Use of Event Types for Temporal Relation Identification in Chinese Text

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Abstract

This paper investigates a machine learning approach for identification of temporal relation between events in Chinese text. We proposed a temporal relation annotation guideline (Cheng, 2007) and constructed temporal information annotated corpora. However, our previous criteria did not deal with various uses of Chinese verbs. For supplementing the previous version of our criteria, we introduce attributes of verbs that describe event types. We illustrate the attributes by the different examples of verb usages. We perform an experiment to evaluate the effect of our event type attributes in the temporal relation identification. As far as we know, this is the first work of temporal relation identification between verbs in Chinese texts. The result shows that the use of the attributes of verbs can improve the annotation accuracy.

1 Introduction

Extracting temporal information in documents is a useful technique for many NLP applications such as question answering, text summarization, machine translation, and so on. The temporal information is coded in three types of expressions: 1. temporal expressions, which describe time or period in the actual or hypothetical world; 2. event or situation expressions that occur at a time point or that last for a period of time; 3. temporal relations, which describe the ordering relation between an event expression and a temporal expression, or between two event expressions.

There are many researches dealing with the temporal expressions and event expressions. Extracting temporal expressions is a subtask of Named Entity Recognition (IREX committee, 1999) and is widely studied in many languages. Normalizing temporal expressions is investigated in evaluation workshops (Chinchor, 1997). Event semantics is investigated in linguistics and AI fields (Bach, 1986). However, researches at temporal relation extraction are still limited. Temporal relation extraction includes the following issues: identifying events, anchoring events on the timeline, ordering events, and reasoning with contextually underspecified temporal expressions. To extract temporal relations, several knowledge resources are necessary, such as tense and aspect of verbs, temporal adverbs, and world knowledge (Mani, et al., 2006).

In English, TimeBank (Pustejovsky, et al., 2006), a temporal information annotated corpus, is available to machine learning approaches for automatically extracting temporal relation. In Chinese, Li (2004) proposed a machine learning based method for temporal relation identification, but they considered the relation between adjacent verbs in a small scale corpus. There is no publicly available Chinese resource for temporal information processing. We proposed (Cheng, 2007) a dependency structure based method to annotate temporal relations manually on a limited set of event pairs and extend the relations using inference rules. In our previous research, the dependency structure helps to detect subordinate and coordinate structures in sentences. Our proposed criteria can reduce the manual effort for annotating the temporal relation tagged corpus.

Our research focuses on the relations between events where they are assumed to be described by verbs. Verbs in an article can represent events in actual world (which describe actual situations or actions) and events in hypothetical world (which describe possible situations, imagination or background knowledge). However, our previous research does not define the class of event types. Our
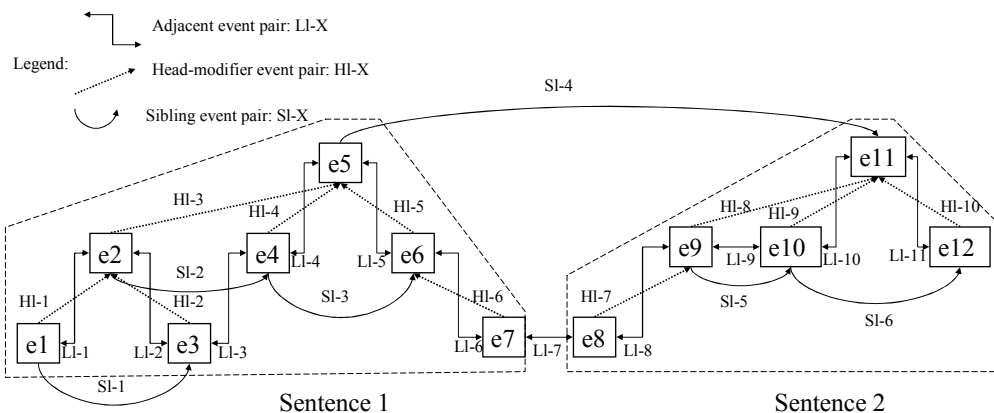
Figure 1: The example of annotating the temporal relations between events.

previous annotation guideline requires annotators to decide the attributes of temporal relations of a verb by annotators' own judgment but does not describe the difference between events (verbs) in actual and hypothetical world.

