

TOWARD A MULTIPLE ENVIRONMENTS MODEL OF NATURAL LANGUAGE

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Abstract

The idea of treating utterances as programs to be run in human brains or on a computer is pursued by advocating the use of the environment notion for natural language semantics. One structure of environments is devoted to keeping track of the real or fictive interlocutors and another to distinguishing somebody's linguistic behavior from its pretense and belief, while the third one represents the structure of topics in a discourse. The required flexibility of environment manipulation is expected to be supplied by the Bobrow-Wegbreit primitives.

Introduction

It is now obvious that the human ability to use language is related closely to intelligence itself. Nevertheless, the complexity of natural language is still rather underestimated by linguistics, including in some measure also computational linguistics. That underestimation results usually in using relatively primitive tools for a formal description of language. Winograd [14] claims rightly that the best test of a complex model of natural language is to implement it as a language understanding system. There is also a more radical approach, insisting that natural language texts are just programs to be run in our brains [9]. Some interesting analogies between language understanding and running a program have been shown, e. g. in [4]. Considering all utterances as imperatives is not entirely a new idea; it can be found also in linguistics papers, e. g. in [13]. But if we treat the utterances as programs, we can describe their semantics by means of notions much more sophisticated and exact than were ever used in linguistics. The purpose of the paper is to advocate the use of the multiple environments model of Bobrow and Wegbreit [2] for natural language semantics. The basic ideas of this approach will be shown by discussing some well-known problems of reference and presupposition. In the early stage of this inquiry's development, the paper tends to a rather theoretical bias. The Bobrow-Wegbreit primitives do not intervene directly into its content, but the flexibility of environment manipulation supplied by them is a necessary condition for the feasibility of the present approach, which is expected to give valuable guidelines for designing discourse understanding systems, including literary discourse like children's stories treated by Charniak [3].

Notion of discourse

The notion of discourse is a rather vague one; therefore, it is necessary to state what I mean by the term. I use it as a synonym for a coherent

text and I recognize four possible aspects of coherency, which correspond intuitively to different types of acceptability.

First, there is contextual coherence, realized in a text by inter-sentence and inter-phrase links represented by specialized linguistic means which I call pointers. They can be distinguished, more or less arbitrarily, in every language. They entail first of all the pronouns (in a large sense, including pro-adverbs etc.). The second important type of pointers consists of presuppositions, which differ from the pronouns in two ways: they rarely occur on the surface of the text, and they point exclusively to propositions. There are also pointers peculiar to given languages; e. g., for English it is reasonable to treat the Past Tense as a pointer, following the approach of McCawley [10] and Isard [7]. Now, if there is a pending pointer (without a value) in a text, the text is not contextually coherent. There is also situational coherence, i. e. the coherence of a text with the situation of its particular usage; e. g.,

(1) Be careful, he might bite you.

is perfectly acceptable if the addressee is near a dangerous animal. Introducing a narrator can change such a text into an contextually coherent one, by substituting its indices (referring to the elements of the real world) back into pointers (referring to more or less abstract text elements). When the addressee has to apply his knowledge of the real world to interpret the text as a coherent one, I use the notion of relative coherence. This is the case in the text

- (2) Ann's eldest son has left Warsaw for a scholarship study in the Sorbonne.
 (3) France is an interesting country to study in.

where the knowledge that the Sorbonne is a French university supplies the missing link. In general we can call a text coherent relative to a given domain of knowledge.

Most texts which are incoherent according to the already mentioned rules can still be regarded as coherent ones if the addressee wishes to do so. I call such a situation volitional coherence. The addressee's will can be expressed in two ways. First, he can supply himself the values for pending pointers. In particular, the events required by the presuppositions are frequently accepted as true, as has been pointed out by e. g. Bellert [1], Wierzbicka [13], recently Karttunen [8], and illustrated by examples:

- (4) I would like to introduce you to my wife.

- (5) We regret that children cannot accompany their parents to commencement exercises.

where the presuppositions carry brand new information. Secondly, the addressee can decide to consider pending pointers and indices as not relevant to the matter; this procedure seems to be applied only for some literary texts.

