THE SEMANTIC INTERPRETATION OF NOMINAL COMPOUNDS

Timothy Wilking Finin *

Coordinated Science Laboratory
University of Illinois
Urbana IL 61801

ABSTRACT

This paper briefly introduces an approach to the problem of building semantic interpretations of nominal compounds, i.e. sequences of two or more nouns related through modification. Examples of the kinds of nominal compounds dealt with are: "engine repairs", "aircraft flight arrival", "aluminum water pump", and "noun noun modification".

I INTRODUCTION

This paper briefly introduces an approach to the problem of building semantic interpretations of nominal compounds, i.e. sequences of two or more nouns related through modification. The work presented in this paper is discussed in more detail in [3] and [4].

The semantics of nominal compounds have been studied, either directly or indirectly, by linguists and AI researchers. In an early study, Lees [8] developed an impressive taxonomy of the forms. More recently, Levi [8] and Downing [2] have attempted to capture the linguistic regularities evidenced by nominal compounding. Rhyne explored the problem of generating compounds from an underlying representation in [10]. Brachman [1] used the problem of interpreting and representing nominal compounds as an example domain in the development of his SI-Net representational formalism in [1]. Gershman [6] and McDonald and Hayes-Roth [9] attempt to handle noun-noun modification in the context of more general semantic systems.

In this work, the interpretation of nominal compounds is divided into three intertwined subproblems: lexical interpretation (mapping words into concepts), modifier parsing (discovering the structure of compounds with more that two nominals) and concept modification (assigning an interpretation to the modification of one concept by another). This last problem is the focus of this paper. The essential feature of this form of modification is that the underlying semantic relationship which exists between the two concepts is not explicit. Moreover, a large number of relationships might, in principal, exist between the two concepts. The selection of the most appropriate one can depend, in general, on a host of semantic, pragmatic and contextual factors.

As a part of this research, a computer program has been written which builds an appropriate semantic interpretation when given a string of nouns. This program has been designed as one component of the natural language question answering system JETS [5], a successor to the PLANES query system [13]. The interpretation is done by a set of semantic interpretation rules. Some of the rules are very specific, capturing the meaning of idioms and canned phrases. Other rules are very general, representing fundamental case-like relationships which can hold between concepts. A strong attempt has been made to handle as much as possible with the more general, highly productive interpretation rules.

The approach has been built around a frame-based representational system (derived from FRL [11]) which represents concepts and the relationships between them. The concepts are organized into an abstraction hierarchy which supports inheritance of attributes. The same representational system is used to encode the semantic interpretation rules. An important part of the system is the concept matcher which, given two concepts, determines whether the first describes the second and, if it does, how well.

II THE PROBLEM

Let's restrict our attention for a moment to the simplest of compounds - those made up of just two nouns, both of which unambiguously refer to objects that we know and understand. What is the fundamental problem in interpreting the modification of the second noun by the first? The problem is to find the underlying relationship that the utterer intends to hold between the two concepts that the nouns denote. For example, in the compound "aircraft engine" the relationship is part of, in "meeting room" it is location, in "salt water" it is dissolved in.

There are several aspects to this problem which make it difficult. First, the relationship is not always evident in the surface form of the compound. What is it about the compound GM cars which suggests the relationship made by? The correct interpretation of this compound depends on our knowledge of several facts. We must know that GM is the name of an organization that manufactures things, and in particular, automobiles. Another fact that helps to select this interpretation is that the identity of an artifact's manufacturer is a salient fact. It is even more important when the artifact is an automobile (as opposed to, say, a pencil).

A second source of difficulty is the general lack of syntactic clues to guide the interpretation process. The interpretation of clauses involves discovering and making explicit the relationships between the verb and its "arguments", e.g. the subject, direct object, tense marker, aspect, etc. Clauses have well developed systems of syntactic clues and markers to guide interpretation. These include word order (e.g. the agent is usually expressed as the subject, which comes before an active verb), prepositions which suggest case roles, and morphemic markers. None of these clues exists in the case of nominal compounds.