In this paper, we attempt to give the definition of actual / hypothetical world events (verbs). We collect usages of verbs in Penn Chinese treebank and classify them to actual / hypothetical worlds. We add another attribute to our previous criteria. Then we train the temporal relation annotated corpus to investigate the effect of using the event types for automatic annotation.

In the next section, we describe the criteria of temporal relations between events that are proposed in our previous research (Cheng, 2007). In section 3, we discuss the event types of verbs and define the actual / hypothetical world events. In section 4, we perform an experiment of a machine learning based temporal relation identifier with and without the event type information. Finally, we discuss the results of experiments and our future direction.

2 Temporal relations between events

We propose an annotation guideline for developing a Chinese temporal relation annotated corpus. The guideline is based on TimeML (Saurí, 2005) and focuses on the temporal relations between events. To reduce manual effort, we introduce several constraints on the original TimeML. First, we restrict the definition of events to verbs. Second, we focus on three types of event pairs according to syntactic dependency structure.

2.1 The definition of the events

According to the TimeML guideline for English, verbs, nominalized verbs, adjectives, predicative

and prepositional phrases can represent events. However, to recognize an instance of nominalized verb represents whether an event or not is difficult in Chinese articles. Chunking phrases and clauses is another difficult process in Chinese. To simplify the process of recognizing events, the criteria only regard verbs as events.

2.2 Three types of event pairs

The criteria of temporal relation between events include three types of event pairs in the complete graph as follows:

- RLP (Relation to Linear Preceding event): Relation between the focus event and the adjacent event at the immediately proceeding position. (Relation of adjacent event pair).

- RTA (Relation to Tree Ancestor event): Relation between the focus event and the ancestor event in a dependency structure (Relation of Head-modifier event pair).

- RTP (Relation to Tree Preceding event): Relation between the focus event and its sibling event in a dependency structure (Relation of Sibling event pair).

The first type stands for the adjacent event pairs. The second and third types are the head-modifier event pairs and the sibling event pairs in dependency tree representation of a sentence. Figure 1 describes the relation of three types of event pairs in an article. There are two sentences with twelve events (from e1 to e12) in the figure and the polygons with dashed-lines show the boundary of sentences. The angle-line links show adjacent event pairs (from Ll-1 to Ll-11). The dotted-line links show head-modifier event pairs (from Hl-1 to Hl-10) and the curve links show sibling event pairs (from Sl-1 to Sl-6). The first type (adjacent event

pairs) and the other two types (head-modifier or sibling event pairs) are not exclusive. An event pair can be a head-modifier event pairs and can be a head-modifier event at the same time.

The adjacent event pair links and the sibling event pair links can be used to connect the temporal relations between sentences. The links Sl-4 and Ll-7 span two sentences in the example.

Subordinate event pairs are head-modifier relations and coordinate event pairs are sibling relations. Using dependency structure can help to extract subordinate relations and coordinate relations in a sentence.

2.3 Deficiency of our previous criteria

Our criteria can reduce manual effort of temporal relation annotation. However, our previous guideline does not distinguish actual world and hypothetical world events. Because all verbs in the previous guideline are regarded as events, verbs of hypothetical world events are also included in the events. For example: (the italicized words in our examples indicate verbs)

- (a) 工業區/***成立***/後/大量/***吸引***/外資 (after the industrial estate ***was established***, it ***attracted*** a great deal of foreign capital)

- (b) 工業區/***成立***/後/可能/大量/***吸引***/外資 (after the industrial estate ***is established***, it can ***attract*** a great deal of foreign capital)

The difference between examples (a) and (b) is only with or without the word "可能 (can)", which governs a verb phrase and explains a possible situation. It should be noted that verbs in Chinese do not have morphological change. The complete meaning of verbs in the examples should consider the global context in the article. The example (a) explains an actual world event that the industrial estate attracted a great deal of foreign capital. However, in example (b), the word "可能 (can)" changes the phrase "大量/吸引/外資 (to attract a great deal of foreign capital)" into a hypothetical world event. This clause presents a possibility and does not indicate an event in the actual world.

