A Relational Representation of Modification

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Abstract

The KING KONG parser being developed at The MITRE Corporation combines an argument-structure shorthand with recent work on the relationship between spatial and non-spatial sets of relations and a relational model of abstract relations to produce a robust approach to modifier constructions.

I. Introduction

One of the overlooked problems in natural language processing is the representation of abstract relations like LENGTH, DURATION, and DISTANCE and the definition of words which refer to them. The natural language group at The MITRE Corporation, in the course of designing a portable, extensible natural language interface for expert systems, has drawn strategies from work in three areas to implement a robust and easily extensible approach to comprehending such terms. This paper will discuss these three strategies and the motivations behind them, and then provide an example of their cooperation.

II. Relational Approach to Attributes

Crucial to our design is a relational approach to abstract relations, as opposed to some sort of attribute-value representation. The latter is present in the parsing strategy of DYPAR and its descendants and in the knowledge representations KL-ONE and NIKL in the form of ROLES. The problem with this sort of approach is the restriction it places on the nature of its relations: as pointed out in [Vilain85], ROLES correspond semantically to two-place relations (one-place predicates). However, while this accounts for attributes like LENGTH quite nicely, it does not, in its simplest form, permit the description of three-place relations like DISTANCE.

The attribute-value approach can certainly be augmented to handle predicates of more than one argument; two common alternatives are coercing such predicates into combinations of predicates of one argument (perhaps by allowing the values of attributes to be predicates themselves), or adding some primitive representation of predicates of three or more arguments. However, as [Woods75] points out, it is far from clear in the former strategy that all predicates of more than one argument can be broken down into predicates of just one argument in a conceptually satisfying way. The latter strategy, as Woods states, might amount to a reevaluation of the ontological status of relation statements. In an attribute-value representation the relation is represented by a link between two nodes; Woods introduces the work of Fillmore and his notion of case, and notes that, in a case representation of events, "Instead of the assertion of a fact being carried by a link between two nodes, the asserted fact is itself a node (p. 229)." KL-ONE, which already has ROLES as nodes rather than links, takes this latter approach; however, since the semantics of ROLES restricts them to two-place relations, KL-ONE requires a separate mechanism as well.

We find such an account to be formally divisive. Since an additional mechanism in which assertions about abstract relations like DISTANCE exist as nodes instead of links seems motivated, why not use it for all assertions of this type, rather than just those which do not adhere to the two-argument restriction? Our goal of developing an interface which can be ported to many target systems makes this choice even easier; we must be concerned with access rather than organization, and one of the major advantages of a relational representation over an attribute-value representation is its uniform access of data. Since an attribute-value representation has the arguments of its relations in distinguished, non-parallel positions, queries in such a representation must be handled one way in questions involving the value of an attribute and another way in questions involving the object which bears the attribute. A general relational scheme, on the other hand, allows any argument to be accessed with equal ease. The processing required by the backend might vary widely, but the role of the interface, as I said, is that of access, not organization.

The one drawback to an approach like this, where relations belong to an ontological category distinct from objects and events, is that it is not conceptually object-based, as opposed to an attribute-value representation such as a nominal case-frame, which is. Indisputably, there are many situations in which an attribute must be tightly bound to an object, but a relational representation does not preclude the expression of such a connection; it is merely silent about it. An attribute-value representation, without augmentation, on the other hand, actively precludes the expression of more complex relationships; and an attribute-value representation with a conceptually adequate augmentation amounts to the addition of a relational mechanism, which renders the attribute-value mechanism redundant.

III. Shorthand for Representation of Argument Structure

Once we have settled on this relational representation, we need to extract the arguments of these relations from linguistic structures. In addition, we would like the method of extraction to embody generalizations about the possible ways these arguments can fit together. We have implemented a linguistically motivated shorthand for argument positions which captures just such generalizations.

In general, there seem to be three classes of expressions which associate relations with objects:

(a) expressions of predication:
The runway is long.

