"Abstract" Understanding:

The Relation between Language and Memory

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CUCS-12-81

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1 Introduction

Natural language is primarily a tool of communication. This implies that whatever roles syntax, semantics, pragmatics, and world knowledge play in language understanding, the comprehension process must be driven by the need to understand the text or conversation, where understand means sufficiently relating the new information being conveyed to existing memories in order to remember the information and/or respond.

The need for memory-driven text processing becomes especially clear during the construction of a computer system designed to read large numbers of texts and add them to a coherent memory. However, the recognition that information such as syntax and semantics play only a subsidiary role in text processing does not make understanding more difficult; rather, it makes it possible.

A current natural language processing project underway at Columbia involves the creation of a computer program, known as RESEARCHER, that will read large numbers of technical abstracts, such as patent abstracts, and builds up a coherent memory based on the information obtained. This memory is then used in turn to help in the understanding process. RESEARCHER will use some of the same understanding principles as did IPP, a program that reads and remembers news stories [Lebowitz 80, Lebowitz 81]. One of the goals of RESEARCHER is to show that memory-based understanding techniques are as applicable to physical descriptions as to descriptions of events. In fact, due to the knowledge-intensive nature of technical descriptions, it is expected that the application of memory will be even more important in driving processing.

Further discussion of the interrelations among different sources of information in language processing can be found in [Lebowitz 80], [Schank, Lebowitz and Birnbaum 80] and [Schank and Birnbaum 80].

2 Understanding Abstracts

The following example, typical of those to be processed by RESEARCHER in the domain of patent abstracts, illustrates why memory must drive processing.

> A1 - THREE DIMENSIONAL TELEVISION SYSTEM
>
> A method of displaying by projecting a stereo pair of images to present a single three dimensional image to normal human perception comprising the steps of positioning a pair of video cameras in stereo relation to each other to view a scene, switching the video signal from first one camera and then the other camera, controlling the time interval that each of the cameras is operative so that one camera is active nearly all the time while the other camera is active only briefly, synchronizing the video of the two cameras and switched

> video signals, and transmitting and displaying the switched video signals on a conventional television receiver thereby allowing the human visual perception process to interpret the switched signals as a single three dimensional image.

Admittedly, this abstract is not easy for any reader, especially one without previous experience with patent abstracts to read. (Patent abstracts seem to have relatively rigid, if extremely obscure, stylistic conventions and vocabulary.) However, one thing that is clear is that we cannot hope to first determine the syntactic structure of the abstract (which is, it should be noted, simply one long "sentence", lacking certain syntactic niceties, such as a main verb). Instead, any reasonable processing algorithm must be incrementally understanding the text, using whatever syntactic, semantic and long-term memory clues are available to relate new information to old. This is the strategy used by RESEARCHER.

In this paper, I will only be able to give a flavor of the kind of processing that must go on. I will do this by outlining how it is intended for RESEARCHER to process the title of A1.

The processing of A1's title, "Three Dimensional Television System", provides an excellent example of how memory-based understanding occurs. RESEARCHER begins its left-to-right processing by looking at the phrase "three dimensional" (RESEARCHER allows phrases to appear in its lexicon). This phrase's definition states that it is a modifier, indicating that the modified concept has, in some way, three spatial dimensions.

As will be seen in a moment, the exact conceptual meaning of "three dimensional" depends very heavily on the concept being modified. For this reason, it is processed using a "save and skip" strategy, i.e, it is saved in a short-term buffer until a concrete object is found, in a manner described in [Lebowitz 80].

When "television" is read, RESEARCHER does most of its processing of the title ("system" is basically ignored as being a "patent-world" buzzword, significant only in that it indicates we are dealing with a complex object). The definition of "television" simply indicates that the word describes a concrete object and supplies a pointer to the cluster of information about televisions in memory. At this point in the processing, it is possible to retrieve "three dimensional" from short-term memory, recognize that it is modifying television (which it clearly is, despite the fact that "system" is technically the head noun in the phrase), and determine the combined meaning of "three dimensional television".

The final determination of the meaning of "three dimensional" is the most difficult and interesting part of the processing of the title. Notice that this phrase does not have the obvious meaning. "Three dimensional" here does not simply refer to an object with three spatial dimensions, but rather indicates that the television in question presents a picture that has (or appears to have) three dimensions. How can this be determined?

To understand how this processing occurs, we must look at how information about televisions is stored in RESEARCHER's memory. The memory used in RESEARCHER is organized around the way that specific items, in this case kinds of televisions, vary from the norm. That is, we store the general information about televisions once, and record only how specific instances are unusual. This is completely analogous to the Generalization-Based Memory used in IPP (as well as similar to the memory used in the program CYRUS [Kolodner 80] or Schank's Failure-Driven Memory [Schank 81]), and, in fact, RESEARCHER's memory will be built up in the same way -- through generalization.