Considering the temporal relation between the verbs "成立(establish)" and "吸引(attract)", the temporal relation in the example (a) means that the event 成立(establish) occurs before the event 吸引(attract). On the other hand, in the example (b), the verb "吸引(attract)" indicates a possibility.

We cannot make sure if it could really happen. We regard that the temporal relation in the example (b) is unidentifiable. In the previous guideline, we request annotators to decide the temporal relation between them. However we do not classify the difference between actual and hypothetical worlds. The annotators annotate even some incomprehensible temporal relations (such as the relation in example (b)) with the tag "unknown". We clarify the issue by introducing event types to verbs.

Aside form the problem of actual and hypothetical world events, verbs in our temporal relation annotated corpus still include some incomprehensible events (We consider these in the next section). For solving these problems, we investigated different types of events (verbs) in the Penn Chinese Treebank (Palmer, 2005) then give a clear classification of event types. We use this classification of events to annotate events in the temporal relation tagged corpus.

3 Event types of verbs

Our criteria restrict events to verbs according to the POS-tag of Penn Chinese Treebank. Therefore, all the words tagged with the POS-tags (Xia, 2000), "VA", "VE", "VC", and "VV" are the "event candidates". However, these POS-tags include not only actual world events but also hypothetical world events, modifiers of nouns, and subsegments of named entities. We will exemplify these situations in this section.

3.1 Verbs of actual world events

The "event" that we want to annotate is an action or situation that has happened or will definitely happen in the actual world. We define these events as actual world events. For example:

- (c) 市場/***發生***/火災 (A fire ***occurred*** in the market.)

- (d) 市政府/大樓/將於/年底/***完工*** (The construction work of the city hall will ***finish*** at the end of the year.)

- (e) 金融/市場/運行/***平穩*** (The function of financial market is ***smooth.***)

The verbs in these examples represent actual world events. We want to distinguish between these events and hypothetical world events.

The example (c) is a general instance of an actual world event. The verb "發生 (happen)" in the

sentence indicates an occurrence of an event. The verb "完工 (finish)" in example (d) is a confirmative result that definitely happens. The word "將於 (will)" indicates that the sentence describes a future statement. If there is no other statement that describes an accident event in the context, we can trust the event in the example (d) is an actual world event.

In Chinese, an adjective can be a predicate without a copula (corresponding to the verb "be"). The example (e) contains no copula. Still, the adjective "平穩 (smooth)" is a predicate and represents an actual world situation. This kind of adjective is the POS-tag "VA" in Penn Chinese Treebank and also can represent an actual world event.

3.2   Verbs of hypothetical world events

Sometime verbs indicate hypothetical world events. In such situations, verbs describe a possibility, a statement of ability, anticipation, a request or an inconclusive future. For example:

- (b) 工業區/*成立*/後/可能/大量/*吸引*/外資 (after the industrial estate *is established*, it can *attract* a great deal of foreign capital)

- (g) 新港口/能/*停靠*/大型油輪 (A big oil tanker can **berth** at the new port)

- (h) 他們/*希望*/政府/*訂立*/相關/法案 (They **wish** the government to **legislate** against affiliated bill)

- (i) 政府/*要求*/工廠/*改進*/設施 (The government **requires** the factory to **amend** their equipments)

- (j) 此/技術/*有助於*/未來/*開發*/新藥 (this technology can **help** to **develop** a new kind of medicine)

The verb "吸引 (attract)" in example (b) explains a possibility that "may" occur after a confirmative result "成立 (establish)" in future. We cannot decide the temporal relation between the actual world event "成立 (establish)" and the possible event "吸引 (attract)" in the example (b), because we do not know if the event "吸引 (attract)" will realize.

