A Logic-based Temporal Knowledge Representation in Mandarin Chinese

Hsiu-Hui Lee, I-Peng Lin, and Chien-Ping Wu

Graduate Institute of Computer Science and Information Engineering
National Taiwan University
Taipei, Taiwan 10764, R.O.C.
T8506027@TWNTUCC1

Correspondence :

Hsiu-Hui Lee

Graduate Institute of Computer Science
and Information Engineering

National Taiwan University

Taipei, Taiwan 10764, R.O.C.

(TEL) 886-2-3630231 EXT 3234

(FAX) 886-2-3628167

(E-MAIL) T8506027@TWNTUCC1

Abstract

This paper concerns the representation of temporal knowledge in Mandarin Chinese. We investigate a variety of temporal information and adopt a logic-based approach to analyze and specify interpretation procedures for each of the constituents. Then we represent temporal knowledge in a formal way. Finally a temporal semantics algorithm is proposed to construct the temporal meaning of sentences.

1.   Introduction

The concept of time is crucially important because of its highly frequent use in utterances. However, the temporal information in natural languages is fairly complex. It may refer to some date in the calendar such as Nov. 18, 1989, or some deictic time adverbial such as yesterday on which the event occurred. Temporal reference can be an exact point of time such as 2 o'clock, vague period of time such as this year. The above information may refer to the beginning point, the end point, or the duration of event. And the temporal relationships between events can be explicitly or implicitly specified. In summary, most of temporal knowledge is introduced without reference to an explicit date. That is, relevant temporal information is distributed within and across distinct constituents and may be implicit and imprecise.

A fundamental issue in natural language processing is the determination of the semantic structure or the meaning of a sentence from its syntactic structure. We observed that natural language sentences contain several kinds of elements expressing their meaning. Among these are **propositions, tense, aspect,** and **time adverbials** at least. Propositions should be viewed as corresponding to the core verb phrases rather than simply to the verbs. Tense has some specific markers (e.g. -s, -ed in English) of past versus present to indicate relative position in time with respect to the moment of speaking. Aspect, which concerns the different viewpoints that can be utilized for describing a situation, has to do with such distinctions as perfective vs. imperfective, extension in time vs. instantaneity [5, 15]. And time adverbials are used to specify temporal relations between events, or give the time span occupied by the event [24]. For example,

John has finished his homework today.

The tenseless proposition *John finish his homework* can be interpreted as some kind of logical formulae. Since many formalisms have been proposed to represent the logical formulae successfully [4, 6, 16], we will not consider them here. However, the other constituents of tense,

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aspect and the time adverbial (*has, -ed, today*) which are all time-related notions should also be represented in a formal way. In recent years, studies on natural language analysis have mainly concerned with propositions, but algorithms for analyzing tense, aspect and time adverbials which are indispensable for natural language understanding and machine translation have not been sufficiently developed [11, 21, 22]. This paper concerns the temporal representation in natural languages especially in Mandarin Chinese. We will adopt a logic-based approach to analyze temporal knowledge, specify interpretation procedures for each of the temporal constituents and represent temporal knowledge in a formal way.

In English, many linguists and philosophers have investigated the temporal phenomena about verb tense, aspect, and temporal adverbials [8, 9, 19, 20]. However, till now only a few formalisms [7, 10, 18] have been proposed to represent such constituents, and how to use them is still not obvious. Kowalski and Sergot's calculus of events [12], and Lee *et al.*'s logic of time and events [13] concern only the explicit date associated with the event. Those are not general in natural language processing. Though the problem of time is repeatedly discussed in artificial intelligence, much of the work focuses on such domains, e.g. planning [1], database updates [12, 13], medical texts [17], etc. Those discussions are not suitable for reasoning in natural language sentences, either.

