

# Determining the Temporal Ordering of Events in Discourse

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## Abstract

The main goal of this project is to unify and extend the models that have been proposed for determining the temporal ordering of events in discourse. Rules that indicate when to override the default of the narrative reference time moving forward have been suggested in the literature and I have combined and refined these rules. In extending these models, I've added more rules for how syntactic knowledge such as relative clauses and gerunds can also override the default of the narrative reference time moving forward. An additional area I considered is how verbs that take event arguments can influence the narrative reference time. Generally, it is true that the nominal arguments will not cause the narrative reference time to move forward but this is not always the case. So instead of a nominal event always halting the forward movement of the narrative reference time, I allow lexical knowledge to override this default. This project shows that discourse structure, domain knowledge, lexical knowledge, event structure and syntax are all necessary for determining the temporal ordering of events in discourse.

## 1 Problem Statement

Work in temporal anaphora began with the intuition that the time of events in discourse are referential[Par84, Web88]. That is, the time of one event will be relative to the time of an event earlier in the discourse. Given these intuitions that time in discourse is referential, researchers have attempted to characterize the nature of temporal anaphora.

In a narrative discourse, identifying the temporal relation between an event in an utterance and an event in a preceding utterance depends on a combination of information sources. At minimum this information is provided by explicit tense and aspect markers, the Aktionsart of a eventuality, and the discourse relations between eventualities. There are a number of theories in the literature about how temporal relations between events can be determined, but none of these theories extend to account for all of the data covered by each of the individual theories. A more unified account for some of this data is desirable. Also the current theories do not satisfactorily extend to cover the temporal relations of events expressed in subordinate clauses, such as relative clauses. There is also an additional problem of determining whether a temporal adverbial is modifying an event time or a reference time.

In this project I have drawn from the body of existing work in temporal anaphora, proposed a more unified theory, implemented this theory, and evaluated it on a set of naturally occurring text for a restricted domain. The implementation sets the reference times and event times of eventualities in a discourse relative to the times of one other eventuality in the discourse

and provides an accounts for relative clauses, gerunds, temporal connectives and nominalized events.

## 2 Significance to Computational Linguistics

Providing a more unified, enhanced account of how temporal relations between events are determined extends this area of language processing theory more towards being able to recognize the temporal relations in naturally occurring discourse. While this work is directly relevant to the analysis of naturally occurring discourse, it should also provide insights for the generation of more natural discourse. By having a better understanding of the legal possibilities for expressing eventualities in a non-default ordering, generation can exploit these same mechanisms to make a generated text more readable.

In addition, establishing the temporal relations between two events in a discourse could be extended to provide a determination of the temporal relations between a larger number of events in a discourse as the need arises in various applications. This extension could be achieved by using an inference algorithm such as that described by Allen[All83]. With such an extension, this temporal analysis approach could be incorporated into question answering applications and machine translation applications. In the case of machine translation applications, the need sometimes arises to recognize implicit temporal information so that it can be made explicit in the target language.

## 3 Background

Most of the research on temporal anaphora is based on Reichenbach's notion of temporal structure. Reichenbach's temporal structure associates three times with every event; a speech time (S) which is the time at which an utterance was produced, an event time (E) which is the time at which the described event occurred, and a reference time (R) which is the time from which the speaker is "viewing" the event on a timeline. With the simple tenses, the reference time and the event time are simultaneous. The event and reference time move in relation to the speech time so that R and E are before S with the past tense, after S for the future, and simultaneous with S for the present. With the perfect tenses E is before R and R moves with respect to S in the same way as for the simple tenses. However, with the future perfect there are two other possibilities; the event could be occurring at the time of speech or before the time of speech. This represents that the speaker does not know whether the event has already occurred. If the speaker knew that the event had occurred or was taking place at the time of speech then he or she would have said so. These temporal structures are illustrated in figure 1.

## 4 Overview of Research in Temporal Anaphora

### 4.1 Hinrichs, Partee and Dowty

Hinrichs[Hin81], Dowty[Dow86], and Partee[Par84] assumed Reichenbach's notion of associating three times with each event and explored how the reference and event times are related in a simple past-tense narrative. The intuition shared by each of these approaches is that the

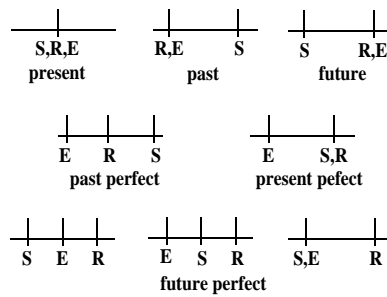


Figure 1: Reichenbach's representation of temporal structure

reference time moves forward unless explicitly set by a definite temporal adverbial. Dowty stated this with his interpretation principle. In Dowty's account, the semantics of tense and aspect then set the event time relative to the reference time and pragmatic inferences set the event time relative to the event time of a preceding utterance. Unfortunately, as noted by Dowty, his approach cannot account for elaborations of preceding events or for co-extensive events. In these cases the reference time does not appear to move forward.

## 4.2 Webber

Webber[Web88] improves upon the above work by specifying rules for how event and reference times are to be related to one another. These rules depend on the tense, aspect and the tripartite structure of events as defined in Moens & Steedman[MS88] and Passonneau[Pas88]. Webber's rules are that when an event is expressed in the perfect or is co-extensive with a preceding event, the reference time remains the same as the reference time of the preceding event. In the other cases, the relation of the reference time to the preceding event depends on the tripartite representation for events. If the event is in the preparatory phase of a preceding event then the reference time moves backward. If the event is part of the consequent of a preceding event then the reference time moves forward. Temporal focus is introduced to account for cases where an event moves forward relative to an event expressed as a perfect, instead of from the previous reference time. What is happening is that the reference time is getting reset to an earlier time. The idea of a temporal focus parallels Grosz and Sidner's[GS86] discourse focus in that a focus stack is associated with the hierarchically related discourse segments. The focus stack accounts for both the reference time, or temporal focus, as well as the nominal entities that are currently in focus. A temporal focus is pushed onto the stack whenever an embedded discourse segment is encountered and popped whenever a discourse segment is completed.

This account has problems with extended flashbacks of the type accounted for by Kamp. With an extended flashback, a simple past event is followed by a sequence of events expressed in the past perfect. Each of these events seems to refer back to the simple past tense event. At the same time, a progression of time is permitted between the past perfect events. My interpretation of what would happen when following Webber's rules is that the ordering of the event times for the past perfect events would be unspecified. The reference time would remain fixed at that of the first clause expressed with the simple tense and each of the past perfect event times would be before that reference time. Nothing is said about how the past perfect

events relate to one another if there is strong domain knowledge or other ordering information, such as temporal adverbials, present in the extended flashback.

### 4.3 Kamp

Kamp's[Kam93] hypothesis is that reference time moves forward but that the reference time for a narrative is different from the reference time for the perfect. He uses the term, temporal perspective, to refer to the reference time in the case of the perfective, and the term, reference point, to refer to the progression of time in narrative. He adopted this distinction as a way to account for extended flashbacks. With the extended flashback, the temporal perspective would remain fixed but the reference point would move forward and establish a temporal ordering between the events expressed with the past perfect.

### 4.4 Lascarides & Asher

Lascarides & Asher[LA91] propose that in a simple past-tense narrative discourse, the event time moves forward as the default case and this default can be overridden by examining the temporally significant rhetorical relations[MT87]. The narrative relation is the default case where E1 precedes E2. The definitions of the other relations are:

- explanation, the second event causes the first and therefore precedes the first
- elaboration, the second event is preparatory to the first and therefore precedes it
- result, the event caused the state
- background, the event is overlapped by the state

Lascarides & Asher have formalized how these rhetorical relations can be derived from world knowledge and the tripartite structure of events. In deriving the rhetorical relations they show how a discourse structure, that embodies Polanyi's notion of openness can constrain the search for a related clause. So far, they have focused on the past tense and have not yet provided an account for perfectives and progressives. With the past tense, the reference time is the same as the event time so the separate settings of these times does not have to be addressed. In addition, they have not yet accounted for the effect of temporal adverbials on the setting of the event and reference times.

### 4.5 Passonneau

Passonneau describes an implementation of a temporal analysis module that excludes the treatment of future events since their truth evaluation involves hypothetical or potential times rather than real-world times. To exclude such future events there is a submodule that determines whether a situation (state or event) has an actual time associated with it (i.e. it has occurred or is occurring) and filters out any that do not. She has focused on determining the temporal placement of intrasentential events relative to another and has not specifically addressed intersentential events. She accounts for, for example, "before" and "after" clauses. Although she has not considered the placement of intersentential events relative to one another,

she claims that her approach lays the groundwork for this type of analysis along the lines of what Webber has suggested.

