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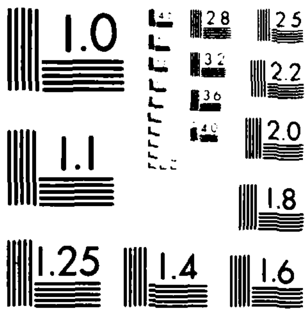

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REPORT T-119 DECEMBER 1982

UNDERSTANDING AND REPRESENTING NATURAL LANGUAGE MEANING

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During this contract period we have: (a) continued investigation of events and actions by means of representation schemes called "event shape diagrams"; (b) written a parsing program which selects appropriate word and sentence meanings by a parallel process known as activation and inhibition; (c) begun investigation of the point of a story or event by modeling the motivations and emotional behaviors of story characters; (d) started work on combining and translating two machine-readable dictionaries into a lexicon and knowledge base which will form an integral part of our natural language understanding programs;

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(e) made substantial progress toward a general model for the representation of cognitive relations by comparing English scene and event descriptions with similar descriptions in other languages; (f) constructed a general model for the representation of tense and aspect of verbs; (g) made progress toward the design of an integrated robotics system which accepts English requests, and uses visual and tactile inputs in making decisions and learning new tasks.

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Annual Report for the Office of Naval Research

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1. Abstract

During this contract period we have: (a) continued investigation of events and actions by means of representation schemes called "event shape diagrams"; (b) written a parsing program which selects appropriate word and sentence meanings by a parallel process known as activation and inhibition; (c) begun investigation of the point of a story or event by modeling the motivations and emotional behaviors of story characters; (d) started work on combining and translating two machine-readable dictionaries into a lexicon and knowledge base which will form an integral part of our natural language understanding programs; (e) made substantial progress toward a general model for the representation of cognitive relations by comparing English scene and event descriptions with similar descriptions in other languages; (f) constructed a general model for the representation of tense and aspect of verbs; (g) made progress toward the design of an integrated robotics system which accepts English requests, and uses visual and tactile inputs in making decisions and learning new tasks.

2. Introduction

During the past reporting period, we have concentrated on understanding language that requires the representation of time, space, physical mechanisms, causal relationships, and the motivations of event participants. Major new ideas and research methods during the past year include the following:

a. The use of "event shape diagrams" to represent verb and adverb meanings. Event shape diagrams are based on the idea that verb meanings can be decomposed into a set of predicates whose values vary together through time. Thus, the verb hit can be decomposed into the following predicates: trajectory, position, velocity, contact, force, etc. These predicates, along with adverbs (quickly, hard, softly, etc.) and knowledge of object properties, allow programs to make inferences about object behavior such as breaking, bending, shattering, deflecting, etc.[1]

b. We have programmed a new type of model of natural language processing that selects appropriate meanings for words and sentences by a process of activation and inhibition between different word senses and the context in which words are used.

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[1] A detailed account of event shape diagrams was reported in our last progress report, T-114, Coordinated Science Laboratory, University of Illinois, May 1982.

c. We have begun investigation of the point or moral of a story or event description. This work involves modeling the motivation, reasoning, and emotional behavior of both the participants and the narrator of the story or event, and understanding the metaphorical usage of words. Some preliminary programming work has been done on metaphor understanding based on event shape diagrams.

d. We are designing mechanisms for automatically combining and translating two machine-readable dictionaries into a lexicon and knowledge base that will form an integral part of our natural language understanding programs. Different word senses will be represented by a set of special predicates called primitives, by event shape diagrams, and other schemas we are now investigating.

e. We are constructing a general model for the representation of role-based cognitive relations. Evidence from four languages (English, Spanish, Basque, and Mandarin) indicates that relations between actors and objects can be expressed syntactically (for example, by the use of word order), morphologically (for example, by means of word endings) and semantically (for example, via semantic roles such as <u>actor</u>, <u>goal</u>, <u>location</u>, <u>time</u>, etc.). These primary distinctions are intended to serve as the basis for a representation language which enables us to map natural language expressions onto cognitive representations, and vice versa.

f. Tense and aspect of verbs have been studied for several languages, and a general representation model constructed. Tense and aspect refer to the meaning changes induced by adding auxiliary constructions to verbs. Our model aims to systematically assign appropriate meaning structures to phrases such as: <u>would have hit</u>, <u>had hit</u>, <u>attempted to hit</u>, <u>almost hit</u>, and <u>allowed to hit</u>. These models are now being programmed into an event meaning representation system.

g. We are designing a robust robotics system which will use natural language input and feedback from human language users to make decisions and perform goal-based tasks The system is based on a high-level programming language which represents a task as a series of goals and subgoals. Knowledge about goals enables the system to request information from other systems (for example, visual or tactile) when completion of a subgoal required to achieve a main goal is blocked. The system will also rely on information from its subsystems in the process of learning about new tasks.

3. Parallel Network Natural Language Processing

3.1. Goals of this Research

Natural language processing requires the cooperation of many kinds of knowledge, both language-specific knowledge and "real-world" knowledge. Much of the current research in NLP, in this research group and elsewhere, is concerned with the problems in the representation of knowledge. Our research on parallel network natural language processing, on the other hand, addresses itself to the problems in the cooperative application (or, interactive integration) of knowledge.

Specifically, we have been looking at highly parallel and analogue techniques for the cooperative application of knowledge expressed in standard structures (e.g. grammars, case structures, scripts, etc.) to language processing. (Evidence for parallel integrated processing has been reported [Marslen-Wilson and Tyler, 1980], and AI researchers have started talking of integrated processing [Schank and Birnbaum, 1980], but the models put forth have been serial and top-down.)

In a concurrent effort, we are looking towards parallel computer architectures to support these techniques.

3.2. Methods

Our method is an experimental, and highly computational one. Rather than taking a tightly circumscribed subproblem of language processing, collecting examples of how humans deal with the subproblem, and writing a program which approximates it, we are looking at the kinds of decisions needed in a host of subproblems, assuming that these decisions need to interact, and we are hypothesizing mechanisms which can account for both the decisions and their interactions. Thus we do not suffer from the "big switch[2]" problem, nor the "chicken and egg[3]" problem, but still have problems, mainly in the lack of expressive power of our computers. With this in mind, we are scaffolding our way to a natural language understanding system through a series of programs, each building on and refining its predecessor.

Currently, our model fuses ideas from semantic network representation schemes, including structured inheritance [Brachman, 1978], marker-passing algorithms [Quillian, 1968], and virtual copies [Fahlman, 1979], with concepts

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[2] If A. writes a program for syntactic analysis, B. writes a program for pronoun resolution, C. writes the noun phrase handler, D. writes a script selector, etc., how do they fit together?

[3] Researchers still argue whether the "syntax box" feeds the "semantics box" or vice versa.

[4] The current serial computer architectures and languages are computationally powerful enough (theoretically) but not expressively powerful enough to enable us to easily write the programs we envision. Consider writing a PL/1 compiler on a Turing machine!

from cooperative computation, mainly, spreading activation and lateral inhibition [McClelland and Rumelhart, 1981; Feldman and Ballard, 1982]

More specifically, we are designing a virtual machine which will **uniformly handle several aspects of language processing which have,** historically, used different "boxes", including:

(1) assignment of syntactic structure;

(2) selection of lexical categories;

(3) selection of word senses;

(4) filling of case roles;

and

(5) use of contextual constraints.

The current machine model includes several concurrent processes that operate on a weighted, labeled network: Input stimuli (i.e words) cause **breadth first instantiation of certain nodes and their active neighboring** concepts into a "short term memory," where patterns (already in this memory) "fire", and perform **purposeful connection, of the newly created nodes to** existing structure. The dual processes of **spreading activation and lateral** inhibition work together to select well-connected and consistent structures over disconnected fragments, and those nodes that become inhibited past a certain threshold are subject to **termination, whereby they are disconnected** from the network.

This model is similar to research in progress at the University of Massachusetts, [Gigley, 1982], at Carnegie-Mellon [Thibadeau, Just, and Carpenter, 1982], at the University of Rochester [Cottrell, 1982], and at U.C. San Diego, but is much more computationally oriented than any of them.

3.3. Progress

Progress has been made over the past year in several areas, and each will be discussed separately.

3.3.1. Progress in Application

Working on small examples, we have shown the applicability of this style of processing to the interactions between various kinds of knowledge, including lexical, syntactic and semantic. For example, consider the (syntactically) ambiguous sentence:

John ate up the street.

We manually set up a network for this sentence based on the output of a chart parser [Kay, 1973]. Using a proportional activation/inhibition process [McClelland and Rumelhart, 1981] the network was confused at first, but stabilized on the locational reading of "up". Next, the weights in the network were adjusted to represent a lexical preference for interpreting "up" as an particle, and the network quickly selected all nodes participating in the comical reading of the sentence, the one in which John ate concrete. Finally, some semantics were added, filling in the LOCATION case of "ate" with "up the street" and the normal sentence reading was again selected. These results were reported at the Cognitive Science Society 1982 Conference in August [Pollack and Waltz, 1982].

One of the original uses devised for spreading activation systems was memory priming [Collins and Quillian, 1972] and context [Ortony, 1976]. We have experimented with this type of contextual pressure in the sentence:

John shot some bucks

In a null context, the constructed network was unable to make a decision between the "fired at" and "wasted" readings of "shot" and the corresponding "deer" versus "money" reading of "bucks", but when the network was slightly perturbed in favor of either, (as if there were a preceeding context "While hunting," or "While gambling") the confusion rapidly cleared up. These results will be reported in in detail in a forthcoming paper.

