TOWARD A STATE BASED CONCEPTUAL REPRESEMTATIOH

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Abstract

This paper discusses representations of seaantic inforRation derived froi these of Schank (1S72, 1971), Milks (1973a, 1973b, 1973c), and Schank et al. (1973). A critical review ot th-^ir related approaches is given that shoes representational inadequacies for language cosprehension in their theories. r.ore ger. srally, various piobl*as in representing knowledge ar» investigated and aethods suggested for handling soae of thee. These problcss concern the representation of states, events, actions, and cases, as veil as the handling of logical and natural language quantifiers, adverbials, fuzziness, and the aeanings of co»f1«x concepts,

I. INTRODUCTION

The priea, . facie appeal of many natural language understanding systems diainishes under close scrutiny. Tnis is duo in part to a lack of detailed consideration ot aany classas of probleas inherent in language understanding. Oftentimes an existing theory cannot be augaented to account for a new class of probleas. Thus the original tbeoty aust be restructured or replaced.

To facilitate the foraulation of a general theory of natural language ur.dtrs-anding, a representational &cbeaa is required that has sufficient expressive pov*r to reprosent the aeaning content of ordinary language. This entails aaking exactly those predictions and inferencss from the representation of an utterance that can be made from the original utterance. The followinq is a development of soae ideas concerr.inq the representation cf individual items of "factual knovledge" in a coaputer, where this knowledge is thought of as being conveyed to the ccmputer in natural language.

The next section enumerates what we btlieve to be the advantages of two related approaches to the problem ot representing natural language in terns of meaning structures. Those approaches are those of Schank (1972, 1973), Milks (1973a, 1973b, 1973c), and Schank et al. (1973). we believe their work exemplifies the correct approach to the problem of rapretenting the conceptual content of natural language utterances.

Subsequent sections outline several difficulties with Schank's and wilks» thooiies. These difficulties concern the representation ot states, «vents, action.'., and cases, as »t?l 1 AS th* handling of logical and natural language quantifiers, adverbials, referential opacity, fuzziness, and the aeanings of coaplex concepts.

II. TWO RELATED APPROACHES

The conceptual dependency approach of Schank and the preference semantics approach oi Milks have the fcllowmg desirable features regarding knowledge representation. These features have not all been articulated by either Schank or wilks and they would perhaps dispute this characterization of thair respective approaches.

the neanir.g structures correspond ing to natural language utterances aro f o r d According to siaple structural rules. Powerful heuristic criteria, based on the central role ot verbs and on preferred seaantic catsgorios for the subjects and objects of verbs, guide each choice in the crwition of mening structures. Interpretation of utterances then takes on a "slct and fillsr" character, th«-r than requiring ejrtentiive trial and error search.

(ii) De-emphasis of syntax
in ordinary discourse it would be absurd not to accept "ungrammatical" constructions such as dangling participles or fanciful locutions such as metaphor. Neither preference semantics nor conceptual dependency impose a syntactic "straightjacket" on admissible utterances. Therefore tho abnormal is not excluded as it is in many linguistic systems.

a major part of out interpretative effort in understanding natural language is focusod on events, i.e., time-dependont relationshipr.. By contrast, "static" relationships in the world are relatively easy to understand. Therefcre the search for fundamental senantic structures and priaitives should concentrate on the representation of events.

(iv) Simplicity of primitives
both Scbank and wilks have shown that there does exist t small, mcre or less adequate, set of action primitives through which a surprising nueber of action concepts car. be expressed. K minimal set of a»iantic primitives shouldbe sought that makes it relatively easy to use the ■earing representations in a lar.guagt (and paraphrase) indapendent way. Relatively few inference sechanisss will then be required.

Me will now consider specific difficulties with these two related approaches and suggest possi bl ways of overcoainj SOB' ct those difficulties. Perhaps the most important difficulties are thos^ encountered when attempting to represent complex concepts and adverbials. However, other points ne^d to be discussed first. In the following discussion ve have in mind Schank's theory more frequently than silks*. How3V£r, Milks* theory is quite closs to Schank's in its general approach.

III. VAGOENESS AND UNCERTAINTY

Under this first heading we bristly confront two related, very pervasive probleas, but offer no definite solutions.

Conceptual vagueness is a seemingly inescapable feature of nearly every ordinary concept, specifically vaguen*ss in the extension of a concept (Is a 1000 foot hill a mountain or the nississippi-Hissouri a rivsr?) and vagueness in the extent of an instance of a concept (where does a mountain or river end?).

Schank deaands that his seaantic structures express ideas ur.aebiguously and precisely. Yet th? concepts which are theaselvas the building blocks of conceptualizations are "vague" to a greater or lesser ixt«nt. Virtually any ordinary concept will •erv» as ar. exanple, e.g. house, aountair, river. Typically a house has rigid walls, a roof, windows, separate rooos, and is suitable for huear. habitation. Yet we can think of unusual houses wh«re any one or aore ot these features is lacking. Fach of these features contributes to "houseners" without being necessary. Siailarly one can show that perceptually related aodifiers such as "trown" or dynamic eodifiers such as "walking" are vague (whers is the boundary between walking and running? is cliabing a str-pp hill, cr a ladder walking? Does a •an with crutches walk? Do centipedes walk? Co seals valk Et cetera). This conceptual vagueness inevitably carries over into conceptualizations. No longer can ve say that it eithsr is or is not the case that "John built a nous-?" or "John was walking hose"; all we can sey is that thesse are tore or lorr, apt descriptions or what John was doing.