A second submodule determines the temporal structure of the situations passing through the above filter. This submodule analyzes the manner in which the situation evolves through time and represents this with the temporal structure. The temporal structure is made up of intervals and each interval has associated with it two features. One indicates aspectual information (i.e. state, process, event) and the other indicates how the interval is located relative to other intervals (i.e. bounded, unbounded, unspecified). Each temporal structure also has an event time which is set by its tense (simple or perfect). Passonneau indicated that the implementation she describes can process untensed clauses such as nominalizations but it is not clear to me how this would be done since it was not the focus of the paper. She indicates that the event time is set by the tense but I am curious as to what happens in this regard with tenseless clauses.

The third submodule determines the temporal locations of the situations with respect to the speech time and the times of other situations in the sentence. To locate the time, she follows Reichenbach[Rei47] but separates the event time from the temporal structure of the situation. Temporal adverbs are analyzed on the basis of the event they are modifying. Passonneau only discusses durational adverbs in her paper and it seems that these are modifying the event time and not the reference time. With temporal connectives such as “when”, “before” and “after”, they are relating the reference times of the two events.

#### 4.6 Seligman & ter Meulen

Seligman & ter Meulen[tM93, StM93] introduce Dynamic Aspect Trees(DAT) as a representation for the temporal relations between events in a past tense narrative discourse. The motivation for this representation is that they wanted one that would better support temporal inferencing. In this representation, they claim that the need for reference times is eliminated and that inferencing is insensitive to the current reference time as represented in Discourse Representation Theory(DRT)[Kam93]. With DATs, the temporal dependencies between events are represented by the labeled arcs of the tree. Temporal inclusion is represented by pointing to a node at a lower level in the tree and precedence is indicated by the branching of the tree. There are two types of nodes in the tree; holes and plugs. Holes and plugs influence the way the tree grows as a text is being analyzed. When the previous situation is represented by a plug, a sister node is created and when it is a hole, a child is created. The determination of whether a situation is a hole or a plug depends on its Aktionsart:

- Activity: the node will be a hole
- Achievement: the node will be a plug
- Accomplishment: the node can be either a hole or a plug

If the current node jumps to an ancestor and the ancestor is a hole then the hole will become a plug. I think this is a similar notion to the idea of openness[LA91]. For instance, a jump back to an ancestor seems to occur at the end of an elaboration. Seligman & ter Meulen indicate that the plugging of a hole occurs under two conditions. The first is when the text describes the end of the event depicted by the ancestor hole (which is like an elaboration). The

second is when an event is incompatible with the continued growth of the tree. For example, if a sub-event is not part of the event represented by the ancestor node then that would be an incompatibility. This information seems to be represented by the situation types of the nodes.

Statives are represented by “stickers” rather than nodes. Statives include progressives, perfects and states. The stickers are attached to the nodes in the DAT according to the type of the node (hole or plug). When the current node is a plug, the sticker attaches to it. If there is no current node or the node is a hole, the sticker will attach to the next node that gets created. I do not yet understand the motivations behind the machinery for stickers but one effect is that inferences can be made about the events over which a state holds.

It is not clear how this could be modified to deal with temporal adverbials, such as “at 5” but they mention that the representation for a situation includes a start and a finish. Perhaps the start and finish would account for a temporal adverbial. In looking at the extended flashback in the example below, “had got up at 5” has a start and finish of “5” and then the state that obtains after “getting up” holds up until “10” which is the reference time for the narrative. However, I think that the inability of the DAT to represent the temporal sequencing between the events in the extended flashback is a failing of the representation. Perhaps the representation could be extended to allow the events of the perfect to be represented but I think it may be difficult since it is not clear that the events associated with the past perfect are always included in the time of any of the ancestor nodes. For example, if a discourse starts on a particular day and then refers back to the previous day it is certainly not the case that the event occurred during the time represented by the DAT. Perhaps the solution would be to build a second DAT and then relate the two DATs to one another.

- (1) Fred arrived at 10. He had got up at 5; he had taken a long shower, had got dressed and had eaten a leisurely breakfast. He had left the house at 6:30.<sup>1</sup>

#### 4.7 Hwang & Schubert

Hwang & Schubert[HS91] point out an error in Reichenbach’s notion of temporal structure that occurs during the processing of subordinate clauses. In (2) the interpretation is that “he” thinks Mary left before the speech time. It is not likely that “he” will know of the speaker’s utterance. To correct this problem they suggest that in keeping with modern syntax and semantics, the operators for past, present, future (modals) and perfect be applied separately rather than as a unit. The result is that for the simple tenses there is just one time associated with the event and then in a narrative the event is oriented by the clauses it relates to in the discourse. For a case like “John will have left.” there will be three times; one each for “will”, “have” and “left”.

- (2) He will think Mary has left.

To represent the relation between the times and the events, they use tense trees. To build these trees, one does not need to know the discourse relations of the clauses since they use an “orient” operator during the building process. Later, after the tree is built, discourse relations can be used to determine whether the “orient” relation is precedence, overlap, co-extensive, and so on. However, not all of the orienting relations are left to the end of the tree building

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<sup>1</sup>from Kamp

process. Each of the operators (present, past, perfect, etc) have rules on how they effect the tense tree. For example, past produces e1 before e2, and perfect produces e1 before-or-until e2. The orienting that is left until the end is just between the event tokens at a particular node in a tree. For example, when the past operator is applied, the event it effects is not yet picked up and a token which I will call a “reference” token is produced. Then when the event the past operator is to be applied to is processed, an event token gets generated for it and this new token gets added to the node of the tree where the “reference” token has been placed. This is the manner in which multiple tokens accumulate at a node of the tense tree.

This approach can deal with extended flashbacks, but to handle flashbacks where the tense changes from the perfect back to the past, Hwang & Schubert had to introduce a mechanism for shifting the perspective. To recognize when a perspective shift is needed, one must know the discourse structure. However, all that is needed in this case is a segmentation that indicates a subnarrative. A more detailed representation that indicates the discourse relations between clauses is not required. To represent this shift in perspective then, Hwang & Schubert build a separate tree for the subnarrative. The subnarrative tree is then attached by a special link that can be blocked once the subnarrative is completed. Blocking the link prevents further expansion of this subtree. This is a similar to the notion of openness in Lascarides & Asher’s work.

The thing that seems to be missing from this approach, is a treatment of states. States seem to be treated the same as other events. I think that the time over which a state is applicable needs to be represented in some way. Also, Hwang & Schubert have not indicated in this paper what they would do with temporal adverbials such as “at 5”. Perhaps they plan to save this analysis for a later stage of processing. Maybe temporal adverbials could be incorporated into the analysis when the “orient” relations get re-assigned.

While the work of Seligman & ter Meulen and Hwang & Schubert is interesting, I do not think either of these are good foundations for combining the ideas represented in the literature. There are too many open questions still to be resolved in this work, particularly for the treatment of temporal adverbials and stative events. Instead, I will take as a starting point the approach suggested by Webber. This approach deals with co-extensive events, and elaborations, and is able to handle relative clauses that are expressed in the perfective. With some modifications, that were suggested to me by the other work I covered in the previous section, I believe this approach can be improved. There are three areas that I will consider in the discussion that follows; the treatment of reference time and temporal adverbials, the treatment of subordinate clauses and temporal connectives, and the recognition of co-extensive events. One other area that I would have included but have not had time to consider is untensed clauses. This is a problem it seems for all but Passonneau’s account but in her paper she did not discuss her treatment of untensed clauses.

## 5 The Temporal Model

To determine the temporal orderings between two eventualities in a discourse, the temporal model I defined uses:

- domain information
- the lexical semantics of verbs

- the semantics of temporal connectives
- local discourse structure
- syntactic information

The discourse relations, such as “narrative”, “elaboration”, “explanation” are determined by domain and lexical information and temporal connectives (e.g. “as” can be an elaboration or explanation). These discourse relations define the local discourse structure and constrain what eventualities can be related to one another. The discourse relations also help in determining the setting of the narrative reference time. With any relations other than narrative and result, the narrative reference time does not move forward. The final piece of information used in temporal ordering is syntactic information about clause-types (i.e. relative clause).