3.3.2. Progress in Computational Models

Four versions of the program have been written, incorporating more and more of the proposed model. The first version did not have labeled links, and was just an experimental vehicle for understanding the nature of activation and inhibition. The second version incorporated a primitive semantic network superimposed on the weighted network, but had no dynamic construction capability; the networks had to be built by hand. The third version included some of the ideas on breadth-first instantiation and connection, but the pattern system was not robust enough. The fourth version is undergoing refinement (read "debugging") currently and has incorporated several efficiency and expressiveness improvements, including the removal of floating-point operations in favor of scaled integers, and a better language for network initialization.

3.3.3. Progress in Architecture

Probably the most important question in Computer Science today is how to effectively build and program highly parallel architectures to take advantage of the economies of large scale integrated circuitry[5].

With this in mind, we have designed part of an architecture for the parallel simulation of activation/inhibition networks. It is organized as a linear array of cells in NMOS. Each cell in the hardware corresponds to a node in a network, and has a register holding its activation value and a self-sorting array holding its links. In a fixed and finite amount of time, all the cells can send contributions to a programmed set of other cells, receive all

[5] [Backus, 1978] points out the need for alternative models of computation to free the mind of the shackles of seriality; [Sutherland and Mead, 1977] discuss the constraints on VLSI architecture design.

the contributions sent to them, and update their activation registers. The crucial element in the achievement of this performance is the recognition that messages heading towards the same location may be added together because they are numeric. The architecture takes advantage of this knowledge by adding messages whenever possible, rather than after they reach their destination. More details of this architecture are given in Working Paper 31 [Pollack, 1982].

3.3.4. Progress in Theory

Besides continuing work on refinement of the model and of the program, and on their application to more difficult problems in NLP such as pronoun resolution and nominal compounds, we are investigating the formal mathematical behavior of such networks. Activation and inhibition approximately solve the following graph-theoretic problem:

> Given a graph, G = {V,E} where E is the union of two disjoint sets B (black edges) and R (red edges), find a maximal subset of V, V', such that the graph induced by V' is black-connected with no red edges.

Consequently, we are working to understand the computational complexity of this problem: If it is NP-complete (or NP-hard), then activation and inhibition may provide a good parallel approximation algorithm for these difficult problems; if it is P(olynomial), then there may be a very efficient way to program a network simulation on current generation computers.

4. The Role of Affect in Narrative Comprehension

4.1. Goals and Implications of the Research

The goal of the present study is to develop a structural model of emotion which will be suitable for computer implementation. Following Lehnert's definition of an affect unit[6] the first part of the study will attempt to identify affect units which commonly occur in short stories, such as fables or folktales. Once a set of affect units has been identified, children and adults will be experimentally tested on their ability to recognize affect units, and to make inferences on the basis of affective information. The final stage of the project will consist of the construction of a computer model for story understanding which is capable of affective inference-making. Ideally, the implementation will reflect aspects of human performance consistent with the experimental findings. The implications of the present research are two-fold: (1) to construct a highly integrated model of natural language processing, and (2) to advance cognitive science in the areas of knowledge representation, language understanding, inference, and learning.

4.2. Previous Research

While language understanding systems in artificial intelligence have focused on knowledge structures such as frames [Minsky, 1975], scripts [Schank and Abelson, 1977] and goals [Wilensky, 1978], considerably less attention has been devoted to the role of affect in natural language processing. In psychology, there have been a number of attempts to develop a structural theory of the emotions [Osgood, 1966; Roseman, 1979, in preparation; and Brewer, in press]. Roseman, for example, indicates that emotional reactions are based on the cognitive dimensions Availability, Desirability, Probability, Agency, and Legitimacy. In various combinations, these dimensions give rise to 13 discrete emotions: Joy, Relief, Hope, Liking, Pride, Distress, Sorrow, Fear, Frustration, Disliking, Anger, Regret, and Guilt. Anger, for example, may result from the perception that some agent (Agency dimension) is preventing us (Probability dimension) from obtaining some goal (Availability dimension) that we want (Desirability dimension) and deserve (Legitimacy dimension). An early goal is to compare Roseman's work with similar taxonomies in order to identify redundant categories and/or possible omissions.

In artificial intelligence, interest in emotion has been promoted by research on memory representation and story summarization [Lehnert, 1980; Dyer, 1982]. Lehnert claims that narratives can be represented in terms of three primary affect states: states associated with positive events, states associated with negative events, and states associated with internal needs or desires. In addition, Lehnert specifies four types of connections, or affect links, which describe an oriented arc between any two states. A MOTIVATION

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[6] Lehnert uses the term "affect unit" to describe affective causal relations among events in a narrative. The affective unit for retaliation, for example, consists of the following causal sequence: A given event results in X's success and Y's failure. Y's failure motivates him to bring about an event which ensures his own success and X's failure. Y experiences happiness as a result of X's misfortune.

link, for example, connects a positive or negative event to a need state. Other affect links include ACTUALIZATION links, TERMINATION links, and EQUIVALENCE links. According to Lehnert, states and links can combine to produce affect units, which are capable of representing different types of plot structures.

While Lehnert's work provides an appropriate starting point for the identification of emotional primitives and complex emotional units, Lehnert's representation system requires further empirical justification. For example, are affect units reliably recognized by readers? How are readers able to make inferences on the basis of affective information which is not explicitly stated in the text? How does affect interact with other types of knowledge structures, such as beliefs or values? These are some of the questions which we intend to address in the present research. hopes to address.

4.3. Methodology

The present study will be carried out in several stages, employing research methods from experimental psychology and artificial intelligence. The first stage (currently underway) is to identify (1) a set of emotional primitives, and (2) a set of affect units which commonly occur in short stories, such as fables or folktales. Once a set of affect units has been identified, children and adults will be tested on their ability to recognize affect units, and to make inferences on the basis of implicit and explicit affective information. The hypotheses which will be tested are as follows:

(1) The recognition of affect units is necessary for the comprehension of short stories, such as fables or folktales.

(2) Stories which contain well-formed[7] affect units are more cohesive and, thus, easier to understand than stories which don't.

(3) There is a developmental progression in the ability to make affective inferences on the basis of inexplicit affective information. That is, the youngest children will have the most difficulty interpreting stories in which some degree of empathy or emotional perspective-taking is required.

(4) There is a developmental progression in the ability to generalize familiar affect units to new situations. That is, the youngest children will have the most difficulty interpreting stories which consist of affect units which must be learned by analogy to a preceding story.

The final stage of the project will include the construction of a story understanding system which will be capable of making affective inferences on

[7] Presently, I know of no independent criteria to support the notion of well-formedness for affect units. Hopefully, we will be able to predict acceptable patterns of co-occurrence and sequential occurrence of emotional reactions by means of statistical techniques such as factor analysis.

the basis of (often) incomplete or inexplicit information. Ideally, the implementation will reflect aspects of human performance consistent with the experimental findings (for example, what kind of information is required for affective frame selection and role instantiation). Finally, constructing a model of affect will require an understanding of the interaction between affective knowledge and other knowledge sources, such as beliefs and values. Since such topics have been relatively unexplored in artificial intelligence, the construction of a fully integrated system of the sort proposed here is particularly timely.

5. Automatic Lexicon Building

5.1. Goals

This paper describes work aimed at the eventual construction of an automatic lexicon-builder[8] for natural language processors. The lexicon-builder will use the vast amount of information in common dictionaries, transducing it into a form more appropriate for natural language processing. A major intermediate step in the project is the formulation of an internal representation sufficient to record all the information contained in common dictionaries. The availability of an automatic lexicon-builder would enable rapid development of natural language processors by freeing the system developer from hand-coding large lexicons, therby enabling him/her to concentrate on larger problems.

5.2. Background

Natural language processors store a great deal of their knowledge in word definitions and in schemas[9]. Assembling this knowledge by hand is becoming impractical as increasingly larger and more comprehensive lexicons become necessary. Vast lexico-semantic knowledge will be needed for industrial strength natural language processors, and perhaps more pressingly, for advanced research in Artificial Intelligence, Linguistics, Cognitive Science, and other areas. DeJong's work in schema learning [DeJong, 1982] addresses this issue on the level of "real-world knowledge." Automated assembly would certainly speed the construction of larger lexicons, and in all probability, yield a more thorough and internally uniform product than hand construction.

Dictionaries may be of some help in automating lexicon construction. They contain morphological, syntactic, semantic and usage information that must be included in a lexicon. We should be able to take advantage of the inherent structure and regularity of dictionaries. Amsler [Amsler and White, 1979] has already begun to catalogue some of that structure. Further work in this area is vital.

5.3. Knowledge Representation for Verb Meaning

One important goal of A.I. work in natural language is the formulation of a representation system adequate to encode the knowledge humans use to communicate about their world. Many formalisms have been invented for representing both highly specialized and general, common-sense knowledge. Schank's system [Schank and Riesbeck, 1981; Schank, 1975] is very powerful, but it is not "fine-grained" enough to capture many important details of

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[8] In the following discussion, I use the word <u>dictionary</u> to mean the printed (or machine-readable) books published by such companies as Random House, Merriam-Webster, etc. By <u>lexicon</u>, I mean the component of a natural language processor which holds the program's knowledge about words.

[9] Frames, scripts and schemas belong to the same genus of data structure. The word "schema" is used here to refer to all three, since schemas are the most general of the group.

meaning. For example, in Schank's system the verbs in Figure 1 all map into the same conceptual dependency primitive, INGEST. The similarities are apparent, yet the differences in meaning evaporate when all these verbs are reduced to their common element of "motion-resulting-in-containment." [Waltz, 1982]
In addition, there are many verbs whose representation within the system is grossly inadequate. The verbs in Figure 2 all map into the conceptual dependency primitive STATE-CHANGE. Clearly they all do involve some change of state, but the exact nature of the change is not specified. A more powerful representation is certainly required to record and reason with a fuller range of the nuances available to natural language speakers.

