARED-TO &GOAL.9
   CONSE-OF    &LEADTO.10
   ACTOR       &GROUP.10
   OBJECT      &OCCUPATION.7
   STATUS      FAILURE)
```

```
***** GROUP INSTANCES *****
(GROUP &GROUP.14
   TYPE #{HUMAN})
(GROUP &GROUP.13
   TYPE #{HUMAN})
(GROUP &GROUP.12
   TYPE #{HUMAN})
(GROUP &GROUP.11
   NAME PEOPLE
   TYPE #{HUMAN})
(GROUP &GROUP.10
   TYPE #{HUMAN})
(GROUP &GROUP.9
   TYPE #{HUMAN})
(GROUP &GROUP.8
   REF  INDEFINITE
   NAME PEOPLE
   TYPE #{HUMAN})

***** LEADTO INSTANCES *****
(LEADTO &LEADTO.15
   ATTACK-STRATEGY   (&AS-1 &BELIEF.5)
   ATTACKS           &LEADTO.10
   COMPARED-TO       &LEADTO.14
   JUSTIFICATION-OF &BELIEF.7
   CONSE             &GOAL.14
   ANTE              &MANUFACTURE.10)
(LEADTO &LEADTO.14
   COMPARED-TO       &LEADTO.15
   JUSTIFICATION-OF &NEW-BELIEF
   ATTACKS           &LEADTO.11
   ATTACK-STRATEGY   (&AS-1 &LEADTO.11)
   CONSE             &GOAL.12
   ANTE              &MANUFACTURE.16)
(LEADTO &LEADTO.13
   CONSE &MANUFACTURE.16
   ANTE  &WANT-COMMODITY.3)
(LEADTO &LEADTO.12
   ANTE  &WANT-COMMODITY.3
   CONSE &GOAL.12)
(LEADTO &LEADTO.11
   ATTACKED-BY       &LEADTO.14
   JUSTIFICATION-OF &BELIEF.6
   COMPARED-TO       &LEADTO.10
   ANTE              &MANUFACTURE.12
   CONSE             &GOAL.9)
(LEADTO &LEADTO.10
   ATTACKED-BY       &LEADTO.15
   COMPARED-TO       &LEADTO.11
   JUSTIFICATION-OF &BELIEF.5
   ANTE              &MANUFACTURE.11
   CONSE             &GOAL.8)

***** MANUFACTURE INSTANCES *****
(MANUFACTURE &MANUFACTURE.17
   PRODUCTION-METHOD NEW-TECHNOLOGY)
```

```
(MANUFACTURE &MANUFACTURE.16
   COMPARED-TO &MANUFACTURE.10
   ANTE-OF     &LEADTO.14
   CONSE-OF    &LEADTO.13
   PRODUCT     &PHYS-OBJ.6)
(MANUFACTURE &MANUFACTURE.15
   REF     DEFINITE
   PRODUCT HORSE-CARRIAGE
   NAME    HORSE-CARRIAGE-INDUSTRY)
(MANUFACTURE &MANUFACTURE.14
   REF     DEFINITE
   PRODUCT &PHYS-OBJ.7
   NAME    AUTOMOBILE-INDUSTRY)
(MANUFACTURE &MANUFACTURE.13
   PRODUCT HORSE-CARRIAGE
   NAME    HORSE-CARRIAGE-INDUSTRY)
(MANUFACTURE &MANUFACTURE.12
   COMPARED-TO &MANUFACTURE.11
   ANTE-OF     &LEADTO.11
   REF         DEFINITE
   PRODUCT     &PHYS-OBJ.5
   NAME        AUTOMOBILE-INDUSTRY)
(MANUFACTURE &MANUFACTURE.11
   COMPARED-TO       &MANUFACTURE.12
   ANTE-OF           &LEADTO.10
   PRODUCTION-METHOD COMPUTER
   NAME              COMPUTER-INDUSTRY)
(MANUFACTURE &MANUFACTURE.10
   COMPARED-TO       &MANUFACTURE.16
   ANTE-OF           &LEADTO.15
   PRODUCTION-METHOD COMPUTER
   NAME              COMPUTER-INDUSTRY)

***** OCCUPATION INSTANCES *****
(OCCUPATION &OCCUPATION.13
   SETTING &MANUFACTURE.10)
(OCCUPATION &OCCUPATION.12)
(OCCUPATION &OCCUPATION.11
   SETTING &MANUFACTURE.15
   ACTOR   &GROUP.14)
(OCCUPATION &OCCUPATION.10
   SETTING &MANUFACTURE.14
   ACTOR   &GROUP.13)
(OCCUPATION &OCCUPATION.9
   ACTOR &GROUP.12)
(OCCUPATION &OCCUPATION.8
   ACTOR   &GROUP.11
   REF     DEFINITE
   SETTING &MANUFACTURE.13)
(OCCUPATION &OCCUPATION.7
   ACTOR &GROUP.9)

***** PHYSICAL OBJECT INSTANCES *****
(PHYS-OBJ &PHYS-OBJ.7
   NAME              AUTOMOBILES
   TYPE              WORK-TOOL
   SCALE             (<NORM)
   PRODUCTION-METHOD ASSEMBLY-LINE)
```

```
(PHYS-OBJ &PHYS-OBJ.6
   NAME               AUTOMOBILES
   TYPE               WORK-TOOL
   SCALE              (<NORM)
   PRODUCTION-METHOD ASSEMBLY-LINE)
(PHYS-OBJ &PHYS-OBJ.5
   NAME               AUTOMOBILES
   TYPE               WORK-TOOL
   SCALE              (<NORM)
   PRODUCTION-METHOD ASSEMBLY-LINE)

***** WANT COMMODITY INSTANCES *****
(WANT-COMMODITY &WANT-COMMODITY.3
   ANTE-OF (&LEADTO.13 &LEADTO.12)
    NAME    CONSUMER-DEMAND-FOR
    OBJECT     &PHYS-OBJ.6)
```

A.6. HIGH-TECH-4 Trace

The first four sentences of HIGH-TECH-4 are identical to the complete text of HIGH-TECH-1. HIGH-TECH-4 also contains two additional sentences, which parallel the last two sentences of HIGH-TECH-1. Processing of the first portion of this fourth text is the same as for earlier text. However, in this case, the the argument-by-analogy is explicitly completed. Rather than processing the demons on the expectation agenda after sentence four, as is done with HIGH-TECH-1, ARIEL continues reading and constructing a representation for the final portion of the text. When all the text has been read, the problem is to tie together the given components. Details of the trace has been omitted where possible for the sake of brevity.

```
> (pparse-ht1)

HIGH-TECH-4:
Some people are against CAM
because CAM eliminates jobs *period*
However the automobile-industry
did-the-same-thing-to people
in the horse-carriage-industry *period*
Yet consumer-demand-for autos was strong enough
that more jobs were created in the automobile-
industry than jobs were lost in the horse-
carriage-industry *period*
In-the-end the economy benefitted-by
the-introduction-of-the-new-technology *period*
Likewise consumer-demand-for CAM-produced-goods
eventually-will-be strong enough that more jobs
will be created in other areas than jobs will be
lost on the-assembly-lines *period*
In-the-end the economy will-benefit-by
the-introduction-of-CAM technology *period*
```

The processing of the first four sentences of HIGH-TECH-4 is identical to the processing of the first four sentences of HIGH-TECH-1, and is omitted here. The trace begins as sentence five is being read.

```
...
```

```
--------------------------------
Processing word: LIKEWISE...CONSUMER-DEMAND-FOR...
    CAM-PRODUCED-GOODS
--------------------------------
Found Phrase: #{LE51}
-----> CAM-produced goods <-----

Created Concept:
(PHYS-OBJ &PHYS-OBJ.4
   NAME              CAM-PRODUCED-GOODS
   PRODUCTION-METHOD CAM)

Found Phrase: #{LE30}
-----> consumer demand for <phys-obj> <-----

Created Concept:
(WANT-COMMODITY &WANT-COMMODITY.2
   NAME   CONSUMER-DEMAND-FOR
   OBJECT &PHYS-OBJ.4)
--------------------------------
Processing word: EVENTUALLY-WILL-BE
--------------------------------
Found Phrase: #{LE52}
-----> eventually will be <-----

Created Concept:
(AUX-VERB &AUX-VERB.5
   NAME  TO-BE
   TENSE FUTURE)
--------------------------------
Processing word: STRONG...ENOUGH...THAT...MORE...JOBS
--------------------------------
Found Phrase: #{LE7}
-----> jobs <-----

Created Concept:
(OCCUPATION &OCCUPATION.6
   ACTOR &GROUP.8)
--------------------------------
Processing word: WILL...BE...CREATED...IN...OTHER...AREAS
--------------------------------
Found Phrase: #{LE53}
-----> <occupation> will be created in other areas <-----

Created Concept:
(GOAL &GOAL.7
   OBJECT &OCCUPATION.6
   STATUS SUCCESS)
--------------------------------
Processing word: THAN... JOBS
--------------------------------
Found Phrase: #{LE7}
-----> jobs <-----

Created Concept:
(OCCUPATION &OCCUPATION.7
   ACTOR &GROUP.9)
```

```
--------------------------------
Processing word: WILL...BE...LOST...ON...THE-ASSEMBLY-LINES
--------------------------------
Found Phrase: #{LE54}
-----> <occupation> will be lost
             on the assembly lines <-----