The rules governing the temporal model can be summarized as follows:

- The semantics of the temporal connective are used in the absence of domain knowledge or lexical semantic input from verbs to provide a temporal ordering between the matrix and subordinate clause it relates.
- Past Perfects stop the forward movement of reference time and the event times of related events are left unspecified relative to one another unless there is a temporal adverbial present to specify the ordering.
- Relative Clauses have a default of stopping the forward movement of the reference time and leaves the relation of the event time to reference time unspecified unless temporal adverbials, past perfects or domain information are available to specify it.
- Verbs with Event Arguments: Verbs with event arguments can specify event orderings with the default being a causal relationship where if event-a causes event-b then event-a precedes event-b.
- Gerunds stop the forward movement of reference time.

To arrive at these rules I analyzed the behavior of point adverbials, temporal connectives (“as”, “before”, “after”, and “during”), relative clauses, gerunds, nominals and infinitives in newspaper stories on football game highlights.

## 5.1 Reference Time and Temporal Adverbials

In the football game highlights that I analyzed there was extensive use of point adverbials (e.g. “with 1:45 left”). So one of my first questions was how these point adverbials effected event and reference time. The observation has been made by Partee, Hinrichs and numerous other researchers that time generally moves forward in a narrative discourse and the claim has been that it is the reference time that is moving. Since with simple tenses the reference time and the event time are at the same time, the effect is that both are moving forward. In Reichenbach’s system, the only time the reference time stands alone is with the perfect. So, it seems reasonable to me to eliminate the reference time for at least the simple tenses. With the perfect, I claim that the event is stative in nature, which is supported by Comrie’s

characterization of the perfect as well as Seligman & ter Meulen’s treatment of the perfective. An event occurs prior to the current reference time and the resulting state produced by the event extends up to the reference time. When a temporal adverbial scopes an event expressed as a perfect, it is an indication of when the event occurred and marks the beginning of the time period during which the resulting state holds. It seems to me then that the reference time of the narrative can act as the reference time for the perfect. In this way, only one reference time is needed and that is the narrative reference time.

However, most of the work in this area has assumed that it is the reference time that is specified by the temporal adverbial. One exception to this is Hornstein[Hor90]. He believes it is possible for the adverbial to specify either the reference time or the event time. I think that Passonneau, Seligman & ter Meulen, and Hwang & Schubert have allowed or would need to allow the event time to be specified by the temporal adverbial in their approaches as well.

Going back to Webber’s account, I claim, just as she does, that in the case of the perfect, the event time can move forward while the narrative reference time remains fixed. This interpretation accounts for the extended flashback shown in (3) in the same manner as suggested by Kamp. He claims that the reference time for each of the past perfects is “10” and that there is a separate narrative reference time that moves forward between the past perfect events. If this is the case, then it is unclear whether “5” is specifying the event time, the narrative reference time, or both. It could be both if one assumes that the event time and the narrative reference time are at the same time. A difference in what I am suggesting is that instead of having two reference times, one for the narrative and one for the perfect as Kamp does, there is no reference time for the simple tenses, or the perfect, only a reference time for narrative. In the example below, all of the past perfect states are stretching from the event time up to at least the event and narrative reference time “at 10”. This means Fred was in a state of “having gotten up” from 5 to at least 10. As ter Meulen suggests, we could infer from this that at 10, Fred was still “up”.

- (3) Fred arrived at 10. He had got up at 5; had showered; had got dressed; and had eaten a leisurely breakfast.

The event times are then ordered relative to one another by temporal adverbials when they are present or in the case of an extended elaboration where the simple past is used, the usual order in which we expect these events to occur (i.e. domain or world knowledge).

An advantage of this treatment of perfects is seen in (4). Because the “promising event” is a perfect the “promise” holds up to at least the reference time. This reference time is at same point as the “go to florist” event since the reference time does not advance for an elaboration of an event. So the “promise” event holds at least up until the “go to florist” event.

- (4) John went into the florist shop. He had promised Mary some flowers. She said she wouldn’t forgive him if he forgot.<sup>2</sup>

To process extended elaborations and flashbacks as with (5) below, where the time moves forward from the time of the event expressed in the perfective, Webber used a temporal focus stack.

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<sup>2</sup>from Webber

- (5) He had been hurt on a Monday. He had just paid for his last week’s room and board, and spent nearly all the balance of his Saturday’s pay. He was on his way to the bank for a loan when the car hit him.<sup>3</sup>

The reference time is pushed onto the temporal focus stack and the reference time is then reset to the event time for “making payments” when the “payment” utterance is recognized as an embedded discourse segment. Once the segment is completed the previous reference time is popped so that the reference time is reset to that of the unfinished segment. I make use of a similar idea in that I pick up the reference time from the last open event that the current event can be related to. This will be further explained in Section 6.

However, to completely handle an elaboration such as the ones above, it is necessary to know whether the current eventuality is a continuation of a narrative. If it is not, the reference time needs to be moved to an earlier time than that of the related eventuality’s reference time. Without this resetting of the reference time, the reference time would move forward from a time after the event being elaborated (i.e. “went to the florist”. This treatment seems justifiable since, presumably, all the narrative relations connected to the elaboration are also elaborations of the same event.

## 5.2 Subordinate Clauses and Temporal Connectives

Relative clauses, as in the example below, can be handled by Webber’s account as long as they are expressed using a perfect. When they are expressed in the perfect, the reference time will not move forward and I believe this is the desired behavior for relative clauses. The relative clause acts as background information or an elaboration of the matrix clause and should not cause the reference time to move forward. However, when the relative clause is not expressed as a perfect and is not stative, then Webber’s approach will allow the reference time to move forward. It does not seem likely that one would want to treat the relative clause as an embedded discourse segment but it appears that this is the only way Webber’s approach could avoid this problem. By using discourse relations to drive the pushing and popping of the open events in the discourse this problem can be avoided. I can claim that the relative clause is always in a background or elaborative relation to the matrix clause and this will cause the times associated with the matrix clause to be available for further temporal reference. Then when the next clause is related to the matrix clause, the times associated with the relative clause will be popped and those associated with the matrix clause can be used. In this way the narrative is able to be picked up from the matrix clause’s reference time and not the relative clause’s.

- (6) O’Ferral ran 4 yards to the 12 in the middle of the field with 31 seconds left. Nickels who (had/Ø) missed a 22 yard attempt with 1:45 left, then had to wait as East Carolina called two timeouts.<sup>4</sup>

Another problem area is temporal connectives, that is temporal adverbials that are clauses (e.g. “when”, “during”, “after”). There are no discourse relations in the set Lascarides & Asher discuss that would be directly applicable for encoding a “before” or “after” relation

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<sup>3</sup>revision based on excerpt from “The Jungle” by Upton Sinclair

<sup>4</sup>from Pittsburgh Post-Gazette

between a subordinate clause and its matrix clause. I checked the relation definitions from rhetorical structure theory[MT87] and did not find a suitable match there either. However, this difficulty might be resolvable in an indirect way since a “before” could be coded as a narrative relation, an “after” as an explanation or elaboration, and a “during” as a background. With these discourse relations the event times would be treated in the proper way.

Looking more closely at the football stories, a temporal connective such as “after” can supply explicit information about the temporal ordering of the events in the clauses that may not be part of a readers general knowledge about the world or the domain of the discourse.

(7) Milanovich left the game after taking a hard hit.

In (7), we have two types of information that indicate the temporal ordering. The first is that there is a possible causal relation that may be part of the reader’s domain knowledge. So the “hitting” event is a possible cause for the “leaving” event and from this knowledge the reader could infer that the “hitting” event was followed by the “leaving” event. The second type of temporal information comes from the temporal connective “after”. If the reader did not know a “hard hit” could cause a player to leave the game then the “after” would still give the temporal ordering of the “hitting” event followed by the “leaving” event.

(8) After the Seminoles stopped McDougal on a fourth-and-1 play, Notre Dame came back on the next series to take the lead.

In (8), it is unlikely that there will be a possible causal relationship between the “stopping” event and the “coming back” event as part of the reader’s domain knowledge. In this case the “after” connective and the default of the event time moving forward will agree that the “stopping” event is followed by the “coming back” event.

However, temporal connectives can be ambiguous. The connective “as”, can indicate either a causal relationship or a part-of relationship. In (9), the relationship between the two clauses is causal. A reader who has enough football knowledge, may have a representation of the possible events that could cause the prevention of “get in the endzone”. However, if the reader does not have this much knowledge about football they might infer there is either a causal or part-of relationship.

(9) Maryland couldn’t get in the end zone as quarterback Milanovich was intercepted three times.

In (10), the relationship between the two clauses is a part-of relationship. In this case, football knowledge is restricting the reading to a part-of relation.

