

## Processing and Representing Temporally Sequential Events

**Kiyong Lee**

Korea University

5ka-1 Anam-dong, Seongbuk-ku

Seoul 136-701, Korea

klee@korea.ac.kr

### Abstract

In a discourse, events are narrated one by one linearly. But the temporal sequence of events does not always match the linear sequence of narration. One of such cases involves the mixed occurrences of durative and punctual events, as illustrated by "Mia took aspirin and slept, for she was ill. She then fell off a cliff in her dream." In this narration, five events are reported: three are durative events of sleeping, being ill and having a dream and two are punctual events of taking aspirin and falling off a cliff.

This presentation aims at establishing some systematic way of processing such events and representing them in a reasonably understandable temporal sequence. For this, events are analyzed in terms of an interval semantics that allows them to be anchored to appropriate temporal intervals and be ordered in an appropriate temporal sequence. In order to provide a simple syntactic basis, the presentation attempts to develop a small computational program that derive representations in feature structure by analyzing a small fragment of Korean.

### 1 Introduction

Events are often ordered in a temporal sequence and such sequential events are expressed in natural language either explicitly or implicitly. They are explicitly expressed by some subordinating conjuncts like "before" or "after" in English or by some unbound nouns like "cen-ey" (before) or "tawum-ey" (after) in Korean. But they may also be expressed in coordinate structures by the sequential occurrences of verbs. Here is a simple example in English, "Mia went to Tokyo, met a friend and stayed at her home." This sentence narrates three sequential events of Mia's going to Tokyo, meeting a friend and staying at the friend's home.

The sequence of narration, however, does not always match that of events. One such case involves the mixed occurrences of durative events and punctual events. Consider a case "Mia was ill and took pills and took a nap. She then had a bad dream. She fell off a cliff." This sentence narrates five events, three durative events of being ill, taking a nap, and having a bad dream and two punctual events of taking pills and falling off a cliff.

This paper aims at showing how such events can be processed and represented for the proper interpretation of their temporal sequences. For this aim, I make two basic assumptions: one is a minimal syntax as argued for in Lee (2002) and another, a minimal semantic representation that will be shown in this work.

### 2 Two Types of Temporal Relations

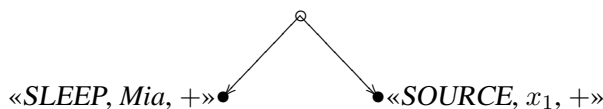
There are at least two types of temporal relations over events: precedence and inclusion. The past tense is a typical example of temporal precedence. An event described by a statement made with an utterance "Mia slept" is understood as preceding the event of making such an utterance, thus being an event in

the past. Another example may be given by two events, where one precedes the other. A sentence “Mia drank wine and slept” illustrates a case of temporal precedence among two events, describing a situation in which Mia’s drinking wine occurred before her sleeping.

Some events are durative, while others are punctual. A durative event that occurred before another event may last even after this event has occurred. For example, a situation described by “Mia felt ill and slept” involves two events, Mia’s feeling ill and her sleeping, where the former event may have lasted even during the event of Mia’s sleeping. This is classified as a case of temporal inclusion.

In her pioneering work on dynamic temporal semantics, ter Meulen (1995) uses a tree called *Dynamic Aspect Tree*, or simply DAT, to represent temporal precedence and inclusion. In a DAT form, we may have the following semantic representation for “Mia slept”.

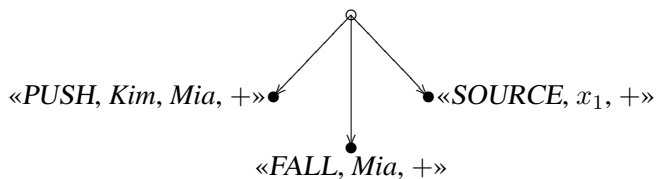
(1) Past Event



This tree represents a situation where the source of temporal perspective is anchored to the present moment of time or the time of utterance and the event of Mia’s sleeping precedes it. Mia’s sleeping is thus interpreted as occurring in the past.

