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, 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.
Keywords temporal anaphora and ellipsis, temporal reasoning, scheduling dialogues, discourse processing

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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, temporal relations are primary because they contain much of the anaphora and ellipsis to be resolved. Filling in missing information in our context has two main purposes: to support the translation of dialogues, and to provide updated information for further interpretation. An outline of the paper is as follows. In the first section we describe a number of different approaches to processing temporal information. We then describe the Artwork project, which provides the domain within which temporal information is characterized in this work. In the next section we describe a 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) (1983), a cognitive approach to temporal reasoning developed by Borillo, Borillo and Bras (1989), and a logic for calculating temporal interpretation in discourse defined by Lascarides and Asher 1993).

Many different temporal reasoning systems have been the result of research on temporal relations which vary in computational complexity and expressive power. IA (Allen 1983) has been the basis for a number of systems (van Beek and Cohen 1990, Vilain, Kautz, and van Beek 1990, Gerevini, Schubert and Schaeffer 1993) 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 set to define our binary relations because they are well defined and have been utilized in scheduling and planning systems.

Borillo, Borillo and Bras (1989) have used linguistically *observed* (their italics) values to deduce a third relation from two other given relations, instead of using Allen's (1983) 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 examine the expressions being used to refer to times in a corpus of dialogues in Spanish to define the relations between pairs of such expressions in terms of sets of constraints. 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 (1993) 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 (1993) method using default logic.

3 Artwork

The Artwork project began as a study of the feasibility of adapting a machine translation system developed for translating expository texts to processing speech. It then adopted the goal of developing a discourse processing module that addresses, among other phenomena, anaphora and ellipsis resolution within the context of the Enthusiast system being developed at Carnegie Mellon University (CMU). The domain of application is scheduling dialogues. The corpus of real dialogues in Spanish has and is being collected by researchers at the University of Pittsburgh.

In order to accomplish these goals, the Artwork project has been divided into three phases. (For a more detailed account of the various phases of the project see Wiebe et al. (1994). For an in depth description of the Enthusiast system refer to Rosé (unpublished manuscript, 1994).)

The initial phase of the research on temporal relations was to uncover the sort of relations and clarify the kinds of temporal anaphora and ellipsis to be found in scheduling dialogues.

The input to the discourse processing module is a set of ILTs (Interlingua Text) produced by the analysis of each of the utterances in a dialogue using a semantic grammar. The ILT representation has been the basis for Knowledge-Based machine translation systems, and was developed at CMU by Nirenburg et al. (1992).

The information contained in the ILT about time appears as DAY, DAY-OF-WEEK, MONTH, HOUR, MINUTE, TIME-OF-DAY, AM-PM, INCL-EXCL (a more detailed description of the ILT is presented below).

The Artwork project has been implemented in Quintus Prolog because we have found that the unification mechanism embedded in Prolog facilitates the testing and filling of the information represented in the arguments.

4 Temporal Relations in scheduling dialogues

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 relations (Allen 1983, Allen 1984, van Beek and Cohen 1990, Vilain, Kautz and van Beek 1990, Bernard, Borillo, and Gaume 1991). In particular, temporal relations are central in scheduling dialogues which contain a great deal of temporal ellipsis and anaphora that needs to be resolved, in order to understand the text, and to assist in disambiguating and identifying speech acts.

4.1 Temporal Relations in Artwork

Examinations of the scheduling dialogues, in Spanish, collected for Artwork and the Enthusiast projects show a great deal of what Carbonell (1983) calls *semantic ellipsis* within expressions being used to refer to times (*temporal expressions*). Among the most common examples found in the dialogues are temporal expressions used to refer to a time (hours and/or time of the day) where the day, the date, and month are implied; the reference to a day, where the date and month are implied; and the reference to a date, where the month is implied. The goal of attempting to establish temporal relations is to fill in the implied information.

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 (see details below), 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 restrictions: anaphoric references not explicit in the input ILT are not resolved, and it is assumed that later parts of the discourse cannot affect the interpretation of earlier anaphoric references.

Computationally speaking the dialogues are partitioned into utterances following a take-turning pattern. 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 most common top-level slots contain the intended speech act of the sentence (e.g., accept, confirm, reject, state-constraint), possible speech acts, and the type of sentence (declarative/wh-question/yes-no question, etc.) being uttered. The top-level frames include frames that represent information related to time and space of the speech act: *WHEN, *TOPIC, and *WHERE, and store information about the speakers (agents), *WHO, among others. It is within the *WHEN and *TOPIC frame that most of the temporal expressions are found. The only difference between the *WHEN and the *TOPIC frame is in what they denote. The former indicates that the temporal expression is the "direct object", the latter that it is the "subject" in a sentence. The *WHEN and *TOPIC frames contain one or more of the following frames: *SIMPLE-TIME containing information about a point in time, *SPECIAL-TIME that stores information about unspecified periods of time or anaphoric references, *INTERVAL that includes bounded and unbounded intervals (this is marked with the slot INCL-EXCL, i.e. INCLUSIVE for bounded, and EXCLUSIVE for unbounded intervals). This is illustrated for the example given above taken from one of the dialogues. (Note that only part of the ILT is presented).