It is not clear to us at present how to allow for vagueness in conceptual representations. we expect *to* adopt Zadehes (1905) approach, but have not followed this through. zadeh associates a degree of truth with every proposition and calculates th: truth value of compound propositions from

$$\tau(\neg p) = 1-\tau(p)$$
$$\tau(p \& q) = \min(\tau(p),\tau(q))$$
$$\tau(p \vee q) = \max(\tau(p),\tau(q))$$

This is the standard truth value algebra of many-valued logic (e.g., Rosser and Turquette, 1952). However, we must be very circumspect in our application of this algebra to compound predicates. For example, the term "small" is hardly appropriate for a baby elephant, yet "small elephant" is entirely appropriate. Thus minimization of truth values for the conjoined terms fails. The reason in this case appears to be that most adjectives are operators on predicates (usually nouns) rather than being predicates themselves. Nevertheless adjective-noun combinations can often be analyzed as conjoined pairs of predications, as Bartsch and Vennemann (1972) have shown. Essentially they substitute <u>comparative</u> predicators for monadic adjectival operators. For example, a "small elephant" is something that is an elephant and is appreciably smaller than the average elephant. It seems that we could reasonably apply minimization of truth values to this conjunction.

Some further remarks on vagueness will be made in the sections on complex concepts and adverbials.

Statements can not only be more or less vague but also more or less <u>credible</u>, depending on the reliability of the sources and principles of inference on which they are based. Again we make no definite proposals for dealing with such credibilities. An obvious first step would be to allow credibility values to be attached to any proposition. But the real problem lies in combining credibilities of propositions, particularly "interdependent" propositions. Also there seems to be a close relationship between "fuzziness" and credibility (as we shall point out again in the section on complex concepts). For example the statement "John is young" is based on the fuzzy concept "young" but also appears to induce a <u>credibility distribution</u> on possible ages of John.

IV. LOGICAL AND NATURAL LANGUAGE QUANTIFIERS

Quantification needs to be included in any representation for natural language understanding for several reasons. First of all, logical and natural language quantifiers appear in discourse, for example "John sent the cards to all of his friends" and "Several of my friends were at the game today". Secondly, the use of quantifiers is required in general knowledge as in "It is always windy near tall buildings". Definite descriptions implicitly make use of quantification as the example "the people of China" shows. Lastly, the definitions of complex concepts require quantification. Any complex action concept like <u>walking</u> has associated with it as part of its definition assertions such as "at all times, some of the limbs of the individual engaged in walking support the individual".*

There seem to be three methods in conceptual dependency theory for expressing universal quantification. The first method involves the use of variables assumed to be universally quantified, as in "if <u>one</u> smokes this may cause <u>one</u> to get cancer." Here "one" stands for any person. It is not clear whether a similar approach is envisaged for universal quantification over other (nonhuman) sets. In any case this device is inadequate, as it does not allow for multiple quantification, e.g. "Any politician can fool some of the people all of the time".

A second method for expressing universal quantification is the inference rule. We might have an inference rule in our system that determines "If X is thirsty, infer that X will drink something" where X is a universally quantified object that stands for any person. Thus a machine might easily answer a question like "John is thirsty. Will John drink something?"; however, the existence of this inference rule will not allow a machine to answer questions like "Will John drink something <u>if</u> he is thirsty?" and "Do thirsty people drink liquids?", since no assertion to the effect that someone is in fact thirsty has been made. The problem is that we lack accessibility to a procedurally encoded piece of knowledge <u>as a fact</u>. In other words, knowing how to use a fact does not guarantee knowledge of the fact.

The use of the conceptual tenses <u>timeless</u> and <u>continuing</u> is yet another method for expressing quantification. Schank appears to use timeless to designate <u>habitual actions</u>, for example, "John sells cars". The tense continuing is closely related. It is used in the sense of <u>activity</u> as defined in Evans (1967). However, these special devices do not address the general problem of quantification.

Basically the problem in semantic net representations of quantification is that of indicating the <u>scopes</u> of universal and existential quantifiers, which presents little difficulty in predicate calculus representations. This problem, and others that involve quantified objects of discourse, has been dealt with for semantic network representions by Schubert (1974) in a companion paper. The notation for the graphical representations is fully explained in that paper. Basically, the conventions that are used include: solid loops for proposition nodes and existentially quantified concept nodes; broken loops for universally quantified concept nodes; solid lines to link the parts of a proposition to a proposition node; dotted lines for dependency links joining each existentially quantified node to all universally quantified nodes on which it depends; and broken lines for logical links.

We can classify natural language quantifiers along a spectrum with <u>absolute</u> indicators of set size at one end, and <u>comparative</u> indicators of set size at the other, i.e. those comparing the size of one set to that of another set. The logical quantifier E (there exists) belongs to the first of these categories, since (Ex)P(x) tells us that the set of P's contains <u>at least one</u> member. The quantifier A (for all), by virtue of its equivalence to ¬E¬, can also be placed in the first category. In the context (Ax)(P(x)=>Q(x)) however, where the number of P's is finite, it can alternatively be placed in the comparative category. It tells us that the subsets of P's that are Q's is <u>as large as</u> the set of P's itself. Common absolute quantifiers are "none", "one", "two", "three", ... , "several"; common comparative quantifiers are "all of", "most of", "a small fraction of", "a slight majority of", "one-half of", "two-thirds of", "as many as", "twice as many as", etc. Some quantifiers show both absolute and comparative attributes, especially "some" and "many". For example, in "Many artificial satellites are orbiting the globe" "many" is used absolutely - it appears to imply a cardinality of at least about a dozen. In "Many students attend John's class" "many" is used in the sense "considerably more than attend the average class". This particular use of "many" is discussed quite satisfactorily in Bartsch and Vennemann (1972). They do not appear to be aware of the absolute indicativeness of "many", however, nor of its comparative use in selecting a <u>subset</u> of another set, as in "Many of the world's people are undernourished". Contrast the numerical indication here with that in "many of the apples in the basket were rotten".

In any case, recognizing the absolute/comparative behaviour of quantifiers, we can characterize them systematically by means of predicates on set cardinality and on pairs of set cardinalities as in the following examples. Let "#" denote set size (cardinality).

