A Temporal Analysis of Natural Language Narrative Text

by

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(ABSTRACT)

Written English texts in the form of narratives often describe events that occur in definite chronological sequence. Understanding the concept of time in such texts is an essential aspect of text comprehension and forms the basis for answering time related questions pertaining to the source text. It is our hypothesis that time in such texts is expressed in terms of temporal orderings of the situations described and can be modelled by a linear representation of these situations. This representation conforms to the traditional view of the linearity of time where it is regarded as a horizontal line called the timeline.

Information indicating the temporal ordering of events is often explicitly specified in the source text. Where such indicators are missing, semantic relations between the events enforce temporal orderings. This thesis proposes and implements a practical model for automatically processing paragraphs of narrative fiction for explicit chronological information and employing certain guidelines for inferring such information in the absence of explicit indications. Although we cannot claim to have altogether eliminated the need for expensive semantic inferencing within our model, we have certainly devised guidelines to eliminate the expense in certain cases where explicit temporal indicators are missing. We have also characterized some cases through our test data where semantic inferencing proves necessary to augment the capabilities of our model.
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1 INTRODUCTION

Temporal reasoning as a topic of Artificial Intelligence research has wide applicability to several interdisciplinary problems. Concepts relating to time are especially significant in the domain of natural language processing. These concepts have blended into the fabric of language during the course of its evolution. Today, linguistic time is such a well-expressed and complex concept that it deserves to be regarded as a separate area of natural language research. Written English texts in the form of narrative fiction and mystery stories often describe events that occur in definite chronological sequence. The concept of time in such texts is mostly expressed in terms of the chronological ordering of the events described.

Understanding time in narrative texts is a crucial aspect of text comprehension. Knowledge about the chronological ordering of events is essential for answering time related questions pertaining to the source text. Such knowledge can also be instrumental in deriving additional temporal information not explicitly stated in the text. The aim of this thesis is to model the concept of time relating to narrative texts by determining the chronological ordering of the events described. A conceptual representation of narrative time is constructed from the information derived. This representation is based on a traditional view of the linearity of time where time is regarded as a horizontal line like the real number line. Past time is signified by a leftward movement while future time is signified by a rightward movement along the line.
This linear model of time is called the *timeline model*. In this model, stretches of time correspond to intervals each of which has a distinct start and end. Instants correspond to points on the line. Fig. 1 (page 11) shows an example timeline representation with four events each being represented by an interval with an associated label. Note that simultaneous events such as E1 and E2 are shown on parallel timelines. The intervals corresponding to these events overlap for a finite extent of time. The events E1, E3 and E4 occur in sequence and are therefore depicted on the same timeline.

It has been hypothesized [Miller and Johnson-Laird, 1976] that people conceive of a timeline model of situations as they read narratives. This model is a representation of narrative situations arranged in accordance with the positional constraints imposed by the temporal sequence information indicated in the text. These constraints impart line-like trends to the positional arrangements of situations and explain the significance of the term *timeline model*. Our purpose in constructing a timeline representation is to use it as a platform for deriving additional temporal information.

### 1.1. The notions of Aspect and Tense

Narratives are essentially composed of sentential descriptions of situations. Situations correspond to physical phenomena such as events and states of affairs that can be described linguistically. The situation characterized by a description is termed its *underlying situation*. To give an example, the description *John ate an apple* has an underlying event signifying the subject’s eating of an apple.

Verbal elements in natural language descriptions convey information about the nature of the underlying situations. Associated with these elements are temporal characteristics that indicate the time of occurrence of the underlying situation. The commonplace linguistic notion of
tense is in essence a temporal characteristic that indicates the time of occurrence of the underlying situation in relation to the present time. For instance, the tense of the event description *John swam a length* indicates that the underlying event occurred at some time before the current time. Similarly, a future tense description such as *Jack will go to the movie* signifies an upcoming event at the current time.

Until recently, existing temporal theories of natural language, especially Arthur Prior’s tense logic, concentrated solely on the notion of tense in their attempts to provide logical accounts of linguistic time. A drawback of these theories has been their failure to account for finer distinctions that can exist between sentences even having the same tense. For instance, tense fails to explain the distinction between the following two sentences:

1. Jack rode his bike downhill.
2. Jack was riding his bike downhill.

Both these sentences essentially describe the same underlying event but differ in their treatment of the event. The first sentence describes the event as though it were point-like (i.e., as a completed action) without regard to its internal constituency while the second sentence describes the same event as an ongoing situation. In other words, the first sentence describes the entire event as a complete whole while the second sentence offers a *snapshot* of the event in progress. Comrie (1976) points out that sentences such as the above differ in the perspective (view) they offer of the underlying situation. For instance, if the event described by the above pair of sentences occurs over an interval of time, the first example describes the entire interval within the scope of a single sentence while the second sentence describes the event only at a time internal to the associated interval at which the event is ongoing. Therefore, unlike the first sentence the second sentence is only a partial description of the event. The notion of aspect captures the finer distinctions between linguistic descriptions such as the
ones in this example. In Holt's words¹ "aspects are different ways of viewing the internal temporal constituency of a situation."

Behind the notion of aspect is the intuitive concept of phases of a situation. For instance, a description such as Jack started swimming highlights the initial phase of the event signified by Jack's swim. Similarly, the description Mary finished cooking highlights the terminal phase of the event signified by Mary's cooking. Likewise, descriptions such as Jack was sleeping highlight an internal or progressive phase of the underlying event. In essence the notion of aspect enables the description of individual phases of a situation while offering the flexibility of disregarding other phases. A representation for descriptions is systematically derived in Chapter 4 based on these observations.

1.2. Our hypothesis

Our hypothesis in this research is the following:

The concept of time in narrative texts is expressed in terms of temporal relations between the situations and can be modelled by determining the chronological sequence from explicit temporal information indicated in the narrative and the aspect and tense of sentential descriptions. The resulting temporal sequence may or may not be a total ordering of the situations over time. A given set of situations is totally ordered over time if the temporal relationship between any two situations in the set can be determined precisely. For instance, the events E1, E3 and E4 in Fig. 1 (page 11) are totally ordered since the relationship between any two of these three events is precisely known. On the contrary, we cannot precisely determine the relationship between E3 and E2 based on the fact that E1 and E2 overlap. It is

¹ Page 3, Aspect - An Introduction to the study of Verbal Aspect and Related Problems, Comrie
possible for E2 to have ended before E3 was under way. Similarly, it is also possible for E2 and E3 to overlap. As a result the four events in the figure are not totally ordered.

1.3. Testing our hypothesis

We have implemented a Prolog based system for testing our hypotheses. This system has the capability to process the temporal information contained in paragraphs of fictional narratives and scientific process descriptions and constructing timeline representations of the events described. The positioning of the events relative to one another on the timeline is governed by the temporal sequence information indicated in the text. This information is translated into positional constraints on the situations described.

Our system has been tested on six discourses ranging from fictional narratives to scientific process descriptions. These discourses have been adapted from a total of five books (novels and English textbooks) and illustrate not only capabilities but also limitations of our system. We have achieved 84% accuracy in our results for the test data (the ratio of the number of correct temporal relations to the total number of temporal relations expressed as a percentage). The incorrect results are encountered in cases where explicit temporal indicators are missing and semantic relations between the events govern their temporal ordering. For instance, the semantic relation between the situations described by the following sentences enforces sequentiality.

The boy reached home safe and sound. His mother was happy.

In this example, the mother's state of happiness is apparently caused by the boy's safe return. Semantic analysis is required to detect the sequentiality in this case. In certain cases, however, the overhead of semantic analysis can be cut down in determining temporal sequence
information despite the absence of explicit temporal indicators. The following sentences exemplify such a case.

Jack went to the pool. He swam for a while.

The events in this example can be assumed to occur in sequential order based on the common agent Jack involved in them. Writers of narratives frequently make use of such sentences to report a sequence of events from the perspective of a common agent. In such cases the need for semantic inferencing using world knowledge can be cut down by assuming sequentiality as a guideline. We have formulated certain guidelines (involving checks on agents etc.) for sequencing events in the absence of any explicit indications.

Chapter 9 presents an assessment of the capabilities and limitations of our system along with the identification of some cases where semantic analysis proves necessary to achieve full accuracy in our results.

1.4. Sources of temporal information in discourse

Information indicating the chronological order of the events is often supplied in narrative text. Such information can be conveyed through a variety of sources, some of which are outlined below.

1. **Temporal Connections**: Temporal adverbials like *before, after, while*, etc. connect descriptions of situations and provide indications of the time ordering of those situations. For instance, *John saw Mary before he went to sleep* is a temporal connection between two event descriptions with the adverbial *before* as the connector.
II. **Time Phrases:** Time phrases like *three days later, today, earlier,* etc. appearing in descriptions are another significant source of temporal information.

III. **Aspect and Tense:** As pointed out earlier, both aspect and tense are properties of descriptions relating to time. These temporal properties can provide valuable information for deriving temporal ordering.

The modelling of these linguistic sources of temporal information is discussed in Chapter 5 and Chapter 6.

1.5. **An example timeline representation**

We now illustrate the timeline representation for the following example narrative.

Jack went to the gym while Mary was asleep. He met a couple of friends there and accompanied them to Larry's house.

This small example involves the following four events.

I. \(E_1\): Jack's going to the gym.

II. \(E_2\): Mary being asleep.

III. \(E_3\): Jack meeting a couple of friends at the gym.

IV. \(E_4\): Jack accompanying his friends to Larry's house.

Fig. 1 (see page 11) shows the timeline representation for this short narrative. Each of the four events occur over a finite stretch of time and can therefore be represented by intervals on the timeline. The intervals corresponding to \(E_1\) and \(E_2\) overlap as indicated by the adverbial while between the two event descriptions. \(E_1\) is sequentially followed by \(E_3\) which in turn is se-
quently followed by E4 as indicated in the figure. The information in this figure can be equivalently expressed by the following event-event temporal relations. Internally, the system stores the timeline representation in this form. The figure is merely a pictorial realization of the information.

I. \( E1 \) overlaps \( E2 \)

II. \( E3 \) follows \( E1 \)

III. \( E4 \) follows \( E3 \)

These relations exemplify the chronological information derived by our system as a result of processing source narratives.

1.5.1. **Inferring additional temporal relations**

The relations in our example can be used to derive additional temporal information not explicitly stated in the text. For instance, knowing that \( E3 \) is after \( E1 \) and \( E4 \) is after \( E3 \) we can transitively infer that \( E4 \) is after \( E1 \). Similarly, from the knowledge that \( E2 \) overlaps with \( E1 \) and \( E3 \) is after \( E1 \), we can at least infer that \( E2 \) starts prior to \( E3 \). Note that \( E2 \) may or may not have ended before \( E3 \) started. This explains why the interval corresponding to \( E2 \) is shown without an endpoint. These additional inferences are shown below.

1. \( E4 \) follows \( E3 \), \( E3 \) follows \( E1 \) \( \longrightarrow \) \( E4 \) follows \( E1 \)

2. \( E2 \) overlaps \( E1 \), \( E3 \) follows \( E1 \) \( \longrightarrow \) \( E2 \) starts-before \( E3 \)

The relation *starts-before* indicates that \( E2 \) starts prior to \( E3 \) but leaves open the relation between the end of \( E2 \) and the start of \( E3 \). The left hand sides indicate the relations that must hold for the relations on the right hand sides. The timeline representation facilitates the derivation of additional temporal information about the narrative from existing information.
1.6. Outline of the thesis

Given below is a chapter by chapter outline of the thesis.

Chapter 2 presents a review of previous related work in the field. Various classificatory schemes for situations are explored to gain insights into representing situations on the timeline.

Chapter 3 discusses the problem in detail along with the key aspects. The chapter provides an overview of our solution to the problem by highlighting various aspects of our model.

Chapter 4 addresses two important issues: representations of situations and their descriptions. A scheme for representing these discourse elements is proposed.

Chapter 5 discusses guidelines for modelling the role of two important sources of temporal sequence information in discourse: temporal connections and time phrases.

Chapter 6 essentially continues the discussion of temporal sequencing mechanisms initiated in Chapter 5 by providing guidelines for modelling the role of aspect and tense in sequencing situations. A major focus of this chapter is a set of default guidelines for sequencing situations whose temporal ordering is not explicitly indicated in the discourse.

Chapter 7 discusses the notion of a temporal focus to aid the process of deriving temporal sequence information from the text. The idea of a temporal focus helps to characterize narrative time at any given stage in the processing of the text.

Chapter 8 discusses the translation of the temporal sequence information derived by our system (in the form of temporal relations) into positional constraints on the representations
of situations. These constraints are essential for assembling timeline representations for source texts.

Chapter 9 reports the results of testing our hypothesis on paragraphs of fictional narratives and scientific process descriptions. An assessment of the capabilities and limitations of our system is made.

Chapter 10 summarizes the major observations and contributions of this thesis. Directions for future work are outlined.

1.7. Summary

This chapter introduced the problem of interest in this thesis: a temporal analysis of natural language narrative texts. The significance of the problem was pointed out and the major goal sketched out. The primary hypothesis of our research was stated.
Timeline Model --- An Example

timeline 1

E2

timeline 2

E1 E3 E4

timeline 1 is parallel to timeline 2

Figure 1. TIMELINE REPRESENTATION --- AN EXAMPLE

1 INTRODUCTION
2 LITERATURE REVIEW

2.1. Introduction

The organization of this chapter reflects the order in which the literature survey was conducted to prepare for the research reported in this thesis. As mentioned in chapter 1, a natural way to perceive a narrative is by regarding it as a sequence of sentences describing situations which are chronologically ordered by information indicated in the narrative. The starting point of this research was to address the issue of how to represent situations on a timeline.

To gain some intuition about how to answer this question, we need to know the temporal characteristics of various events. For this purpose let us take a look at some of the classificatory schemes for events that have emerged in the literature on this subject.
2.2. The Vendler Verb Classification

One of the pioneering contributions to the classification of situations is Zeno Vendler’s scheme which has been a precursor to many other classificatory schemes for situations. The basis for this scheme is the intuition that the physical phenomena of events are signified by the category of verbs in sentential descriptions of events. As a result, verbs are the focal elements in this classification. Fig. 2 (page 40) depicts Vendler’s classification along with the criteria for classification used in this scheme. We now discuss the details of Vendler’s scheme. The source for the following review is Linguistics and Philosophy [Zeno Vendler, 1967].

2.2.1. Stative Verbs vs. Event Verbs

Vendler proposes a dichotomy of situations based on the observation that certain verbs cannot appear in the progressive -ing form. Such verbs are called stative verbs in this scheme and the situations signified by these verbs are called states. States are essentially conditions that hold at moments. Examples of stative verbs include know, love and be. The following sentences are instances of their use in sentences.

John knows French.

* John is knowing French.

The asterisk before the second sentence signifies an ill-formed sentence (note the -ing suffix on the main verb). All verbs apart from stative verbs are categorized as event verbs. Situations signified by event verbs are called events. Events unlike states do not hold at moments.
They are situations that occur over time. Event verbs may appear in the progressive form as illustrated by the following examples.

John is driving a truck.
John is sleeping.

2.2.2. Classification of Event Verbs

Event verbs can be further classified based on whether or not the situation described by the verb has a terminal point of completion or climax. Dahlgren (1988) notes that situations having a terminal point of completion entail a change of state at that point. Event verbs describing situations that do not entail such a change of state belong to the category of activity verbs as in John slept for a while. (Stative verbs such as know and love also have no associated change of state inherent in their meaning). The other categories of event verbs describe situations embodying an inherent change of state. These verbs may be further subdivided based on whether the change of state is gradual or punctual (abrupt). Accordingly, we have the categories of accomplishment verbs and achievement verbs. Accomplishment verbs signify situations characterized by a gradual change of state, as in the sentence John built a house, which describes a situation involving an ongoing cumulative activity of building, until the actual completion. The change of state is indicated by the completed house after the event has occurred. On the other hand, achievement verbs characterize situations where the state change occurs abruptly. An example of a sentence involving an achievement verb is John reached the summit. Before he reaches the summit, John is climbing. Reaching the summit is a punctual event of a different category from the activity of climbing, that leads up to it. The accompanying change of state that occurs when John reaches the summit results in the state of John being at the top of the summit. Prior to the achievement John is not at the summit but engaged in the activity of climbing.
Stative and activity verbs exhibit an important property called the *subinterval property.* This property states that if a state of affairs obtains for an interval or stretch of time, then it is said to have obtained at every point or instant of time within that interval, no matter how finely the time is subdivided during that interval. For instance, if a person slept for an hour then we can say that he was sleeping at any point of time during that hour. On the other hand, if a person built a house over a stretch of time, then it cannot be said that he built the same house over a subinterval of that stretch. It may be remarked that the subinterval property is orthogonal to the other criteria discussed above since it provides an alternative way of subdividing the categories of verbs above. To summarize the four categories of verbs discussed above we have the following:

I. Stative  
II. Activity  
III. Accomplishment  
IV. Achievement

### 2.2.4. Disadvantages of Vendler’s Scheme

One of the serious pitfalls of Vendler’s scheme was pointed out by Steedman (1977), Dowty (1979) and Moens and Steedman (1987). They observed that certain verbs like *build* can fall into more than one of Vendler’s categories. For instance, we can easily conceive of an *activity* of building culminating in an *accomplishment* of building a house. To rephrase the problem, *senses of the verb* have not been accounted for in this classification.

---

1 formulated by Bennett and Partee, 1978
2.3. Extensions to Vendler’s Scheme

Moens and Steedman (1988) propose an elegant solution to the problem (outlined in the previous section) with Vendler’s classificatory scheme. Their classificatory scheme is an adaptation of Vendler’s scheme and has the following categories.

**Process** events that correspond to the events characterized by the category of activity verbs of Vendler’s scheme.

**Culmination** events that correspond to the events characterized by the achievement category of Vendler and are accompanied by an abrupt change of state.

**Culminated Process** events that correspond to the events signified by accomplishment verbs in Vendler’s scheme. In other words, a culminated process event is essentially a process event leading to a culmination event. Culminated processes are accompanied by a gradual change of state.

**States** that correspond to situations characterized by the class of Vendler’s stative verbs.

**Point** events that is an additional class missing in Vendler’s scheme. Some examples of point events are signified by verbs like *hiccup, tap, wink*, etc. This class embodies atomic events with no accompanying state changes. Point events have short durations.

Culmination events are accompanied by an abrupt change of state resulting in a consequent state. For instance, the culmination event signified by the sentence *John reached the top of the hill* has an accompanying change of state leading to the consequence of *John being at the top of the hill*. It may also be pointed out that a culmination carries intimations of a process event leading up to it. Thus, in the example *John reached the summit* we have a *process* or an activity of *climbing* leading to the culmination of *reaching the summit*. By the same token, it can be argued that a culmination also carries intimations of a *consequent* state following it, which includes the state resulting from the culmination event. Thus, in the example situation the consequent state after *John reaches the summit* includes the state of John being at the top
of the hill, and some far reaching consequences, such as John being acclaimed for performing this feat. The consequences can themselves be other states or events which, in Moens and Steedman's terminology, are perceived as being contingently related to the culmination event. Broadly speaking, contingency relations have their basis in semantic dependencies between events. Some examples of these relations are causes, enables, prevents, etc. These relations have their basis in the reader's generic assumptions and knowledge about the events related by them.

2.3.1. Coercive Transformations: An Elegant Solution

Moens and Steedman propose an elegant solution to account for the senses of verbs. They advocate a set of transformations that can coerce or transform events of one category into events of another category based on contextual information. Given the sentence John reached the summit in an hour, Vendler's scheme would characterize it inadequately as an achievement without accounting for the activity of climbing implicitly signified by the sentence. The adverbial phrase in an hour, implies a preparatory process of climbing leading up to the culmination event of reaching the summit. In fact, it is the phrase in an hour that highlights the process of climbing in this case and gives a definite measure of its duration. A coercive transformation in this case accounts for the implied preparatory process of climbing in addition to the overtly stated culmination event of reaching the summit. In Moens and Steedman's terms "such coercive transformations enable us to transform events of one category into events of another category." The knowledge of when to apply such transformations comes from contingent information. Thus in the example on hand, the contingent information is the common knowledge that any event of reaching a destination location has an implied motion leading up to the culmination of reaching the destination.
The above discussion clearly gives a flavour of the enhancements proposed by Moens and Steedman to Vendler's scheme. Fig. 3 (page 41) depicts the categories (the nodes of the transition network) arising in this classificatory scheme along with the coercive transformations (indicated along the transition arcs) between nodes. The transformation along the arc labelled "- culmination" can be thought of as an operation of stripping off the culmination from a culminated process resulting in a process. Similarly, the transformation along the arc labelled "+ culmination" results in a culminated process from a preparatory process leading up to the culmination. In effect, we are adding a culmination to a process event to generate a culminated process.

Repeated occurrences of point events are captured by using the progressive form of the main verb, as in the tap has been dripping. This sentence is interpreted as the description of an ongoing process of dripping. This explains the iterative transformation along the arc from point to process in Fig. 3.

This concludes our discussion of Moens' and Steedman's scheme.

2.4. Tense Logic

One of the earliest pioneering contributions to the domain of time reasoning was made by Arthur Prior (1967). Prior proposed a logic of the tenses in language which extends the theory of propositional logic to include the temporal dimension. Propositional logic associates truth values with logical statements or propositions. The theory allows for the derivation of propositions from other propositions by suitable operations like conjunction, disjunction and negation.
Linguistically, propositions can be identified with sentences, each of which can be affixed with a truth value. Thus, John is swimming is a proposition that is true if John is engaged in the act of swimming at the time of uttering the sentence. The logical operations conjunction, disjunction and negation are comparable to the use of linguistic connectors such as and to conjoin sentences and or to disjoin sentences to obtain more complex sentences and the word not to achieve the effect of negation. However, there is a major element missing in a proposition logic account of an actual situation. There is no representation of the time or moment when propositions can be stated to be true. Intuitively, any rendering of an actual situation is not complete if it does not address temporal (time related) issues. Arthur Prior (1967) was the first person to note this flaw in propositional logic theory; he repaired it by making logical extensions to account for the element of time in descriptions of actual situations. Accordingly, the theory of tense logic was born. This logic stipulates the variation of the truth value of a proposition with time. The logic includes four operators called the tense operators. These operators carry out time transformations on propositions that are true at a particular point of time to yield other propositions true at other points of time. The operators are denoted by P, F, H, G and can be applied to propositions to yield other propositions. Suppose p is a proposition. The following items describe the effect of applying each of the tense operators to it. The notations used are indicative of the tense operation applied to the proposition p. Thus, \( Pp \) signifies the application of the tense operator P to p.

I. \( Pp \) denotes another proposition that is true at the current time if and only if p was true at some past time.

II. \( Fp \) denotes another proposition that is true at the current time if and only if p will be true at some future time.

III. \( Hp \) denotes another proposition that is true at the current time if and only if p has always been true in the past upto the current time.

IV. \( Gp \) denotes another proposition that is true at the current time if and only if p will always be true in the future.
Let us take a look at some illustrations to see the effectiveness of these operators in working out representations for natural language sentences. Let \( p \) denote the sentence *John lives in London*. Then the following items illustrate some example sentences (resulting from tense logical transformations applied to \( p \)) and their tense logical representations.

I. \( \mathcal{P}p \) denotes the sentence *John lived in London*, which is true at the current time if and only if *John lives in London* was true at some past time.

II. \( \mathcal{F}p \) denotes the sentence *John will live in London* which is true at the current time if and only if *John lives in London* will be true at some future time.

III. \( \mathcal{H}p \) denotes the sentence *John has always lived in London* which is true at the current time if and only if *John lives in London* has always been true in the past.

IV. \( \mathcal{G}p \) denotes the sentence *John will always live in London* which is true at the current time if and only if *John lives in London* will always be true in the future.

This concludes our review of tense logic.

### 2.5. Reichenbach’s model

Hans Reichenbach (1947) postulates a temporal model for a sentence (event or state description) in which three characteristic times are associated with it: the event time, the reference time and the speech time. The significance of these times are explained below.

I. **Event time**: Each event description has an underlying situation that is the object of the description in a temporal sense. The event time of a description is the time of occurrence of the underlying situation. The event time could be an interval
or a point of time. For the sentence I saw Mary, the event time is a past interval during which the durative event occurred.

II. **Speech time:** An event description has an utterance or speech time associated with it. For instance, if I utter the event description I saw Mary at a time, say \( x \), then \( x \) is the speech time of the description. The speech time is synonymous with the present in a conversational context.

III. **Reference time:** A description has a characteristic time of reference that is the focus of the description in a temporal sense. Thus, given the sentence I was swimming, the reference time is based on a past moment contained within the interval of occurrence of the underlying event. The event is ongoing at the moment of reference.

The relationships between these three times are depicted in Fig. 4 (page 42) for some example sentences. The figure depicts the orderings of the three characteristic times for each sentence. From the figure it is evident that the tense of a sentence can be expressed by the positional relationship between the speech time and the event time. If the event time precedes the speech time, the sentence has the past tense. Similarly, if the speech time precedes the event time, the sentence has the future tense. The first three sentences have the simple present, simple past and simple future tense. The reference time coincides with the event time for these three sentences since they directly refer to the underlying event. Sentences 4 through 6 have the perfect usage as indicated by the presence of the auxiliary have and its tensed variants, had and will have. Such sentences refer to a time after the underlying event. Hence, in these three cases the event time precedes the reference time on the timeline.

Reichenbach's model provides a concise representation for situation descriptions in terms of positional relationships between the three characteristic times of each description. We shall make use of this model for representing descriptions within our system.
2.6. A Discussion of Aspect

We now pause to understand the significance of aspect. The notion of aspect may be viewed as a linguistic mechanism that provides us with different perspectives to characterize situations. For instance, consider the following sentences which report the same event, namely, *John's swim*.

1. John was swimming
2. John swam for a while

Sentence 1 describes the event from an *internal point of view*. That is, if the event has an associated interval of occurrence with a definite beginning (when John *starts* to swim) and a definite ending (when he *stops* swimming), then we may say that sentence 1 offers a snapshot of the event by referring to a time when it was ongoing. In other words, the sentence reports a state of affairs indicating the progress of the event at its reference time. Sentence 2, unlike sentence 1, is a complete description of the event. The event is treated as a unitary whole and described as such by this sentence. This sentence refers to the entire interval of event occurrence. Sentence 1 is said to have the *imperfect perspective* while sentence 2 has the *perfective perspective*.

Comrie (1976) points out that sentences with the English perfect usage relate their underlying event to a reference point that comes after the event. The event is described *retrospectively* in such cases. Comrie uses the following example sentences to elaborate on the distinction between such sentences and simple past tense sentences.

---

Note the use of the *progressive -ing* form of the verb *swim* signifies an ongoing event
3. I have lost my penknife (perfect usage)

4. I lost my penknife (simple past usage)

Sentence 3 bases its reference time (also the speech time in this case) after the underlying event. This sentence implies that the speaker does not have his penknife at the time of reference as a result of his recent loss. Sentence 4, on the other hand, does not imply anything about the speaker's state of possession of his penknife (the penknife could still be lost or could have been regained in this case). The distinction between these two sentences lies in the positioning of the reference point relative to the underlying event.

By symmetry, English also admits sentences describing prospective situations. Such descriptions refer to a time before their underlying situation and thereby offer a prospective view of the situation. An illustration of a prospective description is the sentence Jack is going to see Mary which refers to the current time (also the speech time) and expresses the prospectiveness of the event Jack's seeing Mary at this time.

The above discussion indicates that the positioning of the reference time with respect to the event time indicates the perspective of a sentence. Figure 5 (page 43) shows the four perspectives (perfective, imperfective, retrospective and prospective) by positional relationships between the reference time and event time.

2.6.1. Tense vs. Aspect

In this subsection we use Galton's views to explicate the differences between the notions of tense and aspect. The following review is based on Galton's book The Logic of Aspect (1984). We begin with Galton's analysis of the following three sentences each of which describes a state of affairs.
5. I was writing a book.
6. I am writing a book.
7. I shall be writing a book.

All of the above sentences report the same state of affairs and differ only with respect to the moment chosen to characterize the state.

Sentence 5 characterizes the state at a past moment,
Sentence 6 characterizes the state at the current moment and
Sentence 7 characterizes the state at a future moment.

It is easy to derive representations for sentences 5 and 7 by applying appropriate tense transformations to sentence 6. Accordingly, sentence 5 is representable as $Pp$ while sentence 7 is representable as $Fp$ where $p$ denotes sentence 6. So the three sentences may be represented as $Pp, p$ and $Fp$ respectively. The tense operators merely have the effect of shifting the time point of association with the state of affairs into the past or future.

Next, consider the following triplet of sentences each of which have the perfective aspect since they report whole occurrences of the underlying event.

8. John walked home.
10. John will walk home.

Applying tense logical notions to these three sentences leads to an inconsistency. While sentences 8 and 10 describe past and future occurrences of the same event (John’s walking home), sentence 9 cannot be interpreted as the description of a present occurrence of the
same event. In fact sentence 9 is not an event description at all. It is impossible for an event of walking to occur entirely at the present moment since such an event normally takes time. A present occurrence of an event of walking can only be in progress at the present moment. Therefore, the description of a present occurrence of walking must necessarily have the progressive form of the main verb in order to report the event ongoing at the present time. Sentence 9 is more appropriately interpreted as the description of a habit of walking home on the subject's part and is therefore an altogether different type of description in comparison to sentences 8 and 10. The lack of a common element between sentences 8, 9 and 10 precludes the derivation of sentences 8 and 10 by applying tense transformations to sentence 9.

The habitual interpretation of sentence 9 results from the interplay between the present tense and the perfective aspect of the sentence. The description of a present occurrence of an event cannot have the perfective aspect. The following two sentences have the present tense but differ in their interpretations because of their different aspects.

11. John is walking home.

Sentence 11 is interpreted as the description of an ongoing event while sentence 12 is most sensibly interpreted as a habitual description. From this analysis we observe that the aspect of a sentence governs its interpretation. This in turn leads to one of Galton's primary hypotheses: the aspect of a sentence is primary over its tense and determines the interpretation of the sentence.
2.6.2. Event Radicals

In the last subsection we saw that tense logic fails to provide a logical account for event sentences such as 8, 9 and 10 primarily because it ignores the notion of aspect. The remedy, according to Galton (1984) is an enhanced theory that accounts for aspect notions. In this subsection we provide a superficial overview of Galton's proposal for such a theory.

In the previous subsection we saw that even though there is no common element linking sentences 8, 9 and 10 nevertheless sentences 8 and 10 are related by the fact that they have the same underlying event and describe different occurrences of this event. Sentence 8 describes a past occurrence of that event, while sentence 10 describes a future occurrence of the same event. Sentence 9, however, describes a habit and therefore does not logically fit in between the other sentences. This sentence cannot be transformed into sentences 8 and 10 by applying tense operators. As a result, there is no present tense counterpart of the sentences 8 and 10 in the domain of event sentences. This results in a logical gap between sentences 8 and 10 as far as the present is concerned. Galton proposes a formulation to relate sentences such as 8 and 10 by factoring out the event (the common element) underlying these sentences and using it to bridge the gap between the sentences. Accordingly, Galton introduces a construct called an event radical as a representation for the event underlying an event sentence. The sentence itself describes a specific occurrence of the event signified by the event radical. Events are generic entities that have specific occurrences over time. Based on the above observations, Galton defines the radical for the event underlying a sentence as a representation obtained by writing the main verb in infinitival form and in uppercase to emphasize the fact that it is the main verb of a sentence signifying the underlying event. Hence, working along the lines of the above suggestions, the event radical for the sentences 8 and 10 is as follows.
John - WALK - home

This representation is a tenseless construct as indicated by the infinitival form of the verb. The radical signifies the event of Jack walking homeward. The hyphenation between the words is deliberate and is done to make the radical look different from a proper English sentence.

Having defined the event radical as a generic representation for characterizing events underlying sentential descriptions, Galton tackles the important task of imparting a firm logical footing to his theory of events and aspect. First, since the event radical is tenseless, he states that we require suitable transformations to obtain from it sentences describing specific occurrences of the event signified by it. These transformations enable the movement from tenseless entities (event radicals) to tensed event sentences. He defines a set of operators, called aspect operators to bring about such transformations. Two such operators are the Perf (denoting perfective) and the Pros (denoting prospective). The Perf operator transforms an argument event radical into a sentential description of a past occurrence of the underlying event. The Pros operator, on the other hand, yields a description of a future occurrence of the underlying event. The reverse set of transformations from tensed sentences describing events to event radicals is brought about by another category of aspect operators. More will be said about them in our review of Galton’s taxonomy of situations.

2.7. Galton’s Classification

The following review of Galton’s classificatory scheme is derived from The Logic of Aspect [Galton,1984]. Galton’s classificatory scheme is dealt with in detail since it constitutes the basis of our research. Following Vendler, Galton proposes a dichotomy of situations into states and events and outlines several criteria to distinguish between them.
2.7.1. States vs. Events

Some of the distinctions between states and events, as proposed by Galton, are outlined in the following items.

1. A state is **dissective** in the sense that any stretch of time during which a state holds can be broken down into substretches during each of which the state holds. For example, if John was sleeping from 2pm to 3pm then we can safely conclude that he was sleeping from 2pm to 2.30pm and again from 2.30pm to 3pm. By contrast, an event is **unitary** in nature. A particular event occurrence may be divided into phases but each of these phases is not of the same type as the original event occurrence. Thus, if we say John ran two miles then even though we can subdivide this occurrence into 2 phases during each of which he runs a mile, each of these phases is not a case of his running two miles.

2. A state is said to **hold** at moments while an event is said to **occur**. Therefore, a state holds at any moment within a stretch of time during which it holds. By contrast, an event does not occur at every single moment within an interval over which it occurs.

3. An event is characterized as a **generic entity** that can have specific occurrences over time. As a result, it makes sense to speak in terms of the number of times it occurs over a given time span. On the other hand, a state **either holds at a given moment or it does not**. It is inappropriate to talk of the number of times a state occurs within a stretch of time. In other words, event occurrences are **countable** whereas states are not.

4. A state may be **negated** to yield another state. Thus, it is appropriate to negate the state description John is swimming to obtain another state description John is not swimming. On the other hand, it is nonsensical to negate an event. For instance, the sentence John did not swim does not report an event occurrence. It merely states that the event of
John’s swimming failed to occur. This is a very important distinction between a state and an event.

5. Finally, states are homogeneous. That is, states persist without changing over the stretches of time during which they obtain. For instance, if John is swimming throughout a given stretch of time, then he is essentially swimming at each moment of that stretch. An event, on the other hand, is associated with a notion of change. For instance, if John stops swimming then this changes the state that John was in when he was swimming. Therefore, an event occurrence is associated with an interval of time that is flanked by a definite startpoint and a definite endpoint, each of which are associated with a change of state.

Galton’s scheme differs from Vendler’s scheme in its treatment of sentences describing ongoing events. Thus, the sentence John is walking is a state description according to Galton’s scheme but is the description of an activity according to Vendler’s scheme.

2.7.2. Punctual Events

In this section we discuss a major category of events arising in Galton’s scheme called punctual events. Such events occur instantaneously. From tense logic, we know that a state proposition \( p \) is an assertion with a truth value that can vary with time. Such a proposition may be logically negated to yield another proposition, which likewise describes another state of affairs (the negative of the original state). If a state of affairs holds at a given moment in time, then the tense proposition describing it has a true value. If the same state ceases to obtain at a particular moment, then the proposition also ceases to be true at precisely that moment. In other words, the proposition \( \neg p \), which is the logical negation of \( p \), turns true at
that moment. Tense logic stipulates the following logical constraint that has to be obeyed by all propositions.