(10) Richardson also ran for a touchdown as the Tigers piled up 278 yards on the ground.

To show that “as” has two readings and that the domain knowledge is restricting the reading, we can substitute semantically neutral events for these two sentences. This will indicate whether the causal and part-of relations arise from “as” or from the lexical semantics of other words in the sentences. The first substitution below, covers both of the above sentences. A part-of reading is possible since an individual team member event could be part of a team event. Also, it could be a causal relationship since the outcome for a team could be caused by an individual’s action. Also, if we remove the information about which team the player is a member of, the causal and part-of readings still arise.

Team A Xed as player B of Team A Zed.

Team A Xed as player B Zed.

Now I will consider whether the semantics of groups and individuals has an effect on the readings of “as”. In the above substitutions, there is a player who is a member of a team, and a player who may or may not be a member of the team mentioned. The question is whether the knowledge of teams and players is effecting the readings of “as”. In the substitutions below this interaction does not occur and it is still possible to have a causal and a part-of reading.

Player A Xed as Player B Zed.

Team A Xed as Team A Zed.

On the basis of this evidence, I can conclude then that “as” is ambiguous and can indicate either a causal or part-of reading.

### 5.3 Tenseless Events: Nominals, Gerunds and Infinitival Clauses

In the newspaper stories reporting on college football games that I examined, nominal events are frequently used (e.g. “Shea Morenz’s 41-yard pass” -> “Shea Morenz passed the ball 41-yards”). The questions for nominal events are:

- how does the tense of the verb effect its event arguments
- how if at all does the verb effect the ordering of its event arguments relative to one another when there are multiple event arguments
- how are the event arguments ordered relative to the event indicated by the verb

The tense of the verb can help indicate the time of the event arguments but it is not necessarily a direct application of the tense to the event argument nor does it always fully specify the placement of the events with respect to speech time. For example, in (11), e1 is before e2 and e2 is before the speech time, but we cannot tell the location of e1 with respect to the speech time.

(11) [e1 Shea Morenz’s 41-yard pass to Mike Adams] will help [e2 Texas strike back].

This is easier to see in (12). Here again e1 is before e2 but context will have to determine whether e1 is in the future or not. For example, if a telephone solicitor is asking for a donation then e1 will be in the future or if someone is collecting door-to-door and is thanking you for a contribution you just made then e1 will be in the past.

(12) [e1 Your contribution] will help [e2 the soup kitchen feed the homeless].

However, if as in the case of past tense narrative, e2 is prior to the speech time then e1 will be as well. This is the case in (13).

(13) [e1 Shea Morenz’s 41-yard pass to Mike Adams] helped [e2 Texas strike back].

In the stories I examined, there was no use of the future tense so I did not have to specifically address this question, but the setting of e1 in the case of the future would be partially determined by how it relates to a previous event in the discourse. I hypothesize that the lexical semantics of the verb will place the event arguments relative to one another and to the event expressed by the verb when it is not a meta-event (i.e. X follows Y). Further, I hypothesize that the tense of the verb will not place all of its event arguments with respect to speech time. However, without looking at more data, I am not ready to claim whether this would be indicated by the semantics of the verb or not. In (14) the verb “follow” places e2 before e1 but it also seems that the future applies to both events. It is possible that the future applies only to e2 and that in turn will place e1 in the future.

- (14) [e1 John’s demonstration] will follow [e2 Mary’s presentation].  
 [e2 Mary’s presentation] will be followed by [e1 John’s demonstration].

In my model, I chose to let the ordering of nominal events follow a default of a causal relation and then allow the semantics of the verb to override this default as in (15).

- (15) [e1 Texas struck back on/via [e2 Shea Morenz’s 41-yard pass.]]

So, in this case, e2 is an argument of “strike back” and when “strike back” has an event for a theme, this event can be part of the main event e1. Whereas in a default case, as with (16), e1 caused e2 so that the default ordering is e1 is before e2.

- (16) [e2 [e1 John’s bad decision] ruined the company].  
 [e1 Betty’s speech gave [s2 John an idea for a dissertation]].  
 [e1 Betty’s speech gave [s2 John a headache]].

In my encoding of the logical forms, I let the tense of the verb apply to all of its event arguments which works for the type of past tense narrative text I worked with.

Gerunds are another kind of untensed construction that I encountered. Gerunds are similar to nominal events in that they are tenseless but they have a function similar to relative clauses in that they provide background information. Based on the past tense narrative data I examined, the tense of the main verb does not appear to effect the placement of the gerund event. However, if I modify the data to use future tense then it is not clear what the placement of the gerund event is with respect to speech time. For example, in (17), the “playing” event could be during a pre-game commentary giving the interpretation that the “playing” is in the future. If (17) is made during the game then the interpretation is that the “playing” is in progress. However, I have some doubts about whether this is something that anyone would say during a game.

- (17) [e1 The Sooners, [e2 playing against the NCAA’s 104th-ranked defense], (will have/had) to go to the air to win].

In the past tense version of (17), the interpretation is that the “playing” is an activity in which at least the main events of the sentence occur. Another example is (18).

- (18) [e1 Trinity [s2 trailing 29-17 in the fourth quarter], marched 68 yards in 13 plays for one score]...Marty Thompson missed the extra-point kick, and CMU seemed comfortable with a 29-23 lead...

In this text, the activity s2 started during the fourth quarter and this state continues up until an unknown point during which the events of the sentence occur. We can infer that Trinity is still trailing given the rest of the text (i.e. the score later is 29-23) and that the events are during s2.

In my encodings of gerunds, they are represented as activities and are therefore stative. This means the main events of the clause will be during the eventuality expressed by the gerund. I also applied the past tense of the main verb to the gerund although this may not be entirely correct in the case of the future.

Infinitive clauses also occurred in the data I examined. (19) shows some examples of infinitives. In the first case, e1 results in e2 so that the default ordering of events applies. In the second case e3 caused e4 so the default ordering is maintained so that e3 is before e4. In these cases, the direct application of the main verb's tense seems to apply but I believe this would depend on the lexical semantics of the verb.

- (19) [e1 Bailey hit receiver David Marston]...[e2 to tie the score].  
[e3 O'Ferral intentionally downed the ball] [e4 to stop the clock on the next play].

For example, in (20), although the main verb is either present tense or past tense, “want” indicates that the event argument e2 did not occur by the speech time.

- (20) [e1 I want/wanted] [e2 to stop the clock on the next play]

In my model, I rely on the domain knowledge to supply the necessary information on event ordering and apply the tense of the main verb to the infinitive. I did not encounter any verbs like “want” and did not implement anything in the model to handle this. Were I to have included this, I would have done so at the lexical semantics level.

#### 5.4 Co-Extensive Events

Although Webber indicates that with co-extensive events the reference time does not move forward it is a difficult problem to recognize that two events are co-extensive. Neither the tripartite structure of events, a segmentation of a discourse, nor the discourse relations between clauses clearly indicates that events are co-extensive. For example, in (21) below, “played the piano” could be narratively related to “sang” and this would indicate that the events were not simultaneous. However if they are both related as elaborations to “entertain” then it is ambiguous as to whether they are coextensive or simultaneous. However, this is then an extended elaboration and the events “sing” and “play” would be narratively related and this would force them to be interpreted as not being co-extensive.

- (21) We went to John and Mary's for dinner. To entertain us after dinner, Mary sang “Moon River” and John played the piano.

The ambiguity is cleared up by other information in the discourse. For example, in the discourse below if the “play” and “sing” events are both elaborations of “they performed” then we have to use knowledge of what it means for a group of people to perform a song in order to select the reading where the “play” and “sing” events are simultaneous and to override the narrative default.

- (22) We went to John and Mary’s for dinner. To entertain us after dinner, they performed “Moon River”. Mary sang and John played the piano.

A different approach is needed in the example below to get the same result. In this one we have to use the lexical semantics of “accompany” to select the reading where the “play” and “sing” events are simultaneous.

- (23) We went to John and Mary’s for dinner. To entertain us after dinner, Mary sang “Moon River” and John accompanied her on the piano.

In the case below, the relation between “sing” and “play” is clearly narrative because of “and then”.

- (24) We went to John and Mary’s for dinner. To entertain us after dinner, Mary sang “Moon River” and then John played the piano.