Utterance: El lunes ocho tengo dos horas entre las once y las dos
(On Monday the eight I have two hours between eleven and two)

ILT:
```
((SPEECH-ACT *SUGGEST)
 (A-SPEECH-ACT (*MULTIPLE* *ACCEPT *SUGGEST *STATE-CONSTRAINT))
 (SENTENCE-TYPE *STATE)
 (WHO ((FRAME *I)))
```

```
(WHEN
  ((WH -)
   (FRAME *INTERVAL) (INCL-EXCL INCLUSIVE)
   (START ((FRAME *SIMPLE-TIME) (HOUR 11)))))
   (END ((FRAME *SIMPLE-TIME) (HOUR 2)))
(FRAME *FREE)
(TOPIC
  ((WH -)
   (FRAME *SIMPLE-TIME)
   (SPECIFIER DEFINITE) (DAY 8) (DAY-OF-WEEK MONDAY)))
(HOW-LONG ((SPECIFIER PLURAL) (QUANTITY 2) (UNIT HOUR))))
```

Among the binary temporal relations between temporal expressions are: before, after, equal, covers, covered-by, and refines, (an adaptation of Allen's 1983 set of thirteen relationships). These binary relations are characterized below. We will use T1 to indicate a *WHEN frame in a previous ILT (not necessarily the immediate previous one), and T2 to indicate a *WHEN frame in the ILT being processed.

Before_Relation: T1 "before" T2 holds whenever one of the following holds:

1. MONTH in T1 $<$ MONTH in T2.
2. DAY-OF-WEEK in T1 $<$ DAY-OF-WEEK in T2
   AND DAY in T1 $<$ DAY in T2.
3. DAY in T1 $<$ DAY in T2.
4. HOUR in T1 $<$ HOUR in T2
   AND DAY in T1 $\leq$ DAY in T2.
5. HOUR in T1 $<$ HOUR in T2
   AND DAY-OF-WEEK in T1 $<$ DAY-OF-WEEK in T2.
6. HOUR in T1 $<$ HOUR in T2
   AND DAY-OF-WEEK in T1 $<$ DAY-OF-WEEK in T2
   AND DAY in T1 $<$ DAY in T2.

After_Relation: T1 is "after" T2 is the inverse relation of "before".

Equal_Relation: T1 is "equal" to T2 holds if one of the following holds:

1. MONTH in T1 = MONTH in T2
   AND the rest of the features are NULL.

2. DAY-OF-WEEK in T1 = DAY-OF-WEEK in T2
   AND DAY in T1 = DAY in T2
   AND the rest of the features are NULL.

3. DAY in T1 = DAY in T2
   AND the rest of the features are NULL.

4. HOUR in T1 = HOUR in T2
   AND DAY in T1 = DAY in T2
   AND the rest of the features are NULL.

5. HOUR in T1 = HOUR in T2
   AND DAY-OF-WEEK in T1 = DAY-OF-WEEK in T2
   AND the rest of the features are NULL.

6. HOUR in T1 = HOUR in T2
   AND DAY-OF-WEEK in T1 = DAY-OF-WEEK in T2
   AND DAY in T1 = DAY in T2
   AND the rest of the features are NULL.

7. All the features in T1 = all the features in T2.

Covers_Relation: T1 "covers" T2 holds if one of the following holds:

1. DAY in T2 is not NULL
   AND NAME in T1 = WEEK.

2. DAY in T2 is not NULL
   AND NAME in T1 = MONTH.

3. HOUR in T2 is not NULL
   AND NAME in T1 = TIME-OF-DAY.

Covered_by_Relation: T1 is "covered by" T2 holds is the inverse relation of "covers". An example follows.

Previous Utt:	Quisiera reunirme algún rato contigo (I would like to meet some time with you)
Current 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 is defined in different ways depending on the frames present in T1 and T2. For reasons of exposition we present only two together with examples.

Refines_Relation: T1 "refines" T2 holds whenever the following holds:

1. There is an *INTERVAL frame in T1 and an *INTERVAL frame in T2 such that:
   START in T1 is not NULL
   AND INCL-EXCL in START in T1 = EXCLUSIVE
   AND HOUR in START in T1 is not NULL
   AND START in T2 is not NULL
   AND HOUR in START in T2 is not NULL
   AND INCL-EXCL in START in T2 = INCLUSIVE
   AND END in T2 is not NULL
   AND HOUR in END in T2 is not NULL
   AND INCL-EXCL in END in T2 = INCLUSIVE
   AND HOUR in START in T1 is $\geq$ HOUR in START in T2.