Created Concept:
(GOAL &GOAL.8
   OBJECT &OCCUPATION.7
   STATUS FAILURE)

Found Phrase: #{LE34REV}
-----> more <goal1> than <goal2> <-----

Created Concept:
(GOAL &GOAL.9
   NAME   IMPROVED-ECONOMY
   OBJECT &OCCUPATION.8
   INSTR  JOB-SHIFT
   FROM   &OCCUPATION.7
   TO     &OCCUPATION.6
   STATUS SUCCESS)

Found Phrase: #{LE33}
-----> <want-commodity> <aux-verb>
                strong enough that <goal> <-----
-----------------------------
If consumer demand for a product
Increases the number of jobs available,
We can infer the implicit causal chain
That consumer demand for the product
Caused the product to be manufactured,
And the manufacturing of the product
Caused the increase in the number of jobs.
-----------------------------
-----------------------------
Inferring an implicit causal chain
-----------------------------
-----------------------------
Inferring that: #{WANT-COMMODITY.2}
Caused: #{MANUFACTURE.9}
-----------------------------
-----------------------------
Inferring that: #{MANUFACTURE.9}
Caused: #{GOAL.9}
-----------------------------
Created Concept:
(LEADTO &LEADTO.7
   ANTE  &WANT-COMMODITY.2
   CONSE &GOAL.9)
--------------------------------
Processing word: *PERIOD*
--------------------------------
```

```
------------------------------
Testing phrase:  Likewise <leadto>.
Is there a preceding concept
Which is analogous to <leadto>?
------------------------------
------------------------------
Looking for a concept analogous to: #{LEADTO.7}
------------------------------
------------------------------
Checking whether #{LEADTO.7}
and #{LEADTO.9} are analogous...
------------------------------
(LEADTO &LEADTO.7
   ANTE  &WANT-COMMODITY.2
   CONSE &GOAL.9)

(LEADTO &LEADTO.9
   CONSE &GOAL.9
   ANTE  &MANUFACTURE.9)
------------------------------
Checking whether #{WANT-COMMODITY.2}
and #{MANUFACTURE.9} are analogous...
------------------------------
------------------------------
Checking whether #{LEADTO.7}
and #{LEADTO.8} are analogous...
------------------------------
(LEADTO &LEADTO.7
   ANTE  &WANT-COMMODITY.2
   CONSE &GOAL.9)

(LEADTO &LEADTO.8
   CONSE &MANUFACTURE.9
   ANTE  &WANT-COMMODITY.2)
------------------------------
Checking whether #{WANT-COMMODITY.2} and
#{WANT-COMMODITY.2} are analogous...
------------------------------
(WANT-COMMODITY &WANT-COMMODITY.2
   ANTE-OF  (&LEADTO.8 &LEADTO.7)
   NAME     CONSUMER-DEMAND-FOR
   OBJECT   &PHYS-OBJ.4)

(WANT-COMMODITY &WANT-COMMODITY.2
   ANTE-OF  (&LEADTO.8 &LEADTO.7)
   NAME     CONSUMER-DEMAND-FOR
   OBJECT   &PHYS-OBJ.4)
------------------------------
Checking whether #{GOAL.9}
and #{MANUFACTURE.9} are analogous...
------------------------------
------------------------------
Checking whether #{LEADTO.7}
and #{LEADTO.6} are analogous...
------------------------------
(LEADTO &LEADTO.7
   ANTE  &WANT-COMMODITY.2
   CONSE &GOAL.9)
```

```
(LEADTO &LEADTO.6
   ANTE  &WANT-COMMODITY.1
   CONSE &GOAL.6)
------------------------------
Checking whether #{WANT-COMMODITY.2} and
#{WANT-COMMODITY.1} are analogous...
------------------------------
(WANT-COMMODITY &WANT-COMMODITY.2
   ANTE-OF (&LEADTO.8 &LEADTO.7)
   NAME    CONSUMER-DEMAND-FOR
   OBJECT  &PHYS-OBJ.4)

(WANT-COMMODITY &WANT-COMMODITY.1
   ANTE-OF (&LEADTO.6 &LEADTO.4 &LEADTO.3)
   NAME    CONSUMER-DEMAND-FOR
   OBJECT  &PHYS-OBJ.2)
------------------------------
Checking whether #{GOAL.9}
and #{GOAL.6} are analogous...
------------------------------
(GOAL &GOAL.9
   CONSE-OF (&LEADTO.9 &LEADTO.7)
   NAME     IMPROVED-ECONOMY
   OBJECT   &OCCUPATION.8
   INSTR    JOB-SHIFT
   FROM     &OCCUPATION.7
   TO       &OCCUPATION.6
   STATUS   SUCCESS)

(GOAL &GOAL.6
   CONSE-OF &LEADTO.6
   OBJECT   &ECONOMY.1
   INSTR    &MANUFACTURE.8
   STATUS   SUCCESS)
------------------------------
Checking whether #{OCCUPATION.8}
and #{ECONOMY.1} are analogous...
------------------------------
------------------------------
Checking whether #{LEADTO.7}
and #{LEADTO.5} are analogous...
------------------------------
(LEADTO &LEADTO.7
   ANTE  &WANT-COMMODITY.2
   CONSE &GOAL.9)

(LEADTO &LEADTO.5
   CONSE &GOAL.5
   ANTE  &MANUFACTURE.7)
------------------------------
Checking whether #{WANT-COMMODITY.2}
and #{MANUFACTURE.7} are analogous...
------------------------------
------------------------------
Checking whether #{LEADTO.7}
and #{LEADTO.4} are analogous...
------------------------------
```

```
(LEADTO &LEADTO.7
   ANTE  &WANT-COMMODITY.2
   CONSE &GOAL.9)

(LEADTO &LEADTO.4
   CONSE &MANUFACTURE.7
   ANTE  &WANT-COMMODITY.1)
------------------------------
Checking whether #{WANT-COMMODITY.2} and
#{WANT-COMMODITY.1} are analogous...
------------------------------
(WANT-COMMODITY &WANT-COMMODITY.2
   ANTE-OF (&LEADTO.8 &LEADTO.7)
   NAME    CONSUMER-DEMAND-FOR
   OBJECT  &PHYS-OBJ.4)

(WANT-COMMODITY &WANT-COMMODITY.1
   ANTE-OF (&LEADTO.6 &LEADTO.4 &LEADTO.3)
   NAME    CONSUMER-DEMAND-FOR
   OBJECT  &PHYS-OBJ.2)
------------------------------
Checking whether #{GOAL.9}
and #{MANUFACTURE.7} are analogous...
------------------------------
------------------------------
Checking whether #{LEADTO.7}
and # {LEADTO.3} are analogous...
------------------------------
(LEADTO &LEADTO.7
   ANTE  &WANT-COMMODITY.2
   CONSE &GOAL.9)

(LEADTO &LEADTO.3
   ATTACKS   &LEADTO.2
   JUSTIFICATION-OF &BELIEF.3
   ATTACK-STRATEGY  (&AS-1 &BELIEF.2)
   ANTE   &WANT-COMMODITY.1
   CONSE  &GOAL.5)
------------------------------
Checking whether #{WANT-COMMODITY.2} and
#{WANT-COMMODITY.1} are analogous...
------------------------------
(WANT-COMMODITY &WANT-COMMODITY.2
   ANTE-OF (&LEADTO.8 &LEADTO.7)
   NAME    CONSUMER-DEMAND-FOR
   OBJECT  &PHYS-OBJ.4)

(WANT-COMMODITY &WANT-COMMODITY.1
   ANTE-OF (&LEADTO.6 &LEADTO.4 &LEADTO.3)
   NAME    CONSUMER-DEMAND-FOR
   OBJECT  &PHYS-OBJ.2)
------------------------------
Checking whether #{GOAL.9}
and #{GOAL.5} are analogous...
------------------------------
```

```
(GOAL &GOAL.9
   CONSE-OF (&LEADTO.9 &LEADTO.7)
   NAME     IMPROVED-ECONOMY
   OBJECT   &OCCUPATION.8
   INSTR    JOB-SHIFT
   FROM     &OCCUPATION.7
   TO       &OCCUPATION.6
   STATUS   SUCCESS)

(GOAL &GOAL.5
   CONSE-OF (&LEADTO.5 &LEADTO.3)
   NAME     IMPROVED-ECONOMY
   OBJECT   &OCCUPATION.5
   INSTR    JOB-SHIFT
   FROM     &OCCUPATION.4
   TO       &OCCUPATION.3
   STATUS   SUCCESS)
------------------------------
Checking whether #{OCCUPATION.8} and
#{OCCUPATION.5} are analogous...
------------------------------
(OCCUPATION &OCCUPATION.8)

(OCCUPATION &OCCUPATION.5)
------------------------------
Comparing the concept: #{GOAL.9}
With the concept: #{GOAL.5}
------------------------------
------------------------------
Comparing the concept: #{LEADTO.7}
With the concept: #{LEADTO.3}
------------------------------
------------------------------
Comparing the concept: #{WANT-COMMODITY.2}
With the concept: #{WANT-COMMODITY.1}
------------------------------
------------------------------
Comparing the concept: #{GOAL.9}
With the concept: #{GOAL.5}
------------------------------
Found Phrase: #{LE55}
-----> Likewise <leadto>. <-----
------------------------------
Checking whether #{LEADTO.3} is part of a belief...
------------------------------
------------------------------
Checking whether #{LEADTO.3}
Is the justification for the belief: #{BELIEF.3}...
------------------------------
------------------------------
#{LEADTO.3} is the justification
For the belief: #{BELIEF.3}
------------------------------
------------------------------
The analogous concept #{LEADTO.3}
Is part of the belief #{BELIEF.3}
------------------------------
```

