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CASE SYSTEMS FOR NATURAL LANGUAGE

Bertram C. Bruce

Bolt Beranek and Newman, Incorporated

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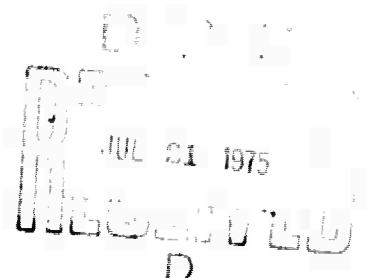
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1.



ABSTRACT

In many languages (e.g. Latin, Greek, Russian, Turkish, German) the relationship of a noun phrase to the rest of a sentence is indicated by altered forms of the noun. The possible relationships are called (surface) "cases". Because (1) it is difficult to specify semantic-free selection rules for the cases, and (2) related phenomena based on prepositions or word order appear in apparently case-less languages, many have argued that studies of cases should focus on meaning, i.e. on "deep cases".

Deep cases bear a close relationship to the modifiers of a concept. In fact, one could consider a deep case to be a special, or distinguishing, modifier. Several criteria for recognizing deep cases are considered here in the context of the problem of describing an event. Unfortunately, none of the criteria serves as a completely adequate decision procedure. A notion based on the context-dependent "importance" of a relation appears as useful as any rule for selecting deep cases.

A representative sample of proposed case systems is examined. Issues such as surface versus deep versus conceptual levels of cases, and the efficiency of the representations implicit in a case system are also discussed.

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1. INTRODUCTION

The problem of meaning representation is an old one which appears in discussions of deep structures for natural language utterances and storage structures for artificial intelligence programs. A profusion of issues relating to questions of efficiency, flexibility, scope, grain, and others has been considered [32,52]. In this paper I want to examine a particular class of representations, namely, case structures for natural language.

The notion of "case" has been used to refer to many different concepts. Traditionally, it has meant the classification of noun forms according to their "inflection". In languages such as Greek, inflectional forms of a noun indicate gender and number. In addition they give information about the syntactic role the noun plays in a sentence. This latter distinction was recognized and named "case" by the Stoic philosophers over two thousand years ago.

Cases appear in many languages besides Greek. Even in English, where nominal inflections are minimized, there are at least the three cases found for pronouns (see Table 1).

Table 1
Declension for the First Person Pronoun in English

	<u>Singular</u>	<u>Plural</u>
Nominative	I	we
Objective	me	us
Possessive	my	our

A table, such as the one given above for the first person pronoun in English, is known as a "declension". A case, then, can be considered as a distinction which must be drawn in order "to state rules of selection valid for all declensions in both the singular and plural" [29].

The idea of a one-to-one relationship between inflections and cases is an obvious concept but not the only one which has been suggested. The problem is that the "rules of selection" can become quite complex and in fact, have not been well defined. Attempts at specifying the set of cases, or case system, for a given language frequently become mired in semantic problems as well as syntactic ones. This has led to a distinction between "surface", i.e. syntactic level, cases and "deep", i.e. semantic level, cases.

The notion of deep cases is not new. For instance, Sonnenschein's demand that cases "denote categories of meaning" [25] is in effect a statement that there are two levels of cases, the surface level indicated by case-affixes

and a deeper level which may be common to more than one language. Fillmore [16] presents a good argument for the universality of deep cases in natural language, saying (pp. 2-3) that

What is needed is a conception of base structure in which case relationships are primitive terms of the theory and in which such concepts as 'subject' and 'direct object' are missing. The latter are regarded as proper only to the surface structure of some (but possibly not all) languages.

This paper discusses the use of case systems for natural language understanding. Sections 2-5 cover some theoretical questions concerning the existence of deep cases and their relationship to surface cases. Section 6 is a survey of several proposed case systems and some computer programs for natural language understanding which use cases. Section 7 points to some other issues related to case systems.

2. DEEP CASES AND GRAMMATICAL EXPLANATION

Deep cases are useful both in accounting for the relative "acceptability" of certain sentences and in explaining how an intelligent system might understand language. This explanatory power is derived from a focus on (conceptual) events rather than on syntactic constructions. For example, we probably have a concept of the event, "refreshing", as in

- (1) Harry refreshed his exhausted partner with a towel and cup of water.

This concept encompasses such notions as "the one who does the refreshing", "the one who is refreshed", "the instrument used to refresh", "the place in which the refreshing occurs", and so on. Acceptance of these notions, along with an understanding of concepts such as "partner" and "water", makes it possible to recognize sentence (1) as being perfectly acceptable. At the same time it makes us wonder about sentences such as

- (2) Harry refreshed the cup of water
(3) The towel refreshed Frances with a cup of water
(4) The cup of water refreshed

We feel that sentence (2) is strange because the sense of "refresh" we have been using seems to require an animate recipient, i.e. "the one who is refreshed". Sentence (3) is odd because it seems that "the one who does the refreshing" (the agent) should also be animate. Inanimate objects like a cup of water or a towel can serve only as the instrument for "refresh". Sentence (4) seems strange because we expect the recipient of the "refreshing" to be mentioned explicitly. Strong clues from the discourse as to his/her identity (or a different interpretation of "refresh") are needed to enable us to understand the sentence.

Suppose we wanted to propose a simple theory to account for the acceptability of (1) and the strangeness of (2) - (4). We could do this in terms of a case structure and selection restrictions. The case structure for "refresh" would be the set of cases allowed in a description of a "refreshing". Selection restrictions then place semantic constraints on the objects which fill the case slots.

The case structure for "refresh" might be {agent (A), recipient (R), instrument (I)}, where each case may appear at most once. The recipient must be present in the surface sentence but the agent and instrument are both optional. If the agent is present in the surface expression then it becomes either the subject of an active sentence or the

object of the preposition "by" in a passive sentence. If there is no agent the subject of an active sentence is the instrument. The instrument can also be the object of "by" (if there is no agent) or the object of "with". The recipient is always present as either the subject of a passive sentence or the object of an active sentence, unless it is easily determinable from context.

Selection restrictions may vary from global constraints on the use of a case with any predicate (e.g. "every agent must be animate") to local constraints on the use of a case with a particular predicate (e.g. "the object of 'spend' must be a resource"). For "refresh" we might infer the selection restrictions (a) that the agent be animate, and (b) that the recipient be animate.

The prepositions and word order in a sentence indicate which case is intended for each noun. If the indicated cases pass the appropriate selectional restrictions and if they correspond to the cases allowed by the case structure then the sentence should be easy to understand. Otherwise we may reject it as being ungrammatical or at least re-evaluate our interpretation of the event and the objects involved. We can express the form of our theory by two questions:

Q1. Does each indicated case pass the selection restrictions for that case?

Q2. Do the set of cases which are indicated to the case structure?

Let us apply our theory to sentence (1). There the indicated cases are (A,R,I) as found by applying the rules given above. The indicated agent (Harry) and the recipient (his partner) are both animate, thus passing the selection restriction we inferred. The set of indicated cases matches exactly with the "refresh" case structure. Thus (1) can be understood easily.

But consider now sentence (2). There the indicated recipient, the cup of water, fails to pass the selection restriction that the recipient be animate. If we are to understand (2) we must either interpret the cup of water as being animate or, perhaps, consider a different sense of "refresh" which does not require an animate recipient. Similarly, sentence (3) is odd because the indicated agent, the towel, is not animate. In both (2) and (3) our understanding is strained because of a failure on question Q1.

On the other hand, sentence (4) does not pose any selection violations. There the indicated instrument, the cup of water, is easily understood. However, the indicated cases, (I), do not match the case structure, thus failing on Q2. In order to understand (4) fully, we must determine the recipient from the context. Taken in isolation the sentence is difficult to comprehend.

The following sentences (5) - (19) illustrate the application of our theory to some uses of "refresh". Each example shows the indicated cases. Some of the sentences are difficult to understand, especially out of context.

Sentences which are perfectly acceptable:

- (5) Harry (A) refreshed himself (R)
- (6) The cup of water (I) refreshed Harry (R)
- (7) Harry (R) was refreshed by the cup of water (I)
- (8) Harry (R) was refreshed by his partner (A)
- (9) Harry was refreshed with his partner
[where R is "Harry and his partner"]
- (10) Harry and Sam (A) refreshed their partner (R)
- (11) Harry (R) was refreshed by a towel and cup of water
(I)
- (12) Harry (A) refreshed Sam and his partner (R) with a
towel (I)

Sentences which are difficult to understand because of a failure on Q1:

- (13) The cup of water (I) refreshed itself (R)
- (14) The cup of water (I) refreshed the towel (R)
- (15) Harry (R) was refreshed by the towel (A) with a cup of water (I)
- (16) Harry and a cup of water (A) refreshed his partner (R)

Sentences which are difficult to understand because of a failure on Q2:

- (17) The towel (I) refreshed
- (18) Harry (R) was refreshed with the towel (I) with the cup of water (I)

A sentence which is difficult to understand because of a failure on both Q1 and Q2:

- (19) Harry (R) was refreshed with a cup of water (I) with his partner (I)

The degree to which a case based theory can account for linguistic behavior depends upon the way the cases mediate between surface forms and conceptual structures. Section 3

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is a discussion of event descriptions in terms of deep cases with the goal of identifying the nature of the deep cases.