**Constraint:** At any given moment only one of the propositions \( p \) or \( \neg p \) can be **true**. Therefore, any change in the truth value of \( p \) has to be instantaneous and vice versa for \( \neg p \).

**The Notion of Change**

Let us again use examples to get a better feel for concepts emerging in the forthcoming discussion. Let the proposition \( p \) in an example situation denote the sentence *it is raining*. The logical negation of \( p \) denoted \( \neg p \) stands for *it is not raining* which is another state of affairs. The change from \( \neg p \) being true to \( p \) being true accompanies the onset or start of rain in the physical situation. Likewise, the change from \( p \) being true to \( \neg p \) being true accompanies the cessation of rain. The interval of time from the onset of rain till the time of its cessation corresponds to the interval of occurrence of the rainy situation. The **start** and **stop** instants are associated with changes in state that are logically captured by changes in the truth value of the corresponding propositions. Such changes have to be instantaneous in the light of the constraint stated above. Accordingly, we have Galton's first category of events called **punctual events** whose occurrences over time are accompanied with a change of state. The state resulting from the punctual event is the negated counterpart of the state prior to the event.

Now, let us address the following question:

**Why should changes in state be associated with event occurrences?**

Generally speaking, when a situation involves a change of state, the change itself can be instantaneous in cases where the resulting state is the negation of the previous state, or it can be extended in time over an interval of finite duration in cases where the resulting state is not necessarily the negated counterpart of the original state. An example of a **durational change**
is the change involved from a state in which a ship is afloat to a state in which the ship is submerged. This change is brought about by a process of the ship’s sinking. The right way to perceive a change of state is to regard it as taking place over an interval of time with finite durational extent (zero or positive). In general, it does not make much sense to speak of changes in state as obtaining at moments since they may also take place over intervals of time. Earlier in this chapter we contrasted situations of two types namely states and events. The characteristic properties of events are that they may be associated with intervals of occurrence; they are unitary and cannot be negated. Applying each of these properties to the phenomena of changes in states we arrive at the following conclusions.

I. A change takes place over a stretch of time that can have zero or some finite positive durational extent.

II. If a change takes place over an interval we cannot have instances of the same change taking place over subintervals of that interval.

III. Unlike a state of affairs, the result of negating a change of state is not itself a change of state but a state of affairs that indicates the failure of the change to occur.

Accordingly, a change of state is characterized as an event occurrence rather than a state of affairs.

Representation of Punctual Events

In section 2.6.2. we saw how Gallon introduced the event radical as a representation for the event underlying a sentential description. Punctual events can be represented by suitable event radicals that depict the inherent punctual character of the underlying event. Since such events occur instantaneously, it is impossible to catch them in the act of occurring. The previous subsection on punctual events established that these events are associated with
changes in the state of affairs where the state resulting from an occurrence of the event is the logical negation of the state that persisted before the occurrence.

Galton points out that a punctual event can be appropriately characterized by a radical of the form:

\[
\text{It - BEGIN - to - be - the - case - that - } p.
\]

The punctuality of the corresponding event is brought out by the word BEGIN appearing in the radical. It has the effect of expressing the instantaneity of the change leading to the proposition \( p \) being true.

For instance, the transition from \textit{it is not raining} being \textbf{true} to \textit{it is raining} being \textbf{true} marks the onset or beginning of rain. So by letting \( p \) in the radical above denote \textit{it is raining} we have the representation of the event at the start or beginning of rain. This radical is instrumental in causing \( p \) to turn true. The process of synthesizing punctual radicals from state propositions like the one above can be expressed as a logical operation that can be performed on \( p \) to obtain the corresponding radical. This operation is performed by one of Galton’s operators arising in his theory of aspect and events. He calls this operator the \textit{ingressive} operator, denoted as \textbf{Ingr}. We obtain the following equivalence:

\[
E \equiv \text{Ingr } p
\]

where \( E \) is a punctual radical and \( p \) is a state of affairs that comes into effect as a result of an occurrence of \( E \). The \textbf{Perf} and \textbf{Pros} aspect operators, discussed earlier, can be applied to a punctual radical to obtain descriptions of past and future occurrences of the event.
2.7.3. Durative Events

The second category of events in Galton's ontology is the class of *durative events*. The definition of a durative event follows.

**Definition** A durative event is an event whose occurrences have finite *durational extent* unlike punctual events. These event occurrences are extended in time, which is why they are associated with intervals of occurrence. Each of the intervals are delimited by a distinct *start* and *stop* time. Within this interval the durative event is said to be *ongoing* or *in progress*.

*Punctual vs. Durative Events*

Some of the major distinctions between punctual and durative events may be enumerated as follows.

I. Durative event occurrences have corresponding finite and non-zero durational extents, while punctual event occurrences have zero durational extents.

II. Durative event occurrences can be described as ongoing or in progress at any moment of time within their intervals of occurrence, while it is practically impossible to catch a punctual event in the act of occurring. Hence, punctual events cannot be reported as ongoing at moments. This is an important distinction between these two categories.
Telic Events

Durative events can be classified based on whether or not they entail a notion of completion. For instance, the sentence *John walked a mile* carries with it an associated notion of completion. The event occurrence reported by this sentence involves not only an element of participation on John’s part in the act of walking but also the completion of a *mile*. In other words, for this event occurrence to be successfully realized, we require that John cover the distance of a mile by walking. Such durative events are called telic events. It may seem at first glance that telic events in this classification have a one-one correspondence to the accomplishments of Vendler’s scheme (since they also imply a notion of completion) and the culminated processes of Moens and Steedman. The correspondence with Vendler’s category of accomplishments, however, is superficial because Vendler’s work centers around the classification of verbs. In the example *John walked a mile*, the concerned event is signified not only by the main verb in the sentence but also by other elements like the noun phrase *a mile*, which is instrumental in establishing a criterion for completion of the event of John’s walking in this case.

The correspondence of telic events with the culminated processes of Moens and Steedman is more exact. It may be recalled from section 2.2 that the culminated processes in Moens and Steedman’s ontology are events that consist of a preparatory process (which in the above example corresponds to John’s walking *for some though not necessarily a definite amount of time*) and a culmination event (which in the example is the punctual event occurrence of completion of a *mile by John*). Thus, the culmination events in Moens and Steedman’s ontology correspond to the criterion for completion of telic events in Galton’s work. In the above example, if we strip off the phrase *a mile* then we are left with *John walked*, which possesses the characteristics of a process event in terms of the terminology used in Moens and Steedman’s work.
Representation of Telic Events

The radicals that represent telic events must account not only for durativeness of these events but also for the notion of completion. Let us consider the same example that arose in our discussion on telic events, namely John walked a mile. Now walking is intrinsically a durative event from our common experiences. So if we write walking in infinitival (tenseless) form we have a suitable denotation for the durative event. As for the criteria for completion we simply incorporate the phrase a mile into the radical to give the radical

John - WALK - a - mile

This is a durative telic radical. Notice that unlike a punctual radical the above radical does not have words like BEGIN or START appearing in the radical.

Atelic Events

The other major category of durative events, called atelic events do not entail the notion of completion that telic events do. All Galton requires for such events to occur is the involvement on the part of the actor(s) for some amount of time in the action signified by the underlying event (this amount need not be specified or concrete as in the case of telic events). Thus, the sentence John swam for a while describes an atelic event since the event is reported to have occurred for some unspecified amount of time. Another example of an atelic event description is the sentence John spent a while eating. Notice that in all of the above sentences there is no criterion embodied for completion of the underlying event. An interesting point worth mentioning here is the one to one correspondence between atelic events in Galton’s work and the process events in Moens and Steedman’s work.

Representation of Atelic Events
The representation of atelic events can be worked out along lines similar to those for telic events. In this case the radicals need only depict the durative character of the underlying event. Thus, given the sentence *John spent a while eating* its underlying event is

\[ \text{John} - \text{EAT} - \text{for} - \text{a} - \text{while}. \]

The adjunct "for - a - while" explicitly indicates the *durative* nature of the underlying event.

### 2.5.5.3. Aspect Analysis of Durative Events

In the section on punctual events we saw the introduction of aspect operators that serve to transform punctual radicals into propositions about punctual event occurrences and vice versa. The process of synthesizing a durative radical from a state description \( p \) parallels the synthesizing of a punctual radical from a state description \( p \). The difference between the two cases lies in the focus of the operation.

In the punctual case we were interested in the exact instant of *change* in the truth value of a proposition \( p \) (state description) whereas in the durative case we are interested in the resulting state's *attainment* for a finite amount of time. The resulting state is called the *progressive* state if it is associated with a durative event occurrence. This state characterizes the situation at any moment when the event is ongoing or in progress. In other words, a durative event in progress, is described by means of a state of affairs that obtains at any moment within the interval of occurrence. Consider for example the sentence *John swam for a while* which describes an occurrence of the event signified by the following event radical:

\[ \text{John} - \text{SWIM} - \text{for} - \text{a} - \text{while}. \]

The progressive state characterization for this event is a proposition \( p \) denoting the sentence *John is swimming*. The progressive state is like any other state of affairs obtains at moments
within the interval of occurrence of the corresponding durative event. Galton defines an aspect 
operator called the perfective (denoted as Po) which transforms a progressive state description 
into a durative event radical. This operator is the analogue of the ingr operator which trans-
forms a progressive state description into a punctual event radical. The above radical results 
from the transformation: Po(John is swimming).

The Progressive Operator

In the preceding subsection, we saw that ongoing durative events can be characterized by a 
progressive state. Punctual events on the other hand, cannot be described in progress be-
cause of their instantaneous nature. Galton defines an operator called the progressive (de-
noted as Prog) which when applied to a durative event radical yields a progressive state 
description that is true during an occurrence of the concerned event. For example, if the 
durative radical E is:

John - SWIM · for - a - while

then Prog E denotes the state proposition John is swimming which is the progressive state 
obtaining at any moment within the interval of occurrence of the underlying event. The Prog 
operator cannot be applied to a punctual radical simply because a punctual event cannot be 
captured in the act of occurring.

This concludes our discussion of Galton's taxonomy of situations. The various categories in 
this scheme are shown in the tabular diagram (please see Fig. 6, page 44). This diagram gives 
a categorization of the various situations in this classification along with example radicals and 
sentences. The diagram should be self-explanatory in light of our literature survey.
2.8. Allen’s Temporal Model

One of the most highly regarded research efforts in temporal logic is James Allen’s interval temporal logic. In his paper *Towards a general theory of action and time* (1984) Allen postulates a linear model of time where it is regarded as a horizontal line like the real number line. Past time is signified along the leftward direction while future time is signified along the rightward direction. Allen dispenses with the notion of time points in his theory by advocating that points of time can be regarded as very small intervals of time. Allen also proposes a model of thirteen possible positional relationships between any two time intervals as shown in Fig. 7 (please see page 45). These relationships can be used to represent temporal relations between any two situations.

The construction of a timeline model for situations requires the determination of temporal relations between them. These relations express the chronological ordering of the situations and can be used to position the representations of situations on the timeline. We shall make use of Allen’s positional relationships to characterize temporal relations between situations.

2.9. Summary

In the course of this survey we explored several classificatory schemes for situations. Comparatively speaking, of the three schemes considered in this chapter, Vendler’s scheme is based on the view that the main verb of a situation description is the only determinant of the nature of the situation. As a result, we run into problems in giving an account of example sentences like *John built a house* where using Vendler’s classification of the verb *build* as an activity we end up incorrectly characterizing the described situation as an activity. The
correct characterization of this situation is an *accomplishment* since there is a gradual change of state resulting in a completed house after the event occurrence. In terms of Galton's scheme we can correctly characterize the above situation as a *telic* event since the verb adjunct a *house* is accounted for as a criterion for completion.

Returning to the issue of representing situations on a timeline, we conclude that durative events can be represented by *intervals* since they occur over stretches of time. Punctual event occurrences can be associated with *points* since they occur instantaneously. States can be associated with intervals since they hold over stretches of time.
<table>
<thead>
<tr>
<th>Example</th>
<th>Activity</th>
<th>Accomplishment</th>
<th>Achievement</th>
<th>State</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>run, think</td>
<td>build a house</td>
<td>recognize, find</td>
<td>have, want</td>
</tr>
<tr>
<td>Possesses Progressive Tenses</td>
<td>+</td>
<td>+</td>
<td></td>
<td>-</td>
</tr>
<tr>
<td>Terminus</td>
<td></td>
<td></td>
<td></td>
<td>+</td>
</tr>
<tr>
<td>Change of State</td>
<td></td>
<td>Gradual</td>
<td>Punctual</td>
<td>-</td>
</tr>
<tr>
<td>Subinterval Interval</td>
<td>+</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The Vendlor Verb Classification Scheme

+ : Possesses Property
-
: Does not Possess Property

Figure 2. THE VENDLER VERB CLASSIFICATION (Adapted from Page 83, [Dahlgren, 1988])
Figure 3. COERCIVE TRANSFORMATIONS (Adapted from Page 18, [Moens & Sleedman, 1988])
1. Present: I agree

Event time
Speech time
Reference time

2. Past: I agreed

Event time
Speech time
Reference time

3. Future: I will agree

Speech time
Event time
Reference time

4. Present Perfect: I have agreed

Event time
Speech time
Reference time

5. Past Perfect: I had agreed

Event
Reference
time
Speech
time
time

6. Future Perfect: I will have agreed

Speech
time
Event
time
Reference
time

Figure 4. REICHENBACH'S MODEL — EXAMPLES (Adapted from page 439, [Miller & Johnson-Laird, 1976])

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1. Perfect Perspective: Reference time coincides with Event time

2. Imperfect Perspective: Reference time within Event time

3. Perfect Perspective: Reference time after Event time

4. Prospective Perspective: Reference time before Event time

Figure 5. ASPECT PERSPECTIVES
<table>
<thead>
<tr>
<th>States</th>
<th>Irrevocable</th>
<th>Temporary</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Jane has swum a length</td>
<td>Jane is swimming a length</td>
</tr>
<tr>
<td>Atelic</td>
<td>Jane-SWIM for-a-while</td>
<td>Jane-SWIM-a-length</td>
</tr>
<tr>
<td>Telic</td>
<td>Jane-STOP-swimming</td>
<td></td>
</tr>
</tbody>
</table>

**EVENTS**

*Aspectual Character Diagram*

---

**Figure 6.** ASPECTUAL CHARACTER DIAGRAM (Adapted from page 69, [Galton, 1984])

---

2 LITERATURE REVIEW
Figure 7. JAMES ALLEN'S INTERVAL-INTERVAL RELATIONSHIPS (Adapted from page 158-159, [Gallion, 1987])
3 PROBLEM ANALYSIS

3.1. Brief Overview

In the previous chapter, a variety of classificatory schemes for situations (states and events) were reviewed in considerable detail in order to gain insights into the representation of situations on a timeline. In this chapter, we define our problem and overview various aspects of the design of our model.

3.2. Problem Definition

A narrative discourse has multiple sentences describing situations (events and states) that occur in definite chronological sequence. Situations are essentially the focal elements of sentences from a temporal standpoint and are signified by the verbal elements. Our goal in this research is the construction of a conceptual representation for the time flow of a narrative
by determining the chronological sequence of the situations described in the source text. The representation of the time flow of a narrative is based on a linear model of time called the timeline model. Situations (events and states) of a narrative are represented by intervals and points arranged in accordance with positional constraints imposed by the temporal sequence information supplied in the text. During the course of this chapter, we will explain how such a model is constructed for any given narrative discourse. This model can be used to infer additional temporal information not explicitly stated in the narrative text.

3.2.1. Scope of the investigation

The focus of this research is the domain of narrative discourse. We have excluded from our investigation descriptions of hypothetical and modal situations (such as *If Jack comes here Mary will be happy, He might have gone there*), descriptions of habitual phenomena (such as *John walks home*) and negated sentences like (*John did not go to Chicago*). The test data for our investigation are paragraphs of narrative fiction and scientific process descriptions adapted from novels and textbooks on creative English writing.

3.3. Representation of Situations

Our literature review indicated the utility of a dichotomy of physical situations: states and events. States are associated with moments, i.e., they obtain at all moments within stative intervals. Events, on the other hand, have occurrences over time. Henceforth, the term situation signifies either an event occurrence or a state. From a purely temporal standpoint, events can be subdivided based on the *durational extent* of their individual occurrences. As a result, we have punctual events that occur instantaneously (zero durational extents) and
durative events whose occurrences have finite extents. Building a timeline model for narrative text requires the definition of representations for situations on a timeline. Therefore, an issue that immediately confronts us is the identification of appropriate timeline representations for situations in terms of intervals and points of time. First and foremost, we have the observation that each durative situation (durative event or state) must have a distinct beginning and a distinct ending -- its startpoint and endpoint respectively. These points delimit the durational extent of the occurrence of the durative situation. Punctual event occurrences, on the other hand, have no identifiable beginnings or endings, i.e., have a degenerate structure since they occur at instants or points of time. Recall from our discussion of punctual events that each of their occurrences is accompanied by a change of state where the resulting state is the logical negation of the state prior to the occurrence. Based on this property, we observe that punctual events initiate and terminate states. In our survey we also saw that ongoing durative event occurrences are characterized by a progressive state description. The progressive state holds while the durative event is ongoing. Prior to the start of the durative event occurrence the progressive state does not hold since the durative event occurrence is not ongoing. From the logical constraint that only one of the states denoted by the propositions \( p \) and its logical negation \( \neg p \) can obtain at any moment of time, we can conclude that the state transition resulting in the initiation of a progressive state must be instantaneous in nature. In other words, there is a punctual event occurrence associated with the initiation of a progressive state. This punctual event starts the durative event. By the same argument, a progressive state ceases to obtain as a result of a change of state associated with another punctual event occurring at the endpoint of the durative event occurrence. This punctual event occurrence causes the cessation of the progressive state thereby terminating the durative event occurrence. Likewise, purely stative situations are also begun and ended by punctual event occurrences. The state begins or ceases to obtain as a result of punctual event occurrence. An example in support of the above remarks is the description \textit{John stopped swimming} which reports a punctual event causing the cessation of the progressive state signified by \textit{John is swimming}.  

3 PROBLEM ANALYSIS
In general, the initiation or termination of a state involves the occurrence of a punctual event. We therefore argue that punctual event occurrences mark the beginnings and endings of durative situations. We propose a timeline representation for durative situations where intervals are associated with each of their occurrences. Each such interval is delimited by a distinct start point and a distinct end point that mark points where punctual events occur. Within the interval, the durative situation is in progress in case it is a durative event and is persistent in case it is a stative situation.

3.4. Representing Descriptions

A narrative discourse can be perceived as a sequence of sentences each describing situations. From a temporal standpoint, there are two elements involved in such a discourse: situations (events and states) and their linguistic descriptions. In the last section we addressed the issue of representing situations on the timeline. In this section we examine the linguistic descriptions used in characterizing them in narrative discourse. To clarify what we mean by a situation description, consider the example sentence *John saw Mary leave* which involves two event descriptions: one of them describing a perceptual event involving *John* and the other describing a motion event involving *Mary*. As can be seen, a *situation description is a sentential fragment describing a state or event occurrence*. Henceforth, the term *description* implies a situation description. From this example we can conclude that a single narrative sentence can involve more than one description. Now we raise the following pertinent question:

How can we map descriptions to the representations of situations?
Recall Reichenbach's theory from Chapter 2. This theory posits three characteristic times for any situation description: the event time (time of the underlying situation), the speech time (utterance time of the description) and the reference time (time that provides the basis for characterizing the underlying situation). Descriptions can be associated with representations based on how they characterize their underlying situation. Thus, given the representation of a situation in terms of intervals and points, a description can be represented in terms of the situation. Some event descriptions, such as Jack went to the store, treat their events like points and characterize them entirely. Such descriptions refer directly to their underlying events and have the perfective aspect. Not all descriptions, however, characterize their underlying situations entirely. For instance, progressive state descriptions (such as John was swimming) characterize only an internal phase of their event by referring to a time when the event is ongoing. Such descriptions have the imperfective aspect. We now analyze a few examples to give an idea of how descriptions can be represented in terms of their underlying situations based on the relationship between their reference time and the time of their underlying situation. Our first example is

1. John is walking.

If this sentence is uttered at time x then its speech time is x. This sentence describes a durative event that occurs over an interval of time. Therefore, the event time is an interval. Recall that tense predicates the relationship between the event time and speech time. This sentence describes its event to be in progress at the speech time and therefore has the present tense. Time x is also the reference time in this case and is located within the interval of event occurrence. The sentence therefore offers an internal perspective of its event and has the imperfective aspect.

Our next example is the following sentence.

4 See page 22
2. John was walking.

Suppose this sentence has speech time $x$. The event time of this sentence is an interval (the underlying event is durative) in the past of $x$ because of the past tense of the sentence. Like the previous example, this sentence also refers to a time (before $x$) when the event was ongoing. Hence, its reference time is contained within the interval of event occurrence. Our next example is the following sentence.

3. John walked for a while.

Suppose this sentence has speech time $x$. The event time of this sentence is a past interval. Unlike the previous examples this description directly refers to the entire event and as a result provides a perfective or point-like characterization of its event. Descriptions having this perspective essentially treat their underlying events like points by directly referring to the events without regard to their internal phases. The following example has the English perfect usage.

4. John had walked for a while.

Suppose this sentence has speech time $x$. This sentence has the English past perfect usage. The corresponding interval of event occurrence (event time) is in the past of speech time $x$ since the sentence has the past tense. Furthermore, this sentence refers to a point in time after the interval of occurrence of the underlying event. This sentence states that as of its time of reference, the event had already occurred. This is signified by the presence of the auxiliary verb had. This example differs from the previous one with respect to the positioning of its reference time in relation to its underlying event.

Our last example illustrates a description having the prospective usage.
5. Jack is going to leave

Suppose that this sentence has speech time \( x \). In this case the event of Jack’s leaving is prospective at the speech time which is also the reference time of the description. Recall that descriptions with the prospective usage refer to a time before their underlying situation.

The following observations emerge from the above discussion.

I. A description that refers to a time when its underlying situation is ongoing offers an internal view or perspective of the situation.

II. A description that treats its underlying situation like a point has the perfective aspect. Such descriptions offer a unitary perspective of their situations without regard to internal constituency.

III. Descriptions with the perfect usage provide a retrospective view of their underlying situation by referring to a time after the situation.

IV. Descriptions with the prospective usage refer to a time before the underlying situation and provide a prospective view of their situations.

These observations can serve as the basis for representing narrative descriptions. Such representations correspond to the objects referred to by narrative descriptions and provide indications of their aspects. The following examples suggest a representation for situation descriptions along the guidelines of the examples above. In the next chapter, we develop this representation in detail.

1. John is swimming: This description has its point of reference situated within the interval of occurrence of the durative event and its tense is present. Therefore, it has the representation, PRES_INTERNAL (PRES indicating the present tense and INTERNAL indicating a point of reference internally within the interval of event occurrence).
2. *John had swum for a while:* This description has the past tense and its reference time is situated after the interval of occurrence of its underlying event. Therefore, it has the representation, PAST_POSTINTERVAL (POST signifying after).

3.5. *From single event descriptions to discourse*

Earlier, we pointed out that a narrative discourse involves multiple descriptions, each characterizing a situation (event or state). The construction of a timeline model for the temporal order of the described situations involves positioning the intervals of occurrence in relation to one another. Information that guides the positioning of the situations in relation to one another can be derived from the discourse text. A natural question that arises in this regard concerns the nature of this information. In the ensuing discussion, we examine some common mechanisms of expressing temporal information in text. Again, we motivate the discussion through examples where appropriate.

3.5.1. *Temporal Sequencing*

The construction of a timeline model for situations requires the determination of temporal relations between them. These relations are used to position the representations of the situations on the timeline. The process of imposing temporal relations between situations using explicit indicators of temporal information in the text is termed *temporal sequencing.* In the next few subsections, we investigate common sources of temporal information that aid in the temporal sequencing of situations.
3.5.2. Sequencing by Temporal Connectors

In narrative discourse, temporal adverbials such as before, after, when, while, etc. constitute an important source of temporal information between the situations connected by them. Each of these adverbials connect a description called the main clause with another description called the subordinate clause. Both these clauses are essentially descriptions of situations. Henceforth, we use the term temporal connector for these adverbials. The connector imposes a temporal ordering on the situations involved in the connection. In other words, these adverbials give temporal sequence information, helpful in placing the involved situations on a timeline relative to one another. Presented below are some examples of temporal connections.

Jack had lunch before he saw Mary.

In this example, two event descriptions are connected by the adverbial before. The main clause is an event description involving Jack's having lunch while the subordinate clause describes another durative event Jack seeing Mary. The temporal connector before gives the information that the first event occurred before the second one. In other words, the connector indicates the positioning of the first event relative to the second event. Our next example

Jack went to the store while Mary did her homework.

involves two event descriptions connected by the adverbial while. The main clause, in this case, is an event description involving Jack's going to the store while the subordinate clause describes an event involving Mary. The temporal adverbial while gives the information that the first event occurrence overlaps with the second one for a finite stretch of time.

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3.5.3. Sequencing by Time Displacement Phrases

Another way of expressing sequence information involves the use of time displacement phrases and words such as earlier, later, ten seconds later, three days ago, etc. Such words and phrases have the effect of time displacements between situations. Let us take a look at some examples below.

Jack went to the station. Later he had a workout at the gym.

In this example, we have two event descriptions and a temporal displacement lexeme later which indicates that the positioning of the second event is after the first one. The time displacement lexeme later indicates a displacement of time from the event time of the first description to the event time of the second. Our next example is

Jack went to the station. Mary had gone there three days earlier.

This example has a temporal displacement phrase three days earlier that clearly indicates the positioning of the second event occurrence before the first one. Time displacement phrases constitute an important linguistic source for temporal information relating two event occurrences.

3.5.4. Sequencing by Aspect and Tense

In connection with our discussion of Reichenbach's temporal model of a situation description, the relational nature of tense was pointed out. Tense is a grammatical device that relates the speech or utterance time of an event description to its event time (the time of the underlying
situation). Sometimes the tense of an event description can indicate the positioning of the described event with respect to another described event. Consider the following example where tense plays the sequencing role.

Jack went to the store. From there, he will go to the pool.

In this example the first sentence has the past tense and describes a past event occurrence in relation to the speech time while the second sentence describes a future event occurrence. If we utter these two sentences one after the other then for all practical purposes their speech times are equivalent. So we are justified in comparing their tenses to determine their order of occurrence. Both these descriptions base their time of reference on the interval of occurrence of the events described by them. It is fairly straightforward to see that the first event occurs before the second one. This is evident from the change of tense from past to future in this example.

The next example illustrates temporal sequencing based on aspect alone.

Jack went into the living room. Mary was sleeping there.

This example involves two descriptions - the first describes an event while the second describes a progressive state associated with the event of Mary’s sleep. Both descriptions are in the past tense. From a temporal standpoint, the descriptions differ in their aspect characteristics. The first description treats its underlying event like a point. In other words, it adopts the unitary or perfective aspect in reporting its event. The second description on the other hand refers to a time when its event is ongoing and as a result has the imperfective aspect (since it offers an internal perspective of its situation). The difference in the aspect of the descriptions causes the event and the state to overlap. The intervals corresponding to the two situations overlap.

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The above subsections give a broad perspective of common linguistic means of supplying information to order situation occurrences over time. In our system, we have modelled these linguistic devices by means of inference rules triggered by the temporal (tense and aspect) characteristics of situation descriptions and the linguistic units of temporal information categorized above. Chapters 5 and 6 discuss the guidelines behind these inference rules.

3.6. Default Temporal Sequencing

In the previous section, we investigated common mechanisms used in discourse to convey temporal information. In this section, we treat cases where there is no explicit source of temporal information. We start our investigation with the following example

    Jack went into the room. He turned off the light.

These descriptions have the same tense (past) and aspect (perfective). World knowledge is required to deduce a semantic inferential link (this would involve inferring a link between the room and the light in the room and also taking into account the fact that Jack is physically present in the room). Such semantic inferencing involves a lot of computational overhead even in simple cases. We have implemented a default sequencing mechanism that simulates the effects of semantic inferencing in certain cases and helps cut down on the computational overhead. Our example depicts two event descriptions having the same agent (subject). Both descriptions have the same tense and aspect. Under such circumstances, the default mechanism prescribes a sequential order of occurrence of the described situations. Writers of narratives often make use of such descriptions to report a sequence of events involving common subjects.
3.6.1. Vagueness

There are cases where the default rule of *sequentiality* does not hold. These cases have a characteristic vagueness associated with them. An instance of a vague example is

John went to the store. Mary went to the bank.

In this example, it is not clear how the two events are temporally ordered. The second event occurrence could be after the first one or could have some temporal overlap with it. In other words, the temporal models that apply are those involving either overlap or sequentiality between the intervals representing the two durative events. The default rule of *sequentiality* is applicable only to cases where the subjects of the event descriptions overlap.

In certain cases we can cut down on the number of possibilities even in vague examples. To see how, consider the example below:

Jack reached the bus stand. Mary walked toward him.

This is considered a vague example because the two sentences have no subjects in common. Under the circumstances of this example it is possible that the two events occurred sequentially with *Jack’s motion toward the bus stand* being followed by the event of *Mary walking toward him*. On the contrary, it is also possible that *Mary started walking* prior to the time *he reached the bus stand*. From the way this example is stated, however, it appears that Jack reached the bus stand prior to the time Mary reached Jack’s location. In other words, Jack’s motion to the bus stand ends prior to the end of Mary’s motion toward him. Mary’s may have started walking before Jack reached the bus stand.
These examples illustrate our modelling of cases where all other mechanisms fail to provide information about the temporal order of the situations involved. In our default sequencing model we exploit certain characteristics of the situations involved, such as common agents.

3.7. Notion of Temporal Focus

So far in this chapter, we have considered various mechanisms (linguistic and default) that can be used to derive temporal relations. Given a discourse involving $n$ event occurrences there are $n(n-1)/2$ possible temporal relations involving them. Now we raise a pertinent question:

Given a narrative involving $n$ events do people reading the narrative derive all the possible relations spoken of above?

Let us approach this question by considering what people do as they read a narrative text. If the text involves a large number of event occurrences then the number of possible temporal relations can turn out to be very large. For instance, if $n$ is 10 then there are 45 possible temporal relations. Obviously, people do not figure out temporal relations for all pairs of event occurrences. We hypothesize instead that they maintain a rather localized temporal view of the narrative as they read. In her paper *Tense as Discourse Anaphor*, Bonnie Lynn Webber (1988) hypothesizes that at any given point in a narrative, a single situation symbolically characterizes the localized temporal view that people have of the narrative at that point. She uses the term **temporal focus** to denote this situation. Let us now examine the real significance of temporal focus.

Associated with a narrative at any given point is a notion of the time of the narrative called the *now point* of the narrative in discourse terminology. The process of reading a narrative text
involves keeping track of the narrative time or the now point along with the shifting of attention from one event description to the next one. Accompanying each shift of attention, there may or may not be a shift of the now point of the narrative.

At the conceptual level, the process of reading involves the construction of a time model for the narrative discourse from the situations encountered in the narrative. This conceptual model evolves incrementally with the processing of each incoming situation description. At any given stage in this conceptual processing, a single situation symbolically characterizes the narrative time (the now point). At that stage, this situation is the locus of the conceptual time model for the discourse and is termed the temporal focus. At any given stage the next situation in the narrative is processed with respect only to the current temporal focus. The conceptual model is then modified by the information gained as a result of this processing step and the temporal focus updated for the next processing step. In other words, the notion of temporal focus helps keep track of where we are in the conceptual time model of the narrative text. Temporal movements of the now point are symbolized by changes in the temporal focus as reading progresses.

Given below is an example that illustrates the notion of temporal focus and characterizes its movement as the text is processed.

Jack went to the store and purchased a pair of swimming trunks. Later he went to the pool where Mary was swimming.

The above narrative text involves the four event occurrences shown below.

I. E1: Jack went to the store.
II. E2: Jack purchased a pair of swimming trunks.
III. E3: Jack went to the pool.
Each of the items above is affixed with a label that denotes the event occurrence described by the item. Initially the temporal focus is set to the first event occurrence, E1. The next event occurrence, E2, is processed for temporal relations with respect to E1. From E1 to E2, we detect a sequential shift of narrative time. As a result, the temporal focus shifts from E1 and E2. The next event occurrence, E3, indicates a displacement of the now point of the narrative because of the time displacement lexeme later associated with it. The temporal focus is changed to E3 as a result of deriving the temporal relation (before E2 E3). At this point, we do not look for relations between E1 and E3 since E1 is not temporally relevant any more. The next event occurrence, E4, is processed with respect to E3, the temporal focus at this stage. From E3 to E4, there is no indication of movement of narrative time; E4 merely reports an event occurrence, ongoing simultaneously with the time of E3. It does not indicate a shift of the narrative time. As a result, E3 still remains the temporal focus after this processing step. The interval corresponding to E4 overlaps with that of E3.

This example gives a feel for the notion of temporal focus and the nature of its movement across a narrative text. Chapter 7 discusses a Prolog implementation of temporal focus in our computer system. The notion of temporal focus is used as a controlling mechanism for deriving temporal relations between situations in a narrative text. Each processing step involves a new situation that is processed with respect to the temporal focus at that stage.

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5 In this case, E4 has its reference time based on the event time of E3.
3.8. Building a timeline representation

So far, we have enumerated mechanisms that can be used to derive temporal relations between the situations of a narrative text. In the previous section, we investigated the notion of temporal focus as a controlling mechanism for deriving these relations. In this section we describe how the information gathered from the source text is used to build a timeline model for narrative text. The timeline is an analogical representation of narrative time where it is regarded as a unidimensional line. It is our general hypothesis that people conceive of such a model of narrative time as they read. Our purpose in building such a model is to use it as a platform for deriving additional temporal information and for answering time based questions relating to the source text. The process of setting up the timeline representation from the information derived by our system is facilitated by another computer system discussed in Hostetter (January, 1990). This system implements the timeline as a line-like model with instants represented by points and stretches of time represented by intervals on the line. Each interval is delimited by a pair of timepoints: the startpoint and endpoint of the interval. Internally, the system converts temporal relations between events into temporal relations between the startpoints and endpoints of the occurrences. There are three possible temporal relations between any pair of points. They are precedes, follows and coincides. This system represents the timeline model for the discourse as a set of time points corresponding to the startpoints and endpoints of the intervals of occurrences along with a set of temporal relations between those points. Suppose, for example, that we have three event occurrences denoted by E1, E2 and E3 and the following temporal relations involving them.

I. (before E1 E2)

II. (after E2 E3)
Internally, the three events are represented by intervals each with a startpoint and endpoint. The given temporal relations between the events are translated into the following point-point relations:

\[
\begin{align*}
\text{endpoint}_E1 & \quad \text{precedes} \quad \text{startpoint}_E2 \\
\text{endpoint}_E3 & \quad \text{precedes} \quad \text{startpoint}_E2
\end{align*}
\]

The first temporal relation is encoded by making the endpoint of E1 precede the startpoint of E2. The second temporal relation is encoded by making the endpoint of E3 precede the startpoint of E2. Three additional point-point constraints are obtained from the fact that the startpoint of each interval must precede its endpoint. So, the timeline representation for the three event narrative discourse involving the two temporal relations stated above consists of six points (three startpoints and three endpoints) and five point-point relations prescribed on these points. Additional relations involving these points can be derived from these direct relations.

This simple example illustrates the nature of the internal representation of the narrative situations for a discourse. The point-point relations depicted above are essentially positional constraints on the points. The timeline system is accessed through an interface module that defines the intervals and points for the narrative situations and translates temporal relations between the situations to positional constraints for the timeline representation.