(b) expressions of attribution where the object is the head:
the long runway

(c) expressions of attribution where the attribute is the head:
the length of the runway
the runway's length

While these phrases denote different things, the connection between *runway* and the notion of length is the same in all of them. Ideally, our statement of how *long* relates to the LENGTH relation will be the same in both (a) and (b), and should extend trivially to the relation between *length* and LENGTH in (c). Not only is the semantic similarity between these two cases great, but their syntactic behavior can be quite similar at times as well, since nouns like *length* and *distance* can at times function in constructions like (a) as well as (c) compare, for example, *Dresden is far from Hahn* and *Dresden is a great distance from Hahn.*

In order to capture these patterns, we use the following shorthand. The possessive position, for example, in *the runway's length* in (c) corresponds to the THEME (or OBJ, in the terms of Schank) in *The runway is long* (case (a)), as far as the roles of the relation LENGTH are concerned. In most circumstances, this position is the same as the head in object-centered NPs (case (b)). As a mnemonic for this position we use the symbol POSS-OBJ, combining possession with the semantic OBJ position.*

The POSS-OBJ argument location looks at the relation from the point of view of the word or phrase which denotes the relation; the argument in POSS-OBJ is either the semantic OBJ of the relation word or the POSSessor. The other shorthand argument location, PRED-MOD, looks at the relation from the point of view of one of the arguments. The PRED-MOD position corresponds to the value of the relation, either designated by the word that designates the relation (as in *far* in *Dresden is far from Hahn*; this is the PRED position), or by its modifiers (as in *great* in *Dresden's great distance from Hahn*; this is the MOD position). Once again, case (b) usually behaves like the others (but see previous note).

With the use of this argument shorthand, we can capture the meaning of designators of length, for example, by saying that the object measured is in the POSS-OBJ position and the value of the measurement is in PRED-MOD for the relation LENGTH. The only difference between the meaning of *length* and the meaning of *short* or *long* is that the latter two have scalar designations to fix their value in the relation. *Long* is designated as :GREAT, while *short* is designated as :SMALL.** This generality allows us to handle examples like *Dresden is a great distance from Hahn* as hoped, since once we recognize that there is an attribute designator in PRED position and a potential argument in OBJ position, we can handle it in the same way as we handle *Dresden is far from Hahn,* since their "meanings" are quite similar.

IV. Generalizations among spatial and non-spatial fields

We have argued for a relational approach to abstract relations in an interface and have shown how such an approach can combine with a thematic representation of argument structure to express the relationships in meaning between semantically related words. We can simplify our representation of relation words even further, by generalizing between senses which are related in a coherent way. This research is based on the recent work of Jackendoff, recasting older work of [Gruber65].

The problem is to relate the meanings of *long* in *the long runway* and in *the long meeting.* Jackendoff begins with a detailed analysis of the former and arguably more complex class of relations, that is, spatial relations, concentrating on the relations denoted by prepositions. Jackendoff distinguishes between the notion of PLACE and the notion of PATH, the former exemplified by the phrase *in the room* in *John is in the room* and the latter by the phrase *into the room* in *John ran into the room.* Jackendoff recognizes three different types of PATHs: bounded paths, directions, and routes. *From* and *to* typically designate bounded paths, in which the argument is an endpoint of the movement. These contrast with directions, designated by *toward* and some uses of *from,* where the argument is in the direction of the motion but not necessarily reached. The third type, routes, presents the argument as some point along the path. *By,* in *the man ran by the river,* demonstrates this function.

However, these PATHS and PLACES can exist not only in space. *At night* is a PLACE in time, while *towards sunrise* is a temporal direction. The great insight of Gruber, Jackendoff notes, is that the meaning of these path and place functions represented by prepositions can be parametrized, in general, by the ontological category of their argument, and that those non-spatial expressions that result will be a subset of the possible spatial expressions. So while the preposition *at* converts a THING into a spatial PLACE, it converts a TIME into a temporal PLACE. Similarly, the preposition *to,* which produces a spatial PATH out of a THING, produces a temporal PATH out of a TIME, and a possessive PATH out of a

*However, there are circumstances in which the head NP does not correspond to the position of POSS-OBJ: The behavior of the notion of ACCEPTABILITY differs between predicative and non-predicative constructions. *The airbase is acceptable as a target* and *the airbase's acceptability as a target* both have the object in POSS-OBJ position and the role it is to play in the *as* PP; however, *the acceptable targets* has the role in head noun position, the position that usually reduces to POSS-OBJ. This difficulty, I feel, is most likely a subproblem of the general issue of representing adjectives such as *late* whose predicational and attributive meaning differ radically.