In terms of temporal concept, Mandarin Chinese is different from English at least in the following two respects. First, Chinese is one of the languages that have no specific tense markers. Many Chinese sentences without overt temporal reference and other context information can be translated into English with more than one kind of tense. For example,

<p style="text-align:center">張三在看這本書。</p>

can be translated into past progressive tense *ChangSan was reading this book* or present progressive tense *ChangSan is reading this book*. Second, Chinese punctual verbs (e.g. '畢業', '死') can also co-occur with durational adverbials. For example,

<p style="text-align:center">張三畢業兩年了。</p>

In English, punctual verbs cannot co-occur with FOR-adverbials. Thus, it is ungrammatical to say that

<p style="text-align:center">* ChangSan has graduated for two years.</p>

Instead it should be translated into

<p style="text-align:center">ChangSan graduated two years ago.</p>

This paper will analyze and extract all the time-related information in Chinese sentences, and put them into an appropriate semantic form. This form can show when the events occur, how long they carry on, and what their chronological orders are. Though the language investigated here

is restricted to Mandarin Chinese, the concepts are quite general, and may be applied to other natural languages. Since we use the term **situation** as the combination of proposition, tense, and aspect, we first describe the classification of situations and their representation in Section 2. Section 3 gives an analysis of time adverbials and their interpretations, and Section 4 gets temporal semantics of the whole sentence based on this scheme. Section 5 is the concluding remarks.

2.   Situations

2.1   Classification of Situations

In a sentence, the meaning of situation is composed of proposition, tense, and aspect. Since Mandarin Chinese is one of the languages that have no tense and use aspect and other constituents to denote their temporal meaning, we need not consider tense in situations. Traditionally, situations have been classified into four categories, i.e. **accomplishments, achievements, activities,** and **states** [23]. Achievements (e.g. dying, graduating, arriving at the station, finding an umbrella) are non-extended dynamic situations that occur momentarily in time. Accomplishments (e.g. walking to the store, singing a song) and activities (e.g. playing the piano, looking for an umbrella), both are extended dynamic situations that last or endure through time. In some literatures, accomplishments and activities both are referred as **processes.** Accomplishments are distinguished from activities in that the former are completed in time, have their natural terminal points, rather than merely going on and coming to an end in time. States (e.g. knowing the answer, liking somebody) are like processes in that they too last or endure through time, but they differ from processes in that they are homogeneous throughout the period of their existence. Because aspect serves to distinguish such things as whether the beginning, middle, or end of an event is being referred, and whether the event is completed or possibly left incomplete, it seems reasonable for us to further expand traditional classification of situations. The subcategories of situations are shown in Table 1.

Situation Types		Examples
achievement	simple	張三死了。
	progressive	張三快死了。
activity	simple	張三看書。
	progressive	張三在看書。
	inchoative	張三開始看書。
	terminative	張三看完書。
accomplishment	simple	張三蓋了一棟房子。
	progressive	張三在蓋一棟房子。
	inchoative	張三開始蓋一棟房子。
	terminative	張三蓋好一棟房子。
state	simple	張三喜歡李四。
	inchoative	張三開始喜歡李四。

Table 1. Situation classification and examples.

It is noted that the identification of situation types is not a trivial problem. Here, though we do not discuss how we identify situation types in sentences, we can see that many constituents (such as verbal aspect, locative prepositional phrase, objects, etc.) have something to do with it. For example,

(1)張三看書。 (simple activity)

(2)張三看這本書。 (simple accomplishment)

In sentence (1), the activity-denoting verb '看' with the generic object '書' denotes a simple activity situation, but the same verb '看' in sentence (2) with the referential object '這本書' denotes a simple accomplishment situation. This is because the event '看這本書' can reach a

natural terminal point of '看完這本書' and the event '看書' just goes on and comes to an end. Let's take another example,

(3)張三找一把傘。(simple accomplishment)

(4)張三找到一把傘。(simple achievement)

The situation described in sentence (4) is a simple achievement, but this is not the case with sentence (3), which indicates a simple accomplishment situation. The reason is that the verb '找到' is a kind of resultant verb compound (RVC, [14]) that has the meaning of success in '找'. Besides, the event '找到一把傘' can occur momentarily in time and the event '找一把傘' may endure a lot of time.

