Empirical Study of Predictive Powers of Simple Attachment Schemes for Post-modifier Prepositional Phrases

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Abstract

This empirical study attempts to find answers to the question of how a natural language (henceforth NL) system could resolve attachment of prepositional phrases (henceforth PPs) by examining naturally occurring PP attachments in typed dialogue. Examination includes testing predictive powers of existing attachment theories against the data. The result of this effort will be an algorithm for interpreting PP attachment.

Introduction

Difficulty in resolving structural ambiguity involving PPs arises because of the great variety of syntactic structures which PPs can modify and the varying distances PPs may be from the constituents with which they are associated. Simple schemes to resolve attachments utilize information drawn from reported tendencies in the human parsing mechanism, such as the preference for PPs to attach to constituents that immediately precede them. It is always tempting to utilize such schemes in computer NL processors because they provide clear models for resolution that are both easy and cheap (in terms of steps involved) to implement. The problem with these schemes is that they can easily be made to fail by manipulating parameters that they 'know' nothing about, such as semantics, context, and intonation. Clearly, more elaborate schemes for attachment resolution are needed, but what these schemes should contain and how they should be implemented remain open.

This study attempts to find answers to the question of how a computer program should resolve attachment by examining naturally occurring PP attachments in a typed dialogue domain drawn from a study by Brunner, Whittemore, Ferrara, and Hsu (1989). Various previously developed theories of PP attachment are tested against the data to see how well they predict correct attachments of PPs in the typed dialogues. The result of this effort will be a hypothesis of attachment resolution that seems to fit the data.

Empirical overview

The methods for generating the 13 naturally occurring dialogues are described in Brunner, et al. (1989). In essence, this study employed a "wizard of Oz" paradigm in which a human confederate — the Wizard – simulates an advanced computer system engaged in written/interactive dialogue with the experimental participant. Participants of the study were each asked to plan a specific travel agenda of their choice with information obtained solely by typing natural language messages and requests through a VT220 terminal to a *human-assisted travel information system* located in a separate room. In response to this, the Wizard, who had access to both computerized and hard-copy travel data, was instructed to engage in constructive and free-form dialogue with the participant in order to best obtain the reservations and flight information required by them. Each dialogue took one and a half hours to complete, allowing enough time for about 70 sentences per dialogue

for a total of 910 sentences.

In another study, Whittemore, Ferrara, and Brunner (1989) quantify the occurrence of PPs in the 13 dialogues in terms of the syntactic types to which they attach and the overall syntactic environments in which they appear. Data is presented in terms of *Tension Sites* to illustrate possible syntactic attachment interpretations and actual interpretations that occurred. For instance in the sentence *John eats his bananas in his backyard*, potential attachment ambiguity lies in the fact that the PP *in his backyard* can attach to the noun phrase object *his bananas* or to the verb *eats*. Such positions were referred to as Tension Sites. All such Tension Sites for sentences with PPs were recorded along with actual attachments. Some instances were simple as in the example above with only a minimum of Tension Sites, while others were quite involved and had up to seven Tension Sites in which a verb and np-object along with the objects of five other prepositions were available as attachment sites. Of the 910 sentences in the 13 dialogues, 745 had instances of potential ambiguity in attachment. Much of the analysis presented in this paper is drawn from the Whittemore, et al. study.

Theories of Preferencing for Post-modifier PP Attachment

Several of the PP attachment schemes available in the literature were used as a backdrop for examining attachment tendencies in the typed dialogues. These predictors (listed below) were basically employed as individual templates which were applied against the data. Percentages of correct predictability were recorded and some investigation into their failures was made. Only attachments to **nouns and verbs** were made in this study, giving a corpus of 724 examples.

The attachment predictors tested were:

RIGHT ASSOCIATION (RA) – the tendency for constituents to associate with adjacent items to their right (Kimball 1973), also known as low attachment. Late Closure (Frazier 1979) is a similar notion.

MINIMAL ATTACHMENT (MA) – the tendency to attach in a manner in which the least number of syntactic rules are employed (Frazier 1979).

