

SITUATIONS AND PREPOSITIONAL PHRASES

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ABSTRACT

This paper presents a format for representing the linguistic form of utterances, called situation schemata, which is rooted in the situation semantics of Barwise and Perry. A treatment of locative prepositional phrases is given, thus illustrating the generation of the situation schemata and their interpretation in situation semantics.

Introduction

A natural language system aims to provide an overall framework for relating the linguistic form of utterances and their semantic interpretation. And the relation between the two must be algorithmic. In this paper we pursue an approach which is based on an algorithm for converting linguistic form to a format which we call a *situation schema*.

A situation schema has a well-defined formal structure, suggestive of logical form. This is a structure which is different from the standard model-theoretic one; we will argue that it is a structure better adapted for the analysis of the meaning relation in natural languages. A situation schema is effectively calculable from the linguistic form and we believe that it provides a format usefull for further processing, e.g. in the construction of a natural language interface with a data system and also in connection with mechanical translation systems.

The general structure of situation schemata

We begin by explaining the general structure of the situation schemata and how they are rooted in the situation semantics of Barwise and Perry (Barwise and Perry 83).

Situation semantics is grounded in a set of

primitives	
S	situations
R	relations
L	locations
D	individuals

The format of a *basic (located) fact* is

at l: r,a₁,...,a_n; 1

at l: r,a₁,...,a_n; 0,

the first expresses that at the location l in L the relation r in R holds of the individuals a₁,...,a_n in D; the second expresses that it does not hold.

A *situation* s in S determines a set of facts of the form

in s: at l:r,a₁,...,a_n; 1

or

in s: at l:r,a₁,...,a_n; 0.

We can think of a situation s as a kind of restricted, partial model (data base) which classifies certain basic facts. The set of primitives <S,L,R,D> may come with some internal structure, e.g. the set L of locations is or represents connected regions of space time and thus could be endowed with a rich geometric structure. We shall see how this can be exploited in our analysis of locative prepositional phrases.

A *situation schema* is a complex feature-value structure computable from the linguistic form of the utterance and with a choice of features matching the primitives of situation semantics:

REL	-	
ARG1	-	
⋮	⋮	
ARG _n	-	
LOC	-	
POL	-	

Here the features REL, ARG₁,...,ARG_n, and LOC correspond to the primitives: relation, individuals,

location. POL, abbreviating polarity, takes either the value 1 or 0. The values in the schemata can either be atomic or complex feature-value structures. The value of the LOC feature is always complex.

The interpretation of a situation schema is relative to an utterance situation u and a described situation s . The utterance situation decomposes into two parts

d discourse situation
c the speaker's connections

The discourse situation contains information about who the speaker is, who the addressee is, the sentence uttered, and the discourse location. The latter information is necessary to account for the tense of a sentence. The speaker's connections is a map determining the speaker's meaning of lexical items. The *meaning* of a sentence ϕ_1 is a relation between the utterance situation u ($=d,c$) and a described situation s . We write this relation

$d,c [SIT.\phi_1] s,$

where $SIT.\phi_1$ denotes the situation schema of ϕ_1 .

Remark. In other works, e.g. (Fenstad et. al. 87), we have developed the mathematical study of the structures $\langle S,L,R,D \rangle$; in particular, several axiomatization theorems have been proved, providing a complete inference mechanism for a multi-sorted logic based on a semantics of partial information. Since the *model theory* of these structures seems to be a natural formalism for a (relational) data base theory, it would be interesting to build a PROLOG-style system based on the *proof-theory* which we have developed.

Oblique objects and adjuncts

In the next section the general theory will be illustrated by the analysis of a couple of sentences that contain locative prepositional phrases. In this section we make some preliminary remarks. See (Colban 85) or (Fenstad et. al. 87) for more details. The PP's we consider here are all attached to a verb (not a noun phrase), and will be divided into two classes: oblique objects and adjuncts (Kaplan and Bresnan 82). An oblique object fills one of the argument slots of the verb if one considers the verb to be a relation with a fixed number of arguments. In e.g. the sentence "Tom handed the book to Anne" the verb *handed* is a ternary relation with arguments *Tom, the book* and, one might say, *Anne*. However, we will consider the

third argument to be something that has to be in the relation *to* to *Anne*. An oblique object is thus a constraint on an (unexpressed) argument of the verb. This way a verb may have several oblique objects without the number of arguments necessarily increasing. In the sentence "Tom sent a letter from Norway to France" both *from Norway* and *to France* are constraints on the same argument.