In my model, I wanted to give a weak interpretation to co-extensive events. Simultaneous events should be elaborations or explanations of the same event otherwise the reader may not recognize them as possibly being co-extensive. The weak interpretation should leave open the possibility for co-extensiveness (i.e. retains an ambiguous reading between a co-extensive and a precedence reading). A stronger interpretation could be given at a later point in the analysis by utilizing information from other sources such as lexical semantics, and nominal anaphora resolution (e.g. “they = John and Mary” in (22) above). However, to do this I would have had to change the model for extended elaborations to override the narrative relation. But some extended elaborations are clearly not co-extensive as in (25).

- (25) Gundy capped the drive as he faked a pitch and strolled 18 yards for the touchdown.

In this case, the events “faking” and “strolling” elaborate the event “capping the drive” but the “fake” is before the “stroll”. This means I would have had to have information on what cannot be simultaneous in the domain knowledge base. Since I encountered very few cases of co-extensiveness in the data I examined, in the interest of time, I did not address this problem in my implementation. One example is (26).

- (26) [e1 Pitt free safety Doug Whaley was covering] when [e2 the ball found Mitchell around the 15], but Whaley slipped on the wet turf and left Mitchell with a clear path to the end zone.

Here, the semantics of “when” indicates that it is ambiguous between a precedence and a co-extensive reading. However, given the domain and type of text, it might be possible to use a heuristic that would prefer the co-extensive reading when the two actors of events connected by “when” are different. Otherwise it would require a great deal of domain knowledge and a strong inferencing capability to conclude the events are co-extensive.

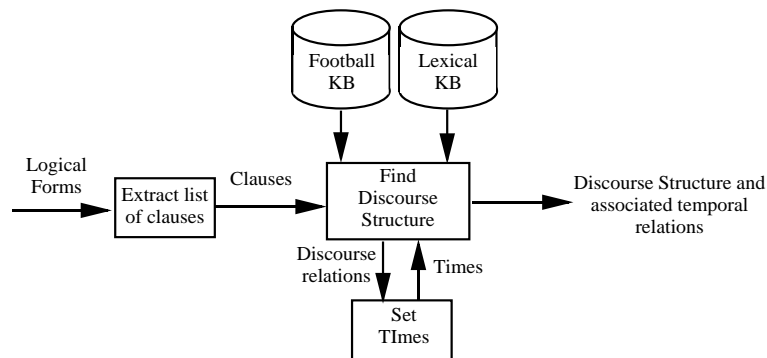


Figure 2: Top-Level System Architecture

## 6 The Implementation

The input to the system is a set of hand encoded logical forms representing the sentences of the text. The input texts are newspaper stories recounting the plays of a football game. Since the logical form for a sentence may include subordinate or coordinate clauses and nominal events, the eventualities must be extracted from the logical forms as the first step of processing. All of the eventualities in the text are extracted and kept in the order in which they occurred in the logical form. Then for each eventuality, the next step is to identify the possible discourse relations between it and the preceding eventuality. This process requires knowledge about the domain of football (e.g. time-out causes stop-the-clock), knowledge about the interaction of various discourse relations (e.g. how to override the default of narrative), lexical knowledge about verbs that can have event arguments, and the semantics of temporal connectives. As the possible discourse relations are determined, the speech, reference and event times are set relative to those of the eventuality it is related to. The setting of times also depends on syntactic information (e.g. perfect, relative clause) as well as the discourse relation (e.g. the reference time moves forward for a narrative relation). The output of the process then is a set of possible discourse structures for the input text and the temporal analysis of each structure.

### 6.1 Input

The implementation takes as input the logical forms of a discourse. The logical form for each sentence includes tense features, the aspect (i.e.  $\pm$ perfect), the states or events contained in the main clause and any embedded clauses. Each embedded clause is encoded in this same way and includes information on the syntactic type of the clause (e.g. relative clause). If the clause is non-finite the tense feature is not set. Each state or event is coded with the Aktionsart[Ven67] of the clause or sentence. The values for Aktionsart are: accomplishment/achievement, state, or activity. In the implementation and the model, I did not make a distinction between accomplishments and achievements since it did not appear to effect the temporal ordering of events for the football domain.

For each sentence, the matrix clause is at the top-level of the logical form and the subordinate clauses are embedded. In addition, events and states may have eventualities as arguments. Even with a BNF defining the syntax of the logical form, different people or automatic an-

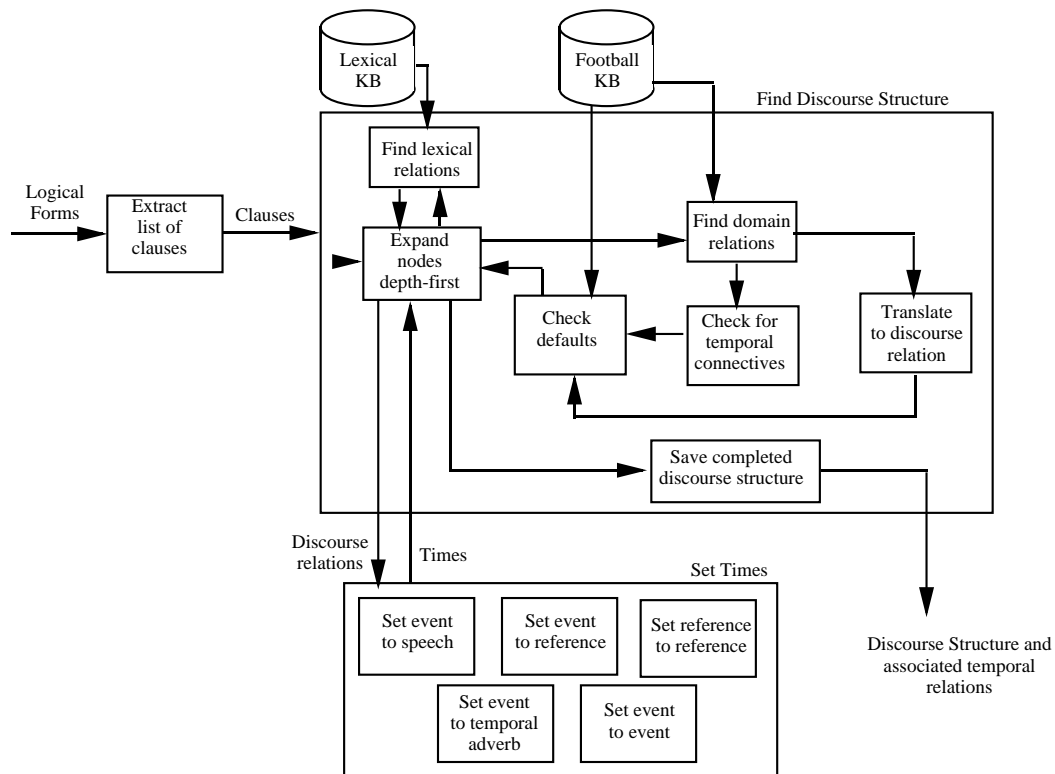


Figure 3: Detailed System Architecture

analyzers would produce different logical forms for a text. This would reflect the ambiguities of the text as well as the varying granularities of analysis that are possible for eventualities. For instance, there may be multiple encodings for “score a touchdown”, where “touchdown” is an event or not and the granularity of the “touchdown” event could vary. As long as the lexical and domain knowledge is consistent with the granularity of the representation in the logical form the temporal ordering should be valid. A good future experiment would be to get encodings from multiple sources to verify that the temporal orderings would still be valid despite variation in granularity. It would also be worthwhile to recognize multiple encodings for a text and to see if the temporal ordering process could help identify the best encoding of each sentence in the text based on the most specific information about temporal ordering.

## 6.2 Extracting Eventualities

Given the above inputs, the implementation will extract all the eventualities from the input discourse, and then for each eventuality extract its tense features, the Aktionsart and any temporal adverbials associated with the eventuality. Eventualities are extracted from main clauses, subordinate clauses, adjuncts, and from event arguments. The ordering of eventualities is maintained according to the order in which they occur in the logical form.

### 6.3 Finding Possible Discourse Structures

The discourse relations (narrative, explanation, elaboration, background and result, as described above in Section 4.4 and repeated below) are used to define a discourse structure for the input narrative text. Only one relation is given between an eventuality and a previous eventuality although the results of this project show that it may be necessary to relate units of discourse larger than just an eventuality (discussed in section 7.1). It is also possible that it will be necessary to relate an eventuality to more than one other one in the discourse. There was not enough time to address this problem during this project.

The process of finding the discourse structure is shown in more detail in Figure 3. There are four sources of information that contribute to finding the discourse structure. To simplify the implementation, I directly incorporated default specificity into the architecture. The order of specificity is: lexical knowledge ordering events and event arguments, the default of causal for event arguments, domain knowledge, the semantics of temporal connectives and the default discourse relation narrative.

