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AUTHOR	Borden, George A.
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ABSTRACT

ARIS is an artificial intelligence system which uses the English language to learn, understand, and communicate. The system attempts to simulate the psychoneurological processes which enable man to communicate verbally. It uses a modified stratificational grammar model and is being programed in PL/1 (a programing language) for an IBM 360/67 computer. In its present state of development, ARIS uses a crude simulator of verbal communication similar to Weizenbaum's ELIZA program. From this base an attempt will be made to develop a concept network having human-like characteristics. The stratification model will be extended to the concept strata, using Piaget's developmental theories regarding the dynamic nature of knowledge. The two necessary characteristics for the structure of knowledge--hierarchical and dynamic relations-- will then be the natural consequences of the resulting network. (Author/JY)

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ASPECTS OF A NATURAL LANGUAGE BASED ARTIFICIAL INTELLIGENCE SYSTEM

REPORT #7

LANGUAGE AND THE STRUCTURE OF KNOWLEDGE

by

George A. Borden
207 Old Main
The Pennsylvania State University
University Park, Pennsylvania 16802

International Communication Association
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ABSTRACT

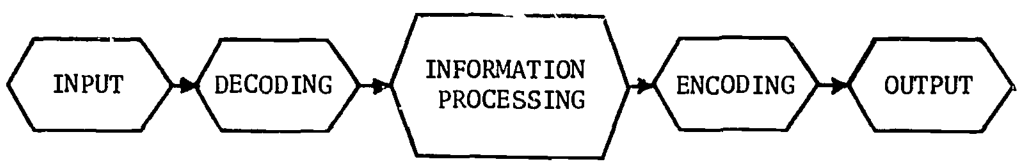
ARIS is an artificial intelligence system which uses the English language to learn, understand, and communicate. Based on present psychoneurological theories, it attempts to simulate the psychoneurological processes man has which enables him to communicate. It uses a modified stratificational grammar model and is being programmed in PL/1 for an IBM 360/67. This paper outlines its present state comparing it with Weizenbaum's ELIZA program, and speaks to the problems of developing a concept network having human like characteristics. This is accomplished by extending the stratificational model to the concept strata. The two necessary characteristics for the structure of knowledge, i.e., hierarchical and dynamic relations, are then natural consequences of the resulting network.

ASPECTS OF A NATURAL LANGUAGE BASED ARTIFICIAL INTELLIGENCE SYSTEM
Report #7

LANGUAGE AND THE STRUCTURE OF KNOWLEDGE

ARIS is a natural Language Based Artificial Intelligence System. It is characterized by its ability to learn, understand, and communicate through the use of the English language. It uses written language as the medium for communicating, and the word as its smallest unit of analysis (all punctuation marks are treated as words). Dr. William Nelson, of the State University of New York at Oneanta, and I have been developing the theoretical bases for this system for the past two years. We are now to the stage where we are beginning programming of the system.

Our approach is rather elementary. We are beginning with a crude simulator of verbal communication similar to Weizenbaum's ELIZA.(1) The main objective of this system is to simulate verbal output. It does this at the expense of gross over simplifications of the internal processes of decoding, information processing, and encoding. It does not have the ability to learn, and thus, is totally inadequate as an artificial intelligence system. The progress of the project will be measured by the degree to which the many internal processes involved in human verbal communication are simulated. The basic model for ARIS may be schematized as follows:



Input is no problem. It consists of typed English sentences from an on-line terminal. Decoding presents few problems as well. It is accomplished by determining the boundaries of each word and locating the word in ARIS' lexicon. We are using a HASH code which uniquely identifies each word and computes its location in memory. Whether the word is found or not is noted and the processing moves on to the information processing unit. Now the fun begins. If the word is not found in the lexicon it must be added. This is not so difficult once we understand the information format for a lexical entry. If the word is found the information processing unit begins to establish the boundaries of the semantic space mapped by the verbal stream being processed. When the processing is complete the output decision is made. If a reply is to be made, the encoding process is instigated. (This too, of[illegible] some sticky problems which I shall not consider in this paper.) As the message is encoded into a verbal signal it is typed out on the same terminal as the input was entered.