**These degree designations will become much more sophisticated with time, but we intend to resist specifying values.

THING in proper contexts: *I gave a book to my cousin.** The meanings of prepositions, then, are not relations per se but a group of relations, differentiated in part by the ontological category of their argument. Such an analysis can be extended to an adjective such as *long* in an analogous way, substituting the notion of EXTENT for the notions of POSITION, DIRECTION–TOWARD, DIRECTION–FROM and the like that are active for prepositions.

Our implementation of Jackendoff's and Gruber's ideas recognizes relation TYPES, which are basically the groups of relations alluded to above, and relation FAMILIES, the ontological parameters which interact with the TYPES to determine the actual relation involved. We currently recognize such TYPEs as POSITION, EXTENT, INTERVAL, ORIGIN, and DESTINATION (leaving aside for the moment Jackendoff's distinction between bounded paths and directions), and such FAMILIES as SPACE, TIME, and POSSESSION. The definition of *long* and *length* designate the EXTENT type, with the family left undetermined. Similarly, the definition of *at* specifies the POSITION type, with the family left similarly unspecified.**

This explicit account of relationships between relations combines with our argument structure shorthand described above to broaden the possible coverage of a natural language understanding system in some fascinating ways. First, Jackendoff points out that a significant subset of the ordinary semantics of words is inherently metaphorical: that is, a significant number of possible relations between entities is expressed, ultimately, in terms of spatial relations. The metaphorical power embodied in this approach is exploitable by an interface, especially if the analysis is extended to verbs (see fn. 3). An expression like *Time flies*, for example, could be comprehended by considering the definition of *fly*, relaxing the conditions on the ontological category of the subject, and find a corresponding action in the temporal family which embodies the concept of rapid motion.

Second, our shorthand argument representation allows us to generalize the meaning of relation–designating words across structures and parts of speech. This suggests that morphological derivation from attribute words can be at times trivial; the *–ness* and *–ly* suffixes, which effectively change the part of speech of a word without affecting its meaning in the productive case, can be handled generally without worrying about semantic effects. *The longness of the runway*, if such a phrase were coined, or even *the closeness of the plane to the runway* could be handled simply, with a distinction in the morphology and syntax and not in the semantics.

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*This last example demonstrates that there are interrelationships between verbs and these functions; while Jackendoff discusses these interrelationships extensively, we will not investigate their utility here.

**More than one relation may be present at the type–family intersection; thus EXTENT of SPACE may be SPACE–LENGTH, WIDTH, or ALTITUDE. One relation is the default, selected by those words like *length* which specify only a type; others are accessed directly. The definition of *altitude*, then, while fitting into the type–family matrix, specifies the relation ALTITUDE explicitly.

V. Implementation

The KING KONG parser being developed at MITRE implements most of the ideas above. As an illustration, consider the definition and processing of *long* and *length*. We will examine three stages: the relation type EXTENT, the structure which connects the relation–designating words to this type (structures which we call *accessors*),*** and finally the relation itself.

Consider first the definition of the type which will be part of the definitions of *long* and *length*.****

```
(def-db-type
  extent
  '(topic span)
  :mapping-to-families
  '((((topic . event) (span . time)) . time)
    (((topic . object)) . space)))
```

Figure 1.

The EXTENT type has an arbitrary ordered argument structure which all relations of this type must have; it maps to families via an a–list of argument positions and ontological restrictions on that argument.

The definition of the query accessor associates words with queries or query types and tells the parser how to assemble the argument structure.

```
(def-query-accessor
  3
  extent
  '((topic poss-obj) (span pred-mod))
  :simple-designations
  '(long length short)
  :degree-designations
  '((long . :great)
    (short . :small)
    (great . :great))
  :relation-designations
  '(((width) . width)
    ((altitude) . altitude)
    ((range comrad) . range)
    ((very great) . size))
  :canonical-accessor-p t)
```

Figure 2.