The discourse relations to be determined by this module to represent the discourse structure are those defined in[LA91]:

- (narrative  $\alpha \beta$ ): event  $\beta$  is a consequence of event  $\alpha$
- (explanation  $\alpha \beta$ ): event  $\beta$  caused event  $\alpha$
- (elaboration  $\alpha \beta$ ): event  $\beta$  is part of event  $\alpha$
- (background  $\alpha \beta$ ): state  $\beta$  is background to event  $\alpha$
- (result  $\alpha \beta$ ): event  $\alpha$  caused eventuality  $\beta$

In addition to these discourse relations, I found it necessary to define inverses for the narrative and elaboration relations. The inverse narrative represents the effect of an after-clause and an inverse elaboration reflects the behavior of some verbs and their event arguments (e.g. “Shea Morenz’s 41-yard pass helped Texas strike back.”)

As processing begins on a new eventuality, it needs to be related to one other eventuality in the preceding discourse. The possibilities are limited by the focus stack which represents the events that are open for further reference in the discourse. The popping of the focus stack is motivated by the restriction on the narrative relation as defined in [LA91]. This restriction is a Nixon diamond and when a conflict arises that means that the narrative relation cannot possibly be true (because of this conflict) and then the focus stack is popped and the next eventuality tested to see if the current event can be related to it. The rule is that for narrative(b,c) to hold when elaboration/explanation(a,b) is true, elaboration/explanation(a,c) must hold and when it does not then  $\neg$ narrative(b,c). But the default is for narrative(b,c) to hold so this causes the conflict that leads to popping the stack. An example of this is seen in (27) which has the discourse structure shown in Figure 4

- (27) The 65-yard drive was capped by Gundy, [<sub>RC</sub> who faked a pitch on the option] and [<sub>RC</sub> strolled 18 yards for the touchdown.]

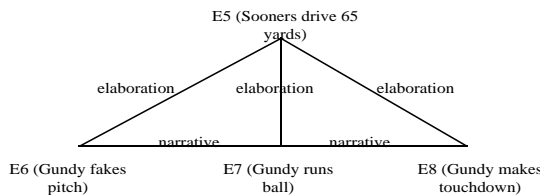


Figure 4: Discourse Structure

In addition to the Nixon diamond, anytime a narrative relation is found between two eventualities, for example  $\text{narrative}(d,e)$ , then any relation that relates  $d$  to another eventuality in the previous discourse is popped from the focus stack. This closes  $d$  so that no other eventuality can be related to it. It is no longer open for further discussion. Any other relation leaves the eventuality open for further discussion and it is retained on the stack.

Once a discourse relation is found to exist between two events the event and reference times are obtained from the module that sets the times. The discourse structure is then updated by expanding the search tree for the possible discourse structures with each each new node of the tree being the relation that is possible for the two events. As a node is added to the search tree, the associated temporal settings for the event are included in the node as well as the relation found between the event and a previous event, and the temporal focus stack.

### 6.3.1 Finding Lexical Relations

First if the eventuality was an argument of an eventuality, the lexical knowledge base is checked for information to override the causal default. Otherwise a causal default is used to relate the eventuality and its argument and no other information is used to determine the discourse relation.

Passoneau[[Pas88](#)] states that in addition to aspectual distinctions there are other distinctions that are also relevant to temporal semantics. She noted there are first, second and third-order verbs which are analogous to the distinctions between first, second and third-order logics. A first-order verb is one whose arguments are concrete entities, a second-order verb can have states, processes and events as arguments and the semantics of the verb is temporal or aspectual such as with “occur” or “follow” and are similar to what have elsewhere been called aspectual verbs. Third-order verbs take as arguments situations. In Passoneau’s representations, situations have a situation type, a kinesis and a boundedness. I do not make this type of distinction between events and situations and it is not clear to me that the arguments of second-order verbs would not also be situations as opposed to events. I have given a slightly different interpretation to Passoneau’s idea of first, second and third-order verbs. In my definition, second-order verbs take one eventuality argument and third-order verbs take two. With second-order verbs, the eventuality in the argument must be related to the eventuality expressed by the verb and with third-order verbs the eventualities in the arguments must be related to one another. With third-order verbs, I treated the verb as a meta-event and I did not try to relate it to any events in the discourse.

When the eventuality is a nominal event the lexical knowledge base is checked to see if the causal default should be overridden. In the case of a third-order verb, lexical information should always be present but I do not have a special check to ensure that this is the case.

When a third-order verb is found, the main verb is treated as a meta-event which means that the stack of open eventualities must be adjusted to remove the meta-event and to modify the time settings to refer not to the meta-event but to the eventuality argument that occurs first according to the lexical definition of the verb. The algorithm shown here summarizes the above description:

```

when order-2 verb
  return translated-relation from lexicon
when order-3 verb
  replace current item on open-stack and
    adjust times (current item is a meta-event)
  get next eventuality and put it and
    translated-relation from lexicon
    on open-stack with times
when no information in lexicon
  use the default

```

My lexical knowledge base in this implementation was not generalized in the interest of getting the project completed on schedule. However, I envision that verbs of different orders could be classified as to their behavior and that verbs can optionally take events as arguments and that the order information would only apply in the case of event arguments.

### 6.3.2 Finding Discourse Relations

For non-argument events, the processing to find the possible discourse relations starts with a search of the football domain knowledge base for possible part-of or causal relations between the events. When such a relation is found it overrides the defaults and any information supplied by other sources. Any knowledge base relations that are found are translated to discourse relations. Currently this is a one-to-one mapping but this module allows for a one-to-many mapping should the need arise.

If no domain information is available for relating the two eventualities then any temporal connectives relating the two events in the text are used. The semantics of each temporal connective are the possible discourse relations it could indicate for this domain. However, there is a flaw in the implementation. A temporal connective means that the event in the matrix clause and the event in the subordinate clause should always be related to one another. This relationship is not enforced and this leads to errors. This is discussed in more detail in Section 7.1. So once a temporal connective is found, giving information on what event relates to what other one, then if the temporal connective is ambiguous then the domain knowledge base should be consulted to see if it can provide information that will reduce or eliminate the ambiguity. This last check was not implemented but is something that should be done in the future.

Finally, the discourse relations accumulated so far (there may be none at all) are checked to see if the narrative relation would be in conflict with any of them. If there is no conflict or there were no other discourse relations, then the narrative relation is added to the accumulated list of discourse relations. There is an additional conflict check and this is the idea expressed earlier that if event b elaborates event a, and event c is to be narratively related to b, then c

must also elaborate event a. If c cannot elaborate event a according to the domain knowledge then the narrative relation cannot hold and the focus stack is popped so that event c can be directly related to event a.

## 6.4 Setting Times

Once a discourse relation between two eventualities is established there is enough information to set the event and reference times. The event, reference and speech times are described using the following temporal relations as defined in Allen[All83]:

- (during a b): a is during or included in b
- (starts a b): a is included in b and starts b
- (finishes a b): a is included in b and finishes b
- (< a b): a wholly precedes b
- (= a b): a is simultaneous with b
- (overlaps a b): a precedes and overlaps b

First, the event-time of the eventuality is set relative to the speech time (now). This setting is based on the tense of the clause from which the eventuality was extracted. Then the reference time is updated by first setting the event time relative to the reference time on the basis of the Aktionsart of the event, the tense, the clause-type, the aspect and the  $\pm$ narrative discourse relation. activities and accomplishments/achievements. Next the reference time is set relative to the reference time of the related event. This is based on the aspect ( $\pm$ perfect), the discourse relation and in the case of a narrative discourse relation, the higher-level discourse relation if there is one (i.e. as in an extended elaboration), and the clause-type (i.e. relative clause or gerund).

In setting the reference time, the higher-level discourse relation is needed to determine whether the current eventuality is a continuation of a narrative or an extended elaboration/explanation. If it is not the continuation of a narrative then the reference time needs to be moved to an earlier time than that of the related eventuality's reference time. This accounts for cases where an elaboration is expanded into a narrative. Without this resetting of the reference time, it would move forward from a time after the event being elaborated. Presumably all the narrative eventualities connected to an elaboration, for example, are also elaborations of the same event.

Finally the event time is updated by first setting the event-time relative to any temporal adverbials associated with the event on the basis of the tense for the current event and the current discourse relation. Next the event time is set relative to the event time of the related event according to the discourse relation between the two when the aspect is  $-$ perfect based on the clause-type, the discourse relations, and the higher-level discourse relation. If the aspect is  $+$ perfect then the event times are not set relative to one another. The events in this case can only be ordered via the setting of event times by temporal adverbials.