3. DESCRIBING AN EVENT

Let us consider the notion of deep cases relative to the need to describe events. Of course, not everything communicated is a description of an event. There are also objects and states and perhaps other entities. However, events are of fundamental importance and it is often useful to see both objects and state descriptions as special types of events.

In English an event description is usually given, i.e. realized, by a simple (one-verb) sentence. For example, we say

(20) Susan kicked the football

to indicate an event of "kicking". But an event description can also be realized as a noun phrase. We can say "they ate", or "the eating", or, completely nominalized, "the meal".

Thinking of events as the primary entities leads us to think of a large set of unary predicates which classify these events. We can then quantify over the set of all events and write

(21) ($\exists$ x) [kicking* (x)]

(there is an event which is a "kicking"; the use of the "*" indicates that this is a primitive, undefined predicate)

Since we usually want to distinguish events within a class we need to write complex formulas which further constrain (specify) the variables. Returning to our example, we could write

(22) ($\exists$ x) [kicking* (x)
 & agent (x, Susan)
 & object (x, a₀)
 & time (x, past)]

(there is an event which is a "kicking"; the agent of the event is Susan, the object is a₀, i.e., "the football", and the time is "past")

Of course, other properties of the event can also be specified. For example,

(23) Susan awkwardly kicked the football to Mary with her left foot in the park

could be represented

(24) ($\exists x$) [kicking* (x)
 & agent (x, Susan)
 & object (x, a_0)
 & time (x, past)
 & manner (x, awkward)
 & goal (x, Mary)
 & instrument (x, a_1)
 & location (x, a_2)]

(where a_1 represents "her left foot" and a_2
represents "in the park")

In general, an indefinite number of properties may be specified for a given event. However, these properties are not equivalent in their usefulness for defining the event. The fact that Susan kicks a football and not a turnip seems more significant than that she does it with her left foot rather than her right. There are important, or distinguishing, or significant properties and there are modifying, or auxiliary properties.

The labeling of a property as "distinguishing" or "modifying" is rarely obvious. It would not be surprising to hear someone say that the foot is more important than the

object kicked, and it is not difficult to imagine a context in which the object is relatively insignificant but the foot used is of critical importance. Obviously, this grouping of properties is sensitive to the context, including the purpose of the speaker and the beliefs of both speaker and hearer. Nevertheless, there is often a strong intuition that certain properties belong with certain events.

By defining a new, n-ary predicate for each event we can isolate those properties which seem central to the event in most contexts. Again, with the "kicking" example we could write

(25) ($\exists$ x) [kicking (x, Susan, a_0 , a_2 , past)
& manner (x, awkward)
& goal (x, Mary)
& instrument (x, a_1)]

(where "kicking" is defined in terms of kicking* and expresses the relationship among the event and its agent, object, location, and time; other properties are appended as before).

Clearly, it would be desirable to have a criterion for deciding which cases are central to an event description. We must admit in advance that such a criterion must be relative, both in the sense that it be sensitive to context

and that it can only be expected to rank the properties on "centrality" rather than provide a strict separation. We could say that properties vary in their degree of binding to an event and that those properties which are most tightly bound are the deep cases.

4. CRITERIA FOR DEEP CASES

4.1 Alternative Rules for Deciding on Deep Cases

Despite the compromises which seem necessary for any rule which attempts to dichotomize properties of events, there is a need for such a rule. A simple procedure for assigning a small set of properties to an event could be used to define events as structures -- known configurations which facilitate parsing and inference [5,30,35,39,41,45,46]. Let us call the central relations for an event the "deep cases". The deep cases are then binary relations which specify an event regardless of the surface realization of that event description as a sentence or noun phrase. There are several alternatives for a rule for distinguishing deep cases:

A case is a property which must be used to distinguish different senses of a word

A deep case could be considered to be a property which is necessary for separating different senses of the same word. Celce [10] gives "smear" as an example. We can say

(26) John smeared paint on the wall

or

(27) John smeared the wall with paint

Celce claims that two different senses of "smear" appear in (26) and (27). Sentence (26) is an assertion about "paint"; i.e. the "theme" of the sentence is "paint". "Smear" expresses the motion of the paint towards or on the "wall", which serves as both the "locus" and the "goal" for the theme. On the other hand, there are two themes in (27), the "wall" and "paint", and "smear" expresses the joining of these themes. Thus the same surface predicate can have more than one sense and the different senses are given by the possible case paradigms of the predicate (e.g. [causal-actant, theme, locus and goal] in (26) or [causal-actant, primary theme, secondary theme] in (27). (See also Section 6.1.2).

It should be pointed out that Celce's analysis is not universally accepted. Fillmore [16], for instance, says that "paint" fills the instrumental case and "the wall" fills the locative case in both (26) and (27), the sense of "smear" being roughly the same in each example. In either Celce's or Fillmore's analysis, though, it is the differential postulation of deep case relations which accounts for the difference or sameness of the event described.

A case is a property which must be used for unique specification of an event

Another criterion for distinguishing the deep cases from other relations might be to select those properties which are necessary for unique specification of an event. In

(28) Roger played the blues on his guitar last night

we see an event described with several relations. Which of these are essential for defining the event? The subject, "Roger" and the time are clearly not enough, since Roger may at the same time have been singing, visiting with friends, digesting, etc. We must specify more of the relations, e.g. the music, the place, and the instrument. However, at some point additional relations begin to serve only a describing function and not a defining one. Thus a description of Roger's audience, as in "for Bill and Sue" might be relevant but unnecessary for a complete isolation of this event from others.

A generalization of the unique specification criterion is to consider as deep cases those relations which are necessary relative to some set of sufficient relations. That is, while the audience (often called the benefactive case) might be an unnecessary property given the agent,

instrument, time and location, it might be necessary relative to another sufficient set of defining (or distinguishing) relations such as agent, mood, music and location. Some relations, such as time, may be necessary for any sufficient defining set and would thus be deep cases under both the restricted and the generalized unique specification rule.

A case is a property whose value needs to be known, even if it is not explicitly specified

A third criterion which can be used for deciding on deep cases is to pick those relations which need to be filled if not explicitly specified in a sentence. The values for these relations are necessary when an event concept is described by a definite noun phrase or by elliptical constructions like, "the arrow hit". For example, consider the phrase "the [baseball] pitcher". Such a phrase is puzzling unless it is possible to establish from context defining relations such as "for team x", "at time y", or "in place z".

A case is a property whose value is usually specified for a given type of event

A similar criterion is to select those relations which are usually specified when discussing a certain type of event. When we describe a trip we frequently mention the --

- people taking the trip
- point of departure
- destination(s)
- starting time
- length of the trip
- cost
- mode of travel
- purpose

On the other hand there are relations such as the --

- clothes worn
- comfort
- weather

which might be relevant in certain contexts but are less commonly specified. Relations in the first group would be considered to be deep case relations on "take a trip" whereas those in the second group would be only modifying relations. Despite the vagueness of such a criterion it can be useful within limited contexts. Furthermore there is reason to believe that the "usually specified" criterion is not that different from the other criteria presented.

A case is a property which is particularly relevant to the domain of discourse

A final possible criterion for deep cases is to base the selection on the domain of discourse, that is, on task specific requirements. Thus a data base for physiology might represent explicitly such relations as medium ("in the blood") or derivative ("increasing rapidly"). A language understander discussing physiology should then distinguish relations like medium and derivative and treat them as fundamental structural components of physiological concepts (Chokhani [11]).

4.2 Problems with Any Criterion for Deep Cases

Arguments can be made for each of the criteria given above. However, none of them are without weaknesses. To say that different sets of cases should be assigned to distinguish among different senses of a word is reasonable, but there are always disagreements over the extent of difference in sense as in the "smear" example. At one extreme we could consider different senses to be accounted for by different values for the case relations, e.g. "run" in

(29) Judy ran down the street
and

(30) Judy ran the machine

has the same sense; in (29) the object case has the same value as the agent, namely "Judy", while in (30) it has a different value. At the other extreme we could consider every token of a word to express a different sense. Then cases would have to be indefinite in number, perhaps generated by a set of "meaning" rules. A decision for any particular example seems to depend upon pragmatic considerations and upon specific world knowledge.

In a similar way the arguments for the other criteria are both imprecise for specific examples and apparently dependent upon context and world knowledge. I want to argue for a definition of "deep case" which, while not necessarily contradictory to any of the above, is nevertheless more general and makes explicit the context dependent nature of the deep case distinction. Unfortunately, it leaves open the question of finding an ideal set of cases by relying on the notion of importance in context.