2.2 Representation of Situations

In our system, each subcategory of situation is represented by a unique two-place situation predicate

pred_of_situation(P,T)

with two arguments: one for proposition P and the other for time T. This predicate not only indicates the situation type, but also associates the proposition with the time on which it occurs. All the situation predicates are listed in Table 2. For example, if the proposition '張三看書' is denoted by P, then the following predicates

simp_acty(P,T1)

prog_acty(P,T2)

inch_acty(P,T3)

term_acty(P,T4)

denote situations of simple activity, progressive activity, inchoative activity and terminative activity respectively.

Situation Types		Predicates
achievement	simple	simp_ahvt
	progressive	prog_ahvt
activity	simple	simp_acty
	progressive	prog_acty
	inchoative	inch_acty
	terminative	term_acty
accomplishment	simple	simp_apsh
	progressive	prog_apsh
	inchoative	inch_apsh
	terminative	term_apsh
state	simple	simp_state
	inchoative	inch_state

Table 2. Situation types and their corresponding situation predicates.

2.3 Aspectual Properties of Situations

It is obvious that there exists some relationship among those situations with the same propositions. Here, we use a kind of PROLOG form to reflect it. For example,

$$prog\_acty(P,T1) :- simp\_acty(P,T2), d(T1,T2).$$

That means if a simple activity situation of proposition P occurs at time T2, and T1 is during T2, then a progressive activity situation with the same proposition occurs at T1. Note that we adopt Allen's thirteen kinds of primitive relations among intervals of time [2]. They are <, >, eq, m, mi, o, oi, d, di, s, si, f, and fi. This rule can reflect the so called **sub-interval property** [3]. It

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refers to the fact that any segment of interval of certain kinds of events (i.e. activities and states) is an event of the same type (at least down to a certain grain size). Thus, we have the rules

simp_acty(P,T1) :- simp_acty(P,T2), in(T1,T2).

simp_state(P,T1) :- simp_state(P,T2), in(T1,T2).

According to Allen's notation, *in(T1,T2)* means the relation of T1 and T2 may be eq, s, d, or f.

As a consequence of the sub-interval property is that, for activities, if *John V-ed* then at some time *John was V-ing*, and if *John was V-ing* then at some time *John V-ed*. For example,

張三看書。 (ChangSan read books.)

implies that at some time

張三在看書。 (ChangSan was reading books.)

and vice versa. That is,

inch_acty(P,T1) :- simp_acty(P,T2), s(T1,T2).

prog_acty(P,T1) :- simp_acty(P,T2), d(T1,T2).

term_acty(P,T1) :- simp_acty(P,T2), f(T1,T2).

simp_acty(P,T1) :- inch_acty(P,T2), si(T1,T2).

simp_acty(P,T1) :- prog_acty(P,T2), di(T1,T2).

simp_acty(P,T1) :- term_acty(P,T2), fi(T1,T2).

In other words, the predicate *simp_acty* can imply the predicates of *inch_acty*, *prog_acty* and *term_acty* as well as the relation of time among them, and vice versa. States also have the sub-interval property, that is,

inch_state(P,T1) :- simp_state(P,T2), s(T1,T2).

simp_state(P,T1) :- inch_state(P,T2), si(T1,T2).

On the other hand, accomplishments and achievements have no the sub-interval property but have the problem of **imperfective paradox** [8]. The problem of imperfective paradox refers to the fact that the truth of the progressive form proposition does not imply the truth of the corresponding simple form proposition, while the truth of the simple form proposition does imply the truth of the corresponding progressive form proposition. In other words, if *John V-ed* then at some time *John was V-ing*, and if *John was V-ing* then it does not imply that at some time *John V-ed*. For example,

張三在蓋一棟房子。 (ChangSan was building a house.)

merely says that ChangSan was engaged in some process, and says nothing about whether he completed it or not. But

張三蓋了一棟房子。 (ChangSan built a house.)

means that ChangSan built a house and at some time ChangSan was building a house. In our

system, we can reflect it by the following rules:

> inch_apsh(P,T1) :- simp_apsh(P,T2), s(T1,T2).
>
> prog_apsh(P,T1) :- simp_apsh(P,T2), d(T1,T2).
>
> term_apsh(P,T1) :- simp_apsh(P,T2), f(T1,T2).