### 6.4.1 Rules for Setting Times

Setting event time relative to reference time:

```

If eventuality is a state or activity then
  If present tense (for cases like "John has brown hair")
    Then the reference time is during event time
  If past tense (for cases like "John had brown hair")
    Then the reference time finishes the state
If eventuality is an accomplishment then
  If perfect aspect
    Then the event time overlaps the reference time
  If simple past, present or future and
  not a relative clause or a gerund and
  not part of an extended elaboration/explanation
  Then
    If narrative discourse relation
      Then the event time equals the reference time
    Else the reference time finishes the event

```

Setting reference time relative to reference time of the related eventuality:

```

If simple tense and narrative relation to previous eventuality
  Then
    If this is the continuation of an existing narrative or
    the start of a new discourse and not a relative clause
    or a gerund
      Then the reference time moves forward relative
        to the previous reference time
    Elseif it is a relative clause or a gerund and is not
    part of an extended elaboration/explanation then
      the reference time is the same as the narrative
      reference time
    Else it is not the continuation of a narrative so reset
      the reference time to be before that of the related
      event's reference time
  Else
    it is perfective or is not a continuation of a narrative so
    the current reference time does not move

```

When there is a temporal adverbial set the event time to the time indicated by the temporal adverbial:

```

If simple tense and the discourse relation is not
result or background
  Then the event time equals the temporal adverbial time
Elseif the discourse relation is result

```

```

    Then the temporal adverbial time finishes the event
Elseif the discourse relation is background
    Then the temporal adverbial time begins the event
Elseif perfective and the discourse relation is not
result or background
    Then the temporal adverbial time finishes the event

```

Set the event time relative to the previous event time:

When not perfect

```

If the discourse relation is narrative

```

```

    Then

```

```

        If is a relative clause or gerund and not part
        of an extended elaboration

```

```

            Then the previous event is during the current event

```

```

            Else the previous event is before the current event

```

```

Elseif the discourse relation is result

```

```

    Then the current event overlaps the previous event

```

```

Elseif the discourse relation is background

```

```

    Then the previous event is during the current event

```

```

Elseif the discourse relation is explanation or inverse narrative

```

```

    Then the current event is before the previous event

```

```

Elseif the discourse relation is an inverse elaboration

```

```

    Then the previous event is during the current event

```

```

Elseif the discourse relation is elaboration

```

```

    Then the current event is during the previous event

```

## 7 Evaluation of the Model

### 7.1 Correctness of the Model

Discourse Name	No. of events	No. of clauses	No. of sentences
dis-1	9	9	3
dis-2	4	4	2
dis-3	15	10	2
dis-4	10	6	3
dis-5	10	5	2
dis-6	3	3	1
dis-7	3	2	1
dis-20	6	6	3
dis-30	5	5	4
	65	50	21

Table 1: The Test Data

The model was tested on 7 hand-encoded excerpts from newspaper stories reporting on college football games. In addition to these, I tested the model on 2 non-domain discourses

	No. in test set	No. unambig correct	No. ambig - 1 correct	No. unambig incorrect	No. ambig - all incorrect
Extended Flashback	1	1			
Extended Elaboration	3	3			
Relative Clauses	5	5			
Past Perfect	6	6			
Relative Clauses + Past Perfect	1	1			
Temporal Connectives	7	3	1	1	2
Gerunds	2	2			
Nominal	6	5		1	
	31	26	1	2	2

Table 2: The Model’s Performance

from the literature on temporal anaphora (dis-20, dis-30). For the 2 non-domain discourses, I set up separate knowledge bases but I did not need any lexical knowledge since there were no nominals or gerunds in these two discourses. Table 1 gives some idea of the complexity of the sentences in the discourse and the size of the discourse itself. In the cases where the number of events is equal to the number of clauses, the text did not have any nominals or I did not encode the nominal events. This would be the case in dis-1 and dis-2 since these were encoded earlier in the project and I did not have time to go back and recode them.

All of the phenomena listed in Table 2 were correctly treated except for temporal connectives and nominals. All of these errors have to do with the interaction between states and events. There are just two relations defined currently that involve states;  $\text{result}(\alpha, \beta)$ , where event  $\alpha$  causes state  $\beta$  and  $\text{background}(\alpha, \beta)$ , where state  $\beta$  is background for event  $\alpha$ . In both types of errors the state follows the event it is to be related to. There are no allowances for a state to be related to an event that follows it given the definitions for result and background. However, as I saw in the data such cases do arise as in (28).

(28) [s1 He was unfazed] as [e2 his attempt split the uprights.]

Using the current discourse relations there must be an event in the prior discourse that the state s1 is related to. Since background is the default this relation is established with the first event that is still accessible in the prior discourse. The relation that needs to be made in this case is between s1 and e2, where e2 is evidence for s1. [LA93] note that there is an inverse of the background relation. I suppose that this means the state will overlap with the event that precedes it and any events that follow it.

(29) [s1 The Commodores trailed] when [e2 Gordon replaced freshman Douglas].

The other failure for temporal connectives is (29). I consider “trailed” to be a state/activity rather than an accomplishment/achievement. Here “when” indicates that state  $s_1$  holds at the time of the event  $e_2$ . So in this case I think that if I had allowed of an inverse definition of background in the case of “when” this could have been correctly handled.

(30) [s1 Marty Thompson missed [e2 the extra-point kick]]

With nominals the problem occurred in (30). Again I consider “miss” to be a resulting state of “[e2 Marty kicking the ball]”. If an inverse result relation were allowed then this could have been correctly handled. I think in this case that this relation should have been indicated in the lexical knowledge base since when “x missed event-y” where the agent of the event-y is x, the state “miss” will be a result of event-y. It is also the case that the causal default between a verb and its eventuality argument does not hold if the eventuality is a state.

(31) [s1 Mary missed [e2 the opening performance].  
[s1 Mary finished [e2 the opening scene].

In (31) I believe the relation between  $e_2$  and  $s_1$  would be the default and that it is neither a background or a result relation since background indicates that the event occurred while the state held and result is causal. I think this should be called a consequent in keeping with the tripartite event structure defined in [MS88] or since  $\text{narrative}(\alpha, \beta)$  is where event  $\beta$  is a consequent of event  $\alpha$ , the typing of  $\beta$  should be changed from event to eventuality to accommodate consequent states.

What is difficult to resolve in these cases is how to prevent the state from being related to a prior event. This is a problem because the state gets processed before the next event is examined and the erroneous relation to a prior event is made. So, when these errors between events and states occurred, it resulted in the times for  $s_1$  and  $e_2$  being incorrectly described.

There were two other problems that I found, that do not directly relate to the phenomena in table 1. The first is that the discourse relations do not always get correctly assigned in the case of relative clauses and perfects but this does not effect the setting of times in these cases since these are driven by the syntax and lexical knowledge and not the discourse relation. So, while the discourse information is not always needed to set the times the openness of what can be discussed further is adversely effected.

In the case of a relative clause, it should not close off the event it is supplying background information for. But as is seen in (32) two relative clauses can be narratively related and a relative clause can elaborate the matrix clause. So the relative clause should not be assigned a narrative discourse relation.

(32) The 65-yard drive was capped by Gundy, [<sub>RC</sub> who faked a pitch on the option] and [<sub>RC</sub> strolled 18 yards for the touchdown.]

Also, if the default of the reference time moving forward is overridden as in (33), it is still not the case that the relative clause should close off the previous clause for further elaboration (the forward movement is from “missing the kick” to “slipping”). I think then that in the absence of any discourse or lexical knowledge that the relative clause should be an elaboration or explanation in the case of events or background in the case of states.

- (33) The team was plagued with injuries. The first ones occurred when the team decided to go for a 30-yard field goal. Kevin Beam, who *missed the kick*, *slipped* on the wet turf when leaving the field and the holder broke his finger on the snap.<sup>5</sup>

As noted in [LA93], the past perfect when related to simple past is limited to either an explanation relation, an elaboration relation or is parallel under a common topic where the past perfect event occurs before the simple past event. I was not careful about this in my implementation and did not allow the past perfect to override the default of narrative. This was detrimental in only one case since the narrative relation did not allow the next clause to be related back to the matrix clause.

- (34) Nickels, [e2 who had missed a 22 yard attempt with 1:45 left], then [e1 had to wait] as [e3 East Carolina called two timeouts].