### 3.9. Summary

In this chapter we introduced various problems that arose in connection with our goal of constructing a timeline representation for a narrative. We started by identifying the two major
elements of a narrative discourse: situations and their linguistic descriptions. The next problem was to define suitable representations for situations and their descriptions. We then investigated common linguistic mechanisms for temporal sequencing of situations and indicated the necessity for default temporal sequencing in cases where explicit indicators of sequence information are missing. Finally, we introduced the notion of temporal focus as a controlling mechanism for deriving temporal relations between the situations of the narrative text.
4 REPRESENTING SITUATIONS AND DESCRIPTIONS

4.1. Brief Overview

In the investigation of our problem in the previous chapter, we mentioned two major issues: the timeline representations of situations and their linguistic descriptions. We illustrated these problems through a series of examples. In this chapter, we propose a representation for different types of situations. A representation for narrative descriptions is systematically derived based on the possible ways of positioning the reference time of a description relative to its underlying situation. The problem of parsing situation descriptions into their representations is then addressed.
4.2. Low level representation for situations

In the last chapter we observed that punctual events initiate or terminate states. That is, punctual events are associated with an instantaneous change of state. This lead us to the important conclusion that punctual events mark the start and end of durative situations (events and states). Any durative situation involves the attainment of a state for a finite duration. Thus, ongoing durative events are characterized by a progressive state. Likewise, states hold at moments within stative intervals. These states are initiated and terminated by punctual event occurrences. As a result, points or instants of punctual event occurrences are either startpoints or endpoints of durative situations (durative events and states). Some examples of punctual event descriptions along with the point characterized by them are illustrated below.

John stopped swimming (endpoint)

George left the house (startpoint)

Our interpretation of punctual events as startpoints and endpoints also accounts for the durative situations initiated or terminated by them. A durative event description like John wrote a letter is taken to refer to the entire interval corresponding to the durative event (defined by its startpoint and endpoint).

From the above observations, we propose representations for each type of situation. The details of our representation scheme are enumerated below.

1. Punctual events mark the beginnings and endings of durative situations as pointed out above. They are represented by the startpoints or endpoints of durative situations.
II. Durative events can be represented by intervals of occurrence each with a distinct startpoint and an endpoint that mark points of punctual event occurrences. Within each interval the durative event is ongoing.

III. Situations that are states hold over intervals of time, each with a distinct startpoint and endpoint that mark punctual event occurrences.

4.3. Representing English descriptions

A major element of any narrative is the sequence of linguistic descriptions of situations. Each description has an underlying situation that can be an event or a state. From Reichenbach’s model⁶, each description also has three characteristic times associated with it: the event time, the speech time and the reference time. The event time (time of the underlying situation) can have three possible representations according to our scheme to represent situations: startpoint, endpoint and interval. The reference time can either be before, after or coincident with the event time or can also be situated internally within the event time in cases where the underlying situation is durative. These positional relationships between the reference time and event time can be succintly expressed as follows:

\[(\text{before, after, to}) \ X \ (\text{startpoint, endpoint, interval})\]

\[(\text{within}) \ X \ (\text{interval})\]

In each of the above lines, the first list indicates relations between the reference time and the underlying situation while the second list indicates the possible representations of the underlying situation to which the relations in the first list can apply. For instance, the second line

---

⁶ See page
indicates that the relation within applies only to an underlying durative situation (represented by interval) and does not apply to punctual events because such events lack durational extent. These reference relations constitute the basis for representing descriptions. The following table enumerates the possible representations for descriptions in terms of their underlying situations along with indications of the corresponding positional relations of reference time to the underlying situation.

<table>
<thead>
<tr>
<th>Reference Relation</th>
<th>Representation</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>to startpoint</td>
<td>STARTPT</td>
<td>Jack started reading</td>
</tr>
<tr>
<td>to endpoint</td>
<td>ENDPT</td>
<td>John reached Chicago</td>
</tr>
<tr>
<td>to interval</td>
<td>INTERVAL</td>
<td>Jack wrote a letter</td>
</tr>
<tr>
<td>before startpoint</td>
<td>PRESTARTPT</td>
<td>Jack is going to leave</td>
</tr>
<tr>
<td>before endpoint</td>
<td>PREENDPT</td>
<td>Mary is going to arrive</td>
</tr>
<tr>
<td>before interval</td>
<td>PREINTERVAL</td>
<td>Tom is going to swim</td>
</tr>
<tr>
<td>after startpoint</td>
<td>POSTSTARTPT</td>
<td>Jack has left New York</td>
</tr>
<tr>
<td>after endpoint</td>
<td>POSTENDPT</td>
<td>Jim had finished eating</td>
</tr>
<tr>
<td>after interval</td>
<td>POSTINTERVAL</td>
<td>Tom had swum a length</td>
</tr>
<tr>
<td>within interval</td>
<td>INTERNAL</td>
<td>It is raining</td>
</tr>
</tbody>
</table>

The first column of the above table indicates the relationship between reference time and event time while the second column is a mnemonic representation for the aspect of the description. Note the prefixes, such as PRE (signifying before) and POST (signifying after) of the representations.

These ten representations provide a structure for narrative descriptions. They depict the possible ways descriptions refer to their underlying situations. Note that these representations relate to the aspects of descriptions as pointed out in the previous chapter. Therefore, aspect provides the structural representation for the description (its reference time) in terms of the underlying situation. This structural representation is then related to the utterance time by the tense of the description. The primacy of aspect over tense is on account of this fact.

A description is completely represented only after affixing its tense to its structural representation. In other words, the complete representation of a description indicates the positioning
of its reference time with respect to its speech time. This information includes the tense of the description in addition to its aspect representation. The tense can be affixed or concatenated to its structural representation to obtain a complete representation of the temporal information contained in the description. The following table indicates all the possible complete representations for a given narrative description. The tense is indicated in each case by a prefix: PAST (for past), FUT (for future) and PRES (for present).

Table 2. Aspect/Tense Representations

<table>
<thead>
<tr>
<th>PAST_INTERNAL</th>
<th>PRES_INTERNAL</th>
<th>FUT_INTERNAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>PAST_POSTINTERVAL</td>
<td>PRES_POSTINTERVAL</td>
<td>FUT_POSTINTERVAL</td>
</tr>
<tr>
<td>PAST_POSTSTARTPT</td>
<td>PRES_POSTSTARTPT</td>
<td>FUT_POSTSTARTPT</td>
</tr>
<tr>
<td>PAST_POSTENDPT</td>
<td>PRES_POSTENDPT</td>
<td>FUT_POSTENDPT</td>
</tr>
<tr>
<td>PAST_INTERVAL</td>
<td>PRES_INTERVAL</td>
<td>FUT_INTERVAL</td>
</tr>
<tr>
<td>PAST_STARTPT</td>
<td>PRES_STARTPT</td>
<td>FUT_STARTPT</td>
</tr>
<tr>
<td>PAST_ENDPT</td>
<td>PRES_ENDPT</td>
<td>FUT_ENDPT</td>
</tr>
<tr>
<td>PAST_PREINTERVAL</td>
<td>PRES_PREINTERVAL</td>
<td>FUT_PREINTERVAL</td>
</tr>
<tr>
<td>PAST_PRESTARTPT</td>
<td>PRES_PRESTARTPT</td>
<td>FUT_PRESTARTPT</td>
</tr>
<tr>
<td>PAST_PREENDPT</td>
<td>PRES_PREENDPT</td>
<td>FUT_PREENDPT</td>
</tr>
</tbody>
</table>

4.4. Parsing Surface Level Narrative Descriptions

In this section we address the problem of mapping surface level descriptions into the thirty low level representations shown in Table 2. A related problem that arises in this context is the parsing of descriptions. Briefly stated, the parsing problem involves the conversion of the description into an intermediate form that expresses the information contained in the original description. This intermediate form can then be used for further processing.
4.4.1. Parsing Narrative Descriptions

For parsing surface level descriptions into an intermediate form we made use of a pattern based parser [Virkar, forthcoming]. This parser is based on a set of semantic primitives each of which represents the concept underlying a set of words. These primitives are organized into four categories: **events**, **abstracts**, **entities** and **relationals**. These categories are briefly described below.

**Events**: This category includes primitives that correspond to the verbs in sentential descriptions. Examples of primitives in this category are MOTION (includes verbs such as *walk*, *reach*, *run*, etc. that signify motional events), MENTAL-EVENTS (includes verbs such as *think*, *forsee*, etc. that signify mental events), etc.

**Entities**: This category includes primitives that correspond to words denoting individuals. In other words, these primitives characterize the nouns and noun phrases in sentential descriptions. Examples of entity primitives are ADULT (includes words such as *John*, *the king*, etc. that signify animate entities), LOCATION (includes words such as *the store*, *Manhattan*, etc. that signify locations), etc.

**Relationals**: This category includes primitives that express relations between different entities or events. The primitives in this category correspond to the prepositions and adverbials in sentential descriptions. Some examples of relationals are TEMPORAL (that includes words such as *before*, *after*, etc. that are time related), DIRECTIONAL (includes words such as *from*, *to*, etc. that give directional information), etc.

**Abstracts**: This category includes primitives corresponding to concepts such as numbers, time and qualities used to describe entities or their attributes in descriptions. Examples of abstracts include TIME (includes words such as *hours*, *seconds*, etc. that give time information), NUMBER (includes words such as *five*, *ten*, etc. that signify numbers), etc.
The parser operates by first associating a primitive pattern for an input sentence consisting of the semantic primitives corresponding to the words of the sentence. The semantic pattern thus generated is checked using a set of axiomatic rules to ensure that the sentence is semantically valid. The semantic pattern is then transformed into a corresponding meaning structure. A meaning structure (essentially a semantic net) is a construct composed of fragments corresponding to the events, relationals, entities and abstracts in the input sentence. It is the semantic equivalent of a syntactic sentence. The working of this parser is best illustrated with an example. Suppose we have the following sentence. Its semantic primitive pattern is illustrated beneath the sentence.

Sentence: Jack reached Manhattan
Pattern: HUMAN MOTION LOCATION

After validating the pattern, the parser creates the following meaning structure for the sentence:

(MEANING-FORM
  (EVENTFRAGMENT (EVENT g1 reach MOTION TERMINATIVE
                   (ENTITYFRAGMENT
                     (ENTITY Jack HUMAN)
                     (ENTITY Manhattan LOCATION)))))

This meaning structure has an event fragment indicated by the tag EVENTFRAGMENT within which is nested an entity fragment indicated by the tag ENTITYFRAGMENT. Each of these fragments are lists of atoms that specify the information content of the original sentence. Each input sentence is parsed into a meaning structure that contains a separate event fragment for each event description in the sentence. Thus, a meaning structure is the semantic equivalent of a syntactic sentence while an event fragment in a meaning structure for an input sentence.
is the semantic equivalent of a situation description in the input sentence. A meaning structure can have many event fragments each corresponding to a description in the input sentence. An event fragment has the following structure:

\[(\text{EVENT} \hspace{5pt} \text{label} \hspace{5pt} \text{lexeme} \hspace{5pt} \text{primitive} \hspace{5pt} \text{situation-type} \hspace{5pt} \text{entityfragment})\]

The event fragment in the sample meaning structure is interpreted as follows:

1. EVENT signifies that the described situation is an event (in the case of a stative situation this word is replaced by STATE).
2. The label in the example is g1. This serves to identify the event occurrence or state described.
3. The lexeme form of the event in the example fragment is the verb reach.
4. The primitive corresponding to the event (the primitive corresponding to reach) in the example is MOTION.
5. The situation-type is an argument that indicates the nature of the situation underlying the description that corresponds to the event fragment. This argument is based on taxonomic information stored in the lexicon entries for verbs and verb phrases that signify situations. Our taxonomy derives from Galton’s scheme where situations are perceived as states and events. Situations can be of four types: Punctual events, Durative events, Momentary events and States. Punctual events are further differentiated into initiative events (occur at startpoints) and terminative events (occur at endpoints). Momentary events are durative events of very short duration. Some examples of such events are wink, tap, hiccup, etc. States are the inherently stative situations signified by verbs such as live, be, etc. The situation type argument provides taxonomical information about the nature

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Recall that a single sentence can describe many situations and can therefore have many descriptions each characterizing a situation.
of the underlying situation. Thus, in the example above, the event signified by reach is punctual and terminative (since it marks the termination of a durative motional event).

VI. The entity fragment argument represents any nested entity fragment corresponding to the entities of the description.

An event fragment contains no aspect or tense information in the previous version of the parser. As part of this research, the parser was enhanced by providing it with capabilities to extract aspect/tense information from the verbal elements of an input description. A module for analyzing the use of the verbal elements of a description for aspect/tense information has been programmed into the parser. This module is invoked from within the parser for each description in the input sentence. On each invocation, the module analyzes the verbal information of an input description and information about the nature of the situation of the input description. As pointed earlier, the nature of the underlying situation can be of five types: Durative, Momentary, Stative, Initiative and Terminative. The module for verbal pattern analysis is based on a set of rules each triggered by a distinct surface level verbal pattern. The verbal pattern of an input description triggers exactly one such rule that maps the verbal pattern into an aspect/tense representation. The trigger patterns essentially index corresponding mapping rules. Each mapping rule returns the aspect/tense information associated with its triggering pattern to the parser which then incorporates the information into the event fragment corresponding to the input description.

4.4.2. Mapping Rules

The mapping rules are essentially organized into four categories based on the auxiliaries of an input description’s verb. We now discuss each category individually to give a picture of how the aspect/tense representation is determined for an input description.
4.4.2.1. Category_1

This category consists of trigger verbal patterns that appear in imperfective (stative) descriptions of situations. Included in this category are mapping rules for progressive state descriptions and descriptions of stative situations. The triggering patterns in this category are enumerated below.

\{ is, was, will be \} < MAIN VERB >

The above is a concise way of representing triggering patterns. The trigger patterns can have one of the auxiliaries *is*, *was* and *will be* in addition to the main verb of the description. In other words, the patterns can be generated by choosing one entry from within the curly braces along with the main verb. For instance, a trigger pattern of this category is: *was* < MAIN VERB >.

Each triggering pattern has an associated mapping rule that yields an aspect/tense representation for the triggering pattern. The auxiliaries *is*, *was* and *will be* are the key elements in the indexing of the mapping rules in this category. These auxiliaries also provide the tense information of the description. The auxiliary *is* signifies the PRESENT tense, *was* signifies the PAST tense and *will be* signifies the FUTURE tense. The main verb of the description (enclosed within angular braces) is analyzed by a triggered mapping rule and a table accessed using the information obtained from the analysis of the main verb and the situation type of the description. The use of the main verb and the situation type are the determinants of the aspect information in this case. The main verbs can appear in progressive -ing form especially in descriptions of ongoing durative events. The main verb is morphologically analyzed to determine its use, which can be progressive or non-progressive. The table accessed with these two pieces of information (usage and situation type) provides the aspect representation for the input description as shown below.
Table 3. Aspect Representations for Progressive State Descriptions

<table>
<thead>
<tr>
<th>Situation Type</th>
<th>Main Verb Usage</th>
<th>Aspect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initiative</td>
<td>Progressive</td>
<td>PRESTARTPT</td>
</tr>
<tr>
<td>Terminative</td>
<td>Progressive</td>
<td>PREENDPT</td>
</tr>
<tr>
<td>Durative</td>
<td>Progressive</td>
<td>INTERNAL</td>
</tr>
<tr>
<td>Momentary</td>
<td>NonProgressive</td>
<td>INTERNAL</td>
</tr>
<tr>
<td>Initiative</td>
<td>NonProgressive</td>
<td>STARTPT</td>
</tr>
<tr>
<td>Terminative</td>
<td>NonProgressive</td>
<td>ENDPT</td>
</tr>
<tr>
<td>Durative</td>
<td>NonProgressive</td>
<td>INTERVAL</td>
</tr>
<tr>
<td>Momentary</td>
<td>NonProgressive</td>
<td>INTERVAL</td>
</tr>
<tr>
<td>Stative</td>
<td>NonProgressive</td>
<td>INTERNAL</td>
</tr>
</tbody>
</table>

The first four rows of Table 3 give the aspect information corresponding to the progressive use of the main verb. Punctual events (initiative or terminative events) cannot be described as ongoing because of the instantaneous nature of their occurrences. In English, the progressive form of punctual verbs is interpreted as signifying prospective occurrences of the underlying punctual events as in the following examples:

Tom is arriving at New York shortly (maps to PREENDPT).
Jack is leaving soon (maps to PRESTARTPT).

The main verb, arrive, in the first description signifies a terminative punctual event (marking the end of a durative motional event) that is prospective at the time of reference (also the time of speech). This explains its mapping to PREENDPT. Similarly, the main verb leaving in the second description signifies the initiation of a durative motional event that is prospective at the reference time of the description. Hence it maps to PRESTARTPT. The third row in Table 3 states that if the main verb signifies a durative event and appears in progressive form then the description maps to INTERNAL, signifying an ongoing occurrence of its durative event at the reference time of the description. The fourth row states that a momentary event description with its main verb in progressive form maps to INTERNAL. In English, if a verb signifying a momentary event is used in progressive form it denotes a repeated or iterated occurrence of the momentary event. Such a repeated occurrence is regarded as a repeated
activity ongoing at the reference time of the description. Hence, the mapping to INTERNAL and the activity is like a durative event. An example of a momentary event description with a progressive use of the main verb is *The tap is dripping*. This description signifies a repeated activity of dripping and is regarded as an activity ongoing at the time of reference. The next four rows of Table 3 correspond to passive voice descriptions. An example of such a description is the description *Mary was stung by a scorpion.* It is our hypothesis that passive descriptions, like their active voice equivalents, treat their underlying situations like points. In other words, such descriptions have the perfective aspect. The above argument is substantiated by observing that their active voice equivalents characterize the same underlying situations with a point-like perspective. The active voice equivalent of the above description is *A scorpion stung Mary.* This description treats its underlying event like a point. Therefore, our treatment of the aspect of passive voice descriptions is based on the aspect of their active voice equivalents. This explains the mapping of passive descriptions in Table 3. A passive description of an initiative event occurrence is mapped onto STARTPT since the active voice equivalent maps onto STARTPT. Likewise, the other three entries are self-explanatory. Finally, the last row states that a state description such as *Jack is dead* is mapped to the representation INTERNAL. This is because the only way to characterize a stative situation is by describing it at a time at which it holds. In other words, states can only be characterized at points within stative intervals. Therefore, state descriptions are always imperfective.

### 4.4.2.2. Category 2

This category consists of mapping rules triggered by verb patterns containing auxiliaries such as *had, has, will have, has been, had been* and *will have been*. These auxiliaries feature in descriptions with the English perfect usage (recall that the perfect usage signifies a reference time after the underlying situation). The triggering patterns for the first three auxiliaries are
({} had, has, will have { < MAIN VERB > })

The tense of the descriptions with these three verbal patterns is obtained from the auxiliaries: had signifies the PAST tense, has signifies the PRESENT tense and will have signifies the FUTURE tense. The descriptions covered by this category of mapping rules involve the English perfect form. The main verb in the above three verb patterns cannot appear in progressive form. For instance, the description John has walking for a while is not proper English). Thus, in this case there is no morphological analysis of the main verb in the mapping rules. Here verb use is not at issue in the mapping. The table accessed for the above three trigger patterns is shown below.

Table 4. Aspect Representations for English Perfect forms

<table>
<thead>
<tr>
<th>Situation Type</th>
<th>Aspect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initiative</td>
<td>POSTSTARTPT</td>
</tr>
<tr>
<td>Terminative</td>
<td>POSTENDPT</td>
</tr>
<tr>
<td>Durative</td>
<td>POSTINTERVAL</td>
</tr>
<tr>
<td>Momentary</td>
<td>POSTINTERVAL</td>
</tr>
<tr>
<td>Stative</td>
<td>POSTSTARTPT</td>
</tr>
</tbody>
</table>

The aspects in the second column of Table 4 are obtained by positioning the reference time of the descriptions (conforming to any of the three patterns above) after the underlying situation. The first four rows are self-explanatory in light of the remarks above. Thus, if a description characterizes an initiative punctual event, the positioning of its reference time after the event is described as POSTSTARTPT. The last row of Table 4 is explained by observing that descriptions with underlying stative situations that have the perfect usage, such as The tribe has lived here for years, are analogous to event descriptions with the perfect continuous use, such as It has been raining. Both types of descriptions characterize states (progressive or inherent states) to have obtained for the stretch of time between the startpoint of the stative situation and the reference time of the description. The reference time of these descriptions occurs after the startpoint of the underlying situation. As a result, these descriptions map to the representation POSTSTARTPT.
The trigger patterns with the other three auxiliaries in this category are

\[ \{ \text{had, has, will have} \} \text{ been} < \text{MAIN VERB }> \]

The main verb in such cases can appear in progressive -ing (for example \textit{it has been raining}). Hence, use of the main verb has to be examined to determine the mapping. As before, the auxiliaries provide the tense information: \textit{had been} signifies the PAST tense, \textit{has been} signifies the PRESENT tense and \textit{will have been} signifies the FUTURE tense. The table for the aspect information in this case is

\begin{table}
\centering
\begin{tabular}{|c|c|c|}
\hline
\textbf{Situation Type} & \textbf{Main Verb Usage} & \textbf{Aspect} \\
\hline
Durative & Progressive & POSTSTARTPT \\
Momentary & Progressive & POSTSTARTPT \\
\hline
\end{tabular}
\caption{Aspect Representations for Perfect Continuous Forms}
\end{table}

The two rows of this table correspond to the descriptions with the English perfect continuous usage such as \textit{it has been raining}. These descriptions characterize progressive states that have obtained for the stretch of time between the start times of the underlying situations and the reference times of the descriptions. Such cases map to POSTSTARTPT since the point of reference definitely occurs after the startpoint of the underlying situation. The second row corresponds to a description of a repeated activity (consisting of several occurrences of the underlying momentary event) that is stated to be ongoing for some time at the reference time of the description. An example of such a description is \textit{the tap has been dripping}. Hence, the mapping in this case is also to POSTSTARTPT.

\textbf{4.4.2.3. Category_3}

This category consists of mapping rules indexed by the verb phrases: \textit{is going to}, \textit{was going to} and \textit{will be going to} that occur in descriptions of prospective situations. Recall that such
descriptions have the English prospective usage and position their reference time before the underlying situation (e.g. *it is going to rain*). The main verb in such descriptions cannot appear in progressive form. Hence, the use of the main verb is not an issue in determining the aspect of these descriptions. The triggering patterns in this category are:

\[ \text{is, was, will be \ going to \ <MAIN VERB>} \]

The tense of such descriptions is indicated by the auxiliaries *is, was* and *will be* in the trigger patterns. The descriptions in this category have their reference time occurring before their underlying situation. The table that provides the aspect representation in such cases is given below.

**Table 6. Aspect Representations for Prospective Forms**

<table>
<thead>
<tr>
<th>Situation Type</th>
<th>Aspect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initiative</td>
<td>PRESTARTPT</td>
</tr>
<tr>
<td>Terminative</td>
<td>PREENDPT</td>
</tr>
<tr>
<td>Durative</td>
<td>PREINTERVAL</td>
</tr>
<tr>
<td>Momentary</td>
<td>PREINTERVAL</td>
</tr>
<tr>
<td>Stative</td>
<td>PRESTARTPT</td>
</tr>
</tbody>
</table>

The entries in Table 6 are derived by positioning the point of reference before the underlying situation signified by the entries of the first column. Thus, positioning the reference time before a durative event yields the representation, PREINTERVAL. The other representations are self-explanatory.

**4.4.2.4. Category_4**

This category consists of mapping rules for simple tense descriptions. Such descriptions either have future tense auxiliaries such as *will, shall*, etc. or no auxiliaries at all. In other words, the verb patterns in such descriptions could consist of only the main verb of the description as in the simple past description *Jack slept for three hours* where the verb *sleep*
appears in the past tense without any auxiliaries. The triggering patterns for descriptions in this category are:

\[
(\{ \text{will}, \text{shall} \} < \text{MAIN VERB}>)
\]

\[
(< \text{MAIN VERB}>)
\]

An example of a description covered by this category is *The man jumped the fence*. The process of determining the tense in such cases is more involved than in the previous cases primarily due to the absence of auxiliaries in the case of the past and present tense descriptions in this category. The FUTURE tense is indicated by the presence of auxiliaries *will* or *shall* in the description. Otherwise, the tense is obtained by morphological analysis of the main verb. The present tense is signalled by an -s suffix to the root form of the main verb as in *swims*, *walks*, etc. It is often difficult to identify the simple past form of the main verb even by morphological analysis since verbs in the past tense can have several morphological forms (for e.g. *swum*, *walked*, etc.).

We can ascertain the past tense as a default, however, if the tense is confirmed to be neither FUTURE nor PRESENT along the guidelines above. From these observations we have the following rules to determine the tense in such cases.

I. If *will* or *shall* is present in the verbal pattern of a narrative description then its tense is FUTURE,

II. A morphological analyzer has been implemented for identification of the PRESENT and PAST tense usages [Virkar, forthcoming]. This analyzer infers the tense by examining the suffixes of the main verbs.

The table for the aspect representations of this category is given below.
Table 7. Aspect Representations for Simple Tense Forms

<table>
<thead>
<tr>
<th>Situation Type</th>
<th>Aspect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initiative</td>
<td>STARTPT</td>
</tr>
<tr>
<td>Terminative</td>
<td>ENDPT</td>
</tr>
<tr>
<td>Durative</td>
<td>INTERVAL</td>
</tr>
<tr>
<td>Momentary</td>
<td>INTERVAL</td>
</tr>
<tr>
<td>Stative</td>
<td>INTERNAL</td>
</tr>
</tbody>
</table>

The first four rows of Table 7 cover simple tense event descriptions. These descriptions treat their underlying events like points by referring to them directly. Thus, an initiative punctual event description such as *it started raining* has the representation STARTPT as indicated in Table 7. The last row of the table indicates that the representation of a description characterizes a stative situation such as *it is warm* is INTERNAL since such descriptions characterize the state with reference to a time when it holds. This time occurs within a stative interval.

This concludes our discussion of the mapping transformations for narrative descriptions implemented in our system. These transformations accomplish the parsing of surface level descriptions to their aspect/tense representations outlined earlier in the chapter.

4.4.2.5. Event Fragments Revisited

The mapping transformations enhance the capabilities of the parser by providing it with capabilities to extract temporal information (aspect/tense related) from input descriptions. The aspect/tense representations are returned to the parser which then incorporates the information into the event fragments as an additional argument corresponding to the input descriptions. The event fragment list previously stated has been modified into the form below to accommodate the additional information.

(EVENT label lexeme primitive situation-type aspect/tense entity/fragmen)

The argument aspect/tense of the above list is the additional argument of event fragments.

* See page 72
4.5. Summary

In this chapter we proposed representations for narrative situations (states and event occurrences) and their linguistic descriptions. The problem of parsing descriptions into their representations was investigated in detail. Our taxonomy of situations consisting of Initiative Punctual Events, Terminative Punctual Events, Durative Events, Momentary Events and States was also illustrated through its use in the parsing of descriptions to their aspect/tense representations.
5 TEMPORAL SEQUENCING

5.1. Introduction

In the last chapter, we proposed representations for situations and their linguistic descriptions in narrative text. The representation model for descriptions consists of an aspect component (which provides the structural representation) and a tense component (which locates the structural representation over time with respect to the time of speech). So far our efforts have been focused on isolated descriptions. In this chapter we take our first step towards dealing with multiple descriptions. In any narrative, temporal information is often supplied to sequence the situations underlying descriptions in the text. As pointed out in Chapter 3, such information may be in the form of temporal connectors (adverbials such as before, after, when, etc.) between descriptions or time displacement adverbials such as later, earlier, etc. In some cases both aspect and tense play the sequencing role. In this chapter, we discuss temporal connectors and time displacement phrases as temporal sequencing mechanisms.

Temporal adverbials and time displacement phrases indicate the temporal ordering of situations underlying the descriptions involved in the temporal connection or time displacement.
Considerable diversity (of combinatorial proportions) in expressing temporal information through these mechanisms is generated from the reasonably large number of aspect representations of these descriptions. This leads to enormous amounts of data to be accounted for by the model. The present chapter discusses the modelling of these mechanisms by grouping the data based on the nature of the underlying situation (durative event, punctual event and state) and developing guidelines for each group. The resulting model consists of tables of inference rules activated by the aspect representations of the descriptions involved. These rules yield temporal information in the form of relations between situations.

5.2. Temporal Connections

As mentioned earlier, a narrative discourse is most naturally perceived as a sequence of descriptions. Associated with each description is an underlying situation that can be an event occurrence or a state. Often in narrative discourse, a situation's time of occurrence is temporally related to the occurrence time of another situation. Such relations between situation times is achieved through the use of linguistic devices such as temporal connectors and time displacement phrases that connect descriptions and thereby relate their underlying situations temporally. Some examples of temporal connections are:

1. Mary saw Jack when he was swimming.
2. While Peter was in New York, he met his father.

Each of these examples depict a description that we call the main clause of the temporal connection whose underlying situation is positioned relative to the underlying situation of another description called the subordinate clause of the temporal connection. The subordinate
clause is the description immediately following the adverbial connector. Thus, the subordinate clauses of the above temporal connections are:

I. He was swimming
II. Peter was in New York

Temporal connections involve the positioning of the main clause situation relative to the subordinate clause situation. The subordinate clause situation provides the point of reference for locating the main clause situation. The nature of the positioning is governed by the adverbial connector. The relative positioning of the situations in a temporal connection is independent of their relationships to the present time or the utterance time. The relative positioning of the situations in a temporal connection is determined by the adverbial connector. Consider the following example:

3. Jack went to the store before he played basketball.

In this example both clauses have the past tense. Since both clauses have the same tense, it has no impact on the sequencing. The order of occurrence of the two events is determined solely by the connector before and the aspects of the descriptions. The tense information is redundant. The temporal adverbial governs the relative positioning.

The two original example connections presented in this chapter may be rewritten in the following form:

I. INTERVAL when INTERNAL
II. INTERVAL while INTERNAL

In this notation the clauses of the temporal connections are replaced by their aspect representations. Note the omission of the tense from the representations. The above notation ex-
presses a temporal connection in infix form with the connector adverbial between the main and subordinate clause aspects (in that order). The result of a temporal connection is a relation expressing the relative positioning of the main clause situation with respect to the subordinate clause situation on a timeline. This relation denotes one or more of the thirteen interval-interval models of James Allen's temporal logic. In the first example of this chapter the durative event of the main clause is stated to have occurred at a time when the durative event of the subordinate clause was ongoing (i.e., Mary saw Jack at a time when he was engaged in swimming). Given this information we can deduce that the two durative events (and hence their intervals) overlap in time. The connector when in this case prescribes overlap (simultaneity) between the two durative situations. The time of the main clause situation overlaps with the time of the subordinate clause situation. Denoting the main clause event by E1 and the subordinate clause event by E2 we have the relation (overlaps E1 E2) describing the possible ways of positioning interval E1 with respect to E2. Henceforth, we shall adopt this type of notation for representing temporal connections.

In the last chapter we proposed a representation scheme for narrative descriptions based on how they refer to their underlying situations. The representations are repeated below.

I. STARTPT (STARTPT_<Elable>)

II. ENDPT (ENDPT_<Elable>)

III. INTERVAL (INTERVAL_<Elable>)

IV. INTERNAL (INTERNAL_<Elable>)

V. POSTSTARTPT (POSTSTARTPT_<Elable>)

VI. POSTENDPT (POSTENDPT_<Elable>)

VII. POSTINTERVAL (POSTINTERVAL_<Elable>)

VIII. PRESTARTPT (PRESTARTPT_<Elable>)

IX. PREENDPT (PREENDPT_<Elable>)

X. PREINTERVAL (PREINTERVAL_<Elable>)
Each representation on the left hand side is annotated in the manner indicated alongside. The purpose of the annotations is to qualify the representations by attaching the label <Elab> of the associated situation. Thus, given a description with an underlying punctual event that terminates a durative event E1, the representation of the description is ENDPT_E1 where E1 indicates the situation terminated by the punctual event of this description. Without the annotation, the representation ENDPT conveys no information about the situation terminated. In this case, E1 is the situation terminated by the underlying punctual event. If a description refers directly to an underlying punctual event that initiates or starts a durative event denoted by E1 then its annotated representation is STARTPT_E1. Again, the representation INTERNAL_E1 signifies reference to an internal time within the durative situation (durative event or state) E1. Likewise, POSTSTARTPT_E1 signifies a reference to a time after the startpoint of E1.

Any temporal connection involves the positioning of the main clause situation with respect to the subordinate clause situation. There are essentially three ways to position the main clause situation relative to the subordinate clause situation. These are depicted below.

I. The main clause situation is placed before the subordinate clause situation. This type of positioning is encountered in temporal connections involving the adverbial before.

II. The main clause situation is placed after the subordinate clause situation as observed in temporal connections involving the adverbial after.

III. The main clause situation is placed simultaneous with the subordinate clause situation. This type of positioning is encountered in temporal connections involving adverbials such as when, while, etc.

We now discuss guidelines for modelling the role of adverbial connectors in temporal connections. These guidelines constitute the theory behind our model of temporal connections. They are based on the nature of the underlying situation (durative event, punctual event and
state) and have been derived by a systematic analysis of a large number of examples. In this chapter we will present an analysis of several examples (21 to be precise) to substantiate the guidelines employed for deriving temporal relations from them. The guidelines are based only on concrete knowledge and account for all possibilities in case of uncertainties.

The aspect representations of the main and subordinate clauses indicate the nature of the underlying situation. The following table shows the correspondence between aspect representations and underlying situations.

<table>
<thead>
<tr>
<th>Aspect Representation</th>
<th>Underlying Situation</th>
</tr>
</thead>
<tbody>
<tr>
<td>INTERVAL _&lt;Elabel&gt;</td>
<td>Durative Event</td>
</tr>
<tr>
<td>POSTINTERVAL _&lt;Elabel&gt;</td>
<td>Durative Event</td>
</tr>
<tr>
<td>PREINTERVAL _&lt;Elabel&gt;</td>
<td>Durative Event</td>
</tr>
<tr>
<td>STARTPT _&lt;Elabel&gt;</td>
<td>Punctual Event</td>
</tr>
<tr>
<td>POSTSTARTPT _&lt;Elabel&gt;</td>
<td>Punctual Event</td>
</tr>
<tr>
<td>PRESTARTPT _&lt;Elabel&gt;</td>
<td>Punctual Event</td>
</tr>
<tr>
<td>ENDP _&lt;Elabel&gt;</td>
<td>Punctual Event</td>
</tr>
<tr>
<td>POSTENDPT _&lt;Elabel&gt;</td>
<td>Punctual Event</td>
</tr>
<tr>
<td>PREENDPT _&lt;Elabel&gt;</td>
<td>Punctual Event</td>
</tr>
<tr>
<td>INTERVAL _&lt;Elabel&gt;</td>
<td>State or Ongoing Durative Event</td>
</tr>
</tbody>
</table>

Each connector adverbial is modelled as a table of inference rules indexed by the aspect representations of the main and subordinate clauses of a connection as shown in Fig. 8 (page 113). The figure shows the basic organization of each table. The aspect representations are grouped on the basis of the underlying situation. The aspect representations of the main and subordinate clauses are used to index the tables. Each entry of a table stores a temporal relation (an interval-interval relation) for the combination of main and subordinate clause aspects indexing into that entry. In the event of a temporal connection between two descriptions, the aspects of the descriptions are used to index the table of the adverbial connector involved in the description to retrieve the temporal relation stored there.
5.2.1. Guidelines for Before Temporal Connections

Temporal connections with the adverbial *before* involve the positioning of the main clause situation before the subordinate clause situation. Our guidelines for evaluating *before* temporal connections are based on the nature of the underlying situation (punctual event, durative event or state). They are as follows:

I. When the main clause of a *before* temporal connection is a punctual event description, the point corresponding to the punctual event is positioned before the subordinate clause situation on the timeline.