The predicate *simp_apsh* can imply the predicates of *inch_apsh*, *prog_apsh* and *term_apsh* as well as the relation of time among them, but the predicate *prog_apsh* cannot imply the predicate *simp_apsh*.

As for achievements, the predicate *prog_ahvt* cannot imply the predicate *simp_ahvt*, either. Because achievements are relatively point-like in nature and consequently do not tend to occur in the progressive. For some situations of progressive achievement, they refer to only a portion of the complete process. For example,

> 張三快死了。 (ChangSan was dying.)

does not imply that

> 張三死了。 (ChangSan died.)

because we can say that

> 張三本來快死了，但新藥救了他所以他並沒有死。
>
> (ChangSan was dying but the new medicine cured him so he didn't die.)

3. Time Adverbials

It is common in sentences with time adverbials. The functions of time adverbials are to specify temporal relations between events, to place events in calendrical intervals, and to give the durations of events. In our system, the classification of time adverbials is shown in Figure 1.
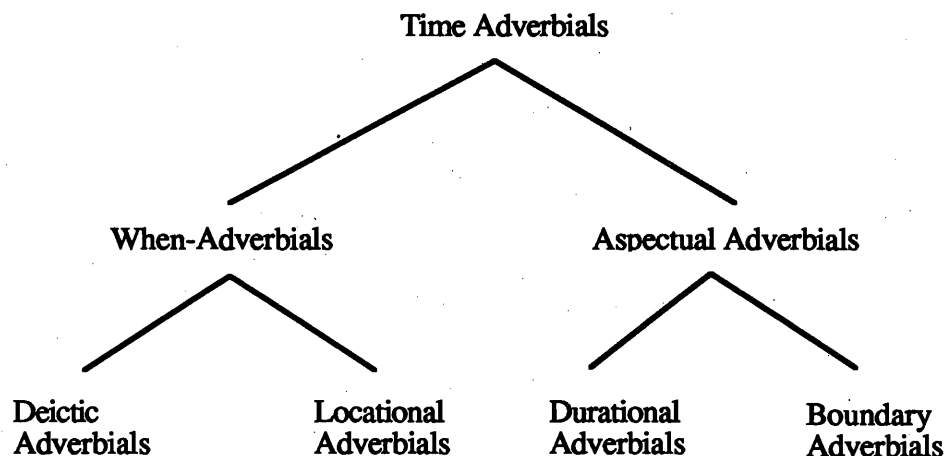
Figure 1. The classification of time adverbials.

Time adverbials are divided into two categories: one for when-adverbials, and the other for aspectual adverbials. When-adverbials that are used as answers to "when" questions are subclassified into deictic adverbials and locational adverbials. Deictic adverbials are adverbials that have explicit relations with the moment of speech, for example, 昨天', '去年', '下星期', '這個月', '兩天後', etc. Locational adverbials are adverbials that identify the location of time without any reference to the speech time, such as dates (like '一九八九年十一月十八日'), days (like '星期三') and times (like '兩點鐘'). Aspectual adverbials that are used as answers to "how long" questions are subclassified into durational adverbials and boundary adverbials. Durational adverbials specify the periods of time (like '兩個月', '三天'). And boundary adverbials (like '自 ··· ', '從 ··· ', '到 ··· ', '從 ··· 到 ··· ') give the beginning points and/or the end points of the intervals.

When-adverbials can be represented as predicates and have separate interpretation procedures to interpret their meanings. For example, 昨天' is represented by the predicate *yesterday(D)*, and its interpretation is "one day ago". Thus, we have the rule

yesterday(D) :- n_days_ago(1,D).

where the predicate *n_days_ago(N,D)* means that the day D is N days ago and it is further interpreted as

n_days_ago(N,D) :- today(DT), distance_day(D,DT,N).