LEXICAL PREFERENCE VIA VERBS (LP) – the tendency for PPs to attach to verbs that have a preference for them (Ford, Bresnan, and Kaplan 1982).

LEXICAL PREFERENCE VIA NOUNS (LP) – is similar to verb LP, but PPs attach to nouns that may have a preference for them as discussed briefly in Rappaport (1983).

LEXICAL PREFERENCE VIA PREPOSITIONS (LP) – is similar to verb and noun LP, but prepositions themselves may have a tendency to seek out certain kinds of constructions. For instance, temporal PPs may have a preference for attaching to entities such as events that have temporal qualities to them. Prepositions acting as functors like this are mentioned in Wilks, Huang, and Fass (1985).

REFERENTIAL SUCCESS (RS) – dictates that one first checks to see if there are any 'like' entities in the discourse, namely ones that have similar PPs as modifiers. If there are matches, then attachment takes on the same look as the antecedent. There are also notions of presupposition in the theory that make predictions about definite, indefinite, generic, and generic plural noun phrases (Crain and Steedman 1984). In a streamlined version of the theory (Hirst 1987), definite noun phrases require the recipient of discourse to try to make a connection to existing knowledge. Because of this added effort in which one must search his discourse space, it has been predicted that attachment to a definite noun phrase would be less preferred. Other noun phrases — indefinites, generics, and bare plurals — along with verbs are preferred over definites as attachment sites since they supposedly require less search over discourse space.

Success of Preferencing Schemes Against the Data

The 'effect' that each of the preferencing schemes reviewed above has on the attachment of the post-modifiers is explored in the remaining sections. Not every possible PP attachment found in the corpus is examined. An attempt is made to explain only attachments to nouns and verbs (thus those made to adverbs, adjectives, prepositions themselves, or within idiomatic expressions are excluded).

RIGHT ASSOCIATION

From the data evident in the dialogues it can be seen that RA seems to have a fairly strong influence within the typed discourse domain of travel. As noted in the Tension Site tabulations (Whittemore, et al.), low attachment was observed 55% of the time. However, its almost equally high failure

rate of 45% dictates that RA by itself is not a satisfactory scheme for deciding PP attachments.

MINIMAL ATTACHMENT

The success of MA in the attachment of PPs in the 13 dialogues is rather poor. Out of 488 instances in which there was an opportunity for MA to take a role, only 177 examples (or 36%) behaved according to a strict notion of MA. By a strict notion we mean that whenever possible, the least number of rules are applied.

REFERENTIAL SUCCESS AND PRESUPPOSITION

Using only definite NPs as a guide for indicating that a noun phrase is being used to refer to some antecedent, strict notions of RS failed miserably — out of 101 definite noun phrases only 12 instances of exact match with some antecedent occurred. There were also 17 cases in which some subsequent phrase was used to 'restrict' or refer to some semantic subset of an antecedent. There was one additional case in which a subsequent noun phrase was a rephrasing of an antecedent. For the remaining 71 instances, no antecedent could be located within the text. Altogether there were only 30 out of 101 that could be deemed successful. It should also be noted that for a NL understanding system to correctly interpret just these few examples much machinery would be required to 'understand' when something was a 'rephrasing' or 'restriction' of an antecedent.

The accompanying notion of presupposition, in which PP attachment to definite NPs is avoided when no such NP+PP already exists in the discourse, would, numerically, need to be regarded as a semi-successful predictor of attachment site. Disregarding the 30 cases in which an antecedent for an NP was found in the discourses, one would have to say that avoiding attachment to NP was successful since for the remaining 694 instances (724 total minus the 30 cases above) correct decision attachment was made to avoid attachment to definite NPs 623 times (694 cases minus the 71 cases of non-anaphoric NP+PPs) for a 90% success rate. However, predicting correct attachment beyond avoiding definite NPs was not successfully performed. It is not enough to just try to avoid attaching to definite NPs; there must also be a way of specifying how PPs are to link up with other non-definites and verbs. In the study, Hirst's (1987) modified version was used in which one attaches to the last occurring non-definite or verb in a RA fashion. Employing a combined presupposition/RA approach, the success is still low — only 52% (or 362 attachments) are correctly predicted.