The above quick run-through is offered only as a brief introduction to the total system. I'm sure you all have questions about how we plan to solve the many problems in each phase of the total process. We have solved some of them and have a few ideas about how we can solve many of those that remain. Since we are attempting to simulate the human processes involved in verbal communication as closely as possible we lean heavily upon existing theories about these processes. I would like to speak now about one particular problem we have encountered in the information processing phase of this system.

The decoding and encoding processes in the ARIS system are built around a modified stratificational grammar for written English*. Stratificational grammar is a natural for this system since it is based on the assumption that language is a network of relations in which one can proceed from sound to meaning or from meaning to sound using the same network**. This relational network can be programmed for computer manipulation using the word as the basic unit of analysis rather than the phoneme. When this is done the mechanics for the encoding-decoding processes exist and decoding can be accomplished quite easily though encoding is a bit more difficult. The encoding difficulty lies at the level of message generation which is at least one strata above the sememic strata. This is also the point where the information processing phase is least understood.

In the decoding process the input stream is analyzed into its several linguistic components called sememes. At this point we have done all we can do with linguistics, but we still do not have an understanding of what the verbal input said except in a linguistic sense. What lies beyond this stage? Roger Schank has suggested the Conceptual Dependency theory as the next step toward meaning.(2) This fits in well with stratificational grammar but does not give us the mechanism we want. Therefore we have decided to modify this approach also.

In developing my approach to artificial intelligence I have tried to keep in mind the idea of Piaget (3) that "Knowledge is neither solely in the subject, nor in a supposedly independent object, but is constructed by the subject as an indissociable subject-object relation." To establish this relation we must

*Dr. James Copeland, Rice University, is working on these phases of the system.
**"Linguistic Cues to the Workings of the Mind", a lecture by Sydney Lamb given at the Pennsylvania State University, November 16, 1970.

interact with the object. This appears to be saying that when a brain is stimulated with an external signal the resulting neurological trace constitutes the relation of subject to object. Knowledge then, becomes a network of relationships, with each node being a concept. The evaluation of these concepts in the mind of a receiver may be accomplished by triggering any number of paths leading into this node. The outside signal may, of course, be either verbal or nonverbal. My problems are considerably reduced since I am working only with verbal signals. This means that I have the problem of tying together two relational networks--the one for language and the one for concepts.

Piaget's developmental theories also make the point that knowledge is not a stated quality but a dynamic relation. One is only aware of his knowledge when it is brought forth, which means, when the nodes constituting that piece of knowledge, or subtending that area of semantic space, are activated. Which nodes are to be activated is dependent upon the subject area being discussed and the focus of the discussion*. It may be assumed that this is also the way new knowledge is acquired. As information is processed new connections are activated between nodes in the network. This may mean that the internal signal must pass through several other nodes to activate the primary concept sought. When this is the case, the primary concept becomes more abstract and/or less definable. The connotative meaning is traceable to the periferal concepts stimulated in the process of activating the primary concept.