Pronouns

We will discuss now some problems of reference. Let us start from the assumption that every person (human being or robot) who uses natural language perceives also some aspects of the current situation, in particular he recognizes the persons engaged in the discourse and usually realizes possible differences between his own perception of the situation and the perceptions of others. Restating this in multiple environments terms, we assume that a special type of environments is used to represent the world as perceived and known by a person; a global environment represents the person under consideration and local environments entailed in it are images of its interlocutors.

An utterance is received together with the information about its sender and its addressee; therefore, it can be run in such a way that the personal pronouns "I", "we", "you" etc. translated into variables are evaluated respectively in the sender and the addressee environments, yielding their identification. In this way the evaluation of the sentence (6) said by Fred to Stanley:

- (6) I like your book.

supplies the value equivalent to the utterance

- (7) Fred likes Stanley's book.

run in the proper environment. Which environment is proper depends on the robot's attitude to the discourse. If he believes Fred and assumes Stanley's knowledge to be basically identical with his own, he may run (7) in the environment of himself. But if he wants to keep track of all the possibilities, he has to allocate in Fred's environment which holds mainly the data about his behavior, a new environment for Fred as described by Fred and evaluate (7) in it to obtain Fred's pretense, and then to evaluate (7) again in Stanley's knowledge environment to obtain its probable effect on Stanley's mind. The merit of the approach lies in the fact that it can be applied recursively in the case of direct and indirect speech. E. g., in the text

- (8) Frank said:
(9) "When I came back, John was already waiting for me and asked:
(10) 'How are you?'"

(8) should be run both in the current addressee and sender environments, (9) in the environment of the sender and the new environment of the Frank as quoted by the sender, and (10) in the Frank as quoted by the sender and John as quoted by

Frank as quoted by the sender. The interpretation of utterances with indirect speech, e. g.,

- (11) Fred said to Stanley he liked his book.

and in general the utterances with the 3rd person pronouns, is much more complicated. To account for it we will introduce auxiliary phrase environments for running some utterances, with a special variable similar to the context of CONNIVER [11]. The variable named TOPIC has a tuple as a value and when accessed yields the first element of it, but when accessed because of backtracking yields consecutive elements of the tuple, and after exhausting it takes the tuple of TOPIC from its super-environment. During a run of an utterance, TOPIC is frequently modified by adding and permuting its elements. The elements of TOPIC are pointers to environments of (real or fictive) persons and other data structures representing objects, and also pointers to other phrase environment with his own TOPICs. The interpretation of a text with indirect speech and also single sentences with the 3rd person pronouns can be described now in the following way.

- A. Every access to a TOPIC element resets TOPIC in such a way that the accessed element becomes the first one in the tuple.
 - B. Pronouns in a main clause and proper names execute immediately the access to the TOPIC variable.
 - C. Execution of the access required by pronouns in a subordinate clause can be suspended until the end of the main clause processing, if there is no suitable value for them in the local TOPIC.
 - D. The verbs "say", "describe" etc. create a clause environment with his own TOPIC variable and put the pointer to it as the first element of TOPIC in the environment of the verb.
 - E. The subordinate clauses introduced by "say", "describe" etc. are evaluated in the environment taken from the TOPIC of the main clause environment.
- Let us see with examples how the rules given above work.

- (12) After John left his apartment, he went to the pool hall.

John sets TOPIC to the pointer to the John environment; his is evaluated because there is already suitable value in TOPIC; he evaluates also to John.

- (13) After he left his apartment, John went to the pool hall.

After introduces the subordinate clause, which is being evaluated, but it is suspended before executing access by the pronouns, because of the lack of suitable values for them in TOPIC. John sets TOPIC, after the end of the main clause processing the subordinate clause is resumed and the pronouns are properly bound to John.

- (14) John went to the pool room after he left his apartment.

No problem; John sets TOPIC and the pronouns

access it.

- (15) He went to the pool room after John left his apartment.

He is evaluated immediately because it is contained in the main clause; therefore it is already bound when John sets TOPIC. The strong feeling that the value of he should be different from John can be explained in terms of computational efficiency: there is no reason to set TOPIC to John if it is already the value.

- (16) What did John say about Dick?
(17) He said that
(18) he looked like a drunken giraffe on ice skates.