A case is a relation which is "important" for an event in the context in which it is described

Let us assume that there are concepts (i.e. events) and relations which at least modify the concepts. We can then make statements which have the form of (24) above, i.e.

(31) ($\exists x$) [kicking* (x) & ...]

Furthermore, assume that associated with each concept-relation pair there is a function whose value is a measure of the importance of the relation as a modifier of the concept. This function is similar to the "importance tags" in SCHOLAR (Carbonell & Collins [8]) with one important difference. In SCHOLAR the domain of discourse and the student-SCHOLAR relationship are relatively fixed. Thus the importance tags can reasonably be constant functions. A general language understander must, however, be able to determine importance as a function of context. These functions must examine the world model, including the current discourse, purpose, and speaker-hearer relationship in order to determine the relative importance of a relation to a concept.

We then say that a deep case for a given concept is a modifying relation which has an importance greater than some (pragmatically determined) threshold. With this view, deep cases become relative, both in the sense that one relation may be more or less deep-case-like than another, and in the sense that the deep-case-likeness of a relation is dependent upon its importance, and therefore upon the current context.

5. SURFACE CASES

What then can we say about surface cases? It is interesting to observe that surface case distinctions are not as sharp as one might expect. In Latin, for example, there are usually five or six different cases distinguished: nominative, accusative, genitive, dative, ablative, and sometimes vocative. As Lyons [29] points out, a case distinction is made for all nouns whenever it is needed to state selection rules for any noun. But the principle is violated many times (e.g., locative case). It is simply not possible to state simple, categorical selection rules for all sentences.

Without the selection rules the notion of case is trivialized to a cataloguing of word endings. By including varying amounts of semantics in a case system it is possible to convert the catalogue into a small set of rules. The problem, of course, lies in the word "varying". Jespersen [25] discusses how attempts to include semantics in case systems for English have led to one, two, three or more cases being distinguished.

Corresponding to the criteria for deep cases we can consider the factors which determine surface cases. The primary one is the case-affix, i.e., an ending attached to a noun form. Many would consider that prepositions (or

postpositions) serve a similar function. Word order, as in English, can also be viewed as a syntactic signal of case. In addition, case assignment interacts with such features as gender and definiteness of the noun phrase. Finally, of course, there are exceptions to be found in any natural language to the rules for determining surface cases. These exceptions are sometimes specific for single words but often are expressed in terms of classes of verbs or other more general semantic considerations.

There are several other issues which need to be addressed. I believe it is most productive to look at cases for a natural language in terms of some deep case system, either pragmatically determined by means of importance tags, or purely conceptual (see Section 6.1) as in Schank [42] or Rumelhart, Lindsay and Norman [38]. Surface cases then become epiphenomena of the deep cases; that is, the exact number of surface cases and their relationship to each other are dependent upon language specific mapping rules and upon the degree of emphasis upon semantics (i.e. the consideration of deep cases).

6. SOME REPRESENTATIVE CASE STRUCTURE SYSTEMS

6.1 Theoretical Systems

As in any area of active research there are variations in terminology for cases. In the discussion to follow I will use the following definitions, where possible:

(deep) case - A (deep) case is a binary relation which holds between a predicate (usually, but not necessarily, realized as a verb) and one of its arguments. The motivation for deep cases is usually to provide a better account of grammaticality. Thus the links to surface structure need to be explicit and (usually) easily computable.

surface case - A surface case is a syntactic category for noun groups based on such things as word endings, word order, and prepositions.

conceptual case - A conceptual case, like a deep case, is a binary relation which holds between a predicate and one of its arguments. However, its existence is entirely independent of surface structure considerations. A conceptual case is postulated, not because it is apparent in surface language, but

because it is a kind of information about actions which people attempt to communicate.

case marker - A case marker is a surface structure indicator (preposition, case affix) of a case.

case structure (or case frame) - The case structure for a predicate is the set of cases allowed for that predicate. Usually the cases are marked as being either optional or obligatory in the surface structure realization. (This is not true in a conceptual case structure). For example, one sense of the verb, "cut", might be said to have the cases {agent, object, instrument}, where only the object is obligatory at the surface level.

case system - A case system is a complete set of cases for a language.

This section covers several proposed case systems. The emphasis here is on systems with some theoretical justifications as opposed to purely ad hoc collections of cases. In the next section (6.2), some implementations of these and other systems are considered. This distinction between theoretical and applied systems is not an absolute one, but rather suggests a difference in approach or

methodology.

6.1.1 Fillmore [16,17,18,19]

Fillmore has proposed a deep structure based on cases. A sentence in this deep structure consists of a modality plus a proposition:

$$(32) S \rightarrow M + P$$

The modality constituent (M) includes negation, tense, mood, and aspect. The proposition (P) is a tenseless structure consisting of a verb, noun phrases, and any embedded sentences:

$$(33) P \rightarrow V + C_1 + C_2 + \dots + C_n$$

where each C_i is a case name which generates either a noun phrase or an embedded S. There is a global constraint on rules of the form (33) which says that at least one case must be present but that no case may appear twice.

Rules (32) and (33) are argued to be universal. In order to produce the case markers of specific languages the so-called Kasus element is introduced, thus the rule:

$$(34) C_i \rightarrow K + NP$$

K generates a preposition, postposition, or case affix. (We might generalize this notion to a Kasus function which maps a deep structure proposition into a surface structure clause with possible word order changes.)

Fillmore makes an argument for deep case relations in analyzing verbs of any language, including English. He has proposed several systems which capture various aspects of the meaning of certain verbs. An example of his case systems is shown in Table 2.

Table 2

Fillmore's [18] Case System

Agent(A) -	the instigator of the event
Counter-Agent(C) -	the force or resistance against which the action is carried out
Object(O) -	the entity that moves or changes or whose position or existence is in consideration
Result(R) -	the entity that comes into existence as a result of the action
Instrument(I) -	the stimulus or immediate physical cause of an event
Source(S) -	the place from which something moves
Goal(G) -	the place to which something moves
Experiencer(E) -	the entity which receives or accepts or experiences or undergoes the effect of an action.

In addition to these cases there are also other relations "that identify the limits and extents in space and time that are required by verbs of motion, location, duration, etc." (Fillmore [18], p. 376)

Fillmore proposes that verbs be classified according to "sentence types" or "case frames". A case frame tells what case relationships may exist between a verb and its nouns. For example "open" may be used in four ways:

- (35) The door opened. (O)
- (36) John opened the door. (A O)
- (37) The wind opened the door. (I O)
- (38) John opened the door with a chisel. (A O I)

We can represent the case frame for "open" as [O (A) (I)]. This says that when "open" is used its object must appear in the surface sentence but the agent and instrument are optional.

A virtue of the case grammar approach is a reduction in the number of constructs needed to explain such things as the difference in meaning between "listen" and "hear" (or "learn" and "know"). For each of these verbs there is an object (O) and an animate noun phrase. The difference is that when the verb implies active participation of the animate subject the case is the agent; whereas a less active involvement suggests the dative. Thus the case frame for "listen" is [O A], while for "hear" it is [O D].

Fillmore shows by example the case markers (Kasus functions) of various languages. He also gives some tentative rules for English. For example ([16], pp. 32-33):

The A preposition is by; the I preposition is by if there is no A, otherwise it is with; the O and F [factitive case] prepositions are typically zero; the B [benefactive case] preposition is for; the D [dative case] preposition is typically to...

If there is an A it becomes the subject; otherwise, if there is an I, it becomes the subject; otherwise the subject is the O.

6.1.2 Celce [10]

In Celce's system there are five deep case relations, {causal actant, theme, locus, source, and goal}. Verbs are classified into paradigms according to the case sequences they allow. For example, the ergative paradigm consists of the sequences (for the active voice):

(causal-actant₁, theme, causal-actant₂)
(causal-actant₁, theme)
(causal-actant₂, theme)
(theme)

Note that a paradigm consists of both the case structure for the verb and constraints on the order of the case fillers. For example, the ergative paradigm says that the theme can never precede the causal-actant₁.

"Break" is an example of an ergative verb. Thus

- (39) John broke the window with a hammer
- (40) John broke the window
- (41) The hammer broke the window
- (42) The window broke

are all well-formed since in each sentence one of the case sequences is matched (where "John" is the causal-actant₁, "window" is the theme, and "hammer" is the causal-actant₂).

Another example is the "reflexive-deletion paradigm" where the theme is deleted if it corresponds to the CA1 [causal-actant₁]. Thus "run" may be used in several ways:

- (43) John ran to school
- (44) John ran a machine
- (45) The machine ran
- (46) The brook ran

In each of the sentences there is a theme - John, machine, or brook. The paradigm allows the deletion of the theme if it is the same as the causal-actant. Thus the paradigm is

- (causal-actant, goal)
- (causal-actant, theme)
- (theme)

6.1.3 Grimes [21]

Grimes has developed a rather sophisticated case system to serve as a foundation for discourse analysis. The definitions of the cases and their organization reflect his concern with event and episode representations. Grimes distinguishes between "roles" (deep cases) which describe motion and position and those which have to do with changes of state. In addition to these orientation and process roles there are special roles such as agent and benefactive. These cases are shown in Table 3.