The verb "停靠 (berth)" in example (g) explains the capacity of the new port. The verb "停靠 (berth)" does not indicate truth or a confirmative result. We cannot confirm when an oil tanker will berth at the new port. This verb represents a hypothetical world event. The verb "訂立 (legislate)" in the example (h) and the verb "改進(amend)" in the example (i) explain a wish and a request. Even the sentences describe that the government (in the example (h)) or the factory (in the example (i)) was required to do something; the descriptions do not show any evidence that the request will be executed. Although the wish and request will be realized in future, we cannot identify the time point of the realization of these events. Therefore we should consider that these verbs represent hypothetical world events.

The verb "開發 (develop)" in the example (j) explains an inconclusive plan in future. The developed technology can be used for a new development plan. However, we also cannot make sure if the development plan will be realized or not. We cannot identify the verb "開發 (develop)" on a timeline. Since the verb represents a hypothetical world event.

These examples (from the examples (b), (g) to (j)) indicate hypothetical world events. However, as we introduced in section 2.3 (the examples (a) and (b)), the instances with different types of events have the same context in local structure (the phrase "大量/吸引/外資 (to attract a great deal of foreign capital)"). The difference between the example (a) and the example (b) is that the word "可能 (can)" exists or not. To distinguish an actual world event and a hypothetical world event with similar local context, the dependency structure analysis is quite helpful.

3.3   Copula verbs

There are two special POS-tags of verbs in Penn Chinese Treebank, VC and VE. These verbs are copulas in Chinese. The copula verb (such as the verb "是 (be)") indicates existence and corresponds to "be" in English. In TimeML, these copulas are not considered as an independent verb. It is included in another verb phrase or in a nominal phrase that represents an event. However, the copula verb "是 (be)" is an independent verb in Penn Chinese Treebank. We should investigate how to deal with this copula verb. For example:

- (k) 舊/法律/*是*/三年前/*修訂*/的 (The older version of bill **was legislated** at three years ago.)

- (l) 該/公司/*是*/世界上/最大/的/電力公司 (The company *is* the largest electric power company in the world.)

Considering the use of copula in Penn Chinese Treebank, sentences that include copula verbs can be distinguished to two types. The copula verbs describe existence. The existence could be a verb phrase (the example (k)) or a nominal phrase (the example (l)). In the example (k), the verb phrase "三年前/修訂 (was legislated at three years ago)" represents an event that the copula verb accentuates the existence of the verb phrase. Although there are two verbs in the example (k), the sentence only includes an event which is the verb phrase "三年前/修訂 (was legislated at three years ago)".

According to the dependency structure of sentence, copula verbs represent the root of the dependency structure and the head of a verb phrase that modifies a copula verb. We define a pair of a copula and a verb that modifies the copula as a "copula phrase". Therefore we regard the copula verb in the example (k) as the main verb of the verb phrase "修訂 (legislate)" and it represents an actual world event[1].

The copula verb "是 (be)" in the example (l) accentuates the truth of the nominal phrase "世界上/最大/的/電力公司 (the largest electric power company in the world)". According to the discussion in the previous paragraph, the meaning of this copula comes from the nominal phrase. We can recognize the nominal phrase as a truth at the time point "NOW" (the company is largest in the world now). However, this phrase does not indicate any specific period of time that the fact holds. We can regard it as the background knowledge and it does not include an event. To identify the temporal relation between this noun phrase and other actual world event is impossible[2]. We also regard this copula verb as a hypothetical world event.

3.4   Non-event verbs

[1] Whether the copula verbs are actual world events or hypothetical world events depend on the modifier verb phrases.
[2] We cannot know when the company became the largest one on the world. And other events in the context distribute in a shorter period on a timeline. Therefore to compare the existence period of the truth and other events is impossible. However, if a temporal expression with a passed time period in the context, the truth could have a boundary of occurrence time. Then the copula can be recognized as an actual world event.

There are several types of words that have a verbal POS-tag but do not represent events. These words include non-event predicative adjectives and named entities.

