

# Handling Temporal Relations in Scheduling Dialogues for An MT System \*

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## Abstract

*Handling temporal information has been a main concern of areas such as natural language processing, planning, and knowledge representation. In scheduling dialogues, i.e., dialogues whose goal is setting up a meeting in this paper, temporal reference is central, and the relations between temporal expressions contain much of the ellipsis and anaphora to be resolved. As a consequence, filling in missing information contributes to the understanding of the text. In this paper, we first identify the various binary relations present in this kind of dialogue, characterize them, and, finally, present a mechanism for processing with temporal relations that is based on using the constraints found during the analysis.*

## 1 Introduction

Temporal information has proven to be a central issue in areas such as planning, scheduling, natural language processing, and knowledge representation. In scheduling dialogues, specially those directed to setting up meetings, temporal relations are primary because they contain much of the anaphora and ellipsis to be resolved. Filling in missing information due to either anaphora or ellipsis in our context has two main purposes: to support the translation of dialogues, and to provide updated information for further interpretation. In the second section of the paper we describe a number of different approaches to processing temporal information. We then describe the Artwork project, which provides the context within which temporal information is characterized in this work. In the fourth section we describe the characterization of the temporal relations in the scheduling dialogues used in the Artwork project and the mechanism for filling in missing information. In the last section, we draw some conclusions and suggest some directions for future work.

## 2 Background

There are different approaches to dealing with temporal information. The approaches that we have considered for our work are Allen's Interval Algebra (IA)

[1], a cognitive approach to temporal reasoning developed by Borillo et al. [5], and a logic for calculating temporal interpretations in discourse defined by Lascarides and Asher [9].

Many different temporal reasoning systems have been the result of research on temporal relations which vary in computational complexity and expressive power. IA [1] has been the basis for the implementation and evaluation of a number of systems [3], [7], [12], [14] addressing the representation of qualitative temporal information about the relationships between pairs of intervals. According to IA, there are 13 basic relations (including inverses) that can hold between two intervals; e.g. *x before y*, its inverse *x after y*, and *x equal y*. We have adopted Allen's relations to define our binary relations because they are well defined and have been utilized in scheduling and planning systems.

Borillo et al. [5] have used linguistically *observed* (their italics) values to deduce a third relation from two other relations, instead of using Allen's [1] transitive closure rule. In this approach, the introduction of constraints, that are the result of analyzing linguistically acceptable inferences, reduces the combinatorial cost of formal deduction. Similarly, in our work we define the relations between expressions in terms of constraints that have been derived from a study of such expressions in a corpus of Spanish dialogues. These sets of constraints will be used to make a relation between a pair of temporal expressions "hold" producing a new or updated temporal expression.

In their approach, Lascarides and Asher [9] propose that to calculate temporal interpretations, it is necessary to have a logic supporting all the patterns of inference involved in calculating temporal and rhetorical relations. The authors present a set of defeasible rules to determine the preferred temporal interpretation of a text. In our discourse processing module, whenever there is not sufficient information to identify the relation between a pair of temporal expressions, we first need to select a set of candidates that could potentially hold. From this set we can make assumptions under which certain relations would actually hold. This is similar to Lascarides and Asher's [9] method using default logic.

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### 3 Artwork

The Artwork project has the goal of developing a discourse processing module that addresses, among other problems, the interpretation of anaphora and ellipsis to support the translations of dialogues in the speech-to-speech machine translation (MT) system Enthusiast being developed at Carnegie Mellon University (CMU), on one and, and the understanding of the text, in order to identify speech acts and resolve parser ambiguity. The domain of application is scheduling meeting dialogues. A corpus of such dialogues in Spanish is currently being collected by researchers at the University of Pittsburgh. (For a more detailed account of the various phases of the project see Wiebe et al. [13]. For an in depth description of the Enthusiast system refer to Rosé [11].

The initial phase of the research on temporal relations within the Artwork project was to classify the kinds of temporal anaphora and ellipsis to be found in scheduling dialogues and to identify the relations that supported the relevant inferencing.

The input to the discourse processing module is a set of ILTs (Interlingua Text) produced by the semantic grammar citations. The ILT representation has been the basis for Knowledge-Based machine translation systems, and was developed at CMU by Nirenburg et al. [10].