```
------------------------------
CONTAINING-BELIEF: #{BELIEF.3}
CONTAINING-BELIEF-OBJECT: #{B-OBJECT.3}
CONTAINING-BELIEF-IS-COMPARED-TO: NIL
CONTAINING-BELIEF-OBJECT-event: #{MANUFACTURE.3}
CONTAINING-BELIEF-OBJECT-event is compared to:
#{MANUFACTURE.2}
------------------------------
------------------------------
Inferring a new belief analogous
To the existing belief: #{BELIEF.3}
------------------------------
------------------------------
Inferring the name of new belief: TO-BE-FOR
From the analogous belief...
------------------------------
------------------------------
Inferring the justification
Of the new belief: #{LEADTO.7}
------------------------------
------------------------------
Inferring value judgment
Of the new belief object: POSITIVE
From analogous belief's belief-object.
------------------------------
------------------------------
Linking the analogous beliefs:
#{BELIEF.3} and #{BELIEF.4}
------------------------------
------------------------------
Comparing the concept: #{BELIEF.3}
With the concept: #{BELIEF.4}
------------------------------
Created Concept:
(BELIEF &BELIEF.4
   COMPARED-TO   &BELIEF.3
   B-OBJECT   &B-OBJECT.4
   JUSTIFICATION &LEADTO.7
   NAME    TO-BE-FOR)
---------------------------------
Processing word: IN-THE-END...THE
---------------------------------
Found Phrase: #{LE23}
-----> the <-----

Created Concept:
(ARTICLE &ARTICLE.9
   TYPE DEFINITE)
---------------------------------
Processing word: ECONOMY
---------------------------------
Found Phrase: #{LE41}
-----> economy <-----

Created Concept:
(ECONOMY &ECONOMY.2
   INSTITUTION UNITED-STATES
   RESOURCES   (GOODS AND SERVICES))
```

```
Found Phrase: #{LEB12}
-----> <article> <thing> <-----

Created Concept:
(ECONOMY &ECONOMY.2
   REF   DEFINITE
   INSTITUTION UNITED-STATES
   RESOURCES    (GOODS AND SERVICES))
---------------------------------
Processing word: WILL-BENEFIT-BY...
    THE-INTRODUCTION-OF-CAM-TECHNOLOGY
---------------------------------
Found Phrase: #{LE62}
-----> the-introduction-of-CAM-technology <-----

Created Concept:
(MANUFACTURE &MANUFACTURE.10
   PRODUCTION-METHOD CAM)

Found Phrase: #{LE61}
-----> <economy> will benefit by <manufacture> <-----

Created Concept:
(GOAL &GOAL.10
   OBJECT &ECONOMY.2
   INSTR  &MANUFACTURE.10
   STATUS SUCCESS)
---------------------------------
Processing word: *PERIOD*
---------------------------------

Found Phrase: #{LE44REV}
-----> <belief>  In-the-end <goal>. <-----

Created Concept:
(BELIEF &BELIEF.4
   COMPARED-TO    &BELIEF.3
   B-OBJECT       &B-OBJECT.4
   JUSTIFICATION (&LEADTO.7 &LEADTO.10)
   NAME           TO-BE-FOR)

Processing Complete
Result of Parse
#{BELIEF.1}
#{BELIEF.2}
*PERIOD*
#{BELIEF.3}
#{BELIEF.4}
------------------------------
Entering: EXPECT::EXPECT-RUN EXPECT-CONTRAST-TO #{BELIEF.1}
------------------------------
------------------------------
Contrast to: #{BELIEF.1} is expected...
------------------------------
```

```
------------------------------
#{BELIEF.1} is analogous to: #{BELIEF.2}
Whose justification: #{LEADTO.2}
Has been attacked by: #{LEADTO.3}
------------------------------
------------------------------
The justification of #{BELIEF.2}: #{LEADTO.2}
Has been attacked by: #{LEADTO.3}
Using the strategy: #{AS-1}
Thus, #{LEADTO.3} attacks #{BELIEF.1} by analogy.
------------------------------
------------------------------
Form an analogous attack on: #{BELIEF.1}
Using the strategy #{AS-1}
And using #{LEADTO.3} as a source analog.
Check first for an existing attack.
------------------------------
------------------------------
Checking whether: #{LEADTO.7}
Can attack #{BELIEF.1}
Using attack strategy: #{AS-1}
------------------------------
------------------------------
Attack Strategy 1:
    If X is bad because X causes Y and Y is bad,
    Then show that X causes Z and Z is good.
------------------------------
------------------------------
Checking whether #{WANT-COMMODITY.2}
Is similar to #{MANUFACTURE.1} (X)
------------------------------
------------------------------
Checking similarity of #{MANUFACTURE.1}
and #{WANT-COMMODITY.2}
------------------------------
(MANUFACTURE &MANUFACTURE.1
   PRODUCTION-METHOD COMPUTER
   NAME              COMPUTER-INDUSTRY)

(WANT-COMMODITY &WANT-COMMODITY.2
   COMPARED-TO &WANT-COMMODITY.1
   ANTE-OF     (&LEADTO.10 &LEADTO.8 &LEADTO.7)
   NAME        CONSUMER-DEMAND-FOR
   OBJECT      &PHYS-OBJ.4)
------------------------------
#{WANT-COMMODITY.2} is not directly similar
to #{MANUFACTURE.1} (X)
------------------------------
------------------------------
Checking whether #{WANT-COMMODITY.2}
Causes something that
Is similar to #{MANUFACTURE.1} (X)
------------------------------
------------------------------
Checking similarity of #{MANUFACTURE.1}
and #{GOAL.10}
------------------------------
```

```
(MANUFACTURE &MANUFACTURE.1
   PRODUCTION-METHOD COMPUTER
   NAME              COMPUTER-INDUSTRY)

(GOAL &GOAL.10
   CONSE-OF &LEADTO.10
   OBJECT   &ECONOMY.2
   INSTR    &MANUFACTURE.10
   STATUS   SUCCESS)
------------------------------
Checking similarity of #{MANUFACTURE.1}
and #{MANUFACTURE.9}
------------------------------
(MANUFACTURE &MANUFACTURE.1
   PRODUCTION-METHOD COMPUTER
   NAME              COMPUTER-INDUSTRY)

(MANUFACTURE &MANUFACTURE.9
   ANTE-OF  &LEADTO.9
   CONSE-OF &LEADTO.8
   PRODUCT  &PHYS-OBJ.4)
------------------------------
Looking in slot: PRODUCTION-METHOD...PRODUCT
------------------------------
------------------------------
#{MANUFACTURE.1} and #{MANUFACTURE.9} are similar
------------------------------
------------------------------
#{GOAL.9} involves having jobs having jobs is good
------------------------------
------------------------------
Noting that #{LEADTO.1}
Is being attacked by #{LEADTO.7}
------------------------------
------------------------------
Killing expectation: (EXPECT-CONTRAST-TO #{BELIEF.1})
------------------------------
------------------------------
Entering: EXPECT::EXPECT-RUN EXPECT-CONTRAST-TO #{BELIEF.1}
------------------------------
------------------------------
Contrast to: #{BELIEF.1} is expected...
------------------------------
------------------------------
Contrast was already made.
The justification of: #{BELIEF.1}
Is attacked by: #{LEADTO.7}
------------------------------
------------------------------
Killing expectation: (EXPECT-CONTRAST-TO #{BELIEF.1})
------------------------------
(BELIEF &BELIEF.4
   COMPARED-TO   &BELIEF.3
   B-OBJECT      &B-OBJECT.4
   JUSTIFICATION (&LEADTO.7 &LEADTO.10)
   NAME          TO-BE-FOR)
```

```
(B-OBJECT &B-OBJECT.4
   V-JUDGE POSITIVE
   EVENT   &MANUFACTURE.2)

(MANUFACTURE &MANUFACTURE.2
   COMPARED-TO       &MANUFACTURE.3
   ANTE-OF           &LEADTO.1
   PRODUCTION-METHOD COMPUTER
   NAME              COMPUTER-INDUSTRY)

(LEADTO &LEADTO.7
   ATTACKS          &LEADTO.1
   ATTACK-STRATEGY  (&AS-1 &BELIEF.1)
   JUSTIFICATION-OF &BELIEF.4
   COMPARED-TO      &LEADTO.3
   ANTE             &WANT-COMMODITY.2
   CONSE            &GOAL.9)
(LEADTO &LEADTO.10
   ANTE  &WANT-COMMODITY.2
   CONSE &GOAL.10)

Processing Complete
```

The conclusion formed to HIGH-TECH-4 is slightly different than the one reported for the other HIGH-TECH texts:

```
(THE MANUFACTURE OF CAM-PRODUCED GOODS IS GOOD
BECAUSE CONSUMER-DEMAND-FOR CAM-PRODUCED GOODS
WILL HAVE THE RESULT THAT THE ECONOMY WILL BENEFIT
BY COMPUTER-AIDED MANUFACTURING AND CONSUMER-
DEMAND-FOR CAM-PRODUCED GOODS WILL
HAVE THE RESULT THAT THE ECONOMY WILL IMPROVE AS
JOBS ARE SHIFTED BETWEEN OCCUPATIONS)


***** BELIEF OBJECT INSTANCES *****
(B-OBJECT &B-OBJECT.4
   V-JUDGE POSITIVE
   EVENT   &MANUFACTURE.2)
(B-OBJECT &B-OBJECT.3
   V-JUDGE POSITIVE
   EVENT   &MANUFACTURE.3)
(B-OBJECT &B-OBJECT.2
   V-JUDGE NEGATIVE
   EVENT   &MANUFACTURE.3)
(B-OBJECT &B-OBJECT.1
   EVENT   &MANUFACTURE.1
   V-JUDGE NEGATIVE)

***** BELIEF INSTANCES *****
(BELIEF &BELIEF.4
   COMPARED-TO   &BELIEF.3
   B-OBJECT      &B-OBJECT.4
   JUSTIFICATION (&LEADTO.7 &LEADTO.10)
   NAME          TO-BE-FOR)
```

```
(BELIEF &BELIEF.3
   COMPARED-TO   &BELIEF.4
   ACTOR         #{HUMAN}
   NAME          TO-BE-FOR
   B-OBJECT      &B-OBJECT.3
   JUSTIFICATION (&LEADTO.3 &LEADTO.6))
(BELIEF &BELIEF.2
   ACTOR         #{HUMAN}
   B-OBJECT      &B-OBJECT.2
   JUSTIFICATION &LEADTO.2
   NAME          TO-BE-AGAINST
   COMPARED-TO   &BELIEF.1)
(BELIEF &BELIEF.1
   COMPARED-TO   &BELIEF.2
   NAME          TO-BE-AGAINST
   ACTOR         &GROUP.1
   B-OBJECT      &B-OBJECT.1
   JUSTIFICATION &LEADTO.1)

***** ECONOMY INSTANCES *****
(ECONOMY &ECONOMY.2
   REF         DEFINITE
   INSTITUTION UNITED-STATES
   RESOURCES   (GOODS AND SERVICES))
(ECONOMY &ECONOMY.1
   REF         DEFINITE
   INSTITUTION UNITED-STATES
   RESOURCES   (GOODS AND SERVICES))

***** GOAL INSTANCES *****
(GOAL &GOAL.10
   CONSE-OF &LEADTO.10
   OBJECT   &ECONOMY.2
   INSTR    &MANUFACTURE.10
   STATUS   SUCCESS)
(GOAL &GOAL.9
   COMPARED-TO &GOAL.5
   CONSE-OF    (&LEADTO.9 &LEADTO.7)
   NAME        IMPROVED-ECONOMY
   OBJECT      &OCCUPATION.8
   INSTR       JOB-SHIFT
   FROM        &OCCUPATION.7
   TO          &OCCUPATION.6
   STATUS      SUCCESS)
(GOAL &GOAL.8
   OBJECT &OCCUPATION.7
   STATUS FAILURE)
(GOAL &GOAL.7
   OBJECT &OCCUPATION.6
   STATUS SUCCESS)
(GOAL &GOAL.6
   CONSE-OF &LEADTO.6
   OBJECT   &ECONOMY.1
   INSTR    &MANUFACTURE.8
   STATUS   SUCCESS)
```

```
(GOAL &GOAL.5
   COMPARED-TO &GOAL.9
   CONSE-OF     (&LEADTO.5 &LEADTO.3)
   NAME         IMPROVED-ECONOMY
   OBJECT       &OCCUPATION.5
   INSTR        JOB-SHIFT
   FROM         &OCCUPATION.4
   TO           &OCCUPATION.3
   STATUS       SUCCESS)
(GOAL &GOAL.4
   OBJECT &OCCUPATION.4
   INSTR  &MANUFACTURE.6
   STATUS FAILURE)
(GOAL &GOAL.3
   OBJECT &OCCUPATION.3
   STATUS SUCCESS)
(GOAL &GOAL.2
   COMPARED-TO &GOAL.1
   CONSE-OF     &LEADTO.2
   ACTOR        &GROUP.5
   OBJECT       &OCCUPATION.2
   STATUS       FAILURE)
(GOAL &GOAL.1
   COMPARED-TO &GOAL.2
   CONSE-OF     &LEADTO.1
   ACTOR        &GROUP.3
   OBJECT       &OCCUPATION.1
   STATUS       FAILURE)

***** GROUP INSTANCES *****
(GROUP &GROUP.9
   TYPE #{HUMAN})
(GROUP &GROUP.8
   TYPE #{HUMAN})
(GROUP &GROUP.7
   TYPE #{HUMAN})
(GROUP &GROUP.6
   TYPE #{HUMAN})
(GROUP &GROUP.5
   TYPE #{HUMAN})
(GROUP &GROUP.4
   NAME PEOPLE
   TYPE #{HUMAN})
(GROUP &GROUP.3
   TYPE #{HUMAN})
(GROUP &GROUP.2
   TYPE #{HUMAN})
(GROUP &GROUP.1
   REF  INDEFINITE
   NAME PEOPLE
   TYPE #{HUMAN})

***** LEADTO INSTANCES *****
(LEADTO &LEADTO.10
   ANTE  &WANT-COMMODITY.2
   CONSE &GOAL.10)
```

```
(LEADTO &LEADTO.9
   CONSE &GOAL.9
   ANTE  &MANUFACTURE.9)
(LEADTO &LEADTO.8
   CONSE &MANUFACTURE.9
   ANTE  &WANT-COMMODITY.2)
(LEADTO &LEADTO.7
   ATTACKS           &LEADTO.1
   ATTACK-STRATEGY   (&AS-1 &BELIEF.1)
   JUSTIFICATION-OF &BELIEF.4
   COMPARED-TO       &LEADTO.3
   ANTE              &WANT-COMMODITY.2
   CONSE             &GOAL.9)
(LEADTO &LEADTO.6
   ANTE  &WANT-COMMODITY.1
   CONSE &GOAL.6)
(LEADTO &LEADTO.5
   CONSE &GOAL.5
   ANTE  &MANUFACTURE.7)
(LEADTO &LEADTO.4
   CONSE &MANUFACTURE.7
   ANTE  &WANT-COMMODITY.1)
(LEADTO &LEADTO.3
   COMPARED-TO       &LEADTO.7
   ATTACKS           &LEADTO.2
   JUSTIFICATION-OF &BELIEF.3
   ATTACK-STRATEGY   (&AS-1 &BELIEF.2)
   ANTE              &WANT-COMMODITY.1
   CONSE             &GOAL.5)
(LEADTO &LEADTO.2
   ATTACKED-BY       &LEADTO.3
   JUSTIFICATION-OF &BELIEF.2
   COMPARED-TO       &LEADTO.1
   ANTE              &MANUFACTURE.3
   CONSE             &GOAL.2)
(LEADTO &LEADTO.1
   ATTACKED-BY       &LEADTO.7
   COMPARED-TO       &LEADTO.2
   JUSTIFICATION-OF &BELIEF.1
   ANTE              &MANUFACTURE.2
   CONSE             &GOAL.1)

***** MANUFACTURE INSTANCES *****
(MANUFACTURE &MANUFACTURE.10
   PRODUCTION-METHOD CAM)
(MANUFACTURE &MANUFACTURE.9
   ANTE-OF  &LEADTO.9
   CONSE-OF &LEADTO.8
   PRODUCT  &PHYS-OBJ.4)
(MANUFACTURE &MANUFACTURE.8
   PRODUCTION-METHOD NEW-TECHNOLOGY)
(MANUFACTURE &MANUFACTURE.7
   ANTE-OF  &LEADTO.5
   CONSE-OF &LEADTO.4
   PRODUCT  &PHYS-OBJ.2)
```

```
(MANUFACTURE &MANUFACTURE.6
   REF     DEFINITE
   PRODUCT HORSE-CARRIAGE
   NAME    HORSE-CARRIAGE-INDUSTRY)
(MANUFACTURE &MANUFACTURE.5
   REF     DEFINITE
   PRODUCT &PHYS-OBJ.3
   NAME    AUTOMOBILE-INDUSTRY)
(MANUFACTURE &MANUFACTURE.4
   PRODUCT HORSE-CARRIAGE
   NAME    HORSE-CARRIAGE-INDUSTRY)
(MANUFACTURE &MANUFACTURE.3
   COMPARED-TO &MANUFACTURE.2
   ANTE-OF     &LEADTO.2
   REF         DEFINITE
   PRODUCT     &PHYS-OBJ.1
   NAME        AUTOMOBILE-INDUSTRY)
(MANUFACTURE &MANUFACTURE.2
   COMPARED-TO       &MANUFACTURE.3
   ANTE-OF           &LEADTO.1
   PRODUCTION-METHOD COMPUTER
   NAME              COMPUTER-INDUSTRY)
(MANUFACTURE &MANUFACTURE.1
   PRODUCTION-METHOD COMPUTER
   NAME              COMPUTER-INDUSTRY)