There may be two past events one of which temporally precedes the other. This situation can also be easily represented in a DAT.

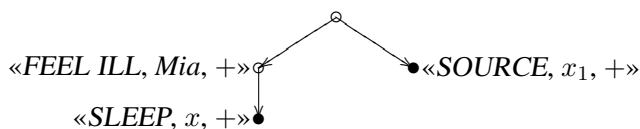
(2) Sequential Events



Here are two events: Kim’s pushing Mia and Mia’s falling. They both occurred in the past. But Kim pushed Mia before she fell.

Temporal inclusion is represented by the relation of descendence or vertical connection in a DAT. Consider a situation in which Mia felt ill and slept. Both are events that occurred in the past, preceding the time of utterance. At the same time, Mia still felt ill while sleeping and thus the event of Mia’s feeling ill temporally includes that of her sleeping. Such a situation is represented in a DAT as follows:

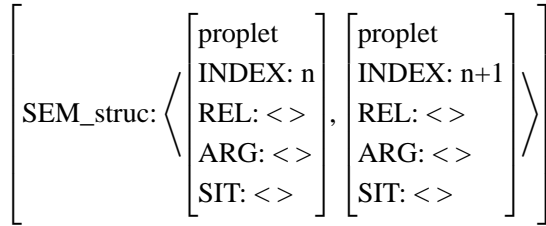
(3) Temporal Inclusion



In a DAT, a daughter is understood as being temporally included by her mother or mother’s mother node. Temporal inclusion is thus understood as a strict partial order.

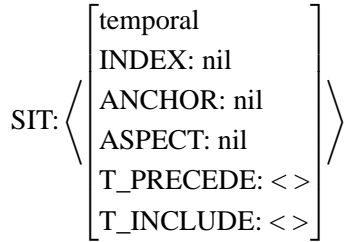
In this paper, each atomic proposition called *proplet* expressed by natural language is represented in feature structures. As part of the semantic structure of such a proplet situational information contains temporal information which is again represented in feature structures. A general frame for the semantic structure of proplets is presented as follows:

(4) Semantic Structure



The feature SIT may contain various kinds of temporal as well as other contextual information as represented below:

(5) Temporal Features in SIT



The temporal feature INDEX for a proplet has a numeric value like 0, 1, 2, and so on. The temporal feature ANCHOR has a value either past or present, depending on the tense of a verb. The temporal feature ASPECT carries aspectual information like *culminated*.

Temporal relations are represented by the two features T\_PRECEDE and T\_INCLUDE with their values as lists of temporal indices. Given a feature specification T\_PRECEDE: <0, 1>, we interpret it as a sequence of two events where the event with index 0 precedes or overlaps the other event with index 1. Given a list of temporal indices, the feature T\_INCLUDE is interpreted similarly.