Figure 1 illustrates one small piece of the memory for televisions. It indicates that a television is made up of a number of components, among them a picture tube that is used to display a flat picture and is physically quite bulky. Two kinds of televisions are recorded in memory -- a three dimension version that differs from the norm in its function and a liquid crystal model that has a flat "tube".

Using the existing memory of television, it becomes possible to analyze the meaning of "three dimensional television". Since it is a general rule of communication that the novel characteristics of a concept are used to identify it, RESEARCHER can simply look at all the possible variants of television, and see which could be described by the concept included in the definition of "three dimensional". This is easily done, since

```
--------------   Instances
¦ Television ¦-------------------------------------
--------------            ¦                  ¦
¦ Parts                   V                  V
¦-------> case, tuner   -----------------  --------------
V         tuner, etc    ¦ 3D            ¦ ¦ ¦ LCD        ¦
--------------------    ¦ key diff:     ¦ ¦  key diff:  ¦
¦ Tube             ¦    ¦  ¦ is display ¦ ¦  ¦ is flat  ¦
¦ purpose: display ¦<---¦---  3D picture ¦ ¦  ¦  LCD     ¦
¦     flat picture ¦    -----------------  ---¦----------
¦ size: bulky      ¦<---------------------------
--------------------
```

Figure 1: Simplified Memory for "Television"

the variants from the norm are used as indices for the variants. Also note that the conceptual definition of "three dimensional" is used in the memory search, not the words. This allows RESEARCHER to identify "solid TV" as an instance of the same variant in memory.

Notice that this processing scheme can also understand the phrase "two dimensional television", where "two dimensional" refers to the <u>structure</u> of the picture tube, not its <u>function</u>, as did "three dimensional". In this case, when RESEARCHER looks for variants of the standard television, it will find the LCD model, with the flat screen, rather than all the televisions with the two dimensional, but normal, pictures.

One last point is worth considering in this example. Suppose that the concept of the three dimensional television was not already in memory when A1 was read, certainly a reasonable possibility. RESEARCHER then would have to deal with its failure to find a variant of television described by "three dimensional".

This would be done by looking at the various properties of television it does know about, until it finds one contradicted by "three dimensional". In this case it would be found that the function of the picture tube is to project a two dimensional image. Then RESEARCHER would assume that this is what is being modified, and create the 3D variant, just as shown in Figure 1.

RESEARCHER's processing of the main body of A1 would have the save flavor as that shown here -- identifying the relevant structures in memory -- but would obviously be more involved. It would take as a starting point the concepts described in the title, and determine how the abstract modifies them. This sort of memory-guided processing will allow the understanding of complex texts without detailed analysis of their syntactic vagaries.

3 Conclusion

The kinds of texts to be processed by RESEARCHER graphically illustrate the need for memory-guided language processing. All other sources of information simply serve as ends towards this goal. The development of detailed computer algorithms, of the sort described here, that are required to account for large numbers of texts serves as an important tool in the understanding of language as an element of communication.

As a final example of the potential of the techniques presented here, I will present one further example of the kinds of texts that we are dealing with. A2 is a patent abstract that has been used in the development of the prototype RESEARCHER.

A2 - FILLED CABLES

A cable comprising:
a plurality of conductors within a sheath leaving voids between the conductors, and between the conductors and the sheath, and a filling material filling the voids the invention characterized in that the filling material comprises a mixture of:

(X) an ASTM Type 103, 104A or 104B, or mixtures thereof, (paraffinic or naphthenic) oil, having a minimum sp. gr. of 0.860, a minimum SUS viscosity at 210 degrees F. of 45, a maximum pour point ASTM D 97 of 20 degrees F. and a maximum of 5 percent aromatic oils,

(Y) a styrene-ethylene butylene-styrene block copolymer having a styrene-rubber ratio of approximately 0.2 to 0.5,

(Z) polyethylene having a softening point of 110 degrees C. to 130 degrees C.

the ingredients, X, Y and Z having relative proportions falling within the shaded area bounded by ABCDEF of the FIGURE.

The prototype RESEARCHER that we have developed using the techniques in this paper is able to successfully process a slightly modified version of this abstract (the X, Y, Z paragraphs were slightly simplified, as this is not indended to be a study in organic chemistry). Notably, even in the basic version of RESEARCHER we are working on, if the program reads this abstract a second time, it does an absolute minimum of work, recognizing a description of a concept it has already learned.

Being able to base understanding of complex texts such as A2 on concepts already in memory is the crucial ability gained with a memory-based understanding system.

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