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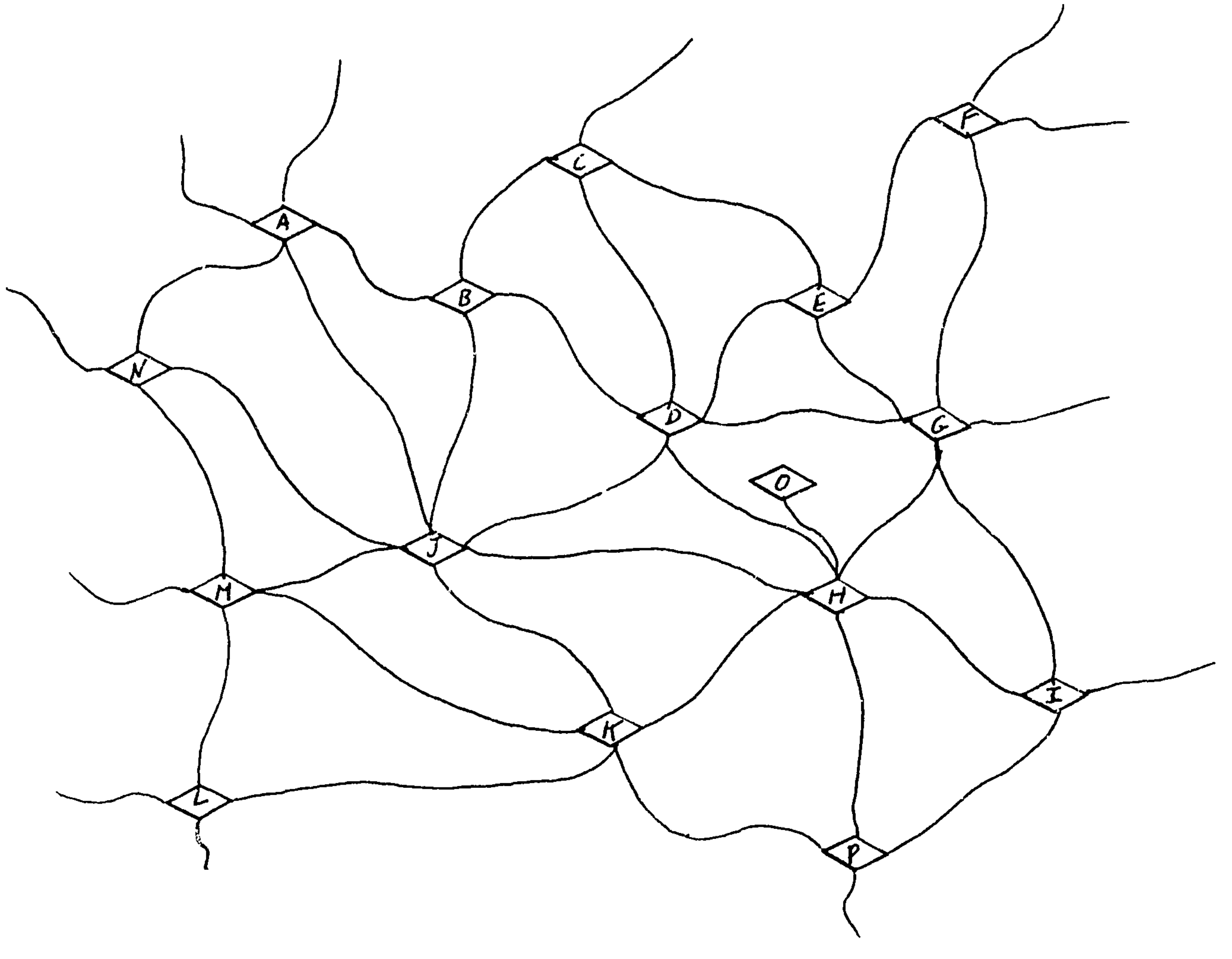
*It is at this point that theories concerning "attitudinal frame of reference, (Rokeach) and psychological set or one's bias enter. Space does not allow a discussion of these forces at this time. It should be obvious that one's view of reality will have a definite affect on the way messages are created both from the decoding process and for the encoding process. Dr. William Nelson (SUNY at Oneanta) is working on this problem in our project.

Though knowledge is only realizable through stimulation of dynamic relations, it should be obvious that, if this network were to be forzen, one could construct a hierarchical structure of the concept contained in the system. Such a structure would have ambiguitics where the connecting links between three or more concepts are circuitous, i.e., when it depends upon where you start as to which concept is subordinate to which. Since the English language has a high degree of redundancy and any degree of precision is often lacking in our attempts to define various concepts, we see how rapidly this hierarchical structure dissipates into a myrad of paths leading everywhere. Yet we can build such a hierarchy of concepts, when pressed, indicating that this is a necessary part of the simulation model for verbal communication.(4)

ILLUSTRATION

The hierarchy of concepts may be distinguished in several ways. All of these hierarchies are interconnected and influence the meaning we give to any particular concept. We may talk about the affective concepts which culminate in the three major dimensions of Osgood (5) (evoluative, activity and potency). Each concept we encounter has associated with it varuous aspects of these dimensions. Concepts may also be ordered according to their subject area, or by categories such as Roget's Thesaurus uses, or as the rhetoricians have presented.(6) It should be noted that these hierarchical structures are not super-imposed upon the concepts contained in the knowledge bank but rather evolve from the relations developed in the concept structures. In this way it follows that concepts from many different hierarchical structures may be associated with any given concept, and depending upon what focus you choose around which to structure your hierarchy, you find that other concepts become subordinate to the concepts found in your main structure. It is this