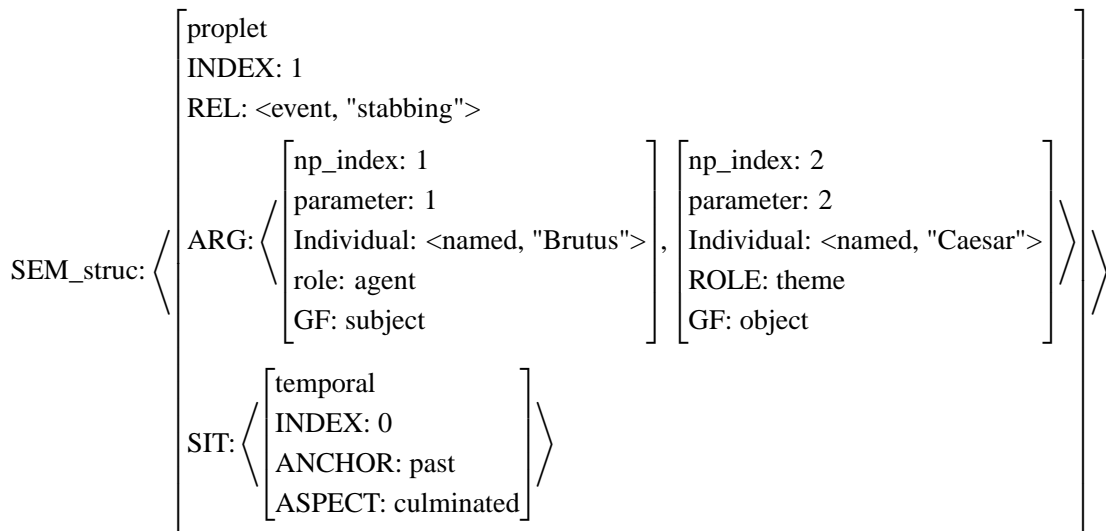
**3 Framework**

In his theory of subatomic semantics, Parsons (1990) argued successfully that an event like one expressed by "Brutus stabbed Caesar" be represented like the following:

$$(6) \exists e [\text{Stabbing}(e) \ \& \ \text{Subject}(e, \text{Brutus}) \ \& \ \text{Object}(e, \text{Caesar}) \ \& \ \text{Culminate}(e, \text{before now})]$$

This representation can be converted into a feature structure, as shown below:

(7) Temporally Situated Proplet



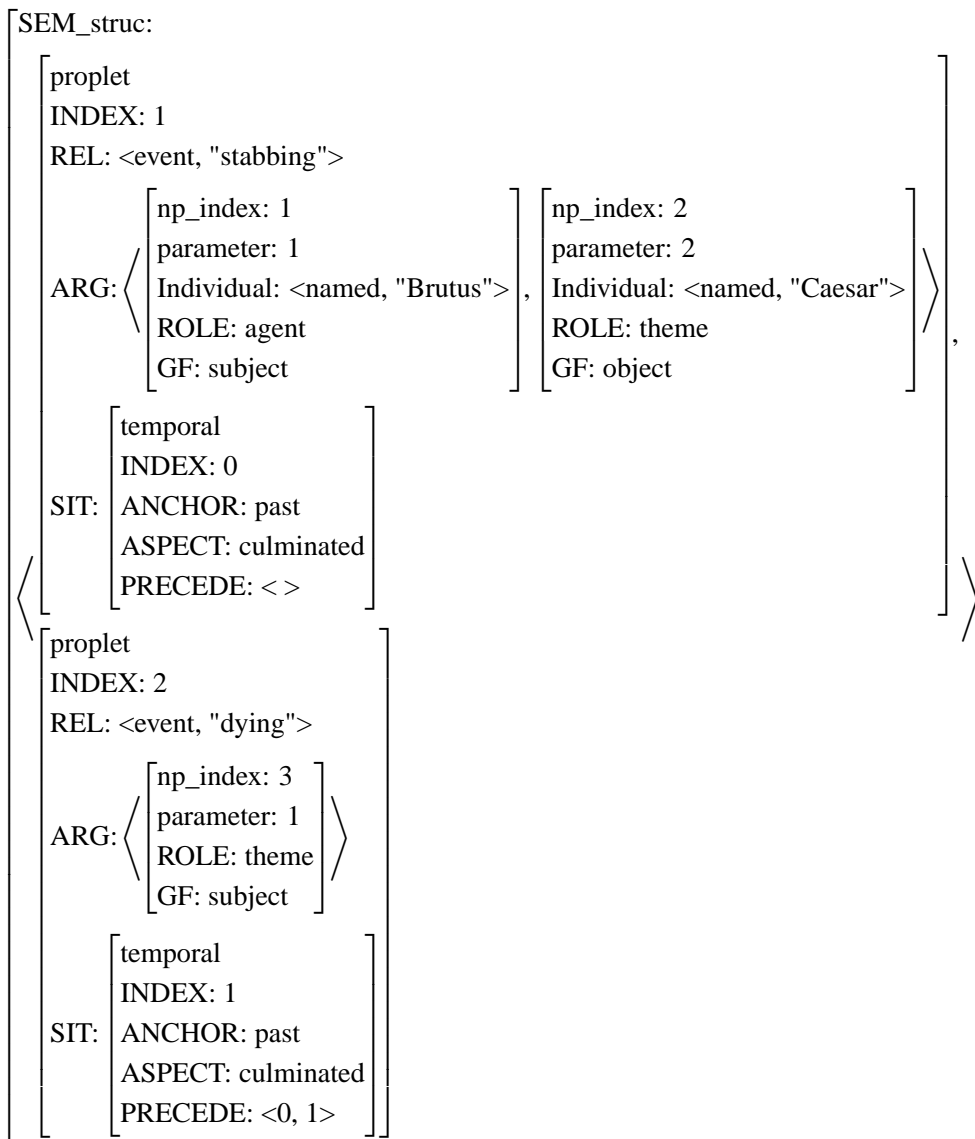
With the feature PRECEDE as discussed in Section 2, a sequence of events can also be represented in feature structures.