In Chinese, adjectives can be predicates of a sentence without verbs. This kind of adjectives are predicative adjective and have a POS-tag "VA" in Penn Chinese Treebank. These predicative adjectives indicate situations. However, some instances in the Treebank are close to normal adjectives. We should distinguish the difference between the predicative adjectives that describe situations and predicative adjectives that are normal adjectives. For example:

- (e) 金融/市場/運行/*平穩* (The function of financial market is *smooth.*)

- (n)*提供*/*新*/的/動力 (*To provide* a *new* kind of power)

The adjective "平穩 (smooth)" in the example (e) indicates a situation. We regard this adjective as an actual world event. However, the adjective "新 (new)" in the example (n) is a modifier of the noun "動力 (power)". This adjective do not indicate a situation, therefore it dose not represent an event.

Another situation of non-event verbs is a verb in a named entity. Because of the strategy of the POS-tagging of Penn Chinese Treebank, a named entity is separated to several words and these words are tagged independently. For example:

- (o) "*解放*/剛果/民主/同盟 (Alliance of Democratic Forces for *Liberating* Congo-Zaire)"

The example (o) shows a named entity that includes a word "解放 (liberate)" has the POS-tag "VV". However, this verb does not represent an actual event or a hypothetical event. It is a substring of the named entity. We define this kind of verbs as non-event verbs.

3.5   Attribute of event types

Figure 2 summarizes the event types of verbs in section 3.1-3.4. We divide the verbs roughly into two types "actual world" and "hypothetical world". Each type includes several sub-types. We annotate these two event types of verbs to our previous temporal relation annotated corpus. The definition of these event types in previous sections is a guideline for our annotators. This new attribute has two
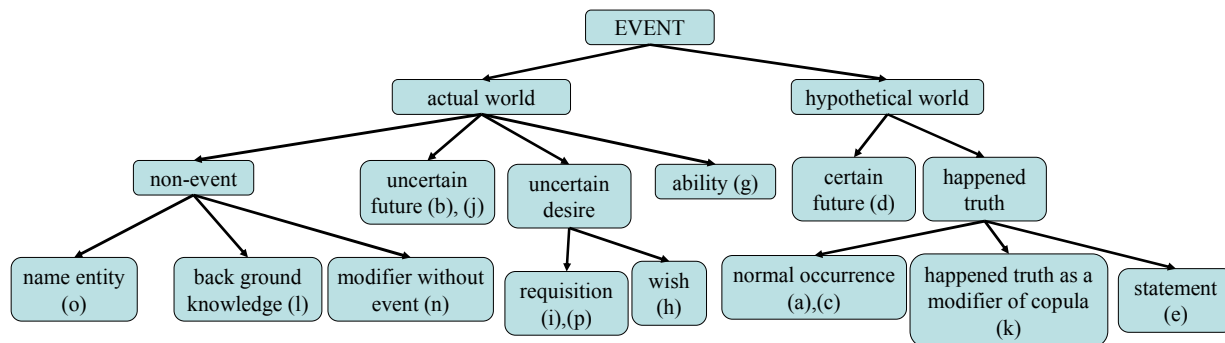
Note: the characters in the brackets refer to the examples of each event type

**Figure 2: The classifications of event types**

values "actual world" and "hypothetical world". Although the types of values are coarse-grained, this attribute can describe whether a verb can be recognized as an event with understandable temporal relation on the timeline or not.

However, the value "hypothetical world" of the event types means not only that the verbs with this value are temporal relation un-recognizable events, but also that the verbs with this value are "locally recognizable" events. For example:

- (p) 他們/***希望***/政府/***增加***/預算/來/***修補***/ 堤防 (They ***wish*** the government to ***increase*** budget to ***repair*** the bank)

The verb "希望 (wish)" governs the verb phrase "政府/增加/預算/來/修補/堤防 (the government increases budget to repair the bank)". Therefore the verb phrase represents a hypothetical world event (because we do not know if the government will do it or not). However, considering the local context of the verb phrase, it includes two verbs that have a causal relation between them. The event "增加 (increase)" should occur before the event "修補 (repair)"[3]. The temporal relation between the two verbs exists in the local context. We do not ignore this kind of temporal relations and annotate them. The temporal relation between the verb "增加 (increase)" and the verb "修補 (repair)" is not unknown but the temporal relation between the verbs "增加 (increase)" and the verb "希望 (wish)" is unknown.