ILLUSTRATION

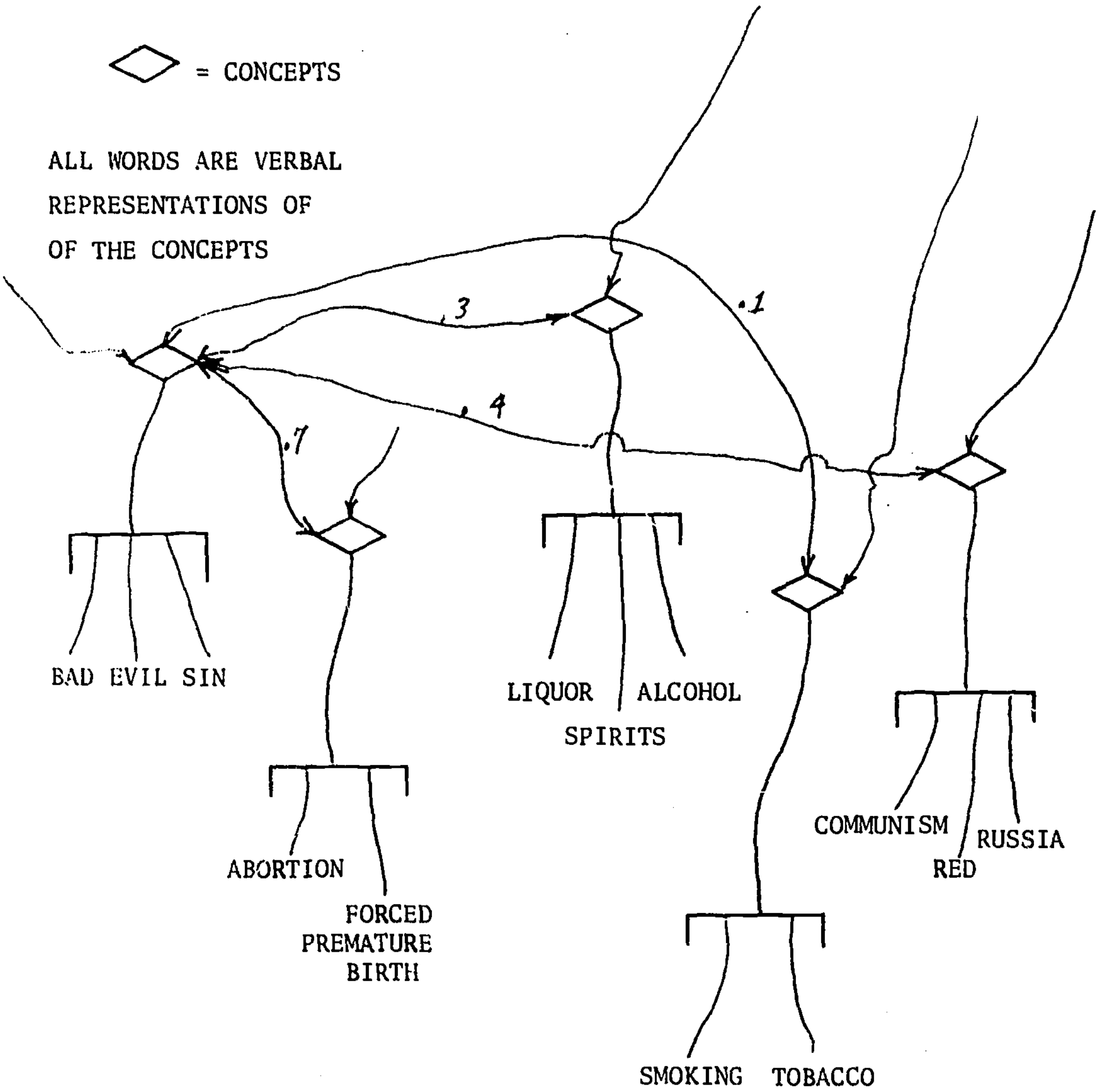


All connecting lines are two way. Therefore, one can start at any node and progress to any other node. There are also many different routes by which this process can be accomplished. Given this type of network, it follows that the hierarchy of concepts depends on where one starts.

mechanism which allows us to start at any concept and proceed to any other, establishing new hierarchies as we search our memory.