Consider the following sentence.

(8) Brutus stabbed Caesar and he died

This sentence is interpreted as describing a situation in which the event of Brutus's stabbing Caesar occurred before his dying.

(9) Sequential Events



#### 4 Kinds of Eventualities

The interpretation of temporal relations depends on types of events involved as well as world knowledge. Consider the following sequence of sentences:

(10) Mia took aspirin. She had a headache.

Here are two sequential events. Mia's taking aspirin is stated before her having a headache. But because of our world knowledge, we understand that Mia took aspirin because she had a headache, thus the latter event occurring before Mia took aspirin. In a particular situation, aspirin may have caused Mia's headache. As was pointed out by ter Meulen (1995), it may not be the task of semantics to deal with world knowledge in interpreting sequential events. Semantics, however, should be able to explain how sequential events are recognized even when they are narrated in random order. It was again pointed out in ter Meulen (1995) that verbal types play an important role in determining temporal relations, especially temporal inclusion.

Verbs are ordinarily treated as standing for kinds of actions or states. Following Bach (1986), so-called eventualities are divided into the traditional four-part classification of accomplishments, achievements, states and processes (activities). Depending on each particular purpose, these four could be divided into several different ways. If we are interested in the durative aspect of verbs, achievement verbs are separated out from the other three. For own purpose, these classifications are freely used as cues for deciding on temporal relations. In categorizing relations, the terms like *event*, *state*, *activity* or *act* are freely used in this treatment, especially at this experimental stage.