Table 3
Grime's [21] Case System

Orientation Roles:

- Object(O) - the thing whose position or motion is being described
- Source(S) - the location of the object at the beginning of a motion
- Goal(G) - the location of the object at the end of a motion
- Range(R) - the path or area traversed during a motion
- Vehicle(V) - the thing which conveys the object and moves along with it

Process Roles:

- Patient(P) - the thing changed by a process or the thing whose state is being described
- Material(M) - the thing changed by a process in its state before the change
- Result(Re) - the thing changed by a process in its state after the change
- Referent(Rf) - the field or object which defines the limitation of a process (as opposed to the thing affected by the process)

The Agentive Complex:

- Agent(A) - the one who is responsible for an action
- Instrument(I) - the tool used in performing an action
- Force(F) - the noninstigative cause of an action

The Benefactive Role:

- Benefactive(B) - the someone or something on whom an action has a secondary effect

Perhaps the best explanation for these cases is a set of examples (all from Grimes [21]):

- (47) The letter (O) fell to the floor (G)
- (48) His house (O) is situated on top of a hill (R)
- (49) The tide (V) floated the oil slick (O) into the harbor (G)
- (50) This idea (O) came to me (G) from Austin Hale (S)
- (51) This book (P) costs three dollars (Rf)
- (52) She (A) makes dresses (P Re) from flour sacks (P M)
- (53) Fred (A) fixed the engine (P) with this screwdriver (I)
- (54) Sally (A) handed John (G) the biscuits (O)
- (55) He (A) parted the rope (P G) with an axe (O I)
- (56) The girl (P) died of malaria (F)
- (57) The milk (P) turned sour on me (B)
- (58) We (A) talked about politics (Rf)

The cases which Grimes distinguishes are strongly influenced by linguistic as opposed to conceptual considerations, e.g. in (50) the transfer of the idea is not a physical movement. However, the form of the expression is the same as that in

- (59) A breeze (O) came to him (G) from the sea (R)

Grimes also suggests the possibility of a more tightly defined role structure based on certain similarities in the roles:

The roles set up for orientation all have counterparts on the process side, and vice versa. Both kinds could be considered complementary variants of a single set of roles. (Grimes [21])

For example,

Object and patient both identify what is affected, the one in terms of motion or position and the other in terms of change of state in a process. [ibid]

There are similarities in roles and also an apparent limitation in the number of roles which may appear with a single concept.

Regardless of whether orientation or process roles are involved, the maximum number of role relations that seems to enter into the semantics of any lexical item in English or in any of the other languages for which the idea has been tried out is eight if we push the limit: for example, we (AS) carried the supplies (O) all the way up (G) the cliff (R) for them (B) on our backs (V) with a rope (I), which pulls out all the stops in the system. [ibid]

These observations suggest the combined role structure shown in Fig. 1.

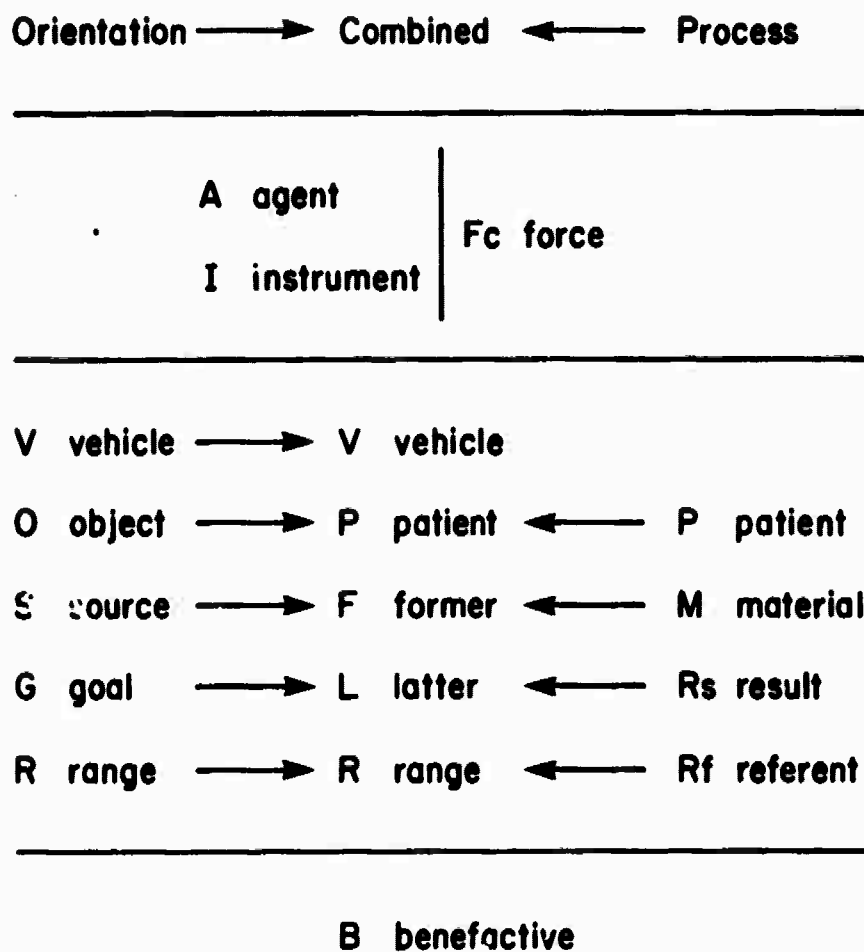


Fig. 1 Interrelationships among roles (Grimes [21])

6.1.4 Schank [39,40,41,42,43]

Schank's cases , unlike those of Fillmore [16] or Celce [10] are purely conceptual. Neither the primitive act nor its cases need be explicitly mentioned in an utterance. Instead, the argument for conceptual cases depends upon considerations of the pragmatics of human communication. One postulates a conceptual case because it is a relation relevant to the typical kinds of tasks which people address via language.

In a sense, conceptual cases can be viewed as the result of an extreme position on the task-specific criterion discussed above; i.e. the cases are relevant to typical non-technical language use. For example, an essential element of most communication is the description of actions. Our knowledge of actions implies a "conceptual structure" built out of actions and their role fillers:

ACTORS perform ACTIONS
ACTIONS have OBJECTS
ACTIONS have INSTRUMENTS
ACTIONS may have RECIPIENTS
ACTIONS may have DIRECTIONS (Schank [42], p. 6)

One kind of conceptual structure or "conceptualization" comprises an act, with its "actor", and the relations "object", "direction", and either "recipient", or "instrument". Each of these relations must be present

(except that only one of direction or recipient is present).

Schank argues that a small number of concepts corresponding to "primitive acts" can be used to construct meaning representations for most descriptions of events. These primitive concepts are simple actions of the kind "move a body part" (MOVE), "build a thought" (MBUILD), "transfer a physical object" (PTRANS), and "transfer mental information" (MTRANS). The primitive ACTS together with the conceptual cases are the components of meaning representation with a "unique representation" feature:

We have required of our representation that if two sentences, whether in the same or different language, are agreed to have the same meaning, they must have identical representations. (Schank [42], p. 4)

There is a question whether such a criterion can be met in a non-trivial sense: Do distinct utterances (by different speakers using different phrasings, at different times, in different situations) share significant portions of a conceptual network? Furthermore, a non-redundant representation such as Schank's raises serious questions of both psychological validity and efficiency for diverse tasks. Nevertheless, in many cases the mapping of utterances to conceptualizations seems to be exactly the process which humans exhibit. The unique representation

also facilitates general inferencing by reducing the number of cases to be considered:

The use of such primitives severely reduces the inference problem in AI (see Schank and Reiger (1973)), since inference rules need only be written once for any ACT rather than many times for each verb that references that ACT. For example, one rule is that if you MTRANS something to your LTM [long term memory], then it is present there (i.e., you know it). This is true whether the verb of MTRANSing was see, hear, inform, remember or whatever. The inference comes from the ACT rather than the verb. (Schank [42], p. 10)

6.1.5 Rumelhart, Lindsay, and Norman [37,38]

The memory representation proposed by Rumelhart, Lindsay and Norman [38] (see also Norman [36], Rumelhart and Norman [37]) is another example of a system where conceptual cases are used. In their system knowledge is encoded as a set of propositions and concepts linked together. A concept "token", e.g. a particular table, is connected to its "type", e.g. the concept of a table, by an ISA link. Similarly, a proposition token, e.g. a particular going, is connected to its type, e.g. the concept of going, by an ACT link.