Although dictionaries define words in terms of other words, and not in terms of conceptual primitives, they still embody a representation system. It may be that the words used in definitions are just synonyms for unnamed primitives. If so, this will be revealed by careful study. We may also hope to extract the relations between words that dictionaries employ in definitions (e.g. IS-A; IS-PART; various case-argument roles such as INSTRUMENT, AGENT, OBJECT; causal relations; topological relations; spatial relations; evolutionary relations; and others). Because they define words using more words, it is inevitable that dictionaries contain cycles. I expect that these cycles are not meaningless, but rather, may conceal information that could lead us to the abovementioned primitves and relations. Dictionary studies will serve to justify the relations that are currently employed in Artificial

eat	drink	breathe in	inoculate
eat up	swig	inhale	inject
nibble	sip	smoke	shoot up
wolf	swallow	respire	.
gobble	gulp	gasp	.
overeat	imbibe	.	.

INGEST
Figure 1.

divide	shatter	slice	bend
separate	smash	crack	tear
connect	scratch	warp	chip
join	cut	wear	crease
slide	shake	spread	open
scrape	waver	congeal	close
fall	roll	dissolve	block
grow	turn	flow	fill
shrink	veer	precipitate	add
rise	swerve	swirl	remove

STATE-CHANGE
Figure 2.

Intelligence work, and will likely turn up some new ones. Nearly every concept that has a name in English has an entry in a good dictionary. This leads us to expect that a representation system derived from dictionaries will be closer to adequate than current systems.

5.4. Limits of Dictionaries

Clearly, there are limits to what we can learn from dictionaries. There are issues they do not address. For example, the American Heritage Dictionary [Morris, 1970] defines "needle" as:

1. A small, slender sewing implement, now usually of polished steel, pointed at one end, and having an eye at the other through which a length of thread is passed and held.

But it says nothing about:

a) how the needle is used in sewing (i.e. that it is forced through the materials to be joined, pointed end first, dragging the thread through the hole it has made, causing the thread to bind the materials together;

b) how small is small;

c) what they used to be made of;

d) how the thread is held in the eye;

e) what is an "eye?"

"Sew" is defined as:

1. To make, repair, or fasten with a needle and thread.

2. To furnish with stitches for the purpose of closing, fastening, attaching, or the like. Often used with up: sew up a wound.

We still have no information about how or why sewing works (see point a, above). For "stitch" we have:

1. A single complete movement of a threaded needle in sewing or surgical suturing.

2. A single loop of yarn around a knitting needle or similar implement.

3. The link, loop, or knot made in this way.

The problem is that our dictionary does not tell us about the <u>process</u> of sewing. In exploring dictionaries for the purposes outlined above, it is a good idea to keep track of the places where dictionaries are inadequate. From there we can proceed to find other sources for the missing information.

5.5. Conclusions

To summarize, my research is currently oriented along the following lines.

1. Analyzing dictionaries to uncover their structure both within word entries, and on the macroscopic level. Progress in the areas below will hinge on the results of this analysis.

2. Formulating a representation scheme. This includes isolating primitives, and developing a logic for primitives and relations.

3. Devising and testing methods for converting a dictionary to a lexicon.

4. Determining what information cannot be found in dictionaries.

5. Finding other sources to compensate for this deficiency.

In conclusion, I believe that the dictionary is a large untapped resource. My goals are to use dictionaries to facilitate the assembly of large lexicons; to improve currently used representation systems for language; and to extend our understanding of words and the way we use them. The dictionary is not a cure-all, but it is a useful source of information and a revealing object for study.

6. Modeling Events

6.1. Goal

The goal of the present research project is (1) to characterize a set of role-relations for the various elements involved in any given event or state-of-affairs which is both lingustically relevant and cognitively plausible, (2) to outline a system for representing the conceptualizations associated with natural language sentences in terms of those role-relations and (3) to develop a procedure for mapping natural language expressions onto such cognitive representations and vice versa.

By developing an explicit procedure for mapping between language token and conceptual representation, we hope not only to shed light on the theoretical status of "primitive cognitive relations" but to provide a sound basis for further work in the psychology of language processing as well. In addition, such a theory would present the appropriate descriptive framework for work in such applied areas as computerized natural language processing, automated translation, and so on.

6.2. Structure of Research

The project is divided into four parts.

A. The classification of role distinctions and the systems for marking these distinctions on the basis of the formal properties of a number of actual natural languages.

This problem has been approached by:

--preparing a survey which is designed to elicit the role distinctions made and the strategies employed for making them in any given natural language and administering the survey to speakers of typologically distinct languages from different geographical areas

--analysing the data gathered with an eye toward establishing a hierarchy of role classes, a listing of the distinctions made within each class, and a system for the marking of these distinctions.

B. The classification of role distinctions on the basis of functional considerations with respect to cognitive processing (i.e. reasoning, inferencing, and so on).

This problem is being approached by:

--reviewing proposals for role distinctions above and their motivations in works dealing with event analysis

--reviewing the proposals for role distinctions and their motivations in works dealing with reasoning and inferencing systems

--developing a classification of roles as motivated by the needs of these systems.

C. The development, on the basis of comparing and contrasting the results of the previous parts, of a "neutral" class of roles which would be appropriate for the characterization of a conceptual level of representation for any parser operating on natural language input or of an organizational level of representation for any natural language generator.

D. The instantiation of the results of the analysis in the form of a natural language interpretor-generator which would be tested for both adequacy and extensibility.

6.3. Summary of the Progress to Date

Work was begun in January of 1982. The initial concentration has been two pronged in that both parts A and B have been addressed simultaneously although the former has received much more emphasis up to now. Of course, parts C and D of the research cannot be approached until parts A and B are essentially completed.

A. A summary of the results from Part A

1. The preparation and the administration of the language survey

During the Spring of this year I prepared a survey consisting of some four hundred sentences and phrases in English for the purpose of gathering data concerning some fifty different role relations which nominals could potentially bear with respect to verbs or other nominals. The survey was developed along the lines of the Lingua Descriptive Series Questionnaire [Comrie and Smith, 1977] and includes roles of both a syntactic as well as a semantic nature. For instance, it covers such syntactically defined roles as:

--subject of transitive verb (agent-controller)
(e.g. John hit Mary.)

--subject of transitive (non-agent)
(e.g. John received a telegram.)

--object-complement
(e.g. They elected John president.)

--agent of passive
(e.g. Mary was hit by John.)

--concessive
(e.g. They had fun in spite of John.)

It covers such semantic role as:

--benefactive
(e.g. They wanted to win the game for John.)

--circumstantial
(e.g. John went out without his umbrella.)

--reason
(e.g. Mary lost her job because of John.)

--price
(e.g. John bought the watch for five dollars.)

--function
(e.g. John used the baseball bat as a cane.)

It also includes such locational roles as:

--interior/position
(e.g. John was in the bathroom.)

--proximate/destination
(e.g. John went up to the door.)

--superior/origin
(e.g. The plane dove down from above the clouds.)

--medial/referencial
(e.g. The taxi drove between the two pedestrians.)

--surface/parallel
(e.g. John ran his hand along the wall.)

In addition, each of the roles was viewed in three to five different syntactic contexts, in part, to uncover different strategies for marking the same relation and, in part, to better understand the nature of the relation itself. For instance, in analysing the roles of subjects as in

--The hunters left.

--The lions roared.

it is often enlightening to compare their behavior in different constructions. In this case, by comparing the gerundives of these clauses, i.e.,

--the hunters' leaving
--*the leaving of the hunters

--the lions' roaring
--the roaring of the lions

there comes to light a variation in the behavior of the subject noun phrases which may well be a result of a difference in the roles which they fulfill. Here "the hunters" are, perhaps, non-causal agents while "the lions" are causal agents. In other cases, variation of context may lead to a reinterpretation of the role being examined. For example, the preposition "for" in

--John bought the book for five dollars.

is often said to mark a price relation. However, given that price is most certainly a property of objects and that properties of objects can be explicitly stated by way of the copular construction, the ungrammaticality of

*It is for five dollars.

comes as somewhat of a surprise. As it turns out, what was at first thought to be a price relation is, in fact, a more general relation of exchange which, being impossible to interpret as a property, explains the ungrammatical copular.

During the summer, the survey was administered to native speakers of Spanish, Basque and Mandarin and the results reviewed in terms of the accuracy of the translation equivalences and the awkwardness of the target language constructions. It should be pointed out that, in addition to an expected handful of poorly constructed source language items, there are some serious inadequacies in the survey. For one, because of the size of the survey, items pertaining to temporal role relations were not included. For another, because it is virtually impossible to tell beforehand which roles are going to be impossible in which contexts, many items were included in the survey despite being ungrammatical or marginal in the source language. The result was that confusion arose on the part of the informants as to precisely what was being investigated. Finally, the survey is perhaps inefficiently long as it now stands. As I am planning on collecting data from some ten or so languages altogether, the revision and streamlining of the survey will most likely be required.

2. Preliminary results from the analysis of four languages

Across the board I found evidence for the motivation of three linguistic classes of role relations:

-- syntactic: roles necessary for judging syntactic well-formedness (e.g., the role of "subject" is necessary in order to understand why "Is raining." is not a grammatical sentence in English).

-- morphological: roles necessary for judging the morphological well-formedness of constituents within sentences (e.g., in Basque, the role of "means" is necessary in order to determine that "auto-an"(in the car) is inappropriate in "Ni autoan noa." (I am going by car)).

-- semantic: roles necessary for judging the well-formedness of propositions (e.g., the role of "location" is necessary in order to determine that "Juan puso el libro" (John put the book) is ill-formed in Spanish).

Each of the above sets of relations relies on different marking strategies and all three interdependently contribute to or derive from the cognitive representation of the event described.

The syntactic roles motivated by the languages surveyed are: subject, primary (direct) object, secondary (indirect) object, and oblique object. Some of these roles are exempified in

--[Eng] They gave Mary a present.