II. When the main clause of a *before* temporal connection describes a durative event, the interval corresponding to the durative event is positioned before the subordinate clause situation. As a result, the endpoint of the interval associated with the main clause durative event is before the subordinate clause situation.

III. When the main clause of a *before* temporal connection describes a state, the startpoint of the interval associated with the state is positioned before the subordinate clause situation. The endpoint of the interval may or may not be before the subordinate clause situation. For instance, given the example *it was raining before Mary went to the store* it is possible though not necessary that it stopped raining prior to the start of Mary’s motion to the store. The only concretely known fact is that it started raining before Mary went to the store. This explains why only the startpoint and not the endpoint of the interval associated with the state is constrained.

These guidelines provide a simple interpretation of the positional constraints in *before* temporal connections. The following table succinctly expresses these guidelines as point-point constraints.
### Table 9. Guidelines for BEFORE temporal connections

<table>
<thead>
<tr>
<th>No</th>
<th>Main Clause Situation</th>
<th>Subordinate Clause Situation</th>
<th>Guideline</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Punctual (P)</td>
<td>Durative (l)</td>
<td>P precedes startpt_l</td>
</tr>
<tr>
<td>2</td>
<td>Durative (l1)</td>
<td>Durative (l2)</td>
<td>endpt_l1 precedes startpt_l2</td>
</tr>
<tr>
<td>3</td>
<td>State (l1)</td>
<td>Durative (l2)</td>
<td>startpt_l1 precedes startpt_l2</td>
</tr>
<tr>
<td>4</td>
<td>Punctual (P1)</td>
<td>Punctual (P2)</td>
<td>P1 precedes P2</td>
</tr>
<tr>
<td>5</td>
<td>Durative (l)</td>
<td>Punctual (P)</td>
<td>endpt_l1 precedes P</td>
</tr>
<tr>
<td>6</td>
<td>State (l)</td>
<td>Punctual (P)</td>
<td>startpt_l1 precedes P</td>
</tr>
<tr>
<td>7</td>
<td>Punctual (P)</td>
<td>State (l1)</td>
<td>P precedes startpt_l</td>
</tr>
<tr>
<td>8</td>
<td>Durative (l1)</td>
<td>State (l2)</td>
<td>endpt_l1 precedes startpt_l2</td>
</tr>
<tr>
<td>9</td>
<td>State (l1)</td>
<td>State (l2)</td>
<td>startpt_l1 precedes startpt_l2</td>
</tr>
</tbody>
</table>

Each row of the above table illustrates the guideline for positioning the main clause situation indicated in the first column of the row relative to the subordinate clause situation indicated in the second column of that row. Incidentally, *punctual* signifies a punctual event and *durative* signifies a durative event. The bracketed labels adjacent to each situation indicates the point or interval associated with the situation. For instance, all labels beginning with *P* signify points of punctual event occurrences while the labels beginning with *l* signify intervals associated with the corresponding durative situations. The guidelines are essentially point-point constraints on the situations. Thus, given a main clause durative event associated with the interval *l1* and a subordinate clause durative event associated with *l2*, *l1* must precede *l2*. In other words, the endpoint of *l1* must precede the startpoint of *l2* (as indicated in the second row of the above table). Thus, we have a point-point interpretation of the relationship between *l1* and *l2*. Again, given a main clause state associated with interval *l* and a subordinate clause punctual event associated with point *P*, the endpoint of *l* must precede *P* (as indicated by the fifth row of the table).

Given the main and subordinate clause aspect representations, the temporal relation between the underlying situations can be obtained by applying the above guidelines.

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*5 TEMPORAL SEQUENCING*
5.2.1.1. Examples

Given below are a few example connections illustrating the use of the above guidelines.

4. John left for office before Mary went to the pool.
5. It was raining before Anne went to school.

Example 4 involves a main clause punctual event (*leaving for a destination* marks the start or initiation of a durative motion event towards that destination). The aspect of the main clause is STARTPT_E1 where E1 denotes the durative motion event initiated by the punctual event described by the main clause. The subordinate clause refers to the durative motion event involving *Mary’s motion to the pool* (denoted by E2). This clause has the representation INTERVAL_E2. This temporal connection may be written concisely as

STARTPT_E1 before INTERVAL_E2, or (starts-before E1 E2)

In this notation, the temporal connection is represented on the left side (in infix form) with the main and subordinate clause aspects respectively while the resulting temporal relation is depicted by the predicate on the right side. The relation is expressed between two labels denoting timeline intervals associated with the main and subordinate clause situations. Applying the guideline for a main clause punctual event and a subordinate clause durative event (first row of Table 9) we observe that the startpoint of E1 is before the interval E2. Hence, E1 starts before E2. Note that the resultant temporal relation is always expressed as an interval-interval relation. Constraints on points of punctual event occurrences are essentially constraints on the beginnings and endings of intervals associated with durative situations.
Example 5 is a connection where the main clause describes the state of progress of a rainy situation E1 and therefore has the representation INTERNAL_E1. The subordinate clause has an underlying durative event involving Mary's schoolward motion designated by E2. The connection can be rewritten as follows:

\[
\text{INTERNAL}_E1 \text{ before INTERVAL}_E2, (\text{starts}-\text{before} \ E1 \ E2)
\]

The only concrete fact in this example is that it started raining prior to the start of Mary's schoolward motion. The temporal connection is expressed as a constraint on the startpoints of the two situations (as indicated by the third row of Table 9 which expresses the guideline for evaluating a temporal connection between a main clause state and a subordinate clause durative event). We now discuss the guidelines for after temporal connections.

### 5.2.2. Guidelines for After Temporal Connections

Temporal connections with the adverbial after involve the positioning of the main clause situation after the subordinate clause situation. The following are the guidelines for modeling after temporal connections:

I. When the main clause of an after temporal connection is a punctual event description, the point corresponding to the punctual event is positioned after the subordinate clause situation.

II. When the main clause of an after temporal connection describes a durative event, the interval corresponding to the durative event is positioned after the subordinate clause situation. As a result, the startpoint of the interval associated with the main clause durative event is after the subordinate clause situation.
When the main clause of an after temporal connection describes a state, the endpoint of the interval associated with the state is positioned after the subordinate clause situation. The startpoint of the interval may or may not be after the subordinate clause situation. For instance, given the example It was raining came Mary came home it is possible though not necessary that it started raining prior to the Mary’s arrival. It is certain, however, that it stopped raining only after Mary’s arrival given the fact that it was raining at some time after Mary’s arrival. This explains why only the endpoint of the interval associated with the state is constrained.

The following table succinctly expresses the above guidelines as point-point constraints.

Table 10. Guidelines for AFTER temporal connections

<table>
<thead>
<tr>
<th>No</th>
<th>Main Clause Situation</th>
<th>Subordinate Clause Situation</th>
<th>Guideline</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Punctual (P)</td>
<td>Durative (i)</td>
<td>P after endpt_i</td>
</tr>
<tr>
<td>2</td>
<td>Durative (i1)</td>
<td>Durative (i2)</td>
<td>startpt_i1 after endpt_i2</td>
</tr>
<tr>
<td>3</td>
<td>State (i1)</td>
<td>Durative (i2)</td>
<td>endpt_i1 after endpt_i2</td>
</tr>
<tr>
<td>4</td>
<td>Punctual (P1)</td>
<td>Punctual (P2)</td>
<td>P1 after P2</td>
</tr>
<tr>
<td>5</td>
<td>Durative (i)</td>
<td>Punctual (P)</td>
<td>startpt_i after P</td>
</tr>
<tr>
<td>6</td>
<td>State (i)</td>
<td>Punctual (P)</td>
<td>endpt_i after P</td>
</tr>
<tr>
<td>7</td>
<td>Punctual (P)</td>
<td>State (i)</td>
<td>P after endpt_i</td>
</tr>
<tr>
<td>8</td>
<td>Durative (i1)</td>
<td>State (i2)</td>
<td>startpt_i1 after endpt_i2</td>
</tr>
<tr>
<td>9</td>
<td>State (i1)</td>
<td>State (i2)</td>
<td>endpt_i1 after endpt_i2</td>
</tr>
</tbody>
</table>

5.2.2.1. Examples

The following examples illustrate the use of the above guidelines for evaluating after temporal connections.

6. Jack finished his homework after he had lunch.

7. Peter rested for a while after he had walked around the block.
Example 6 involves a main clause terminative punctual event that marks the endpoint of *John doing his homework* (denoted by E1). The subordinate clause refers directly to an underlying durative event E2 (*Jack’s having lunch*). Applying the guideline for a main clause punctual event and a subordinate clause durative event (first row of Table 10) we obtain the following:

\[
\text{ENDPT}_E1 \text{ after INTERVAL}_E2, \text{ (ends-after E1 E2)}
\]

The only concrete fact is that the endpoint of E1 is after the interval E2. As far as the startpoint of E1 is concerned, the above relation makes no assumptions. The startpoint of E1 is free to be positioned anywhere with respect to E2.

Example 7 involves a connection between two durative events: E1 (denoting *Peter’s rest*) and E2 (denoting *Peter’s walking around the block*). The subordinate clause has the perfect usage as signalled by the auxiliary *had*. Applying the guideline for a main clause durative event and a subordinate clause durative event (second row of Table 10) we obtain the following:

\[
\text{INTERVAL}_E1 \text{ after POSTINTERVAL}_E2, \text{ (after E1 E2)}
\]

These examples give a broad flavor of the modelling of temporal connections involving *before* and *after*.

### 5.2.3. While Connections

Temporal connections with the adverbial *while* involve positioning the main clause situation at a time when the subordinate clause situation is ongoing. The subordinate clause situation cannot be punctual since punctual events being instantaneous cannot be ongoing. This is a requirement in connections involving this adverbial. Hence, *while* connections require their
subordinate clause situations to be durative. As a result, the temporal table for while connections does not have columns corresponding to aspects that indicate underlying punctual events. Some examples of while connections are illustrated below.

8. It rained while Mary was walking to school
9. Jack left the house while the carpenters were working

It may seem at first glance that the main clause situation in while connections occurs entirely during the time of the subordinate clause situation; that is, the point or interval corresponding to the main clause situation is entirely within the interval corresponding to the subordinate clause situation. This need not necessarily be the case. Example 8 is a case where it is clear that the two situations connected have some temporal overlap but it is not necessary for the occurrence of the rainy situation, E1 to be entirely within the time of Mary’s homeward motion (the subordinate clause event). In other words, it is possible that it was raining prior to the start of Mary’s homeward motion and it could still be raining after she reached home. The only fact known for certain is the temporal overlap between the two situations. If the main clause situation in a while connection is punctual then its point of occurrence is within the time of the subordinate clause situation. Example 9 illustrates a while connection involving a main clause punctual event of Jack leaving the house (this event starts Jack’s motion away from the house) that occurs while the the carpenters are at work. In this case the point corresponding to the punctual event is internally within the interval of time over which the carpenters were at work.

We now state the guidelines for states and events in while connections keeping in mind that the subordinate clause situation cannot be punctual. We then illustrate examples with the guidelines applied to them. The guidelines are
I. **Punctual Events:** As explained above, punctual events can arise only in the main clause of *while* connections. The subordinate clause situation in such connections must necessarily be durative. When the main clause has an underlying punctual event its point of occurrence is contained within the subordinate clause durative situation.

II. **Durative Events:** When the main clause describes a durative event the event overlaps with the subordinate clause situation (state or durative event).

III. **States:** When the main clause describes a state the state overlaps with the subordinate clause situation.

The following table illustrates the above guidelines in the form of constraints between points and intervals.

**Table 11. Guidelines for WHILE temporal connections**

<table>
<thead>
<tr>
<th>No</th>
<th>Main Clause Situation</th>
<th>Subordinate Clause Situation</th>
<th>Guideline</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Punctual (P)</td>
<td>Durative (I)</td>
<td>P within 1</td>
</tr>
<tr>
<td>2</td>
<td>Durative (I1)</td>
<td>Durative (I2)</td>
<td>I1 overlaps I2</td>
</tr>
<tr>
<td>3</td>
<td>State (I1)</td>
<td>State (I2)</td>
<td>I1 overlaps I2</td>
</tr>
<tr>
<td>4</td>
<td>Punctual (P)</td>
<td>State (I)</td>
<td>P within 1</td>
</tr>
<tr>
<td>5</td>
<td>Durative (I1)</td>
<td>State (I2)</td>
<td>I1 overlaps I2</td>
</tr>
<tr>
<td>6</td>
<td>State (I1)</td>
<td>State (I2)</td>
<td>I1 overlaps I2</td>
</tr>
</tbody>
</table>

Note that the subordinate clause situation cannot be punctual. The third column indicates how the positioning of the main clause situation relative to the subordinate clause situation is done. Thus, given a main clause punctual event at *P* and a subordinate clause durative event associated with interval *I*, *P* lies within *I* implying that the punctual event occurs at a time when the durative event is in progress.

**5.2.3.1. Examples**

Given below are some examples of temporal connections involving *while*.
10. John finished reading while Mary took a shower.

11. The crowd watched spellbound while the composer played the symphony.

Example 10 involves a main clause terminative punctual event that marks the end of John's reading (denoted by E1). The subordinate clause describes a durative event E2 (Mary taking a shower). The main clause punctual event occurs while the subordinate clause durative event is ongoing. Therefore, the endpoint of E1 is within the interval E2 as indicated by the first row of Table 11. The connection is represented as follows:

\text{ENDPT}_E1 \text{ while } \text{INTERVAL}_E2, \text{ or } (\text{ends-while } E1 E2)

Example 11 illustrates a connection between clauses describing durative events. Both clauses have the aspect INTERVAL since they refer directly to their underlying events. The two events overlap as required by the connector while. The connection and the resulting temporal relation are shown below.

\text{INTERVAL}_E1 \text{ while } \text{INTERVAL}_E2, \text{ or } (\text{overlaps } E1 E2)

5.2.4. Temporal Connections involving As

The lexeme as is sometimes used to indicate simultaneity of the main and subordinate clause situations. Temporal Connections involving as can be modelled using event/state guidelines similar to those for while connections. The following table summarizes the guidelines for modelling connections involving as.
Table 12. Guidelines for AS temporal connections

<table>
<thead>
<tr>
<th>No</th>
<th>Main Clause Situation</th>
<th>Subordinate Clause Situation</th>
<th>Guideline</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Punctual (P1)</td>
<td>Punctual (P2)</td>
<td>P1 coincides P2</td>
</tr>
<tr>
<td>2</td>
<td>Punctual (P)</td>
<td>Durative (l)</td>
<td>P within l</td>
</tr>
<tr>
<td>3</td>
<td>Durative (l)</td>
<td>Punctual (l)</td>
<td>I contains P</td>
</tr>
<tr>
<td>4</td>
<td>Durative (l1)</td>
<td>Durative (l2)</td>
<td>I1 overlaps I2</td>
</tr>
<tr>
<td>5</td>
<td>State (l1)</td>
<td>State (l2)</td>
<td>I1 overlaps I2</td>
</tr>
<tr>
<td>6</td>
<td>Punctual (P)</td>
<td>State (l)</td>
<td>P within l</td>
</tr>
<tr>
<td>7</td>
<td>State (l)</td>
<td>Punctual (P)</td>
<td>I contains P</td>
</tr>
<tr>
<td>8</td>
<td>Durative (l1)</td>
<td>State (l2)</td>
<td>I1 overlaps I2</td>
</tr>
<tr>
<td>9</td>
<td>State (l1)</td>
<td>State (l2)</td>
<td>I1 overlaps I2</td>
</tr>
</tbody>
</table>

These guidelines match the corresponding ones for *while* connections. In addition, temporal connections involving *as* also allow for subordinate clause punctual events. When *as* connects two punctual events their points of occurrence coincide as indicated by the first row of the above table. Similarly, in the event of an *as* temporal connection between a subordinate clause punctual event and a main clause state or durative event, the point of occurrence of the punctual event lies within the interval associated with the durative situation. All the other guidelines are similar to the corresponding ones for *while* connections.

Given below is an example of an *as* temporal connection between two durative events.

12. *As the stream cascaded,* the *emanating foam* formed a white *curtain.*

The intervals associated with the durative events overlap as indicated by the connector *as.* The representation for this connection is as follows:

```
INTERVAL_E2 AS INTERVAL_E1, (overlaps E2 E1)
```
5.2.5. When Connections

Temporal connections with the adverbial when involve positioning the main clause situation simultaneous with the subordinate clause situation. As a result, the two situations overlap temporally. Heinamaki points out that certain temporal connections involving when connote sequential rather than simultaneous occurrence of the situations connected by them. In such cases the main clause situation sequentially follows the subordinate clause situation. Given below is a connection involving when that imposes sequentiality on the events involved in the connection.

13. Jim started swimming when it stopped raining.

This example involves two punctual events that have sequential rather than simultaneous occurrence. The main clause punctual event signified by Jim started swimming occurs after the subordinate clause punctual event signified by It stopped raining. Apparently, the stoppage of rain in this case causes the main clause punctual event to occur. Miller and Johnson-Laird (1976) note that sequentiality of the two situations in a when connection arises in cases where both situations are point-like or punctual events as in the example above. Hence, the adverbial when can either have sequential or simultaneous interpretation. The main clause situation can either occur simultaneously or sequentially after the subordinate clause situation. Before proceeding further, we clarify the notions of sequentiality and simultaneity of situations. We shall interpret these notions from a timeline perspective (in terms of intervals and points).

Simultaneity of durative situations (durative events or states) implies temporal overlap between the intervals corresponding to the situations. Note that all forms of overlap between
intervals (as encountered in Allen’s interval-interval model) are covered in this interpretation of simultaneity.

*Simultaneity of a punctual event and a durative event or state* involves the containment of the point corresponding to the punctual event by the interval corresponding to the durative event or state. In other words, the punctual event occurs while the durative event or state is ongoing.

*Sequentiality between situations* may be of two types; *delayed* sequencing and *immediate* sequencing. Two situations occur in delayed sequence if one follows the other after the lapse of a finite amount of time. In other words, a gap exists between the two situations if they occur in delayed sequence. On the other hand, immediate sequentiality involves contiguity of the two situations. There is no time gap between the situations in such cases. Immediate sequentiality between durative situations is depicted by two intervals that adjoin with no intervening gap between them. The endpoint of the first interval coincides with the startpoint of the other. Delayed sequence on the other hand implies that the endpoint of the first interval is before the startpoint of the second. Thus, two intervals E1 and E2 are in sequence (either delayed or immediate) if the endpoint of E1 either coincides with or precedes the startpoint of E2. This constraint can be written as: *endpoint_E1 coincides-or-precedes startpoint_E2.*

Immediate sequentiality between punctual events implies no intervening gap between their points of occurrence. There is a certain imprecision associated with defining immediate sequentiality between punctual events. Galton (1987) points out that two punctual events occurring in immediate sequence essentially have coincident points of occurrence. In other words, for two punctual events to occur in immediate sequence, there must be no gap between their points of occurrence. There is no time lapse between their points of occurrence. This essentially implies that their points of occurrence coincide. On the other hand, two punctual events occurring at points *point_1* and *point_2* are in delayed sequence if *point_1* precedes *point_2*. Thus, sequentiality between punctual events occurring at points *point_1*
and \textit{point}_2 \text{ implies the following constraint between their points of occurrence: } point_1 \text{ coincides-or-precedes } point_2. \text{ }

Sequentiality between a punctual event and a durative event can be defined in terms of point-point sequentiality between the point corresponding to the punctual event and the startpoint of the durative event. Designating the point of punctual event occurrence by \textit{point}_1 we have \textit{point}_1 \text{ coincides-or-precedes startpoint}_E2. \text{ E2 denotes the durative event and startpoint}_E2 \text{ denotes its startpoint. Likewise, when a durative event } E1 \text{ is sequentially followed by a punctual event occurring at } point_2 \text{, the sequentiality between the events may be expressed by the following point-point constraint between the endpoint of the durative event and the point of punctual event occurrence: } endpoint_E1 \text{ coincides-or-precedes } point_2. \text{ }

With the notions of sequentiality and simultaneity clarified, we now state guidelines for events and states in \textit{when} connections. Once again our approach in presenting the guidelines is based on the nature of the main and subordinate clause situations.

\textbf{Guideline} 1: When both the main and subordinate clause situations are durative events, the events either overlap or occur in sequence. In other words, both simultaneity and sequentiality of occurrence are possible in such cases. In the case of sequential occurrence the main clause event follows the subordinate clause event. The following examples illustrate \textit{when} connections between durative events.

14. John bought a pair of jeans when he went to the store.

15. Peter played poker when Mary cooked dinner.

Example 14 illustrates a \textit{when} connection where the main clause durative event signified by \textit{John's purchase of a pair of jeans} sequentially follows the subordinate clause event of \textit{John's going to the store}.\text{ }

\textsc{5 TEMPORAL SEQUENCING}
Example 15 illustrates two durative events that overlap on time. The main clause event *Peter playing poker* occurs simultaneously (overlaps) with the subordinate clause event *Mary cooking dinner*. Thus, both sequential and simultaneous occurrence are possible when durative events are connected by *when*. From a timeline perspective the interval corresponding to the main clause event either overlaps with or follows the interval corresponding to the subordinate clause event.

Both the above examples involve clauses that refer directly to their durative events. Hence, both clauses have the aspect INTERVAL. Denoting the main clause event by E1 and the subordinate clause event by E2 in each case we have the following representations for these examples.

\[ \text{INTERVAL}_E1 \text{ when } \text{INTERVAL}_E2, \text{ or (overlap-or-follows } \ E1 \ E2) \]

**Guideline 2**. When the main clause situation is a punctual event and the subordinate clause situation a durative event, the punctual event either occurs while the durative event is ongoing or occurs sequentially after it. In both cases the punctual event occurs after the startpoint of the interval corresponding to the durative event. Denoting the point of punctual event occurrence by *point₁*, the following point-to-point constraint accounts for all possibilities that can arise: *point₁* after *startpoint_E2*. An example when connection between a main clause punctual event and a subordinate clause durative event is:

16. Mary started cooking when John went to the store.

This example has a main clause punctual event that marks the initiation of *Mary's cooking* (denoted by E1). The subordinate clause describes a durative event involving *John's going to the store* (denoted by E2). The main clause punctual event occurs after the startpoint of E2.
according to the above point-point constraint. Hence, E1 starts after E2 does. This example may be represented as follows:

\texttt{STARTPT\_E1 when INTERVAL\_E2, or (starts-after \ E1 \ E2)}

\textbf{Guideline 3}: When one or both the clauses in a \texttt{when} connection describes a state, the adverbial imposes simultaneity of the two situations involved in the connection. Thus, in the following example the main clause progressive state (state of progress of Anne's swim) holds simultaneously with the subordinate clause durative event (Jack playing football). Hence, the intervals corresponding to the state and durative event overlap.

17. Anne was swimming when Jack played football.

\textbf{Guideline 4}: When the main and subordinate clauses describe punctual events, the point corresponding to the main clause punctual event either coincides with or follows the point corresponding to the subordinate clause punctual event. Thus, given that the main and subordinate clause punctual events occur at \texttt{point\_1} and \texttt{point\_2} respectively the following constraint gives the possibilities that can arise: \texttt{point\_1 coincides-or-follows point\_2}. An example of a \texttt{when} connection between two punctual events is the following:

18. Jim left for the store when Larry reached home.

The main clause punctual event marks the initiation of Jim's \textit{motion to the store} (denoted by E1) and therefore has the representation \texttt{STARTPT\_E1}. The subordinate clause punctual event marks the termination of Larry's \textit{homeward motion} (denoted by E2). This clause is represented by \texttt{ENDPT\_E2}. Applying the above point-point constraint we observe that the startpoint of E1
either follows or coincides with the endpoint of \( E_2 \). Hence, the interval corresponding to \( E_1 \) is sequentially after \( E_2 \). The representation of this example is shown below.

\[
\text{STARTPT}_E_1 \text{ when ENDPT}_E_2, \text{ or (sequence} \quad E_2 \quad E_1) \]

**Guideline 5.** When the subordinate clause describes a punctual event and the main clause describes a durative event, both events occur in sequence with the punctual event coming first. In other words, the punctual event occurs before the durative event starts. This may be succinctly written as the following point-point constraint: \( \text{point}_1 \) precedes \( \text{endpoint}_E_2 \), \( \text{point}_1 \) denotes the point of punctual event occurrence and \( E_2 \) denotes the durative event. An example when connection involving a main clause durative event and a subordinate clause punctual event is given below.

19. Jack went to the store when Mary reached home.

This example sounds odd when the adverbial is interpreted as having a simultaneous sense. Such an interpretation would imply that the durative event (which normally takes time) occurs entirely at the instant that the subordinate clause punctual event occurred. This absurd interpretation is what makes the simultaneous sense of the adverbial inappropriate in cases where the subordinate clause event is punctual. Since simultaneity is ruled out on account of the awkward interpretation above the only interpretation that applies in such cases is sequentiality. In other words, the main clause durative event occurs sequentially after the subordinate clause punctual event. The main clause has the representation \( \text{interval}_E_1 \) where \( E_1 \) denotes the durative event of \( \text{Jack going to the store} \) and the subordinate clause has the representation \( \text{endpt}_E_2 \) where \( E_2 \) denotes \( \text{Mary's homeward motion} \). Thus, our representation for this example based on the guideline that the punctual event coincides or precedes the startpoint of the durative event is:
INTERVAL_E1 when ENDPT_E2, or \( \text{sequence E1 E2} \)

The following table summarizes the event/state guidelines for evaluating \( \text{when} \) connections explained above. The guidelines are point-point, point-interval constraints.

<table>
<thead>
<tr>
<th>No</th>
<th>Main Clause Situation</th>
<th>Subordinate Clause Situation</th>
<th>Guideline</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Punctual (P)</td>
<td>Durative (I)</td>
<td>( P ) after startpt_1</td>
</tr>
<tr>
<td>2</td>
<td>Durative (I1)</td>
<td>Durative (I2)</td>
<td>I1 overlaps-or-follows I2</td>
</tr>
<tr>
<td>3</td>
<td>State (I1)</td>
<td>Durative (I2)</td>
<td>I1 overlaps I2</td>
</tr>
<tr>
<td>4</td>
<td>Punctual (P1)</td>
<td>Punctual (P2)</td>
<td>P1 coincides-or-follows P2</td>
</tr>
<tr>
<td>5</td>
<td>Durative (I)</td>
<td>Punctual (P)</td>
<td>P coincides-or-precedes startpt_1</td>
</tr>
<tr>
<td>6</td>
<td>State (I)</td>
<td>Punctual (P)</td>
<td>I contains P</td>
</tr>
<tr>
<td>7</td>
<td>Punctual (P)</td>
<td>State (I)</td>
<td>P within I</td>
</tr>
<tr>
<td>8</td>
<td>Durative (I1)</td>
<td>State (I2)</td>
<td>I1 overlaps I2</td>
</tr>
<tr>
<td>9</td>
<td>State (I1)</td>
<td>State (I2)</td>
<td>I1 overlaps I2</td>
</tr>
</tbody>
</table>

We now consider \( \text{when} \) connections where one or both clauses can have the English perfect usage. Recall that descriptions with the perfect usage refer to a time after their underlying events. Such descriptions essentially view their underlying situation retrospectively, i.e., from a point of reference after the situation. Consider the following example

20. Tom had read a novel when Janet reached home.

This example connects a main clause durative event description having the perfect usage (as signified by the auxiliary \textit{had}) to a subordinate clause that describes a terminative punctual event. The main clause refers to a time after its underlying event while the subordinate clause refers directly to its underlying punctual event. It is clear from this example that at the time Janet reached home Tom had already read the novel. In other words, the time of \textit{Janet's arrival} is after the time during which \textit{Tom read the novel}. The adverbial \textit{when} imposes simultaneity of reference times in this example. According to Reichenbach (1947), the simultaneous interpretation of \textit{when} connotes simultaneity of the reference times of the connected
clauses. The main clause in this example is represented by POSTINTERVAL_Ε1 while the subordinate clause has the representation ENDPT_Ε2. The temporal connection is represented as shown below.

\[
\text{POSTINTERVAL}_\text{Ε1} \text{ when ENDPT}_\text{Ε2}, \text{ or } (\text{ends-before} \quad \text{Ε1} \text{ Ε2})
\]

The main clause durative event occurs before the subordinate clause punctual event. Hence, Ε1 ends before Ε2. Nothing is known about the startpoint of Ε2 in relation to Ε1. All possibilities that can arise are accounted for by the relation on the right side.

The following example illustrates a case where both clauses have the perfect usage.

21. The burglar had run after Larry when he had screamed at him.

Both clauses have underlying durative events in this case and base their reference times after those events. Denoting the main clause event by Ε1 and the subordinate clause event by Ε2 the two clauses are represented by POSTINTERVAL_Ε1 and POSTINTERVAL_Ε2 respectively. This example is essentially treated in the same manner as the following one: The burglar ran after Larry when he screamed at him. The guideline for durative events in when connections (Guideline_1) applies to this example. According to this guideline the two events either overlap or occur in sequential order. Therefore, this example is represented as follows:

\[
\text{POSTINTERVAL}_\text{Ε1} \text{ when POSTINTERVAL}_\text{Ε2}, \text{ or } (\text{overlaps-or-follows} \quad \text{Ε1} \text{ Ε2})
\]

Given below are the guidelines for when connections where one or both clauses have the perfect usage.
I. If one of the clauses in a when connection has the perfect usage while the other does not, the temporal sequencing is based on the guideline of simultaneous reference times.

II. If both clauses in a when connection have the perfect usage, the temporal sequencing of their underlying events is based on the guidelines (Guideline_1 through Guideline_5) for events and states stated earlier.

This concludes our discussion of temporal connectors as sequencing mechanisms. Appendix A gives additional examples of temporal connections along with explanations for each.

5.2.6. Implementation

Our system encodes the representations for temporal connections in the form of two dimensional tables indexed by the aspects of the main and subordinate clauses (see Fig. 8). Each temporal connector has an associated table. The entries of these tables are based on the guidelines stated in this chapter. Each entry yields a temporal relation for a given combination of main and subordinate clause aspects. Each such relation denotes the possible timeline models for the situations involved. The format of each table entry is illustrated below with brief descriptions of the arguments in the items that follow.

```
(TEMP-CONNECTOR   MAIN-CLAUSE-ASPECT

    SUBORDINATE-CLAUSE-ASPECT TEMP-RELATION)
```

I. TEMP-CONNECTOR is the temporal adverbial used to identify the table to be indexed.

II. MAIN-CLAUSE-ASPECT is the aspect representation of the main clause. This serves as the row index of the table for TEMP-CONNECTOR.
III. SUBORDINATE-CLAUSE-ASPECT is the aspect representation of the subordinate clause. This serves as the column index of the table for TEMP-CONNECTOR.

IV. TEMP-RELATION is the temporal relation denoting the possible temporal models between the main and subordinate clause situations.

5.3. Time Displacement Phrases

In this section we consider time displacement phrases as temporal sequence mechanisms between situations. Often in narratives, temporal information is supplied in the form of adverbials like earlier, later and time phrases like three hours ago, eight days later etc. Such adverbials and time phrases convey information about the occurrence time of the situation underlying the description in which they appear relative to the time of another situation. We now consider some examples to clarify these remarks.

22. Jack went to the store. Later, he had lunch with Mary.

23. Peter played poker with Mary. Earlier, he had worked on his car.

These examples illustrate the use of time displacement to provide temporal sequence information between situations. Example 1 illustrates a time displacement in the forward direction (advancement of time) by the adverbial later. The durative event underlying the second sentence Jack having lunch with Mary occurs at a later time with respect to the durative event underlying the first sentence Jack’s going to the store. In other words, there is an advancement of narrative time from the first event to the second. The adverbial later essentially positions the second event after the first event. The role played by the adverbial later parallels the role of after in the following temporal connection: Jack had lunch with Mary after he went to
the store. In essence, this connection reflects the positioning of the second event relative to the first. The first event provides the reference for positioning the second event after it and hence functions like the subordinate clause situation of an after temporal connection. The second event, which is reported occurring at a later time with respect to the first, is like the main clause of such a temporal connection. Hence, time displacements can be treated like temporal connections as far as sequencing is concerned. In example 22, the time displacement between the two events results in the following temporal relation between the first event and the second event: (after E2 E1). This temporal relation is obtained by accessing the table for after temporal connections using the aspect of the second sentence as the main clause and the aspect of the first sentence as the subordinate clause.

Example 23 illustrates a backward time displacement by the adverbial earlier between the durative events underlying the first and second sentences. As a result, the second event occurs before the first event. This example is like the following temporal connection involving the adverbial before: Peter had worked on his car before he played poker with Mary. The first event functions like the subordinate clause event by providing the reference point for locating the second event. This example is handled by accessing the table for before.

The following example illustrates a time displacement of a different kind. The two examples above only provide information as to the direction of time displacement. The following example also indicates the extent of time displacement in addition to the direction.

24. Jack reached the house. Ten seconds later, he left with Mary.

In this example, the direction of displacement is indicated by the lexeme later while the measure or extent of displacement is indicated by the phrase ten seconds. Because of the additional information about the extent of time displacement, such time phrases are handled in a different manner than single adverbials like later, earlier etc. In this example both de-
criptions or sentences have underlying punctual events: the first sentence describing an event that terminates Jack's motion to the house (a durative event denoted by E1) and the second sentence describing an event that initiates Jack's motion away from the house (another durative event denoted by E2). The two events are separated by a time span of ten seconds. This time span numerically constrains the positioning of the second punctual event with respect to the first punctual event. Chapter 8 describes how numeric constraints are imposed between points and intervals corresponding to events.

A recursive descent (top down) parser for commonly used time displacement phrases and adverbials in narrative descriptions has been implemented in our system. This parser functions as a component of the semantic pattern based parser discussed in the previous chapter. It is based on a context free grammar consisting of a set of production rules for parsing commonly encountered time displacement phrases and adverbials. This parser is invoked by the semantic grammar parser whenever a word or a lexeme that can begin a time displacement phrase is encountered in the input sentence. Along with the parsing of time displacement phrases, the direction and extent of the displacement signified by the phrase is extracted. The format and specification of this list are indicated below:

(TIME-DISPLACEMENT SECONDS MINUTES HOURS DAYS MONTHS YEARS)

The arguments of the above list are signed integers with sign indicating direction of displacement (minus sign connotes backward time displacement while positive sign connotes forward time displacement) and magnitude indicating extent of displacement. For instance, given the phrase ten seconds earlier the seconds argument of the above list is instantiated to -10. Depending on the unit of specification of the displacement the corresponding argument gets instantiated accordingly. The TIME-DISPLACEMENT list depicted above is incorporated into the meaning fragment created for the input sentence: John went to the pool two days earlier. This sentence is parsed into the following meaning structure.
(Meaning-Form
  (EVENTFRAG (EVENT g1 went MOTION DURATIVE PAST_INTERVAL
  (ENTITYFRAGMENT
    (ENTITY John HUMAN)
    (ENTITY pool LOCATION)))
  (ABSTRACTFRAG
    (ABSTRACT [ unk unk unk -2 unk unk ] TIME)))

This meaning fragment for the input sentence includes an abstract fragment for the time displacement phrase two days earlier in the input sentence. This fragment is identified by the tag ABSTRACTFRAGMENT. Nested within this fragment is a list whose first argument is ABSTRACT. This list is interpreted in the following format:

  (ABSTRACT time-displacement-list primitive)

The significance of each argument in the above list is explained below

I. The word ABSTRACT signifies that the time displacement phrase two days earlier is interpreted as an abstract since it gives information of the time of occurrence of the event underlying the description.