Propositions are represented by one or more "primitives", connected, via case links, to other primitives and concepts. For example the representation of the proposition

(60) The train moved out of the station at 3 o'clock

is in terms of the primitives *CHANGE and *LOC. *CHANGE indicates a change of state, e.g. from the train being at the station to the train not being at the station. *LOC indicates a simple location/time description. Each of these primitives has various cases such as FROM-STATE, TO-STATE, SUBJECT, FROM-TIME, AT-LOC, etc. (See Fig. 2).

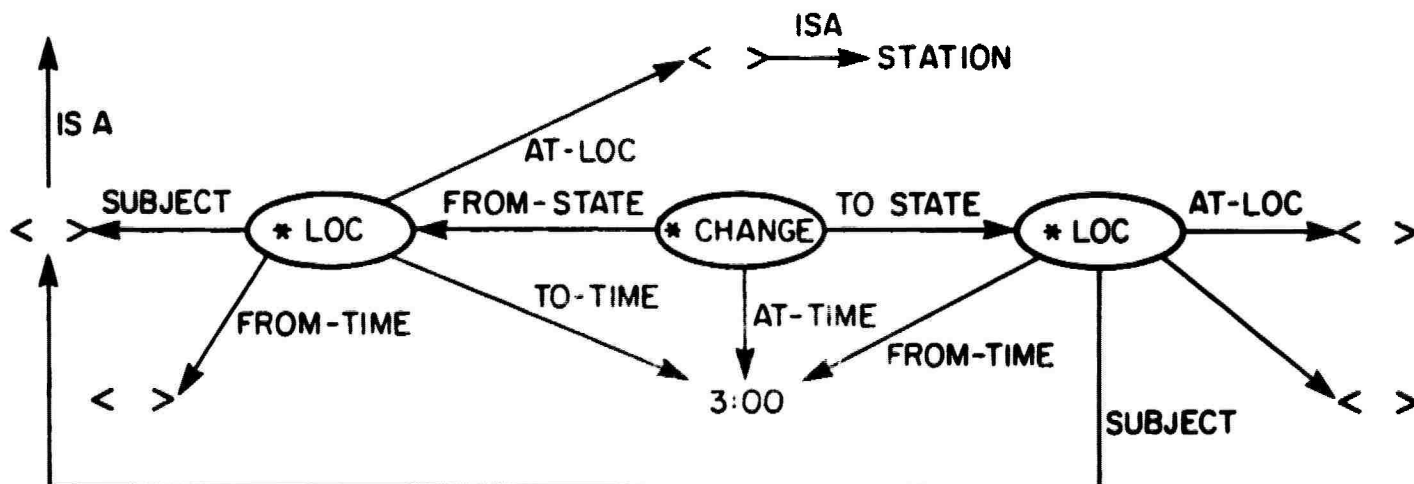


Fig. 2 Conceptual representation of "the train moved out of the station at 3 o'clock." (Rumelhart & Norman [37])

The construction of a propositional representation is guided by verb definitions, which can be given in the English-like language, SOL. For example, see Fig. 3.

Define as predicate MOVE1.
X MOVE1 (FROM-LOC L1 TO-LOC L2 AT-TIME T),
Is when a *CHANGE from that state that X
is located at L1 to the state that
X is located at L2 occurs at T.

Fig. 3. Definition of one sense of "move"
in the SOL language

[Rumelhart and Norman [37], pp.453]

This definition shows that the verb being defined is MOVE1 (the sense of "move" in (60)); that its argument frame (or case structure) is {agent, from-loc, to-loc, at-time}; that only the agent is required, since the other cases are parenthesized; and that the verbs *CHANGE and LOCATE are used in its definition.

When a sentence is processed by the system, the definition of its main verb is invoked. The noun phrases and subsentences are matched to the arguments of the verb on the basis of the argument frame and restrictions on prepositions and semantic characteristics of the arguments.

Associated with each case name (e.g., FROM-LOC or METHOD) is a list of prepositions which can occur at the surface level to indicate or mark that argument. Each label also is associated with a set of semantic characteristics which can be interrogated during the parse. The prepositions and the semantic characteristics can be used together to disambiguate which of the variety of concepts a given noun phrase is representing.

At every point during the parse the goal is to find and correctly fill the argument slots of the predicate word in question. If some arguments do

not fit into the frame of the sense of the predicate word in question, a new sense of the predicate word is tried until either a fit occurs, or no more senses exist (in which case, the parse fails).

[Rumelhart and Norman [37], pp.450-451]

6.2 Applications

Much of the research in natural language processing has focused on the problem of storage structures, or the question, "How is the information or meaning of a sentence to be represented once a sentence has been parsed?". Several recent systems use structures based on deep case relations. Some systems which do not explicitly use a case structure have nevertheless used case-like mechanisms. In addition, case-like systems have been used in modeling in medicine and psychology, even without natural language. The systems discussed here are presented as examples of approaches to the use of cases for natural language understanding.

6.2.1 Simmons [46,47,48]

Simmons gives an extensive account of semantic networks and their use in processing natural language by computer. An essential feature of his networks is a set of deep case relations connecting nominal concepts to verbs. While a

semantic network does not require any specific case structure, Simmons has chosen one which follows from the work of Celce [40]:

Table 4
Simmons's [47] Case System

Actant -	animate doer of the action
Theme -	takes the main effect of the action
Source -	place or state of the origination of the act
Goal -	place or state of termination of the act
Instrument -	some other process that contributes
Locus -	general location of the action
Time -	any time predicate, e.g. Saturday, on the action (Simmons [47], p. 1-1)

Simmons discusses other aspects of the case structure portion of semantic networks as well. He points out that a "semantic definition" of a verb can be given by describing the properties of the nominal concepts serving in each case relationship to the verb. A parser must check that the features of nominal concepts satisfy the selectional restrictions implied by the cases of the verb.

6.2.2 Hendrix, Thompson, and Slocum [24]

The system of Hendrix, et al [24] uses a case system together with a "canonical" event approach similar to Schank's primitive act approach. The basic assumption is that

... the problems of representing factual material, making inferences, solving problems and answering questions may be significantly reduced if identical meanings expressed by diverse surface structures can be represented by a single conceptual construct. A major cause of surface structure diversity is the existence of a wide variety of "surface verbs" for describing basically the same situation. (Hendrix, et al, [24], p. 262)

For example, the canonical event EXCHANGE can be used to represent the meaning underlying such surface expressions as "buy", "sell", and "cost".

One interesting feature of this system is that it makes explicit the knowledge used in transforming the surface cases of a verb like "buy" into the deep cases of a canonical event like EXCHANGE. As the authors admit, the structure used is not completely adequate for representing all the knowledge needed. Nevertheless it is valuable in showing what can be done with a transparent representation (see also Section 6.2.8), as opposed to the customary use of more general, but opaque procedures.

Each verb in the system has a pointer to the associated canonical event. It also has a list of P-RULES which define the surface to deep case mapping. Each P-RULE is a triple. The first element is either a preposition or OK, signifying a noun phrase. The second is a list of semantic classes and the third is a deep case. The P-RULES are ordered to indicate their relative likelihood.

Following a parse of a sentence into its verbal and nominal constituents, the P-RULES are applied to produce a canonical event representation. For each noun phrase or prepositional phrase the P-RULES are examined, in order. If the preposition matches; if at least one semantic marker on the head noun of the phrase is also one of the semantic classes; and if the deep case has not been assigned already, then that phrase is assigned the deep case.

An example list of P-RULES for the verb "buy" is shown in Fig. 4.

```
( (OK (HUMAN ORGANIZATION) BUYER
  (OK (PHYSOBJ) THINGBT)
  (FROM (HUMAN ORGANIZATION) SELLER)
  (FOR (MONEY) THINGGIVEN)
  (AT (PLACE) LOC)
  (IN (PLACE) LOC)
  (OK (DAYPART) TIME)
  (IN (DAYPART) TIME) )
```

Fig. 4. P-RULES for "buy"

[Hendrix, et al, [24], p. 263]

While the P-RULE mechanism seems to work for simple sentences it needs to be extended. Hendrix et al suggest several specific directions. One is the inclusion of word order constraints, which are only weakly handled by the ordering of the P-RULES. Another is the inclusion of complement clauses as possible fillers of deep case slots.

6.2.3 Chokhari [11]; Kulikowski and Weiss [27]

Another system is the glaucoma model of Kulikowski and Weiss [27]. In their model various primitive descriptors of physiological conditions or states (e.g. "pressure", "atrophy", "age", "adhesion", etc.) are given attributes (e.g. "medium", "location", "time", "magnitude", etc.). The specification of a state is an assignment of values to some or all of the various attributes for a descriptor.

Describing the medical model in case terms, we would say that the primitive descriptors are predicates and the attributes are cases. The restrictions on the objects which may fill attribute slots are features which affect the understandability of sentences. The case structure of a primitive descriptor, P, is given by the set of rules which determine whether or not an attribute may be omitted. For example (in this domain), it seems necessary to state the location of pressure explicitly, but the medium may be unspecified.

