# The Interpretation of Temporal Relations in Narrative

**Fei Song and Robin Cohen**
Logic Programming and Artificial Intelligence Group
Dept. of Computer Science, Univ. of Waterloo
Waterloo, Ontario, Canada, N2L 3G1

## Abstract

This paper describes an algorithm for the interpretation of temporal relations between events mentioned in narrative (such as which event occurs before another). These relations are decided through three different levels of linguistic concepts: aspectual information for verbs, time relations for tenses, and time relations between clauses and/or sentences. One contribution of this paper is to present a more rigorous description for time relations of tenses, which is able to express all the 16 tenses in English and incorporate the interval properties of events from the aspectual analysis into the tense relations. For interpreting time relations between clauses, we emphasize the use of anaphoric references to events and introduce the concept of a situational description for an event (including the participants, place, time duration, etc.), used to make the interpreting algorithm deterministic, i.e. the set of interpreting rules are applied in a fixed order rather than in parallel. Last, we suggest a tree-like structure for the representation of temporal relations between events, which allows us to include vaguely specified relations (which may be clarified later), to facilitate the interpretation of subsequent temporal relations.

## 1 Introduction

One important part of the understanding of narratives is the interpretation of temporal relations between events mentioned in the narrative (e.g. event1 before event2). These temporal relations are often explicitly indicated by some linguistic categories like tense, aspect, and certain temporal adverbials. They may also be implicitly determined using context-dependent default rules. For example, a rule of "narrative time progression" provides that in narrative, time does not move backward unless an explicit time marker is given [Hirschman and Story, 1981].

In this paper, we consider temporal relations in terms of three different levels of linguistic concepts. At the lowest level, we distinguish events as situations, which are a classification for predications, drawn from aspectual information, including states, processes and transition events [Passonneau, 1987]. We generally treat events as intervals, interpreted against some reference points on a time line. The situation types and their interpretations are briefly discussed in section 2.

At the middle level we consider tense, which is usually described by three abstract times [Reichenbach, 1947]: the time of the event (ET), the time of speech production (ST), and the time of reference (RT) from which the event is interpreted. The concept of RT is a theoretical entity used to distinguish different tense structures. For example, simple past is represented on a time line as RT,ET–ST, and past perfect would be ET–RT–ST, where the comma indicates simultaneity and the hyphen "temporally precedes". In this paper, we present a more rigorous description of tense relations by introducing more than one RT for some tenses so that we are able to describe all the 16 tenses in English. Moreover we treat ET as an interval, which implies that we actually incorporate aspectual information into tense relations. These modifications are the topics of section 3.

At the highest level we study time relations between clauses and/or sentences. The key idea in establishing these relations is the management of temporal focus (TF), which is the node on the time line that provides a context for the interpretation of RT and ET of the next clause or sentence [Webber, 1987]. In this paper, we give a deterministic algorithm for interpreting these relations, using a set of default rules to manage the change of TF. Included are the concepts of anaphoric reference to a situation and situational description for a situation (including participants, place, and other information). The temporal relations between events are represented in a tree-like structure, which allows some relations between events to be left vaguely specified, to delay interpretation. A detailed account for the representation structures and the interpreting algorithm is given in section 4.

Finally in section 5, we summarize the paper and give some suggestions for future research.

## 2 Temporal Relations of Situations

According to [Passonneau, 1987], events are classified as situations, which are aspectual classes for predications, determined on the basis of lexical aspect (or verb type like: stative, process, or transition event) and grammatical aspect (i.e. progressive tenses) together with suggestions from temporal adverbials. Here we follow [Passonneau, 1987] and consider only four types of situations:

```
States:  The pressure is low at 8:00.
Temporally unbounded processes:
         The alarm is sounding.
Temporally unspecified processes:
         The alarm sounded.
Transition events: The engine failed.
```

A detailed account on the distinction between these four types of situations is presented in [Passonneau, 1987]. In this paper, we generally treat events as intervals[1] and interpret these intervals against some reference points, sometimes explicitly mentioned, as 8:00 in the example for state. One difference from Passonneau is that we add a default rule for the interpretation of a temporally unspecified process, i.e. we interpret the associated interval for the event time against some reference point which coincides with the start point of the interval. Later on, we can modify the interpretation if the speaker uses a progressive verb or certain temporal adverbial to indicate that the reference point should lie within the interval.