--[Spn] (Ellos) le dieron un regalo a Maria.
(they) her-i.o. gave-they a present to Mary

--[Bas] (Haiek) Mireni oparia eman zioten.
(they-erg) Mary-dat present-abs given it-have-her-they

--[Man] Tamen gei-le Mali yi ge liwu.
they give-past Mary one meas. gift

which contain subjects, primary objects and secondary objects. In English, one of the major marking strategies is word order; subjects precede the verb while objects follow it. The other major marking strategy is the use of prepositions; oblique objects are preceded by prepositions. The indirect object is marked either by word order (it may precede the direct object as in the example above), or by preposition whenever it does not precede the direct object. In Spanish, one of the major marking strategies is noun-verb agreement; subjects determine verb conjugations, objects determine the form of direct and indirect object clitics (i.e. pronominals like "le" in the example above which are obligatorily juxtaposed with verbs). The other major marking strategy, as in English, is the use of prepositions; oblique objects are preceded by prepositions. In Basque, the major marking strategy is again noun-verb agreement; subjects, objects and indirect object all play a role in determining the form of the verb. In Chinese, one of major marking strategies is again word order; subjects precede the verb, objects follow the verb, indirect objects precede direct objects as in the example above. The other major marking strategy is the use of pre-verbs; oblique objects are preceded by pre-verbs.

The major marking strategies for syntactic roles, then, are:

--word order

--noun-verb agreement

--prepositions/pre-verbs

while the minor marking strategies, which were not discussed, are:

--bound affixes (e.g. Harry' s horsing around)

--morphophonemic alternations (e.g. I saw them. They saw me.)

--derivational rules (e.g. subjects of gerunds undergo N > ADJ: My leaving so early)

The lexical roles distinguished fall into two general classes: event related and location related. Schematically the event related roles include:

relation	marker English	marker Spanish	marker Basque	marker Mandarin
agent-actor	--	--	-k	--
patient	--	--	-0	ba
source	from	de	-tik	cong
possessor	of/'s	de	-en	de
property	of	de	-tako	you
mode	with	con	-z	--
instrument	with	con	-z	yong
accompaniment	with	con	-ekin	gen
causer	by/ because of	por/ a causo de	-gatik	bei
benefactor	for	por	-tzat	wei
purpose	for	para	-rako	yingwei
reference	about	sobre	buruz	--
goal	to	a	-i	gei

while the location related roles are:

relation	marker[10] English	Spanish	Basque
destination	to	a	-ra
limitation	up to	hasta	-raino
direction	toward	hacia	-runtz
origin	from	desde	-tik
position	at	en	-an
contact	against	contra	-an
interior	in	dentro de	barru-an
	into	a	barru-ra
	through	por	-tik
exterior	outside	fuera de	kampo-an
	out of	de	-tik
anterior	before	delante de	aurre-an
posterior	behind	detras de	atze-an
superior	on	encima de	gain-ean
inferior	under	debajo de	azpi-an
lateral	beside	al lado de	ondo-an
	by/past	al lado de	alde-an
circumfer.	around	alrededor de	inguru-an
medial	between/ amoung	entre	-en arte-tik
parallel	along	a lo largo	-tik
perpendic.	across	a traves de	-an zehar
ulterior	beyond	mas alla de	haruntz-ago

The major strategy for marking lexical roles is, unsurprisingly, through the use of lexical or morphological items. In English, it is by way of prepositions for all roles other than those related to the direct participants in the event expressed by the verb: agent-actor, patient, experiencer. The same is true of Spanish. In Basque, the marking of lexical roles is for the most part by way of case markers in the form of bound suffixes. However, in the case of the direct participants, the language relies redundantly on noun-verb agreement while for the orientationally determined locational roles, postpositions are called upon. In Chinese, the lexical roles are marked by pre-verbs.

The semantic roles which have been tentatively identified are: actor, theme, goal, source, location, time, manner, and cause. These roles are marked by way of a variety of syntactic, lexical and morphological devices many of which are, at present, not well understood.

B. A summary of the results from Part B

The following is largely derived from a description by John Lyons of a theory of linguistics advanced by L. Tesniere which is based on event analysis [Lyons, 1978]. Any situation can be described as either a state or a happening. Happenings can be categorized as processes or events, which,in turn, can be subclassified in terms of doings or goings-on. States require the presence of some neutral entity (unmarked for role) but, beyond that, may or may not possess such circumstancial roles as time or place or the roles of attribute or class. Happenings, on the other hand, will variously require such participant roles as agent, patient, goal and source as well as the circumstancial roles mentioned above along with the roles of cause and effect. Unfortunately, the motivations for the roles in this system are in many ways linguistic and there remains a good deal more review before a solid proposal can be made.

With respect to inferencing, perhaps the most effective systems to date are those based on Prof. R. Schank's "conceptual dependency" representations [Schank and Riesbeck, 1981]. The basic set of primitive role relations posited include: actor, object, goal and source. Roles such as instrument, cause and effect are captured by way of dependencies between CDs. Again the motivation for the roles is to some extent determined linguistically; the actor and object slots in a CD, for instance, are more motivated by the existence of the grammatical relations of subject and object than by any justification in terms of event analysis. But, for the most part, the roles are determined on the basis of the kinds of inferences which the systems is meant to reason about, namely, causal connections. Again, much material remains to be reviewed before a solid proposal can be made.

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[10] Data from Mandarin has yet to be analysed.

7. Encoding the Natural Language Meaning of Time[11]

7.1. Introduction

This paper is more in the nature of a progress report than a treatise on time; it offers certain conclusions and insights stemming from our recent work in the language-universals and cognitive-universals of time. We have been concerned with understanding encoding strategies for time and why they are manifestly different from language to language. This investigation on encoding strategies has covered a variety of unrelated languages, including English, and by virtue of the fundamental association between space and time, dealing also with spatial meaning has been inevitable. This functional interdependence between time and space in perception and language has been long recognized both in psychology [Miller and Johnson-Laird, 1976; Piaget, 1956, 1964, 1969], and in linguistics [Lyons, 1978; Anderson, 1971]. Although this intimate relationship between space and time is a phenomenon of fundamental importance for a general theory of cognition and language, our reasons for studying the encoding strategy of time and space are quite different. We are primarily interested in designing and implementing computer programs that will be ultimately capable of understanding natural language meaning, and for this purpose we need to develop the ability to deal with the meaning of time and space as they are encoded in natural language. We are also interested in developing a conceptual representation of time and space that is sufficiently general as to be applicable successfully to English as well as other natural language systems such as Burmese, Chinese, Cree or any other language.

In this paper our primary goals are to present a general conceptual model of time, and to discuss the consequences of viewing the NL meaning of events, event-interval, and interval relationships in terms of that model. We do not yet know the full range of implications attendant upon a model such as this, nor are we in a position to claim that these universal concepts of time are appropriate as bases for representing time. We have only reached the stage where we can suggest as universal a list of concepts of time, and a tentative plan for using this list as basic material for representing time in natural language.

7.2. The Universal Model of Temporal Meaning

The most basic role of time lies in understanding the meaning of events in the real world. We understand events in terms of their duration, serial order of occurrence, overlappings, the aspects of beginning and concluding, and so forth, all intrinsically temporal concepts. The categories presented here and the conceptual classificatory systems proposed are all represented in all the languages surveyed. We shall refer to the natural language categories of the meaning of time as natural language metaphors.

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[11] Submitted to the Inter-Disciplinary Workshop on Motion: Representation and Perception, Toronto, April 4-6, 1983.

7.2.1. Natural Language Metaphors

Natural language metaphors for real-time meaning may be organized under three headings.

7.2.1.1. Natural Language Metaphors for Event Types

The distinction that is conceptually most basic within the natural language meaning of time is the contrast that exists between those events that are processes in time, as against those that exist as states. This is the process vs. state categorical distinction; all natural phenomena occur either as a process-type or as a state-type.

The second most basic distinction of the universal model of time is the inherent duration-type contrast; a process-type event, or a process that is in reality a state in flux, may have a duration length that is either durative or punctual.

In English, the duration span of events related to the word-sense of verbs such as "hit, blink, kick, smash, etc." is considered punctual; notice that because it is part of our real world knowledge that these durations are brief and momentary, when we use these verbs in the present progressive tense, as in "John is blinking his eyes," the meaning imparted is one of repetition of the act "blink" and not the protraction of a single act. The default meaning concerning repetition corresponds to our stored knowledge about the type of events encoded into these word-senses.

The verbs, "siphon, bathe, perform, swim, drive, etc." entail durative spans or intervals when realized in real time. In the expression "John is bathing," we do not infer a series of repeated acts of "bathe." The act "kill" seems to embody in its word-sense inventory both of the properties of the punctual and durative meanings. For instance, in

(1) John is killing me,

the present progressive tense is killing entails a meaning for kill where the agent (John) is doing things that may eventually bring about the effect of "kill." In this case, "kill" is durative. However, in

(2) Look, John is killing rats in the alley.

"kill" seems to be a punctual verb and the repetition of a series of punctual acts seems to be the most natural reading.

This probably suggests that both "punctual and durative" time values are listed as alternates in the word-sense definition for "kill." It is interesting to note that in Burmese and Jinghpaw the word for "kill" is used only in the punctual sense of time duration.

7.2.1.2. Natural Language Metaphors for Event Orientation: Aspect

Aspectual distinctions add two conceptual organizers to the available categories· boundary reference system (onset and terminal) and the values indicating the state of time flow, (progressive and completive). The boundary reference categories enable the perception of a given event with reference either to its beginning (inception in the case of the process of state change), or to its ending. The time-flow categorical distinction enables us to distinguish events in progress from those that have been completed.