In regard to temporal information the ILT recognizes such categories as DAY (e.g., the 1st, 15th, 28th, etc.), DAY-OF-WEEK (Monday, Tuesday, etc.), MONTH (e.g., May, December), HOUR (ten, five, etc.), MINUTE (fifteen, thirty, etc.), TIME-OF-DAY (e.g., morning, noon, afternoon, evening), AM-PM (am to indicate a time from midnight until noon, pm to indicate a time from noon until midnight), INCL-EXCL (is used whenever the time is considered an interval). Intervals of time are defined in terms of 1) their start and end point, and 2) whether the start and end point is included (i.e., INCL-EXCL takes the value inclusive) or not (i.e., INCL-EXCL takes the value exclusive) within the interval. The inclusion of the start point in the interval means that the interval is closed to the left, whereas its exclusion means that the interval is open to the left. Similarly, the inclusion of the end point in the interval means that it is closed to the right, its exclusion means that the interval is open to the right. Thus, intervals may: a) have both a start and an end point as in "I can meet with you from 10 to 11" where the start point is 10, the end point is 11 (which means that the interval is [10,11]) and hence, the interval is inclusive, or as in "We can schedule the meeting between Monday and Wednesday" where the start point is Monday and the end point is Wednesday (which means that the interval is [1,3] since we map Sunday into 0, ..., Saturday into 6) and the interval is inclusive; b) have a start point but no end point as in "I can meet from 2pm on" where the start point is 2pm (which means that the interval is [2,∞)) and its start point is considered as inclusive; c) have an undefined start point as in "Are you in town after the 12th?" where the start point is some point after the twelfth (which means the interval is (12,∞)), hence its start point is exclusive; or d) have an end point as in

"I will be out of town until the seventeenth" where the end point is the seventeenth (which means the interval is (-∞,17]) and its end point is considered inclusive.

The Artwork project has been implemented in Quintus Prolog in order to take advantage of the unification mechanism embedded in Prolog for testing and filling in the information represented in the arguments.

### 4 Temporal relations in scheduling dialogues

As mentioned above, temporal relations have been studied in different contexts and, as a consequence, a number of logics and algorithms have been designed to deal with such relations [1], [2], [3], [4], [5], [12]. However, most of these systems have not dealt with the problem of filling in missing information due to ellipsis or anaphora [8]. In what follows, we address what we mean by "ellipsis and anaphora resolution" and then characterize the temporal relations needed to fill in missing information.

#### 4.1 Ellipsis and anaphora in Artwork

One of the largest questions we faced in defining what precise problems we address is what we mean by "ellipsis resolution." Carbonell [6] distinguishes between *sentential level ellipsis*, which is characterized by syntactically incomplete structures, and *semantic ellipsis*, "where ellipsed information is manifest ... as semantically incomplete propositions." (p. 164). Our operational definition of ellipsis can be seen as an elaboration on this description of semantic ellipsis: "that information which the speaker intentionally expressed implicitly as part of his or her utterance but did not state explicitly". Given the goals stated above, there is no reason for a machine translation system to limit itself to ellipsis arising from syntactically incomplete structures: the idea is to recover implicit information from the dialog, whether or not arising from syntactically incomplete structures. Thus, we address semantic ellipsis.

In the case of temporal anaphora, the system attempts to resolve only those anaphoric expressions appearing in the input ILT. If the input is the utterance:

"On Monday the eighth I have two hours  
between eleven and two, is *that* good for you?"

the ILT will contain in a \*WHEN frame, a slot indicating the presence of a possibly anaphoric reference, i.e., (WHEN ((WH - (FRAME \*SPECIAL-TIME) (NAME THAT)))). For this example, the relevant slot is (NAME THAT). We operate under two assumptions: anaphoric references not explicit in the input ILT are not resolved and later parts of the discourse will not affect the interpretation of earlier anaphoric references.

#### 4.2 Temporal relations in Artwork

Examination of the scheduling dialogues in Spanish collected for Artwork and the Enthusiast projects show a great deal of semantic ellipsis within the expressions being used to refer to times (*temporal expressions*) rather than temporal anaphora so, our focus

will be on the former. Among the most common examples of semantic ellipsis found in the dialogues are temporal expressions used to refer to times (hours and/or time of day) where the day, the date, and month are implied; to days, where the date and month are implied; and to dates, where the month is implied. The goal of establishing temporal relations is to provide a basis for filling in the implied information.

Computationally speaking the dialogues are partitioned into utterances. The ILT for each of the utterances is structured as a frame with different slots that are (top-level) frames in themselves or pointers to other frames.

The binary temporal relations that can be applied to two temporal expressions include: before, after, equal, covers, covered-by, refines, and refined-by, (an adaptation of Allen's [1] set of thirteen relationships). These binary relations are characterized below. We use the index "1" as in "T1" to refer to temporal information in a previous ILT (not necessarily the immediately previous ILT), and the index "2" as in "T2" to refer to temporal information in the ILT currently being processed.