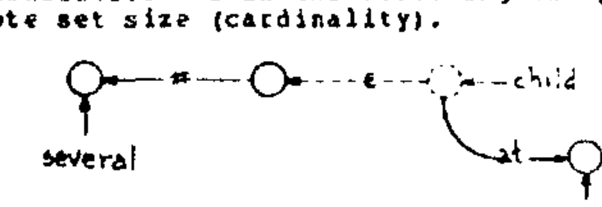


Fig. 1. "Several children were at the door"

We are regarding "#" as a function from sets onto integers and "several" as a (fuzzy) property of numbers. If instead we regarded "several" itself as a possible value of set size, then it would not be possible to talk about <u>the</u> size of the set, as "#" would be many valued (eg., a 6-element set might have both size "6" and size "several"). In the next example "many" is expressed in two parts, the first being an <u>absolute</u> indicator of size (about a dozen or mores), *and* the second ccaparing set size to an average set size, as in Dartdch and Vnnnr-aann (1972). In the construction "avg " is rrqarded as a function on classes of sets whose value is the average cardinality of the sets in a given class of sets.

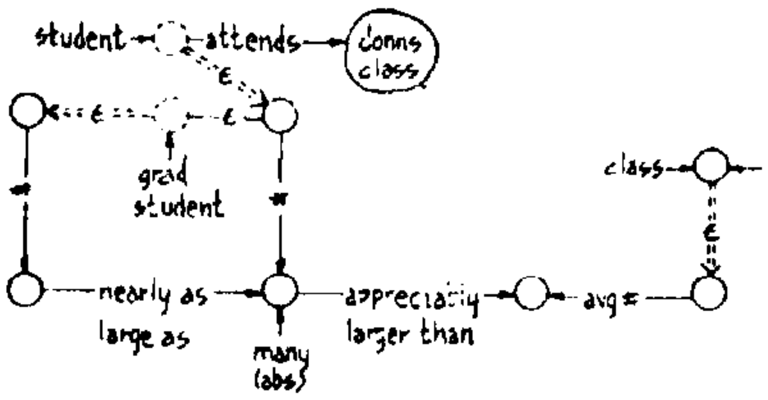


Fig. 2. "Many students attend John's class. Most of them are graduate students."

To conclude this section we briefly indicate the special notation for time. Moments of time, unlike other concepts, are represented as pairs of parentheses and intervals of time as pairs of square brackets. Propositional links to such time rodes are labelled T and TI respectively. The links may be suppressed altogther by placing times directly alongside the predicate tokens to which they apply. With this notation, complex time relations can be represented quite conveniently. The sentence "While he was in Rome, before he met his murderer, he first sang in La Traviata" is diagrammed in Figure 3. For universally quantified time we use broken parentheses or brackets, in keeping with the general quantification conventions.

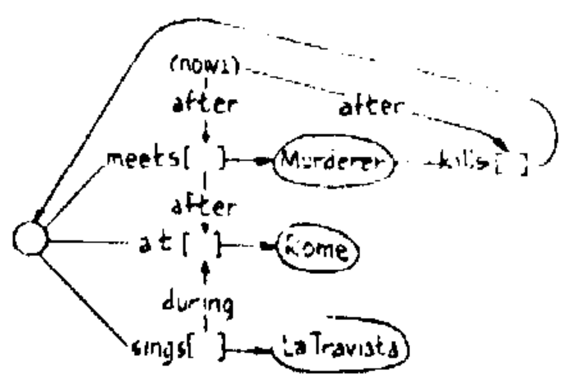


Fig. 3. "While he was in Rome, before he met his murderer, he first sang in La Traviata."

V. STATES, EVENTS, ACTIONS, CASES, CAUSES, AND INTENTIONS

Conceptual dependency diagrams and preference semantics templates are capable of expressing four sorts of assertions:

(1) states - ascribing a modifier to an object or set of objects at some time;
(2) events - ascribing a change of state to an object or set of objects at some time;
(3) actions; and (4) causes.

Nonetheless, a sentence such as

The sun was turning red and approaching the Western horizon. <5.1>

raises many questions. In <5.1> the motion of the sun must be done by somebody or something whereas its change *of colour* cannot *be done by somebody or* something. Thus, using the <actor-action-object> formalism espoused by both Schank and Wilks, modes of behaviour which are expressed by actions must have actors whereas all other modes of behaviour cannot have actors. In the case of the (apparently) moving sun in sentence <5.1>, one is hard pressed to identify the actor; similarly in the sentence "The breaker was moving toward shore." Consequently we are compelled to regard certain ongoing activities which intuitively just "happen" as instigated by soaeone or soaething."

Just as we are coapelled to regard certain ongoing activities as instiqated by sosebody or soaething, we are denied the option of regarding certain actions as having an agent as shown in

John was hurting nary by pulling hor hair <5.2>

In <5.2> the "hurting" not being an action, has no actor whereas in

John was dragging Nary by pulling her hair. <5. 3>

the "dragging", insofar as it involves FTSANS'irg does have John as an actot.

He aay wonder by what criterion we draw the line between what an actor does and what *be causes*. In <5,2>, according to Schank, we are to regard thf "hurting" as caused by the "pulling" action. 3ut th? sane is true ot P?fcNS' ir.g in <5, 3>. Furthermore, even direct bodily acticn such as Bowing ar an can be viewed as caustd by BUSCIO contraction or, subjectively, as caused by an act of will, either of which again Bay hava antecedent causes.

Hith respect to the <actor-act ion-object > foraalisa, it E«°IE to us that no structural priaitiv^s should be atsocisteJ with actors a* all. Instead we will propose a neutral tepreseent.ta'.ion ir. which evjnts arc expressed as seguer.cts of states of the participants. The Euccesr.i v,> states si»ply express "what hapientd", without explicit cc»»i'mpr* as to "who did it". However, tho ag«nt (s) in -w. event can be identified by supplem^n* ir y propositions. Thus the notion of an ig?n* can continue to bo us*d to aid interpretation ind inftrtnea. However, it would b^a regarded as a rath-t "fuzzy" higher level concept, understood by t*U** syst^n in tens of the role of a supposed ag-»r* within a sequ^nc-? of causally and tel»ologics11y related states. Fcr exasple, in th* sentence "John uprooted the saplinq" th; t-»r» agent would b^ consider?d highly applicable *zo* John•s role *in* 'he event while in the s^pntrnc^j "The avalancn* uprooted the tree" its applicability to th-s rolt of th^rt avalanche would b? consid^r^d relatively low. Two factois deterBining the degr»" of applicability of the tera "agent" to an objict in a sequ^enc* *ot* states (event) would be the degree tc whtcn autoncBous ccntrcl of its behaviour can be ascribed to the object and the extent to which a state of th? object can b* held exclusively responsible for initiating the sequence of states.