Examples:

(1) Onset-progressive aspect, process-durative verb
"John is starting to siphon gas from your Volvo."

(2) Onset-completive, process-durative verb
"John has started to siphon gas from your Volvo."

The "onset" aspect is still being effected in (1), but has already been accomplished in (2).

(3) Onset-progressive, process-punctual verb
"John is starting to blink the headlights."

(4) Onset-completive, process-punctual verb
"John has (already) started blinking the headlights."

(5) Terminal-progressive, process-punctual verb
"John is stopping blinking the headlights now."[12]

(6) Terminal-completive, process-punctual verb
"John has stopped blinking the headlights."

etc.

7.2.1.3. Natural Language Metaphors for the Speakers Point of View: Tense

Natural language encoding of the temporal aspects of event meaning provides three categorically distinct vantage points from which the realization of given events is recorded and regarded. The interplay between the speaker's position and the relationship it has to an event are the crucial considerations behind this distinction. First, the speaker may place himself as an on-scene witness of the event that is unfolding, and regard the event as happening in the temporal present. Second, the speaker may retrospectively recall an event and give an account to it as having happened in a time frame already past. Third, the speaker may speculate and conjecture an event which has not yet been realized in terms of real time.

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[12] The meaning of this expression can be characterized as a script consisting of all the physical steps necessary to execute the act "stop blinking"; hand-eye coordination to locate headlight dial, placement of hand, taking hold of dial with thumb and first two fingers, muscle tone to turn off switch, etc., will be captured by this expression. The moment itself when blinking stops will be a punctual event, which is why steps leading to that moment are perceived as being prior to, rather than during, the punctual event "stop."

The first tense is present, the second past, and the third modal in traditional grammars. However, for considerations of universal application we adopt a slightly modified version of the Cree distinction and will refer to the tense categories as WITNESS, RETROSPECTIVE and MODAL. A number of reasoning exists for not retaining the traditional terms of the present, past, and future tenses. Although one may deem these terms appropriate for English, when considered against the requirements of a universal model of time in natural language, there are serious drawbacks. These terms overlook, for instance, the role of spatial concepts in encoding the meaning of time in natural language; in the vast majority of languages, mechanisms for spatial meaning (e.g. prepositions at, from, up, etc.) play crucial parts in conveying the meaning of time. The future tense is also problematic because it tends to conceal basic semantic relations and syntactic patterns. For instance, "I will come on Thursday" and "I plan to come on Thursday" yield the same inference as regards to the speaker's intention, and yet, by criteria of tense, only the former is syntactically conceptually modal in the tense value specified, meaning that both assertions indicate an action or event that have not yet been realized in real time.

Diagram I shows the conceptual model of time in natural language that we propose; the terminal items of each tree represent the primary concepts of time in natural language. In our opinion the aspect-tense meaning of time is probably adequate in its present form as a model of the kernel concepts of time; the modal among the tense concepts requires the most extensive work to be done. For conceptual as well as semantic reasons, the modal tense category embodies the future tense, potential events that may or may not actually happen, events that may be predictable from one's knowledge of habits of a given subject-actor, obligations and compunctions, etc. In other words, we have grouped together as a semantic domain those tense values which do not fall into the witness and retro tenses. The internal configuration of this complex rubric is being explored.

7.2.1.4. Conceptual Representation of Time in NL: An Illustration

Let us first schematize the categories of lexically encoded information, and then the grammatical, and finally, the conceptual representation.

In Diagram II, we give an illustration of our ideas for representing the meaning of time in the verbs siphon and hit. The concepts of time -- aspect and tense -- interdigitate with those pertinent temporal information that are part of the word-sense meaning of the verbs and yield a series of plausible natural language expressions. This may be a possible approach to the representation of time in natural language, however we realize that we have yet to investigate the ramifications possible and implications entailed by the approach.

This type of meaning representation, when combined with the sort of case-role information that the Schankian conceptual dependency provides, can, we believe, become a rich and viable system to capture the meaning of natural language.

7.2.1.5. Implications of Conceptual Representation of Time in Natural Language

Some general remarks may be made as regards our ideas for the conceptual representation of time just outlined. For one thing, this representation corresponds to the fact that the conceptual and natural language levels have a one many relationship. A single specification of reference boundary aspect, say [+onset,-term] corresponds, in English, to the semantic behavior of a class of auxiliary verbs like "begin, start, initiate, commence, get to, etc." In this relationship the higher (conceptual) level governs and constrains the lower level, the lower level is more complex vis-a-vis the higher level, etc. Further, the specification [verb,+durative] will treat all the word-senses having the process-durative values in the lexicon as fulfilling the conditions of the specification. The natural language realization of conceptual tense is another case in point; [+RETRO], for instance, will induce tense inflexion in most verbs and assign grammatical auxiliaries of tense in the other cases. For instance, "broke, got, was mad, were spirited," are in RETRO tense.

Furthermore, the coupling relationship between the conceptual and natural language levels is a principled relation. Consider this fact: we have in English auxiliaries such as "planning, trying, starting, etc."; now observe the conceptually systematic meaning behind these verbs in the following.

(1) John is planning to save money for Christmas.

(2) John is starting to save money for Christmas.

(3) John is trying to save money for Christmas.

(4) John has been saving money for Christmas.

The auxiliary mechanism "planning to save" represents a meaning of time where, in one reading, John is in the "planning" time slot, and perhaps not yet in the actual "save" slot. Therefore, in relation to the "tense" of the main verb "save," John's temporal location at the time of speaking is MOD. The meaning of "save" is thereby rendered a potential act, an intention, rather than a realtime event. There are other syntactic approaches to this meaning; e.g. "John will be saving." Whether in this instance the semantic auxiliary "plan" is chosen, or whether the grammatical auxiliary "will" is picked, similar inferences will be obtained concerning the time value of MOD tense of the main verb "save" because "plan" and "will" have, conceptually identical modifying influence on the main verb.

In (2), the onset portion of "save" has already been achieved; thus, the interval span for "save" is already in the progressive aspect.

In (3) the auxiliary "trying" expresses the progressive aspect of "save," but it also introduces new information -- the fact that "save" may not be having a successful result, hence the impression of repeated efforts to "save."

In (4) the temporal meaning of "save" is in the progressive aspect, and the perfect tense "has been" indicates that John has been at it for a long time. This is the persistive-progressive aspect, a category we have not dealt with.

The point that we wish to allude is this: syntactic mechanisms may vary if they are associated with a given conceptual function, as "will" and the auxiliary "plan" are to MOD.

In the following section we want to explore the natural language description of events by using the conceptual categories we now have to characterize it.

7.3. The Natural Language Description of Event and Event-Interval

"Events happen, states do not ... the only events that can happen are those identified perceptually as occurring as some location during some brief span of time" according to Miller and Johnson-Laird [1976]. While we will not be dealing with the problem of trying to define the perceptual meaning of event in its full setting (for example, see Waltz [1982]) we will be interested, however, in developing a framework for dealing with it in the sense of its duration and in terms of its role in understanding motion. We will draw illustrative examples from English in developing a conceptual model for understanding "event." However, since we are approaching the natural language meaning of "event" and "motion" only from the temporal perspective, our characterizations cannot possibly cover all the essential aspects. For instance, we have no way of knowing whether our approach can be conveniently linked up with conceptual dependency accounts of case-role information, and yet, it is clear to us that a full meaning representation of event/motion will not be possible until such a linkage has been achieved, and that will require far more than a preliminary suggestion.

Conceptually and linguistically, there are two interlocking components in specifying event, the kernel and the shell components. The kernel component specifies the basic or core meaning of event, whereas the shell component contains a series of modifiers of the nuclear meaning of event. In specifying the nucleus of the meaning of event the kernel component provides the linguistic-cognitive universal conceptual categories of time that we discussed in the preceding chapter. The shell component features modifiers which specify special conditions on the interpretation of the nuclear meaning of event. The following schematic constructs illustrate the components of event meaning.

Roughly, the kernel component can be thought of as where "practical and lexical knowledges" [Miller, 1977] come together, resulting in lexical selection; a verb whose word-sense matches a perceptual event to oversimplify it of course, is selected to characterize that event verbally. A given word-sense meaning (state/process; durative/punctual process) is initially specified with the selection of a verb. Next, presumably grammatical assignment of aspectual meaning is accomplished, and additional structure is thereby acquired by the core meaning of event; boundary orientation (onset/terminal), and flow-state description (progressive/completive), now provide a hypothetically adequate basis for characterizing the event (see Diagram II). Further, the grammatical tense meaning provides communicative salience by channeling event meaning through one of three possible perspectives (speaker as on-scene witness, speaker in retrospective mood, or speaker as speculating the potential and possible happening, whether already realized or not of an event).

These items of information provide the basic milieu of event meaning. Should there be reason for modifying in some way the nuclear configuration (see Diagram II), the shell component will provide the mechanism. To show the domains of conceptual and semantic functions involved in specifying the primary meaning of event in time the following schematization may be made.

In terms of natural language correlates, the shell component contains such modifiers, auxiliaries, and other time expressions, many of which are in the form of adverbial expressions. We shall give illustrations of these within a taxonomic schema of modifiers of basic event meaning.

The shell component is made up of two basic types of modifiers of the basic meaning of event, the adverbial modifier system and the auxiliary modifier system. The distinction is overtly syntactical but primarily a semantic-conceptual distinction. The shell functions seem to form a natural taxonomy in the following way.

7.3.1. Locative Reference Time

This modifier function may be manifested in the surface syntactic configuration as a prepositional expression (see (1a), below) or as time adverb (see below).

(1a) I saw Ambrose at noon.

Here, "at noon" is a locative reference point of time realized as a prepositional expression, as is also the case with "in 1808," next.

(1b) Franz Joseph Haydn died in 1809.