It is interesting to note that the medical model introduces time and location, typically adverbial constituents, as attributes of descriptors. Fillmore suggests a similar collapsing of (many) adverbs to cases in English. In fact, a commitment to cases often leads to a reduction in the number of grammatical categories - verbs, adjectives and some nouns become predicates, and adverbs and other nouns fill the case positions.

The fact that the glaucoma model can be viewed as incorporating a case system suggests that for convenient, efficient, or flexible implementation of such a model a computer program should be amenable to a case system. It also indicates a direction to follow when adding a natural language interface to the model.

A version of the CHRONOS program [4] has been implemented for the glaucoma model (see Chokhani [11]). In it the cases are {agent, object, location, instrument, time, frequency, derivative, medium} where time points to the duration of an event, derivative is indicated by words like "increasing" and "suddenly", frequency is indicated by adverbs like "rarely" and "often", and agent, object, location, and instrument are as in Fillmore [16]. Medium indicates a fluid location. This allows a distinction between "in the blood" and "in the blood vessel". Other cases may be added as the need for finer distinctions arises. The effect of such a case system on storage structures can be seen by comparison with a traditional {subject, object, indirect object} system. Consider the clause

(61) the pressure in the aqueous humor increased

A traditional parse (see Fig. 5) seems less useful than one which arises from cases suited to the problem (see Fig. 6).

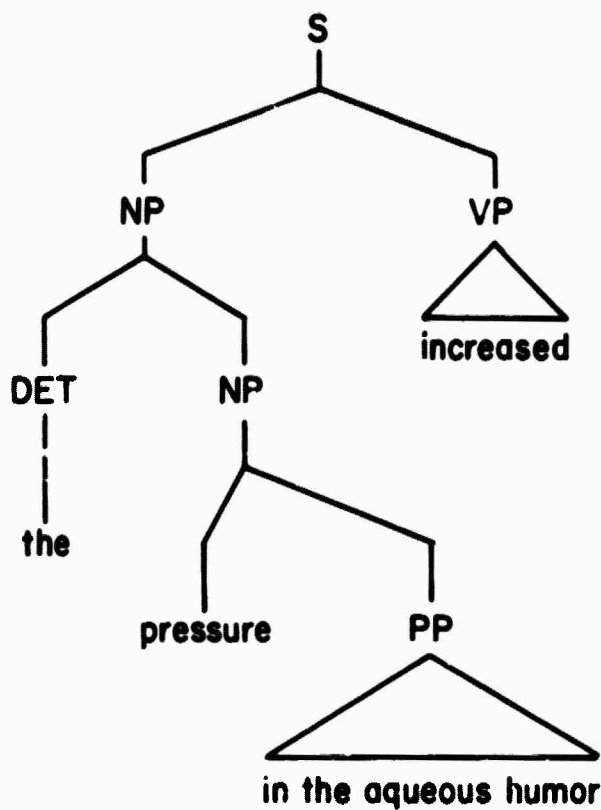


Fig. 5 A traditional parse for "the pressure in the aqueous humor increased."

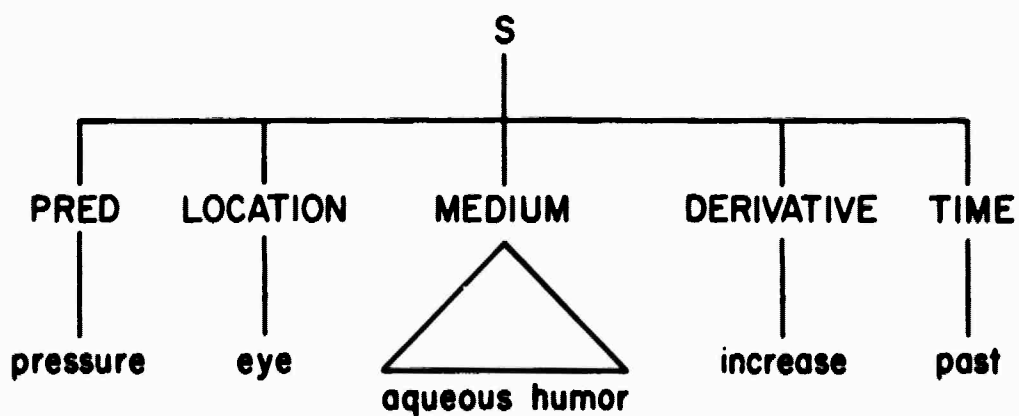


Fig. 6 A case oriented parse for "the pressure in the aqueous humor increased."

Note that in the second parse, "pressure" has become the predicate. Thus the representation focuses on the logical predicate (relative to the purpose of discussion) rather than the syntactic predicate (usually the verb).

6.2.4 Martin[30,31]

The understanding of natural language is ultimately a major part of an automatic programming system. Martin's [30,31] work on automatic programming has led to an extensive case system (30+ cases) for a portion of English. Concerned with representing a large volume of information efficiently, Martin argues [30, pp. 8-9] that

Any scheme which represents the inputs by throwing away information cannot succeed, and there is no reason to expect any small set of concepts to have great explanatory power. Thus we shouldn't expect to find a small number of cases or primitive semantic cases or ideas.

An important feature of Martin's system is the inclusion of sentence elements other than noun phrases as the values of cases. Thus the "expected effect" as in (62) is realized as a verb phrase.

(62) I went home to get a book

(A similar feature appears in other systems. For instance

Schank has an entire conceptualization as the instrument for another conceptualization.)

6.2.5 Cohen [12]

A recent language understanding system, designed by Cohen [12], illustrates an integration of a case grammar approach with procedural semantics. The system is written in 1.PAK (Mylopoulos, et al [33], Badler, et al [1]), a programming language with a flexible control structure and with graph processing features which facilitate the construction and analysis of case structured representations of events. An example question-answering interaction with his system is the following:

Story The rag doll stayed in the holly bush for a whole week. He was soaked by rain and became so stiff and uncomfortable that he shed tears.

Human: Who is in the holly bush?

Computer: The rag doll.

Human: Why was the rag doll stiff?

Computer: Because he was soaked by rain.

Human: Is the rag doll sad?

Computer: Probably.

In order to answer questions of the kind shown above a system must be able to represent the events described in the story in a form which does not obscure the relationship of

entities such as the rag doll to the events. Cohen uses a case system derived from Fillmore [16] and Martin [31] to express these relationships. The cases are {agent, instrument, experiencer, result, location, object, source, destination, duration, nominative, time}. (Nominative is a general case corresponding to the subject of a sentence, especially one with a static verb, e.g. "John is sick.")

The system has both a structural and a procedural dictionary. The structural dictionary contains the case frames for each sense of a verb and could contain the information used to impose selectional restrictions as well. Selectional restrictions are used to reject interpretations such as "the farmer grew the child". The procedural dictionary is composed of procedures which define words. These procedures can be EVENT functions for verbs which take as arguments the cases for the verb, or CONCEPT functions for nouns. When a sentence is processed, the CONCEPT functions build structures for the nominal concepts and the EVENT functions link these together with the verb using the cases as link names.

Understanding a sentence may require disambiguations of several levels. For example, consider the first sentence in the story above, "The rag doll stayed in the holly bush for a whole week". "Stay" has at least two senses, one similar to "remain" and another as in, "the judge stayed the

injunction". A first order disambiguation can be done on the basis of the cases which can be filled from the sentence. Since there is no object present and the second sense of "stay" requires one, we can assume that it is the "remain" sense which is intended. Other disambiguations may occur for nominal concepts or on the basis of applying the selected event procedures.

6.2.6 Brown, Bruce, and Trigoboff [4]

CHRONOS is a natural language system with a flexible case structure. For example it has been used with one case structure for the analysis and summarization of the nurse's notes section of medical records, with another for the study of belief systems within the context of social episodes (Bruce & Schmidt [7], and with a third for building, maintaining, and answering questions about a causal network model of disease (Chokhani [11]).

The storage structures in CHRONOS are propositions which correspond to events or to atomic formulas. They are connected by logical connectives, causation links, and temporal relations. Each proposition has a predicate and a number of cases. These cases may include important adverbial modifiers, temporal indicators and other propositions as well as the usual nominal cases.

Parsing in CHRONOS is done within a control structure which allows re-entrant processes to analyze sections of a sentence independently. The processes perform the usual syntactic analyses, with semantic checking. A major motivation for the design is the desire to make it easy to modify the parser for different case structures. One of the re-entrant processes in the CHRONOS parser is the case parser itself, a function which assigns elements of a sentence to cases. The description which follows is a rather abbreviated description of its salient characteristics.

