CTEMP: A Chinese Temporal Parser for Extracting and Normalizing Temporal Information

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Abstract. Temporal information is useful in many NLP applications, such as information extraction, question answering and summarization. In this paper, we present a temporal parser for extracting and normalizing temporal expressions from Chinese texts. An integrated temporal framework is proposed, which includes basic temporal concepts and the classification of temporal expressions. The identification of temporal expressions is fulfilled by powerful chart-parsing based on grammar rules and constraint rules. We evaluated the system on a substantial corpus and obtained promising results.

1 Introduction

Temporal information processing is valuable in many NLP applications, such as information extraction, machine translation, question-answering and multi-document summarization. However, a wide scope of linguistic means, from lexical to syntactic phenomena, can represent this information. It is hard to catch the internal temporal meanings which are behind surface texts. The potential applications and the flexibilities of temporal representations motivate our research in this direction.

In this paper, temporal information is defined as the knowledge about time or duration. This information is crucial for both temporal reasoning and anchoring events on the time line. Temporal expressions are defined as chunks of text which convey direct or indirect temporal information. TIMEX2 annotating guidelines [4, 6] give good descriptions about temporal expressions. According to the guidelines, temporal expressions include dates, times of day, durations, set-denoting expressions, event-anchored expressions, and so on. To retrieve the useful temporal information contained in these temporal expressions, we need to identify the extents of temporal expressions in raw text and then represent temporal information according to some standard. The two tasks are called temporal extraction and temporal normalization, respectively. We have implemented a full system CTEMP, which consists of two modules: extractor and normalizer. The two modules fulfill temporal extraction and temporal normalization, respectively.

A comprehensive temporal framework is investigated to analyze the elements involved in the mapping procedure, from surface text to internal temporal information. This framework includes basic temporal objects and relations, the measurement of time, and the classification of temporal expressions from Chinese texts. To cope with

the flexibilities of the temporal expressions, we have built the temporal parser based on chart-parsing and effective constraints. Experiments with respect to a substantial corpus show that the temporal parser achieves promising results. We took part in TERN 2004 Chinese temporal expression extraction with this temporal parser and our performance is the highest in that track.

The rest of the paper is organized as follows: In Section 2 we give a brief discussion on related works; Section 3 describes the temporal framework, which is the basis of the whole temporal parser; extractor and normalizer of the temporal parser are discussed in Section 4 and Section 5, respectively; Section 6 gives the description about experiments and evaluations. Finally, conclusion and future work are presented in Section 7.

2   Related Work

Motivated by the potential applications, temporal information processing has absorbed more attention recently than ever, such as ACL 2001 workshop on temporal and spatial information processing, LREC 2002 and TERN 2004 [14]. Mani [10] gives a good review about the recent trend. Research works in this area can be classified into four types: designing annotation scheme for temporal information representation [4, 6, 12]; developing temporal ontology which covers temporal objects and their relationships between each other [2, 7]; Identifying time-stamps of events or temporal relationships between events [5, 9]; Identifying and normalizing temporal expressions from different languages [1, 3, 8, 11, 13, 15].

Temporal annotation, temporal ontology and temporal reasoning are not the focuses in this paper. Among the research works on temporal expression extraction and normalization, most of them are based on hand-written rules or machine-learnt rules. Mani and Wilson [11] resolve temporal expressions by hand-crafted and machine-learnt rules. Their focus is resolving temporal expressions, especially indexical expressions, which designate times that are dependent on the speaker and some reference time. We concentrate on the procedure of extraction and normalization, and try to cover more temporal expressions. Schilder and Habel [13] employ several finite state transducers based on hand-written rules to extract and normalize time-denoting and event-denoting temporal expressions. Evaluation of the system is presented on a small corpus.

Vazov [15] identifies temporal expressions based on context constraints and regular expressions, but temporal expression normalization is not investigated. Estela et al. [3] present a temporal parser on Spanish based on grammar rules and evaluate the tagger on a small corpus. Jang [8] reports a time tagger for Korean based on a human-edited, automatically-derived dictionary of patterns. The dictionary is induced from training data and is used to extract and normalize temporal expressions in texts. Ahn et al. [1] adopt the task of TERN 2004 evaluation and investigate machine learning methods for extraction of temporal expression and rule based methods for normalization. However, they focus on Korean and English text respectively and may not consider some characteristics of Chinese language.

3   Temporal Framework

The goal of the temporal parser is to extract and normalize temporal expressions. First we should realize the elements involved in this procedure. We propose a temporal framework to describe temporal concepts, the measurement and all kinds of temporal expressions in the surface text. Our temporal parser is based on this comprehensive framework.

3.1   Basic Objects and Relations

In the field of time, basic objects are just time and durations. Time is a point or interval on the time line. Given the origin and a measurement, it can be evaluated with a real number. If there is no extra specification in Chinese text, the calendar is the Gregorian calendar. Duration is the distance between some two times. We can anchor duration by the start time and the end time, or by one of them and the length of the duration. However, if duration is referred to just length, it cannot be anchored on the time line. In temporal field, relations between objects are also defined. Between two times, relations are "before", "same", "include", "after". These objects and relationships are internal concepts behind surface text and we hope to fetch them.