(2a) Ambrose was building superintendent here from May 1964 to June 1981.

(2b) I waited for Ambrose from noon till six today.

In (2a,b) the locative reference item is specified in the form of duration intervals. Locative reference time provides the basic description of event with concrete landmark reference.

7.3.2. Auxiliary Modifiers

The auxiliary modifer function of time in the shall component may be a grammatical form, as in "will begin to broadcast," or a verbal-semantic form, as in "expect to begin to broadcast." The typology of auxiliary modifier functions[13] that we have adopted is based upon the interaction pattern between the time value of the main verb (MV) and the auxiliary (AUX). There are three clear patterns.

(3) John is trying to get home for Christmas.

The time value of the auxiliary "try" is a functional part of the temporal value of the main verb "get," and the direct witness (present) tense meaning indicates that this temporal relationship between the auxiliary and the main verb is a real-time interaction. John is, in fact, already engaged in activities that will contribute directly to his being able to "get home for Christmas." The auxiliary has no time value that is independent from the value specified for the main verb.

Now consider the next example.

(4) John plans/intends/hopes/expects to get home for Christmas.

The time value of the auxiliary here cannot be taken as being within the real time frame of the main verb; in fact, the meaning of "expect, hope, intend, ..." may be in the nature of mental states, and not real-time actions. The interaction between this type of auxiliary and the time valueof the main verb is modal; in other words, if John occupies at the time of speaking, the "intend, plan, hope ..." frame, then "get home" is really no more than a declared goal. Hence the modal pattern.

The grammatical auxiliary will/would, may/might, etc., behave correspodingly in their interaction with the time value of the main verb.

Finally, the auxiliary "suppose" deserves a special mention; we have designated this modifier as modulatory because in addition to modifying the time value of the main verb, it also introduces other factors. Although it is not a modifier of time per se, as the other auxiliaries are, it is nevertheless included for the reason that "suppose" does not appear to allow a witness tense reading, as may be observed in the next examples.

(5) I suppose that I will fly to Seattle. (a MOD tense)

(6) I suppose that I did fly to Seattle that time. (a RETRO tense)

(7) I suppose that I fly to Seattle. (a direct WIT tense -- ambiguous meaning)

(8) I suppose I am flying to Seattle. (a MOD tense inference)

The pattern to notice here is the impossibility of a direct witness tense, as in (7), showing that there is a tense constraint associated with the modifying

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[13] See the right-hand branch of Diagram IV.

function of the auxiliary "suppose"; it can function only in the modal and retro tense environments. In psychological terms, these tense types are "mental time," as against the real-time of the witness tense. For instance (7) is completely acceptable if the intended reading is that one, a pilot for instance, regularly flies to Seattle. The point to note is that regularity or habituality is not in itself a real-time event, and hence not a WIT tense, but rather a MOD tense.

The auxiliary "suppose" modifies more than the time value of the main verb, it changes the color of intentionality altogether. However, this is beyond the scope of our present concern.

A schematic for the shell component of event may be given as follows.

7.3.3. Iterative Modifiers

A special variety of adverbial modifiers of time are iterative functions which provide the logical mans for describing repetitive occurrences in time, including linear order of succession of events, and the various manners of overlapping relationship between grups of events. Some examples of these are given in the following.

Repetition of act in time

(9) Every morning, Ambrose would stand by the door and greet you, day in and day out, year after year, until he retired.

(10) See how John keep hitting her, again and again?

(11) We hold this family reunion annually.

Order of succession in time

(12) First John came, then Bill arrived, then Jill, then Tim, then Sophie ....

(13) Sophie was last to get here, and Tim before her, Jill before Tim, Bill before Jill and John before everybody.

(14) John was first, Bill second, Jill third, Tim next and Sophie last.

It is obvious that specifying the order of succession, or linear sequencing, follows procedures based upon the principle of ordinal relationships; and since ordinal numbering is a logical process, counting may be flip-flopped to suit the need of the speaker, as indicated in (13) and (14), especially clearly.

The natural language description of event sequences may refer to boundary landmark references, as in

(15) We are trying to start our journey to Tibet but Bill over there must first finish up his packing.

or to temporal-flow aspect, as in

(16) We are trying to start our journey but Bill there is still packing.

Also

(17) We have finished preparation for starting except for Bill who's still packing.

Facets of aspectual meaning of events display sequencing relationships in these examples. Sequencing and overlapping relations concern only multiple events.

Overlapping intervals

The natural language description of interval relationship that overlap employs such function words as "during, while, through, when ...." These descriptions may present two intervals without reference to boundaries, as in

(18) While I was watching TV Tom was doing his homework.

(19) When I was watching TV Tom was doing his homework.

In principle, these descriptions imply that there was full durational overlapping between the two intervals. Partial overlap is described by means of encoded reference to event boundaries.

(20) I was arriving at the party but Tom was leaving.

Here, "arrive" and "leave" are two separate intervals which may well overlap fully, but each overlaps with the interval "party" only partially. Presumably, one never occupies an entire "party" interval trying to "arrive" or trying to "leave" it. Since the span of the interval "party" is far longer than the other two intervals only partial overlap will be possible in real time.

The natural language meaning of overlap can reflect perceptual bias, as in the next example.

(21) When the Brooklyn Bridge collapsed, Bill had just entered it from Lower Manhattan and Bob from Brooklyn Heights.

The overlap, i.e. temporal simultaneity, between Bill's approaching the bridge and the latter's collapse is apparent; furthermore, the simultaneity between Bob's approaching the bridge and the time of collapse of the bridge is also highly apparent. However, what may not be equally apparent is the fact that the actions of Bill and Bob also overlap in that they are simultaneous events, a relationship that could be inferred by the transitive nature of these events.

(22) I can't leave until Joe gets here.

(23) Now that Joe's here I am leaving.

The overlapping relationship between intervals represented by oriented motion verbs (come/go, arrive/leave) is particularly interesting because it introduces reference boundary aspects that are internal to the structures of events in question. Consider (23) in terms of aspectual details now.

(24) A. At the time of speaking - Joe is here
I am also here

B. But Joe's being here is part of his act (interval) of "arriving," whereas my being here is part of my act (interval) of "leaving."

C. Surely, my act of "leaving" has a longer interval span than the span of my being at the same location with Joe momentarily; presumably, my leaving this place is integral to my going some place else. In the same sense, Joe's "arriving" interval is part of his larger interval "come."

D. In fact, without the aspectual meaning of time which provides internal structure to event intervals, it will be extremely difficult, if not impossible, to understand the natural language meaning of relations such as (23).

7.3.4. Understanding Interval Relationships

Let us return to example (14).

(14) John was first, Bill was second, Jill third, Tim next and Sophie last.

What do the ordinal terms, and "next, last" all mean? This utterance was made in the context of describing the order of arrival, in real time, of the persons named. In understanding natural language descriptions such as this we must surely have access to a conceptual representation where the ordinals stand for event-intervals for "arrive"; now then, it follows that, the ordinals have time value as stand-in for actions which command by their nature, duration spans. The linguistic stand-in for the time intervals, the ordinals, are from the standpoint of understanding natural language, associated with default values of time which are specified in the word-sense of "arrive." Without a model of time that allows robust interaction between the conceptual and the linguistic levels of functioning natural language phenomena will be exceptionally difficult to deal with.

7.4. Conclusion

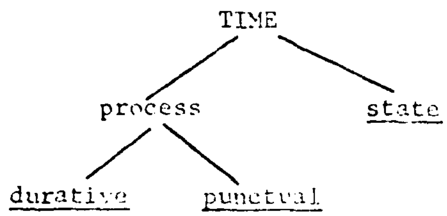
We have tried to propose one possible way to deal with time in natural language, an approach that has been based upon linguistic-cognitive universal concepts gleaned from natural language data. We feel that these concepts can be put to use, whether one's objective is to represent the meaning of time in natural language, or to analyze the meaning.

As developed at this point, the concept of event, or the temporal aspects of the concept of event, includes the kernel and shell components. We have attempted to characterize how aspectual and tense meaning of time, or the elements of the kernel component, fit into the natural language description of event. We feel that the treatment given the kernal component is probably already adequate, with the exception of the modal categories, which is receiving continued attention. As regards the shell component, we may have just touched the surface; while our treatment of the auxiliary system of modifiers of the core meaning of event seems both systematic and intuitively appealing (see Diagram IV), we cannot say at this point whether or not we have found all the auxiliary functions possible. Our treatment of the adverbial modifiers is also highly tentative.

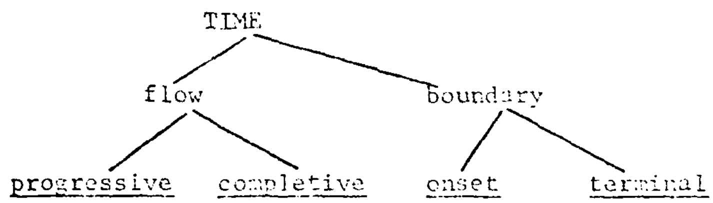
In reports to come we will be able to say more about these areas. Our ongoing efforts emphasize implementation of the ideas reported in the paper. The idea of approaching the natural language meaning of time by using conceptual universals is an extremely appealing idea, and we except to be able to report on the outcome of implementation attempts in the near future.

Diagram I: A Conceptual Model of Time in NL

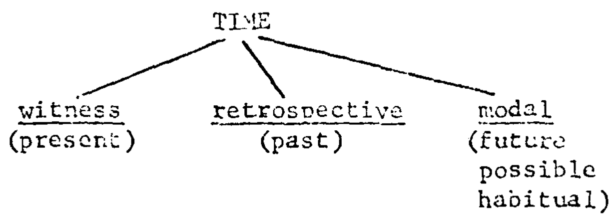
A. Word-sense Meaning of Time



B. Grammatical-Aspectual Meaning of Time



C. Grammatical-Tense Meaning of Time



Explanation. Since the grammatical process is not a word-forming process, grammatical mechanisms are realized in NL as function words (e.g. the prepositions of time --since, until, at, from; conjunctives such as --then, before, after--) and auxiliary mechanisms which use verbs to modify the meaning of the main verb (MV). Thus, starting to eat, finishing doing the laundry, are expressions utilizing auxiliaries (start, finish) for the purpose of encoding the aspectual information of boundary reference and progressivity.