# 3 Temporal Relations of Tenses

Most of the work on time relations of tenses [Reichenbach, 1947; Webber, 1987; Passonneau, 1987] is based on Reichenbach's notions of three times: speech time(ST), event time(ET), and reference time(RT). By considering all of the possible permutations of these three times, we can see that they only denote 13 different temporal configurations on a time line, corresponding to 7 tenses in English [Reichenbach, 1947]. However there are actually 16 tenses in English[2].

In this section, we present a more rigorous description for tenses, which is able to specify all the 16 tenses, by introducing more than one RT. In fact, we even view ST as a kind of reference time to the time when a narrative is given. But ST is more important than other RT's in that it determines the use of tenses for a clause or sentence. There is also one RT which is more important than other RT's. This RT is the reference point for interpreting the interval ET. Besides ST and RT, there may be other RT's for some tenses, denoted as RT', RT". For example, a sentence in the past future (see (4) in the Appendix) will need two RT's[3]:

```
(3.1) (Mary said that) John would climb
      Aconcagua.
```

since the situation "John's climbing Aconcagua" is talked about at RT' before ST, and the situation happens at RT after RT'.

Our description for tenses in the Appendix also includes aspectual information for situations. This can be seen from the comparisons between simple and progressive, perfect and perfect progressive tenses. The progressive and perfect progressive are used for non-stative verbs and suggest temporally unbounded processes. The simple and perfect may suggest states or temporally unspecified processes or transition events, depending on the verb types.

Most of the time relations listed in the Appendix are uniquely determined except past future tenses (marked by *), which correspond to multiple cases. The partial restrictions on times of these tenses can be treated more rigorously in terms of Allen's logic [Allen, 1981]. For example, the past future tense (4) and past future progressive (8) can be expressed as:

```
Before(RT', RT) and Before(RT', ST)
and
(Before(RT, ST) or Equal(RT, ST)
  or Before(ST, RT)
);
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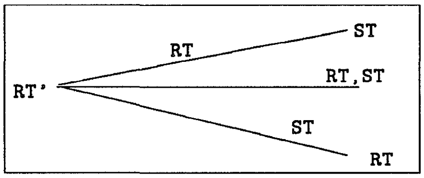



Figure 1.

These tense relations, which correspond to multiple cases, are usually decided in the context of narrative when the relations between the current ET and ST can be decided (see section 4).

# 4 Temporal Relations of Narrative

In this section, we discuss the temporal relations between clauses and/or sentences in narrative. First in section 4.1, we suggest a tree-like structure for representing these relations, and consider the contribution of various kinds of linguistic expressions through examples. Then in section 4.2, we present a deterministic algorithm for interpreting these relations by using the concepts of temporal focus and its default management rules. Last, we show the use of the algorithm through several example narratives.

## 4.1 Representation of Temporal Relations

The temporal relations between intervals can be described in Allen's logic [Allen, 1981], in which there are five primitive relations:

```
(1) Before(i1, i2) --- Time interval i1 is
    before i2, and they do not overlap.
(2) Meets(i1, i2)  --- Interval i1 is before
    i2, but there is no interval between them.
(3) During(i1, i2) --- Interval i1 is fully
    contained with i2.
(4) Equal(i1, i2)  --- Intervals i1 and i2
    are the same.
(5) Overlap(i1,i2) --- Interval i1 starts
    before i2, and they are overlapped.
```

These relations are maintained in a network where the nodes represent individual intervals and the labels on arcs indicate the relations between nodes in the network. However we feel they are too primitive for a representation of a narrative since the relations suggested in English are usually quite vague. For example, by analyzing the tense relations for two sentences, we may decide that ET1 happens at a earlier time than ET2, but we cannot say whether

[1]Classifying events as situations provides additional information (e.g. boundedness properties) for the interpretation of temporal relations between events. The time points associated with transition events can be considered as reduced intervals.

[2]See the Appendix. The 7 tenses in Reichenbach's description are marked by +.

[3]The event "Mary said that" is used to provide a context such that the following event "John's climbing Aconcagua" is explained in past future tenses rather than in modal uses.

ET1 "Before" or "Meets" or "Overlap" with ET2. In most cases, only partial restrictions on temporal relations between situations can be obtained from a narrative at a time. If we try to consider all of the possible cases in terms of the five primitives and the inverses of them, we have to make a lot of inferences. Although "reference intervals" are used in [Allen, 1981] to reduce the possible inferences on temporal relations, there are still quite a few inferences to be made between the intervals with the same reference interval. We instead classify the five primitives into two categories and introduce two high-level relations: "Precedes" and "Includes" for them. They are defined as follows:

```
Precedes(i1, i2) = Before(i1, i2) or
  Meets(i1, i2) or Overlap(i1, i2);
Includes(i1, i2) = During(i1, i2) or
  Equal(i1, i2);
```

We then propose a processing strategy whereby the vaguer relations may be replaced by one of the five primitives, as more information about the relation between the events is presented.

These two high-level relations can be used to organize the representation network into a tree-like structure. "Includes" is used to represent temporal relations between a father and its sons, while "Precedes" represents temporal relations between the brothers. In this way, we can clearly represent the fact that the property P held by a father can be inherited by the sons. For example, the temporal configuration of intervals in Figure 2 can be represented as a tree-like structure at the bottom.

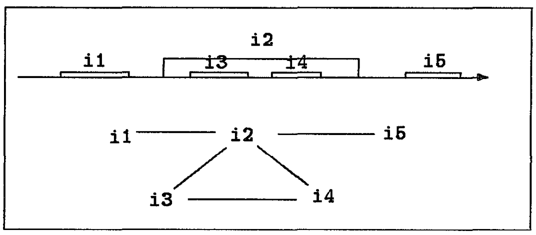



Figure 2. Representation of "Includes" and "Precedes"

where the horizontal links can be labeled by "b" or "m" or "o" if they can be decided as "Before" or "Meets" or "Overlap" relations. Similarly, the vertical links can be labeled by "d" or "e" depending on the "During" or "Equal" relations.

There may be cases where the relations between some intervals cannot be decided in terms of "Precedes" and "Includes" themselves, e.g. "Precedes or the inverse of Precedes" and "Precedes or Includes", etc. However we believe in narrative, these intervals are usually partially related to some intervals in terms of "Precedes" and "Includes", otherwise the narrative is probably incoherent. These cases can be represented in our notation by only specifying the partial relations as different branches, leaving the undecided relations unspecified. For example, the relations of past future tenses (4) and (8) in the Appendix can be represented as follows:

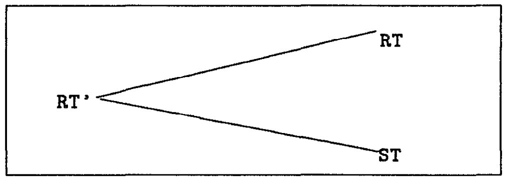



Figure 3. Representation of tenses (4) and (8)

where the relations between ST and RT cannot be decided by tense relations, but the partial relations: "Before(RT', ST)", "Before(RT', RT)" are explicitly specified. When, some time later, the relations between intervals and/or points in the two branches are suggested, we can make inferences to decide them in terms of the five primitive and two high-level relations. For example, in tense (4), if the following situation is given after RT and expressed in the past tense, then we can decide "Before(RT, ST)". We believe that this vague representation facilitates the interpretation of temporal relations in narrative, by postponing some decisions.

The linguistic expressions for temporal relations come from various sources in narrative. They may be: (1) situation types, (2) tense relations, (3) context information, such as references and default rules, (4) temporal adverbials and (5) spatial information. Most of these have been discussed in the previous sections; here, we only explain the use of anaphoric references to events and spatial information in detail.

Anaphoric references to events are important since they can add more temporal information. For instance, in (4.1):

```
(4.1) John has been to California
        once (ET1).  It was in 1986.
```

the "it" refers to the situation "John's being in California" and explicitly provides the time location "in 1986". These references usually take the forms of Prosentential, Pro-verbs, Proactions, etc. mentioned in [Hirst, 1981]. They only provide more information about already mentioned events so that their relations to other intervals can be determined more clearly.

Spatial information can be distinguished into two sorts, the first of which is spatial relations between events. For instance, in (4.2):