***** OCCUPATION INSTANCES *****
(OCCUPATION &OCCUPATION.8)
(OCCUPATION &OCCUPATION.7
   ACTOR &GROUP.9)
(OCCUPATION &OCCUPATION.6
   ACTOR &GROUP.8)
(OCCUPATION &OCCUPATION.5)
(OCCUPATION &OCCUPATION.4
   SETTING &MANUFACTURE.6
   ACTOR   &GROUP.7)
(OCCUPATION &OCCUPATION.3
   SETTING &MANUFACTURE.5
   ACTOR   &GROUP.6)
(OCCUPATION &OCCUPATION.2
   ACTOR   &GROUP.4
   REF     DEFINITE
   SETTING &MANUFACTURE.4)
(OCCUPATION &OCCUPATION.1
   ACTOR &GROUP.2)

***** PHYSICAL OBJECT INSTANCES *****
(PHYS-OBJ &PHYS-OBJ.4
   NAME              CAM-PRODUCED-GOODS
   PRODUCTION-METHOD CAM)
(PHYS-OBJ &PHYS-OBJ.3
   NAME              AUTOMOBILES
   TYPE              WORK-TOOL
   SCALE             (<NORM)
   PRODUCTION-METHOD ASSEMBLY-LINE)
```

```
(PHYS-OBJ &PHYS-OBJ.2
   NAME               AUTOMOBILES
   TYPE               WORK-TOOL
   SCALE              (<NORM)
   PRODUCTION-METHOD ASSEMBLY-LINE)
(PHYS-OBJ &PHYS-OBJ.1
   NAME               AUTOMOBILES
   TYPE               WORK-TOOL
   SCALE              (<NORM)
   PRODUCTION-METHOD ASSEMBLY-LINE)