In (34), e2 was narratively related to e1 although the reference time stopped and the settings of event times were correct. This meant that e1 was no longer open for other events to be related to it and e3 was related to e2 as an elaboration or an explanation since there was an “as” connective. I missed this problem in the original evaluation but the scoring has been corrected in Table 2. The reason it was not a problem in the other cases was that there was domain or lexical knowledge that had overridden the default of narrative or that the event in the relative clause was surrounded by states.

I think that gerunds would have a similar problem but rightly or wrongly, I encoded all gerunds as states. I am not sure if this is reasonable in all cases. In (35), the two gerunds still seem stative and it is not the case that one activity followed the other or were in any way related to one another.

- (35) The Sooners, playing against the NCAA’s 104th-ranked defense and suffering from a losing-streak, failed to build any momentum in the first half of the game.

With nominals, on the other hand, there was not a similar problem. Nominals rely on lexical knowledge and have a causal default as the argument of a verb. Having a narrative default in the case of the object of a preposition being a nominal was not a problem either.

The second problem was with the setting of event times with respect to other event times. The arguments for the temporal relation, overlaps, are not in the correct order for the discourse relation, result. This was just a programming error.

## 7.2 Coverage of the Model Relative to Other Current Models

One of the goals of this project was to provide a more unified, enhanced account of how the temporal ordering of events in discourse is determined. Table 3 lists the phenomena considered by the various researchers according to their published work. The yes/no labels indicate only that the researchers attempted to incorporate this phenomena into their models and not that they claim to have solved all the problems associated with the phenomena. The point is that I have addressed all of the phenomena listed except that I do not have a satisfactory account for co-extensive events. In addition, I have included relative clauses in my model whereas no one else has done so. It is also the case that besides myself, only Passoneau and Webber have addressed untensed events.

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<sup>5</sup>I made this one up

	Jordan	Kamp	Passoneau	Webber	terMeulen & Seligman	Lascarides & Asher	Hwang & Schubert
Extended Elaboration	yes	yes	no	yes	yes	yes	yes
Extended Flashback	yes	yes	no	no	no	yes	yes
Relative Clauses	yes	tense only	no	no	no	no	no
Temporal Connectives	yes	yes	yes	no	yes	yes	yes
Past Perfect	yes	yes	yes	yes	yes	yes	yes
Gerunds	yes	no	?	no	no	no	no
Nominals	yes	no	yes	yes	no	no	no
Co-extensive Events	no	no	no	yes	no	no	deferred processing

Table 3: The Model’s Coverage of Phenomena

## 8 Future Work

There are some limitations and drawbacks to my implementation due to the assumptions I made. I assumed that the non-monotonic reasoning needed when extracting information from the knowledge base is already taken care of. This is not necessarily bad, it is just that I did not address this particular problem.

Another limitation of my implementation is that the order of specificity for defaults is built into the architecture. This makes it very brittle unless a controller is put into the architecture that determines which type of information is more specific in a given context.

Also, if there is information later in the discourse that conflicts with the default decisions then either a truth-maintenance system needs to be included to modify the results or the decisions on specificity must be deferred so that all possible relations are carried along as the discourse is processed. I believe what I have implemented is equivalent to prioritized circumscription which has the drawbacks listed in [LA93]. These drawbacks helped motivate the need for the commonsense entailment logic that they defined.

There were additional linguistic phenomena that I encountered in the newspaper stories on football that should be considered in future work. First, the interaction between nominal and temporal anaphora should be more closely examined. Webber[Web88] discusses this briefly and claims that the discourse reference time should not move forward when nominal events are encountered. I do not understand Webber’s argument for making this claim. An example of this phenomena from the football domain is (36).

- (36) Duquesne has the gold medals, mainly because it came up big on *two fourth down plays*. *The first* was in the third quarter...*The second big fourth-down* came in the fourth-quarter.

A counter-example to Webber’s claim I believe is (37). In this case the “touchdown” event is not anaphorically-linked elsewhere in the discourse and the “extra-point kick” event follows after the “touchdown” event. So in this case the discourse reference time does seem to be moving forward.

- (37) Quarterback Bailey hit receiver Rogala from 5 yards out for *a touchdown*. Marty Thompson missed the extra-point kick, and CMU seemed comfortable with a 29-23 lead.

The second phenomena that should be considered further is plural events. This also has ties to the interaction between nominal and temporal anaphora as in (36) where the later separate references to the “two fourth down plays” would motivate the representation of the two plays as separate events for reference purposes. At other times it may be acceptable to represent the plural event as a single composite event as in (38).

(38) Milanovich was intercepted three times and sacked nine times.

Another phenomena that should be considered is negation and future events. For example, in (39), the event x does happen but it is after event y. And in (40), the reader doesn’t know if the “get flowers” event occurs unless it is mentioned later in the discourse. In both cases it is a matter of the event being mentioned not occurring until later in the discourse.

(39) Actor-a didn’t X until Y happened.

(40) He had promised to get Mary some flowers.

Also the issue of the scope of tense in the case of nominals and gerunds needs to be further considered for the future and present tenses. This was discussed in section 5.3 where I found that there was not a problem with applying the past tense of the verb to the nominals and gerunds in the clause.

Another scoping issue has to do with temporal adverbials. In some cases the temporal adverbial can apply to the clause and in some cases it applies just to the event. The difference in scoping could indicate whether the event begins or ends at the temporal adverbial (in the case of a point adverbial) as in (41) where the “getting up” could have started at 5 or ended at 5..

(41) He had gotten up at 5.

And finally the problem of needing to relate larger units of discourse needs to be addressed. [LA92] discusses this issue. The problem is easier to see in larger discourse excerpts as in (42) where the event at the end of the excerpt, “kept attacking” is simultaneous with some prior events already discussed in the discourse. With my model, this event is taken as an elaboration of the event “get back to a more stable offense”. Although it is still not clear to me exactly what “kept attacking” is co-extensive with, I do know that the result my model gets is incorrect. I would say that the “kept attacking” paragraph is co-extensive with the previous paragraph which was an elaboration of “did a strange thing”. I think then that the third paragraph is narratively related to “Ward’s 12-yard scoring pass” based on the anaphoric relation between “Florida State’s opening touchdown” and “Ward’s 12-yard scoring pass”. However, this is a problem for the idea of openness since “but then the Seminoles did a strange thing” is narratively related the “Ward’s 12-yard scoring pass” and therefore closes off this event for further reference.

(42) Certainly Florida State made it appear as though it would be a long day for the Irish. On their opening possession, the Seminoles drove 89 yards in 10 plays to take a 7-0 lead on Ward’s 12-yard scoring pass to split end Kevin Knox. But then the Seminoles did a strange thing.

They abandoned the run after that first series. Ward went 21 plays in the first half without handing the ball to a running back. *By the time they tried to get back to a more stable offense....*They had not trailed at the half since Nov. 1991, when they trailed Florida, 7-3.

*Meantime, the Irish kept attacking.* They answered Florida State's opening touchdown with a 32-yard scoring run...

## 9 Conclusions

My main goal in doing this project was to unify and extend the models that have been proposed for determining the temporal ordering of events in discourse. By combining the ideas in [Web88] and [LA91] I succeeded in defining a more unified model. Both of these works incorporated the idea of expressing rules for when the default of the narrative reference time moving forward should be overridden. In the case of [Web88] these rules were based on syntactic information such as  $\pm$ perfect and knowledge of event structure and discourse structure. In the case of [LA91] the rules were extended to show how domain knowledge can override the default, in addition to the general ideas of event structure and syntactic information.

In extending the model, I've added more rules for how syntactic knowledge such as relative clauses and gerunds can also override the default of the narrative reference time moving forward. An additional area I have considered is how verbs that take event arguments can influence the narrative reference time. Generally, it is true that the nominal arguments will not cause the narrative reference time to move forward via a causal default for relating events and their event arguments but this is not always the case. So unlike the suggestion in [Web88], instead of a nominal event halting the forward movement of the narrative reference time, I allow lexical knowledge to override this default.

I think the work I have done shows that discourse structure, domain knowledge, lexical knowledge, event structure and syntax are all necessary for determining the temporal ordering of events in discourse. By showing that these types of knowledge are necessary, it helps confirm and elaborate the ideas in [LA91] and [Web88]. I think the next step is to consider how this process could be integrated with an automatic analyzer so that other analysis processes such as those that resolve the anaphoric reference between nominals could further constrain the temporal ordering of events and to see if the rules governing temporal ordering could in turn help constrain the other analysis processes. In addition to this, it is important to analyze the role of the larger discourse structure in further determining the temporal ordering of events.

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