

LANGUAGE PROCESSING VIA CANONICAL VERBS AND SEMANTIC MODELS

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Abstract

A natural language question answering system is presented. The system's parser maps semantic paraphrases into a single deep structure characterized by a canonical verb. A modeling scheme using semantic nets and STRIPS-like operators assimilates the sequence of input information. Natural language responses to questions are generated from a data base of semantic nets by "parsing" syntactic rules retrieved from the lexicon.

Keywords: Question answerer, canonical verb, semantic net, semantic model, generation, deep case, syntactic paradigm, semantic paradigm, time frame, event scenario, grammar.

Introduction

In natural language processing, 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. For example, "buy," "sell," and "cost," etc., all describe essentially the same event. Schank (1) and others have posited the existence of "deep" or "canonical" verbs which unify in the deep structure meaning common to possibly many surface verbs used in ordinary speech. Given a canonical event such as EXCHANGE, the participants (e.g. the BUYER, the SELLER) are ordered in the surface structure, but dependent upon the choice of surface verb and voice (active or passive). This paper describes a language processing system which employs semantic network depictions of canonical events as its fundamental representation of meaning.

The language processor consists of three basic modules as shown in Figure 1. The Parser is used to map English surface structures into a semantic representation utilizing canonical verbs. The sequence of events presented to the language processor over several sentences is woven into a unified knowledge structure by the Modeling System, which builds a STRIPS robot-like model of the situations described. Again, as in the Parser, the canonical event provides the basis of representation. When a question is presented to the system, the Generator is used to produce English output directly from the canonical semantic net built (sometime in the past) by the Modeling System.

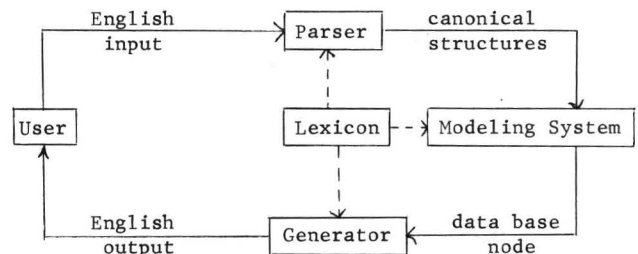


FIGURE 1

A Schematic of the Language Processing System

The Parser

The mapping from English into a canonical constituent structure is accomplished by a variant of the Augmented Finite State Transition Network system described by Woods (2). Since the operation of the system is generally well known, attention will be concentrated on the mechanism which allows for direct translation into canonical structures. The key to this operation is the inclusion of certain information in the Lexicon (Table 1). The property list of each surface verb form (infinitive, past, etc.) contains a reference to a central GENSYM-ed atom which serves as the lexical entry for all forms of a given verb. For readability, these "central" forms will be designated by I-verb, where "verb" is the usual infinitive form. The property list of each central verb contains two special entries (in addition to various others): the attribute CANON-VB indicates the canonical verb (event) associated with the given surface verb; the P-RULES attribute relates the surface noun phrases and prepositional phrases used in conjunction with the given surface verb, to the deep case structure associated with the corresponding canonical verb. This attribute is a list of triples; the first entity in each triple indicates the manner in which an event participant is specified in the surface sentence. If the participant is specified simply as a noun phrase, the first entry of the triple is "OK." If the participant is specified by a prepositional phrase, then the corresponding preposition appears in place of OK. The third entry in the triple names the deep case relation associated with the event participant. For example, consider:

JOHN BOUGHT THE CAR FROM MARY

In Table 1 it may be seen that FROM is associated with the deep case SELLER with respect to the verb BUY. The second entry in each triple is a list of semantic classes: a participant must belong to one of the semantic classes specified by the second triple entry in order to satisfy the deep case relation specified by the third triple entry. This semantic class information is used to help disambiguate the deep cases of sentence components which otherwise appear similar. (This process is also aided by the ordering of the triples.)

L-BUY	
WORDCLASS	VERB
CANON-VB	EXCHANGE
INF	BUY
SG3	BUYS
PAST	BOUGHT
-EN	BOUGHT
-ING	BUYING
PRULES	((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))
GRULES	((BUYER ACTIVE THINGBT (FROM SELLER) (FOR THINGGIVEN)) (THINGBT PASSIVE (FROM SELLER) (FOR THINGGIVEN)))
L-COST	
WORDCLASS	VERB
CANON-VB	EXCHANGE
INF	COST
.	.
GRULES	((THINGBT ACTIVE (BUYER) THINGGIVEN))
L-PAY	
WORDCLASS	VERB
CANON-VB	EXCHANGE
INF	PAY
.	.
GRULES	((BUYER ACTIVE (SELLER) (THINGGIVEN) (FOR THINGBT)))
L-MAN	
WORDCLASS	NOUN
S	MAN
PL	MEN
SPOSS	MAN'S
PLPOSS	MEN'S
MKR	(HUMAN)
L-WHEN	
WORDCLASS	QWORD
PI	WHEN
MKR	(DAY DAYPART)
EXCHANGE	
SURF-VB	(L-BUY L-SELL L-PAY L-COST)