Adjuncts function normally by restricting or modifying the relation expressed by the verb. Examples are: "Tom played *with Anne*" and "Tom ate *in a hurry*." Sometimes the location where the relation takes place is modified and not the relation itself. In e.g. "Tom ran to the car" the location will be restricted to be in the relation *to* to *the car*. This relation will hold if the location is a curve tracing the trajectory in space-time that ends at the (location of) the car.

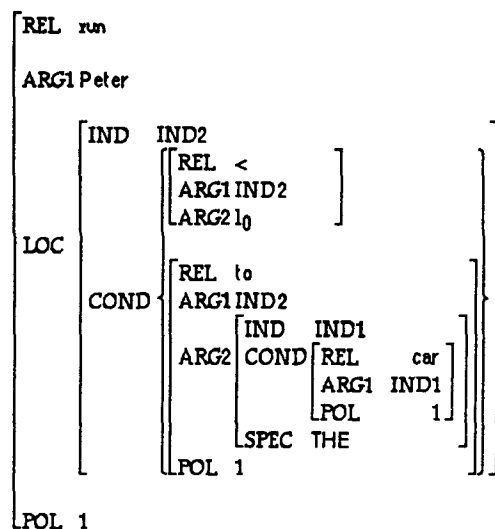
The situation schemata in the examples below have been produced by a parser for LFG-grammars. Usually, f-structures are produced by such a parser, but we have written a grammar that causes situation schemata to be produced instead.

Examples

Example 1:

ϕ_1 : *Peter ran to the car.*

The situation schema $SIT.\phi_1$ is:



The PP is here taken as an adjunct since ran is a unary relation. The values of the ARG_i in the schemata can either be direct references to individuals (e.g. Peter) or *indeterminates* with or without associated constraints (e.g. l_0 , IND1, IND2). The indeterminates have to be anchored to individuals or locations in such a way that the constraints hold in the described situation. The ARG2 in the second constraint of SIT. ϕ_1 .LOC.COND is:

$$\left[\begin{array}{l} \text{IND} \quad \text{IND1} \\ \text{COND} \left[\begin{array}{l} \text{REL} \quad \text{car} \\ \text{ARG1} \quad \text{IND1} \\ \text{POL} \quad 1 \end{array} \right] \\ \text{SPEC} \quad \text{THE} \end{array} \right]$$

This schema tells us that IND1 has to be anchored to an individual *a* that must be a car. The SPEC feature can either be used to pick out the *unique* car in the described situation or to make a generalized quantifier out of ARG2. The situation schemata are hence open to several interpretations.

The LOC feature in this schema has the structure:

$$\left[\begin{array}{l} \text{IND} \quad \text{IND2} \\ \text{COND} \quad \{---\} \end{array} \right]$$

The location is tied to a location indeterminate IND2. The COND feature is a set (notice the set brackets) of constraints on IND2. The first one expresses that IND2 must be anchored to a location *l* that temporally precedes the location that l_0 gets anchored to. By convention l_0 is always anchored to the discourse location l_d . This constraint accounts for the past tense of *ran*. In the second constraint the semantics of *to* tells us that *l* must be a curve in space-time that ends at the location of *a*. The head-relation *run* in SIT. ϕ_1 asserts that the individual named Peter is in the state of running along the trajectory *l*. An interesting project would be to furnish the domain *L* of locations with a set of "primitive" relations which could be used to spell out the meaning of the different prepositions. For the moment the only primitive relation on *L* that has been accounted for in the axiomatization of the structure $\langle S, L, R, D \rangle$ is " $<$ ", the relation "temporally precedes."