Features on nouns and case structures of predicates are given by the lexicon. A noun entry includes the following information:

```
word class-----Noun
properties----- $P_1, P_2, \dots, P_n$ 
 $P_1$ -----[preferred values for  $P_1$ ]
.
.
.
 $P_n$ -----[preferred values for  $P_n$ ]
supersets----- $N_1, \dots, N_j$ 
subsets----- $N_1, \dots, N_k$ 
```

For example the noun HUMAN might have a property STATE-OF-MIND with preferred values, HAPPY, SAD, or BLUE. It could have the superset ANIMAL and the subset WOMAN. A noun also has the properties of its supersets listed. A verb entry includes the information:

word class-----Verb

case structure----(C_1 , ..., C_n)

C_1 -----[preferred semantic features for C_1]

.

.

.

C_n -----[preferred semantic features for C_n]

The case structure for a verb is a set of cases ordered by importance to the verb. Thus the term, "the cases of the verb" is relativized to the task (cf. end of Section 3.1). In a given clause CHRONOS will (currently) allow any or all of the cases to be missing.

Case determination depends on syntactic information as well as semantic feature checking. Currently in CHRONOS the definitions of cases exist as LISP functions for each case. Different versions of CHRONOS require redefinitions of the cases with appropriate modifications of the lexicon.

Each possible case function is called for each noun phrase, prepositional phrase, or adverb, and returns a likelihood value. This is the estimate that the concept corresponding to the given phrase serves that case relationship to the main verb of the sentence. The case whose function returns the highest value is temporarily assigned to the phrase. A failure, consisting of values of 0 for all the cases, forces a backup to the previous phrase and a reassignment of its case.

The case parser is essentially independent of the particular set of cases being used. Its speed and generality are, of course, directly dependent on the accuracy of the likelihood numbers returned by the case functions. There are various features which extend the simple heuristic value assignments, making the case functions easier to write or the parsing more efficient. For example, a variable number of "pre-emptive levels" can be created. Once a case function returns a value at a new and higher pre-emptive level, then only values at that level or higher are considered valid. This is especially useful when one knows that a particular preposition, say, signals one, and only one, case. Then that case function returns a value which pre-empts any previous use of that case.

An example of how case systems affect CHRONOS storage structures can be seen by a comparison of two parses of

(63) John calmly broke the window with a hammer

In Fig. 7 the case system is {subject, object, indirect object}. Note that the subject-predicate organization is maintained, resulting in a rather opaque representation. Using the case system {agent, object, dative, instrument, manner, time, locaton} the representation would be as shown in Fig. 8. The latter structure is not only easier to understand but is also more efficient for the program, since inference rules can operate directly on a task oriented representation.

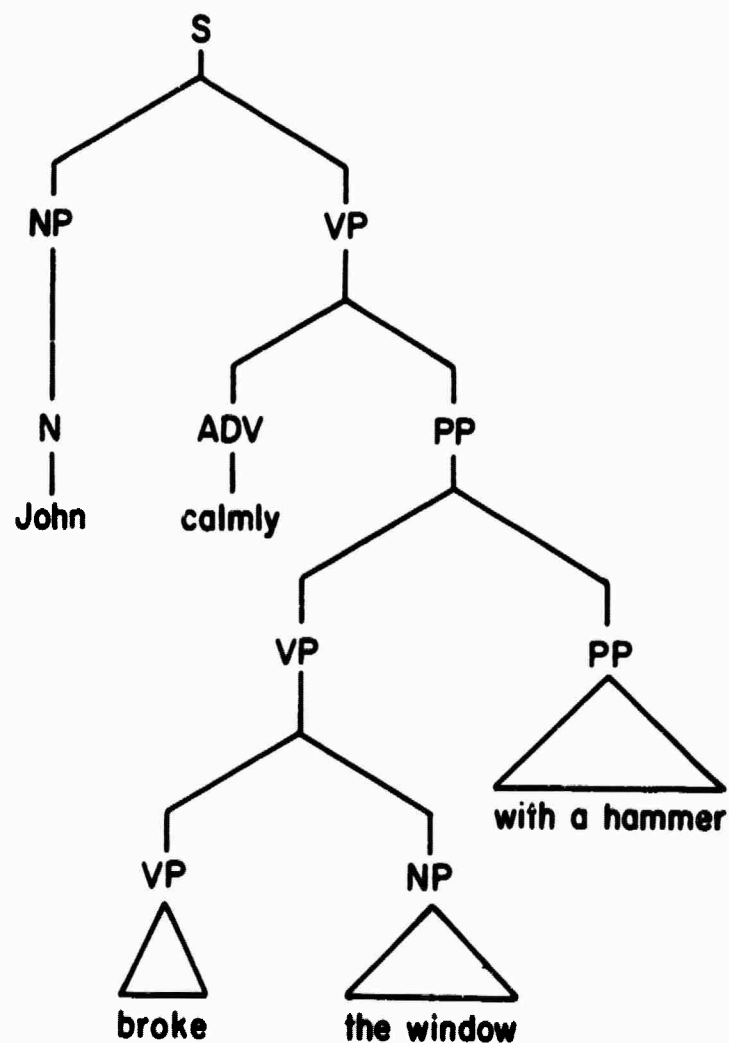


Fig. 7 A traditional parse for "John calmly broke the window with a hammer."

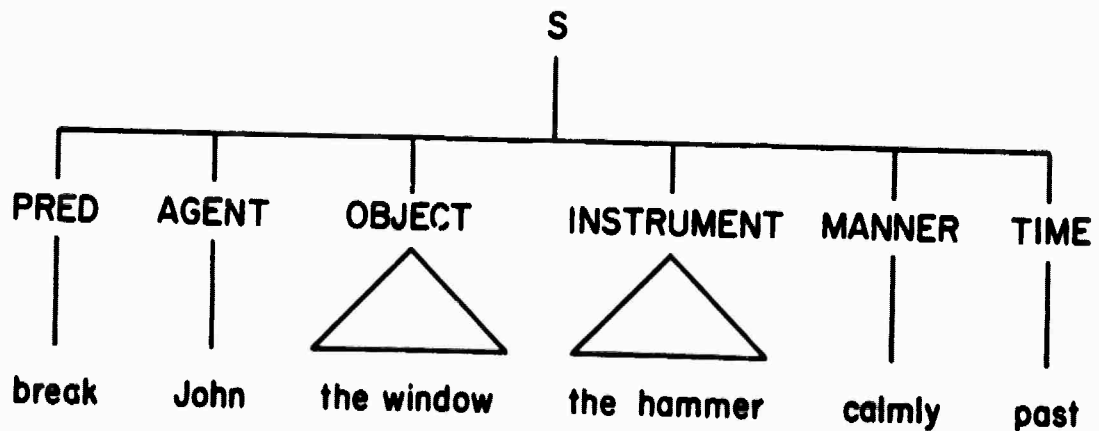


Fig. 8 A case oriented parse for "John calmly broke the window with a hammer."

6.2.7 Baranofsky [2]

Case systems are now being used in speech understanding projects where the need for semantic guidance in parsing is especially relevant. It is interesting to note that two of the speech projects which are imposing the fewest constraints on the input language have implemented case systems as part of their semantics. One of these is the SRI speech understanding system [50]. An early version [2] uses a case system patterned after Celce [10]. A noun group may fill any of the cases: {casual actant, theme, locus, instrument, source, goal}. For each verb there is a

... verb function ... that indicates for each of the verb's senses, what case arguments are obligatory, what semantic constraints are to be placed on each case argument, what prepositions and particles may be expected, and any

peculiarities in sentential ordering of the case arguments. Also, for each sense of a verb, the verb function gives the mapping of the case arguments into a goal state to be achieved by operation of a QLISP procedure. [Baranofsky [2], p.3]

The verb function is called whenever the main verb in an utterance is found. If a noun group preceded the verb then its case is determined. Noun groups and preposition groups are then predicted on the basis of the constraints embodied in the verb function. Paths corresponding to obligatory cases are given a high priority while other paths corresponding to disallowed cases may be deleted entirely.

Consider a sentence whose main verb is "screw", as in

(64) Screw the capnut onto the bolt

or

(65) Screw the screw into the hole.

"Screw" has one obligatory case, the goal, which is realized by "the bolt" in (64) and by "the hole" in (65). It has two optional cases, a theme (e.g. "the capnut" in (64)) and an instrument, such as a screwdriver. The different senses of "screw" exhibited in (64) and (65) are recognized by different features on the theme and goal, and by the different prepositions associated with each case. Once the sense is determined a procedure is called to perform the appropriate action.

6.2.8 Nash-Webber [34]

Another speech understanding project which uses cases is BBN's SPEECHLIS [54]. Extensive use is made of cases in predicting the content of an incoming utterance from words which seem to match some portion of the input, and in verifying the semantic acceptability of a given syntactic structure. Because of its need to face the uncertainties of speech input this system exhibits some useful extensions in its representation of case information. To illustrate SPEECHLIS semantics, let us consider some examples from one of its discourse domains, the lunar rocks. In this domain a speaker is expected to say such things as:

(66) Does each breccia contain olivine?