Similarly we propose to separate *v\\y* something happened (causes, enabling conditions, reasons, explanations, justifications, and tha lik=») froa what happened. *Ks* with "ig^nts", this does not prevent us froa including caunal propositions in tho representation and relying heavily on th^» fo: interpretation and inf^rtince. However, tin-* relations and changes of .state, not cau&es, will give coherence to a set of propositions as an

He feel that Schank's Ingt.ruat?ntal relation b-jtween actions can and should be represented in teras of causation aitd ir.tontion. For example, if a systea has a conceptualization to th» effect that John was TTiUNSMng the ball b£ PBOPn'ir.g it, ther this conceptualiia*ion should also exprers that t:h° fROPEL'ing was CJUS^EJ the PTRANSMnq. In fact, phrases ostensibly expressing instrumental actions often express no aore than causation. An cxaaple is the "ty" clause In

The effluents were killing the fish by raising the t^aperature of the water. <5. 4>

When there Is a difference, it lies in the Intimation of pur/ppsivg causation. In

Jchn woke nary by blowing his tiuapet. <5.5>

purposive causation la expressed, while In

Mary woke up because John was blowing his trumpet. <5.6>

it is not. Sentences <5.5> and <5.6> clearly show that the instrumental relation amounts to a causal relation supplemented by intentional states.

According to Fodor (1972), actions are to be thought of as a proper subclass of events. Let us determine whether this is the case for Schank's notion of an action, and what might justify the special status of actions as opposed to events. According to Schank, an action is something a nominal can be said to be doing at some moment (this is not a quote, but an interpretation of Schank's definition). A study of his proposed inferences shows that in itself an action does not express a definite change in a situation; rather it expresses existence of a situation which tends to produce change, and all actual changes must be inferred. Formulas for actions in Wilks' theory are analogous although they are not described as explicitly as Schank's primitive action concepts. Actions, then, express modes of behaviour which promote but do not guarantee the occurrence of events. For example, the actions PTRANS, INGEST, MOVE do not express changes in location; instead those changes are primary inferences given that an actor is PTRANS'ing, INGEST'ing, or MOVE'ing something. Syntactically, the relationship between an event, say a change in location, and the action, say PTRANS, whose primary inference is that event, corresponds quite closely to the relationship between verbs and their participles respectively. For example to say that John was PTRANS'ing himself with the result that his location changed is quite analogous to saying that he was going somewhere with the result that he went there.* In any case the term "action" is now seen to be quite misleading, since it normally connotes the occurrence of definite events, rather than the existence of a "dynamic" situation which tends to generate events.

Thus Schank's actions (contrary to the connotation of the term) correspond more closely to states than to events! To say that A is PTRANS'ing B is merely to express a momentary truth about the system in which A and B participate, not a change in that system (which remains to be inferred). This view is compatible with the observation that many common modifiers express subtle blends of "passive" and "dynamic" attributes. The examples below bring to mind conceptual images that illustrate a gradually increasing emphasis on dynamics.

blue sky	burning candle
bright sun	blazing fire
glowing (or luminous) candle	billowing smoke

Schank's actions, and, as far as we can determine, Wilks', are "dynamic states," or "activities," or "modes of behaviour" which mediate changes in certain attributes. Thus PTRANS and MOVE mediate changes in location, INGEST and EXPEL mediate changes in containment relationships, and MTRANS mediates changes in awareness.

We believe that the recognition that "actions" in Schank's sense are essentially states rather than events is important, since it leads to a uniform view of all (true) events as sequences of states. In this view the need for identifying "actors" of events does not arise, nor is it necessary to delineate the spurious boundary between "passive" and "dynamic" states.

We now illustrate our representation of states and events. Nothing new needs to be added to the network notation already used in Figures 1-3. We regard any condition which can hold momentarily (blue, moving, running, etc.) as a state. Accordingly, any atomic proposition which is based on a time-dependent predicate is a state proposition. Figure 4 shows two concurrent state propositions: something (the redness of the sun) was increasing throughout some time interval and something else (the distance between the sun and the horizon) was decreasing throughout the same time interval.

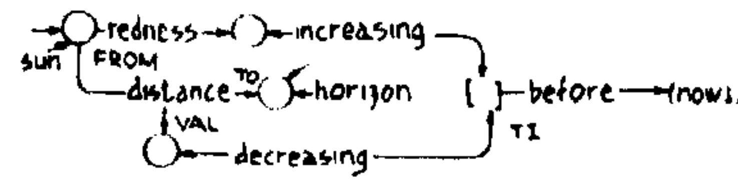
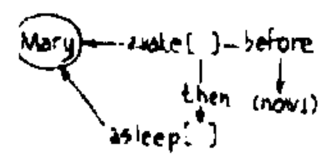


Fig. 4. "The sun was getting redder and approaching the horizon."

Actually there are two additional state propositions, concerned with the existence of unique values of redness and distance at all moments of time within the time interval of interest; these have not been made explicit since they are clearly trivial and would clutter the diagram gratuitously.

Events involve a change in state as "the last leaf fell from the tree" illustrates. The definitive characteristic of state changes is the following: if a system has property A at time t1, and property B at time t2, then A-->B is a change of state if and only if A and B are mutually exclusive properties.* In fact a state attribute such as colour which can assume various values can consistently be defined as a set of mutually exclusive properties, each member of the set being regarded as a value of the attribute. This admits both qualitative attributes such as colour as well as quantitative attributes such as location. Figure 5 shows a simple event involving a single change of state of a "system" with one component (Mary). The time relation "then" implies immediate succession of the two time intervals. Our representation of one of Schank's standard sentences is shown in Figure 6.