The temporal information in T1 and T2 are combinations of dates and times that need to be mapped (i.e., normalized) into a point NT<sub>i</sub> or interval in time [NT<sub>i</sub>, NT<sub>j</sub>] (i=1,2; j=1,2) with the following structure:

NT<sub>i</sub> = [#MM][#WW][#DD][#TT]

However, in the cases when the information is undetermined or vague (e.g., "some time") this mapping is not possible. The normalization process is carried out with the following procedure:

```

normalize(Ti,NTi)
while Ti not NULL
  if MONTH ≠ NULL
    then numberize_month
    concatenate NTi and #MM
  else
    if DAY-OF-WEEK ≠ NULL
    then numberize_day_of_week
    concatenate NTi and #WW
  else
    if DAY > 0 and #MM > 0
    then calculate number of day in year
    concatenate NTi and #DD
  else
    if DAY > 0
    then concatenate NTi and DAY
  else
    if TIME-OF-DAY ≠ NULL
    then numberize_time_of_day
    concatenate NTi and #TT
  else
    if HOUR > 0
    then standardize_hour
    concatenate NTi and #TT

```

The relation before is defined by T1 < T2 which means T1 "less than" T2 (e.g., March "is less than" September, i.e., 3 < 9; Tuesday "is less than" Friday,

i.e., 3 < 6; Tuesday at 8 "is less than" Wednesday at 1, i.e., 30800 < 41300; and, so on).

Before: T1 "before" T2 holds whenever the following holds:

NT1 < NT2

The relation after is defined by T1 > T2 which means T1 "greater than" T2 (e.g., December "is greater than" November, i.e., 11 > 12; June the 13th "is greater than" April the 30th, i.e., 165 > 121; 5pm "is greater than" 11am, i.e., 1700 > 1100, etc.). T1 is "after" T2 is the inverse relation of "before".

The relation equal is defined by T1 = T2 which means T1 "equal" to T2. T1 is "equal" to T2 holds if all the features in T1 = all the features in T2. This relation is the inverse of itself.

The relation covers is defined as T1 includes/contains (cf. Allen's overlaps relation in which interval *i* may or not contain all the temporal information of interval *j*) all the temporal information in T2. It applies mainly whenever the temporal information in T2 is not specific enough or it is possibly anaphoric; in general, this kind of temporal information (e.g., "that day", "some time", etc.) is found in a \*SPECIAL FRAME NAME in the ILT.

T1 "covers" T2 holds if the following holds:

NT2 > 0  
 AND (NAME in T1 = "week"  
 OR NAME in T1 = "month"  
 OR NAME in T1 = "time-of-day")

The relation covered-by is defined as T1 is included/contained in T2; it can be seen as the subset operation for sets. Covered-by: T1 is "covered by" T2 holds is the inverse relation of "covers". An example follows.

Prev Utt: Quisiera reunirme algún rato contigo  
 (I would like to meet some time with you)  
 Curr Utt: Puedo en las próximas dos semanas  
 (I can meet in the next two weeks)

In this case *some time* "is covered by" *the next two weeks*.

The "refines" relation and the inverse relation "refined-by" are defined in different ways depending on the frames present in T1 and T2. For reasons of exposition we present only two for refined-by together with examples.

To illustrate the definition for refined-by which is the inverse of refines we present the following example:

Prev Utt: Podría reunirme contigo a partir de las 9  
 (I can meet with you from 9 on)  
 Curr Utt: Qué tal si nos reunimos de 9 a 11 el 23  
 (So how if we meet from 9 to 11 on the 23)

In this case the closed interval *from 9 to 11* is a refinement of the open to the right interval *from 9 on*.

Refined.by: T1 “refined by” T2 holds whenever the following holds:

There is an interval [NTi,NTj] in T1 and an interval [NTk,NTl] in T2 such that:

$$NTi > 0 \text{ AND } NTi \leq NTk \text{ AND } NTj > NTl$$

To illustrate another definition of the “refined.by” relation we present the following example:

Prev Utt: Tengo tiempo en la tarde a cualquier hora  
(I have time anytime this afternoon)  
Curr Utt: De tres a cinco digamos  
(Shall we say from three to five)

In this case of the non-specified time *any time this afternoon* is refined by the interval *from three to five*.  
Refined.by: T1 “refined by” T2 whenever the following holds:

There is a “calculated interval” [NTi,NTj] in T1 and an interval [NTk,NTl] in T2 such that:

$$NTi \leq NTk \text{ AND } NTj \geq NTl$$

In order to obtain a “calculated interval” it is necessary to consider the following definitions for “TIME-OF-DAY”: morning is defined as the interval from 00:01 to 11:59, noon is defined as the interval from 12:00 to 12:00 (the duration of this interval is *epsilon*), afternoon is defined as the interval from 12:01 to 18:00, evening is defined as the interval from 18:01 to 20:00, and night is defined as the interval from 20:01 to 24:00. Thus, the “calculated start point” of the morning is “0001” and the “calculated end point” of the morning is “1159”.

