This paper discusses the problem of providing natural language access to textual material. We are developing a system that relates a request in English to specific passages in a document on the basis of correspondences between the logical representations of the information in the request and in the passages. In addition, we are developing procedures for automatically generating logical representations of text passages, directly from the text, by means of an analysis of the coherence structure of the passages.

INTRODUCTION

At SRI we are developing a system for natural language access to textual material. The system is to provide access to a textbook or other document of some importance, by returning relevant passages in response to a user's natural language request. Currently we are using the Hepatitis Knowledge Base, a compendium of current knowledge about hepatitis compiled by the National Library of Medicine, although the techniques we are devising are in no way particular to this document [cf. Walker, 1982]. The project has two phases. In the first, we are developing text access procedures for translating a user's request into an underlying logical form and, in order to locate the appropriate passages, matching the logical form with a Text Structure which expresses the structure of the document as a whole and summarizes the content of individual passages in terms of canonical predicates [Walker and Hobbs, 1981]. In the second, longer-term effort, we are developing procedures for automatically generating portions of the Text Structure directly from the text.

THE TEXT ACCESS COMPONENT

In the text access component, a user's request is translated into logical form by SRI's DIALOGIC system, described in another paper submitted to this conference [Grosz et al, 1982]. This logical expression is then turned over to the inferencing component DIANA [Hobbs, 1980], where various discourse problems are solved and a match with the Text Structure is sought.

As an illustration of this process, consider the following example query:

During what period is immunoprophylaxis appropriate following exposure to type B hepatitis?

DIALOGIC translates the request into the following form:

\[
\text{DURING (APPROPRIATE (IMMUNOPROPHYLAXIS (I, X1, Y) | FOLLOW (I, EXPOSE(X2, HEPATITIS-B)))}, \\
\text{TX | PERIOD (TX) ).}
\]

That is, during period TX, the immunoprophylaxis I of X1 against Y, where I follows an exposure event of X2 to hepatitis B, is appropriate.

Two kinds of discourse problems are exemplified here. First, there is the problem of determining implicit arguments. We are not told explicitly what
immunoprophylaxis is against, only what exposure was to. We need to draw the
inference that exposure to something is typically followed by immunoprophylaxis
against it. This problem must be solved if we are to retrieve the proper passages
on immunization against hepatitis B virus (HBV) rather than some other agent.
Similarly, we are not told explicitly that the one who was exposed is the one who
will receive immunoprophylaxis, that is, that X1 and X2 are the same individual.

The second discourse problem illustrated here is that of metonymy. One may talk
about both exposure to HBV and exposure to type B hepatitis. In the first case we
are talking about exposure to a virus, in the second exposure to a disease. The
Text Structure is expressed in canonical predicates in a standardized form, and
one of the standardizations is in the class of entities that can be the argument
of a predicate. We must decide, for each predicate, the type of arguments it can
take. For example, is one exposed to a virus or a disease? For various reasons,
we have decided that one is exposed to a virus and not to a disease. Thus the
inference processes have to analyze the actual query into one involving
exposure to the virus causing type B hepatitis, or to HBV. This coercion is done
by accessing information in a knowledge base that “expose” requires a virus as its
second argument, that type B hepatitis is caused by HBV, and that HBV is a virus.

In order to match the request with the Text Structure, DIANA needs to translate
the original request into the canonical predicates in which the Text Structure is
expressed. For example, since “immunoprophylaxis” is not one of the canonical
predicates, we need to use the axiom

\[ \text{IMMUNOPROPHYLAXIS}(i,p,v) \iff \text{IMMUNIZE}(i,p,\text{PROPHYLAXIS}(v)) \]

that is, i is an immunoprophylaxis event of p against v if and only if i is an
immunization event of p for prophylaxis against v. The result is a translation
into the canonical predicates “immunize” and “prophylaxis”, which are used in the
summaries of the relevant passages in the Text Structure.

GENERATING TEXT STRUCTURE

Our work on the automatic generation of the Text Structure is at a more
preliminary stage. Automatic summarization is a central aspect of this effort. A
certain amount of work has been done in artificial intelligence and psychology on
the automatic construction of summaries, including work by Rumelhart [1975],
Mandler and Johnson [1977], Schank and his colleagues [Schank et al., 1980],
and Lehnert et al. [1981]. Most of this work has focused on narratives rather than
expository discourse, however.

There are two principal techniques that we have brought to bear on the problem.
The most important involves a coherence analysis of the paragraph, in a manner
described in detail in Hobbs [1976, 1978] and similar to work by Longacre [1976]
and Grimes [1975].

It can be argued that, in coherent discourse, one of a small number of coherence
relations, such as parallel and elaboration, holds between successive segments of
the text. The coherence relations can be defined in terms of the inferences that
can be drawn from what is asserted by the segments being linked (called the
assertions of the segments). Thus, very roughly, two sentences are parallel if
their assertions make the same predications about similar entities.

These coherence relations allow one to build up a tree-like coherence structure
for the whole text recursively, as follows: The coherence relations are defined
between segments. A clause (perhaps elliptical) is a segment. When some
coherence relation holds between two segments, the two together constitute a
composed segment, which can itself be related to other segments of the text.