In (16) TOPIC is set first to John, then "say" creates a phrase environment with its TOPIC initialised to Dick, and puts the pointer to it at the top of its own TOPIC. In (17) "he" evaluates to John, then "said" recovers from TOPIC the clause environment and evaluates (18) in it. Therefore the "he" of (18) is bound to Dick.

Indefinite and definite descriptions

Indefinite descriptions of the type

- (19) It is a foreigner who is delivering a speech now.

have clear meaning in our model. They are just declarations, used to create appropriate environment (in general, data structures) initialized to the values supplied by the description; the pointer to the new environment is put into TOPIC. Therefore in the text

- (20) One young boy has flunked his matriculation exam.
(21) He decided to give up further studies.

the "he" of (21) can receive the proper value of the young boy mentioned in (20). Such an interpretation of indefinite descriptions has in fact all properties of the Ref operator introduced for the purpose by Bellert [1]; it agrees also with intuitions of linguists, e. g. Wierzbicka [13]. Definite descriptions are interpreted as functions which when evaluated in a proper environment yield the required value. The interpretation supports the intuition of Donnellan [5] who claims rightly that a definite descriptions does not in itself refer to anything but only its use points to a referent. That interpretation explains also why we can utter

- (22) Her husband is kind to her.

and be understood even if the man is not in fact the husband of the woman. The functions representing definite descriptions can be also just memorized; such a memorizing corresponds to the attributive use (the term of Donnellan) of the definite description, as, e. g., in:

- (23) The Smith murderer is insane.

in the sense of

- (24) Whoever has murdered Smith, he is insane.

To summarize our discussion of reference, let us run a sentence

- (25) A boy who saw her kissed a girl who knew him.

First, an environment for "boy" is created and the pointer to it is put into TOPIC. Next, "who saw her" is evaluated except the "her" because of the lack of a proper value for it in TOPIC; therefore, the clause is suspended. Then the rest of the main clause is evaluated and an environment for "girl" is made, and the TOPIC is respectively changed. Now the suspended clause can be resumed and evaluated in parallel with the clause "who knew him"; both the pronouns will be properly bound.

Presuppositions

Presuppositions are treated as patterns of event representations; depending on the volitional attitude to the text, the pattern can be matched against the memory to retrieve an existing event or the appropriate event can be added to the memory. We express the difference between factual and non-factual sentences like

- (26) John regrets that it is raining.

- (27) John thinks that it is raining.

assuming that the presupposition "it is raining" is evaluated in the environment of the narrator in the case of (26) and in the environment of John's belief in the case of (27). It may seem strange to talk about presuppositions of non-factual sentences but it is reasonable; although we do not expect such a presuppositions to be true, we still expect it to be coherent, as in (27), with somebody's belief. The environment of somebody's belief and the mentioned earlier environment of pretense interact with themselves, e. g. in.

- (28) Fred is lying when he says he likes Stanley's book.

which evaluates both to "Fred likes Stanley's book" in Fred's pretense and to "Fred does not like Stanley's book" in Fred's belief.

The idea of running an utterance proves useful also in the case of presuppositions. The static treatment by projection rules of the relation between the presupposition of a complex sentence as a whole and the presuppositions of its constituent clauses has not been successful. The recent, more dynamic, approach of Karttunen [8] can be easily integrated into our model. E. g., in the following sentences

- (29) If Dean told the truth, Nixon is guilty too.

- (30) If Haldeman is guilty, Nixon is guilty too.

- (31) If Miss Woods destroyed the missing tapes, Nixon is guilty too.

the antecedent clauses should be run before the

consequent clause to obtain right results. In (30) the presupposition of the consequent clause is satisfied by the antecedent and in (31) it can also be the case, depending on the other knowledge present in the environment of the evaluation.

Concluding remarks

The presented approach requires much further development to become a formal model. Nevertheless, the author feels strongly that the ideas are worth pursuing. Their appeal lies in the flexibility of possible treatment of a sentence, which may account for different amounts of attention put to it understanding, differences in hearers attitude, knowledge etc. It is hoped that the flexibility can be also exploited in other way, i. e., to simplify the model as far as possible to obtain an efficient implementation.

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