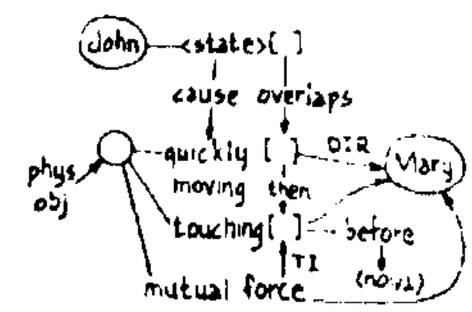


Fig. 5. "Mary fell asleep" Fig. 6. "John hit Mary"

AD explanatory paraphrase is tha followirg."Som- unknown mode of behaviour of John caused scme object to move quickly toward Mary. Subquently the object reached Nary and exerted a forc-i on her." Note that we have a state and an event here, viz. Johr's unknown state and tha event of the object aoving toward nary and striking her. In accordance with our earlier remarks abcut causation, the causal connections between John's state and the ensuing event does not sake John's state part of that event. Only exclusive and successive states of a (articular systea of objects fora events. A natural inf-ranc? in Figure 5 would be that John int'ntior.all v hi* Mary, i.e. that the aissing state of John is tha* h» was trying to briny about the ev*nt in question. w*1 would represent "trying** by th-? state predicate "« has active goal y at tiaa t*. kn additional exaaple

4x ■hnitn in y\eiitre> 7.

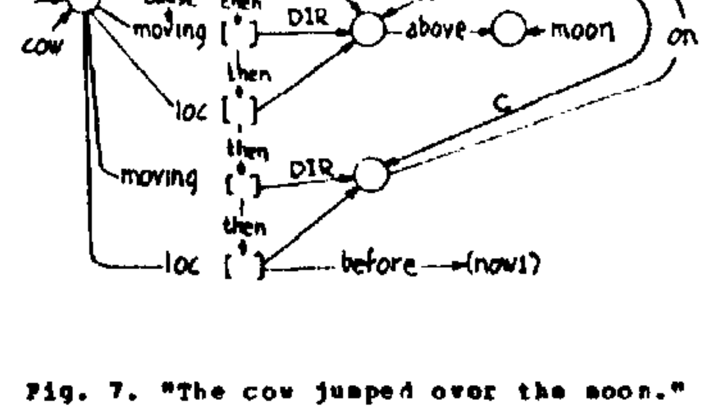


Fig. 7. "The cow jumped over the moon."

The explanatory paraphrase goes an follows. The cuv was somewhere on the ground, propelling itself towards a location above the moon; then it was moving toward that location; then it Was at that location; then it WAS moving towards a plac of destination on the tejiour.d, such that the moon is between the (ildcv *ot* departure and place *of* destination; then it was at the placs et destination. Not" that "moving towards" cculd have been represented in terns of "distance decreasing" as in Figure 4.

An important cor.seguenct: of our very broed conception of states is that new complex stateg (modes of behaviour) can be defined in terms of events involving primitive or already defined states. The time *of* occurrence *of* these events can extend some distance backward and forward from the ■oient at which th? new state is defined to hold. for example "walking" is defined in terms of successive states of motion ani displacement of the valkar's feet and body over a "period of Observation" encemparsing (say) two steps, since in instantaneous "snapshct" cf a person is insuf fici._-r.t for deciding whether or net that person is walking (although it iay of course supply enough cuas tc> prospt tbt *i£l?tt£l}£** that the p-?rson is walking). A tenative definition of "walking" will te given below.

Coaplcx dynaaic states (aodes of behaviour) such as walking, running, dancing, tusbling, flickering, 'tc, can be constructed in terns of ■ore el^a^ntary states. The constructions a:-- necessarily as complex as the states they describe. Coapleiity can result froa the intricate coordination of sov^ral simultaneous activities (e.g. "rolling" ^xprots^F rotation and translation at coordinated rates), or froa coaplcx tin? dependencies (e.g- flickering), or tree both (e.g. "walking" or oven "building a snowaan").

At this point the reader nay wonder whether w? fropose to aike any use of "casos" in our approach to representation. The answer is yes in the sense that w? intend to exploit fully the semantic "preferences" that any given predicate induces on Its arguments. For example the predicate "lovinq" prefers a physical object as Its first arguaent and a physical location as its second argument; 'h-s predicate "has-ac*:ive-qoal" pr-fers a sentient being as its first argument and a state proposition as its second arguaent. FurtIn more, there ate broad siailaritits bet*«»«n th* argument preferences of different pr?Jicates. Tor exaaple, several predicates prefer animate objects in certain arguaent positions. Ue certainly can (and foaetia?s do) ackncwledgd such similarities and give a rough Indication of the sort of preferences invclved by using suggestive arguaent writers such as ANTfl, THING, PLACE, DIRECTION, etc., instead of noncoaaittal Barkers such as A, B, C, ..., . However, we do not think that these aarkers can be chosen so that they express not aerely sifilar but i££Dli£ll argument rol^s and seaantic preferences, no aatt-ar in which predicate they occur. This vi«jw is sufported by Bartsch and v«nneaann (1972):

> "... 'case* is entirely a surface category and not, as Fillaore (1S68) suggests, a category of universal seaantics. Seaantic representations are based on propositions, which consist of a relation (n-ary predicate with n>*0) with a finite nuaber of argueents filled either with constants or with bound variables. The 'aeaning* of an arguient as argument ir. entirely determined by its relation. Therefor*[1], no two arguments hat* precisely the saae aeaning, as arguaents. Thus, if the aeaning of an aiguaent as argument is called a case, then there are as •any cases as there arc arguaents, and this number, if it is finite at all, is a very large one."

Thus seaantic cases, while certainly useful h*uristically in finding cr inferring arguaents of predicates havo no universal or primitive status.

VI. COHPLEX CONCEPTS

According to schank's dictionary. If X gaXKS to Z (where X is huann and 2 is a location) then X PTRANS's *I* by X HOVUng the fent of X in th* direction of Z. A unci criticise of tnis fcrauln *i'*. that it rules out walking on one's handr. and kn* .v,, or walking on one's himl-. (adaittvdly <» rate skill). Wore iapcrtantly, th* tormula adaits running, skipping, hofping, log-iing, shuffling, and ^v■•) skating. Prnsuaably, tl ;i, th-* diet ion.-* ry pntry ir. not int^nd-jd to capture the full aeaning of "walking" as we sees to understand it, tut or.1y those arrets which at- no-st u>r,s»n'. lal to language under standing and (immediate) inference.