II. The time-displacement-list is the list of six arguments explained earlier. An entry unk signifies that the corresponding argument is unknown i.e., uninstantiated. In the example sentence, the only instantiated argument of this list is the one corresponding to day (since the measure of time displacement is in day units). This argument has the value -2 indicating a displacement of two days (extent) in the backward direction as indicated by the directional adverbial earlier.

III. The semantic primitive corresponding to this time displacement phrase is TIME indicating a time abstract.
In the case of time displacement by a single directional adverbial such as *later*, *earlier* etc. an abstract fragment is created without the time displacement list. Thus, in the above example sentence replacing the time displacement phrase *two days ago* by the adverbial *later* yields the following meaning structure. Notice the difference reflected in the abstract fragments.

(Meaning-Form

(EVENTFRAGMENT   (EVENT   g1 went MOTION DURATIVE

(ENTITYFRAGMENT

(ENTITY   John HUMAN)

(ENTITY   pool LOCATION)))

(ABSTRACTFRAGMENT

(ABSTRACT   FORWARD TIME)))

The second argument of the list within ABSTRACTFRAGMENT in the above meaning structure indicates directional information (FORWARD) in place of the time displacement list encountered in the previous case. In this case the argument is instantiated to FORWARD since *later* signifies a forward displacement of time. This argument can have two possible values: FORWARD (indicates a forward time displacement) and BACKWARD (indicates a backward time displacement).

5.4. Summary

This chapter introduced the notion of temporal sequencing of narrative situations and investigated temporal connections and time displacement phrases as sequencing mechanisms. Both these mechanisms constitute effective linguistic sources of temporal information that indicate the positioning of situations with respect to one another.
<table>
<thead>
<tr>
<th>MAIN CLAUSE ASPECT</th>
<th>INTERVAL</th>
<th>POSTINTERVAL</th>
<th>PREINTERVAL</th>
<th>STARTPT</th>
<th>ENDP</th>
<th>POSTSTARTPT</th>
<th>POSTENDPT</th>
<th>PRESTARTPT</th>
<th>PREENDPT</th>
<th>INTERNAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>INTERVAL</td>
<td></td>
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</tr>
</tbody>
</table>

Figure 8. A TEMPORAL CONNECTOR TABLE

5 TEMPORAL SEQUENCING
6 Default Temporal Sequencing

6.1. Introduction

In the previous chapter, we introduced the notion of temporal sequencing and investigated certain linguistic mechanisms that sequence situations over time. Our investigation reveals the notion of relative positioning of situations with respect to other situations. In this chapter we continue with our discussion of temporal sequencing by investigating cases where aspect and tense play the sequencing role. In certain cases even aspect and tense are insufficient for inferring temporal sequence information. Such cases usually require default sequencing or semantic analysis for inferring sequence information. Although our analysis is purely temporal, we shall briefly address the issue of semantic analysis in a separate section of this chapter. Default sequencing is the major focus of this chapter and is based on guidelines such as sequentiality and overlap of situations. The rules for imposing default relations are also triggered by the aspect/tense representations of descriptions (30 in number).

We now discuss temporal sequencing by aspect and tense. Our approach in presenting the guidelines for such cases is similar to that of the previous chapter. Once again, huge amounts
of data have to be accounted for by the model owing to the diverse ways of expressing temporal sequence information through these mechanisms. The diversity results from the fairly large number of aspect/tense representations. Our solution toward modeling these mechanisms consists of inference rules triggered by the representations of the descriptions involved. Since tense is significant in some of these cases, both aspect and tense are required for triggering these inference rules. As before, these rules are organized in the form of a two-dimensional table of inferences indexed by the aspect/tense representations of the two descriptions to be sequenced. This table is called aspect-tense-table.

6.2. Sequencing by Aspect and Tense

As pointed out earlier, the tense of a narrative description relates its event time (occurrence time of its underlying situation) to its utterance time (also called its speech time). Consider the following discourse fragment involving two sentences uttered one after the other. This example is sequenced by indexing the entry (PAST_INTERVAL, FUT_INTERVAL) of the aspect-tense-table.

1. Jack went to see Mary. He will accompany her to the ball.

The first sentence in this example has the past tense and describes an event that occurred prior to the utterance time. The second sentence describes another event (Jack accompanying Mary to the ball) that has yet to take place at the utterance time as indicated by the future tense of the sentence. It is straightforward to conclude that the first event occurs before the second one. This is a consequence of the deictic role played by tense in relating the two occurrence times to the time of speech (also the current time or the now time of the discourse).
In this example the order of occurrence of the underlying situations can be inferred solely from the tense of the sentences.

The following example illustrates a case where both aspect and tense have an impact on the sequencing. The example is sequenced by indexing the entry (PRES_INTERNAL, FUT_INTERVAL) of the aspect-tense-table.

2. John is playing poker. Mary will see him soon.

In this example the first event (John playing poker) is reported ongoing at the time of speech. The second sentence describes an event that is yet to occur relative to the now time. The two sentences have different aspects in this case. The first sentence refers to an internal time within its underlying event and thereby has the aspect INTERNAL. The second sentence offers a point-like perspective of its durative event Mary’s seeing John and has the aspect INTERVAL. Given the circumstances of this example, it is possible that John is still engaged in playing poker when Mary actually meets him. In other words, it is not clear where the endpoint of the first event is positioned in relation to the second event. It is clear, however, that the second event starts after the first one from the fact that the first event is in progress at a time before the second event.

6.2.1. Tense Shifts

From the analysis of the above examples it is clear that the change of tense from one description to another can be a source of temporal information between situations. We shall use the term tense shifts for tense changes. There are two possible kinds of tense shifts: forward shifts and backward shifts. These terms are explained below.
Backward tense shifts arise when any of the following tense changes are detected from one description to another.

I. Change from future tense to present tense
II. Change from future tense to past tense
III. Change from present tense to past tense

Forward tense shifts are indicated by any of the following tense changes.

I. Change from past tense to future tense
II. Change from present tense to future tense
III. Change from past tense to present tense

Temporal sequencing through tense changes can be modelled using aspect guidelines similar to those used for temporal connections involving the adverbials before and after. Any tense shift imposes a positional constraint on the situations involved in the shift. The order of occurrence of the situations is governed by these positional constraints. As pointed out in the previous chapter, temporal connections also impose positional constraints on the situations connected by them. In the case of forward tense shifts the situation underlying the second description is positioned after the first situation.

6.2.1.1. Forward Tense Shifts

We now discuss guidelines for modelling forward tense shifts. The first example of this chapter is an instance of forward tense shift between the two descriptions. This example is repeated below.

1. John went to see Mary. He will accompany her to the ball.
Both sentences in this example describe durative events. The two events are essentially like points with the point corresponding to the first event positioned before the point corresponding to the second event. Both events are durative and are represented by intervals. An interval that is before another interval has its endpoint before the startpoint of the other interval. In this example, if E1 denotes John’s going to see Mary and E2 denotes John’s accompanying her to the ball the following point-point constraint gives the temporal relationship between E1 and E2: endpoint_E1 before startpoint_E2. The example is represented as follows.

(PAST_INTERVAL_E1, FUT_INTERVAL_E2), or (before E1 E2)

We shall adopt the above notation for illustrating the rules for temporal sequencing in this chapter. The left hand side indicates the aspect/tense of the two descriptions (essentially indices into the aspect-tense-table) involved in the shift (PAST denotes past tense while FUT denotes future tense). The representations are annotated with the labels of the associated intervals following the conventions of the previous chapter. These representations state that given a past interval and a future interval (both treated like points) corresponding to the durative events E1 and E2 respectively, E1 comes before E2.

When states are involved the guidelines have to be modified since states cannot be treated like points. They can only be described as holding at moments within intervals. In other words, states can only be characterized using an internal perspective. Recall that state descriptions have the aspect INTERNAL signifying an internal reference within their associated intervals. Thus, given the second example of this chapter

2. John is playing poker. Mary will see him soon.

The first sentence being a progressive state description offers an internal perspective of the durative event John’s playing poker. This durative event could still be in progress at the time
Mary meets John. The change of tense, however, indicates that the first event is in progress at a time when the second event has yet to occur. From this we can at least infer that John started playing poker before the time Mary saw him. When the first situation in a forward tense shift is a state, we cannot assume that it ends prior to the start of the second event. Likewise, when the second situation in a forward tense shift is a state we cannot assume that it starts only after the first situation ends. The representation for the above example is as follows.

\[(\text{PRES\_INTERNAL\_E1, FUT\_INTERVAL\_E2}, \text{or (starts\_before E1 E2)})\]

The above observations are summarized in the following table and constitute the guidelines for modelling forward tense shifts. Each row of the table illustrates the guideline for deriving temporal sequence information, given the situations in the first two columns of that row.

**Table 14. Guidelines for Forward Tense Shifts**

<table>
<thead>
<tr>
<th>No</th>
<th>First Situation</th>
<th>Second Situation</th>
<th>Guideline</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Punctual (P1)</td>
<td>Punctual (P2)</td>
<td>P1 precedes P2</td>
</tr>
<tr>
<td>2</td>
<td>Durative (I)</td>
<td>Punctual (P)</td>
<td>endpt_I precedes P</td>
</tr>
<tr>
<td>3</td>
<td>State (I)</td>
<td>Punctual (P)</td>
<td>startpt_I precedes P</td>
</tr>
<tr>
<td>4</td>
<td>Punctual (P)</td>
<td>Durative (I)</td>
<td>P precedes startpt_I</td>
</tr>
<tr>
<td>5</td>
<td>State (I1)</td>
<td>Durative (I2)</td>
<td>startpt_I1 precedes startpt_I2</td>
</tr>
<tr>
<td>6</td>
<td>Durative (I1)</td>
<td>Durative (I2)</td>
<td>endpt_I1 precedes startpt_I2</td>
</tr>
<tr>
<td>7</td>
<td>Punctual (P)</td>
<td>State (I)</td>
<td>P precedes endpt_I</td>
</tr>
<tr>
<td>8</td>
<td>State (I1)</td>
<td>State (I2)</td>
<td>startpt_I1 precedes endpt_I2</td>
</tr>
<tr>
<td>9</td>
<td>State (I1)</td>
<td>Durative (I2)</td>
<td>startpt_I1 precedes startpt_I2</td>
</tr>
</tbody>
</table>

These guidelines have been incorporated in the design of the aspect-tense-table introduced earlier. For instance, the entry (PAST\_STARTPT\_E1, FUT\_STARTPT\_E2) of the aspect-tense-table for sequencing two punctual event descriptions having the past and future tense respectively stores the following temporal relation: \(\text{(start\_before E1 E2)}\). This entry is based on the guideline for sequencing two punctual events (second row of the above table). From the guideline, the first punctual event precedes the second one thereby indicating that the interval E1 associated with the first punctual event starts before the interval associated with the second punctual event.
6.2.1.2. Backward Tense Shifts

We now illustrate the guidelines for modelling backward tense shifts. We start by analyzing the example below.

3. Tony will see Mary soon. He has had a bath.

This example describes two durative events the first of which is bound to occur in the future (in relation to the utterance time). The second event is reported to have already occurred as of the utterance time. The two events are essentially treated like points. Therefore, the startpoint of the first event comes after the endpoint of the second event. That is, Tony’s bath as a whole precedes his meeting with Mary. Since E1 is after E2 its startpoint is after the endpoint of E2. In the example the first description has the aspect/tense representation FUT_INTERVAL_E1 where E1 denotes Tony’s meeting with Mary. The second sentence, on the other hand, has the present tense and the perfect usage and therefore its representation is PRES_POSTINTERVAL_E2. The example is represented as follows:

(FUT_INTERVAL_E1, PRES_POSTINTERVAL_E2), or (after E1 E2)

The guidelines for states in backward tense shifts differ from those for durative events. The following example illustrates an instance of backward tense shift involving a state.

4. Jack will go after a while. It is raining heavily.

The tense shift in this example is from future to present. The first sentence describes Jack’s departure from the location of the speaker (which is bound to take place in the future) while the second sentence describes the state of progress of a rainy situation. In this example
nothing can be assumed as far the endpoint of the interval corresponding to the rainy situation is concerned. It could still be raining, though not heavily at the time Jack decides to leave. It is clear from the tense change, however, that it started raining before Jack’s leaving since the second event is in progress at the speech time when the first event is yet to occur. Thus, when the second description in a backward tense shift characterizes a state we constrain only the startpoint of the interval associated with the state. Similarly, when the first description in a backward tense shift describes a state, only the endpoint of the interval associated with the state is constrained.

The following table summarizes the guidelines for modeling backward tense shifts.

<table>
<thead>
<tr>
<th>No</th>
<th>First Situation</th>
<th>Second Situation</th>
<th>Guideline</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Punctual (P1)</td>
<td>Punctual (P2)</td>
<td>P1 after P2</td>
</tr>
<tr>
<td>2</td>
<td>Durative (I)</td>
<td>Punctual (P)</td>
<td>startpt_I after P</td>
</tr>
<tr>
<td>3</td>
<td>State (I)</td>
<td>Punctual (P)</td>
<td>endpt_I after P</td>
</tr>
<tr>
<td>4</td>
<td>Punctual (P)</td>
<td>Durative (I)</td>
<td>P after endpt_I</td>
</tr>
<tr>
<td>5</td>
<td>State (I1)</td>
<td>Durative (I2)</td>
<td>endpt_I1 after endpt_I2</td>
</tr>
<tr>
<td>6</td>
<td>Durative (I1)</td>
<td>Durative (I2)</td>
<td>startpt_I1 after endpt_I2</td>
</tr>
<tr>
<td>7</td>
<td>Punctual (P)</td>
<td>State (I)</td>
<td>P after startpt_I</td>
</tr>
<tr>
<td>8</td>
<td>State (I1)</td>
<td>State (I2)</td>
<td>endpt_I1 after startpt_I2</td>
</tr>
<tr>
<td>9</td>
<td>Durative (I1)</td>
<td>State (I2)</td>
<td>startpt_I1 after startpt_I2</td>
</tr>
</tbody>
</table>

### 6.3. Default Sequencing

We now consider sequencing of situations underlying descriptions of the same tense. In such cases tense provides no information about the ordering of the situations involved. The aspect of each description is the sole determinant of sequence information. Two important guidelines that prove invaluable in such cases are **sequentiality** and **simultaneity**. As pointed out in the previous chapter, sequentiality can be of two types: delayed and immediate. Two situations are in delayed sequence if they have no temporal overlap and a finite gap separates the
endpoint of one situation from the startpoint of the other. Immediate sequentiality involves no gap between the situations. In other words, the second situation follows hot on the heels of the first one. Immediate sequentiality is usually encountered in cases where the situations are semantically related. The following example is an instance of immediate sequentiality between the two events.

5. The man hit the ball. It rolled on the grass.

In this example, the first event causes the second one. Both events occur in immediate sequence with the second event following the first one. Immediate sequentiality is also encountered in cases where a state results from or is terminated by an event. Some examples are:

6. Jack turned off the light. It was dark inside.
7. The bag was on the floor. Tom carried it to his study.

Example 6 indicates an event causing a state. In this case John's turning off the light results in the state of darkness of the room. Example 7 depicts an instance where the state of the bag being on the floor is terminated by Tom’s carrying the bag to his study. Since, any event of carrying an object involves lifting, the bag is no longer on the floor with the onset or beginning of the durative event described by the second sentence.

Before illustrating our guidelines for temporal sequencing in cases where the tense of the descriptions is the same, we need to define some terminology employed in these guidelines. The definitions are

1. **Agent set**: This is the set of subjects mentioned in a description. The subjects are essentially protagonists of the underlying situation.
II. **Entity set:** This is the set of all the entities participating in a situation. This set includes the agents of the situation.

For instance, the sentence *John went to the store* has the following agent and entity sets.

**Agent set:** {John}  
**Entity set:** {John, store}

Often in narratives, successive descriptions having the same tense and involving common agents report situations that occur in sequential order. For instance, consider the following discourse fragment consisting of two sentences.

8. *John went to the store. He bought a pair of shoes.*

Both descriptions in this fragment have the same tense (past) and agent (*John*). It is reasonable to expect that the two events described here occurred in sequential order with the motional event coming first. Writers of narratives frequently make use of such descriptions to report a sequence of situations from the perspective of a common agent or agents. There are certain cases, however, where sequentiality of the events is not necessarily the case albeit the descriptions have the same tense and agents. The example below is an instance where a sequential order of the situations is hard to conceive.

9. *Jack rested for a while. He was tired.*

This example involves two sentential descriptions the first of which describes a durative event (*Jack’s rest*) and the second an underlying state (*Jack’s state of tiredness*). It is clear that the event and state overlap in this case. Therefore, when a state description is involved sequentiality does not necessarily hold.
Sequencing an Event and a State

The following possibilities can arise when the sequencing of an event and a state is at issue.

I. Both the state and the event overlap

II. The event terminates the state

III. The state results from the event

The second and third possibilities are indicative of semantic dependencies between the event and the state. Semantic analysis is required to detect such dependencies. The first possibility can be regarded as the default when semantic analysis fails to relate the event and state. In other words, if we are unable to establish either case 2 or case 3 through semantic analysis, case 1 applies as the default. Since this research is concerned with a purely temporal analysis of narrative text we assume the existence of a system for semantic analysis that precedes default sequencing. If semantic analysis succeeds in establishing a relation between the event and state, default sequencing is bypassed. The default case is based on the simultaneity of the event and state. Given below is a table of guidelines for default sequencing an event and state.

<table>
<thead>
<tr>
<th>No</th>
<th>First Situation</th>
<th>Second Situation</th>
<th>Guideline</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>State (I)</td>
<td>Punctual (P)</td>
<td>I contains P</td>
</tr>
<tr>
<td>2</td>
<td>State (I1)</td>
<td>Durative (I2)</td>
<td>I1 overlaps I2</td>
</tr>
<tr>
<td>3</td>
<td>Punctual (P)</td>
<td>State (I)</td>
<td>P within I</td>
</tr>
<tr>
<td>4</td>
<td>Durative (I1)</td>
<td>State (I2)</td>
<td>I1 overlaps I2</td>
</tr>
</tbody>
</table>

In each case, both the event and state are simultaneous. Thus, given a punctual event and a state, the state holds at the instant of occurrence of the punctual event. As a result, the punctual event occurs while the state holds.

Some of the representations for an event description and a state description are:
1. (STARTPT_E1, INTERNAL_E2), or (starts-while E1 E2)
2. (INTERNAL_E1, ENDPTE2 ), or (contains-end E1 E2)
3. (INTERVAL_E1, INTERNAL_E2), or (overlaps E1 E2)

Since these representations accomplish temporal sequencing in cases where the descriptions have the same tense we have omitted the tense in presenting the representations since tense provides no temporal information. In the first two cases the point of punctual event occurrence is simultaneous with a time when the state holds. This time is internally within the interval associated with the state. The left side of each representation indicates the textual order of the event and state descriptions for the representation to match. For instance, the first representation matches when an initiative punctual event description and a state description appear in that order in the text. The punctual event marking the startpoint of E1 occurs while the state E2 holds. The last representation accomplishes the default sequencing of a durative event and a state encountered in that order in the text.

**Sequencing of states**

The default guideline for sequencing two states prescribes overlap between their associated intervals. In other words, the two states hold simultaneously. This is due to the fact that states hold until they are terminated by events. An example involving stative situations is:

10. The weather was humid. Jack was feeling sick.

We now consider the default temporal sequencing of two events. The following three possibilities can arise depending on the nature of the events underlying the descriptions involved.

1. Both events are durative
II. Both events are punctual

III. One of the events is punctual and the other durative

Sequencing of Durative Events

As pointed out earlier, the default rule of sequentiality is an important guideline especially in cases where both the events have common agents. Writers of narratives frequently make use of descriptions having common agents and tense to describe events occurring in sequential order. Thus, given two durative event descriptions that refer directly to their underlying durative events E1 and E2 we have the following representation based on the guideline of sequentiality.

\[(\text{INTERVAL}_E1, \text{INTERVAL}_E2), \text{ or (sequence E1 E2)}\]

The predicate sequence indicates that E2 either immediately follows E1 (in this case the endpoint of E1 coincides with the startpoint of E2) or follows E1 after a gap. Note that this representation applies only to cases where the durative events E1 and E2 have common agents. The following example illustrates such a case.

11. John went to the store. He bought a pair of shoes.

When the two durative events have no common agents (subjects) sequentiality of the events is not necessary although it is a possibility. In such cases, the two events can either overlap or occur in sequential order. The following examples show two durative event descriptions having no agents (subjects) in common.
12. John threw a big stone. It crashed into the window nearby.


In the first example the two events occur in sequence with the second event (the stone crashing into the window nearby) following the first event (John's throwing the stone). The second example, on the other hand, involves two durative events that overlap on time. Therefore, given two durative event descriptions of the same tense and having no agents in common, the events either overlap or occur in sequential order. In such cases the representation is

\[(\text{INTERVAL}_E1, \text{INTERVAL}_E2), \text{ or } (\text{overlaps-or-sequence } E1 \ E2)\]

The relation on the right denotes the set of interval-interval models that either involve overlap between the intervals or have the two intervals in sequence with E2 following E1.

**Sequencing of Punctual Events**

We now consider temporal sequencing of cases involving punctual events. Successive punctual events involving common agents occur in sequential order. Consider the following example which involves punctual events with the same agent John. The events occur in sequential order with the second event following the first one.

14. John reached his office. He started work immediately.

Therefore, given two punctual events occurring at point_1 and point_2 respectively, the sequentiaality between them can be expressed by the constraint: point_1 precedes-or-
coincides point_2. The first event of the above example is a terminative punctual event 
(reaching a destination signifies the end of a motion event toward the destination) while the 
second event is initiative. Hence, the intervals associated with the punctual events are in se-
queness. The following representation applies to this example.

(ENDPT_E1, STARTPT_E2), (sequence E1 E2)

When the punctual event descriptions have no agents in common, the sequencing of the 
events is considerably more complicated. The vagueness associated with such cases makes 
it difficult to infer precise temporal sequence information. Consider the following example, 
involving punctual events with no agents in common.

15. Jack started swimming. Mary left the house.

This example involves punctual events both of which initiate durative events. The first de-
scription in this example has an underlying punctual event that initiates John's swim. Simi-
larly, the second sentence describes a punctual event that initiates Mary's motion away from 
the house. The two punctual events can occur in all possible ways. For instance, the second 
event can either precede, follow or coincide with the first one. The relative ordering of the 
punctual events is therefore vague. Certainly, there is no basis for assuming sequentiality of 
the two punctual events although it is a possibility. Given the circumstances of this example, 
a more tenable interpretation would be that the durative events initiated by the punctual 
events overlap assuming that the two initiative punctual events occur in close proximity on a 
timeline. That is, the interval associated with Jack's swim overlaps with the interval associ-
ated with Mary's motion. The following example again illustrates two punctual events each 
of which terminates a durative event. The chronological order of the punctual events is un-
known but in all likelihood the durative events terminated by the punctual events overlap as-
suming the proximity of occurrence of the punctual events.
16. Tom reached the house. Anne finished cooking.

Therefore, when two initiative or two terminative punctual event descriptions with no agents in common are encountered, the punctual events are assumed to occur in some unknown order but in close temporal proximity of each other. The chronological ordering of the punctual events is vague but the durative events associated with the punctual events overlap given the fact that the punctual events occur in close proximity on the timeline. The following sequencing rules apply to successive punctual events of the same type (both initiative or both terminative) having no common agents.

\[(\text{START}_{E1}, \text{START}_{E2}), \text{or (overlaps } E1 \text{ E2)}\]
\[(\text{END}_{E1}, \text{END}_{E2}), \text{ or (overlaps } E1 \text{ E2)}\]

The previous two examples involved punctual events of the same type (both initiative or both terminative). The following example shows an initiative punctual event and a terminative punctual event having no agents in common.

17. Mary started cooking. Jack finished his homework.

This example is again vague about the order of the punctual events described. The second punctual event can precede, coincide or follow the first punctual event. Assuming that the two punctual events occur in close proximity, however, we can at least conclude that the durative event signified by *Mary’s cooking ends* only after the second punctual event.

From this analysis it is evident that when an initiative punctual event and a terminative punctual event having no agents in common are encountered, the punctual events are taken to occur in some unspecified order but the interval associated with the initiative punctual event ends only after the terminative punctual event based on the assumption of proximity of
occurrence of the punctual events. The above analysis yields the following rules for sequencing an initiative punctual event and a terminative punctual event having no agents in common.

(STARTPT_E1, ENDPT_E2 ), or (ends-after E1 E2)
(ENDPT_E1, STARTPT_E2), or (ends-before E1 E2)

Sequencing of a Punctual Event and a Durative Event

We now consider temporal sequencing in cases involving a punctual event description and a durative event description. As before, the guideline of sequentiality applies to events involving common agents. The following example depicts a punctual event description and a durative event description involving a common agent Tom.

18. Tom reached the house. He met Larry there.

The first description characterizes the culmination of Tom’s motional event to the mentioned house and therefore has the representation, ENDPT_E1 where E1 signifies the durative motional event. The second description has an underlying durative event: Tom’s meeting of Larry. This description has the representation, INTERVAL_E2 where E2 signifies the durative event. Thus, in this case the endpoint of E1 and the interval E2 are in sequential order with or without a gap separating the endpoint of E1 from the startpoint of E2. The representation is:

(ENDPT_E1, INTERVAL_E2), or (sequence E1 E2)
The sequentia1ity in this case can be expressed in terms of a point-point sequentia1ity between the endpoint of E1 and the startpoint of E2. This point-point sequentia1ity may be depicted by the following constraint: endpoint_E1 precedes-nr-coincides startpoint_E2.

We now pause to reconsider the definitions of sequentia1ity between a punctual event and a durative event outlined in connection with our discussion of when temporal connections in the previous chapter. When a punctual event is sequentia1ly followed by a durative event, the sequentia1ity can be defined as a point-point sequentia1ity between the punctual event and the startpoint of the durative event. Similarly, sequentia1ity between a durative event and a punctual event can be defined as a point-point sequentia1ity between the endpoint of the durative event and the punctual event. Some of the rules for default sequencing of a punctual event and a durative event having common agents are shown below. These rules are based on the above definitions.

\[(\text{STARTPT}_E1, \text{INTERVAL}_E2), \text{ or } (\text{simult-start-or-starts-before } E1 \ E2)\]
\[(\text{INTERVAL}_E1, \text{STARTPT}_E2), \text{ or } (\text{sequence } E1 \ E2)\]

When the punctual event and the durative event to be sequenced have no agents in common, the situation is complicated. Two cases arise depending on whether the punctual event description or the durative event description appears first in the text. Given below is an example involving a durative event description and a punctual event description having no agents in common. The durative event description appears first.

19. John went to the store. Mary started swimming.

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9 See page 99
This example illustrates a case where the durative event signified by John's going to the store either overlaps with or precedes Mary's swimming (initiated by the punctual event of the second sentence). Mary's swimming may or may not have started prior to John's motion to the store. It is highly unlikely that she finished swimming before the start of John's motion to the store. In other words, the endpoint of the interval associated with Mary's swimming cannot precede the startpoint of the interval corresponding to John's motion to the store. John's motion to the store should have at least started prior to the time Mary's swimming ended.

From the analysis of this example our guideline for sequencing a durative event and a punctual event appearing in that order in the text is that the interval corresponding to the durative event either overlaps or precedes the interval associated with the punctual event. From this guideline we have the following representations.

\[(\text{INTERVAL}_E1, \text{STARTPT}_E2), \text{or (overlap-or-sequence } E1 E2) \]
\[(\text{INTERVAL}_E1, \text{ENDPT}_E2 ), \text{or (overlap-or-sequence } E1 E2) \]

In the following example a punctual event description appears first and is followed by a durative event description in each case.

20. Tom reached the finish line first. The spectators applauded him.
21. Jack started studying for his exam. Anne cleaned the attic.

The first example illustrates a terminative punctual event Tom's reaching the finish line that is sequentially followed by the spectators' applause (regarded as a durative event). There is scope for uncertainty in this example. For instance, the spectators could have started applauding a split second before Tom's completion of the race. The only fact known for certain is that Tom completed the race before the spectators applause died out. In other words, the point corresponding to the terminative punctual event definitely precedes the endpoint of the
durative event described in the second sentence but may or may not precede the startpoint of the durative event.

The second example again illustrates a punctual event (marking the start of Jack’s study session) and a durative event (signified by Anne’s cleaning of the attic). In this example it is uncertain as to when Anne started cleaning in relation to the time Jack started studying for his exam. However, it is certain that Anne finished cleaning only some time after Jack started studying. If this were not the case we would use the past perfect rather than the simple past for the second sentence to convey that Anne’s cleaning finished prior to the time John started studying for his exam.

From this analysis we observe that when a punctual event description and a durative event description having no agents in common appear in that order in the source text, the punctual event is taken to occur before the durative event ends. The punctual event may or may not precede the start of the durative event. The following rules accomplish default sequencing of a punctual event and a durative event encountered in that order in the text.

\[
(\text{ENDPT}_E_1, \text{INTERVAL}_E_2), \text{ or } (\text{ends-before} \ E_1 \ E_2) \\
(\text{STARTPT}_E_1, \text{INTERVAL}_E_2), \text{ or } (\text{starts-before-end} \ E_1 \ E_2)
\]

**Descriptions with the Perfect usage**

Writers of narratives frequently make use of descriptions with the perfect usage to narrate an earlier sequence of events. Consider the following example in which the second and third sentences each have the perfect usage signifying a reference time after their underlying events.
Jack rested for a while.
He had broken a toe. He had bandaged it meticulously.

In this example the second and third sentences, which have the perfect usage, narrate events that occurred prior to the first event. Reichenbach [Elements of Symbolic Logic, 1947] postulates that descriptions with the perfect usage are employed to narrate events that happened earlier in relation to another event determined from the context. This event provides the point of reference relative to which the events underlying the perfect descriptions occur earlier. In the example above the first sentence provides the point of reference for the second and third sentences. The event of Jack breaking a toe precedes the time of his rest. The first sentence has the representation INTERVAL_E1 where E1 signifies Jack's rest while the second sentence has the representation POSTINTERVAL_E2 where E2 signifies Jack breaking a toe. The reference times of both sentences are simultaneous (in fact they coincide). As a result, E1 is after E2. The representation is:

(INTERVAL_E1, POSTINTERVAL_E2), or (after E1 E2)

The second and third sentences are treated in the same manner as the simple past descriptions of the following example as far as sequencing is concerned.

Jack broke a toe. He bandaged it meticulously.

The guidelines for durative events apply to both past perfect sentences. Both these sentences have the agent Jack in common and as a result their events occur in sequential order with the second event occurring before the third. Both these sentences have the representation POSTINTERVAL. The representation for such cases is:
(POSTINTERVAL_E1, POSTINTERVAL_E2), or (sequence E1 E2)

The label E1 denotes Jack's breaking a toe while the label E2 denotes his bandaging the injured toe.

Successive sentences with the perfect usage describing durative events with no agents in common are sequenced by the following representation:

(POSTINTERVAL_E1, POSTINTERVAL_E2), or (overlap-or-sequence E1 E2)

The following representations are all based on the guideline of simultaneous reference times.

(STARTPT_E1, POSTENDPT_E2), or (after E1 E2)
(ENDPT_E1, POSTSTARTPT_E2), or (starts-after E1 E2)

The first representation states that the startpoint of E1 (as indicated by the aspect STARTPT_E1) is simultaneous with a time after the endpoint of E2 (as indicated by the aspect POSTENDPT_E2). Hence, it is a straightforward observation that E1 is after E2. Similarly, the second representation states that the endpoint of interval E1 is simultaneous with a time after the startpoint of E2. Hence, in this case E1 ends after E2 starts.
6.4. Implementation

The sequencing of tense shifts and default cases have been implemented as Prolog inference rules in our system. These inference rules are triggered by the aspect/tense representations of the descriptions involved. The format of these rules are

\[(\text{aspect-tense-table} \ \ \text{eventlabel1 aspecttense1} \ \ \text{eventlabel2 aspecttense2} \ \ \text{temporalrelation})\]

The rules may be pictured in the form of a two dimensional table called the \text{aspect-tense-table} as indicated above. The indices of this table are the aspect/tense representations of the descriptions to be sequenced. The significance of the arguments in this list are as follows:

I. The argument \text{aspecttense1} denotes the aspect/tense representation of the first description while \text{aspecttense2} denotes the aspect/tense representation of the second description.

II. The arguments \text{eventlabel1} and \text{eventlabel2} are the labels of the associated situations. The symbol \text{eventlabel1} corresponds to the the first description while the argument \text{eventlabel2} corresponds to the second description.

III. The argument \text{temporalrelation} signifies the resultant temporal relation between \text{eventlabel1} and \text{eventlabel2}.

Information about individual events in the text is maintained as a database of facts in the following format:

\[(\text{EVENT-FRAME} \ \ \text{eventlabel aspecttense agentset entityset})\]

There are other arguments besides those mentioned above. Complete details of the arguments of an event frame will be specified in the next chapter. Information about individual
events is essentially stored in frames called EVENT FRAMES. The following items explain the significance of the arguments in an event frame.

I. The argument eventlabel is the label used for accessing the corresponding frame. This field is a primary key that uniquely identifies the frame corresponding to the event signified by it.

II. The argument aspecttense is the aspect/tense representation of the description corresponding to the event.

III. The agent set consists of the protagonists or subjects of the event signified by eventlabel.

IV. The argument entityset is the set of entities involved in the event.

We now illustrate the workings of the default mechanism with an example. Consider the following discourse consisting of two sentences each of which describes an event.

22. The burglar opened the door. He walked into the room cautiously.

Both sentences of the above discourse describe underlying durative events having the agent signified by the burglar in common. The default rule of sequentiality applies to this case. Let us denote the two events by the labels E1 and E2 respectively. A snapshot of the frames associated with the two events are:

(EVENT-FRAME E1 PAST_INTERVAL {burglar} {burglar door})

(EVENT-FRAME E2 PAST_INTERVAL {burglar} {burglar room})

Both sentences have the aspect/tense representation PAST_INTERVAL. The agent set in both cases is {burglar} while the entity sets are {burglar door} and {burglar room} respectively.
The *aspect-tense-table* is accessed at the entry signified by (PAST_INTERVAL, PAST_INTERVAL).