VERB LEXICAL PREFERENCING

To determine the success of LP of verbs in the 13 travel dialogues, each verb used within the dialogues was examined for its potential for LP. Some verbs were determined to have a very strong LP such as some two part verbs like *involved in* or verbs like *live* that have an obviously strong preference for locative PPs. The rest were determined to be LP verbs through a consensus of 3 individuals, and when possible, further substantiated to be LP verbs through the aid of two sources on verbs and their complements – A COMPLETE GRAMMAR OF ENGLISH by Quirk, Greenbaum, Leech, and Svartvik (1972) and VALENCY OF VERBS by Allerton (1982).[1]

After a complete list of the verbs was derived, the number of times that the verbs appeared with sought-after prepositions was determined and tabulated. Next, the success of the LP verbs was determined by quantifying the times that they failed versus the times they succeeded. Reasons for failure in LP verbs were then sought out through an analysis of the sentences in which LP verbs and possible PPs that could go with LP verbs were present, but the two were not associated with each other.

A synopsis of the findings on verb LP is below. The main point to be gleaned from this synopsis is that there seem to be a fairly large number of PP attachments that could be construed to be the result of verb LP — 228 out of 724 total. This is significant because it indicates that the incorporation of an accurate LP scheme could be beneficial in a PP attachment resolution scheme.[2]

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verb lexical preferencing:
  228 instances of verb LP
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[1] There have been several methods suggested in the literature for determining lexical preferencing, but it was felt at the time that their predictive powers were somewhat unreliable, though the authors could very well be wrong. Readers should refer to chapter one in Somers (1987) for a good discussion of various preference-determining schemes.

[2] Closer scrutiny of the different LP verbs also made it apparent that the number of domain-specific LP verbs is comparatively quite large. For instance, the verbs *begin, book, change, depart, fly, get,* and *leave*, to name some, all have senses that seemed particular to the travel domain.

```
 47 different verbs
examples:
 arranged through, arrive at,
 begin from, fly from/to, start at
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The tabulations shown above are only for correct attachments in which it could be decided that a particular LP verb did attach to a PP. There were also 21 LP verbs that failed to link up with existing PPs that they normally seek.

Verb-LP alone failed in 18 of the 21 instances, seemingly because of the presence of multiple LP verbs. In (1) is an example from the dialogues.

```
(1). Before deciding that I want to know
      the flight times for United Air
      Lines LEAVING from Austin and GOING
      TO JFK in New York on August 30.

      The verb LEAVE was determined to
       have a preference for the prepo-
       sition TO, as was the verb GO.
       However, in the example TO
       attaches only to GO
```

To account for the attachments some added machinery is needed. It was earlier demonstrated that there was a 54% tendency for attachment of PPs to be to the most immediate low constituent to their left, or Right Association – RA. RA has also been shown in the work of Wilks et al. (1985) and Frazier (1979) to be beneficial when choosing between two LP verbs. They predict that when multiple LP verbs appear a sought after PP attaches to the last LP verb that precedes it.

In the travel domain in this study, with a combination of RA and verb LP it was found that in every case in which 2 verbs were vying for the same PP attachment, attachment was made to the lower verb. With this additional machinery all but 3 of the incorrect attachments in sentences with LP verbs can be explained.

In the 3 remaining instances in which attachment goes against the notion of LP, attachments were made to nouns. In (2) is one of the instances. In (2), *show* was deemed as normally calling for a PP headed by *to*, but attachment went to the NP object following the verb. Under a strict notion of verb LP there is no provision to allow the attachment of PPs to nouns following LP verbs. The possibility of nouns having LP characteristics will be explored in the next section, and the example below should be re-examined in light of the data there.