TABLE 1
Some lexical structures

Since semantic class information will be useful in determining deep cases, each noun entry in the lexicon contains a special attribute (MKR) on its property list; this specifies the semantic classes to which the noun belongs. Interrogative pronouns and adjectives (QWORDS) also have the attribute MKR.

The application of the transition network parsing grammar to an input sentence produces two (three, in the case of questions) intermediate structures. For example:
WHO BOUGHT A CAKE AT THE NEW BAKERY FROM THE BAKER.
will cause the production of the intermediate structures:

Verbal constituent:

(CANON-VB EXCHANGE MODAL (TENSE PAST MOOD INTERROG CASE AFFIRM))

NP-PP constituents:

((OK (PHYSOBJ) (TOK L-CAKE DET INDEF NBR S))
(AT (PLACE) (TOK L-BAKERY DET DEF
NBR S MOD (AGE L-NEW)))
(FROM (HUMAN) (TOK L-BAKER DET DEF NBR S)))

QWORD constituent:

(OK (HUMAN) (TOK L-WHO))

The Verbal constituent indicates the canonical verb underlying the sentence as well as the sentence modality. The NP-PP constituents list specifies the NP and PP components of the input sentence in the order in which they appeared. Each such component is represented by a triple: the first entry in the triple indicates the syntactic form (PP, or OK in the case of NP) in which the component appeared; the second entry indicates the semantic classes associated with the component (copied from the lexicon); the third entry is an even-order list describing the nature of the component (as given in the input sentence). The appearance of a QWORD in an interrogative sentence will cause a QWORD constituent to be produced: this is a triple having the same form as a (single) NP-PP constituent.

The final stage in mapping English sentences into canonical structures consists of correlating the entries in the NP-PP constituents list, and the QWORD constituent if present, with the PRULES associated with the surface verb. Basically, for each NP-PP constituent a search is made through the first entries of successive PRULES for a preposition or OK which matches the first entry of the NP-PP constituent; when a candidate is found, the rule's second entry is matched against the second entry of the constituent: if the two lists (sets) of semantic markers have a non-null intersection and the deep case indicated by the third entry of the PRULE triple is not already assigned, then that deep case is associated with the constituent as shown below. Once the NP-PP constituents have been assigned their appropriate cases, the QWORD constituent (if any) is considered; the matching process is essentially that described above, except that all the unassigned cases which match are collected in a list to be paired with the attribute ARGS. The resultant structure is assigned the pseudo deep case label Q. Thus the final structure ("canonical structure") produced by the parser for the indicated input sentence is:

(CANON-VB EXCHANGE MODAL (TENSE PAST MOOD INTERROG CASE AFFIRM)
SELLER (TOK L-BAKER DET DEF NBR S)
THINGBT (TOK L-CAKE DET INDEF NBR S)
LOC (TOK L-BAKERY DET DEF NBR S MOD (AGE L-NEW))
Q (ARGS (BUYER) TOK L-WHO))

The purpose of the parser is to provide a simple, expressive "front end" to the modeling system; the version described is (so far) limited to (possibly conjoined) simple, active sentences without embeddings. Work is in progress to extend the parser to include passives and several types of embedded sentences. Natural extensions include: (1) more complex PRULES, which explicitly express the order of NP's and PP's in the constituents list; (2) a more intelligent correlating algorithm, which is able to recognize NP complements and relative clauses; (3) PRULES for nominalized verbs and nouns modified by PP's; and (4) a richer variety of syntactic and semantic markers.