## 5 Implementation

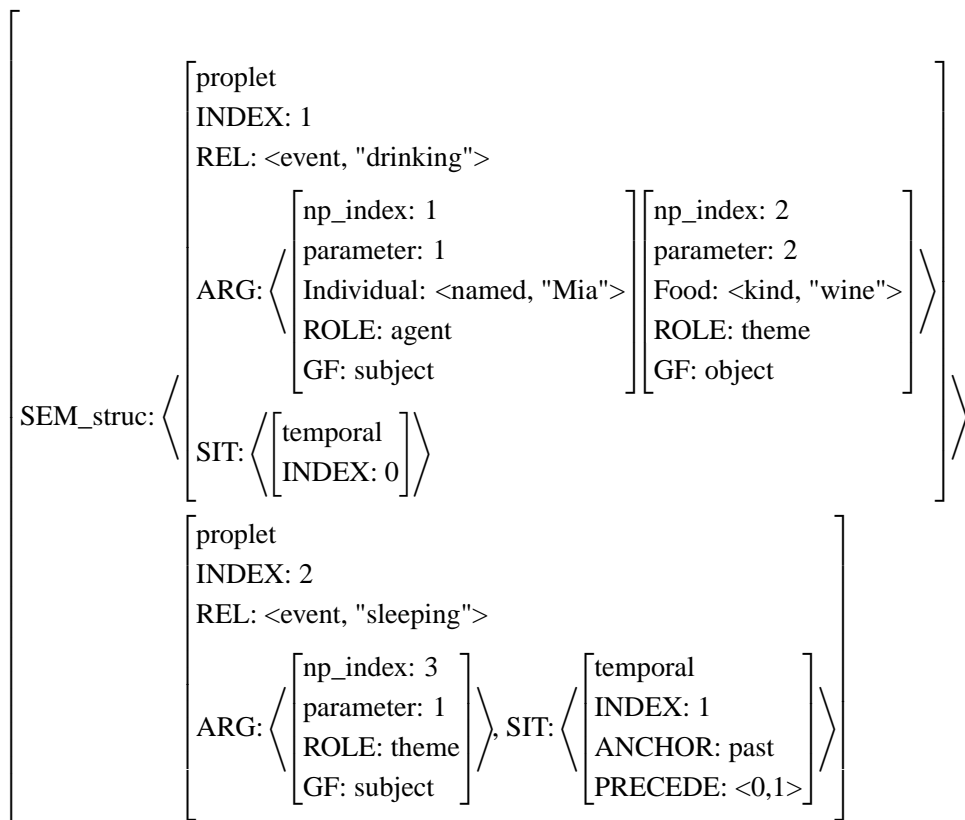
As introduced in Lee (2002), a small grammar system called KORSYN analyzes Korean sentences left-associatively and generates their semantic representations in feature structures. For this presentation, it treats a tiny fragment of Korean that is expected to show adequately how sequential events can be represented for semantic interpretation.

The fragment may contain the following sentences:

- (11) mia-ka wain-ul masi-ko ca-ss-ta  
Mia-NOM wine-ACC drink-CONJ sleep-PAST-DECL  
'Mia drank wine and slept'
- (12) mia-ka aph-ase aspirin-ul mek-ko ca-taka kkwum-ul kkwu-ess-ta  
Mia-NOM sick-Vend aspirin-ACC eat-CONJ sleep-Vend dream-ACC dream-PAST-DECL  
'Being sic, Mia took aspirin and dreamt while sleeping'
- (13) mia-ka wain-ul masi-myense norayhae-ss-ta  
Mia-NOM wine-ACC drink-Vend sing-PAST-DECL  
'While drinking wine, Mia sang'

Sentence (11) is a simple example illustrating how the event of Mia's drinking wine has preceded that of her sleeping. As narrated sequentially, these events took place without any overlap or inclusion. In this example, the verb "masi" (eat) is not tense-marked, but is interpreted as referring to an event that occurred in the past. On the other hand, the verb "ca" (sleep) is marked with the PAST tense marker "ss". The CONJunctive verbal ending "ko" (and) indicates that the event referred to by the left conjunct, namely that of Mia's eating an apple, precedes or overlaps the event referred to by the right conjunct, namely that of Mia's sleeping. Since the latter event is explicitly described as an event in the past, the former event is also interpreted as occurring before that event or simultaneously.

(14) Analysis of Sentence (11)



The feature SIT of proplet 2 contains the information about the temporal precedence about the two events described by proplets 1 and 2. By interpreting this structure, we get the information that the event of Mia's drinking preceded her sleeping. Likewise, we can construct semantic structures for sentence (12) and (13) through a step by step procedure and obtain appropriate information from these semantic representations by applying an appropriate set of interpretation rules to them.

## 6 Conclusion

This paper has aimed at showing how semantic structures containing temporal relations can be represented in feature structures and how they can be interpreted. The proposed implementation system is only at a primitive design stage. It has attempted to accommodate recent research results about event semantics into the design.

## References

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