The predicate *today(DT)* means that DT is the day of today, and the predicate

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distance_day(D,DT,N) means the distance between today DT and the day D is N. Of course, there are several more primitive predicates to interpret these predicates in our system.

Durational adverbials are represented as *length(I,Qty,Unit)*. For example, '三天' is represented by

length(I,3,day)

that means the period of time I is three days long.

As for boundary adverbials, they are represented by predicates *start* and *end*. For example, '從三天前到明天' is represented by

start(I,Ds), end(I,De), n_days_ago(3,Ds), tomorrow(De)

It means that there exists an interval I starting with Ds and ending with De, Ds is the day of three days before today, and De is tomorrow.

4.   Representation of Sentences

In preceding sections, we has proposed a formal representation of situations and time adverbials. Now, it is the time to give the meaning of the whole sentences. For simplicity, we restrict ourself to discuss the representation of simple sentences.

4.1   Sentences without Time adverbials

For Mandarin Chinese is a language of no tense, it does not obligatorily relate the time of the situation being described to the time of utterance by any systematic variation in the structure of the sentence. It is also very common in Chinese sentences without time adverbials. Perhaps, we can make some defaults in semantics of aspect for Mandarin Chinese. For those nonstative verbs without aspect marker or with the aspect marker '了' (-le) or '過' (-guo), we assume that they have perfective meaning. And for those nonstative verbs with the aspect marker '在' (Zai) before the verb or the aspect marker '著' (-zhe) after the verb, we assume that they have imperfective meaning. Stative verbs take no marker, and have only imperfective meaning.

In fact, in the absence of any contextual indication of time reference (e.g. when-adverbial), the imperfective forms (i.e. '在' (Zai) and '著' (-zhe) forms of nonstative verbs or simple stative verbs) are interpreted as referring to the present. For instance,

張三在看這本書。 (ChangSan is reading this book.)

張三喜歡瑪琍。 (ChangSan likes Mary.)

While the perfective forms (i.e. 了 ' (-le) or 過 ' (-guo) forms of nonstative verbs) are interpreted as referring to the past. For instance,

張三看了這本書。 (ChangSan read this book.)

Only in the presence of an overt indication of time would the imperfective forms be interpreted as referring to the past. For example,

昨天張三在看這本書。 (ChangSan was reading this book yesterday.)

Thus, there is a close relationship between imperfective aspect and present time, and between perfective aspect and past time in Mandarin Chinese. For the sentence without when-adverbial, we, therefore, use predicate *present(R)* as its predicate of when-adverbial for imperfective aspect, and use the predicate *past(R)* for perfective aspect.

4.2   Sentences with Time Adverbials

For situations being represented as pred_of_situation(P,T), and when-adverbials as pred_of_when(R), we need another predicate rel(T,R) to relate the event time T and the time of when-adverbial R. The predicate rel(T,R) can be *d(T,R)* or *eq(T,R)*, depending upon the granularity of the system. The minimum scale of time is readjustable to any scale by a straightforward extension. In our system, we choose the granularity of time as "day". Then for those when-adverbials referring to "large" intervals of time (such as 下個星期 ') or "very large" intervals of time (such as 去年 ') during which the events of sentences can occur, we use the predicate *d(T,R)* to indicate the event time is during the time of when-adverbial. And for those when-adverbials (such as 昨天') referring to "small" interval of time, we use the predicate *eq(T,R)* to indicate the event time is equal to the time of when-adverbial. Of course, for predicates of *present(R)* and *past(R)* that represent "not small" intervals, we should use *d(T,R)* not *eq(T,R)*.

For those sentences with aspectual adverbials, we have predicates of *start(I,Ds)*, *end(I,De)*, or *length(I,Qty,Unit)*. We likewise should use another predicate to relate the event time T and the interval I denoted by the aspectual adverbial. For non-achievement situations, we use the predicate *has_duration(T,I)* to indicate that the event lasts for a period of time. Because achievement situations denoted by punctual verbs can occur momentarily in time, we use the predicate *has_distance(T,now,I)* to indicate the interval I being the distance between the event time T and now.