Diagram II: A Conceptual Representation of NL Meaning of Time (Illustrative)

Word-sense Domain	Grammatical Domain: Aspectual :onset	:terminal	:progress.	:complet.	Tense :witness	:retro	:modal		Illustration: Specifying Aspect-Tense Values
e.g. 'siphon' :verb, process-durative time value	+	-	+	-	+	-	-	:	'John is starting to siphon gas'
	+	-	-	+	-	+	-	:	'John had started to siphon gas'
	-	+	-	+	-	+	+	:	'John would have finished siphoning gas (already)'
	-	-	-	-	+	-	-	:	'John siphons gas' Note. This expression is a direct present-tense expression; however, since it has no aspectual time value in its meaning specification, it has no real-time reading; the inference, by default, will be that J. is capable of doing this.
'hit' :verb, process-punctual time value	+	-	+	-	+	-	-	:	'John is beginning to hit Tim'
	-	-	+	-	+	-	-	:	'John is hitting Tim'
	-	+	-	+	+	-	-	:	'John has (just now) stopped hitting Tim'
	-	-	+	-	-	-	+	:	'John will be hitting Tim'
	-	-	-	+	-	+	-	:	'John had hit Tim'
	-	-	-	-	-	+	-	:	'John hit Tim'

Explanation: The temporal meaning underlying each verbal construction, underlined in the examples, is represented in each case by means of specifications of aspect-tense values of time. This illustration reflects a very preliminary stage of development of our ideas as regards the conceptual representation of time in NL. The potential, as well as the limitations, of the approach are being investigated.

Diagram IV: The Shell Component of Event: A Taxonomy of Functions
Illustrative only

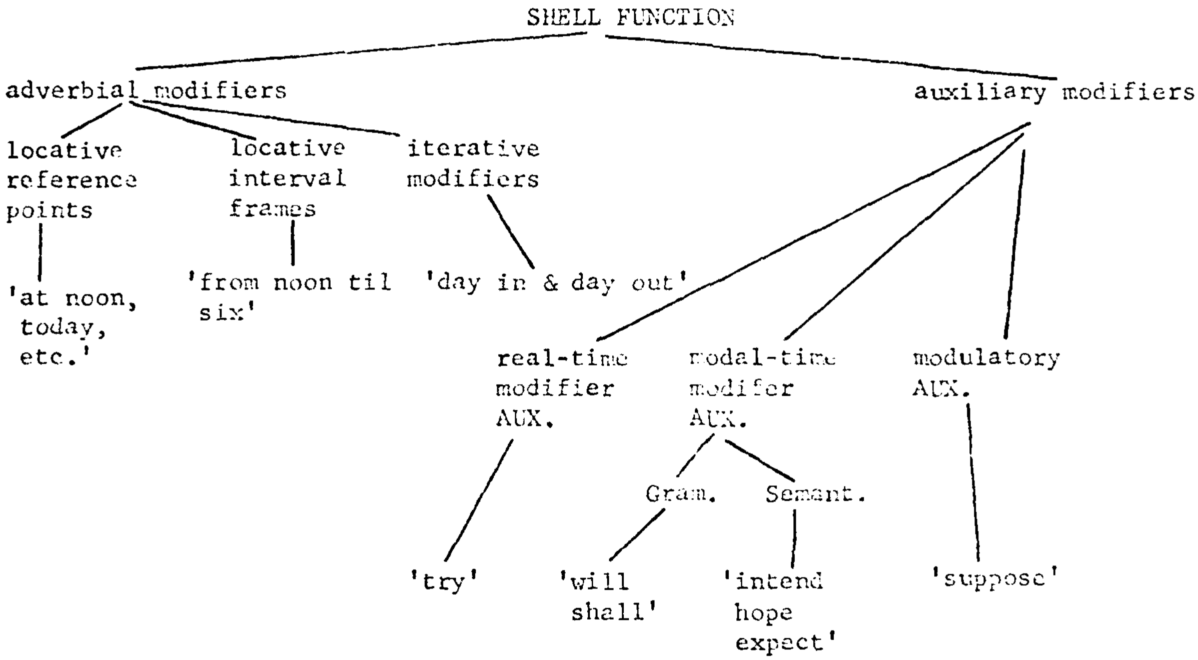


Diagram V: The Shell Component in Event Description: Time Value Slots

#['suppose' ['plan' ['try' [KERNEL] Adverbial Modifier System]]]#
AUX-z AUX.-y AUX.-x
¶real-time ¶
§modal time §

8. Natural Language Front-End for a High-Level Robot Language

8.1. Introduction

To date, most robot manipulators are programmed in a rather primitive fashion. Usually the robots are led through a sequence of steps by a human and the machine remembers the exact position of the motion and plays back this sequence when called upon to perform the task. Of course, with such a system, there is no need for feedback from the environment as long as the situations the robot encounters are identical. In the design of robust robotic systems, it is highly desirable to include a comprehensive feedback network, vision [Maddox, 1982] or tactile, to aid the automation in making decisions and allowing for real-time changes to any planned motion. In the not too distant future Artificial Intelligence research will contribute towards the development of intelligent autonomous robot systems. Current research at CSL will investigate a high-level natural language interface with such a robot system.

8.2. Goals

We believe that it is possible and realistic with the state-of-the-art in Artificial Intelligence to design a natural language system to allow a human to speak[14] to a robot [Winograd, 1970], to express methods and goals for a complex task, and to allow the system to query the human and use feedback to successfully complete the task. The effectiveness of such a system will depend heavily on how well humans can communicate with the robot via the natural language system. Most tasks are far too complex for humans to identify details below some intermediate level. It has been shown that a high-level robot programming language can significantly reduce the detail of interaction between some supervisory system (human, or otherwise) and the robot worker [Finkel, 1974; Geschke, 1979; Liberman, 1976; Paul, 1976]. Taking things one step further, we envision that a natural language system having some explicit representation for goals and methods could aid in developing the algorithm for accomplishing tasks. We envision an interactive system, so that when the system finds that it cannot complete any sub-goal or the overall goal, it will request additional information from a vision system, touch sensing system, or through questioning its instructor. There is also a possibility of using visual and tactile sensing to watch an instructor guiding it or showing the robot how to solve the task. This could either involve watching a human solve the task, or having the human guide the robot, or both.

8.3. Methods

These investigations will be carried out in the following manner:

(1) Determine a domain of tasks which will demonstrate the concept.

(2) Develop the necessary protocol for the instructor/student relationship. Some of this may be borrowed from human to human learning, but new human

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[14] For now, only typed input will be used, however.

to machine and machine to human concepts will be included.

(3) Define a data base consistent with (1) and (2) above that is sufficient to allow the machine to interact with the environment it is to learn from. The knowledge base for the natural language front end will have to be as complete as possible for its task domain, and the range of commands of the robot language should be large. This includes determining what non-English feedback is necessary and what form should it maintain (vision and tactile information, data compression, etc.).

(4) Develop and test the proposed system.

8.4. Accomplishments

Presently we are identifying several tasks which will demonstrate that a robot has learned sufficiently about a goal to accomplish a task. In the beginning, we expect to use the protocol from several exchanges with people to gain a feel for how information is transferred in this context. We expect that by January 1983, we will know the tasks and have a protocol outlined for each. It is anticipated that we will use some high-level robot language which has previously been developed, and will add to it if necessary to enhance its capability. We will use a Stanford robot arm is conjunction with visual information from one or two solid-state cameras. Though color processing would be desirable, most likely we will use only binary or gray-level visual data for now.

8.4.1. Future Work

We anticipate that our research will provide a foundation for integrating many robotic sub-systems and demonstrate that such a composite system can be user-friendly to humans and require a minimum of interaction and detail. We hope to identify major portions of this natural language system, and give detailed specifications of those components so that they may be used in other systems.

9. References

Amsler, R. A. and J. S. White, "Development of a Computational Methodology for Deriving Natural Language Semantic Structures via Analysis of Machine-Readable Dictionaries," Report No. LRC-79-7:1, Linguistics Research Center, Austin, TX, July 1979.

Anderson, J. M., The Grammar of Case, Cambridge University Press, Cambridge, MA, 1971.

Backus, J., "Can Programming be Liberated from the von Neumann Style? A Functional Style and Its Algebra of Programs," CACM, Vol. 21, No. 8, pp. 613-641, 1978.

Brachman, R. J., "A Structural Paradigm for Representing Knowledge," Technical Report No. 3605, BBN, Cambridge, MA, 1978.

Brewer, W. F. and E. H. Lichtenstein, "Stories Are to Entertain: A Structural-Affect Theory of Stories," Journal of Pragmatics, in press.

Collins, A. and M. R. Quillian, "Experiments on Semantic Memory and Language Comprehension," in L. W. Gregg (Ed.), Cognition in Learning and Memory, Wiley, New York, 1972.

Comrie, B. and N. Smith, "Lingua Descriptive Series Questionaire," Lingua Vol. 42, No. 1, 1977.

Cottrell, G., "Connectionist Parsing," Technical Report, Department of Computer Science, University of Rochester, 1982.

DeJong, G., "Explanatory Schema Acquisition," Proceedings of the National Conference on Artificial Intelligence, pp. 410-413, August 1982.