((aspect-tense-table "elabel1" PAST_INTERVAL "elabel2" PAST_INTERVAL sequence)

if ((get-entities-and-agents "elabel1" "entityset1" "agentset1")
 (get-entities-and-agents "elabel1" "entityset2" "agentset2")
 (intersect "agentset1" "agentset2" "intersection")
 (not-empty "intersection"))

The arguments preceded by * denote Prolog variables. This rule is tried when two descriptions with the aspect/tense representations PAST_INTERVAL have to be sequenced. The relation sequence is asserted between *elabel1* and *elabel2* if this rule succeeds. For the rule to succeed the events must have common agents. The rule get-entities-and-agents accesses the event frame corresponding to its first argument (the label elabel1 or elabel2) for the agents and entities stored in the frame. The rule identified by the predicate intersect computes the intersection of the agent sets to determine if there are any agents common to the two events. Finally, the rule identified by the predicate non-empty checks to see whether the intersection of the agent sets (*intersection*) is empty. This rule succeeds only if the intersection of the agent sets is non-empty (thereby indicating common agents between the events).
6.5. A Discussion of Semantic Analysis

Although this research is concerned with a purely temporal analysis of narrative text, we give a sketchy outline of semantic inferencing through the analysis of a few examples. Our first example is:

23. It was dark inside the room. John turned on the light.

The first sentence in this fragment describes the state of darkness of the room. The second sentence describes an event that terminates this state. The semantic information conveyed by the first sentence can be factually expressed as:

\[(\text{STATE} \quad \text{room} \quad \text{dark})\]

The first argument \text{STATE} signifies that the predicate is a state. The second argument \text{room} signifies the agent whose state is at issue. The third argument \text{dark} conveys information about the state. The second description in the above fragment signifies an event that terminates the state. The information about the event is expressed as:

\[(\text{EVENT} \quad \text{turn-on} \quad \text{John} \quad \text{Light})\]

The argument \text{turn-on} indicates the event. The second argument \text{John} indicates the agent of the event. The last argument \text{Light} indicates the affected entity. The following rules roughly sketch out the chain of inferencing involved in this example.
(EVENT turn-on John Light) ----> (STATE Light on)

(STATE Light on) ----> (STATE room lit)

These rules accomplish semantic inferencing by deriving consequent states. The first rule derives the consequent state of the event signified on the left hand side. The argument Light signifies the entity whose state is at issue. This state is depicted on the right hand side. The second inference states that if the light is on the room containing the lighting apparatus (lamp, bulb etc.) becomes lit. This contradicts the initial state of darkness of the room. From this we can reach the conclusion that the event underlying the second sentence terminates the state described by the first. The next example illustrates an event causing another.

24. Jack hit the ball. It rolled on the grass.

This example shows a cause-effect relationship between two events. Jack’s hitting the ball sets it in motion. The second event describes this resultant motion of the ball. The chain of inferencing in this case is depicted below.

(EVENT hit Jack ball) ----> (EVENT motion ball grass)

Since rolling of the ball is a form of motion we can infer that the ball motion results from Jack’s hitting. Our last example follows.

25. I placed the key under the doormat. Somebody stole it.

The first event in this example results in the key being under the doormat. The second event results in the key not being there. From the change of state we can infer that the act of stealing the key occurs after the first event.
6.6. Summary

In this chapter we investigated cases where both tense and aspect are significant in temporal sequencing. The notions of overlap and sequentiality are invaluable guidelines specifically in cases involving default sequencing.
7 TEMPORAL FOCUS

7.1. Introduction

In the last two chapters we investigated common linguistic sources of temporal information. Our approach to modelling these mechanisms is based on tables of representations triggered by the aspect/tense of descriptions. This chapter discusses the implementation of a procedure to control the processing of a narrative and prescribing temporal relations between the situations described. Central to this procedure is the notion of temporal focus introduced in Chapter 3. This notion is of considerable significance in keeping track of the narrative time (its now point) as reading progresses. We now investigate the notion of temporal focus in detail before discussing its implementation in our system.
7.2. Temporal Focus

Associated with a narrative at any given point is a notion of narrative time often called the *now time* (now point) in discourse terminology. The process of reading a narrative involves keeping track of the *now point* as the narrative unfolds. At any given stage, the now point offers a localized temporal view of the narrative.

At the conceptual level, the process of reading involves the construction of a time model for the narrative from the situations encountered in the text. This conceptual model evolves incrementally with the processing of each incoming narrative description. At any given stage in the conceptual processing, there is a single situation that symbolically characterizes the localized temporal view or the now point of the narrative. In other words, this situation is the temporal focus at that stage. Temporal movements of the now point are symbolized by shifts of the temporal focus as reading progresses. The conceptual process of reading consists of steps each of which involves an incoming situation that is processed with respect to only the temporal focus at that stage. After each processing step, the conceptual time model is modified by the information gained and the temporal focus updated for the next processing step. The temporal focus may or may not change after a processing step depending upon whether or not the incoming situation indicates a shift of the now point. Prior to the first processing step, there is an initial setup phase during which the first situation in the narrative is made the *initial temporal focus*. From this point onward processing is done in steps each involving the next situation in the text and the temporal focus at that stage. In short, the notion of temporal focus guides the processing at the conceptual level. As explained above the phases of the conceptual process are

1. Processing the description of a new situation relative to the existing temporal focus.

7 TEMPORAL FOCUS
II. Updating the temporal focus in case the now point shifts.

The phases indicated above constitute the basis for implementing the conceptual process. We now discuss each phase of the conceptual process in detail. Examples are used appropriately to give a better understanding of the concepts.

7.2.1. Processing Phase

The processing phase involves determining how an incoming situation relates temporally to the existing temporal focus. This phase essentially involves checks for explicit indicators of sequence information concerning the existing temporal focus and the incoming situation. In the absence of any such information, default sequencing is applied. The following checks are made in the processing phase.

I. Check for a temporal connection involving the description corresponding to the temporal focus and the incoming description.
II. Check for indications of time shift or displacement.
III. Check for indications of tense shift.

These checks are performed in that order for each incoming situation. Associated with each check is an action performed in case that check succeeds. Thus, in the event of a temporal connection between an incoming narrative description and the description corresponding to the temporal focus, the action involves accessing the table that corresponds to the temporal connector by using the aspects of the two descriptions. The temporal relation obtained from the table is asserted between the temporal focus and the incoming situation. The relations asserted in the processing phase express the chronological information obtained from the narrative. These relations are converted into timeline assertions as will be described in the next chapter.
Consider the following short discourse fragment consisting of two descriptions connected by the temporal adverbial *while*.

John went to the store while Mary was asleep.

The first description (also the main clause of the connection) has an underlying durative event treated as a whole while the second description (the subordinate clause of the connection) has an underlying state. The aspects of the two descriptions are INTERVAL_E1 and INTERNAL_E2 with E1 signifying *John's going to the store* and E2 signifying *Mary's being asleep*. As before, we affix the labels of the underlying situations to the aspects of the descriptions. The initial temporal focus for this example fragment is the durative event, E1. The next situation in our example is the state E2 which is processed with respect to E1. Since there is a temporal adverbial connecting the descriptions corresponding to E1 and E2, the check for a temporal connection succeeds. As a result, the table corresponding to the connector *while* is indexed at the entry indicated by the aspects (INTERVAL, INTERNAL) of the two descriptions. The relation obtained from that entry is asserted: (overlaps E1 E2). Note that indexing of the table corresponding to a temporal connector requires a pair of aspects, the first of which is the aspect of the main clause of the connection and the second the aspect of the subordinate clause. If the temporal connection in our example had instead been the following with the order of the descriptions transposed we essentially would have the same scenario.

While Mary was asleep, Jack went to the store.

The state description appears first in this case and has the aspect INTERNAL_E1 with E1 signifying the state of *Mary being asleep*. The durative event description has the aspect INTERVAL_E2 with E2 signifying *Jack's going to the store*. The initial temporal focus is the state, E1. The second description is processed with respect to E1. Note here that E1 is the subordinate clause situation while E2 is the main clause situation. As in the previous case
access is made to the same entry (INTERVAL, INTERNAL) of the table for while. In this case
the relation asserted is: \( \text{overlaps E2 E1} \). Note the transposition of the labels in this case.

If the incoming situation indicates a time displacement with respect to the temporal focus, the
now point shifts in certain cases. The following example is an instance of time displacement.

Larry bought a pair of swimming trunks. Later he went to the pool.

In this example the lexeme later signals an advancement of narrative time from the time of the
first event to the time of the second. Because of this advancement, the first event occurs be-
fore the second. The first event is the initial temporal focus (initial now point) with respect to
which the second event is analyzed. The lexeme later behaves exactly like the temporal
connector after in terms of sequencing the two situations. As pointed out in Chapter 5 in-
stances of forward time displacement signalled by adverbials such as later can be treated in
the same manner as temporal connections involving the adverbial after. Thus, the above ex-
ample is equivalent to the temporal connection Larry went to the pool after he bought a pair
of swimming trunks and is evaluated by accessing the table for the after temporal connector.
The relation asserted in this case is: \( \text{after E2 E1} \). Here E1 and E2 signify the events
underlying the two descriptions. Sometimes the time displacement also indicates a measure
as in phrases like two days later. In such cases a time displacement list consisting of signed
integers (sign indicating direction of displacement and magnitude indicating measure) is cre-
ated as the sentence is parsed. This list has the following format:

\[ \text{[seconds minutes hours days months years]} \]

The components of this list are signed integers indicating both direction as well as magnitude
of displacement. The following example is an instance of such a displacement.
Jack had an intensive practice session.

Two days later he played in the soccer match.

The phrase *two days later* in this case indicates now time displacement. In the case of time displacement with a measure we do not assert the usual temporal relations. Instead we generate the following code.

(tim_displacement E1 E2 [unk unk unk +2 unk unk])

This relation indicates the time displacement between E1 and E2. The last argument of this predicate gives information about the measure and direction of displacement. In the next chapter we shall discuss the conversion of the information in this list into constraints on points and intervals. The entries *unk* in the time displacement list signify that the corresponding components are not specified (unknown) by the time displacement. The integer +2 corresponding to the day entry signifies that the event E2 occurred two days later in relation to E1.

When an incoming description indicates a tense shift relative to the description that established the current temporal focus, we index the aspect-tense table for the temporal relation. Recall from Chapter 6 that this table is indexed by the aspect/tense representations of the descriptions. Thus, in the following example

Jack told Nancy over the phone that he would meet her at the art gallery.

The first event description has the past tense while the second one has the future tense (the auxiliary *would* signifies the future tense). Both descriptions have underlying durative events that are referred to directly. Therefore, both descriptions have the same aspect INTERVAL. The relation in this case is obtained from the entry (PAST_INTERVAL, FUT_INTERVAL) of the
aspect-tense table. In the case of a tense shift between the temporal focus and the incoming event, the temporal focus remains unchanged since there are no indications of a now point shift. The first event in this example provides the utterance time for the second. The future tense of the second description merely relates the time of the second event to the utterance time.

It is interesting to note that the now point does not shift if the incoming description exhibits both a time displacement and a tense shift with respect to the current temporal focus as can be seen in the following example.

The burglar was scared that he would be proven guilty at the hearing the next day.

The time focus remains at the time of the state signified by the burglar being scared. The second description in the modal future does not shift the focus although it contains a time displacement phrase the next day.

In the absence of explicit indicators between the incoming situation and the current temporal focus, the aspect-tense table is accessed for default relations. Recall from Chapter 6 that default relations are stored in the aspect-tense table and are prescribed in cases where other indicators of temporal sequence information are missing. These are the most frequent cases in narratives. The now point shifts in cases where the temporal focus and the incoming situation occur in sequential order. The following example is an instance where the now point shifts from the first event to the second following the sequential movement.

Larry took the bus to school. He attended his Math class for the first time.
In this example both events have the same agent Larry and occur in sequential order. The first event is the initial temporal focus (initial now point). The processing of the second event relative to this temporal focus involves default sequencing because of the lack of explicit indicators of sequence information between the two events. The second event becomes the new temporal focus following the sequential shift of the now point. Denoting the first event by E1 and the second event by E2 we assert the temporal relation: (sequence E1 E2). The temporal focus does not shift in the following example.

Jack walked to the bus stand. Larry accompanied him.

The second event with Larry as the protagonist does not indicate a shift of the now point. The first event remains the temporal focus after processing the second event.

7.2.2. Updating the Focus

This is the final phase of each processing step. This phase involves updating the temporal focus after processing an incoming situation. The temporal focus is changed to the incoming situation only if there are indications of a shift in the now point. Our system uses the following guidelines for updating the focus.

I. The now point shifts to the incoming event when the current temporal focus and the incoming situation occur in sequential order. This is the usual forward movement of a narrative.

II. Temporal connections relate the time of their main clause situation to the time of their subordinate clause situation. They provide no indications of shifts in the now point. They merely indicate the relative position of the main clause situation with respect to the subordinate clause situation. Hence, the focus remains un-
changed when the incoming description and the description corresponding to the temporal focus are connected by a temporal adverbial.

III. If the incoming description indicates a tense change with respect to the description corresponding to the existing temporal focus, the focus does not change since tense changes do not shift the now point. They merely indicate the relative positioning of the two events involved in the tense change.

IV. If the incoming description indicates a time displacement relative to the description that established the current temporal focus, the focus shifts only when there is no accompanying tense change.

7.2.3. Focus Selection

When the incoming situation does not indicate a shift in the now point (temporal focus does not change) it sets an alternate focus (alternate now point) for the next situation in the text. Consider the following example where after processing the second description no focus shift is indicated.

Mary was asleep. Trevor went to the coffee shop. He had breakfast.

Here, the first situation (a state denoted by E1) is the initial temporal focus. The second event (Trevor’s trip to the coffee shop denoted by E2) overlaps with the state but indicates no shift of the now point. Therefore, this event becomes an alternate focus for the next event in the fragment. There are two candidate foci one of which textually precedes the incoming situation. A selection must be made between the candidates in order to determine the temporal focus for the incoming situation before processing it. The selection is based on the extent of linkage between the incoming situation and each of the candidates. Each candidate binds with the
incoming situation to a different degree. The binding between two situations is strongest when there is a semantic link between them.

Our system employs heuristics for selecting between candidates for temporal focus. One of these heuristics is based on the observation that textually adjacent descriptions (of the same tense) involving common agents report situations from the perspective of the agents involved in them. Thus, when the textually preceding candidate has a common agent with the incoming situation, it is made the temporal focus provided that candidate is not a state. States, in general, do not cause the now point to shift. They merely hold at the time of the current temporal focus. Thus, when the preceding candidate is a state, the previous temporal focus is retained by default.

Another heuristic is based on the intuition that the number of entities that each candidate situation has in common with the incoming situation is an indicator of its binding with the incoming situation. Accordingly, the candidate with the larger number of entities in common with the incoming situation is selected as the temporal focus on the basis of stronger entity binding. In the event of a tie between the two candidates (each having at least one entity in common with the incoming situation), the most recent candidate is made the temporal focus based on the assumption that textual proximity is a measure of the binding between situations. If the textually preceding candidate is a state, the previous temporal focus is retained.

Applying these heuristics to the example above we observe that the third event (Trevor having breakfast) has the agent Trevor in common with the second event but no entities in common with the state described in the first sentence. Hence, the third event binds more tightly with the second event than with the state. The second event E2 is made the temporal focus for processing E3.

The processing of these two events involves access to the aspect-tense table for the default relation due to the lack of an explicit indicator of sequence information. The descriptions
corresponding to E2 and E3 have the aspect/tense representations PAST\_INTERVAL\_E2 and PAST\_INTERVAL\_E3 respectively. The table is therefore accessed using the key (PAST\_INTERVAL, PAST\_INTERVAL) and the relation obtained from the entry is asserted between the two events. The following relations are asserted:

I. (overlaps E1 E2)

II. (sequence E2 E3)

The following example also involves two candidate foci prior to the processing of the fourth event.

The cobra raised its hood and struck the boy on his right ankle. He collapsed on the floor. The cobra slithered into the bushes.

This discourse involves the following events.

I. E1 : The cobra raising its hood.

II. E2 : The cobra striking the boy on his right ankle.

III. E3 : The boy’s collapse to the floor.

IV. E4 : The cobra slithering into the bushes.

All of these events are durative. The corresponding descriptions have the past tense and the aspect INTERVAL. As before, the first event is the initial temporal focus. The initial configuration is

TEMPORAL FOCUS :- E1 INCOMING EVENT :- E2
The first processing step involves E2 as the incoming event. Since both E1 and E2 have the same agent *the cobra*, sequestiality applies between them. E2 follows E1 and therefore becomes the new temporal focus. The incoming event for the next processing step is E3. The processing of these two events involves access to the aspect-tense table for the default relation because of the lack of explicit sequencing between the two events. Since E2 and E3 have different agents, both overlap and sequentiality are possible according to the default. The default relation between E2 and E3 is *(overlap-or-sequence E2 E3)*. Because of the semantic relationship between E2 and E3 it is evident that E3 sequentially follows E2. The overlap models are therefore redundant in this case. The temporal focus is, however, not shifted to E3 after processing since we cannot ascertain sequentiality (sequentiality is a possibility according to the default) based on the default relation (since according to it both overlap and sequentiality are possible in this case). As a result, E2 is retained as the temporal focus with E3 becoming an alternate focus for the next event E4. In other words, there are two candidates for temporal focus at this stage. We do not shift the temporal focus in cases where sequentiality cannot be ascertained from the default relation. The configuration after processing E3 is as follows.

\[
\text{CANDIDATE}_1 := E2 \quad \text{CANDIDATE}_2 := E3
\]

\[
\text{INCOMING EVENT} := E4
\]

A selection has to be made between these candidates to determine the temporal focus for processing E4. Applying our selection heuristics, we observe that E4 has the same agent as E2 but no entities in common with E3. Hence, E2 remains the temporal focus on the basis of stronger entity binding with E4. Now the configuration is

\[
\text{TEMPORAL FOCUS} := E2 \quad \text{INCOMING EVENT} := E4
\]

7 TEMPORAL FOCUS
The processing of E2 and E4 involves access to the aspect-tense table due to the lack of explicit sequencing between them. Since both these events have the same agent, sequentiality is the default relation. This relation is asserted as follows: \((\text{sequence} \ E2 \ E4)\). E4 becomes the new temporal focus at the end of this processing step following the sequential shift from E2 to E4.

When all of the heuristics fail to select a candidate, the previous temporal focus is retained.

Recall that temporal connections position their main clause situation relative to their subordinate clause situation. Hence, if the incoming situation is involved in a temporal connection that has one of the candidates as the subordinate clause situation then that candidate becomes the temporal focus, as in the following example:

Tom was climbing the mango tree. When he spotted a monkey, he was taken by surprise.

In this example there are two candidates prior to processing the third situation (the now point does not shift from the state underlying the first description to the event underlying the second description). The second event is selected as the temporal focus since it is the subordinate clause event of the \textit{when} connection and thereby provides the point of reference for positioning the incoming event (the main clause situation in this case).

Gerunds are descriptions involving a main verb marked by the progressive -ing suffix. Therefore, gerunds can be interpreted as descriptions of ongoing events. Some examples of gerunds are illustrated in the following sentences.

I. Tom went into the room carrying a knapsack.
II. Walking toward the door, she picked a club.
The gerund of the first example, *carrying a knapsack*, appears at the end and describes an event ongoing simultaneously with *Tom’s motion into the room* (*Tom’s motion* provides the reference point for positioning the event underlying the gerund). The gerund of the second example, *walking toward the door*, appears at the beginning and describes an ongoing durative event that provides the reference point for positioning the event of *picking a club* on the timeline. When a gerund appears at the beginning of a sentence, its event becomes the temporal focus (provides the reference point) for processing the next event. Therefore, in the second example the event of *walking toward the door* is selected as the temporal focus for processing the next event.

Sometimes, tense can provide indications of the extent of temporal binding between the incoming situation and the candidates for focus. In the following example we judge the third event to have a stronger binding with the first event (both these events have descriptions with the past tense) than with the second.

Tom promised Sue that he would get some flowers for her.

He took a cab to the market.

There is no shift of focus from the first event to the second because of the tense change. As a result, there are two candidates for temporal focus prior to processing the third event. The first event is selected as the temporal focus based on the tense of its description being the same as that of the incoming description.

The six heuristics for selecting between candidate foci are applied in the following order until one of them succeeds.

I. Selection based on tense
II. Selection based on temporal connection
III. Selection of gerund
IV. Selection based on common agents
V. Selection based on number of entities
VI. Selection of previous temporal focus by default

The last heuristic applies as a default when none of the previous ones succeed.

The examples given above provide a broad perspective of the processing of narrative fragments using the notion of temporal focus. This concludes our discussion of the phases in the conceptual processing of a narrative. We now discuss the internal representation of the information contained in a narrative description.

7.3. Event Frames

In Chapter 6 we pointed out that information about individual events is maintained in the form of event frames accessed by the predicate event-frames. Also recall from Chapter 4 how each surface level sentence is parsed into a meaning form (essentially a semantic net) that expresses the information contained in the sentence. We will now discuss the processing of the meaning structures into frames corresponding to the events in the sentences. Consider the following example sentence: Tom reached Chicago two days ago. This sentence describes a terminative punctual event marking the end of the durative event signified by Tom’s trip to Chicago (denoted by E1). The sentence has the past tense and the aspect ENDPT since it refers directly to its terminative punctual event. This sentence also includes a time phrase two days ago indicating the time of the punctual event relative to the utterance time. The sentence is parsed into the following meaning structure.

10 See page 136.
Nested within the meaning form is an event fragment that contains information pertaining to the event described by the sentence: the label \( E1 \) associated with the event, the aspect/tense representation PAST_ENDPT, the entities involved in the event (Tom, Chicago), the semantic primitive corresponding to the event, etc. The time phrase \textit{two days ago} is parsed into the six argument list within ABSTRACTFRAGMENT.

A program to convert this meaning form into an event frame has been implemented as part of our system. The meaning structures are essentially converted into EVENT FRAMES. The following list of arguments specifies an event frame.

\[
\text{(EVENT-FRAME} \quad \text{label primitive situation-type agents}} \\
\text{entities aspect-tense time-displacement)}
\]

The arguments are explained as follows.

I. \textit{label} serves to identify the event described by the sentence.

II. \textit{primitive} is the semantic primitive of the event described by the sentence.

III. \textit{situation-type} indicates the type of the event described by the sentence. This argument can be one of the following: \textit{Initiative}, \textit{Terminative}, \textit{Durative}, \textit{State} and \textit{Momentary}

IV. \textit{agents} is the set of actors or protagonists involved in the event.
V. *entities* is the set of entities participating in the event. This includes the agents (subjects) of the event.

VI. *aspect-tense* is the aspect/tense representation of the original input sentence.

VII. *time-displacement* indicates the details of time displacement if specified in the input sentence. In the absence of a time displacement adverbial (such as later) or phrase (such as two days later) in the input sentence, this argument is set to *nil* indicating no time displacement.

With the EVENT-FRAMES completely specified, we now address a pertinent issue that arises in the processing of a narrative.

### 7.4. Coreference

Every narrative description has an underlying situation characterized in part or as a whole by it. For instance, the description *John was swimming* characterizes an internal (progressive) phase of its underlying event. Similarly, the sentence *the manager had dinner at a seafood restaurant* characterizes its underlying durative event as a single whole. At times, multiple narrative descriptions characterize different phases (essentially aspects) or parts of the same durative event. Consider the example below.

John ran to the store. He reached there in a short while.

The EVENT-FRAMES for the sentences in the above narrative are:
(EVENT-FRAME E1 MOTION DURATIVE { John } { John store } PAST_INTERVAL nil)

(EVENT-FRAME E2 MOTION TERMINATIVE { John } { John store } PAST_ENDPT nil)

The first description has an underlying durative event E1 that is characterized as a single whole. Hence, this description has the aspect INTERVAL. The second description, on the other hand, has an underlying terminative punctual event that marks the end of a durative motion event denoted by E2 (in the second event frame). Therefore, the second description has the aspect ENDPT. It is clear that in this fragment the labels E1 and E2 signify the same durative event, viz., John's motion to the store. The second sentence refers to the end of the durative event described by the first sentence. Since each sentence is parsed separately, different labels get associated with their corresponding event fragments.

The link between E1 and E2 is established by asserting the following relation between E1 and E2: (same-event E1 E2). The predicate same-event indicates that the labels E1 and E2 denote the same interval (interval of the associated durative event). Both sentences of this narrative have the same agent John and the primitives corresponding to their events are also the same viz., MOTION. Both sentences are in the past tense. The only distinction is in their aspects (the first sentence has the aspect INTERVAL while the second has the aspect ENDPT).

When successive sentences of the same tense and agents describe events of the same primitive form (MOTION in this example), there is a possibility that they corefer.

Our system employs heuristics based on the commonality of agents and event primitives to detect coreference. These heuristics are not, however, always guaranteed to succeed. The heuristics operate by performing the following comparisons.
I. **Comparison of Agents**: If this comparison fails we are certain that there is no coreference between the descriptions.

II. **Comparison of Event Primitives**: This comparison is attempted only when the previous comparison succeeds. If the primitives corresponding to the events are not the same there can be no coreference.

The heuristic checks for coreference are tried before prescribing a default relation between the temporal focus and the incoming event.

### 7.5. Summary

In this chapter we discussed the implementation of a procedure for deriving temporal relations between narrative situations. This procedure uses the concept of temporal focus for maintaining a localized temporal view of the narrative at any given stage. Processing of the narrative is accomplished through a series of steps each involving two phases: the processing phase and the focus update phase. At times, the processing phase is preceded by a selection of the temporal focus for the processing step.
8 THE TIMELINE MODEL

8.1. Introduction

So far our efforts have mainly focused on the high-level processing of narrative situations. This processing involves the extraction and assertion of temporal information (in the form of temporal relations between narrative situations) obtained from the source text. This chapter illustrates the final aspects of the design of our system for timeline representation. The process of converting temporal information derived from the source text to positional constraints between situations in the timeline representation is discussed.

8.2. The Timeline System

The process of deriving additional inferences from existing relations involves transitivity and other inferential mechanisms. These mechanisms have been implemented as a system by Hostetter (Jan. 1990). This system allows the creation of timeline models for narrative fragments from the object code (temporal relations and time displacement) generated by our
system as a result of processing the text. An interface to access the rules of the timeline system has been programmed. This interface translates the object code generated by our system into assertions suitable for constructing a timeline representation for a given narrative fragment.

8.3. Definition of Timeline Representations

The timeline system expects input in the form of intervals and points constrained by positional relations. It provides for primitive rules (programmed as Prolog rules within the system) to facilitate input definition in an expected format. The following are the primitive rules for defining input.

(make_interval INTERVAL STARTPOINT ENDPOINT)

(make_point POINT)

The first of these primitives make_interval defines an interval designated by the label INTERVAL (first argument). The second and third arguments are labels designating the startpoint and endpoint of INTERVAL. The second primitive make_point allows the definition of a point designated by the label POINT. Once an interval is defined, its size (or duration) can be asserted if known by means of the following rule.

(make_linked STARTPT ENDPT duration)

The last argument duration is a positive measure specifying a numeric constraint between STARTPT and ENDPT.
The intervals and points defined by these primitives are internally maintained as Prolog facts within the timeline system. The system allows the retrieval of the intervals and points previously defined by make_interval calls. The following rule enables the retrieval of an interval given its label Elabel.

\[(\text{get\_interval Elabel startpt endpt duration})\]

The arguments startpt and endpt are the labels corresponding to the startpoint and endpoint of Elabel. The argument duration indicates the durational extent of the interval (distance between startpoint and endpoint) in case it is known.

Recall from Chapter 7 that information about individual situations is maintained as EVENT-FRAMES within our system. Associated with each frame is a unique label that also serves the purpose of a primary key for accessing the corresponding event frame. To illustrate with an example, consider the following description and its event frame.

George started running.

\[(\text{EVENT-FRAME E1 MOTION INITIATIVE \{George\} \{George\}}
\begin{align*}
\text{PAST\_STARTPT} & \text{ nil})
\end{align*}\]

As indicated by the aspect/tense representation PAST\_STARTPT, this description has an underlying initiative punctual event that marks the start of George's running. The label E1 provides access to the above frame. Since the labels associated with event frames are unique, they may also be used to denote timeline intervals associated with the situations represented by the frames. In the case of a punctual event, the label in its corresponding event frame signifies the interval started or ended by the punctual event. Recall that punctual events occur at the startpoints or endpoints of intervals corresponding to durative situations. Thus, following our annotation scheme the aspect in the above frame would be STARTPT\_E1.
The first step in the process of building a timeline representation is to create timeline intervals for each of the labels associated with event frames. This is accomplished by make_interval calls to the timeline system. Prior to each call, labels have to be defined for the startpoint and endpoint as these labels are required as arguments for the make_interval call. To give an example let us consider the definition of a timeline interval for the label E1 of the above example. We begin by generating labels for the startpoint and endpoint of the interval to be defined. The label E1 designates the timeline interval. The Prolog primitive function gensym allows the dynamic creation of labels. This sytem function always returns a unique label not already in use within the system. Invocations to this function are made as follows.

I. (gensym *startpt)

II. (gensym *endpt)

The arguments marked by asterisks are Prolog variables that are instantiated with unique labels by the calls to gensym. Having created labels for the startpoint and endpoint of E1, we define the interval for E1 by a make_interval call to the timeline system as shown below.

(make_interval E1 *startpt *endpt)

This call defines an interval denoted by E1 with the values of *startpt and *endpt designating the start and end of the interval. Internally, make_interval imposes the constraint: *startpt precedes *endpt (constraint for an interval). The above set of calls define the interval for E1.

The next step in the construction of a timeline representation for a narrative fragment is the translation of the object code generated by our system into positional constraints on the intervals and points defined by make_interval calls.
8.4. Translation of Object Code

Recall from Chapter 7 that our system generates temporal information in the form of temporal relations and time-displacements between labels. We now discuss the translation of this object code into timeline assertions (essentially positional constraints on timeline intervals and points).

The timeline system accommodates the input of temporal relations in the form of positional constraints that are primarily of two types: point-to-point constraints, interval-to-interval constraints.

8.4.1. Point-to-Point Constraints

Any two points can be constrained by three positional relationships input into the timeline system by means of calls to Prolog rules within the system. These rules are depicted below.

\[
\begin{align*}
(m&ake\_less \quad point\_1 \quad point\_2) \\
(m&ake\_equal \quad point\_1 \quad point\_2) \\
(m&ake\_greater \quad point\_1 \quad point\_2)
\end{align*}
\]

The first rule \texttt{make_less} imposes the constraint: \texttt{point\_1 before point\_2}. Likewise, \texttt{make_equal} imposes the constraint: \texttt{point\_1 equal point\_2}. Finally, \texttt{make_greater} imposes the constraint: \texttt{point\_1 after point\_2}. These constraints are analogous to numeric relations such as (\texttt{<}, \texttt{>}, and \texttt{=}).
8.4.2. Interval-to-Interval Constraints

The thirteen interval-to-interval models proposed by Allen (1984) define the basic interval-interval constraints. These constraints can be imposed by direct calls to rules within the timeline system. A few of these rules are enumerated below.

\[
\begin{align*}
(make\_before & \quad INTERVAL\_1 \quad INTERVAL\_2) \\
(make\_after & \quad INTERVAL\_1 \quad INTERVAL\_2) \\
(make\_meet & \quad INTERVAL\_1 \quad INTERVAL\_2) \\
(make\_contain & \quad INTERVAL\_1 \quad INTERVAL\_2)
\end{align*}
\]

The above rules are self-explanatory. For instance, make_before makes INTERVAL_1 lie before INTERVAL_2. Internally, this is achieved by making the endpoint of INTERVAL_1 before the startpoint of INTERVAL_2. The rule make_before imposes this constraint. The predicate make_meet makes its first interval immediately precede the second interval. Internally, this is accomplished by making the endpoint of INTERVAL_1 coincide with the startpoint of INTERVAL_2. Likewise make_contain causes the containment of the second interval by the first. We now discuss the translation of temporal relations into timeline assertions. We first consider the translation of temporal relations.

8.4.3. Translation of Temporal Relations

Recall that all our temporal relations are interval-interval relations signifying one or more of Allen's temporal models. Thus, given the relation (ends-before E1 E2), E1 and E2 are labels denoting timeline intervals. The predicate ends-before states that the endpoint of the first interval E1 is before the endpoint of E2. The translation of this predicate involves imposing the
above constraint between the endpoints. We now illustrate the process of translating temporal relations into timeline assertions by considering some examples.

Our first example illustrates the translation of the relation (ends-before E1 E2). As pointed out earlier, the predicate ends-before is encoded by imposing a constraint on the endpoints of E1 and E2. The following invocation to the timeline system accomplishes the translation of (ends-before E1 E2).

(make-less endpt1 endpt2)

The first two invocations retrieve the definitions of the intervals E1 and E2 (so that we have the endpoint labels to impose the constraint). The rule invocation to make-less imposes the positional constraint required by ends-before.

To give another illustration, let us consider the translation of the relation (overlap E1 E2) into timeline assertions. Two intervals overlap when the startpoint of either interval is before the endpoint of the other. Therefore, the positional constraints required for overlap between E1 and E2 are:

I. startpt_E1 before endpoint_E2
II. startpt_E2 before endpoint_E1

The following invocations to the timeline system accomplish the translation in this case.

I. (make-less startpt1 endpt2)
II. (make-less startpt2 endpt1)

Our last example illustrates a case leading to the generation of possible worlds. Consider the relation (sequence E1 E2) which indicates that the intervals E1 and E2 are in sequence with
E2 following E1. Both delayed or immediate sequence are possible. These possibilities are mutually exclusive as they impose conflicting positional constraints as illustrated below:

I. \text{endpt}_E1 \text{ before } \text{startpt}_E2  \text{ (for delayed sequence)}

II. \text{endpt}_E1 \text{ equal } \text{startpt}_E2  \text{ (for immediate sequence)}

The above constraints are mutually exclusive and cannot be imposed at the same time (in other words, the constraints cannot be imposed within the same rule) since they lead to conflicting possible worlds (one in which E1 and E2 are in delayed sequence and another in which E1 and E2 are in immediate sequence). We require two invocations, one for each of the above constraints. These invocations are shown below and are made one after the other with the effects of the first undone (by backtracking) before making the second.

I. \text{(make_less endpt1 startpt2)}

II. \text{(make_equal endpt1 startpt2)}

The above illustrations give a broad perspective of the translation of temporal relations into timeline assertions by imposing constraints on points and intervals. The Prolog rules that accomplish the translation of temporal relations into timeline assertions are invoked as follows:

\text{(Translate_Temporal_Relation *elabel1 *relation *elabel2)}

The arguments *elabel1 and *elabel2 denote the intervals related by the temporal relation *relation. The body of the invoked rule accomplishes the translation.

We now consider the translation of time displacement information into timeline assertions. This involves asserting numerical constraints. Before discussing the translation of time displacement information, we digress to touch on one of the pertinent issues.
8.4.4. The Granularity of Time

So far no mention has been made about the representation of time. In our system, time is regarded as consisting of a series of instants (essentially small intervals treated as indivisible points) corresponding to seconds of time. In other words, a second is the smallest unit of time representable in our system. The choice of this granularity follows from the fact that time specifications in units smaller than seconds are rather uncommon in narratives.

A second is associated with a numeric measure of 0 owing to its choice as the smallest unit of time in our system. The distance between consecutive seconds (points of the timeline) is fixed at 0.00001 (the choice of this resolution is arbitrary and can be altered at will). All other time units are viewed as intervals of appropriate measures obtained by scaling the numeric measure of 0.00001 by the number of seconds contained within the unit. For instance, an hour is an interval of size 0.036 (since an hour contains 3600 seconds). Likewise, a time of two minutes corresponds to a size of 0.0012. A day corresponds to an interval of size 0.864 since a day contains 86400 seconds.

8.4.5. Time Displacement

In Chapter 5\textsuperscript{11} we pointed out that time displacement between consecutive descriptions can be specified in two ways: either by a directional adverbial or adverbial phrase alone (such as later, earlier, ago, etc.) indicating only the direction of displacement (forward or backward of the current narrative time) or by a time phrase that combines a directional phrase and a measure phrase (indicating the amount of time displacement). Such displacements are relative because they specify time with respect to the time of another event in the text.