Since the coherence relations are defined in terms of the assertions of segments,
we need to specify what the assertions of the composed segments are. For this
purpose we use a number of heuristics. For example, if two sentences are
parallel, it is because the same predicate is made about similar entities. Then
the assertion of the composed segment makes that same predicate about the
superset to which the similar entities belong. Thus, every node in the coherence
structure has an assertion associated with it. Very frequently the assertion
associated with the top node of the coherence structure of a passage can function
as the summary of the passage.

As an illustration of this technique, consider the following passage:

(P1) Blood probably contains the highest concentration of hepatitis B virus
of any tissue except liver. Semen, vaginal secretions, and menstrual
blood contain the agent and are infective. Saliva has lower
concentrations than blood, and even hepatitis B surface antigen may be
detectable in no more than half of infected individuals. Urine contains
low concentrations at any given time.

After a grammatical analysis, the sentences in this passage can be aligned as in
Figure 1. Every clause considers some body material containing HBV in some
concentration. They are thus linked by the parallel coherence relation, and the
assertion (and the summary) of the passage is as follows:

\[
\text{CONTAIN (BODY-MATERIAL, HBV, CONCENTRATION)}
\]

Many paragraphs we have analyzed in this way turn out to have a parallel
structure, and thus their summaries can often be constructed in a similar manner.

| blood             | contains | highest concentration | HBV |
|------|---------|-----------------------|-----|
| semen |         |                       |     |
| vaginal secretions | contain |                       | agent|
| menstrual blood   |         |                       |     |
| saliva           | has     | lower concentrations  |     |
| (saliva of) infected individuals | in     | detectable ... no HBsAg |     |
| urine            | contains | low concentrations    |     |

Figure 1 Parallels in Passage (P1)

A second factor must also be taken into account in constructing the
summarizations. In addition to containing summaries of individual passages, the
Text Structure contains a representation of the hierarchical organization of the
document as a whole, as well as other aspects of its overall structure. The place
of an individual passage within the hierarchical organization constrains what can
function as a summary of the passage. A summary must distinguish a passage from
other passages at the same level in the hierarchy. Top-down considerations
frequently lead us to refine a summary we arrive at solely by the bottom-up
coherence analysis.

As an example, consider the following passage:

(P2) Generally blood donor quality is held high by avoiding commercial
donors, persons with alcoholic cirrhosis, and those practicing illicit
self-injection. Extremely careful selection of paid donors may provide
safe blood sources in some instances.

---

1 This diagram is similar to the formats developed by Sager and her colleagues [Sager, 1981].
A coherence analysis results in the structure shown in Figure 2. "Selection" contrasts with "avoiding," so we can say that the second sentence expresses an exception to the first conjunct of the first sentence. Because the second sentence is hedged very heavily, the assertion of the composed segment is the assertion of the initial conjunct of the first sentence—"avoid commercial donors." The three assertions of the first sentence stand in a parallel relation since they imply the same proposition about similar entities. They all imply (trivially) that certain classes of potential donors are to be avoided if blood quality is to be held high. Entities are similar if they share some common and reasonably specific property, that is, if they belong to some common and reasonably small superset. Our three classes of potential donors are similar in that they are all potential donors. The similarity would be stronger if there were some more specific property that characterized commercial donors, those with alcoholic cirrhosis, and illicit self-injectors, but there does not seem to be such a property. The most we can say seems to be that they are potential donors, and we arrive at the following assertion for the paragraph as a whole.

AVOID (DONOR | CONDITION (DONOR))

However, such a summary fails to distinguish this paragraph from its siblings in the hierarchical structure of the HKB as a whole. The nodes most immediately dominating this section in the hierarchy of the HKB correspond to sections about the quality of blood products under varying conditions, with respect to the risk of hepatitis in transfusion. There are two broad classes of conditions that are discussed, first, conditions characterizing the donor, and second, conditions characterizing the type of blood product. Among the conditions characterizing the donor are a history of hepatitis, recent transfusions, and positive results on serologic tests, as well as the conditions described in the example. Thus, the structure of the summaries in the paragraphs should be something like that shown in Figure 3.

It is therefore not sufficient for us to characterize the paragraph as being about avoiding potential donors exhibiting some condition. Thus, top-down considerations lead us to reject the summary we came up with solely by the bottom-up coherence analysis. We need something more specific, and the best we can do is simply to have a disjunction of properties as the condition characterizing the donors:

AVOID (DONOR | COMMERCIAL(DONOR) or CIRRHOSIS(DONOR) or SELF-INJECTOR(DONOR))
QUALITY (BLOOD-PRODUCT)
QUALITY (BLOOD-PRODUCT | CONDITION (DONOR) )
[summary of our example]
CONDITION = history of hepatitis
CONDITION = recent transfusion
CONDITION = positive serologic tests
....
QUALITY (BLOOD-PRODUCT | TYPE (BLOOD-PRODUCT) )
....

Figure 3 Hierarchical Structure of Paragraph Summaries

CONCLUSION
While these methods for the automatic generation of summaries of expository text seem promising, difficult problems remain—including the problems of encoding and searching a very large knowledge base. In order to have practical milestone systems in the near term, we are working toward two scaled-down versions of the ultimate system. First, we are experimenting with using a pre-existing Text Structure to aid in the construction of the summaries of modifications of a passage. Second, rather than fully automatic generation of summaries, we are experimenting with ways that interaction with the author of a passage can aid in the task.

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