Third, even when the constituents are unambiguous, the result of compounding them may be multiply ambiguous. For example, a woman doctor may be a doctor who is a woman or a doctor whose patients are women. Similarly, Chicago flights may be those bound for Chicago, coming from Chicago or even those making a stop in Chicago.

A fourth aspect is that compounds exhibit a variable degree of lexicalization and idiomaticity. In general,

* Author's current address: Department of Computer and Information Science, University of Pennsylvania, Philadelphia, PA 19104.

This work was supported by the Office of Naval Research under Contract N00014-75-C-0612.

the same compound form is used for lexical items (e.g. duck soup, hanger queen) and completely productive expression (e.g. engine maintenance, faculty meeting).

Finally, I point out that it is possible for any two nouns to be combined as a compound and be meaningful in some context. In fact, there can be arbitrarily many possible relationships between the two nouns, each relationship appropriate for a particular context.

III THE INTERPRETATION RULES

The implemented system contains three components, one for each of the three sub-problems mentioned in the introduction. The lexical interpreter maps the incoming surface words into one or more underlying concepts. The concept modifier takes a head concept and a potential modifying concept and produces a set of possible interpretations. Each interpretation has an associated score which rates its "likelihood". Finally, the modifier parser applies a parsing strategy which compares and combines the local decisions made by the other two components to produce a strong interpretation for the entire compound, without evaluating all of the possible structures (the number of which increases exponentially with the number of nouns in the compound). The remainder of this paper discusses some of the interpretation rules that have been developed to drive the concept modifier.

Three general classes of interpretation rules have been used for the interpretation of nominal compounds. The first class contains idiomatic rules - rules in which the relationship created is totally dependent on the identity of the rule's constituents. These rules will typically match surface lexical items directly. Often, the compounds will have an idiomatic or exocentric (*) meaning. As an example, consider the Navy's term for a plane with a very poor maintenance record - a "hanger queen". The rule to interpret this phrase has a pattern which require an exact match to the words "hanger" and "queen".

The second class consists of productive rules. These rules attempt to capture forms of modification which are productive in the sense of defining a general pattern which can produce many instantiations. They are characterized by the semantic relationships they create between the modifying and modified concepts. That is, the nature of the relationship is a property of the rule and not the constituent concepts. The nature of the concepts only determines whether or not the rule applies and, perhaps, how strong the resulting interpretation is. For example, a rule for dissolved in could build interpretations of such compounds as "salt water" and "sugar water" and be triggered by compounds matching the description:

```
(a NominalCompound with
   Modifier matching (a ChemicalCompound)
   Modified matching (a Liquid)
            preferably (a Water))
```

The third class contains the structural rules. These rules are characterized by the structural relationships they create between the modifying and modified concepts. The semantic nature of the relationship that a structural rule creates is a function of the concepts involved in the modification. Many of these rules are particularly useful for analyzing compounds which contain nominalized verbs.

IV STRUCTURAL RULES

I have found this last class to be the most interesting and important, at least from a theoretical perspective. This class contains the most general semantic interpretation rules - precisely the ones which help to achieve a degree of closure with respect to semantic coverage [5]. Similar structural rules form the basis of the approaches of Brachman [1] and McDonald and Hayes-Roth [9]. This section presents some of the structural rules I have catalogued. Each rule handles a compound with two constituents.

RULE: RoleValue + Concept. The first structural rule that I present is the most common. It interprets the modifying concept as specifying or filling one of the roles of the modified concept. Some examples of compounds which can be successfully interpreted by this rule are:

```
engine repair  (a to-repair with object = (an engine))
January flight (a to-fly with time = (a January))
F4 flight      (a to-fly with vehicle = (an F4))
engine housing (a housing with superpart = (an engine))
iron wheel     (a wheel with raw-material = (a iron))
```

Note that when the compound fits the form "subject+verb" or "object+verb" this works very nicely. The applicability of this rule is not limited to such compounds, however, as the last two examples demonstrate.

To apply this rule we must be able to answer two questions. First, which of the modified concept's roles can the modifier fill? Obviously some roles of the modified concept may be inappropriate. The concept for the to-repair event has many roles, such as an agent doing the repairing, an object being repaired, an instrument, a location, a time, etc. The concept representing an engine is clearly inappropriate as the filler for the agent and time roles, probably inappropriate as a filler for the location and instrument roles, and highly appropriate as the object's filler.