\textsuperscript{11} See page 108
Another type of time specification, commonly used to assign chronological dates to events, is independent of the time of any other event in the text. An example of such a time specification is the phrase on \textit{July 1st 1976} which is parsed into the following list:

\[
\text{[ unk unk unk (ABSDAY 1) (ABSMONTH 7) (ABSYEAR 1976)]}
\]

Note the prefix ABS signifying an absolute value for each instantiated argument. The values are absolute because they are independent of the time of any other event in the text. Following this convention for representing absolute time descriptions, the time displacement list for a relative time phrase such as \textit{three days later} may be modified as follows to reflect the relative nature of such phrases:

\[
\text{[ unk unk unk (RELDAY +3) unk unk]}
\]

Note that the only instantiated argument is the one corresponding to \textit{day}. The prefix REL signifies a relative value for the argument.

Given below are some examples of time displacement between narrative descriptions.

1. Jack played tennis at the club. Later he dined at the restaurant.
2. The owner reached his estate. He left three hours later.

Example 1 is an instance of a relative time displacement by the adverbial \textit{later} in the second sentence. This adverbial indicates an advancement (forward displacement) of narrative time from the time of the first event (\textit{Jack's playing tennis at the club}) to the time of the second event (\textit{Jack's dining at the restaurant}). The extent of displacement is unspecified. In Chapter 5 we had pointed out that time displacements involving only a directional component are treated like temporal connections involving the adverbials \textit{before} and \textit{after} as far as the po-
sitional relationship between the events involved in the displacement is concerned. Thus, the first example is treated in the same manner as the following temporal connection: *Jack dined at the restaurant after he played tennis at the club*. The sequence information between these two events is obtained by accessing the temporal table for the connector *after* using the aspects of the two descriptions involved. The resultant temporal relation obtained from the table is asserted as object code and translated into timeline assertions in the manner described earlier in this chapter.

Example 2 differs from the previous example because of the additional information conveyed by the time displacement phrase. In this case, the measure of displacement is also specified in addition to direction. The direction is indicated by the adverbial *later* while the measure is indicated by the phrase *three hours*. Both sentences of this example describe punctual events. The first punctual event marks the end of the durative event signifying *the owner's trip to his estate* (denoted by E1) while the second event initiates the durative event signifying *the owner's motion away from the estate* (denoted by E2). The code generated as a result of processing the two sentences of this example is:

```
(time-displacement E1 E2 unk unk (RELHOUR +3) unk unk unk}
```

The labels E1 and E2 are pointers to information contained in the corresponding event frames. Only the hour entry is instantiated in this case (as indicated by the integer +3 in the list). All other arguments are unknowns (as indicated by the *unk* entries in the list). We are supplied the information that the endpoint of E1 and the startpoint of E2 are separated by three hours. Given the circumstances, it would be rather naive to suppose that the points corresponding to the two punctual events are separated exactly by a time extent of three hours. In fact, it is questionable whether or not the time information in this case should be interpreted as a precise measure of the time extent between the punctual events. In our opinion, there is a lot of uncertainty concerning the exact measure of time between the two points despite the specifi-
cation of the precise measure of three hours. Our solution to the problem is to visualize two hour intervals $I_1$ and $I_2$ (essentially intervals to constrain or localize the corresponding events on the timeline) that are three hours apart (as indicated by $+3$ in the time displacement list).

The point corresponding to the first punctual event (also the endpoint of $E_1$) is constrained to lie within $I_1$ while the point corresponding to the second punctual event (also the startpoint of $E_2$) is constrained to lie within $I_2$. The two points are free to be anywhere within the intervals constraining them. The freedom in the positioning of the two points within their respective time intervals accounts for any uncertainty in the extent of time separating them. The above suggestions in our view portray the given time information more accurately since no assumptions have been made regarding the extent of time separating the two punctual events.

Thus, in our view the two punctual events are separated by an unknown time extent $X$ where $X$ can range anywhere between two hours and four hours (this is the usual interpretation of a phrase like around three hours later).

The steps embodied in the above solution lead to the following invocations to the timeline system.

I. Creation of hour intervals by make_interval calls. These intervals constrain the events on the timeline.

$(\text{make\_interval \ I1 \ start1 \ end1})$

$(\text{make\_interval \ I2 \ start2 \ end2})$

$(\text{make\_linked \ start1 \ end1 \ 0.036})$

$(\text{make\_linked \ start2 \ end2 \ 0.036})$

$(\text{make\_linked \ start1 \ start2 \ 0.108})$
II. Constraining the points corresponding to the punctual events to be within the hour intervals created in the first step.

(make_p_i_during endpt1 I1)
(make_p_i_during startpt2 I2)

Two pieces of information are required for processing time displacement: the nature of the events (punctual, durative, state) involved in the displacement and the constraining time unit. The nature of the events is indicated by the aspects stored within the event frames corresponding to the labels E1 and E2. The aspects (ENDPT of the first sentence and STARTPT of the second sentence) indicate the points endpt1 and startpt2 to be constrained. The unit of displacement is obtained by scanning the time displacement list for the first instantiated argument in the time displacement list.

Our analysis of this example indicates that when time displacement is specified in interval units, the events involved in the displacement are constrained indirectly by time intervals created during the processing of the displacement. The following example illustrates a time displacement specified in terms of seconds.

The owner reached his estate. He left twenty seconds later.

Unlike the previous example we do not create time intervals in this case. We regard a measure specified in seconds as conveying precise information. In our opinion, the apparent reason for specifying time displacement in seconds is to convey preciseness. The smaller the unit of specification, the more precise the information is intended to be. Therefore, in this case the points corresponding to the punctual events are assumed to be separated by exactly 20 seconds. The following invocation to the timeline system accomplish the translation in this case.
(make_linked endpt1 startpt2 0.0002)

The call to make_linked asserts the constraint.

The above examples give a flavor of the translation of time displacement information into timeline assertions. The following observations emerge from analysis of the above examples.

I. When the time displacement is specified in seconds (instants of time) we assume that the information indicates a precise measure.

II. When the time displacement is specified in terms of a non-instantaneous (interval) unit (unit other than seconds) we create time intervals of the appropriate unit size and constrain these intervals with the measure indicated in the displacement. The events themselves are made to lie within the respective time intervals.

Consider the following example that illustrates four descriptions, two of them containing time displacements.

Nancy met the man at the tennis club. He attended her birthday party two days later. The following day he had an accident and succumbed to injuries.

Designating the events of the above fragment by the labels E1, E2, E3 and E4 in that order we have time displacements associated with E2 and E3. The first event is the initial temporal focus. E2 is the incoming event during the first processing step. The initial configuration is

\[ \text{TEMPORAL FOCUS} : - \ E1 \ \ \ \ \text{INCOMING EVENT} : - \ E2 \]
From the first event to the second, there is a forward time displacement indicated by the phrase two days later. The temporal focus shifts from E1 to E2 in this case. The following relation is generated during this processing step.

\[(\text{time-displacement } E1 \ E2 \ [unk \ unk \ unk \ (\text{RELDAY} \ +2) \ unk \ unk])\]

The time displacement of two days between E1 and E2 is indicated by the six argument list in the above relation (note the integer +2 in the day entry of the list indicating advancement of time by two days). E3 is the incoming event during the next processing step. This event indicates a time displacement with respect to E2. The code generated between E2 and E3 is

\[(\text{time-displacement } E2 \ E3 \ [unk \ unk \ unk \ (\text{RELDAY} \ +1) \ unk \ unk])\]

E3 becomes the temporal focus as a result of the above processing. E4 is the incoming event in the final processing step. This event indicates a sequential shift of the now point from E3 and thereby leads to the assertion of the following relation (this relation is obtained from the aspect-tense table): \(\text{sequence } E3 \ E4\).

We now consider the translation of the above relations and time displacements into positional constraints.

**Definition of intervals:** The first step is to define intervals corresponding to the labels E1, E2, E3 and E4. This is done by gensym and make_interval calls. The gensym calls define labels for the startpoint and endpoint of each interval being defined. For instance, the code sequence for defining the interval for E1 is illustrated below. The asterisked arguments denote Prolog variables.

1. \((\text{gensym } ^*\text{startpt1})\)
II. \( (\text{gensym} \ *\text{endpt1}) \)

III. \( (\text{make_interval} \ E1 \ *\text{startpt1} \ *\text{endpt1}) \)

**Translation of temporal relations:** There is only one temporal relation asserted for the above fragment: \( (\text{sequence} \ E3 \ E4) \). As pointed out earlier, this relation leads to two possible worlds based on the following point-to-point constraints.

I. \( (\text{make_less} \ *\text{endpt3} \ *\text{startpt4}) \)

II. \( (\text{make_equal} \ *\text{endpt3} \ *\text{startpt4}) \)

The above constraints cannot be imposed simultaneously since they conflict. Hence, the translation of this relation involves two rules, one for each constraint outlined above.

**Translation of time displacement:** There are two time displacements; one between \( E1 \) and \( E2 \) and the other between \( E2 \) and \( E3 \). These are depicted below.

I. \( (\text{time-displacement} \ E1 \ E2 \ [\text{unk unk unk (RELDAY +2) unk unk}]) \)

II. \( (\text{time-displacement} \ E2 \ E3 \ [\text{unk unk unk (RELDAY +1) unk unk}]) \)

The first of these displacements is specified in day units. To process it, we create two intervals, \( I_1 \) and \( I_2 \) each having the size of a day (0.864 units). These day intervals are separated by the time extent of a day (0.864) to ensure their separation by the amount indicated by the displacement information. In other words, if we regard \( I_1 \) as day 0 on a relative time scale, \( I_2 \) would be day 2 on the same scale. The events involved in the displacement are constrained within the day intervals; \( E1 \) being made internal to \( I_1 \) while \( E2 \) being made internal to \( I_2 \).

The second time displacement is also specified in day units and indicates that \( E3 \) occurs the day after \( E2 \) occurs. Accordingly, \( E3 \) occurs during day 3 of the relative time scale.
The picture may be simplified by visualizing a relative time scale whose zero is designated by the point *zeropoint. All day intervals are anchored with respect to this zeropoint by imposing constraints between the zeropoint and the startpoints of the day intervals. The code for processing this example is as follows:

I. (make_point *zeropoint)
II. (make_interval 11 *start1 *end1)
III. (make_interval 12 *start2 *end2)
IV. (make_interval 13 *start3 *end3)
V. (make_linked *start1 *end1 0.864)
VI. (make_linked *start2 *end2 0.864)
VII. (make_linked *start3 *end3 0.864)
VIII. (make_equal *zeropoint *start1)
IX. (make_linked *zeropoint *start2 1.728)
X. (make_linked *zeropoint *start3 2.592)
XI. (make_during E1 I1)
XII. (make_during E2 I2)
XIII. (make_during E3 I3)

Note that the startpoint of $l_1$ (start1) coincides with the zeropoint of the relative time scale in order for $l_1$ to be interpreted as day 0 on this scale. Similarly, the distance between the zeropoint and the start of $l_2$ is 1.728 (or 0.864 X 2). The last three constraints cause the events to be contained within their corresponding day intervals.
8.5. Summary

In this chapter we discussed the definition of timeline constructs (intervals and points) for narrative situations by means of primitive calls to a timeline system. The translation of object code (consisting of temporal relations and time displacements) into timeline constraints was also illustrated through examples. Additional constraints between intervals and points can be derived by querying the timeline system.
9 RESULTS AND EVALUATIONS

9.1. Introduction

In this chapter we illustrate the working of our system on some example paragraphs of narrative fiction and scientific process descriptions. The paragraphs are chosen to illustrate not only the capabilities but also the limitations of our system. An evaluation of the results for each paragraph is presented along with comments on inaccurate/incorrect results. We begin with a brief description of the various modules of our Prolog system.

9.2. Modules of the system

The various modules of our system along with the corresponding source files are enumerated in the following table. All these modules have been implemented in VPI Prolog (a compiled version of Prolog) and run under the VAX/VMS system.
Table 17. Modules of our System:

<table>
<thead>
<tr>
<th>No.</th>
<th>Brief Description</th>
<th>Lines</th>
<th>Source File(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Tables for Modelling Temporal Connections</td>
<td>500</td>
<td>temptab.hc</td>
</tr>
<tr>
<td>2</td>
<td>Table for Sequencing based on Aspect/Tense</td>
<td>3000</td>
<td>asptab.hc</td>
</tr>
<tr>
<td>3</td>
<td>Controlling program based on Temporal Focus</td>
<td>837</td>
<td>tempfocus.hc</td>
</tr>
<tr>
<td>4</td>
<td>Parser for Aspect &amp; Tense Information</td>
<td>723</td>
<td>asp2v2.hc</td>
</tr>
<tr>
<td>5</td>
<td>Interface to pattern based parser</td>
<td>758</td>
<td>parint.hc</td>
</tr>
<tr>
<td>6</td>
<td>Interface to Timeline System</td>
<td>1400</td>
<td>timeline.hc</td>
</tr>
<tr>
<td>7</td>
<td>Parser for Time Displacement Information</td>
<td>1930</td>
<td>timeref.hc, dayref.hc, monthref.hc, yearef.hc</td>
</tr>
</tbody>
</table>

These modules constitute the back-end of the processing with the universal semantic grammar based parser [Virkar, forthcoming] at the front-end. As explained in Chapter 4 the parser generates meaning forms for input sentences. These meaning forms are assimilated into event frames by an interface module to the parser. These frames have the format specified in Chapter 7 (see Section 7.3). The frames contain all relevant information for a temporal analysis of the text. This information includes the aspect/tense of the description corresponding to the event, information about the agents and entities of the event, time information etc. The core of the temporal analysis is accomplished by a table driven module that uses the concept of temporal focus in deriving temporal relations between the events of the text. The tables accessed (lines 1 and 2 of Table 17) by the temporal focus module constitute the bulk of our system and are indexed by the aspect/tense representations of the descriptions whose events have to be sequenced. These tables are two dimensional (at a time two descriptions are sequenced) and contain around 1300 Prolog rules and facts. The entries of these tables store temporal relations. During the course of its operation, the temporal focus program obtains information about individual events from the frames created by the parser interface module. The interface to the timeline system [Hostetter, Jan. 1990] translates these relations into positional constraints as explained in Chapter 8.

Parsing a sentence takes 6 cpu seconds on an average under the RISC based DEC System 5000 running Ultrix. The temporal analysis (includes the conversion of meaning forms to event frames) takes 5 cpu seconds on an average per sentence under MicroVAX/VMS.
9.3. Examples

We now illustrate the working of our system on six examples ranging from paragraphs of narrative fiction to scientific process descriptions. The paragraphs have been drawn from a total of five books and illustrate both the capabilities and limitations of our system. Details of the execution for each paragraph is presented in the following tabular format. The significance of each column is explained in the items that follow the table. Each row of the table signifies a processing step involving the next event in the text.

Table 18. Tabular Format Providing Execution Details

<table>
<thead>
<tr>
<th>No.</th>
<th>Candidate Events</th>
<th>Temporal Focus</th>
<th>Next Event</th>
<th>Output Relation</th>
<th>Update Phase</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The following items explain the significance of each column of the above table.

I. **No:** Indicates the number of the processing step.

II. **Candidate Events:** Indicates the candidate(s) for temporal focus at the beginning of the processing step. If there is only one candidate, that candidate is inevitably the temporal focus for the step. In the case of more than one candidate, selection heuristics are applied to determine the temporal focus for the processing step.

III. **Temporal Focus:** Indicates the situation serving as the temporal focus for the step.

IV. **Next Event:** Is the incoming event for the processing step.

V. **Output Relation:** Signifies the output of the processing step. This relation indicates how the incoming situation temporally relates to the current temporal focus.

9 RESULTS AND EVALUATIONS
VI. **Update Phase**: Indicates whether or not the incoming event becomes the new temporal focus after it has been processed. The indicator *changes* implies a change from the current temporal focus to the incoming event following a movement of narrative time. The label of the incoming event appears in the column **Temporal Focus** of the next row (the next processing step). The indicator *No Change* implies no change to the temporal focus. In such cases, the incoming event along with the current temporal focus become candidates for temporal focus during the next step. One of these candidates is selected as the temporal focus during the next step.

VII. **Comments**: Indicates the precision/correctness of the output. The comments are of three types: *precise* (indicates correct output relation), *incorrect* (indicates incorrect output relation) and *imprecise* (indicates that the correct relation is included as a possibility along with other mutually exclusive possibilities for e.g., the relation *overlap-or-sequence* is imprecise).

Given below are the examples used for testing and evaluation of our system.
Example 1

Our first test paragraph is a process description of the production of copper. The steps of the process are regarded like events. The paragraph is adapted from [Lee D. Rossi and Michael Gasser, 1983]. The paragraph is as follows:

The production of copper is primarily a matter of purifying. Copper ore, about 1 percent copper, is first ground, mixed with water, and concentrated in a flotation cell. The result is a product about 30 to 40 percent copper. Next, iron and sulfur are removed from the concentrate in a series of steps which involve the heating of the concentrate. Finally, the copper is refined in one of two ways.

The events (actually steps of the process) are as follows:

I. e1: The production of copper being a matter of purifying
II. e2: Copper ore being ground
III. e3: Copper ore being mixed with water
IV. e4: Copper ore being concentrated in a flotation cell
V. e5: The result being a product about 30-40 percent copper
VI. e6: Iron and sulfur being removed from the concentrate in a series of steps
VII. e7: Steps involving the heating of the concentrate
VIII. e8: Copper being refined in one of two ways

The following table provides the details of the execution of our system on the above paragraph.
Table 19. Details of Run for Example 1

<table>
<thead>
<tr>
<th>No.</th>
<th>Candidate Events</th>
<th>Temporal Focus</th>
<th>Next Event</th>
<th>Output Relation</th>
<th>Update Phase</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>e1 e2</td>
<td>e1</td>
<td>e2</td>
<td>(overlaps e1 e2)</td>
<td>No Change</td>
<td>precise</td>
</tr>
<tr>
<td>2</td>
<td>e1 e2</td>
<td>e2</td>
<td>e3</td>
<td>(sequence e2 e3)</td>
<td>Changes</td>
<td>precise</td>
</tr>
<tr>
<td>3</td>
<td>e3 e4</td>
<td>e3</td>
<td>e4</td>
<td>(sequence e3 e4)</td>
<td>Changes</td>
<td>precise</td>
</tr>
<tr>
<td>4</td>
<td>e4 e5</td>
<td>e4</td>
<td>e5</td>
<td>(overlaps e4 e5)</td>
<td>No Change</td>
<td>incorrect</td>
</tr>
<tr>
<td>5</td>
<td>e4 e5</td>
<td>e4</td>
<td>e6</td>
<td>(after e6 e4)</td>
<td>Changes</td>
<td>precise</td>
</tr>
<tr>
<td>6</td>
<td>e5 e6</td>
<td>e6</td>
<td>e7</td>
<td>(overlaps e7 e6)</td>
<td>No Change</td>
<td>precise</td>
</tr>
<tr>
<td>7</td>
<td>e5 e6 e7</td>
<td>e6</td>
<td>e8</td>
<td>(sequence e6 e8)</td>
<td>Changes</td>
<td>precise</td>
</tr>
</tbody>
</table>

Table 19 indicates an incorrect relation; the temporal relation between e4 (*Copper ore being concentrated in a flotation cell*) and e5 (*the result being a product about 30 to 40 percent Copper*) is incorrectly determined as *(overlaps e4 e5)* while the correct relation is *(sequence e4 e5)*. These two situations are sequenced by the default mechanism as there are no explicit indications of temporal information between them. The situation e5 being a state and e4 being an event, the default mechanism prescribes overlap between the event and state. However, e5 is not just any state. It is a state that results (as indicated by the lexeme *result* in the corresponding event description) from the sequence of steps e2 through e4. Therefore, it must follow e4 sequentially rather than overlap with it. Semantic analysis is required to characterize e5 as a resulting state.

An interesting feature of this example is the use of lexemes such as *next* and *finally* to characterize steps in the process described. These lexemes are treated as time displacement indicators.
Example 2

The following paragraph of narrative fiction is adapted from [Martin Cruz Smith, 1979].

When the dancers had brought back the snakes to the cotton bower, the head of the Snake Clan made a circle of cornmeal. While he prayed, the dancers threw their snakes into the circle where they writhed in a heap. Finally, all the dancers scrambled for snakes and ran from the plaza down the narrow path to the desert.

The event descriptions of the above paragraph are as follows:

I. e1: The dancers bringing back the snakes to the cotton bower
II. e2: The head of the Snake Clan making a circle of cornmeal
III. e3: The head of the Snake Clan praying
IV. e4: The dancers throwing their snakes into the circle
V. e5: The snakes writhing in a heap within the circle
VI. e6: The dancers scrambling for the snakes
VII. e7: The dancers running from the plaza down the narrow path to the desert

The following table provides the execution details for this paragraph.

<table>
<thead>
<tr>
<th>No.</th>
<th>Candidates</th>
<th>Temporal Focus</th>
<th>Next Event</th>
<th>Output Relation</th>
<th>Update Phase</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>e1</td>
<td>e1</td>
<td>e2</td>
<td>(after e2 e1)</td>
<td>No Change</td>
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<td>2</td>
<td>e1 e2</td>
<td>e2</td>
<td>e3</td>
<td>(sequence e2 e3)</td>
<td>No Change</td>
<td>precise</td>
</tr>
<tr>
<td>3</td>
<td>e3</td>
<td>e3</td>
<td>e4</td>
<td>(overlaps e4 e3)</td>
<td>No Change</td>
<td>precise</td>
</tr>
<tr>
<td>4</td>
<td>e3 e4</td>
<td>e4</td>
<td>e5</td>
<td>(overlap-or-sequence e4 e5)</td>
<td>No Change</td>
<td>imprecise</td>
</tr>
<tr>
<td>5</td>
<td>e4 e5</td>
<td>e4</td>
<td>e6</td>
<td>(after e6 e4)</td>
<td>Changes</td>
<td>precise</td>
</tr>
<tr>
<td>6</td>
<td>e6</td>
<td>e6</td>
<td>e7</td>
<td>(sequence e6 e7)</td>
<td>Changes</td>
<td>precise</td>
</tr>
</tbody>
</table>

This paragraph is well marked by explicit indications and illustrates a when connection between e1 and e2 and a while connection between e3 and e4. The lexeme finally associated with e6 signals an advancement of time from e4 to e6 thereby resulting in e6 occurring after e4.
Table 20 shows one imprecise relation involving the events e4 and e5. There is a semantic relation between these events since *throwing the snakes into the circle* (e4) causes a *writhing heap within the circle* (e5). The causal relationship between these events enforces sequentiality.
Example 3

The following set of paragraphs of narrative fiction is adapted from [Jeffrey Konvitz, 1978]. The descriptions enclosed within square brackets were not handled because they are outside the scope of our system. Recall that our system does not handle modals, negation (including violated expectations as indicated by words such as but) and habitual descriptions.

Annie threw open the door. A chill blast of wind struck her face. She walked out and glanced over the porch railing. The mist had spread everywhere. [She could barely see the car]. Stepping down into the mud, she maneuvered along the path and threw open the car door. [The key wasn’t there. And no sign of Bobby]. She opened the glove compartment, took out a flashlight, turned it on and looked toward the trail over the hood. The hood was partially open; wires extended from inside over the fender to the ground.

[Terrifyingly aware that there was no telephone and no way down the mountain in the storm] she ran back to the cabin, slammed the door, locked it and panned the flashlight carefully over the room examining the corners. [Apart from the shadow of her own body there was nothing].

The cabin was unbearably cold; and she was wet. She ran to the basement, opened the door and looked down the rickety staircase, the flashlight beam dancing from step to step. The basement was a storage area. Toward the rear were several old couches and loveseats, piled on top of each other. The woodbin was underneath the staircase.

Laying the flashlight on the floor, she grabbed the top of the bin. She fought it, prying it up. She grabbed for the logs; the bin seemed empty. [But Bobby had said it was filled!] She picked up the flashlight and pointed it inside. Bobby was in the bin, his eyes staring.

She screamed her guts into the cold damp air. Everything went blank as she ran up the stairs clutching at the walls and bannister, the flashlight beam ricocheting wildly off the walls. She stumbled over the top step, dropped the flashlight, and careened into the couch, falling to the floor. Struggling to her feet, she reached for the door throwing it open.

The event descriptions of the above example used for testing our system are as follows:

I. e1: Annie throwing open the door
II. e2: A chill blast of wind striking Annie’s face
III. e3: Annie walking out
IV. e4: Annie glancing over the porch railing
V. e5: The mist having spread everywhere
VI. e6: Annie stepping down into the mud
VII. e7: Annie maneuvering along the path
VIII. e8: Annie throwing open the car door
IX. e9: Annie opening the glove compartment
X. e10: Annie taking out a flashlight
XI. e11: Annie turning on the flashlight
XII. e12: Annie looking toward the trail over the hood
XIII. e13: The hood being partially open
XIV. e14: Wires extending from inside over the fender to the ground
XV. e15: Annie running back to the cabin
XVI. e16: Annie slamming the cabin door
XVII. e17: Annie locking the cabin door
XVIII. e18: Annie panning the flashlight carefully over the room
XIX. e19: Annie examining the corners
XX. e20: The cabin being unbearably cold
XXI. e21: Annie being wet
XXII. e22: Annie running to the basement
XXIII. e23: Annie opening the door
XXIV. e24: Annie looking down the rickety staircase
XXV. e25: The flashlight beam dancing from step to step
XXVI. e26: The basement being a storage area
XXVII. e27: Several old couches and loveseats being piled on top of each other toward the rear
XXVIII. e28: The woodbin being underneath the staircase
XXIX. e29: Annie laying the light on the floor
XXX. e30: Annie grabbing the top of the woodbin
XXXI. e31: Annie fighting to open the woodbin
XXXII. e32: Annie prying up the woodbin
XXXIII. e33: Annie grabbing for the logs

9 RESULTS AND EVALUATIONS
XXXIV.  e34: The bin seeming empty
XXXV.   e35: Annie picking up the flashlight
XXXVI.  e36: Annie pointing the flashlight in the bin
XXXVII. e37: Bobby being in the bin
XXXVIII. e38: Bobby's eyes staring
XXXIX.  e39: Annie screaming into the air
XL.     e40: Everything going blank
XLI.    e41: Annie running up the stairs
XLII.   e42: Annie clutching at the walls and bannister
XLIII.  e43: The flashlight beam ricocheting off the walls
XLIV.   e44: Annie stumbling over the top step
XLV.    e45: Annie dropping the flashlight
XLVI.   e46: Annie careening into the couch
XLVII.  e47: Annie falling to the floor
XLVIII. e48: Annie struggling to her feet
XLIX.   e49: Annie reaching for the door
L.      e50: Annie throwing open the door

As pointed out earlier, the descriptions within square brackets were excluded because of not being within the scope of our system. The table providing details of the execution of the above example appears on the next page.
<table>
<thead>
<tr>
<th>No.</th>
<th>Candidates</th>
<th>Temporal Focus</th>
<th>Next Event</th>
<th>Output Relation</th>
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<th>Comment</th>
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</thead>
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<tr>
<td>49</td>
<td>e48 e49</td>
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<td>e50</td>
<td>(overlaps e49 e50)</td>
<td>No Change</td>
<td>incorrect</td>
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</tbody>
</table>
The above table indicates an instance where coreference is detected. The events involved are \(e_6\) (Annie's seeping down into the mud) and \(e_7\) (Annie maneuvering along the path). Both these events describe different aspects of the same motional event. Hence, \(e_6\) and \(e_7\) designate the same event. The temporal focus is shifted from \(e_6\) to \(e_7\) since the aspect of the description corresponding to \(e_7\) is different from the aspect of the description corresponding to \(e_6\).

The following table illustrates the incorrect/imprecise relations along with the corresponding correct, precise relations. Brief explanations for the incorrectness/impreciseness are provided in each case.

<table>
<thead>
<tr>
<th>No.</th>
<th>Imprecise/Incorrect Relation</th>
<th>Correct Relation</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>(overlaps-or-sequence (e_1\ e_2))</td>
<td>(sequence (e_1\ e_2))</td>
<td>(e_1) enables (e_2)</td>
</tr>
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<td>2</td>
<td>(overlaps (e_4\ e_6))</td>
<td>(sequence (e_4\ e_6))</td>
<td>(e_4) is Momentary</td>
</tr>
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<td>(sequence (e_29\ e_30))</td>
<td>(e_{29}) enables (e_{30})</td>
</tr>
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<td>(overlaps (e_{39}\ e_{40}))</td>
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<td>(sequence (e_{46}\ e_{47}))</td>
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<td>(sequence (e_{46}\ e_{48}))</td>
<td>(e_{46}) causes (e_{48})</td>
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<td>(overlaps (e_{49}\ e_{50}))</td>
<td>(sequence (e_{49}\ e_{50}))</td>
<td>(e_{49}) enables (e_{50})</td>
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</table>

The incorrect relations are indicated in rows 2, 3, 5, 6, 7 and 8. Incorrect relations are clustered around gerunds in the text. For instance, the description corresponding to \(e_6\) is a gerund (Stepping down into the mud) and features in the incorrect relation 2. Similarly, the description corresponding to \(e_{29}\) is a gerund (Laying the flashlight on the floor) and features in the incorrect relation 3. In the same manner, the gerund corresponding to \(e_{47}\) (falling to the floor) features in incorrect relation 5. Likewise, the description corresponding to \(e_{48}\) is a gerund (Struggling to her feet) and features in the incorrect relations 6 and 7. Finally, the gerund throwing it open corresponding to \(e_{50}\) features in the incorrect relation 8.
Gerunds have no tense but contain main verbs marked by the progressive -ing suffix. Given below is the gerund description corresponding to e29, along with the textually adjacent event description e30. These descriptions are involved in the incorrect relation 3.

Laying the flashlight on the floor, she grabbed the bin.

The verb laying in the gerund has the progressive -ing suffix but has no tense and subject. It depends on the description she grabbed the bin for its tense and subject information. Because of the -ing suffix on the main verb, the gerund is interpreted as the description of an ongoing event. Accordingly, gerunds are treated like a progressive state descriptions in our system. Default sequencing applies to the two descriptions above owing to the lack of explicit indications of temporal information. Because the gerund is like a state description, the default guideline of simultaneity between an event and a state applies here. There is a semantic link between the two events, however, that causes them to occur sequentially rather than simultaneously since laying the flashlight on the floor frees the person’s hand thereby enabling him/her to grab the bin.

The incorrect relation 5 involving e46 and e47 can be similarly explained. These two descriptions are indicated below.

She careened into the couch, falling to the floor.

If a person is careening, he/she is moving in an uncontrolled manner which may eventually cause the person to fall. Hence, there is a causal relationship here that enforces sequentiality. Similarly, relation 6 can be explained by observing that if a person is struggling to his/her feet then he/she could have either fallen down or be seated prior to the action. Hence, e46 causes e48.
Likewise, sequentiality appears to be the most likely interpretation between the events e49 and e49 (featuring in incorrect relation 7). The descriptions corresponding to these events are illustrated below.

Struggling to her feet, she reached for the door...

In this case the subject's struggle to her feet enables her to reach for the door.

Similarly, the incorrect relation 8 can be explained based on the observation that reaching the door (e49) enables throwing it open (e50). Hence, e49 and e50 occur in sequential order.

Within the category of durative events some events have very short durations of occurrence. Such events are called momentary events. Typical examples of momentary events are those signified by verbs such as throw, strike, grab etc. The property of momentariness can be used to cut down on the overhead of semantic analysis specifically in cases involving the sequencing of momentary events. When two events (at least one of which is momentary) appear consecutively in the text, sequentiality of occurrence appears to be the most plausible interpretation irrespective of whether or not the events have the same agent(s). For instance, the events e1 and e2 are momentary and therefore occur in sequence with e2 following e1. Although there is a semantic link between these events (Annie's throwing open the door enables the chill blast of wind to strike her face), we can cut down on the overhead in inferring the correct temporal relation by assuming sequentiality between the events since the events are momentary.

As a default, when two events (at least one of which is momentary) are to be sequenced, sequentiality appears to be the most plausible interpretation. This guideline can be used to cut down on semantic analysis in cases involving the sequencing of events, at least one of which is momentary. The imprecision of the first two relations can be explained by the sequential interpretation when a momentary event is involved.
The incorrect relation 2 between e4 and e6 can also be explained from the observation that e4 (Annie's glancing over the porch railing) is momentary and therefore precedes the durative event e6 (Annie's stepping down into the mud) rather than being simultaneous with it.

Finally, the events e39 and e40 appear to have no semantic relationship that enforces sequentliality and could therefore be regarded as events that overlap.
Example 4

The next test passage is a narrative paragraph adapted from Helen Keller’s autobiography *The Story of My Life* as quoted in [Regina L. Smalley and Mary K. Ruetten, 1986]. The phrases enclosed within square brackets signify descriptions that were not handled because of not being within the scope of our system.

While I was playing with my new doll, Miss Sullivan put my big ragdoll into my lap also, spelled “d-o-l-l” and tried to make me understand that “d-o-l-l” applied to both. Earlier we had had a tussle over the words “m-u-g” and “w-a-t-e-r”. Miss Sullivan had tried to impress it upon me that “m-u-g” is mug and “w-a-t-e-r” is water [but I persisted in confounding the two]. In despair, Miss Sullivan had dropped the subject for the time [only to renew it at the first opportunity]. I became impatient at her repeated attempts and seizing the new doll, I dashed it upon the floor. I was keenly delighted when I felt the fragments of the broken doll at my feet.

The following event descriptions of the above paragraph were used for testing. The descriptions within square brackets were excluded:

I. e1: Helen playing with her new doll
II. e2: Miss Sullivan putting the big ragdoll into Helen’s lap
III. e3: Miss Sullivan spelling the word “d-o-l-l”
IV. e4: Miss Sullivan trying to make Helen understand that “d-o-l-l” applied to her newdoll as well as the ragdoll
V. e5: The word “d-o-l-l” applying to both the newdoll and the ragdoll
VI. e6: Miss Sullivan and Helen having a tussle
VII. e7: Miss Sullivan trying to impress upon Helen that “m-u-g” is mug and “w-a-t-e-r” is water
VIII. e8: “m-u-g” being mug
IX. e9: “w-a-t-e-r” being water
X. e10: Miss Sullivan dropping the subject in despair
XI. e11: Helen becoming impatient at Miss Sullivan’s repeated attempts
XII. e12: Helen seizing the new doll
XIII. e13: Helen throwing the new doll to the floor
XIV. e14: Helen being delighted
XV. e15: Helen feeling the fragments of the broken doll at her feet

Given below are the details of the execution for the above paragraph.