Therefore, we regard the attribute of event type as a "bridge" between an actual world and a hypothetical world. The event in the actual world means that we can identify the temporal relation between
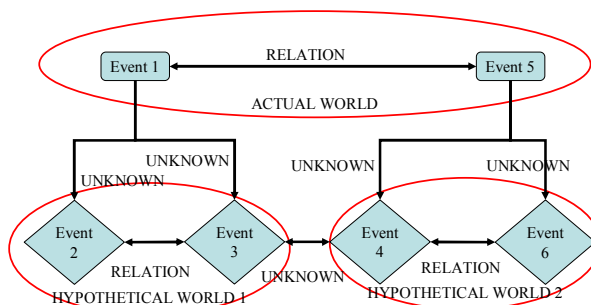
Figure 3: The actual world and hypothetical worlds

an event and the other occurred events in an actual world. The temporal relations between a hypothetical world event and an actual world event can only be identified in a hypothetical world. Figure 3 describes this concept. The index on each event indicates the linear ordering of the event mention in the article. The two events with rectangles represent the actual world and the four events with diamond shapes represent the hypothetical world. There is no understandable temporal relation between actual and hypothetical worlds (for example the relation between the event 1 and event 2). The events in hypothetical world have their temporal relation with other events in the same hypothetical world. However, a hypothetical world is independent to other hypothetical worlds. Therefore, the temporal relation between event 2 and event 3 understandable but the relation between event 3 and event 4 are unknown. We ask our annotators to annotate the understandable temporal relations in each hypothetical world because the instances of the local context are useful in analyzing the temporal relation between events in actual world by machine learning.

4 Evaluation Experiments

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[3] The government must increase the budget and pass the deliberation in the congress, and then the budget can be used to repair the bank.

	RLP		RTA		RTP	
	Train	Test	Train	Test	Train	Test
after	2487	278	580	81	925	101
before	1273	139	1864	191	372	36
simultaneous	1391	75	1011	63	525	20
overlap	212	24	96	15	85	2
hypothetical	⨉	⨉	1587	163	⨉	⨉
copula-existence	⨉	⨉	417	39	⨉	⨉
Unknown	2157	216	⨉	⨉	704	75
Total	7520	732	5553	552	2611	234
Event Types	Train (7520 verbs)		Test (732 verbs)			
	actual world: 4584		actual world: 453			
	hypothetical world: 2936		hypothetical world: 279			

Table 1: The distribution of our data set

After we manually annotate the event type of verbs on our temporal relation tagged corpus, we use support vector machines as machine learner to compose a temporal relation identifier. We perform an experiment to investigate the effect of the event type information.

4.1 The data set

We annotated a part of Penn Chinese Treebank with our previous criteria. The temporal relation tagged corpus includes 7520 verbs. Each verb has three types of temporal relation that we introduce in section 2.3. We annotate the event type information manually and refine some ambiguous instances. For efficiency, we introduce grouping on the temporal relation classes. Our criteria defined ten classes of temporal relation values. We compose three types of temporal relation identifiers (RLP, RTA and RTP) and an event type classifier.

To discriminate the event types of verbs, we add two possible values of temporal relations, the value "hypothetical" and "copula-existence". The value "hypothetical" is introduced in the temporal relation type "RTA". If the verb represents a hypothetical world event or non-event, the verb is enclosed into the hypothetical world. The verb in hypothetical world cannot have a RLP relation (Relation of adjacent event pair) between hypothetical and actual worlds. However, for recognizing the verb that is the root event of the hypothetical world, we annotate the RTA relation (Relation of adjacent event pair) of the root event in hypothetical world as the value "hypothetical". The value "copula-existence" is introduced to annotate the event emphasized by the copula verb. If the copula verb governs a verb phrase with several verbs, the root event of the verb phrase has the value "copula-existence".