***These structures are attached to the definition of the word, and should probably be part of the original definition instead of being defined separately. This is a problem which we will address later.

****The definition of the family is not important for this discussion; it contains information about units relevant to the family (such as MILE for SPACE and HOUR for TIME) and conversions between them.

Its first argument is an arbitrary number assigned to this accessor for reference purposes. The second argument is the relation type which it accesses, while the third argument is an a–list of argument names and sources for those arguments. Here each argument has only one source (although there could be more). Notice the use of the shorthand POSS–OBJ and PRED–MOD discussed above. The simple designations are the words with which this accessor is associated; by virtue of this definition, *long*, *length*, and *short* all have this accessor on their frames and thus point not to a single relation, but to all relations of type EXTENT, spatial, temporal, or otherwise. The relation designations are those words which map directly to a single relation of type EXTENT; by virtue of this definition *width*, for example, has an accessor on its frame which specifies the WIDTH relation.* The degree designations are the strength assignments made for the words listed; so *long* is a GREAT EXTENT.

Now consider the question *How long is the runway?* The parser finds the accessor associated with *long* and uses the definition of the EXTENT type to determine the family. *The runway*, in the OBJ position, will be mapped into the TOPIC argument of whatever EXTENT relation is chosen via the mapping `(topic poss-obj)`. Since *runway* belongs to the ontological class OBJECT (as determined by a frame–like class hierarch which is part of KING KONG's declarative model of the domain), the EXTENT type will specify the family as SPACE. At this point, the interface must examine all the relations which are EXTENT of SPACE, since this is all it knows about the relation designated by *long*; more than one relation lives at this point in the type–family matrix, including LENGTH, WIDTH, and ALTITUDE. We designate one of these relations to be the default relation at its point in the matrix, and this is the one that is chosen:

```
(def-db-relation length
                 (space . extent)
  '(topic span)
  :default-relation-p t
  :reply-string**
  '((span  "The length of ~w is ~d")
    (topic "~@w is ~w"))
  :match-table
 '(((runway distance) . ((span . :of-runway)))))
```

Figure 3.

*Note that these words are not specified for family; this has proven so far to be unnecessary, but we intend to specify the information later anyway.

**The reply string is used in lieu of a natural language generator.

Relations are implemented in KING–KONG as flavors. The name of the relation is LENGTH; the second argument places it in the type–family matrix. The next argument is the argument structure it has by virtue of being an EXTENT relation. It is specified as the default relation at this point in the matrix. The match table determines how the information is accessed; this table has a single entry, which says that a TOPIC of class RUNWAY*** can access information about the SPAN, given all other arguments, by sending the relation the :OF–RUNWAY message.**** Once the connection between the occurrence of *long* in the sentence above and the actual LENGTH relation is made, the analysis of the meaning of this attribute in this context is complete.

VI. Conclusions

We have demonstrated how a faithful implementation of a synthesis of these three approaches can lead to a simple and elegant account of abstract relations in an interface. We have yet to implement all the aspects of these various strategies; as pointed out in the first footnote, a finer granularity must be established in the argument structure shorthand, and Jackendoff makes distinctions between some path functions which we have yet to recognize. The success we've had so far, even without these refinements, testifies to the utility of these ideas; many possibilities that arise with these mechanisms, including the extensions through morphological derivation and metaphorical extension, have yet to be explored. In general, however, we feel that we have developed a powerful and coherent mechanism that can be extended to cover a much wider variety of linguistic phenomena in an insightful way.

***At the moment, the DISTANCE specification for the SPAN argument in this situation is not needed. Our current implementation is most effective, regrettably, when talking about the ontological classes OBJECT and EVENT. The coherent incorporation and representation of other classes in a way faithful to Jackendoff's work is a subject of current research.

****This last part is part of the codification of the "glue" which connects our portable interface to whatever target expert system it is an interface to. We will describe this in detail in a future paper.

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