Secondly, given that we have found a set of roles that the modifier may fill, how do we select the best one? Moreover, is there a way to measure how well the modifier fits a role? Having such a figure of merit allows one to rate the overall interpretation. The process of determining which roles of a concept another may fill and assigning scores to the alternatives is called role fitting. This process returns a list of the roles that the modifier can fill and, for each, a measure of how "good" the fit is. Each possibility in this list represents one possible interpretation. Not all of the possibilities are worthy of becoming interpretations, however. A selection process is applied which takes into account the number of possible interpretations, their absolute scores and their scores relative to each other. Making a role fit into an interpretation involves making a new instantiation of the modified concept, and filling the appropriate role with modifier. Details of this process are presented in the next section.

RULE: Concept + RoleValue. This rule is similar to the first, except that the concepts change places. In interpretations produced by this rule, the modified concept is seen as filling a role in the modifier concept. Note that the object referred to by the compound is still an instance of the modified concept. Some examples where this rule yields the most appropriate interpretation are:

```
drinking water    (a water which is
                       (an object of (a to-drink)))
washing machine   (a machine which is
                       (an instrument of (a to-wash)))
maintenance crew  (a crew which is
                       (an agent of (a to-maintain)))
```

Again, the application of this rule is mediated by the role fitting process.

* An exocentric compound is one in which the modifier changes the basic semantic category of the head noun, as in hot dog and lady finger.

RULE: *Concept + RoleNominal*. This rule is applicable when the modified concept is in the class I call *role nominals*, nouns that refer to roles of other underlying concepts. English has but one productive system for naming role nominals: the agent of an verb can commonly be referenced by adding the -er or -or suffix to the verb stem. This should not hide the possibility of interpreting many concepts as refering to a *role* in another related concept. Some examples are: a student is the *recipient* of a teaching, a pipe is the *conduit* of a flowing, a pump is the *instrument* of a pumping, and a book is the *object* of a reading.

This rule tries to find an interpretation in which the modifier actually modifies the underlying concept to which the role nominal refers. For example, given "F4 Pilot", the rule notes that "pilot" is a role nominal refering to the agent role of the to-fly event and attempts to find an interpretation in which "F4" modifies that to-fly event. The result is something like "an F4 pilot is the agent of a to-fly event in which the vehicle is an F4". Some other examples are:

```
cat food  (an object of (a to-eat with agent = (a cat)))
oil pump  (an instrument of (a to-pump with
                               object = (an oil)))
dog house (a location of (a to-dwell with
                                agent = (a dog)))
```

Viewing a concept as a *role nominal* (e.g. food as the object of eating) serves to tie the concept to a characteristic activity in which it participates. It is very much like a relative clause except that the characteristic or habitual nature of the relationship is emphasized.

RULE: *RoleNominal + Concept*. This rule is very similar to the previous one except that it applies when the modifying concept is a role nominal. The action is to attempt an interpretation in which the modification is done, not by the first concept, but by the underlying concept to which it refers. For example, given the compound "pilot school", we can derive the concept for "an organization that teaches people to fly". This is done by noting that pilot refers to the agent of a to-fly event and then trying to modify "school" by this "to-fly". This, in turn, can be interpreted by the *Concept + RoleNominal* rule if school is defined as "an organization which is the agent of a to-teach". This leads to an attempt to interpret to-fly modifying to-teach. The *RoleValue + Concept* rule interprets to-fly as filling the object (or discipline) role of to-teach.

Some other examples of compounds that benefit from this interpretation rule are newspaper glasses (glasses used to read a newspaper), driver education (teaching people to drive), food bowl (a bowl used to eat food out of).

Other Structural Rules. Other structural interpretation rules that I have identified include *Specific+Generic* which applies when the modifier is a specialization of the modified concept (e.g. F4 planes, boy child), *Generic+Specific* which applies when the the modifier is a generalization of the modified concept (e.g. Building NE43, the integer three), *Equivalence* in which the resulting concept is descendant from both the modifier and modified concepts (e.g. woman doctor) and *Attribute Transfer* in which a salient attribute of the modifier is transferred to the modified concept (e.g. iron will, crescent wrench).

