

Title	機械可読辞書中の語釈文を用いた動詞間の時間関係の解析
Author(s)	森部, 正二郎
Citation	
Issue Date	1997-03
Type	Thesis or Dissertation
Text version	author
URL	<a href="http://hdl.handle.net/10119/1040">http://hdl.handle.net/10119/1040</a>
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Description	Supervisor:奥村 学, 情報科学研究科, 修士

# Analysis of temporal relations among verbs using definition sentences in a machine readable dictionary

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February 14, 1997

**Keywords:** machine readable dictionary, temporal relation on verbs, general knowledge, definition network.

In the intelligent processing of texts, e.g., generating summaries of texts, the task of understanding a content of a text performs an important part. In the task, it is necessary for us to make clear temporal relations among verbs in the text. However, capturing such temporal relations is a difficult problem, because in general a sequence of sentences does not always appear in order of occurrence of events.

To cope with this problem, we first analyze temporal relations among verbs based on the following methods.

- (1) Use temporal information such as tenses, aspects, temporal demonstrative words.
- (2) Use general knowledge concerned with temporal relations on events.

While method(1) is potential in the case of analyzing the temporal relation on verbs in a complex sentence, it uses only temporal informations and consequently sometimes it causes temporal ambiguity. On the other hand, method(2) can determine the temporal relations regardless of temporal informations. So it dissolve ambiguity caused by method(1) and can analyze temporal relations among verbs in two simple sentences. In the case that tenses of two simple sentences are the same and there is no temporal demonstrative words like 'before' and 'after', method(1) cannot analyze the temporal relation between these sentences.

It the past, Azuma et al. used both temporal information and the commom sense of general knowledge and domain knowledge to analyze temporal relation [Azuma 96]. They

determined temporal relations among events using a framework of Event Calculus which integrates their informations. In this approach, since the domain knowledge is separated from the general knowledge, it is possible to determine temporal relation among events of various fields by just changing the domain knowledge. As another work, Alterman represented temporal relations among verbs as semantic networks [Alterman 85]. In his paper, he extracted not only relations on events in texts but also other events which occur in relation to the events, and relations on them. Tojo proposed how to assign each event a temporal property instead of providing general knowledge [Tojo 95]. Temporal relation on events is determined according to relation among temporal interval defined based on temporal properties.

However these previous approach has a common problem that general knowledge needs to be constructed by hand. This task takes a great deal of times, and there is a risk that knowledge base lacks objectivity. In the past, instead of utilizing a hand-crafted general knowledge, we used temporal information, and paid attention to verbs which present change of state in order to extract dependency between verbs. This method can analyze the dependency by determining a kind of verb and object whose state changes. But in the research, there are few sentence satisfying this condition. In this research, to acquire more dependency, we use definition sentences described in Japanese basic verb electronic dictionary IPAL[IPA 87] as general knowledge.

In this research, we extract knowledge concerned with dependent and sequent relation among verbs from IPAL semiautomatically. Definition sentence consists of

- Event and state where a verb is substituted by another word (verb of superordinary clause.)
- Events indicating 'cause', 'purpose' and 'method' (verb of subordinate clause.)
- Case elements indicating states of an agent and an object of a verb.

We extract events and states from a definition sentence, construct a semantic network, called definition network, by linking the events and states each other and use this network as general knowledge. More precisely, a definition network is constructed for each verb in the dictionary.

Utilizing these definition networks, our system analyzes temporal relations among verbs in two simple sentences as follows. First, these two sentence are converted into two definition networks. Then we search for events or states in these networks. Unifying events or states which can unify with other events or states, two verbs in these two simple sentences are linked together. By tracing links of temporal relations, temporal relation between two verbs in simple sentences are acquired.

In this thesis, we first indicate how to generate a definition network from a definition sentence automatically, then we indicate how to analyze temporal relations among verbs, using definition networks extracted from definition sentences.

By formalizing definition sentences of IPAL, we made definition networks that express meanings of verbs. By using the knowledge, we indicated how to analyze temporal relation on verbs which have relation each other. We implemented a system based on our proposed method to analyze temporal relation on a computer. This system analyzes temporal relation among verbs in two simple sentences, and using definition networks, outputs temporal relation among verbs as an output. As our experiments, we analyzed temporal relations of sentences in newspaper articles and tales. As a result, our system could determine only around 10 percentages of temporal relations for newspaper articles, but could determine up to 60 percentages of temporal relations for sentences that the change of the time is clear, like a tale. For result of newspaper articles, the recall was low, but right answers using general knowledge, include temporal relations that failed to analyze by using only temporal relations.