(67) Give the average K/Rb ratio for each of the
fine-grained rocks

(68) Has lanthanum been found in the lunar fines?

A concept such as "contain" has a case frame which gives conceptual information, such as the associated cases and the concepts which can fill these cases. It also gives lexical information, such as the ways various cases can be realized in an utterance. Usually "case" refers to the arguments for a relation. In the BBN system the notion has been extended to include the relation itself as a case, namely the "head" case. This allows the lexical information

about the relation's instantiation to be represented uniformly with information about instantiations of the arguments.

The first part of a case frame specifies how the concept is realized syntactically (REALIZES), i.e. as a clause or a noun phrase. If the concept is realized as a clause then the cases which can serve as its subjects in active (ACTIVSUBJ) and possibly passive (PASSIVSUBJ) sentences are also listed. Any constraints which might arise between cases are also given here, such as any dependency relations between the way cases are instantiated. The second part of the case frame contains information about each case in the frame, specifically

- a) Its name
- b) The way it can be filled
- c) A list of prepositions which could signal the case when it is realized as a prepositional phrase, and
- d) An indication of whether the case must be explicitly specified (OBL), whether it is optional and unnecessary (OPT), or whether, when absent, must be derivable from context (ELLIP). (Nash-Webber [34])

The last item can be viewed as an approximation to the importance indicators discussed in Section 3. In fact plans for the BBN system include the replacement of these static

values with functions to compute the binding value. "These functions will try to take into account such discourse level considerations as who is talking, how he talks and what aspects of the concept he is interested in" (*ibid*, p. 50).

An example of a case frame for "contain" is shown in Table 5, and one for "analysis" in Table 6.

Table 5

Case Frame for CONTAIN

CONTAIN: REALIZES - clause
 ACTIVSUBJ - location
 PASSIVSUBJ - patient

<u>case name</u>	<u>way filled</u>	<u>prepositions</u>	<u>OBL-OPT-ELLIP</u>
head	"contain"	()	OBL
location	type of SAMPLE	(in)	OBL
patient	type of COMPONENT	()	OBL

Table 6

Case Frame for ANALYSIS

ANALYSIS: REALIZES - noun phrase

<u>case name</u>	<u>way filled</u>	<u>prepositions</u>	<u>OBL-OPT-ELLIP</u>
head	"analysis"	()	OBL
object	type of COMPONENT	(of,for)	ELLIP
location	type of SAMPLE	(in,for,of)	ELLIP

Case frames are used in two ways. One is to make local predictions. For example, suppose the word "analysis" is suspected in some region of an utterance. Then several (possibly contradictory) predictions can be made: (1) that COMPONENT will be instantiated to its immediate left as an adjective modifier (e.g. "sodium analyses"), (2) that either "of" or "for" will be found to its immediate right followed by an instantiation of COMPONENT (e.g. "analyses of sodium"), and (3) that either "in", "for", or "of" will be found to its immediate right, followed by a word or phrase instantiating SAMPLE (e.g. "analyses of each breccia"). Such predictions help focus the search for a complete utterance interpretation, but they do not exclude other possibilities.

A second way that case frames are used is in verifying that a syntactic structure built from words recognized in an utterance is indeed meaningful. For example, suppose that the words "analyses", "ferrous", and "oxide", have been recognized in an utterance in that order but it is not clear exactly where "ferrous" begins. SFEECHLIS would use its case frame for ANALYSIS and its knowledge that ferrous oxide can be a rock component to build the semantic deep structure shown in Fig. 9.

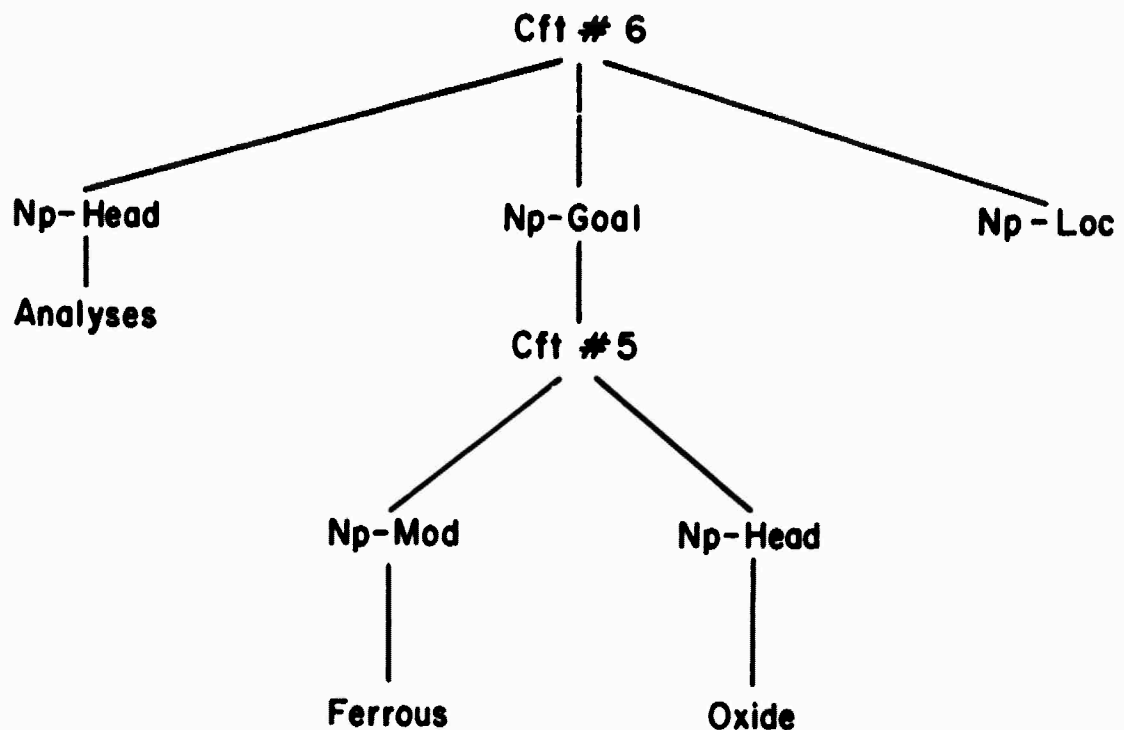


Fig. 9 Semantic deep structure for "analyses of ferrous oxide" (Nash-Webber [34])

Such a deep structure might be realized by "analyses of ferrous oxide" but not "analyses ferrous oxide". That is, if the words are to appear in the order given, there must be an appropriate preposition following "analyses" in order to form a meaningful phrase. This information can be used to modify the system's confidence in a theory about the utterance or to suggest specific acoustic-phonetic or syntactic tests to perform.

7. DISCUSSION

Surface cases were among the first grammatical categories to be distinguished. They are prominent in languages such as Latin, Greek, and Russian and appear residually in languages such as English. Like many other grammatical distinctions the notion of case cannot be handled adequately without some intrusion of semantics, i.e. a notion of the meaning relationship between a case filler and a predicate is necessary to determining the proper case.

The importance of "case" as a syntactic distinction and its relation to semantics have prompted numerous studies of cases at surface, deep, and "conceptual" levels. One purpose of this paper has been to present a framework for examination of the varied results. The notions of "case", "case structure", "semantic feature", and "well formed (case structured) sentence" can also be formalized within a first order logic [5]. Such a formalization may be useful for further comparisons.

It should be stressed that this framework leaves open many questions. One important issue which has not been covered is the relationship between embedded sentences and case structures. What constraints exist on the kinds of embedded sentences? How do these constraints relate to the deep cases of the dominating verb? To the surface cases?

Do characteristics of higher level sentences have consequences on case determination in an embedded sentence? A related issue is the role of cases in the general inference problem. Is a case representation adequate for the kinds of inferences needed in natural language understanding? In what way does it facilitate inferences? Other issues include the specification of surface cases, the relationship of case systems to discourse analysis, and the selection of an ideal case system.

Case systems, since they emphasize a logical structure, rather than a purely syntactic one, lessen the importance of the syntactic predicate and of the sentence as a unit. Many have stressed the need to examine a discourse as an integrated whole rather than as a collection of isolated sentences. It seems that the better a case system is (i.e. the more relevant to the problem solving situation at hand) the easier it is to connect sentences in the discourse in meaningful ways.

Since several case systems are in use, a natural question arises, "What is the best case system?" At this stage in the development of intelligent programs, one can only speak of the goodness of a case system relative to a problem situation. The finely distinguished cases which are arising in the medical model version of CHRONOS, for instance, would probably only clutter a program which

analyzes children's stories. Conversely, certain cases which one would need in discussing everyday life would be unnecessary in a medical model. An important problem, then, is to decide what cases to use in a particular application. Even more interesting might be a study of transformations between various case representations. Problems of summarization and analogical reasoning will probably be more tractable with a better understanding of such case structure transformations.

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