A more precise interpretation of SIT. ϕ_1 is:

The relation $d, c [SIT.\phi_1] s$ holds if and only if there exists an anchor *g* on SIT. ϕ_1 .LOC, i.e.

$$g(l_0) = l_d \\ g(IND2) < g(l_0)$$

and an extension *f* of *g* that anchors IND1 such that $f(IND1)$ is the unique individual such that *in s*: $c(car), f(IND1); l$ such that

$$\text{in } s: c(to), g(IND2), f(IND1); l \\ \text{in } s: at g(IND2): c(run), c(Peter); l$$

Note that relations between locations can easily be extended to include individuals among their arguments. This is done by introducing a function *loc.of* from *D* to *L* mapping individuals on their locations. A relation *r* between locations is extended to a relation *r'* where some of the arguments are individuals by letting:

$$r', \dots, ai, \dots; pol \text{ iff } r, \dots, loc.of(ai), \dots; pol.$$

Example 2:

ϕ_2 : The book was lying on the table.

The situation schema SIT. ϕ_2 is:

$$\left[\begin{array}{l} \text{REL} \quad \text{lie} \\ \text{ARG1} \left[\begin{array}{l} \text{IND} \quad \text{IND1} \\ \text{COND} \left[\begin{array}{l} \text{REL} \quad \text{book} \\ \text{ARG1} \quad \text{IND1} \\ \text{POL} \quad 1 \end{array} \right] \\ \text{SPEC} \quad \text{THE} \end{array} \right] \\ \text{ARG3} \left[\begin{array}{l} \text{IND} \quad \text{IND5} \\ \text{COND} \left[\begin{array}{l} \text{REL} \quad \text{on} \\ \text{ARG1} \quad \text{IND5} \\ \text{ARG2} \left[\begin{array}{l} \text{IND} \quad \text{IND4} \\ \text{COND} \left[\begin{array}{l} \text{REL} \quad \text{table} \\ \text{ARG1} \quad \text{IND4} \\ \text{POL} \quad 1 \end{array} \right] \\ \text{SPEC} \quad \text{THE} \end{array} \right] \\ \text{POL} \quad 1 \end{array} \right] \end{array} \right] \\ \text{LOC} \left[\begin{array}{l} \text{IND} \quad \text{IND2} \\ \text{COND} \left[\begin{array}{l} \text{REL} \quad < \\ \text{ARG1} \quad \text{IND2} \\ \text{ARG2} \quad l_0 \end{array} \right] \end{array} \right] \\ \text{POL} \quad 1 \end{array} \right]$$

The PP gets here two readings; one as an adjunct and one as an oblique object, but we have omitted the adjunct reading since it isn't natural. The relation *lie* takes two arguments: ARG1 and ARG3. The indeterminate IND2 must be anchored to a location that temporally precedes the discourse location. IND1 must be anchored to an individual *a1* which is the unique book in the discourse situation, and IND4 must be anchored to an individual *a2* which is the unique table in the discourse situation. SIT. ϕ_2 .ARG3.COND forces IND5 to be anchored to an individual *a3* such that the relation *on* holds between *a3* and *a2*. The relation *lie* will hold between *a1* and *a3* if *a1* is lying and the locations of *a1* and *a3* are the same.

A precise interpretation is:

The relation $d,c[SIT.\phi_2]$ holds if and only if there exists an anchor g on SIT. ϕ_2 .LOC, i.e.

$$g(l_0) = l_d$$

$$g(IND2) < g(l_0)$$

and an extension f of g that anchors IND1, IND4 and IND5

such that $f(IND1)$ is the unique individual

such that $in\ s: c(book), f(IND1); 1$

and $f(IND4)$ is the unique individual

such that $in\ s: c(table), f(IND4); 1$

such that

$in\ s: c(on), f(IND5), f(IND4); 1$

$in\ s: at\ g(IND2): c(lie), f(IND1), f(IND5); 1$

Final remarks

This analysis has been implemented on a XEROX 1109/1186. Other fragments have been implemented using the D-PATR format. In a study of direct questions (E. Vestre) it turned out to be advantageous to use a DCG-grammar and a PROLOG-implementation. The spirit of the algorithms are however the same, unification and constraint propagation (see (Shieber 86) for a general discussion). We are now studying the problem of text generation based on situation schemata augmented by certain pattern information.

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