Table 23. Details of Run for Example 4

<table>
<thead>
<tr>
<th>No.</th>
<th>Candidates</th>
<th>Temporal Focus</th>
<th>Next Event</th>
<th>Output Relation</th>
<th>Update Phase</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>e1</td>
<td>e1</td>
<td>e2</td>
<td>(overlaps e1 e2)</td>
<td>No Change</td>
<td>precise</td>
</tr>
<tr>
<td>2</td>
<td>e1 e2</td>
<td>e2</td>
<td>e3</td>
<td>(sequence e2 e3)</td>
<td>Changes</td>
<td>precise</td>
</tr>
<tr>
<td>3</td>
<td>e3</td>
<td>e3</td>
<td>e4</td>
<td>(sequence e3 e4)</td>
<td>Changes</td>
<td>precise</td>
</tr>
<tr>
<td>4</td>
<td>e4</td>
<td>e4</td>
<td>e5</td>
<td>(overlaps e4 e5)</td>
<td>No Change</td>
<td>precise</td>
</tr>
<tr>
<td>5</td>
<td>e4 e5</td>
<td>e4</td>
<td>e6</td>
<td>(before e6 e4)</td>
<td>Changes</td>
<td>precise</td>
</tr>
<tr>
<td>6</td>
<td>e6</td>
<td>e6</td>
<td>e7</td>
<td>(sequence e6 e7)</td>
<td>Changes</td>
<td>precise</td>
</tr>
<tr>
<td>7</td>
<td>e7</td>
<td>e7</td>
<td>e8</td>
<td>(overlaps e7 e8)</td>
<td>No Change</td>
<td>precise</td>
</tr>
<tr>
<td>8</td>
<td>e7 e8</td>
<td>e7</td>
<td>e9</td>
<td>(overlaps e7 e9)</td>
<td>No Change</td>
<td>precise</td>
</tr>
<tr>
<td>9</td>
<td>e7 e9</td>
<td>e7</td>
<td>e10</td>
<td>(sequence e7 e10)</td>
<td>Changes</td>
<td>precise</td>
</tr>
<tr>
<td>10</td>
<td>e10</td>
<td>e10</td>
<td>e11</td>
<td>(before e10 e11)</td>
<td>No Change</td>
<td>precise</td>
</tr>
<tr>
<td>11</td>
<td>e10 e11</td>
<td>e11</td>
<td>e12</td>
<td>(overlaps e11 e12)</td>
<td>No Change</td>
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<tr>
<td>12</td>
<td>e11 e12</td>
<td>e11</td>
<td>e13</td>
<td>(overlaps e11 e13)</td>
<td>No Change</td>
<td>incorrect</td>
</tr>
<tr>
<td>13</td>
<td>e12 e13</td>
<td>e13</td>
<td>e14</td>
<td>(overlaps e13 e14)</td>
<td>No Change</td>
<td>incorrect</td>
</tr>
<tr>
<td>14</td>
<td>e14</td>
<td>e14</td>
<td>e15</td>
<td>(overlaps e14 e15)</td>
<td>No Change</td>
<td>precise</td>
</tr>
</tbody>
</table>

This paragraph has two temporal connections; a while connection between e1 and e2 and a when connection between e14 and e15. As indicated by Table 23, there are three incorrect relations. These relations are shown in the following table along with the correct relations. Brief explanations are provided in each case.

Table 24. Incorrect Relations of Example 4

<table>
<thead>
<tr>
<th>No</th>
<th>Incorrect Relation</th>
<th>Correct Relation</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>(overlaps e11 e12)</td>
<td>(sequence e11 e12)</td>
<td>e11 causes e12</td>
</tr>
<tr>
<td>2</td>
<td>(overlaps e11 e13)</td>
<td>(sequence e11 e13)</td>
<td>e12 enables e13</td>
</tr>
<tr>
<td>3</td>
<td>(overlaps e13 e14)</td>
<td>(sequence e13 e14)</td>
<td>e13 causes e14</td>
</tr>
</tbody>
</table>

Semantic analysis is required to obtain the correct relations in each case. The first relation involves the gerund seizing the doll designated by e12. The event e11 (Helen's becoming impatient) causes e12. Hence, these two events must occur in sequence. As a result, e12 should
have become the temporal focus after it is has been processed. Table 23 indicates this to be not the case. This in turn leads to the second incorrect relation in Table 24. In this case e13 should have processed with respect to e12 and not e11. This wrong selection arises as a result of the first incorrect relation of Table 24. Further, the event e12 enables e13 since an event of **throwing an object to the floor** requires prior possession of the object by the agent. An object can be acquired by **seizing it** (e12 in this case). Finally, the third incorrect relation results because of the semantic relation between the event e13 and the state e14. The state e14 expresses **the subject's delight** that results from the preceding event e13. Hence, the state must follow the event sequentially.
Example 5

The following paragraph of narrative fiction is adapted from [Constance Westbie & Harold Cameron, 1978]. Again the descriptions enclosed within square brackets were not used for testing because of not being within the scope of our system. Recall that our system does not handle negations, modals and habitual descriptions.

Ellen heard someone at the door behind her and assumed that it was Dorothy who stood close at her shoulder and was evidently scrutinizing her ironing technique. She chatted happily to Dorothy for a few minutes and then sensed that Dorothy was unusually silent [and hadn’t answered at all]. She looked around. There was no one in the room but herself. [“Mrs. Cameron?” she called tentatively. There was no answer.]

She had heard the door open and had heard footsteps. She had felt a person beside her [and hadn’t heard the person leave]. She dropped the iron and went through the house in search of Dorothy who was upstairs giving Michael a bath. Ellen asked Dorothy about the person downstairs.

Dorothy recognized another crisis. She put Michael down in his crib and handed him a bottle of orange juice.

Downstairs, Dorothy retrieved the iron that Ellen had dropped and noted that the room was empty. Then she took Ellen into the kitchen and poured two cups of coffee. She sat down opposite Ellen at the breakfast table and began to explain about old houses.

The event descriptions of the above paragraph are as follows.

I. e1: Ellen hearing somebody at the door
II. e2: Ellen assuming that it was Dorothy
III. e3: Dorothy standing close at Ellen’s shoulder
IV. e4: Dorothy scrutinizing Ellen’s ironing technique
V. e5: Ellen chatting happily to Dorothy for a few minutes
VI. e6: Ellen sensing Dorothy’s silence
VII. e7: Dorothy being silent
VIII. e8: Ellen looking around
IX. e9: There being no one in the room apart from herself
X. e10: Ellen heard the door open
XI. e11: Ellen hearing footsteps
XII. e12: Ellen feeling a person beside her
XIII. e13: Ellen dropping the iron
XIV. e14: Ellen going through the house in search of Dorothy
XV. e15: Dorothy being upstairs
XVI. e16: Dorothy giving Michael a bath
XVII. e17: Ellen asking Dorothy about the person downstairs
XVIII. e18: Dorothy recognizing another crisis
XIX. e19: Dorothy putting Michael down in his crib
XX. e20: Dorothy handing Michael a bottle of orange juice
XXI. e21: Dorothy retrieved the iron
XXII. e22: Ellen dropping the iron
XXIII. e23: Dorothy noting the emptiness of the room
XXIV. e24: The room being empty
XXV. e25: Dorothy taking Ellen into the kitchen
XXVI. e26: Dorothy pouring two cups of coffee
XXVII. e27: Dorothy sitting down opposite Ellen at the breakfast table
XXVIII. e28: Dorothy beginning to explain about old houses

Given below is a table indicating the details of the run of our system on this paragraph.
<table>
<thead>
<tr>
<th>No.</th>
<th>Candidates</th>
<th>Temporal Focus</th>
<th>Next Event</th>
<th>Output Relation</th>
<th>Update Phase</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>e1</td>
<td>e1</td>
<td>e2</td>
<td>(sequence e1 e2)</td>
<td>Changes</td>
<td>precise</td>
</tr>
<tr>
<td>2</td>
<td>e2</td>
<td>e2</td>
<td>e3</td>
<td>(overlaps-or-sequence e2 e3)</td>
<td>No Change</td>
<td>imprecise</td>
</tr>
<tr>
<td>3</td>
<td>e2 e3</td>
<td>e3</td>
<td>e4</td>
<td>(overlaps e3 e4)</td>
<td>No Change</td>
<td>precise</td>
</tr>
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<td>e3</td>
<td>e5</td>
<td>(overlaps-or-sequence e3 e5)</td>
<td>No Change</td>
<td>imprecise</td>
</tr>
<tr>
<td>5</td>
<td>e3 e5</td>
<td>e5</td>
<td>e6</td>
<td>(sequence e5 e6)</td>
<td>Changes</td>
<td>precise</td>
</tr>
<tr>
<td>6</td>
<td>e6</td>
<td>e6</td>
<td>e7</td>
<td>(overlaps e6 e7)</td>
<td>No Change</td>
<td>precise</td>
</tr>
<tr>
<td>7</td>
<td>e6 e7</td>
<td>e6</td>
<td>e8</td>
<td>(sequence e6 e8)</td>
<td>No Change</td>
<td>precise</td>
</tr>
<tr>
<td>8</td>
<td>e8</td>
<td>e8</td>
<td>e9</td>
<td>(overlaps e8 e9)</td>
<td>No Change</td>
<td>precise</td>
</tr>
<tr>
<td>9</td>
<td>e8 e10</td>
<td>e8</td>
<td>e10</td>
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<td>12</td>
<td>e12</td>
<td>e12</td>
<td>e13</td>
<td>(before e12 e13)</td>
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</tr>
<tr>
<td>13</td>
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<td>e13</td>
<td>e14</td>
<td>(sequence e13 e14)</td>
<td>Changes</td>
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</tr>
<tr>
<td>14</td>
<td>e14</td>
<td>e14</td>
<td>e15</td>
<td>(overlaps e14 e15)</td>
<td>No Change</td>
<td>precise</td>
</tr>
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<td>e14</td>
<td>e16</td>
<td>(overlaps e14 e16)</td>
<td>No Change</td>
<td>precise</td>
</tr>
<tr>
<td>16</td>
<td>e14 e16</td>
<td>e14</td>
<td>e17</td>
<td>(sequence e14 e17)</td>
<td>Changes</td>
<td>precise</td>
</tr>
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<td>e17</td>
<td>e17</td>
<td>e18</td>
<td>(overlap-or-sequence e17 e18)</td>
<td>No Change</td>
<td>imprecise</td>
</tr>
<tr>
<td>18</td>
<td>e17 e18</td>
<td>e18</td>
<td>e19</td>
<td>(sequence e18 e19)</td>
<td>Changes</td>
<td>precise</td>
</tr>
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<td>e19</td>
<td>e19</td>
<td>e20</td>
<td>(sequence e19 e20)</td>
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<td>21</td>
<td>e21</td>
<td>e21</td>
<td>e22</td>
<td>(before e22 e21)</td>
<td>No Change</td>
<td>precise</td>
</tr>
<tr>
<td>22</td>
<td>e21 e22</td>
<td>e21</td>
<td>e23</td>
<td>(sequence e21 e23)</td>
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<td>23</td>
<td>e23</td>
<td>e23</td>
<td>e24</td>
<td>(overlaps e23 e24)</td>
<td>No Change</td>
<td>precise</td>
</tr>
<tr>
<td>24</td>
<td>e23 e24</td>
<td>e23</td>
<td>e25</td>
<td>(sequence e23 e25)</td>
<td>Changes</td>
<td>precise</td>
</tr>
<tr>
<td>25</td>
<td>e25</td>
<td>e25</td>
<td>e26</td>
<td>(sequence e25 e26)</td>
<td>Changes</td>
<td>precise</td>
</tr>
<tr>
<td>26</td>
<td>e26</td>
<td>e26</td>
<td>e27</td>
<td>(sequence e26 e27)</td>
<td>Changes</td>
<td>precise</td>
</tr>
<tr>
<td>27</td>
<td>e27</td>
<td>e27</td>
<td>e28</td>
<td>(sequence e27 e28)</td>
<td>Changes</td>
<td>precise</td>
</tr>
</tbody>
</table>

The above table indicates three imprecise relations. These three relations are shown in the following table along with comments on the impreciseness.

**Table 26. Imprecise Relations of Example 5**

<table>
<thead>
<tr>
<th>No</th>
<th>Imprecise Relation</th>
<th>Correct Relation</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>(overlaps-or-sequence e2 e3)</td>
<td>(overlaps e2 e3)</td>
<td>No relationship</td>
</tr>
<tr>
<td>2</td>
<td>(overlaps-or-sequence e3 e5)</td>
<td>(overlaps e3 e5)</td>
<td>No relationship</td>
</tr>
<tr>
<td>3</td>
<td>(overlaps-or-sequence e17 e18)</td>
<td>(sequence e17 e18)</td>
<td>e17 causes e18</td>
</tr>
</tbody>
</table>

As indicated in the above table the first two imprecise relations involve events that have no semantic relationship to enforce sequentiality. For instance, there is no relationship between the events e2 (Ellen's assuming that Dorothy stood beside her) and e3 (Dorothy standing beside Ellen) that enforces sequentiality.
In the case of the second imprecise relation, it could be argued that e5 (Ellen's chatting with Dorothy) occurs because of Dorothy standing next to her (e3) but this fact does not preclude overlap between these two events.

The third imprecise relation, however, is explained by the semantic relationship between Ellen's inquiry about the person downstairs (e17) which apparently leads to Dorothy recognizing a crisis (e18). Hence, there is a sequential relationship here.
Example 6

The following paragraph of narrative fiction is adapted from [Martin Cruz Smith, 1979].

The helicopters came straight out of the sun, making Youngman’s eyes water. They landed in tandem on the street in front of the Hogan and two figures emerged from each copter carrying medical bags. Later, they came out of the shed holding handguns. Four uniformed Navajo patrolmen joined them from the copters. They ran to the tradingpost and stayed there for some time. Then, they returned to the copters, climbed in and took off.

The following are the event descriptions of the above paragraph.

I. e1: The helicopters coming out of the sun
II. e2: The helicopters making Youngman’s eyes water
III. e3: The helicopters landing in tandem in front of the Hogan
IV. e4: Two figures emerging from each copter
V. e5: The two figures carrying medical bags
VI. e6: The two figures coming out of the shed
VII. e7: The two figures holding handguns
VIII. e8: Four Navajo patrolmen joining the two figures from the copters
IX. e9: The two figures and the patrolmen running to the tradingpost
X. e10: The two figures and the patrolmen staying at the tradingpost for some time
XI. e11: The two figures and the patrolmen returning to the copters
XII. e12: The two figures and the patrolmen climbing in
XIII. e13: The two figures and the patrolmen taking off

Given below is a table indicating the details of the run of our system on this paragraph.
Table 27. Details of Run for Example 6

<table>
<thead>
<tr>
<th>No.</th>
<th>Candidates</th>
<th>Temporal Focus</th>
<th>Next Event</th>
<th>Output Relation</th>
<th>Update Phase</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>e1</td>
<td>e1</td>
<td>e2</td>
<td>(overlaps e1 e2)</td>
<td>No Change</td>
<td>precise</td>
</tr>
<tr>
<td>2</td>
<td>e1 e2</td>
<td>e1</td>
<td>e3</td>
<td>(same-event e1 e3)</td>
<td>Changes</td>
<td>precise</td>
</tr>
<tr>
<td>3</td>
<td>e3</td>
<td>e3</td>
<td>e4</td>
<td>(ends-before e3 e4)</td>
<td>No Change</td>
<td>imprecise</td>
</tr>
<tr>
<td>4</td>
<td>e3 e4</td>
<td>e4</td>
<td>e5</td>
<td>(overlaps e4 e5)</td>
<td>Changes</td>
<td>precise</td>
</tr>
<tr>
<td>5</td>
<td>e4 e5</td>
<td>e4</td>
<td>e6</td>
<td>(after e4 e6)</td>
<td>Changes</td>
<td>precise</td>
</tr>
<tr>
<td>6</td>
<td>e6</td>
<td>e6</td>
<td>e7</td>
<td>(overlaps e6 e7)</td>
<td>No Change</td>
<td>precise</td>
</tr>
<tr>
<td>7</td>
<td>e6 e7</td>
<td>e6</td>
<td>e8</td>
<td>(overlaps-or-sequence e6 e8)</td>
<td>No Change</td>
<td>precise</td>
</tr>
<tr>
<td>8</td>
<td>e6 e8</td>
<td>e8</td>
<td>e9</td>
<td>(sequence e8 e9)</td>
<td>Changes</td>
<td>precise</td>
</tr>
<tr>
<td>9</td>
<td>e6</td>
<td>e9</td>
<td>e10</td>
<td>(sequence e9 e10)</td>
<td>Changes</td>
<td>precise</td>
</tr>
<tr>
<td>10</td>
<td>e10</td>
<td>e10</td>
<td>e11</td>
<td>(sequence e10 e11)</td>
<td>Changes</td>
<td>precise</td>
</tr>
<tr>
<td>11</td>
<td>e11</td>
<td>e11</td>
<td>e12</td>
<td>(sequence e11 e12)</td>
<td>Changes</td>
<td>precise</td>
</tr>
<tr>
<td>12</td>
<td>e12</td>
<td>e12</td>
<td>e13</td>
<td>(before e12 e13)</td>
<td>No Change</td>
<td>precise</td>
</tr>
</tbody>
</table>

Note that our system interprets the events e1 and e3 as referring to the same event. **Landing of the helicopters** is interpreted as the termination of the helicopters motion. Because of the different aspects of the descriptions corresponding to e1 and e3, the temporal focus is shifted to e3.

This example indicates two imprecise relations. The following table indicates these relations along with the corresponding correct relations. Brief explanations are also provided for the impreciseness in each case.

Table 28. Comments on the imprecise relations of example 6

<table>
<thead>
<tr>
<th>No</th>
<th>Imprecise Relation</th>
<th>Correct Relation</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>(ends-before e3 e4)</td>
<td>(sequence e3 e4)</td>
<td>e3 enables e4</td>
</tr>
<tr>
<td>2</td>
<td>(overlap-or-sequence e6 e8)</td>
<td>(sequence e6 e8)</td>
<td>e6 enables e8</td>
</tr>
</tbody>
</table>

In the case of the first relation the landing of the helicopters (e3) enables the two men to emerge from them (e4). In the case of the second relation the men's coming out of the shed (e6) enables the event of the patrolmen joining them from the copters (e8). In both cases sequentiality is enforced by the enabling relations.
9.4. Overall Evaluation

In this section we summarize the results of our test runs. The total number of sentences used for testing our system is 58 and the total number of event descriptions is 120. The following table presents an overall picture of the number of precise, imprecise and incorrect relations identified by our system for each example.

Table 29. Overall Evaluation

<table>
<thead>
<tr>
<th>Example No</th>
<th>Number of Sentences</th>
<th>Number of Relations</th>
<th>Precise</th>
<th>Imprecise</th>
<th>Incorrect</th>
<th>Precision</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5</td>
<td>7</td>
<td>6</td>
<td>0</td>
<td>1</td>
<td>86</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>6</td>
<td>5</td>
<td>1</td>
<td>0</td>
<td>83</td>
</tr>
<tr>
<td>3</td>
<td>25</td>
<td>49</td>
<td>40</td>
<td>2</td>
<td>6</td>
<td>83</td>
</tr>
<tr>
<td>4</td>
<td>6</td>
<td>14</td>
<td>11</td>
<td>0</td>
<td>3</td>
<td>78</td>
</tr>
<tr>
<td>5</td>
<td>13</td>
<td>27</td>
<td>24</td>
<td>3</td>
<td>0</td>
<td>88</td>
</tr>
<tr>
<td>6</td>
<td>5</td>
<td>12</td>
<td>10</td>
<td>2</td>
<td>0</td>
<td>83</td>
</tr>
</tbody>
</table>

The above table illustrates the evaluation of our system through the test paragraphs. The column labelled precision expresses the ratio of precise relations to the total number of relations as a percentage in each case. The overall percentage of precise relations to the total number of relations is 84. The percentage of incorrect relations is 8.7 while the percentage of imprecise relations is 7.3.

9.4.1. Observations

Example 1 is a process description in which a sequence of steps are characterized using explicit temporal markers such as next and finally. These lexemes explicitly indicate sequence
information. There is one instance of an incorrect relation where the state e5 sequentially follows the event e4 (please consult table 19) rather than being simultaneous with it since e5 describes the product resulting from e4. This example indicates the need for semantic inferencing when an event description and a state description (aspect representation INTERNAL) are to be sequenced.

Example 2 illustrates a paragraph well marked by explicit indicators (the connectors while and when and the time displacement lexeme finally.) There is an imprecise relationship involving the events e4 and e5 where a semantic relation enforces sequentiality.

Example 3 illustrates a style of writing where the use of gerunds is significant. The main verb of a gerund is marked by the progressive -ing suffix. Accordingly, gerunds are interpreted as descriptions of ongoing events and have the aspect representation INTERNAL. Gerunds are a source of error in our system and mark points where incorrect relations cluster (as seen in Table 22). The error in our treatment of gerunds arises from assuming simultaneity as a default when a gerund is to be sequenced with another event description. As the paragraphs of example 3 illustrate, semantic relations can also enforce sequentiality when an event description and a gerund are to be sequenced. Therefore, when a gerund is encountered in the text semantic analysis proves necessary.

Example 4 is again a case where a gerund (seizing the doll) is involved in the first incorrect relation. In this case the semantic relation between the situations enforces sequentiality rather than simultaneity as assumed by the default sequencing mechanism. The second incorrect relation in this example occurs as a result of the first incorrect relation as explained in the analysis of this example. The third incorrect relation involves an event description (Helen dashing the doll to the floor) and a state description (Helen was keenly delighted) with the state resulting from the event. Hence, the state and event are sequential.
The paragraphs of Examples 2, 3, 5, 6 illustrate instances of imprecise relations. Imprecise relations arise when two events to be sequenced have different agents (subjects) but their descriptions have the same tense. In such cases we cannot assume sequentiaility (in the absence of explicit temporal information) since simultaneous occurrence of the events is also possible. However, sequentiaility appears to be the likely interpretation in cases where at least one of the events to be sequenced is momentary. This observation can be used to cut down the need for semantic inferencing in rectifying the imprecision when momentary events are involved.

9.5. Summary

This chapter provided an assessment of the limitations and capabilities of our system. We have also identified through our test paragraphs, some cases where semantic analysis is needed to augment the capabilities of our system.
10 Conclusions

10.1. Major Observations and Contributions

Our analysis of narrative texts is primarily temporal and is based on the surface forms of the verbal elements of descriptions. These surface forms encode temporal information in the form of aspect and tense. This information is decoded along with the parsing of descriptions. A distinctive feature of our approach in comparison to other approaches is the centralization of these notions as primary sources of temporal information in a description. The emphasis on these notions is especially pronounced in our modelling of temporal sequencing mechanisms through tables of inferences indexed by these temporal characteristics of descriptions. Aspect, in particular, holds special significance as it defines structural representations for descriptions in terms of the underlying situation.

An interesting idea emerging from our analysis is the concept of phases of a situation. For instance, the punctual event description Jack started swimming, characterizes the initial phase of John's swim (a durative event). Accordingly, this description is represented by STARTPT (signifying that its underlying event is punctual and marks the beginning of a durative event). Similarly, the description It is raining characterizes an ongoing or internal phase of a rainy
situation as signified by its aspect representation INTERNAL. Points marking punctual event occurrences are viewed as the startpoints and endpoints of intervals corresponding to durative situations owing to the initiative and terminative nature of punctual events. Aspect representations indicate the phase highlighted by the description. The notion of aspect provides the ability to describe individual phases of underlying situations while disregarding other phases.

In our analysis we have made use of Galton's dichotomy of situations into states and events. In his classificatory scheme, events are differentiated into punctual events (instantaneous events) and durative events (events of finite duration) based on the durational extent of individual occurrences. Our system incorporates this distinction of events. In addition, a further differentiation of punctual events into initiative punctual events and terminative punctual events is made owing to the initiative and terminative nature of these events. Initiative punctual events mark the beginnings (startpoints) of durative situations while terminative punctual events mark the endings (endpoints) of durative situations. The representations of punctual event descriptions reflect this distinction.

A novel feature of our approach is the set of inference rules for modelling temporal sequencing mechanisms. As emphasized in our discussion of these mechanisms, enormous amounts of data have to encompassed because of the large number of aspect/tense representations that arise. Our model of these mechanisms is extensive enough to account for vast diversity in surface forms. The rules of inference embodied in our model are arranged in tabular form and are activated by the aspect/tense representations of descriptions to yield temporal relations. The role of aspect and tense as indices of these tables emphasizes the critical nature of these notions in our model. The temporal relations yielded by the table entries impose positional constraints on the representations of situations.

The controlling mechanism (driver routine) for the processing of narrative texts is based on the notion of temporal focus proposed by Webber (1988). Our procedural implementation of
this notion consists of two phases: a processing phase during which temporal relations are derived and a focus update phase to reflect movements of the narrative time. The processing phase is sometimes preceded by a selection phase to determine the temporal focus in the event of there being more than one candidate focus. Our heuristics for selection of temporal focus, proposed in Chapter 7\textsuperscript{12} are original and have been formulated on the basis of empirical observations. The procedural implementation of temporal focus is simple and computationally fast.

Uncertainty and vagueness of data are obstacles to precise modelling. These factors hamper modelling to a great degree. Although we do not claim to have solved these complex issues entirely, we do consider them reasonably well-addressed within the scope of our model. For instance, given the temporal connection \textit{It was raining before Tom went to school} no assumptions are made regarding the endpoint of the rainy situation relative to the \textit{Tom's motion}. The rainy situation may or may not have ended prior to Tom's schoolward motion though it is certain that the rainy situation started before the start of Tom's motion. Our event/state guidelines for temporal sequencing mechanisms account for uncertainty and gaps of knowledge by taking all possibilities into account. Another instance of the treatment of uncertainty is illustrated by the following example where there are no explicit indicators of sequence information.

\begin{quote}
Jack went into the room. Mary followed him.
\end{quote}

In our view, both overlap and sequentiality of occurrence are likely (this example requires default sequencing) in this case. In other words, when the agents (subjects) of successive event descriptions differ, sequentiality is a possibility but not a necessity. Thus, the first event may or may not have ended prior to the start of the second. All possibilities that can arise

\textsuperscript{12} See page 150
are considered equally likely. In fact the imprecise relation overlap-or-sequence proves useful in modelling the uncertainty in this example.

The initial hypothesis of this research was that temporal information in narratives is clearly marked by indicators like aspect, tense, temporal adverbials and time phrases. Our analysis shows that semantic relations between events can also be a source of temporal information especially in those cases where explicit temporal markers are missing. Under such circumstances, temporal information is implicit.

Our default sequencing mechanism was formulated to account for uncertainty and lack of explicit information in the data. From our test results in the previous chapter we hypothesize that semantic inferencing is required in the following cases.

I. Sequencing of an event description and a state description.

II. Sequencing of gerunds.

III. Sequencing of events involving different agents. In this case semantic inferencing is needed to rectify imprecision. When at least one of the events to be sequenced is momentary, however, sequentiality appears to be the likely interpretation. This observation can be used to cut down the overhead of semantic inferencing in such cases as in the following example.

Jack hit the ball. It rolled down the hill.

There is a semantic relation (Jack's hitting the ball causes it to roll down) between the two events that enforces sequentiality between the events. From the observation that the verb hitting signifies a momentary event, however, we can assume sequentiality and therefore cut down the expense of semantic inferencing in arriving at the correct relation.
10.3. Directions for Future Work

Some of the issues largely unaccounted for by our analysis are modals, negation and habitual actions. This section briefly addresses these issues to give an initial insight toward future research.

**Negation**: In English, negated descriptions frequently convey non-occurrence of underlying situations. For instance, the sentence *The man hasn't slept today* indicates the non-occurrence of the durative event signified by *the man's sleep* over the stretch of time signified by *today*.

Sometimes negated descriptions are used to describe unaccomplished actions as in the sentence *Jack didn't reach Chicago*. This description apparently indicates that *Jack was on his way to Chicago* but did not accomplish the journey. Descriptions such as this one violate expectations about the completion of an action.

A third use of negation is to convey a set of possibilities. For instance, the sentence *Jack hasn't gone to Chicago* could mean either of the following.

I. Jack has never been to Chicago.

II. Jack has never been to Chicago over a limited time span.

One of the difficult aspects of negation is its representation on the timeline. For instance, the representation of the third example above requires an associated time span over which *Jack made no trips to Chicago*. Another issue to be approached with caution is the scope of negation. For instance, in the sentence *there is nobody in the room* negation applies to the entities. In the sentence *Jack didn't sleep for three hours* negation applies to the duration specification for three hours. In other words, Jack could have slept for less than three hours or more than three hours. The last two examples suggest that identifying the scope of negation
in sentences is a key issue. The problem of negation requires a systematic case by case
analysis.

**Modals**: Modals in English signify varying degrees of conjecture or uncertainty concerning the
occurrence of situations [Grimes, 1975]. Modelling the information conveyed by modals re-
quires possible world semantics. Consider the description *Jack could kill the man*. This de-
scription could be interpreted as a statement indicating the possibility of *Jack killing the man*
or could also be interpreted as a general statement about *Jack’s* capability to do the act.
Having the capability of doing something does not necessarily imply that the person would
do it. This raises the notion of *intentionality* as a key issue. Some modals such as *may*, *might*
etc. signify possibility. Other modals such as *ought* or *should* indicate actions or norms ex-
pected of the subjects. An approach to the complex problem of modality is possible world
semantics.
Appendix A.

In this appendix we illustrate the representation of some example temporal connections using the event/state guidelines discussed in Chapter 5. These examples give a broad spectrum of the modelling of temporal connections within our system and bear testimony to the syntactic diversity of temporal connections.

Example 1: *Mary left for school before John reached home.*

In this connection the main clause punctual event marks the initiation of *Mary's schoolward motion.* Similarly, the subordinate clause punctual event marks the termination of *John's homeward motion.* The main clause is represented by STARTPT_E1 where E1 denotes Mary’s schoolward motion. The subordinate clause has the representation ENDPT_E2 where E2 denotes John’s homeward motion. From the guideline for a main clause punctual event occurring at point P1 and a subordinate clause punctual event occurring at point P2, we note that P1 *precedes* P2. Hence, the startpoint of E1 is before the endpoint of E2. The connection is represented below.

STARTPT_E1 before ENDPT_E2, (starts-before-end E1 E2)
The predicate \textit{starts-before-end} denotes all interval-interval models of James Allen where the startpoint of the first interval E1 is before the endpoint of the second interval E2. Nothing is known about the endpoint of E1 or the startpoint of E2. These two points are free to relate in all possible ways.

**Example 2:** \textit{Jack played football before it was raining.}

A state description as the subordinate clause of a \textit{before} temporal connection signifies awkward usage but can arise sometimes in people’s narration of events. In general, people are not always precise in their narrative accounts. Where possible, our aim is to also account for the impreciseness that can arise in narrative accounts. With this purpose in mind we admit this example. The main clause has the representation \texttt{INTERNAL\_E1} where E1 denotes the durative event. The subordinate clause being a state description (progressive state description) has the representation \texttt{INTERNAL\_E2} where E2 denotes the rainy situation. With regard to such inappropriate temporal connections we assume that the startpoint of the subordinate clause state is constrained in the connection. Thus, we treat this connection as having the same interpretation as \textit{Jack played football before it started raining}. Therefore this connection is represented as follows.

\begin{center}
\texttt{INTERVAL\_E1 before INTERNAL\_E2, (before E1 E2)}
\end{center}

**Example 3:** \textit{It was raining after Mary came home}. This example involves a main clause that describes the state of progress of a rainy situation (denoted by E1) and a subordinate clause that describes the durative event of \textit{Mary’s homeward motion} (denoted by E2). The main clause has the representation \texttt{INTERNAL\_E1} while the subordinate clause is represented by \texttt{INTERVAL\_E2}. From the fact that the main clause progressive state is ongoing at a time after the event E2 we can infer for certain that the endpoint of E1 must be after the endpoint of E1 as reflected by the guideline. It is possible for it to be raining at the time of \textit{Mary’s homeward motion}. Hence, when the main clause is a state description we do not assume anything about...
the startpoint of the underlying interval. The startpoint of E1 is free to be positioned anywhere with respect to E2. The representation for this example is

\text{INTERNAL}_E1 \text{ after INTERVAL}_E2, (\text{ends- after } E1 \ E2)

Example 4: *Jack had eaten dinner before he saw Mary.*

The main clause describes the durative event of *Jack's eating dinner* (denoted by E1) and has the representation \text{POSTINTERVAL}_E1. The subordinate clause describes a durative event E2 denoting *Jack's seeing Mary* and has the representation \text{INTERVAL}_E2. The event/state guidelines also apply to such cases where one or both the clauses have the perfect usage. Accordingly, we note that in this case the endpoint of E1 precedes the startpoint of E2 (from the guideline for a before temporal connection between two durative events). Therefore, this example is represented by

\text{POSTINTERVAL}_E1 \text{ before INTERVAL}_E2, (\text{before } E1 \ E2)

Example 5: *Jack had eaten lunch after Mary had left for school.*

In this example both clauses have the perfect usage. The main clause durative event E1 denotes *Jack's eating lunch.* This clause is represented by \text{POSTINTERVAL}_E1. The subordinate clause describes the punctual event of *Mary's leaving for school* that marks the startpoint of her schoolward motion. Designating Mary's schoolward motion by E2, this clause has the representation \text{POSTSTARTPT}_E2. From the guideline for a main clause durative event and a subordinate clause punctual event in an after temporal connection we note that the startpoint of E1 occurs after the startpoint of E2. Given the circumstances of this example it is possible for Mary to be on her way to school at the time of John's having lunch. The only information that can be ascertained is the constraint between the startpoints stated above. Accordingly, the representation for this example is as follows:
POINTERVAL\_E1 after POSTSTARTPT\_E2, \((\text{starts-after E1 E2})\)

**Example 6:** *Jerry played football before he had started his homework.*

This example has a subordinate clause with the perfect usage. The main clause describes the durative event of *Jerry’s playing football* (denoted by E1) and is represented by INTERVAL\_E1. The subordinate clause describes a punctual event that initiates *Jerry’s doing his homework* (denoted by E2). Because of the perfect usage this clause has its reference time positioned after the startpoint of E2. As a result, it has the representation POSTSTARTPT\_E2. Using the guideline for a main clause durative event and a subordinate clause punctual event we observe that the endpoint of E1 occurs before the startpoint of E2. This example may be represented as follows:

\[
\text{INTERVAL\_E1 before POSTSTARTPT\_E2, (before E1 E2)}
\]

**Example 7:** *John was going to exercise before eating breakfast.*

The guidelines for events and states also apply in cases where one or both clauses have the prospective usage in English. In this connection the main clause has the prospective use and describes the durative event signified by *John’s exercising* (denoted by E1). The subordinate clause describes an ongoing durative event of *John’s eating breakfast* (denoted by E2). The main clause has the representation PREINTERVAL\_E1 while the subordinate clause is represented by INTERNAL\_E2. Since both events are durative we apply the guideline for a main clause durative event and a subordinate clause durative event in a before temporal connection. This connection imposes a constraint on the endpoint of E1 and the startpoint of E2. The endpoint of E1 comes before the startpoint of E2 thereby yielding the following representation.

\[
\text{PREINTERVAL\_E1 before INTERNAL\_E2, (before E1 E2)}
\]
Example 8: John had done his homework while Mary was asleep.
This example illustrates a while temporal connection between a main clause having the perfect usage and a subordinate clause that describes a state. The main clause is represented by POSTINTERVAL_E1 where E1 denotes John's doing his homework. The subordinate clause describes the state of Mary being asleep (denoted by E2) and therefore has the representation INTERNAL_E2. Applying the guideline for durative events and states we observe that both E1 and E2 overlap.

POSTINTERVAL_E1 while INTERNAL_E2, (overlaps E1 E2)

Example 9: Jack was going to swim while John played poker.
The guidelines for events and states in while connections are also applicable when one or both clauses have the prospective usage. The following example involves a main clause with the prospective use.

Both clauses have underlying durative events in this example. The main clause durative event (Jack's swim denoted by E1) is prospective at the reference time of this clause. Therefore this clause has the representation PREINTERVAL_E1 since its reference time is positioned before the interval corresponding to E1. The subordinate clause refers directly to the durative event of John's playing poker. Hence, its representation is INTERVAL_E2 where E2 signifies this event. From the guideline for durative events in while connections we observe overlap between the two events. Hence, the representation for this example is

PREINTERVAL_E1 while INTERVAL_E2, (overlaps E1 E2)
References


Vita

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