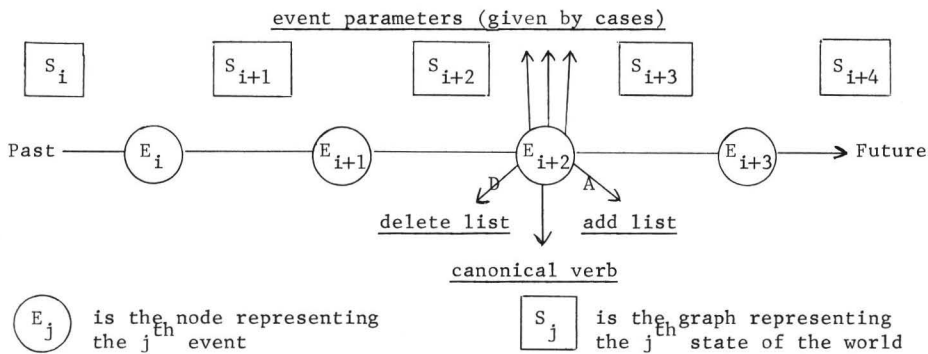


FIGURE 3
Abstract Diagram of the Time Line

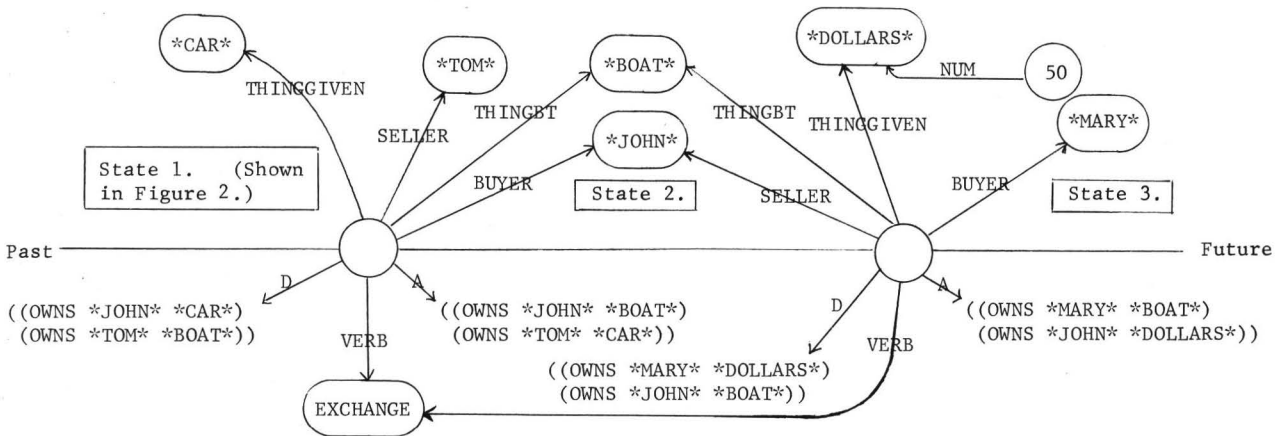


FIGURE 4
Time Line Record of Two EXCHANGE Events
(Note, "intermediate" nodes deleted for simplicity)

reverse order and deleting the adds and adding the deletes. Once a question is answered, an analogous forward process resets the SWG to reflect current conditions.

Questions regarding the nature of events themselves (as opposed to questions concerning relationships which are altered by events) are answered by consulting the record of events on the time line.

As an example of a time line node, consider how the event "John traded his car to Tom for Tom's boat" would change the SWG of Figure 2. The relationships (OWNS *JOHN* *CAR*) and (OWNS *TOM* *BOAT*) would no longer be true. (OWNS *JOHN* *BOAT*) and (OWNS *TOM* *CAR*) would become true. Hence, a time line node like the left node of Figure 4 would be produced.

Events as operators

Since an event transforms one state of the world into another, it is reasonable to think of events as operators. Pursuing this notion, a canonical verb becomes the name of an event procedure (or operation) which transforms the state of the world (an implicit parameter) and a set of explicit event parameters into a new state of the world. The event procedures to be presented here closely parallel the operators used by the STRIPS robot (3).

An integral part of any STRIPS operator is the

"precondition list" which the robot uses in determining a legal sequence of operations. Since our system receives a chronological accounting of events, the necessity of precondition lists for determining event sequence is eliminated. There is, however, a related problem: suppose that part of the input to the language processor is "John bought a clock at the hardware store. Then John bought a cake at the new bakery." Note that John was at the hardware store when he bought the clock. The next event has him buying a cake at the new bakery. Before the event at the bakery could take place (as a precondition to the bakery event), John must have gone (perhaps by a complex route) from the hardware store to the bakery. Thus, the necessity of satisfying preconditions clearly remains a problem even when the event sequence is given. The precondition problem has become the problem of determining the nature of unspecified intermediate events which set the stage for the accomplishment of specified events.

The nature of these unspecified intermediate events may, to a large extent, be determined by the preconditions of the specified events. Returning to the example, before "John bought a cake at the new bakery" some event must have occurred which deleted the relation that he was at the hardware store and added the relation that he was at the bakery. (In general, EXCHANGE events must be preceded by events which bring the participants in the event to the place