V ROLE FITTING

The process of role fitting is one in which we are given two concepts, a *RoleValue* and a *Host*, and attempt to find appropriate roles in the Host concept in which the RoleValue concept can be placed. Briefly, the steps carried out by the program are: [1] Collect the local and inherited roles of the Host concept; [2] Filter out any inappropriate ones (e.g. structural ones); [3] For each remaining role, compute a score for accepting the RoleValue concept; [4] Select the most appropriate role(s).

In the third step, the goodness-of-fit score is represented by a signed integer. Each role of a concept is divided into an arbitrary number of facets, each one representing a different aspect of the role. In computing the goodness of fit measure, each facet contributes to the overall score via a characteristic scoring function. The facets which currently participate include the following:

Requirements	descriptions candidate value *must* match.
Preferences	descriptions candidate value *should* match
DefaultValue	a default value.
TypicalValues	other very common values for this role.
Modality	one of Optional, Mandatory, Dependent or Prohibited.
Multiplicity	maximum and minimum number of values.
Salience	a measure of the role's importance with respect to the concept.

For example, the scoring function for the *requirements* facet yields a score increment of +1 for each requirement that the candidate value matches and a negative infinity for any mismatch. For the *preferences* facet, we get a +4 for each matching preference description and a -1 for each mismatching description. The *salience* facet holds a value from a 5 point scale (i.e. VeryLow, Low, Medium, High, VeryHigh). Its scoring function maps these into the integers -1, 0, 2, 4, 8.

VI SUMMARY

This paper is a brief introduction to an approach to the task of building semantic interpretations of nominal compounds. A nominal compound is a sequence of two or more nouns or nominal adjectives (i.e. non-predicating) related through modification. The concepts which the nouns (and the compound) denote are expressed in a frame-based representation system. The knowledge which drives the interpretation comes from the knowledge of the concepts themselves and from three classes of interpretation rules. Examples of the most general class of interpretation rules have been given.

REFERENCES

[1] Brachman, R. J., "A Structured Paradigm for Representing Knowledge", BBN Report No. 3605, 1978.

[2] Downing, Pamela, "On the Creation and Use of English Compound Nouns", Language, 53:4, Dec. 1977.

[3] Finin, T. W., "The Semantic Interpretation of Noun-Noun Modification", Working Paper 21, Coordinated Science Laboratory, University of Illinois, 1979.

[4] Finin, T., "The Semantic Interpretation of Compound Nominals", CSL Report T-96, Coordinated Science Laboratory, University of Illinois, 1980.

[5] Finin, T., B. Goodman and H. Tennant, "JETS: Achieving Completeness Through Coverage and Closure", in *Proc. IJCAI-79*, Tokyo, Japan, 1979.

[6] Gershman, A.V., "Conceptual Analysis of Noun Groups in English", in *Proc. IJCAI-77*, Cambridge, MA, 1977.

[7] Lees, R. B., *The Grammar of English Nominalizations*, Indiana University, Bloomington, IN, 1960.

[8] Levi, Judith N. *The Syntax and Semantics of Complex Nominals*, Academic Press, New York, 1979.

[9] McDonald, D. and F. Hayes-Roth, "Inferential Searches of Knowledge Networks as an Approach to Extensible Language Understanding Systems", in Waterman and Hayes-Roth (eds.) *Pattern-Directed Inference Systems*, Academic Press, 1978.

[10] Rhyne, J.R., "A Lexical Process Model of Nominal Compounding in English", *AJCL*, mf. 33, 1976.

[11] Roberts, B.R. and I.P. Goldstein, "The FRL Manual", MIT-AI Memo 409, M.I.T., 1977.

[12] Tennant, H., "Experience with the Evaluation of Natural Language Question Answerers", *Proc. IJCAI-79*, Tokyo, Japan, 1979.

[13] Waltz, D., "An English Language Question Answering System for a Large Relational Data Base", *CACM*, vol. 21, pp. 526-539, 1978.