Siailarly Milks' foraulas are also mccapleto.* for exaaple, it is correct to say that DRINK iaplic-s ((*ANI SUCJ) ((FLOW STUFF) OBJE) ((»AM IN) (((THIS (•AHI (THhll PART))) TC) (3E CAUJE))))) but rot th-converse (which could mean scaeone was receiving an eneea). So again a selection of linguistically iaportant features has apparently been aadr.

w« feel that it is iaportant to foraulate aor-coapletc aeaning representations for two re*sons. First, we believe that somewhat aoro irfcraation will be required fcr adeguato coaprehension of "ordinary" discourse. Secondly, auyh nor" inforaaticn will suitly be required to latch th.• huaan ability to describe concepts and r^arcn about thee. For exaaple, suppose we ask a reasonably articulate person to describe huaan "welkirg" in as <u>much</u> d<u>eta</u>il <u>as</u> po<u>ssible</u>. We Bight elicit a*, leas*, the following Inforaatior.: *lAch* foot of the walker repeatedly loaves the ground, aoves fr'tly in -n» walking direction for a distance? comparable to th.- length of the walker's le-gs (while stayinq CIOST TO the ground), then is set down again, and ruair-s m position en the ground, supporting the nalkrr, whil- the ether foot goes through a siailar notun. 7h > repetition rate is abcut cne repetition per s-cend. The legs remain aore or less extendod. Th2 body reaains aoie or less erect and is carriad frrward at a fairly constant rate.

Further details cculd be added abou*- flrxir.g actions of ftet, kne-*s, and hips, the slight up-and-down aoticn of th? body, typical arm action, ar.d forces exrrt*>d on the ground. Figure 8 shows * network which describes "walking" (regarded as a state predicate with thr*»r arguaents besides ti«*M along th« abovu lines, *k* few propositions hav b->en omitted so as not to clutrer th^ diagraa. These ar:■ that each foot is also abov» the ground (and close to it) while aoving, that «iach foot is also supporting x while stationary; that the duration of each of the unlabeled tin- intervals [ ] is approxiaately ha lf a second; and that the spe*d of aotion of the walker's body is apprcxiaately constant. There is no difficulty in adding thes* state propositions, except that the last requirr-s "aoving" to have an additional arguaent, r.aaoly th-^ speed of aotion. Note that [ti] is the "tia* interval cf observation" of th*a* walker, and that it contains t, the tiae at which x is said to *b+>* walking. Thus "walking" is defined by behaviour in the teaporal vicinity of the aoaent of predicatur, specifically about two seconds of aotion allowing about three or four steps.

A liaitation of our representation of "walking" is that It is not applicable to unusual aod»s ot walking (e.g. on hands and kn^»s) or to eniials. Or-' question this raises is how aany "kinds" cf walking should be represented separately. Also, is there a representation which expresses the Conor, features of all kinds of walking? Ue have attempted such a representation in Figure 9. The representation i~*s* bas9d on the following characteristics of walking in general:

(1) It is done using liabs that are a subset of the liabs of the individual invclvad in the walking;
(2) the number of lirbs Invclv>d is greater than or equal to two;
(3) at all times soi» of the limbs used for walking are *in* nonsliding contact with the walking surfar (this is not the same as saying com-? ot th°> limb'. arc in contact with the surface at all ti*°.s);

(4) each limb used for walking is stationary on the walking surface at some time and subsequently is moving for some time; and
(5) the individual as a whole is in motion in the walking direction.

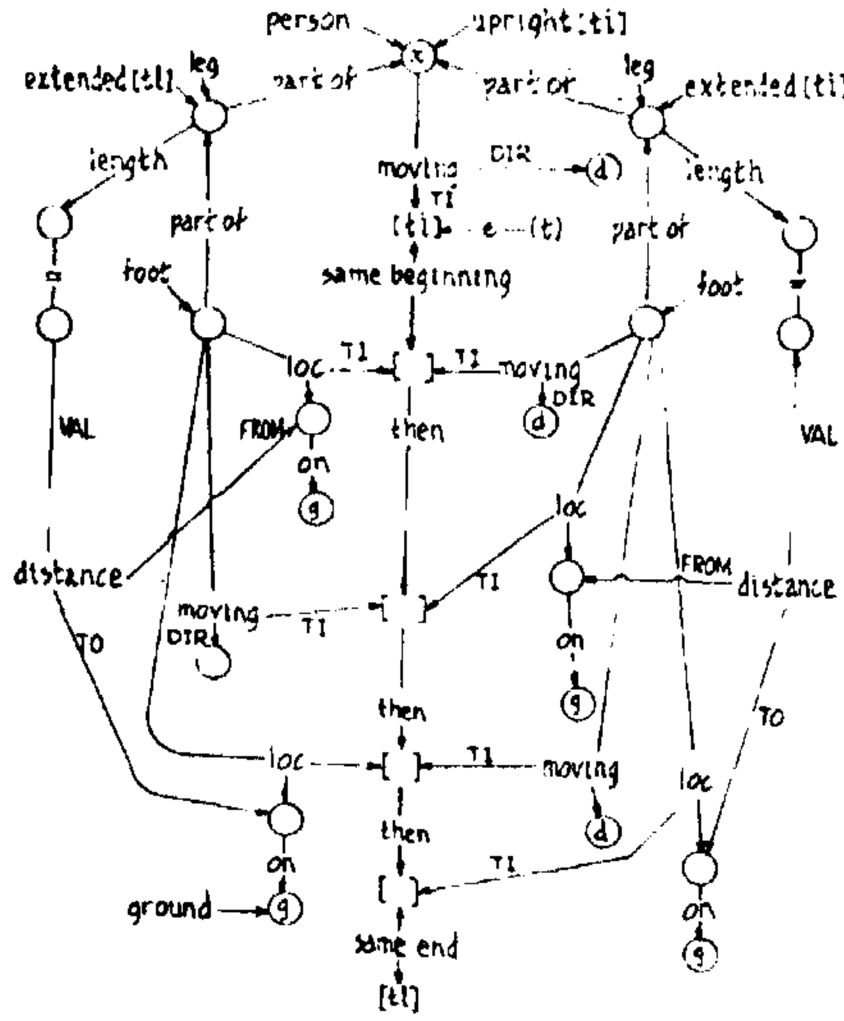


Fig. 8. "Person x walking at time t in direction d on ground g."