The association of concepts in our memory plays a major role, in how we decode and/or encode verbal signals. The fact that many of us have automatic (learned) triggering of a given affective concept (say, the concept represented by Bad, Evil Sin, etc.) when we decode various, highly diversified substantive concepts such as adultery, abortion, smoking, liquor, communism, etc., is an example of the multiple associations established among some concepts. Any time one of the substantive concepts is decoded the affective concept may also be triggered and, if so, becomes part of the meaning generated by the input signal. If this automatic triggering is strong enough it may block the decoding of the rest of the input signal. Automatic triggering will be handled in ARIS by computing a probability factor from the frequency of association of any two concepts in the concept structure (the neurological counterparts for this may be contained in the production of RNA and its associates). Thus the automatic association of two concepts may change with usage (Learning?).

EXAMPLE I


= CONCEPTS
ALL WORDS ARE VERBAL
REPRESENTATIONS OF
OF THE CONCEPTS
.3
.1
.4
.7
BAD EVIL SIN
LIQUOR ALCOHOL
SPIRITS
ABORTION
FORCED PREMATURE BIRTH
COMMUNISM
RUSSIA
RED
SMOKING TOBACCO

When a sentence is decoded, how do we know what has been said? As the verbal stream is processed, concepts are triggered. These usually remain open, that is, the many paths leading from them to concepts are not closed until the input is complete. Closure is then instigated. The resulting ring structure is the meaning we get from the input. The activation of this ring structure (meaning) is remembered through the development of the automatic triggering probability. Inherent in what I have already said is the fact that the focus one is operating under while decoding has a definite affect on the automatic triggering of an associated concept when the target concept has been decoded.

Let's work through an example to see how ARIS will function. Given the input sentence "I HEAR LOS ANGELES IS SINKING." and skipping over much of the linguistic decoding process we might have the following:

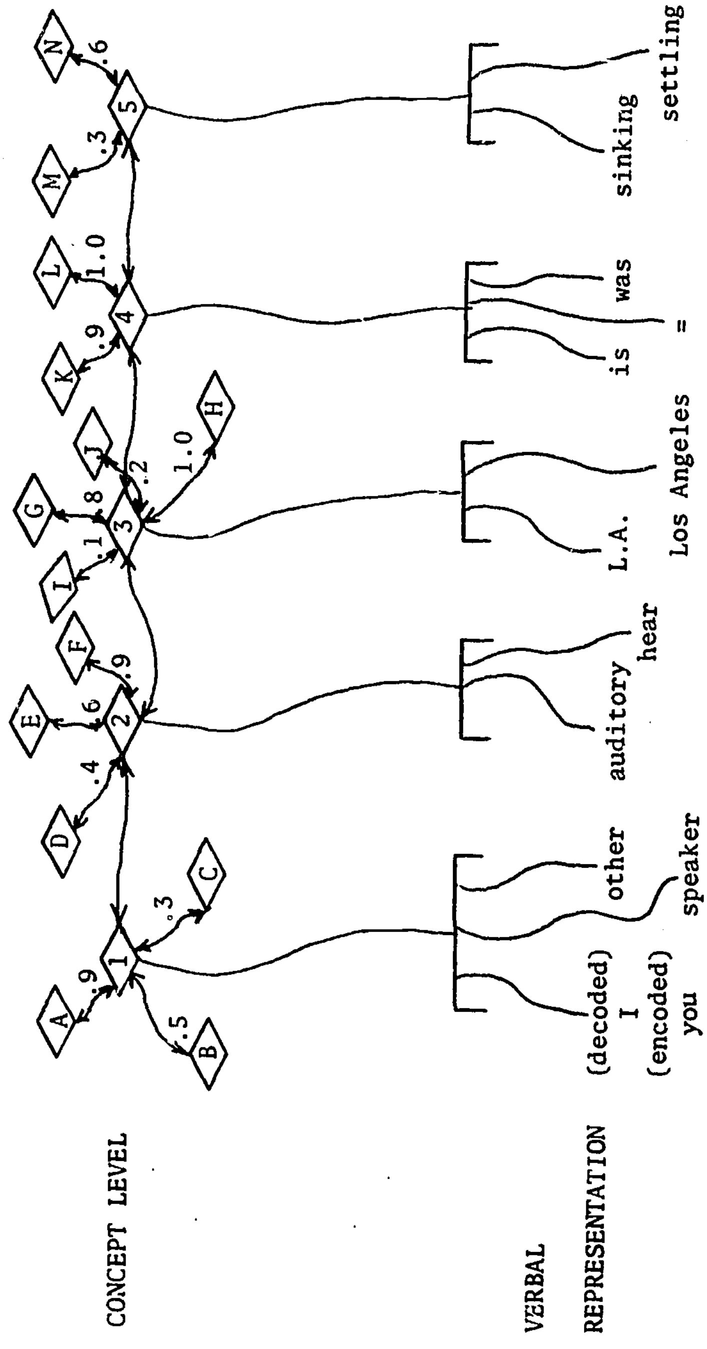
EXAMPLE II

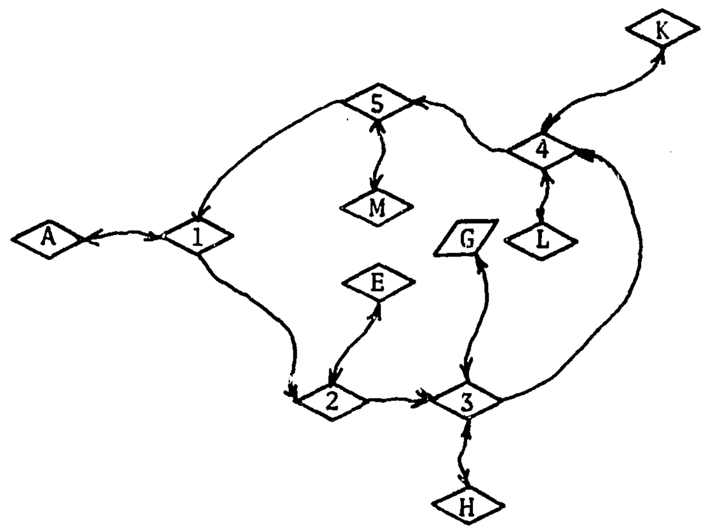
where concepts A-N might be represented verbally by

A= Positive affection
B= Honesty
C= Egotism
D= Understand
E= Know
F= Think
G= Negative affection
H= SMOG
I= Pretty
J= Familiarity
K= Active
L= Presently
M= Destruction
N= Fear

The resulting ring structure, depending on the focus of the decoding, might be

EXAMPLE II


CONCEPT LEVEL
VERBAL REPRESENTATION
A B C D E F G H I J K L M N
1 2 3 4 5
.9 .5 .3 .4 .6 .9 .1 .8 .2 1.0 .9 1.0 .3 .6
(decoded) I
(encoded) you
other
speaker
auditory
hear
L.A.
Los Angeles
is
was
=
sinking
settling



Because concepts 1 and 2 trigger off positive subconcepts A and E the resulting positive statement (concept 3, 4, and 5) develop a stronger probability of automatic triggering if any one of them is decoded from verbal input or encoded for verbal output. In this way the knowledge bank is developed and various hierarchical structures emerge.

The complexity of this system should be apparent to all. The simple sentence used in the above example could have many more possible results than the one given. If the first person I is not known, the whole sentence might be discarded with only minimal strengthening between the concepts represented by LOS ANGELES and SINKING. On the other hand if a strong relation exists between these two concepts already this will help to establish the integrity of the speaker. Thus the speakers identity must be known to the system. Identification of speakers for ARIS is provided at sign on time. ARIS, like humans, relates each user to a hierarchy of concepts represented verbally by trusted friend, friend, acquaintance, etc. Thus if the speaker uses the third person, "Jack said that Los Angeles is sinking" the evoked ring structure would involve ARIS' feelings about Jack. If it knows no Jacks, then its immediate reply would be "Who is Jack?" since it could not complete closure.

One cannot possibly keep track of all the steps taking place in a system such as this. To try and do so is self defeating. Therefore the system is composed of algoriths which compute automatic triggering probabilities, store appropriate data, build lexical entries, etc. Since the whole system is a network of relations forming hierarchical strata, much of the bookkeeping of other systems is unnecessary. It is impossible to discuss many of the problems and the solutions to these problems in a paper of this length. Further, many of the problems that are known have not been solved yet, nor are we fully award of all the problems we shall encounter. However, we do have a few answeres, a few theories, and a few ideas about how the whole system can be developed. With a little luck and a lot of hardwork I think ARIS will become a reality.

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