```
(2). I need to know would you like for
      me to SHOW you some FLIGHT
      schedules to Dublin?
```

NOUN LP FOR PPS

The methodology for exploring noun LP was similar to that of verb LP. Shown below are the overall results for noun LP. As indicated, the number of PPs attaching to LP nouns is again comparatively quite large, almost as large as the number of attachments to LP verbs — 183 versus 228. Thus, as is the case for LP verbs, noun LP seems to be a significant means by which PP attachments can be predicted.[3]

```
noun lexical preferencing
 183 instances of noun LP
  24 different lp nouns
examples:
(air)fare(s) from/to, bus to,
carrier from/to, and travel(ing) by,
```

Under the LP noun analysis, all instances in which there was a single LP noun were correctly accounted for by a noun LP scheme. Under a LP noun analysis PPs that were at a proximal, such as (3), or great distance, such as (4), were able to correctly link up with appropriate nouns.

```
(3). Would you like for me to show you
      some FLIGHTS TO Dublin?
(4). What is the round trip FARE for
      Aer Lingus and for British
      Airlines FROM JFK on August 30
      TO Dublin returning Sept 21?
```

There were three sentences in which multiple LP words appeared in which there was first an LP noun, and later either another LP noun or an LP verb. With these, using the same RA analysis that was employed for LP words, correct predictions about attachment can be made – when any

[3]Again, as with the LP verbs, there are many nouns that seem to have LP for the travel domain. The nouns *bus, carrier, change, connections, dollars, airfare, flights, one way, travel,* and *roundtrip* all seem to have senses particular to the domain at hand.

two LP words that seek the same PP are present, no matter if they are nouns or verbs, attachment is made to the latter LP word. For instance, sentence (5) has two LP nouns, *trip* and *flight*, both of which were deemed to have a preference for the singly occurring PP headed by *from*. By enforcing RA, in which the attachment of the *from* PP is made to the last occurring and lowest LP noun (in this case *flight*), the correct interpretation can be derived.

(5). **Then what you would rather have is a round TRIP to London, with a separate FLIGHT from London to Dublin.**

Similarly, when deriving interpretations in which LP verbs are followed by LP nouns, RA between the competing LP words makes the correct interpretation. Thus in the 3 sentences in which LP verbs are followed by LP nouns, and LP verbs and nouns prefer the same PPs, RA attachment is favored with attachment to the three last occurring LP nouns.

The combined noun and verb LP scheme is:

If an LP verb or LP noun is present, apply verb or noun LP.
If two LP verbs or nouns are present that seek the same PP use the notion of RA and attach the PP to the last word that seeks it.

MODIFYING PPS (OR PP LP)

The verb and noun LP schemes demonstrated above were successful but only for the cases in which LP verbs and nouns appeared. Excluding the 411 PPs that seemed to be accounted for via LP, there still remain to be explained 313 PPs, 43% of the cases.

Since for the remaining PPs, the predominant general preference schemes were either not appropriate (verb LP, noun LP, or RS) or shown not to be powerful enough predictors by themselves (RA and MA), the PPs were examined in terms of the functions they served in hopes that some generalities amongst them would become evident. This proved to be a promising exercise since most of the PPs were found to belong to two function types, **temporal** and **locative** indicators. Of the remaining PPs, 189 (60% of the remaining) were temporal, 90 (28%) were locative, and 34 (12%) were of a mixed variety. Some examples of these are provided in (6).

(6). **TEMPORAL. British Airlines has a flight that leaves AT 12:30.**
LOCATIVE. Could you suggest a few hotels in a moderate price range IN a nice part of London?
OTHER/MIXED. Please book me on these flights WITH an aisle seat.

For the PPs involved in LP, it could be argued that their attachment is determined by the near necessity that some argument position for a LP head be filled. With the remaining PPs, there seemed to be something else required in order to make their attachment. Instead of having something look for the PPs, it appeared that there needed to be a way by which the PPs could serve as functors in which they seek out arguments (a notion also defended in Bresnan, 1982). The items to which the temporal and locative PPs attach are ones that have some temporal or locative quality to them.

For temporals, attachment sites are either actions that can occur at some particular time or some state that must last for some period of time. In the type-written dialogues in the travel domain, the combination of leftward search for a temporal-accepting noun or verb and RA proved to be successful. With a combined PP LP/RA algorithm in which temporal-PPs look for the first NP or VP to their left that has a temporal quality, the attachment of temporal-PPs was successfully predicted in all but one of the 81 instances.