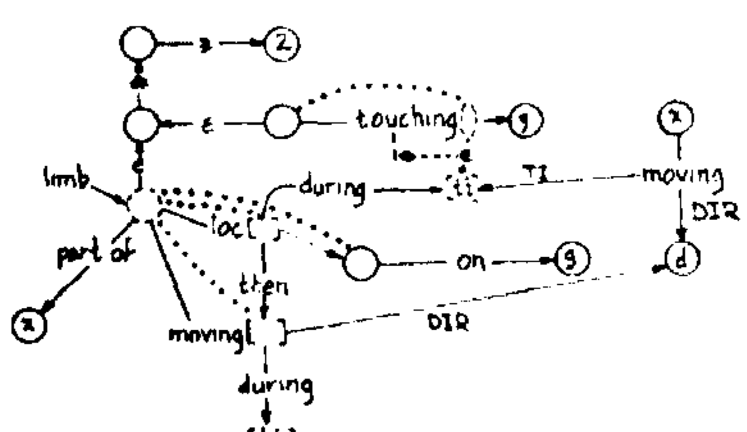


Fig. 9. "x walking at time t in direction d on surface g"

The interesting feature of our representat ion is the use of quantification to describe the rol> of any neabec of legs in the walking. Note that without quantification describing the locoaotion cf say, a ▪illipede would be very tiresome.

A serious flaw in our representation of "walking", and one for which we have no ryr.teaatic roeedj, is that we have ignored the "fuzzlner.s" of many of the aeaninq coeponents. For example, it seas necessary to put some constraints on the length of stride (lest a huaan walker be allowed to eince forward in Billiaet«r incrsaents), yet to giv* an exact distance would bo absurd.

An important consequence of conceptual fuzziness, with regard to complex concept definition, is that we can no longer draw a sharp boundary between extracting the meaning of an utterance and making probable inferences on the basis of the derived meaning structure. This is because we only find the probable meaning of an utterance. For example, the utterance "John built the house" probably means that he built a large, rigid-walled enclosure with a roof, separate rooms, etc.; but none of this is certain. The utterance "John was laughing" probably means that he was producing a series of voiced sounds by staggered exhalation of air, and that his facial expression was merry; but he might have laughed silently, or his facial expression might have been derisive or even hostile. If we try to reduce semantic uncertainty by excluding from the "meaning" of a term all but its absolutely minimal content, and ascribe everything else to inference, we find that this doesn't work too well.' translate under c3 '-' go in the case of "house" all that would remain would be a "partial enclosure" - which accommodates a fenced-off field, a shipping crate, or a jacket.

In the case of "laughing" we would perhaps be left with "spasmodic breathing and intent to convey amusement," which could suggest that John is asthmatic and dancing a jig.

Finally wo wish to point out that aary (perhaps Bost) concepts can be understood in ditftitnt kind.; of ways, for exaBfle, in "John was listenirg to tho incessant chirping of the crickets," i& "chirping" understood siaply by its corr*>spond<*nc» to a particular auditory sensation, or is itur.d.-~rrsr.ood as a rapidly fluctuating, sore or less uniformly high-pitched sound, or evpn as a conplci variation of air pressure with tise? (linsky's (197U) rec^a^nt work on "fraie eysteas" strcngly suggests that th' kind cf understanding of a concept we use at a gi von tiae is extremely task and context depend*itt. This certainly casts dcubt on the one-cancept-or**-foiniulrt approach to language understanding.

VII. ADVEREIALS

Our purpose in this section is to dnw attention to the aajor prcbles of representing adverbial aeanings. In particular we consider artsch and Vennerann's (1972) approach, which seems proaising but will be seen to have serious defects.

Schank (1972) diagrams adverbs as action aodifiers without further analysis. Apparently he has net concerned hiaself with th*Ir Btatinqs so far* In the case cf aany adverbs (as ia the casg of •any adj-scti vt»s) this neglect is probably justified, since lost of th-j aeaning content derives tro* perceptual processes. For exaaple, in the s?ntenc "nary walked gracefully" it is difficult to paraphrase "gracefully" ir. sore eleaentaiy tens. Essentially we knew gracefulness »h*n we see it. Thus perceptual understanding n^eds to be suppleaented only by a few additional facts for language comprehnsicn Purroses, such as the fact that graceful aotion is generally pleasing, is sor° or less the ofposite of awkward action, is sBooth and well-coordinated, and the like. Other adverbial ▪odifiers, howevRr, clearly require syjt^iatic analysis; "quickly" is a good exaaple. Ihis ten appears to say soaetning about th* £j>££d of an action or activity, coaparing it to soae standard. AD adequate auaning representation for "quickly" should spell this out precisely.

Bartach and Venneaann (1972) suggest that adverbial aodlfiers operate on verb aoanir.qs in the saae Banner that adjectival aodifiers operate on noun aeanings. One problce in this approach is best illustrated by the following exaaple.

John owns a large car. <7.1>
John is running quickly. <7.2>

Whereas large in <7.1> has as a reference set the set of cars, and John's car is large in relation to the "average" for that set, "running quickly" cannot be analyzed so easily. If the analogy were perfect then the reference set operated on by "quickly" would be the set of "runnings" (whatever that means); but clearly this set of runnings must be further restricted to the set of runnings John is capable of performing. Thus "quickly" appears to operate not on "running" alone, but on "John running". As further examples consider <7.3> and <7.4>.