4.3 The Temporal Semantics Algorithm

For we have discussed each constituent of temporal knowledge and have given their meanings, respectively, the algorithm to get temporal semantics of the whole sentence can be summarized as follows:

The Temporal Semantics Algorithm

Step 1 : Determine the correct situation type of the input sentence to get the appropriate predicate
pred_of_situation(P,T).

Step 2 : Check for any occurrence of when-adverbials. If yes, we can get
pred_of_when(R), d(T,R),

or

pred_of_when(R), eq(T,R),

else we will get

past(R), d(T,R)

or

present(R), d(T,R).

Step 3 : If there exists some durational adverbial in non-achievement situations, then we can get
length(I,Qty,Unit), has_duration(T,I)

else we will get

length(I,Qty,Unit), has_distance(T,now,I)

Step 4 : If some boundary adverbial is occurred, then we can get
start(I,Ds), end(I,De), has_duration(T,I).

Let's take some examples to illustrate this mechanism.

Example 1:　　張三在看這本書。

In Step 1, by 看這本書', it can be determined as an accomplishment. And by the progressive aspect marker 在', this sentence is further subclassified as a progressive accomplishment, and represented as *prog_apsh(P,T)*. Assume that P is the proposition 張三看 這本書'. In Step 2, because of the imperfective form and absence of any time adverbial, we can

get *present(R)*, *d(T,R)*. Therefore, the temporal meaning of the sentence is

prog_apsh(P,T), present(R), d(T,R).

Example 2:　　昨天張三在看這本書。

This sentence resembles the sentence of Example 1 in that it has the same proposition 張三看這本書', but differs from Example 1 in that it has the when-adverbial 昨天'. 昨天' is represented as *yesterday(R)*. In addition, since the granularity of time in our system is "day", we should use the predicate *eq(T,R)* to relate the event time and the time adverbial. So, the temporal meaning of the sentence is

prog_apsh(P,T), yesterday(R), eq(T,R).

Example 3:　　張三看這本書看了兩年。

The same proposition 張三看這本書' is denoted by P. The durational adverbial 兩年' appears in this sentence, and is represented by *length(I,2,year)*. Since it is a non-achievement situation, we should choose the predicate *has_duration(T,I)* to indicate that the event lasts for a period of time. Then we get the temporal meaning of this sentence as

simp_apsh(P,T), length(I,2,year), has_duration(T,I).

Example 4:　　張三畢業兩年了。

The durational adverbial 兩年' appearing in this sentence is the same as Example 3 and it is also represented by *length(I,2,year)*. Because the verb '畢業' denotes an achievement situation, by Step 3, we choose the predicate *has_distance(T,now,I)* to indicate the distance between the event time and the present moment. Therefore, we get temporal representation as

simp_ahvt(Q,T), length(I,2,year), has_distance(T,now,I).

Example 5:　　張三兩年前畢業了。

This sentence has the same meaning as Example 4, but differs from example 4 in that it uses when-adverbial 兩年前 ' (that is represented by the predicate *n_cal_elts_ago(R,2,year)*). Because our basic units of time are days, we should use *d(T,R)* to relate the event and the time adverbial. Thus, the temporal meaning of the sentence is

simp_ahvt(Q,T), n_cal_elts_ago(R,2,year), d(T,R).

5. Conclusion

This paper touches on the semantics of temporal information in Mandarin Chinese. We has proposed a formal representation for simple sentences that is composed of situations and time adverbials and also describe the interaction of each temporal constituent on sentence level. The representation of situations can easily reflect their aspectual properties such as the sub-interval property and imperfective paradox. And we have interpretations for a variety of time adverbials. So far, our approach has been limited to process one sentence at a time and independent of all other sentences. At last, the semantic form constructed by a temporal semantics algorithm can tell us when something happened, how long it lasts, and how events are related to one another in time. How to accurately capture temporal meaning of the sentences is central aim of this study. That is very important for further temporal reasoning.