For locative-PP modifiers, using the same scheme as was used for temporal-PP modifiers in which after noun and verb LP fail a search is performed for the last locative-accepting item to the left, predictability of attachment of locative-PPs was again almost 100%.[4]

The resulting preferencing scheme for temporal-locative-PP LP is:

- **MUST be ordered after noun and verb LP**
- **If there is a locative PP, attach to the most adjacent constituent to the**

[4] Actually, out of the 90 instances of locative PPs (this excludes those PPs that are called for by LP words) 8 require further elaboration. Examples of further elaboration are permitting gapping out of complex NPs so that PPs can attach to their 'extracted' elements as in (a) and having mechanisms to derive compound nouns and adjective/noun combinations as in (b).

a. Which airport do you want to fly to *GAP* in Paris?
b. Provide DEPARTURE TIMES from Dublin on 9/20/86 to Boston with ARRIVAL TIMES in Boston.

left that has a head with a locative quality.

- If there is a temporal PP, attach to the most adjacent constituent to the left that has a head with a temporal quality.

added notes:

Must be able to link up with EXTRACTED elements.

Characteristics of EXTRACTED elements must be associated with their gaps before linking locative PPs is attempted.

Must first link any temporal/locative qualities of modifying adjectives to the modified head.

OTHER PP MODIFIERS

The remaining PP modifiers, those that are probably not sought after by an LP verb or noun and do not belong to the class of temporal-PPs or locative-PPs, were treated together. The reason for this particular grouping was that there were a number of functions evident in some PPs that occurred very infrequently and since one of the major foci of the study was to try to find general means of deciding attachment of PPs, individualization of these PPs was, at first, discounted. In some of the prior attachment schemes, there were some elements that were given the *power* to seek out some other constituent (e.g. LP verb sought out certain case types presented in particular PPs and temporal PPs sought out temporal-bearing nouns or verbs). Attempting to use LP with the varied **other** group was not possible since no one function type (e.g. such as temporality) and no single preference characteristic was evident. Other schemes were necessary for this group.

What proved to be succesful was the Hirst (1987) modified version of presupposition in which attachment to definites is generally avoided. Adding the notion of RA, one can also decide between equally weighted non-definites and verbs when both are present.

The combined presupposition-RA algorithm is expressed below. When coming upon a PP that was of the **other** type, an attachment is made to the most recent verb or non-definite noun in a RA fashion.

Avoid attachment to definite NPs and attach to most recently occurring verb or non-definite NP to the left.

As shown below under this scheme, correct prediction was made 100% of the time for the non-definite+verb grouping. However, when examining the success of attachment with the definite NPs, the rate of successful prediction was much lower. In 13 instances, avoiding attachment to definite NPs was the correct thing to do, but 7 times it was not, resulting in a 65% success rate. Thus if one permits the RA+non-definite noun preferencing scheme, the only items needing further explanation are the definite NPs.

% of correct predictions of attaching "other" PPs to last occurring available verb or non-definite noun to the left	100%
% of correct prediction to avoid attachment to definite NPs.	65%

With the limited group of 7 definite NPs (these were the remaining, unresolved definite NPs), it was easy to identify a single class to which the conflicting NPs belonged. All the nouns but one[5] that could be associated with PPs were ones that could be used in partitive expressions. Partitive nouns can be separated out from other nouns as those noun expressions that denote a kind or quantity and are typically followed by the preposition *of*. In (6) are two examples from the dialogues.

(6) a. the legs of your trip.
b. the size of the hotel

The algorithm for the **other** group is:

Check to see if preceding lowest constituent is a definite NP and part of a partitive expression,
If it is, attach the PP to the preceding definite NP,
Otherwise, attach to the most recently occurring verb or non-definite NP.

[5]The sole exception was with the noun *feeling* in the expression *the feeling of the community*. It is highly probable that this is an idiomatic noun phrase and should be entered in an idiomatic lexicon.

Overall Algorithm

As laid out below after some preliminary tasks are performed, namely associating nouns with their adjectives and extracted items with their gaps, the first preference to apply is noun and verb LP. If noun and verb LP fails, the two-stepped temporal/locative modifer preference can step in and perform attachments of which it is capable. When all else fails, the **other** modifier routine finishes off anything left over.