There are a number of assumptions that need to be made to handle temporal expressions and the relationships between them. One is that whenever information is not present in a particular \*WHEN or \*TOPIC frame, it is interpreted as being NULL. Another is that there is a preselected calendar which is being used as the basis for calculating: 1) days of the week given a date, (2) a change from one month to the next when referring to periods of time that extend from one month to the next (such as “do you have any time the next two weeks”), and (3) the starting date and time of the discourse processing module. A third assumption is that hours and minutes from the input ILT have been normalized based on military time, i.e., a 2400 baseline.

#### 4.3 Mechanism for making hold binary relations

With the existing set of binary relations identified and characterized, the next step was to design a mechanism for applying the relations and filling out the temporal information in the current ILT; i.e., making the relation “hold” of two times, or **make\_hold**.

This mechanism takes as input a pair of temporal expressions (T1 and T2) and one of the binary relations (before, equal, covers, refined.by, etc.), and then

proceeds to test each of the conjuncts (constraints) in the definition of the relation. The output of the procedure is an updated temporal expression T3 that is the same as T2 plus any information that can be added whenever all the conjuncts in the definition of the relation are true, or a list of features with no values, otherwise. For simplicity, we are considering only temporal expressions in previous ILTs, but a focus list is being designed to provide temporal information in additional ILTs.

In Prolog, this procedure is the following predicate with four arguments:

**make\_hold(Relation,T1,T2,T3)**

Given that there are different combinations of constraints that might apply to a relation, this procedure keeps testing each of the combinations until one of them is true, or exhausts all of the combinations ending with false.

As an example, take as input to **make\_hold** the information from T1 and T2 in the following utterances, and the refined.by relation.

Prev Utt: Mañana puedo reunirme a cualquier hora en la tarde  
(I can meet tomorrow anytime in the afternoon)  
Curr Utt: Estoy en la oficina de dos a cuatro  
(I am at the office from two to four)

For this example, T1 contains a frame with the following temporal information:

```
(FRAME *SIMPLE-TIME)
(SPECIFIER DEFINITE)
(TIME-OF-DAY AFTERNOON),
```

which is normalized and thus, mapped into the interval [NTi,NTj]=[1201,1800], and T2 contains a frame with the following temporal information:

```
(FRAME *INTERVAL)
(INCL-EXCL INCLUSIVE)
(START
  ((FRAME *SIMPLE-TIME) (HOUR 1400)))
(END
  ((FRAME *SIMPLE-TIME) (HOUR 1600))),
```

which is normalized mapped and thus, mapped into the interval [NTk,NTl]=[1400,1600]; for the referring time expression “mañana” (tomorrow), the system takes the current date as the default, unless an initial date is provided, to calculate the date corresponding to tomorrow. For instance, if the date provided is January 3, 1994 the system will infer from tomorrow is the successor of today, and if today is 3 (after normalization) then SUCC(3)=4, i.e., January 4, 1994 (years are taken into account this is just a simplification).

An application of the mechanism for making the Refined.by relation hold between T1 and T2 will test the conditions in the second definition for this relation above:

$NT_i \leq NT_k$  AND  $NT_j \geq NT_l$ , that is,

$1201 \leq 1440$  AND  $1800 \geq 1600$ , that is,

**true AND true  $\Rightarrow$  true**

Whenever the result is **true**, T3 is (1) instantiated with the contents of the arguments of T2, (2) the TIME-OF-DAY argument of T1, and (3) the calculated date for the TIME-REFERENT argument of T1. Thus, T3 will contain a time expression corresponding to "January 4 from two to four in the afternoon".

The output generated will then contain information related to the interval *from two to four* plus part of the information in the previous utterance, namely the time of day, *in the afternoon* and the corresponding computed date for *mañana*. Other relations (after, before, etc.) may succeed. Of all possible temporal relations thus established, one is chosen on the basis of other factors considered by the discourse module (e.g., speech act pairs).

## 5 Conclusions and future work

We have described a system that aims to handle temporal relations, supports the recovery of missing information due to ellipsis and anaphora within a discourse processing module. We characterized the possible temporal relations which have been found in the a of dialogues in the scheduling domain to which the Artwork system is being applied. We have also described the mechanism that makes the relation between two temporal expressions to hold by testing each of the conjuncts in the definition of the relation.

Finally, we consider that our work can be generalized to other tasks as long as the people in a dialogue make concrete references to time and do not get into narrative discussions.

The next step in our work is to evaluate the sets of constraints in these definitions of the relations to see whether they are sufficient to cover the new data and extend the set of constraints if others need to be added. In addition, we wish to investigate spatial information about the location of a meeting needed to understand scheduling dialogues.

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