Dyer, M. G., "In-Depth Understanding: A Computer Model of Integrated Processing for Narrative Comprehension," Research Report 219, Department of Computer Science, Yale University, 1982.

Fahlman, S. E., NETL: A System for Representing and Using Real-World Knowledge, MIT Press, Cambridge, MA, 1979.

Feldman J. A. and D. H. Ballard, "Computing with Connections," Technical Report No. 72, Department of Computer Science, University of Rochester, April 1981.

Finkel, R., R. Bolles, R. Paul and J. Feldman, AL, A Programming System for Automation, Report STAN-CS-74-456, Department of Computer Science, Stanford University, November 1974.

Geschke, C. C., "A System for Programming and Controlling Sensor-Based Robot Manipulators," Ph.D. Thesis, Department of Electrical Engineering, University of Illinois at Urbana-Champaign, 1979.

Gigley, H., "A Computational Neurolinguistic Approach to Processing Models of Sentence Comprehension," COINS Technical Report No. 82-9, University of Massachusetts, March 1982.

Kay, M., "The MIND System," in Rustin (Ed.), Natural Language Processing, Algorithmics Press, New York, 1973.

Lehnert, W. G., "Affect Units and Narrative Summarization," Research Report 179, Department of Computer Science, Yale University, 1980.

Lieberman M. and M. Wesley, AUTOPASS: An Automatic Programming System for Computer Controlled Mechanical Assembly, IBM Thomas J. Watson Research Center, Yorktown Heights, New York, 1976.

Lyons, J., Semantics, Volume 2, pp. 482-511, Cambridge University Press, Cambridge, 1977.

Maddox, A. "Automated Visual Inspection of Fluorescent Lamp Components," MS Project Report, Electrical Engineering Department and Robotics Institute, Carnegie-Mellon University, April 1982.

Marslen-Wilson, W. and L. K. Tyler, "The Temporal Structure of Spoken Language Understanding," Cognition, Vol. 8, No. 1, pp. 1-72, 1980.

McClelland, J. L. and D. E. Rumelhart, "An Interactive Activation Model of the Effect of Context in Perception," Technical Reports 91 and 95, Center for Human Information Processing, UCSD, 1980.

Miller, G. A., "Practical and Lexical Knowledge," in P. N. Johnson-Laird and P. C. Wason (Eds.), Thinking: Readings in Cognitive Science, Cambridge University Press, Cambridge, 1977.

Miller, G. A. and P. Johnson-Laird, Language and Perception, Harvard University Press, Cambridge, MA, 1976.

Minsky, M., "A Framework for Representing Knowledge," in P. H. Winston (Ed.), The Psychology of Computer Vision, McGraw-Hill, New York, 1975.

Morris, W. (Ed.), The American Heritage Dictionary of the English Language, Houghton Mifflin Company, New York, 1970.

Ortony, A., "SAPIENS: Spreading Activation Processing of Information Enclosed in Associative Network Structures," unpublished manuscript.

Osgood, C. E., W. H. May and M. S. Miron, Cross-Cultural Universals of Affective Meaning, University of Illinois Press, Urbana, 1975.

Paul, R., WAVE: A Model-Based Language for Manipulator Control, Technical Paper MR76-615, Society of Manufacturing Engineers, 1976.

Piaget, J., The Child's Conception of Time, Routledge and Kegan Paul, London, 1969.

Piaget, J., Six Psychological Studies, Vintage Books, New York, 1967.

Piaget, J. and B. Inhelder, The Child's Conception of Space, W. W. Norton Co., New York, 1956.

Pollack, J. "An Activation/Inhibition Network VLSI Cell," Working Paper 31, Advanced Automation Research Group, Coordinated Science Laboratory, University of Illinois, 1982.

Pollack, J. and D. Waltz, "NLP Using Spreading Activation and Lateral Inhibition," Proceedings of the 1982 Cognitive Science Conference, Ann Arbor, MI, pp. 50-53, August 1982.

Roseman, I., "Cognitive Aspects of Emotion and Emotional Behavior," 87th Annual Convention of the American Psychological Association, New York, 1979.

Schank, R. C., Conceptual Information Processing, North Holland/American Elsevier, Amsterdam, 1975.

Schank, R. C. and R. P. Abelson, Scripts, Plans, Goals, and Understanding, Lawrence Erlbaum Associates, Hillsdale, NJ, 1977.

Schank, R. C. and L. Birnbaum, "Memory, Meaning, and Syntax," Research Report 189, Department of Computer Science, Yale University, November 1980.

Schank, R. C. and C. Riesbeck, Inside Computer Understanding, Lawrence Erlbaum Associates, Hillsdale, NJ, 1981.

Sutherland, I. E. and C. A. Mead, "Microelectronics and Computer Science," Scientific American, Vol. 237, No. 9, pp. 210-228, September 1977.

Thibadeau, R., M. A. Just and P. A. Carpenter, "A Model of the Time Course and Content of Reading," Cognitive Science, Vol. 6, No. 2, pp. 155-203, 1982.

Waltz, D. L., "Event Shape Diagrams," Proceedings of the National Conference on Artificial Intelligence, pp. 84-87, August 1982.

Wilensky, R. "Understanding Goal-Based Stories," Research Report 140, Department of Computer Science, Yale University, 1978.

Winograd, T., "Procedures as a Representation for Data in a Computer Program for Understanding Natural Language," Ph.D. Thesis, Department of Mathematics, Massachusetts Institute of Technology, August 1970.

10. Professional Activities

10.1. Publications

(1) DeJong, G. F., "An Overview of the FRUMP System," in M. Ringle and W. Lehnert (Eds.), Strategies for Natural Language Processing, Lawrence Erlbaum Associates, Hillsdale, NJ, pp. 149-176, 1982.

(2) DeJong, G. F. and D. L. Waltz, "Understanding Novel Language," to appear in International Journal of Computers and Mathematics.

(3) Dorfman, M., Editorial assistant for the Child Language Bulletin, newsletter of the International Association for the Study of Child Language, 1977-1980.

(4) French, P. and M. Dorfman, "Foreward," in B. Hoffer and R. St. Clair (Eds.), Developmental Kinesics, University Park Press, Baltimore, 1981.

(5) Maddox, A. "Automated Visual Inspection of Fluorescent Lamp Components," MS Project Report, Electrical Engineering Department and Robotics Institute, Carnegie-Mellon University, April 1982.

(6) Pollack, J., "An Activation/Inhibition Network VLSI Cell," Working Paper 31, Advanced Automation Research Group, Coordinated Science Laboratory, University of Illinois, 1982.

(7) Pollack, J.,"Relevant Variable Selection for Inductive Learning Programs," Machine Learning Group Research Note, Department of Computer Science, University of Illinois, 1982.

(8) Waltz, D. L., "Artificial Intelligence," Scientific American, Vol. 247, No. 4, pp. 101-122, October 1982.

(9) Waltz, D. L., "The State-of-the-Art in Natural Language Understanding," in M. Ringle and W. Lehnert (Eds.), Strategies for Natural Language Processing, Lawrence Erlbaum Associates, Hillsdale, NJ, pp. 3-36, 1982.

(10) Waltz, D. L., "Generating and Understanding Scene Descriptions," in A. Joshi, I. Sag and B. Webber (Eds.), Elements of Discourse Understanding, Cambridge University Press, pp. 266-282, 1981.

10.2. Published Presentations

(1) Azkarate, M., D. Farwell, J. Ortiz de Urbina and M. Saltarelli, "Governed Anaphora in Basque," Proceedings of the 8th Annual Meeting of the Berkeley Linguistics Society, Berkeley, CA, 1982.

(2) Azkarate, M., D. Farwell, J. Ortiz de Urbina and M. Saltarelli, "Word Order and Wh-Movement in Basque," Proceedings of the 12th Meeting of the North East Linguistics Society, Cambridge, MA, 1982.

(3) DeJong, G., "Explanatory Schema Acquisition," Proceedings of the National Conference on Artificial Intelligence, pp. 410-413, August 1982.

(4) DeJong, G., "Generalizations Based on Explanations," Proceedings of the 7th International Joint Conference on Artificial Intelligence, Vancouver, B.C., Canada, 1981.

(5) Farwell, D. and W. Wallace (Eds.), "Perspectives in Cognitive Science," Linguistics Students Organization, University of Illinois, Urbana, IL, 1982.

(6) Pollack, J. and D. Waltz, "Natural Language Processing Using Spreading Activation and Lateral Inhibition," Proceedings of the Cognitive Science Society Conference, Ann Arbor, MI, 1982.

(7) Waltz, D. L., "Toward a Detailed Model of Processing for Language Describing the Physical World," Proceedings of the Int'l. Joint Conference on Artificial Intelligence - 81, Vancouver, B.C., pp. 1-6, August 1981.

(8) Waltz, D. L., "Event Shape Diagrams," Proceedings of the National Conference on Artificial Intelligence, pp. 84-87, August 1982.

10.3. Presentations

(1) Azkarate, M., D. Farwell, J. Ortiz de Urbina and M. Saltarelli, "On the Syntax of Free Word Order Languages: Evidence from Basque," presented at the 13th Int'l. Congress of Linguistics, Tokyo, Japan, 1982.

(2) Azkarate, M., D. Farwell, J. Ortiz de Urbina and M. Saltarelli, "Basque as a Free Word Order Language," presented at the 1st Int'l. Conference on Basque Studies, Fresno, CA, 1982.

(3) Pollack, J. "Natural Language Research at the Coordinated Science Laboratory," presented at the Fourth Workshop of the Electromagnetics, Propagation and Communications Affiliates Program, University of Illinois, April 1982.

(4) Waltz, D. L., "Plausibility Judgment," presented at Brandeis University, Waltham, MA, April 1982.

(5) Waltz, D. L., "Artificial Intelligence," presented at Longwood College, Farmville, VA, September 1982.

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