```
(4.2) John went over to Mary's house (ET1).
        On the way, he had stopped by the
          flower shop for some roses (ET2).
```

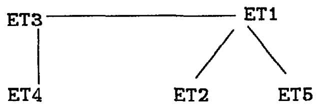
the adverbial "on the way" indicates that the situation ET2 should appear within ET1 " John's going over to Mary's house". Thus this sort of spatial information can also contribute to the determination of temporal relations between intervals.

The other sort is the situational description for a event, which basically consists of participants, place, and time duration for the event. Its use can be illustrated by the following narrative example from [Webber, 1987]:

```
(4.3) a. I was at Mary's house yesterday
           (ET1).
      b. We talked about her brother (ET2).
      c. He spent 5 weeks in Alaska with
           two friends(ET3).
```

d. Together, they made a successful assault on Denali (ET4).

e. Mary was very proud of him (ET5).




In this example, the first sentence has the situational description: (I, Mary, Mary's house), which is inherited by the second sentence, since the participants "we" refer to "I and Mary", so sentence b) can be interpreted against RT1 of sentence a). Strictly, sentence c) should be expressed in the past perfect tense, since RT3 for ET3 should be before RT2, which is after RT1 by default. Unfortunately, such uses are allowed in English and we have to detect them for the past perfect use. This difference can be captured in the situational description for the sentence c): (He, two friends, Alaska), which is quite different from sentences a) and b)'s. This indicates that ET3 cannot be interpreted against RT2, but at some point RT3 before RT2. Similarly, in sentence e), the participant goes back to Mary, which implies that we should interpret ET5 against RT2, since its situational description includes the participant Mary. In conclusion, the situational descriptions can provide more information for us to check the inconsistency of default interpretations based on tenses (see section 4.2).

## 4.2 Interpretation of Temporal Relations

The key idea in interpreting temporal relations in narrative is the temporal focus or TF. In [Webber, 1987], it is maintained by four management heuristics: a Maintenance Heuristic, two Embedded Heuristics, and a Resumption Heuristic. However these heuristics are assumed to be used in parallel since there is no simple way to fix the order. Another problem in [Webber, 1987] is that aspectual information is not incorporated in the interpretation, and ET is treated as a time point. As a result, "Includes" relations between events cannot be represented exactly on the time line. For instance, the temporal relation in example 4.2 is interpreted as ET2 "Precedes" ET1, shown in the Figure 4:

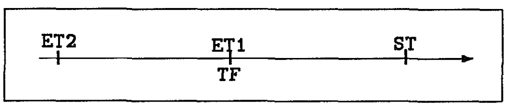



Figure 4.

In this subsection, we try to solve the second problem by treating ET as an interval and describing the tense relations for each kind of situation (see the Appendix). Because in our approach some tenses may have more than one RT's, we will modify Webber's definition of TF as: at any point N in the narrative, TF is the node on the time line that provides a context for the interpretation of the RT's of the next clause. Usually it is the RT which is referred to the current TF, but a new TF has to be created when the RT, against which the next ET is interpreted, is not the same as the current TF.

Next we produce a deterministic algorithm by using the concepts of anaphoric references to situations and situational descriptions. The former provides an explicit way to return to a previously mentioned situation and thus we assign it the highest priority in the algorithm (see (2) below). The latter may suggest an implicit way to change the TF, either return to a previous situation, or establish a new TF. These two concepts, together with tense relations and situation types, lead us to the following algorithm. Like other focusing processes, we also employ a stack to hold the previous TF's, where the top of the stack holds the most recent TF and the stack is searched top-down.

**Algorithm**

**Input**: a set of ET's from clauses in narrative, including their situation types and tense relations with ST and RT's (see section 2 and 3).

**Output**: a tree-like structure, showing the partial temporal relations between the ET's.

(1) set TF to ST.

**while** InputSet $\neq$ empty **do**

**begin**

Input a new situation ETi.

(2) If there is an anaphoric reference to some previous ET, find in the stack a RT against which ET is interpreted. If found, consider RT as TF and pop the elements above RT[4].

(3) Check RTi against TF.

i) If the relation between ST and RTi doesn't match the one between ST and TF, then create a new TF for RTi of ETi and push the current TF onto the stack.

ii) If ETi is in the past tense and its situational description is inconsistent with TF's, then find in the stack a RT which has a consistent description with ETi's. If found, resume RT as TF and pop the elements above RT, otherwise create a new TF before the current TF (for past perfect use) and push the current TF onto the stack[5].

(4) Check the relation between ETi and the ET associated with the current TF, (which is the TF on the top of the stack when a new TF is created in the above steps.). If "Includes" or "Precedes" is suggested explicitly by some adverbials or implicitly by relations between situation types, then do the following:

i) If a new TF has not been created, create a new TF and push the current TF onto the stack.

ii) Put the new TF inside the interval of ET for "Includes" and before or after ET for "Precedes".

(5) Interpret ETi against TF. Moreover, if ETi is a temporally unspecified process, shift TF to the end of ETi.

**end**

This algorithm is deterministic since for each input, we will apply the defaults in a fixed order and it will terminate

[4] If not found, interrupt the algorithm and suggest an message of incoherence to the user.

[5] In this algorithm, the TF change caused by the inconsistency with descriptions is limited to past tense. The change for other tenses will be left for future work.

when all inputs are processed. Now let's illustrate the above algorithm by the following examples [Webber, 1987].