The cheetah is running quickly. <7.3>

The ant is running quickly. <7.4>

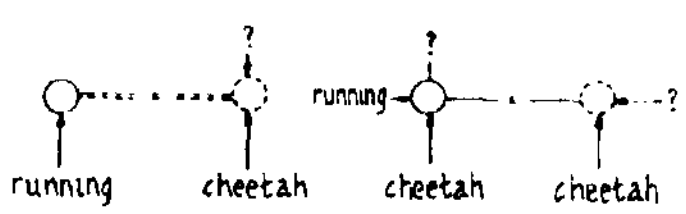
Clearly "quickly" here operates on "running ant" and "running cheetah" respectively.

Thus the nature of the "runner" is being used to narrow the reference set to which we apply a measure function. In <7.2> "quickly" modifies running with respect to John's runnings, or, if we don't know John, at least to human runnings (assuming that John is human). In <7.3> and <7.4> the measure function is applied to the runnings of cheetahs and ants respectively. Unfortunately factors other than the identity or category of the runner can also affect the meaning of "quickly", as shown by <7.5> to <7.9>.

John is running quickly on his hands and knees. <7.5>
John is running quickly on the moor. <7.6>
John is running quickly in Chile. <7.7>
The cheetah is running quickly in the dense forest. <7.8>
The cheetah is running quickly on the plain. <7.9>

The effect of locale on the meaning of "quickly" is seen in the contrast between <7.6> and <7.7> and between <7.8> and <7.9>.

Thus it appears to us that the context which determines the meaning of an adverbial modifier cannot be circumscribed once and for all. In general, adverbials must be allowed to interact with any specific and general knowledge available about the participants in (and setting of) an action. Thus the approach of Zadeh (1972) to the treatment of adverbial "hedges" lacks generality since he needs to specify the (weighted) components of each fuzzy term on which a hedge may operate <u>once and for all</u>. In our semantic network, we would represent <7.3> without the adverb as follows.



(a) (b)

(a) (Ex)((Ay)[cheetah(y) & ?(y) <=> x=y] & running(x))
(b) (Ex)(running(x)&cheetah(x)&?(x)& (Ay)[cheetah(y)&?(y)=>x=y])

Fig. 10. "The cheetah is running."

(a) and (b) are based on alternative (but equivalent) representations of definite descriptions. Figure 11 then shows an attempt to represent the adverbial construction in <7.8> in keeping with Bartsch and Vennemann's (1972) general approach but taking into account the above considerations. In the representation we show the explicit relationship between the speed of the cheetah'srunninyascompatedtotheavor«!>»•.ofarcf'Jienc*setoflunnings(bycheetahsinder forests).

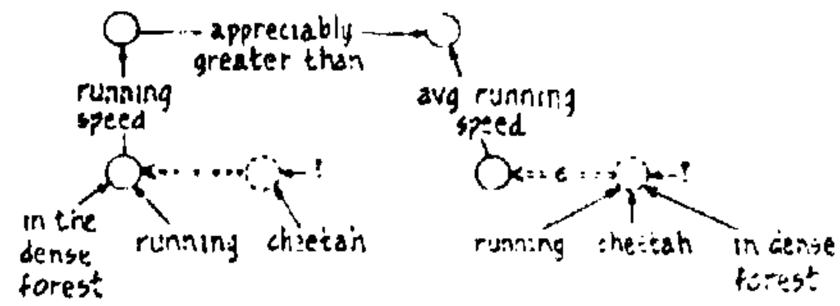


Fig. 11. "The cheetah is running quickly in the dense forest"

Unfortunately the representation suffers from a fatal flaw: the set of cheetahs running in dense forests, required for comparison, may well be empty (if not, replace "dense forest" with "deep snow"). The "reference set" therefore, if it exists at all, is not of this world but of some imaginary world which is our conception of how hard cheetahs <u>would</u> find the going if they <u>were</u> to run through forests (or snow). It remains to be seen whether Bartsch and Vennemann's approach can be modified to overcome these difficulties.

VIII. SUMMARY

We have taken a critical look at what we consider to be the best approaches to a complete language understanding theory to date, namely Schank's conceptual dependency theory and Wilks' preference semantics. In doing so, we exposed many problems and suggested plausible methods for dealing with some of them. In particular, the representation of quantification and of time, the basic representation in terms of states and events, the definition of complex concepts (most importantly action concepts), the handling of adverbial modifiers, as well as the use of time in representations has been examined.

In a companion paper by Schubert (1974), notational difficulties are eliminated for such necessary constructions as logical connectives, descriptions, quantifiers, propositional attitudes and other modalities, as well as other constructions not previously incorporated into semantic nets. This notation appears to be adequate for the "state based" conceptual representation here proposed.

Obviously much work remains to be done. We hope our exposition and partial solution of several major problems will help give direction to this work.

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FCOTNOTFS

[1] Cf. the selectior.al restrictions of Katz (1964).

* For a more complete description see below.

[2] Thia soaething includes natural forces in a vague unspecified sense.

* Unlike Schank we do not regard "he vas going" and "he went" as equivalent; we claim that "he wen*. there," urlike "he was going there," affirms that he did arrive at his destination, and that it is decidedly odd to say "he went there but dide". . get there.**

* Por eiaaple, A*solid, B»liquid; Aground, rectangular.

* Cf. Lakoff's (1972) leiical decospositior tn^s.

[f] It would sees that the huean int*»ifretativ process does not trocced on th-? basis of the ainiaal conceptualization fors«d by eebadding the uranl content of tera£ into the concoptualization. Pather the original i£XJ il*£ll suggests what we could Infer in addition to the ainisal content. This sr:ms lika a reasonable view on the basis of efficiency consideration! as well. It should be such siapl^r to Insert probable inferences in a sssantic structure by direct reference to th* word definitions instead of analyzing the ainieal representation and then looking for applicable inference rules.

* An opaque conteit is one which does net allow substitution of referentlally equivalent etprensions or do-?s not allow eii&tential quantification. This is a well known protlea discussed at length by Quine (I960) and in Artificial Intelligence by McCarthy and Hay«s (1969) and noore (1973).

* See Partee (1972) for details.