***** WANT COMMODITY INSTANCES *****
(WANT-COMMODITY &WANT-COMMODITY.2
   COMPARED-TO &WANT-COMMODITY.1
   ANTE-OF     (&LEADTO.10 &LEADTO.8 &LEADTO.7)
   NAME        CONSUMER-DEMAND-FOR
   OBJECT      &PHYS-OBJ.4)
(WANT-COMMODITY &WANT-COMMODITY.1
   COMPARED-TO &WANT-COMMODITY.2
   ANTE-OF     (&LEADTO.6 &LEADTO.4 &LEADTO.3)
   NAME        CONSUMER-DEMAND-FOR
   OBJECT      &PHYS-OBJ.2)
```

Appendix B

A Survey of Related Work

ARIEL is concerned primarily with recognizing the presence of an analogy in an editorial text, and following and completing the analogical reasoning used by the author of that text. Thus, it is related to three bodies of work: analogical reasoning, argumentation, and natural language understanding. Figure B-1 identifies related work in each of these fields, shows where the research areas overlap, and indicates which area remains to be tackled. As Figure B-1 indicates, work has been done in each of these areas. Various efforts have looked at combinations of these, such as analogical reasoning in argumentation, analogical reasoning in natural language processing, or argumentation and natural language processing. However, no one has modeled the process of understanding analogies in editorial text. Specifically, the issues of recognizing analogy in natural language text and completing indirect arguments by analogy have not been addressed in previous research. Let us look at representative examples of each area, and compare them with the approach taken in ARIEL.

B.1. Analogical Reasoning

Analogical reasoning is an important part of human intelligence. We often employ it as a vehicle for conveying ideas, and we rely upon it whenever we make a decision about a new situation (Ster77). Researchers in linguistics, education, psychology and other academic disciplines have studies this use of analogy and metaphor in depth (Lako80) (Orto79) (Ster77). Our interest is in computational models of analogical reasoning. Recent investigations by AI researchers into computational models of analogical reasoning include work by Carbonell and others on derivational analogy

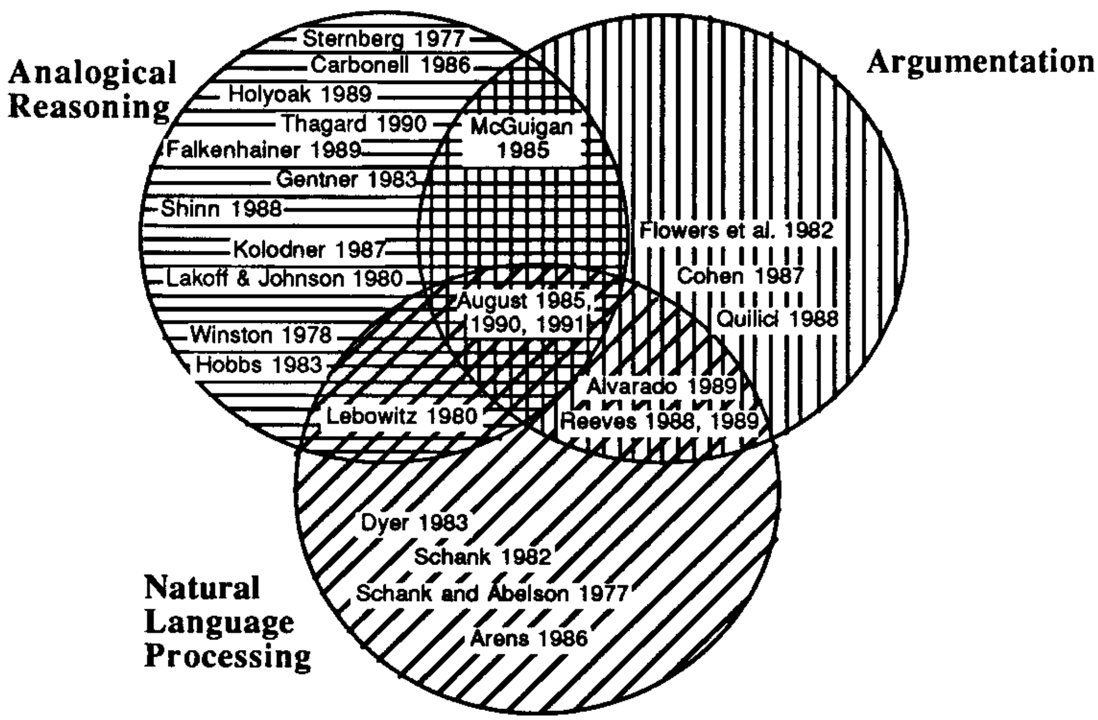


Figure B-1. Research areas related to ARIEL.

(Carb83a) (Carb83b) (Carb85) (Carb86) (Carb88), and work on SME (Gent83) (Falk86) (Skor87). One area of analogical reasoning for which few computational theories exist is the study of analogy from the point of view of its use in editorials, arguments, conversation, debates, narratives, or other aspects of natural language text. Our work falls into this category. Three examples of related work are Winston's work on learning by analogy (Wins82), Lebowitz' IPP (Lebo80), and JULIA (Shin88a).

Analogical reasoning is the process of describing or reasoning about one object or domain in terms of another, similar one. Analogy is often used to explain the unfamiliar in terms of the familiar. The familiar domain is often referred to as the source analog, and the unfamiliar domain as the target analog. An essential part of the analogy is the correspondence mapping between the similar points in the source and target domains, which is often called the ground for the analogy.

Analogical reasoning is usually broken into four tasks:

1. retrieval
2. mapping
3. transference
4. learning

In editorial understanding, the reader is not required to retrieve an analog from long term memory, an issue frequently addressed in research into reasoning by analogy. Instead, in this task the reader must recognize that an analogy has been introduced in the text, and sort the information in the text into source and target analogs. Retrieval from short term memory is needed to piece together the components of the analogy provided in the editorial. Mapping and transference are also needed. Once all has been said and done, the reader must be able to identify the point being made by the author, or draw an appropriate conclusion from the editorial. However, the problem of what information should be transferred to long term memory, or "learned", is not addressed here. The aspects of analogical reasoning, then, which are relevant to this research are:

1. recognition
2. retrieval
3. mapping
4. transference
5. identification of the point of the analogy

In addition to addressing these aspects of analogical reasoning, we must also explore the relationship between analogy and the argumentation techniques used in editorials.

B.1.1. Analogy Recognition

Before understanding *how* the analogy is used in the editorial, the reader must realize that an analogy *is in* the editorial. What prompts the reader to notice that an analogy is being used? Is there an "analogy recognizer" constantly active? Or is analogy recognition triggered by something else? The approach taken in ARIEL is the latter. Analogy recognition is triggered either by lexical clues specifically drawing the reader's attention to the presence of the analogy, as shown in (Augu85a) (Augu85b) (Augu85c), or by the reader's expectations related to reading editorial text.

Let us look at how a reader recognizes the presence of the analogy in HIGH-TECH-1. The letter begins with a discussion of the computer industry. This is suddenly contrasted with a discussion of the automobile industry. Yet the reader is able to identify that at an abstract, conceptual level the topic underlying the discussion has not changed. By reference to "the same thing", the author has directed the reader to the similarity between the two topics.

Knowledge of argument structure can also prompt a reader to notice the presence of the analogy. Knowing that a piece of text is an editorial, a reader will expect the author to support or attack each proposition presented. These supports and/or attacks can be made directly, or by analogy. Thus, these expectations can prompt the reader to recognize the presence of the analogy in the editorial, even when lexical clues indicating its presence are lacking.

Most computational models of analogical reasoning focus on identifying and retrieving a source analog from which to make inferences about a target analog. Winston's work on understanding similes (Wins78) and Hobbs' work on understanding metaphors (Hobb81) (Hobb83a) (Hobb83b) are two notable exceptions. McGuigan does not does not address the issue of recognizing that an analogy is present in the input in discussing MAGAC (McGu85).

B.1.1.1. Winston: Simile Understanding

(Wins78) describes a system which learns by interpreting similes presented by a teacher. When presented with a simile such as "Robbie is like a fox", Winston's system identifies Robbie as the target and fox as the source by the order in which they are specified. Given the simile, the system would then endeavor to transfer properties of foxes onto Robbie, which was previously identified by the teacher as a robot. The focus of Winston's work was to create frames containing information relating to the source object, and chose from among those frame the ones containing information most appropriately transferred to the target object, based upon general knowledge and specific knowledge available about the target. This system does not handle more complex input, and therefore does not address the issue of recognizing analogy in text.

B.1.1.2. Hobbs: DIANA

Hobbs' DIANA system (Hobb81) (Hobb83a) (Hobb83b) understands textual metaphors such as "Mary is graceful, but John is an elephant." A syntactic analysis of a metaphor such as this produces a set of predicate calculus formulas which are given to DIANA as input. Hobbs proposes that relevant inferences can be determined using the same means used to disambiguate other lexical expressions. The idea that metaphor understanding is integrated into natural language understanding is similar to the approach which we take. However, since DIANA does not accept as input a natural language text, but rather a *representation* of a natural language text, and does not identify the analogy underlying the metaphor, it does not address the issue of recognizing the presence of the analogy in the text.

B.1.2. The Role of Analogy in Arguments

In arguing a point, an author can argue directly, or chose to set aside the domain of the original point and argue indirectly, in another domain that is similar to the first. The analogy formed in this indirect argument supports the transfer of information across the domains.

Once the reader of HIGH-TECH-1 has followed the argument in the domain of the automobile industry, she must transfer that argument back to the domain of the computer industry. She can do this by applying the same line of reasoning applied in the case of automobile manufacturing, and inferring that since the use of computers will also lead to the creation of more new jobs, the introduction of computers in manufacturing must be good.

Why do people use analogies to support their beliefs? Analogy can be used as a sort of shorthand notation for conveying information that the author assumes the reader has about one domain, and that the author wants the reader to transfer to a new domain. Analogy can also acts as a vehicle to convey information which is not clearly expressed more directly, perhaps because it involves concepts which are difficult to explain. The inferences associated with the analogy can be made explicitly by the author, with the author drawing a detailed correspondence between source and target analogs, and explicitly declaring the conclusion to be drawn from the argument. This is seen in the following excerpt:

Balancing Freedoms

> *[...] Consider three familiar situations that have much in common: screening of air passengers and their baggage, police roadblocks to catch drunken drivers and random urine testing for illegal drugs. In each of these circumstances, large numbers of innocent people are searched in order to catch a few who are guilty. [...]*
>
> *"Balancing Freedoms"*
> *Los Angeles Times*
> *Part II, page 4/ Thursday, September 25, 1986*

In other instances, the inferences can be left implicit by the author, in which case the reader herself must do the work of drawing the correspondence between source and target, perhaps gleaning the point of the argument by inference as well. This is seen in HIGH-TECH-1.

What is different about parsing editorial text in which points are argued by analogy, rather than being argue directly? Clearly, all the issues relevant to parsing any text -- disambiguation, domain knowledge, integration of semantic and syntactic knowledge -- come into play. In addition, the representation of the argument must also be considered. Also, the parser must deal with representing the analogy itself, and incorporate knowledge about deciding to which domain a phrase belongs, and how to transfer information from one analog to the other.

Previous computational models of argumentation, such as (Flow82), (Alva85a) (Alva85b) (Alva86) (Alva89), and (Cohe87) did not address the issue of how analogy is used in argumentation. The only work related to the role of analogy in arguments is (McGu85), as noted above, and JULIP (Augu85a) (Augu85b) (Augu85c). With JULIP, we showed how knowledge of argumentation facilitates the recognition and understanding of the analogy presented in an editorial text. However, neither of these directly addressed the issue of how analogy is used in arguments. Without such a model, the ability to automate understanding of editorial texts will be limited to processing those editorials in which the authors argue points directly.

B.1.3. Mapping of Source and Target Analogs

In order to answer questions such as "What is being compared in HIGH-TECH-1?" an understander must have some representation of the correspondence mapping between the source and target analogs. How is this mapping directed? If one were to attempt to compare all features of the source analog to those in the target analog, one would surely find many points of dissimilarity. If one were to map only objects, then in HIGH-TECH-1 we would only have the CAM-automobile industry and assembly line jobs-horse carriage industry jobs mappings. The relations that hold within the analogs must be mapped as well. This mapping does not take place only after the entire text has been understood; indeed, the mapping is essential to understanding the text. In editorial understanding, the main point of the editorial constrains the linking associated with the analogy. Only those links which are needed to support the goals of the editorial need to be made. We map the features that are compared in the text. If a causal structure is involved, then the antecedent and consequent of the causal structure are also mapped. Direct comparisons needed to complete the analogy or make an inference are mapped, but the details associated with these features which come from domain knowledge are not mapped.

The literature reflects several views on correspondence mapping between source and target analogs. SME (Gent83) (Falk86) (Skor87), requires identity of predicates at all levels of abstraction and develops different correspondence mappings directly between source and target depending upon the type of analogy sought. Other models (Wins80) (Wins82) (Carb83a) propose that only an indirect mapping exists between source and target, i.e., both are instances of a more general concept. Others incorporate mapping only directly between source and target. We take the approach that direct correspondence is mapped only at major points, and no agreement of predicates is required at minor points.

B.1.4. Transference

In order to complete an analogy, it is essential for the reader to transfer information across domains. How does this happen? A replication of the source knowledge structure in the target domain will not supply context-dependent details in the target representation. In contrast, if the line of reasoning in the source domain is captured and then replicated in the target domain, domain-dependent knowledge can be used to supply details in the target representation.

In editorial understanding, the main point of the editorial constrains the inferences associated with the analogy. Only those inferences which are needed to support the goals of the editorial need to be made.

We transfer from source to target, and also from target to source, as needed, to understand the argument. Other systems transfer only source to target.