```
Associate adjectives with locative (and
 possibly temporal) qualities to the
 nouns they modify.
Associate extracted items with their
 respective 'gaps.'
If an LP verb or LP noun is present,
 apply verb or noun LP.
If two LP verbs or nouns are present
 that seek the same PP, use the notion
 of RA and attach the PP to the last
 word that seeks it.
Otherwise, if a temporal PP is present,
 attach it to the most adjacent consti-
 tuent to the left whose head contains
 a temporal quality.
Otherwise, if a locative PP is present,
 attach it to the most adjacent consti-
 tuent to the left whose head contains
 a locative quality.
Otherwise, if an OTHER modifier (not a
 temporal or a locative) is present
 and if the immediately preceding
 element is a definite NP that could
 be part of a partitive expression,
 then attach the PP to the NP,
Otherwise attach to the last occurring
 verb or non-definite NP.
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Conclusion

The study indicates that there seems to be a way of predicting PP attachment in the typed interactive mode of communication by fairly simple means. By using LP for nouns, verbs and prepositions (temporal and locative PPs seek out temporal- or locative-accepting elements) and a variation on the Crain and Steedman notion of presupposition, attachments are essentially always predictable.

Correct interpretation of the 724 instances in which there existed structural ambiguity in the attachment of PPs to nouns or verbs occurred as follows:

```
Verb LP              228 instances
Noun LP              183 instances
Temporal prep. LP    189 instances
Locative prep. LP     90 instances
Other modifiers       34 instances
(presupposition
 + RA)

:added note - two items were not
    accounted for:
   --- one seemed to be an idiomatic
       expression
   --- one may possibly have been
       contextually related
```

RA played a role within each preferencing scheme as did a weak notion of plausibility. RA was used as the arbitrator whenever there remained an intra-conflict in a preferencing algorithm (and sometimes when there was inter-conflict between schemes). The use of *plausibility* to talk about relationships between verbs or nouns and associated PPs was thought to be a necessary notion in that simple searches for only prepositions were deemed to be too weak of a notion. When verb or noun LP was at work, nouns and verbs sought out PPs (as opposed to single prepositions) that as a whole had some attribute(s) necessary to fulfill some semantic requirements. Sometimes PPs also had to be concluded to be of a particular type in order to search out a unique kind of noun or verb. Apparently, PP Lexical Preferencing allowed PPs that were temporal or locative in nature to look for nouns and verbs that bore temporal or locative characteristics, respectively. Referential Success in its pure sense was a poor predictor of attachments. However, the related notions of presupposition regarding definites, indefinites, etc. were good predictors of attachment for a small number of PPs.

Finally, a more cognitive finding resulting from the study was the great predictability of attachment, suggesting that there is something about the typed interactive mode of communication that constrains the possibilities on attachment such that attachment always goes with the unmarked case. There are at least three pressures that may help to make these constraints come about. One is the

lack of the spoken element which carries with it intonation patterns and variations in pausing that can influence the ways that one parses. One must rely on only the cues available by written means to aid in disambiguating attachments. Secondly, the added comparative slowness at which interlocutors type and the resulting tendency to leave out unnecessary punctuation marks often useful in disambiguating text makes yet a further constrained subset. Thirdly, a speaker may be aware of the time lag (hence taxation on memory) that exists between typing some modified element and its associated PP. The lag may have an effect on how such pairs are presented. Prominent ways of highlighting the links may depend more on notions such as LP or RA that might not be needed as much in other modes of communication. These factors together may make it necessary for participants in typed interactive communication to rely on a set of default structures that each can cue on easily.

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