```
(4.4) a. John went over to Mary's house
         (ET1).
      b. On the way, he had stopped by the
         flower shop for some roses (ET2).
      c. Unfortunately, the roses failed
         to cheer her up (ET3).
```

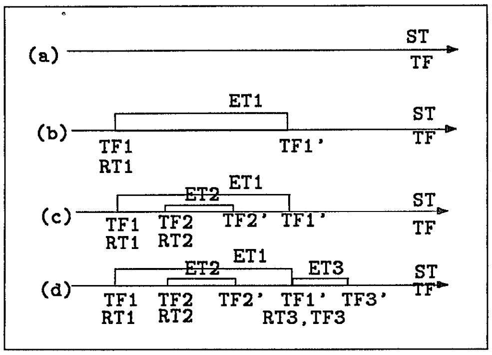



Figure 5.

At the beginning, TF = ST (see Figure 5(a)). When the first sentence is interpreted, RT1 refers to some node before ST, thus a new TF1 before ST is created (step(3) i)). Since ET1 is a temporally unspecified process, we by default (step (5)) interpret it against TF1 and shift TF1 to the end point of ET1 as TF1' after the interpretation (see Figure 5(b)). Since the second sentence is in the past perfect tense, it has two reference times: RT2' and RT2. RT2' can be referred to TF1', but RT2 must be referred to some time point before TF1'. Again a new TF2 before TF1' has to be created (step (3) i)). By the spatial adverbial "on the way", we can decide that TF2 falls within ET1, thus we interpret RT2 and ET2 there, and then shift TF2 to the end of ET2 as TF2' for the next sentence (see Figure 5(c)). Now for the third sentence, the current TF is TF2', and the situational description for ET1 and ET2 are : (John, Mary, Mary's house) and (John, flower shop) respectively. Since the third sentence is in the past tense, there is only one RT which may be interpreted against TF. However by (3) ii) above, the situational description for ET3 is: (Mary), which is inconsistent with TF's: (John, flower shop). Thus we have to check it with TF's in the stack. Because ET1's situational description includes Mary, ET3 can be interpreted against TF1', as shown in Figure 5(d).

In the example 4.5, the first two sentences are the same as in 4.4, but the third sentence is changed.