Example for 1.

Previous Utt:	Podría reunirme contigo a partir de las nueve (I can meet with you from nine on)
Current Utt:	Qué tal si nos reunimos de nueve a once el veintitrés (So how if we meet from nine to eleven on the twenty third)

In this case the bounded interval *from nine to eleven* is a refinement of the non-bounded to the right interval *from nine on*.

Refines_Relation: T1 "refines" T2 whenever the following holds:

2. There is a *SIMPLE-TIME frame in T1 which is not NULL and there is an *INTERVAL frame in T2 such that:
   DAY in T1 is NULL
   AND TIME-OF-DAY in T1 is not NULL
   AND START in T2 is not NULL
   AND HOUR in START in T2 is not NULL
   AND END in T2 is not NULL
   AND HOUR in END in T2 is not NULL
   AND DAY in T2 is not NULL
   AND HOUR in START in T2 $\geq$ calculated start of TIME-OF-DAY in T1
   AND HOUR in END in T2 $\leq$ calculated end of TIME-OF-DAY in T1.[1]

Example for 2.

Previous Utt:	Pero si tengo tiempo en la tarde a cualquier hora
	(But of course I have time anytime this afternoon)
Current Utt:	De tres a cinco digamos
	(Shall we say from three to five)

In this case the interval *from three to five* is a refinement of the special (non-specific) time *any time this afternoon*.

The NULLs are not overwritten whenever explicitly inferrable information is obtained during the discourse processing; instead, they provide information on which variables in the updated relation T3 are to be unified with information from T2 and T1.

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 particular in a *WHEN or *TOPIC frame, it is interpreted as being NULL. Another is that there is a preselected calendar which is being used as (1) the basis for calculating 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

[1] We define the interval comprised by time of day as follows: morning goes from 0001 to 1159, noon goes from 1200 to 1200 (the duration of this interval is *epsilon*), afternoon ranges from 1201 to 1800, evening ranges from 1801 to 2000, and night goes from 2001 to 2400.

have been normalized based on military time, i.e., a 2400 baseline.

4.2 Mechanism for making hold binary relations

With the existing set of binary relations identified and characterized, the next step was to design a mechanism that may be applied for filling in information; 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, overlap, refines, etc.), and then proceeds to test each of the conjuncts (constraints) in the definition of the relation (cf. Borillo's et al. 1989). The output of the procedure is an updated temporal expression T3 that is the same as T2 plus added information whenever all the conjuncts in the definition of the relation are true, or a null list of features, otherwise. For simplicity, we are considering only temporal expressions in previous ILTs, but a focus list is being designed to provide additional temporal information.

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 the corresponding T1 and T2 in the following utterances, and the Refines_Relation.

Previous Utt:	El lunes quince yo tengo dos reuniones
	(On Monday the fifteenth I have two meetings)
Current Utt:	Yo estoy comiendo con una amiga de doce a dos
	(I am eating lunch with a friend from twelve to two)

For this example, T1 contains (FRAME *SIMPLE-TIME) (SPECIFIER DEFINITE) (DAY 15) (DAY-OF-WEEK MONDAY), and T2 contains (FRAME *INTERVAL) (INCL-EXCL INCLUSIVE) (START ((FRAME *SIMPLE-TIME) (HOUR 1200))) (END ((FRAME *SIMPLE-TIME) (HOUR 1400))).

An application of the mechanism for making the Refines_Relation hold between T1 and T2 will test:

*SIMPLE-TIME in T1 is not NULL AND *INTERVAL in T2
AND DAY in T1 is not NULL AND DAY in T2 is NULL
AND DAY-OF-WEEK in T1 is not NULL AND DAY-OF-WEEK in T2 is NULL
AND START in T2 is not NULL
AND HOUR in START in T2 is not NULL
AND END in T2 is not NULL
AND HOUR in END in T2 is not NULL

Whenever the result is **true**, T3 is (1) instantiated with the contents of the arguments of T2, and (2) both the DAY argument and the DAY-OF-WEEK argument in T1 unify with the DAY argument and the DAY-OF-WEEK argument in T3, respectively. The arguments of T3 are variables.

The output generated will then contain information related to the interval *from twelve to two* plus part of the information in the previous utterance, namely the day and date, *Monday the fifteenth.* 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 presented a system that aims to handle temporal relations, supports the recovery of missing information, and resolves anaphora within a discourse processing module. We characterized the possible temporal relations existing in the corpus of dialogues in the scheduling domain to which the Artwork system is being applied. We described the mechanism that makes the relation between two temporal expressions to hold by testing each of the conjuncts defined in the relation.

The next step in our work is to analyze new dialogues and evaluate the sets of constraints in the definition of the relations to see whether the current constraints are sufficient to cover the new data or if others need to be added. Another key issue in scheduling dialogues is to investigate spatial information needed to understand subdialogues about the location of a meeting.

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