In order to complete an analogy, it is essential for the reader to transfer information across domains. This raises two questions: *What needs to be transferred?* and *How is the transfer completed?* In problem solving by analogy, it is the *solution* which is transferred. In metaphor and simile understanding (Wins78), (Hobb81) (Hobb83a) (Hobb83b) only the information relevant to the context established by the non-metaphoric or source words is transferred. In editorial understanding, the decision to transfer information is prompted not only by the context established by the source domain, but also by the expectations which arise during the course of understanding and following an argument.

Once it has been decided what information needs to be transferred from the source to the target domain, some mechanism is needed to complete this transfer. A replication of the relationships which hold in the source knowledge structure in the target domain will not supply context-dependent details related to the features of the target analog. Many existing systems over come this by relying upon the existence of a rich correspondence mapping between the source and target analogs to supply relevant, domain-dependent details, for example (Shin88a) (Shin88b) (Wins80) (Wins82). However, our earlier attempts at analogical transfer in JULIP (Augu85a) pointed out that in editorial understanding a rich correspondence mapping is unlikely to be supplied by the author. Thus, some other mechanism is needed to supply domain-dependent detail during transfer. One possibility is to exploit domain knowledge, and try to figure out what the relevant details would be, given the corresponding details from the source analog, if they exist. An alternate approach, and the one adopted in ARIEL, is to recognize that an analog has been chosen for the purpose of solving some goal, and to use that goal to guide the search for relevant domain-dependent details in the target knowledge base. This approach is proposed in (Holy85). In ARIEL, we use the underlying argument structure in the source domain to guide the transference of the source argument into an analogous target argument.

It is interesting to note that in other computational models of analogical reasoning, including (Wins78) and (Hobb81) (Hobb83a) (Hobb83b), the roles of source and target are never exchanged during understanding or problem solving. However, as seen in the example of HIGH-TECH-1 above, understanding analogies in arguments often requires a reader to transfer information back and forth across the domains or contexts, in order to make the inferences implied by the author. Thus, in ARIEL source and target are not fixed; information can be transferred as needed to facilitate understanding.

B.1.5. Identifying the Point of the Analogy

A reader of HIGH-TECH-1 will conclude that the author thinks the introduction of computer technology will benefit the economy in the long run. Why doesn't the reader simply conclude instead that the introduction of CAM technology is a lot like the introduction of the automobile industry? A reader must be able to recognize the focus of attention of the author in order to draw the conclusion intended by the author.

Other research focuses on inferring missing details; none steps back to try to identify the point being made as a whole. For example, Winston, Hobbs, output only the completed representation, and have no understanding at the end why certain facts were supplied, or what is significant about the analogy.

Computational models of problem solving by analogy seek to translate the solution to a source problem into an analogous solution to a target problem (Carb83a) (Falk86) (Shin88a) (Shin88b). The output of these systems is the solution to the problem, as in (Shin88a) (Shin88b), or a completed representation of the input (Wins78) (Hobb81) (Hobb83a) (Hobb83b). These systems have no understanding about why certain facts were supplied, or what is significant about the analogy.

In editorial understanding, the reader must be able to recognize the focus of the author's attention in order to draw meaningful inferences about the editorial. We have identified three ways in which analogies are used in editorials. These are related to the transfer of information from the generalization formed from the analogy, as well as to the transfer of both static, or time-invariant, and diachronic, related to how things change over time, information between the source and target analogs (Holy85). Recognizing these categories of analogy use enable us to make relevant inferences.

B.1.6. Carbonell

(Carb83a) outlines extensions to means-ends analysis which make use of past experience in solving new problems, integrating skill refinement and plan acquisition processes. Plans and goals are identified as the relevant higher-order relations for analogical mapping (Carb83b). The derivational analogy model of analogical learning stresses the mapping process (Carb86). Analogical reasoning is viewed as an indirect transfer from source to target via a common abstraction (Carb85). Given a generalization of source and target problems and an accompanying binding list, and given the source solution, a general solution is formed by applying the bindings list to the source solution. Derivational analogy has been combined with general problem solving and planning architecture in the PRODIGY system (Carb88). The focus in this system is on drawing meaningful analogies for problem solving by making explicit the underlying reasons for the presence of certain predicates in the source problem.

ARIEL draws upon Carbonell's work in transferring experience among related problems in solving the current problem. However, the emphasis in ARIEL is not so much on problem solving, as on analogical reasoning during natural language understanding, and, in particular, on recognizing and understanding and drawing conclusions. These areas are not addressed in the work of Carbonell et al.

B.1.7. SME

The Structure Mapping Engine (SME) (Falk86) is a computer simulation of analogical processing based upon Gentner's Structure Mapping theory (Gent83). This theory of analogy is based upon the structure of the inputs, and requires identify mapping at all levels of predicates. It provides a "tool-kit" for constructing matchers consistent with Gentner's theory. SME employs different matching rules depending upon whether the type of analogy being sought, and differentiates among true analogy, literal similarity, abstraction, mere appearance analogy, and anomaly. In a true analogy, such as *Heat is like water*, *heat* and *water* share a few attributes and many relations. In an anomalous analogy, such as *Coffee is like a solar system*, *coffee* and *solar system* have few shared attributes and few shared relations. Given a new case, SME will search through a database of cases to find analogous cases, depending upon the type(s) of analogy being sought. SME produces all consistent alternatives to the best match. A number of story sets were encoded and presented to SME (Skor87). Each story is independent of the others, in the sense that none of the stories contains an analogy. SME is used to identify which stories within a set are analogous, according to preestablished matching criteria.

SME differs from ARIEL in several ways. First, SME does not deal with recognizing the analogy within a text. Secondly, it does not deal with natural language processing, since the stories are hand encoded before being input into SME. Thirdly, SME does not incorporate domain knowledge. Another significant difference between SME and ARIEL is that Structure Mapping Theory requires identity of predicates at all levels of abstraction before a match can be considered successful. In contrast, ARIEL must determine the correspondence intended by the author, whether the analogy is easily understood or is anomalous.

B.1.8. Winston: Learning by Analogy

In Winston's system (Wins82), a teacher uses precedents and exercises to teach the system rules about relations in a particular domain. First, the teacher gives the system a precedent-setting story. Next, the system is given an exercise consisting of a second story and a conclusion which the system is to demonstrate is true of this second story. The system forms an analogy between the second story and the specified precedent by pairing off situation parts using acts and other relations as evidence to support the analogy. Using a brute force pattern match, the system searches the space of all possible matches between parts of the two stories to determine how the stories should be mapped to each other. While Winston's system is able to perform some analogical reasoning on the narratives, it does not recognize the narratives as being analogous without the assistance of the teacher. Also, the ability to make analogical mappings relies upon the existence of a common ancestor in the AKO or class hierarchy of the situation parts to be mapped (Wins78) (Wins80) (Wins82). Additional domain knowledge and past experience in making the analogical mappings are not utilized in Winston's system. As a result, the system's performance does not improve over time, and only obviously similar stories can be mapped to one another.

B.1.9. Lebowitz: IPP

IPP (Lebo80) compared new wire service stories to similar events previously stored in memory. Lebowitz used frame-like structures (Mins75) to index events in memory according to their similarities and differences. IPP was successful in finding events similar to the new one and was able to form generalizations allowing it to learn about its domain. However, IPP did not form specific analogical mappings and did not deal with disputes, arguments, or beliefs.

B.1.10. Shinn: JULIA and Abstractional Analogy

JULIA (Shin88a) (Shin88b) is an intelligent caterer's advisory system which interactively plans a meal with a client-user. The user gives JULIA a meal planning problem expressed in natural language. A natural language processor converts the natural language input into a frame representation (Mins75) describing the target problem in terms of goals and constraints. JULIA retrieves a similar case or source problem from memory, based upon identity of goals and functional similarity of constraints. JULIA creates a problem abstraction containing the common aspects of the source and target problems. JULIA then generates a solution to the abstract problem, based upon the solution to the source solution and domain knowledge. The final step is to apply the abstract solution to the target problem to arrive at the target solution. JULIA does form a correspondence mapping between the source and target, but stores them separately from the representations of the problems themselves. In JULIA, analogical reasoning is not integrated with natural language processing, but occurs after the input has been represented.

B.2. Argumentation and Beliefs

An editorial expresses the opinions or beliefs of its author. As such, it is like a one-sided persuasive argument. A belief is stated, then either supported or attacked. After reading an editorial, the reader expects to know what the author believes, and why she or he believes it. To understand an editorial, the reader must be able to identify the beliefs, supports, and attacks mentioned or alluded to by the author. The reader must be able to tie these parts together to form a cohesive argument. This requires the reader to have a basic idea of how arguments usually proceed, and to have the ability to generate arguments as needed to complete the author's thoughts.

Research most closely related to ARIEL has dealt with adversary arguments (Flow82), editorial understanding (Alva85b), the use of clue words in understanding arguments (Cohe87), and the creation and evaluation of arguments (McGu85). It is interesting to note that none of these systems but the last has any ability to understand or generate arguments by analogy, and, in the case of (Cohe87), the natural language understanding component is limited to a parser which translates the input into logical statements and relies only upon syntactic information to tie together the pieces of the argument found in the input. And although (McGu85) does address argumentation by analogy, this work does not provide any mechanism for completing arguments by analogy. Other related bodies of work, such as understanding from a moral perspective (Reev88) (Reev89a) (Reev91), and developing an automated operating system advisor (Quil88) (Quil89a) (Quil89b), deal with issues beyond the immediate scope of this research.

B.2.1. Flowers, McGuire, Birnbaum: ABDUL/ILANA

(Flow82) deals with adversary arguments between two people. It identifies three basic tasks important to understanding an argument:

1. Transforming the input into a meaning representation.
2. Relating the input to long-term memory.
3. Relating the input to the progress of the argument.

Propositions in an argument can either support or attack each other. A support relation contains three main components:

4. A main point.
5. The evidence supporting that point.
6. The claim that the evidence supports the main point.

A support relationship in an argument can be contradicted by an attack on the belief espoused, by attack on the justification given for that belief, or by attack on the claim that the justification supports the belief. An argument graph is used to represent the propositions and argument relations developed during the history of an argument.

Flowers et al. describe the system ABDUL /ILANA, which argues about responsibility for historical events. A sample rule is:

X didn't attack first
if Y preceded X's attack with an attack act.

Rules are tied to specific types of events, and are not domain independent. The argument is not over facts, but, rather, over the interpretation of the facts, slanted by the sympathies of each arguer.

ARIEL draws upon the model of argumentation developed by Flowers et al. However, our approach differs in two significant ways. First, ARIEL's knowledge of argumentation is domain independent. Our system relies upon domain knowledge to understand and infer value judgments about events, and to instantiate argument rules. Secondly, the focus in ARIEL is to understand the argument being presented by the author as impartially as possible, rather than to interpret facts in light of the sympathies of each arguer.