```
(4.5) a-b. are the same as in (4.4)
        c. He picked out 5 red ones, 3 white
           ones and one pale pink (ET3).
```

This time since the situational description for ET3: (John) is consistent with ET2's, so ET3 can be interpreted against TF2' as in Figure 6.

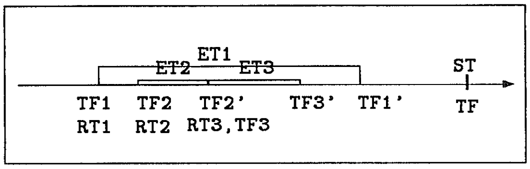



Figure 6.

Another example (4.3) has been discussed at the end of section 4.1, in which the interpretation of sentence 3) needs to create a new TF before the current TF2'. Also since the situational description of ET3 is inconsistent with the ET1's, ET3 should be located before ET1[6].

The examples in this section serve to illustrate the proposed algorithm. Introducing the particular tree-like representation of section 4.1 facilitates discussion of the algorithm and examples. For simplicity, we have omitted some details, for example, the power of our chosen representation is a topic for future work. Unspecified relations between ET's are assumed to undergo a subsequent inferencing procedure, to deepen the representation.

## 5 Summaries and Suggestions

Our deterministic algorithm for interpreting temporal relations in narrative has been described through three levels of linguistic concepts: situation types, tense relations, and time relations between clauses and/or sentences in narrative.

In the lowest situation-level, we generally treat an event as an interval and interpret the interval against some reference point.

In the middle tense-level, we present a more rigorous description by introducing more than one RT for some tenses such that we are able to express all 16 tenses in English and incorporate aspectual information in the description.

In the highest discourse-level, we introduce two high-level relations: "Precedes" and "Includes" besides the five primitive ones[Allen, 1981]. These relations are represented in a tree-like structure such that some vague relations in the processing of a narrative can be specified by "Precedes" or "Includes" or even partially unconnected branches. Later they can be replaced by some primitive relations when further information is suggested explicitly or implicitly in the narrative. Finally we present an deterministic interpreting algorithm based on all possible movements of temporal focus (TF). In particular, we emphasize the anaphoric reference to a situation as an explicit way, and the concept of situational description (including participants, place, tan ime duration, etc.) as implicit way to change TF.

Our work in this paper is mainly on narrative, but most of the discussions, we believe, are applicable to other types of discourse such as goal-oriented ones. From the standpoint of temporal relations, "generation" relation between actions [Grosz and Sidner, 1986; Pollack, 1986] is also an "Includes" relation since the time used in the execution of a subaction is only a part of the time used for the whole

[6]In these examples, we use time line structures to clearly show the change of TF. They can be easily transformed into tree-like structures.

generated action. However the relations between subactions are not always "Precedes" because some subactions may be executed in parallel, while others in sequence. In general, we have to use more than one level of temporal relations to characterize these relations. How "generation" relation affects the temporal relations and vice versa is certainly an interesting topic for future research.

Other remaining problems include the investigation of the interaction between temporal interpretation and reference resolution, and the incorporation of duration information in our representation.

In conclusion, we feel that our approach provides a richer representation for the temporal relations in narrative.

# A The Temporal Relations of 16 Tenses

(1) Simple Present+: ST = RT, (RT = ET (event) or RT in ET (stative or process)), e.g. John climbs Aconcagua.

(2) Simple Past+: ST > RT, (RT = ET (event) or RT in ET (stative or process)), e.g. John climbed Aconcagua.

(3) Simple Future+: ST < RT, (RT = ET (event) or RT in ET (stative or process)), e.g. John will climb Aconcagua.

(4) Past Future +*: ST > RT', RT' < RT, (RT = ET(event) or RT in ET(stative or process)), e.g. John would climb Aconcagua.

(5) Present Progressive: ST = RT, RT in ET (non-stative), e.g. John is climbing Aconcagua.

(6) Past Progressive: ST > RT, RT in ET (non-stative), e.g. John was climbing Aconcagua.

(7) Future Progressive: ST < RT, RT in ET (non-stative), e.g. John will be climbing Aconcagua.

(8) Past Future Progressive*: ST > RT', RT' < RT, RT in ET (non-stative), e.g. John would be climbing Aconcagua.

(9) Present Perfect+: ST = RT', RT' > RT, (RT = ET (event) or RT in ET (stative or process)), e.g. John has climbed Aconcagua.

(10) Past Perfect+: ST > RT' > RT, (RT = ET (event) or RT in ET (stative or process)), e.g. John had climbed Aconcagua.

(11) Future Perfect+: ST < RT < RT', (RT = ET (event) or RT in ET (stative or process)), e.g. John will have climbed Aconcagua.

(12) Past Future Perfect*: ST > RT',RT' < RT < RT",(RT=ET (event) or RT in ET (stative or process)), e.g. John would have climbed Aconcagua.

(13) Present Perfect Progressive: ST = RT', RT' > RT, RT in ET (non-stative), e.g. John has been climbing Aconcagua.

(14) Past Perfect Progressive: ST > RT' > RT, RT in ET (non-stative), e.g. John had been climbing Aconcagua.

(15) Future Perfect Progressive: ST < RT < RT', RT in ET (non-stative), e.g. John will have been climbing Aconcagua.

(16) Past Future Perfect Progressive*: ST > RT', RT' < RT < RT", RT in ET (non-stative), e.g. John would have been climbing Aconcagua.

Note that in many English grammar books, the past forms of future tenses are not listed, but they, like other tenses, have their required verb forms and are better treated as past future tenses.

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