The possible values of three types of temporal relations and event types in our experiment are summarized as follows:

- Event types: actual world and hypothetical world

- RLP: after (includes the values "after" and "begun-by" in our criteria), before (includes the values "before" and "end-by" in our criteria), simultaneous, overlap (includes the values "overlap", "overlapped-by", "include", "during" our criteria)

- RTA: after, before, simultaneous, overlap, unknown, copula-existence, hypothetical

- RTP: after, before, simultaneous, overlap

The training data for SVMs includes 151 articles with 49620 words and 7520 verbs and the testing data is collected from articles in Penn Chinese Treebank other than training data (testing data includes 50 short articles with 5010 words and 732 verbs). The basic information of our corpus and the distribution of the value of attributes in our training and testing data are shown in Table 1. It should be noted that the number of the attributes of the data ignore some negligible instances. Such as, if a verb does not have sibling verbs in the dependency structure, to consider the attribute "RTP (Relation between focus event and its sibling event)" is unnecessary. Therefore the total numbers of the attribute "RTA" and the attribute "RTP" are less than the number of all verbs.

4.2 Experiment

We train each classifier (event types, RLP, RTA and RTP) by an independent model. The features for machine learning are also tuned independently. We evaluate the accuracy of automatic annotation of event types and temporal relations with and without our event types. We use our event type tag as a feature of the three temporal relations. Other features for SVM analyzer to annotate the three types of temporal relations include the morphological information of the focus event pair and the dependency structure of the sentence. These features can be extracted from the dependency structures automatically.

The results are shown in Table 2. The abbreviations "R", "P" and "F" mean "Recall", "Precision" and "F-measure". The row "Accuracy w/o event type" means the results of the temporal relations annotating without using the event type as a feature. Other rows use the event type which is annotated

	RLP			RTA			RTP		
	R	P	F	R	P	F	R	P	F
after	0.70	0.62	0.65	0.45	0.64	0.52	0.71	0.63	0.67
before	0.45	0.51	0.50	0.81	0.68	0.73	0.42	0.52	0.46
simultaneous	0.32	0.35	0.33	0.31	0.32	0.32	0.32	0.35	0.33
overlap	0.45	1	0.51	0.6	0.81	0.69	0.29	1	0.45
hypothetical	✕	✕	✕	0.57	0.68	0.62	✕	✕	✕
copula-existence	✕	✕	✕	0.80	0.67	0.72	✕	✕	✕
unknown	0.73	0.69	0.71	✕	✕	✕	0.74	0.68	0.70
Accuracy	0.62			0.63			0.61		
Accuracy w/o Event type	0.61			0.60			0.61		

Event Types	actual world			hypothetical world		
R /P /F	0.93	0.91	0.92	0.78	0.76	0.77
Accuracy	0.83					

Table 2: The results of our experiment

by a machine learning-based analyzer as a feature. Because there is no similar related research that analyzes temporal relation between Chinese verbs based on machine learning, we cannot make any comparison. We discuss the accuracy of temporal relation annotating with and without using our event type according to the result of our experiment.

4.2 Discussions

Table 2 shows that the model with the result of the event type classifier is better than that without using the result of the event type classifier. However, the improvement of using event types is limited. The reason might be the accuracy of event type is as low as 83%. To improve the performance of event type annotation helps to improve the relation annotation.

There is no research based on the same data set and corpus guideline, therefore we can not compare the result to other research. However, in the shared task: "TempEval[4] Temporal Relation Identification" (Verhagen, 2007), the task "temporal relations between matrix verbs" resembles the goal of our corpus. The F-measure in TempEval shared task distribute between 40%~50%. The result of the shared task also shows the difficulty of automatic temporal relation analysis.

5 Conclusions and future directions

We propose a machine learning-based temporal relation identification method. This is the first work of the temporal relation identification between verbs in Chinese texts. To deal with the deficiency in our previous temporal relation annotat-

ing criteria, we newly introduce the event types of Chinese verb. The result of evaluation experiments shows that the event type information helps to improve the accuracy of the identifier.

A deficient of our experiment is that we do not use semantic information as features for machine learner. Semantic information of temporal and event expressions is important for recognizing temporal relations between events. As a future research, we would like to introduce causal relation knowledge of verbs (this is similar to VerbOcean (Chklovski, 2004)). We are collecting this kind of verb pairs and expect that this causal relation helps to improve the performance of automatic annotation.

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[4] This shared task deals with English news articles.(TimeBank 1.2)