References

[1] J. F. Allen and J. A. Koomen, "Planning Using a Temporal World Model," *Proceedings of 8th International Joint Conference on AI*, 1983, pp. 741-747.

[2] J. F. Allen, "Towards a General Theory of Action and Time," *Artificial Intelligence, 23*, pp. 123-154, 1984.

[3] M. J. Almeida, "Reasoning about the Temporal Structure of Narratives," Ph.D. Thesis, Department of Computer Science, State University of New York at Buffalo, 1987.

[4] A. Colmerauer, "An Interesting Subset of Natural Language," in K. L. Clark and S. -A. Tarnlund (editors), *Logic Programming*, 1982, pp. 45-66.

[5] B. Comrie, *Aspect : An Introduction to the Study of Verbal Aspect and Related Problems*, Cambridge University Press, 1976.

[6] V. Dahl, "Translating Spanish into Logic through Logic," *American Journal of Computational Linguistics*, Vol. 7, No. 3, 1981, pp. 149-164.

[7] M. Dalrymple, "The Interpretation of Tense and Aspect in English," *Proceedings of the Association for Computational Linguistics Conference*, 1988, pp. 68-74.

[8] D. R. Dowty, *Word Meaning and Montague Grammar*, Reidel, 1979.

[9] D. R. Dowty, "Tenses, Time Adverbs, and Compositional Semantic Theory," *Linguistics and Philosophy, 5*, 1982, pp. 23-55.

[10] M. P. Harper and E. Charniak, "Time and Tense in English," *Proceedings of the Association for Computational Linguistics Conference*, 1986, pp. 3-9.

[11] R. R. Hsu and H. J. Lee, "The Analysis of Tense and Aspect in Chinese Sentences for Translating Mechanically to English," *Proceedings of International Conference on Computer Processing of Chinese and Oriental Languages*, 1990, pp. 21-26.

[12] R. A. Kowalski and M. J. Sergot, "A Logic-based Calculus of Events," *New Generation Computing*, **4**, 1986, pp. 67-95.

[13] R. M. Lee, H. Coelho and J. C. Cotta, "Temporal Inferencing on Administrative Databases," *Information Systems, **10***, 1985, pp. 197-206.

[14] C. Li and S. A. Thompson, *Mandarin Chinese*, University of California Press, 1981.

[15] J. Lyons, *Semantics*, Vol. **2**, Cambridge University Press, 1977.

[16] M. C. McCord, "Focalizers, the Scoping Problem, and Semantic Interpretation Rules in Logic Grammars," in D. H. D. Warren and M. Canegham (editors), *Logic Programming and Its Applications*, 1986, pp. 223-239.

[17] K. K. Obermeier, "Temporal Inferences in Medical Texts," *Proceedings of the Association for Computational Linguistics Conference*, 1985, pp. 9-17.

[18] R. J. Passonneau, "A Computational Model of the Semantics of Tense and Aspect," *Computational Linguistics, **14(2)***, pp. 44-60, 1988.

[19] B. Richards, "Tense, Aspect and Time Adverbials," *Linguistics and Philosophy, **5***, 1982, pp. 59-107.

[20] C. Smith, "A Speaker-based Approach to Aspect," *Linguistics and Philosophy, **9***, 1986, pp. 97-115.

[21] J. Tai, "Verbs and Times in Chinese: Vendler's Four Categories," In: D. Testen, V. Mishra and J. Drogo (eds.), *Lexical. Semantics,* Chicago: Chicago Linguistic Society, pp. 289-296, 1984.

[22] F. Van Eynde, "The Analysis of Tense and Aspect in EUROTRA," *Proceedings of 12th International Conference on Computational Linguistics*, pp. 699-704, 1988.

[23] Z. Vendler, "Verbs and Times," in *Linguistics in Philosophy*, Ithaca, NY: Cornell University Press, pp. 97-121, 1967.

[24] 張莉萍，"漢語的時間詞組和語言剖析"，中華民國第一屆計算語言學研討會論文集，pp. 77-86, 1988.