B.2.2. Alvarado: OpEd

In OpEd (Alva85a) (Alva85b) (Alva86) (Alva89), editorial understanding is viewed as a process of recognizing and instantiating relatively large knowledge structures called Argument Units, which are used to organize support and attack relationships in arguments. AUs convey implicit beliefs and are often cued by specific linguistics expressions. OpEd relies on Argument Units to understand arguments in editorials. In OpEd, following an argument involves recognizing these linguistic constructs, accessing the conceptualizations they refer to, and mapping them into their appropriate argument unit. AUs are very useful when the editorial being processed is an instantiation of an existing argument unit. However, OpEd's AU-based understanding is not able to follow an editorial that follows a novel line of reasoning. ARIEL uses more the primitive constructs of argument rules and attack strategies to understand and capture the lines of reasoning in editorials, rather than relying the larger and more comprehensive argument units. This lends a malleability to ARIEL which is essential to transforming arguments across domains and completing arguments by analogy.

B.2.3. Cohen

(Cohe87) discusses a system whose top-level goal is to convince the hearer of some point of view. This is similar in many respects to editorial understanding, since both deal with one-way arguments. Cohen presents a taxonomy of connective clues which set in place a default interpretation of its containing proposition, and argues that clue words are necessary to understand one way arguments. We differ from Cohen on this point. While clue words are helpful in understanding arguments, we argue that the same arguments presented without clue words should be understood equally well. We demonstrate this in ARIEL by relying upon domain knowledge, context, and expectations related to argument understanding in order to follow arguments and to attribute justification for propositions. Another difference between our work and that of Cohen is that Cohen's natural language understanding component is limited to a parser which translates the input into logical statements and relies only upon syntactic information to tie together the pieces of the argument found in the input. Also, Cohen's system relies primarily upon syntactic information to attribute justifications. In contrast, ARIEL is an integrated understanding system, and exploits the semantic information in the text as well as additional world knowledge to augment the understanding process.

B.2.4. McGuigan: MAGAC

McGuigan's MAGAC system (McGu85) simulates how people create and evaluate arguments. Arguments are broken into three categories:

1. Argument by analogy, in which conclusions are made about a target concept, based upon a source concept at the same level of generality as the target concept. For example, President X's policy had consequent Z. President Y's similar policy will also have consequent Z.

2. Categorical argument, in which inferences about a concept are made based upon general knowledge related to the category into which the concept falls; that is, inference relies on induction and deduction. For example, President X has policy Y. All presidential policies of type Y have consequent Z.

3. Causal argument, in which causal knowledge is inferred based upon general knowledge; this category of argument also allows prediction of future events. For example, President X has policy Y. All presidential policies of type Y have consequent Z.

McGuigan divides counter-arguments into two categories:

1. Argument by analogy: counter arguments can be composed of counter-analogies. The relevance of an analogy depends upon the context in which it is used, as determined either by the features under debate, or the current needs of the understander.

2. Categorical argument: contest category membership. Cite either feature conflict, or more appropriate category.

McGuigan's approach supports the approach taken in ARIEL. However, ARIEL extends beyond MAGAC. First, it incorporates a natural language component into the system and exploits the semantic information in the text as well as additional world knowledge to augment the understanding process. Secondly, ARIEL's understanding of categorical and causal arguments goes beyond that in MAGAC by considering not only general knowledge, but also an analogous source concept as well when making inferences related to a target concept. Third, instead of focusing on creation and evaluation of arguments, ARIEL focuses on comprehension of arguments, and is able not only to recognize the presence of an analogy in an argument, but also to complete an argument-by-analogy which has been only implicitly completed by an author.

B.2.5. Reeves: THUNDER

THUNDER (Reev88) (Reev89a) (Reev91) models a reader's attitudes and judgments in an effort to improve attention direction and thematic understanding. The value judgments in this model are used to recognize belief conflict patters (BCPs). BCPs represent abstract situations in which there is a conflict between the ethical judgments of the reader and those of the story characters. The BCPs organize the representation of the story, focus attention on the thematically interesting elements of the story, and identify the theme of the story by resolving the belief conflict.

The focus in ARIEL is on comprehending the author's attitudes as expressed in the editorial, rather than interpreting the events in the story in terms of the reader's attitudes.

B.2.6. Quilici: AQUA

AQUA (Quil88) (Quil89b) is a system that corrects plan-oriented misconceptions of novice UNIX users. AQUA takes a single user belief that a plan is applicable to a goal, or that a state is an enablement or effect of a plan, and searches its memory in a attempt to find some knowledge that would justify holding that belief. The knowledge of plans and goals, as well as the search strategies employed, were designed to work only in the UNIX domain. In addition, the strategies are not used for belief comprehension; they are only utilized in the memory search.

In contrast, the knowledge of argument rules and attack strategies contained in ARIEL, are used during editorial comprehension, as well as for reasoning about the beliefs in the editorial.

B.2.7. Quilici: The Correction Machine

The Correction Machine (Quil89a) models an automated advisor which formulates responses in order to correct mistaken user beliefs about the operation of a computer operating system. The Correction Machine explains the user's misconceptions by comparing the user's failed attempt to use the system in terms of the advisor's own model of the system. Quilici's approach does not attempt to infer the user's mental model of the system.

(Quil89a) describes belief justification patterns or BJPs, which are domain-independent knowledge structures used to capture high-level knowledge about beliefs and how they are justified. Each BJP represents one way to justify one class of belief. Quilici claims that BJPs are useful in systems designed to deal with mistaken user beliefs. BJPs are tied to abstract planning relationships independent of a particular domain. This work presents a model of the process of justifying beliefs and understanding belief justifications. Knowledge about belief justification can be used for both constructing and comprehending belief justifications.

The beliefs in The Correction Machine deal with whether or not an operation will perform a particular task. Either an action will perform the required task or not. In contrast, beliefs in the ARIEL system are related to the author's opinions about events. There are no correct answers in dealing with such beliefs.

B.3. Natural Language Processing

Previous work in developing natural language processing systems has shown how world knowledge and expectations generated by both the text itself and the context in which it is used are essential components of understanding natural language. BORIS (Dyer83) and PHRAN (Aren86) are examples of these systems. Neither BORIS nor PHRAN is designed to recognize or understand analogies in natural language text.

B.3.1. Dyer: BORIS

The BORIS system (Dyer83) took an integrated approach to the problem of achieving an in-depth understanding of natural language, multiple-sentence texts. Earlier systems which strove to develop a conceptual representation of the text, such as ELI (Ries78), PAM (Wile78), SAM (Cull78), and MARGIE (Scha75), were multiple pass systems. First, the text would be analyzed into conceptual dependency primitives (Scha77). Next, the system would try to identify higher level knowledge structures within the representation resulting from the earlier processing. One of the problems with this approach is that the information available at one point in the understanding process was not available to the processor at subsequent steps. The BORIS system sought to handle all of these processes simultaneously in an integrated processor.

BORIS worked under the assumption that the meaning of an utterance could be computed from the meaning of its constituents by the use of general rules. Knowledge was available to the system at the word level. It worked in both a top-down and a bottom-up fashion. As words were read, they would be looked up in the lexicon. Associated with each lexical entry was not only the meaning associated with the word, but also control information specifying, for example, where in the text the controller needed to check for other words and concepts. Information associated with the lexical entries would generate expectations about other words or concepts which might also appear in the text. Each new word was processed in light of the context established by the previous words. The control information for the processor was included as part of the meaning of various words. This diffused control information among the lexical entries. As a result, it was very difficult to incorporate new words into the system, or modify the meaning of existing lexical entries.

BORIS understood stories involving divorce and other interpersonal relationships. It used TAUs or Thematic Abstraction Units to capture the goal and plan interactions that include particular errors in planning often expressed in common adages, such as the pot calling the kettle black. This enabled BORIS to make inferences about the emotions of the characters in the stories, and to make inferences about events in the story that were implied by a character's emotions.

While BORIS did present a theory of how a system could achieve in-depth understanding of natural language and make the inferences people make in reading similar stories, it does not deal specifically with analogical reasoning, except to argue that TAUs can be used to organize, and therefore retrieve, conceptually similar episodes.

B.3.2. Arens: PHRAN

PHRAN, or PHRasal Analyzer (Aren86) presents a slightly different approach to natural language understanding. PHRAN is the language system used with the UC Consultant system. PHRAN stores information about the words of the language as well as information about more complex language constructs in the form of pattern-concept pairs. The linguistic component of this pair is the pattern; the semantic component is the concept. Information about the meaning of a phrase is stored as a phrase, not disbursed among the lexical entries of the words comprising the phrase. In PHRAN, the knowledge about the language includes both meaning of words and meaning of larger utterances. This approach separates knowledge about language, which is kept in the pattern-concept pairs, from processing strategies, which are embedded in the code of the understanding mechanism. Thus, it is very easy to add additional phrases into the lexicon.

PHRAN was designed to provide a natural language interface to the UC Consultant system. It is not able to relate the concepts from one sentence to those from another, and build an overall representation of all of the input which it receives, although it is able to handle some reference across sentence boundaries. As a result, it is not able to handle multi-sentence texts, such as editorials, and has no analogical reasoning component.

B.3.3. NLP in ARIEL

Natural language understanding in ARIEL is based upon PHRAN's phrasal parser. Because we want ARIEL's understanding to proceed in an integrated manner, we have also borrowed from BORIS to enable our parser to handle multi-sentential texts and to be able to generate expectations related to following arguments in the text. In addition, ARIEL is able to develop correspondence mapping between source and target analogs while understanding proceeds.

ARIEL is currently designed to generate an English equivalent of the representation of the conclusion it draws from the text read. This generation ability is based upon PHRAN's phrasal generator, with only minor modifications.

B.4. Question-Answer Processing

An earlier version of this work, JULIP (Augu85a), demonstrated that an analogy had been completed and understood by answering questions relating to the correspondence mapping between the analogs, the transforms performed during understanding, and the basis of the analogy. The heuristics used were based upon the theory developed in Lehnert's QUALM (Lehn78), a computational model of question-answering running in conjunction with comprehensive story-understanding system. The heuristics implemented in JULIP departed from Lehnert's in two ways. First, the concepts in an editorial revolve around arguments, rather than around script instantiations. JULIP's memory search heuristics took this into account. Secondly, JULIP's representation scheme utilized memory links that were not considered by Lehnert in QUALM.

B.5. Conclusions

Many researchers have examined problems in the areas of analogical reasoning (e.g. (Holy89) (Carb86) (Gent83)), argumentation (e.g., (Cohe87) (Flow82) (Quil88)), and natural language processing (Aren86) (Dyer83). Some investigators have integrated two of these three areas (e.g., (Lebo80) (Alva89) (Reev91)). The ubiquitous nature of analogy in human communication and problem solving points to a need for models which integrate all three of these areas. By providing an approach to understanding analogies in arguments, ARIEL provides a contribution to meeting this need.