3.2   The Measurement

To represent lengths on the time line, a measurement should be given. The temporal units consist of two types, macro units and micro units, shown in Fig. 1. To represent a time, the scope of the numbers which can be combined with temporal units is limited. "Century" and "Year" are two special time units, because only these two time units can help to anchor a time concept on the time line. If there is no help from contexts, other time units can not anchor a time concept on the time line. These limitations are valuable in normalization of temporal expression.
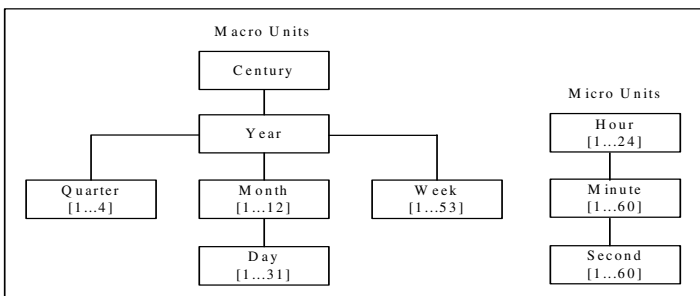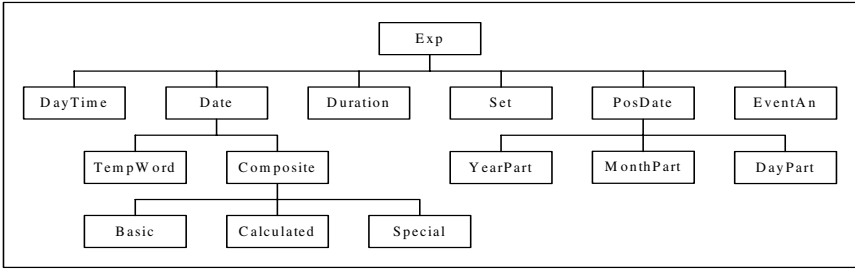

Fig. 1. The scheme of time units

3.3   Representation in Chinese Text

According to our observation on Chinese texts and the annotation standards of TIMEX2 [4, 6] and TIMEX3 [12], temporal expressions can be classified into different classes. They are shown in Fig. 2.

```
                              ┌─────┐
                              │ Exp │
                              └─────┘
   ┌──────────┬──────────┬──────────┬──────────┬──────────┐
┌────────┐ ┌──────┐ ┌──────────┐ ┌─────┐ ┌─────────┐ ┌─────────┐
│DayTime │ │ Date │ │ Duration │ │ Set │ │ PosDate │ │ EventAn │
└────────┘ └──────┘ └──────────┘ └─────┘ └─────────┘ └─────────┘
```

Fig. 2. The classification of temporal expression

In Chinese, if people do not know the exact number at an inferior time level, they may append an imprecise description to denote a position in a larger scope, such as "去年春天/the spring of last year". We named these temporal expressions "PosDate". These expressions consist of date expressions and imprecise appendix.

"TempWord" expressions are some Chinese words which contained temporal meanings, such as "春节/the lunar new year", "目前/now". "Composite" expressions include basic temporal expressions, calculated expressions and special expressions, such as "1999年4月28日/April 28, 1999", and "两年后/after two years" and "1999 财年/ the fiscal year 1999". "Set" expressions denote a set of time and most of them are about frequency, such as "每年/every year" and "每两天/every two days". "EventAn" expressions are relevant to the times of events, such as "当他演讲时/when he was speaking". "EventAn" expressions can be anchored on the time line only after the times of the events are resolved.

4   Extractor Based on Grammar and Constraints

The task of extractor is to identify the extents of temporal expressions in the surface text. A set of context free grammar rules is designed to describe the basic form of all kinds of temporal expressions and a bottom-up chart parser is employed to parse temporal expressions. Word segmentation is a preliminary step in many Chinese NLP applications. However, the performance of word segmentation is not perfect and it may introduce some extra errors. In our system, each possible combination of Chinese characters in a sentence will be looked up, and then all of the constituents are fed into the char parser. If the dictionaries are comprehensive enough, then all the possible explanations of all the possible combinations of characters can be gotten. Ambiguities and overlaps between multiple temporal expressions are left to constraint rules and combination rules.

4.1   Temporal Grammar Rules

A set of grammar rules is designed for each type of temporal expressions. In order to catch more temporal expressions, the grammar rules are given loosely. Some pseudo temporal expressions may be introduced and this problem is addressed in the next

section.Given these grammar rules, "15时24分/15:24" and "15时24分39秒/15:24:39" can be recognized. In these examples, "时/o'clock", "分/minute", "秒/second" are all constituents of the type "Time_Unit".

Table 1. Grammar rules for DayTime expressions

No.1.	Exp -> Time_Of_Day
No.2.	Time_Of_Day -> Time_Base
No.3.	Time_Base -> Time_Temp +
No.4.	Time_Temp -> Integer Time_Unit
No.5.	Integer -> Digit +

4.2 Constraint Rules

There are many complex and variable phenomena in natural language. Even the domain is narrowed down to the temporal field, grammar rules are not enough to extract exact temporal expressions. There are some pseudo expressions which satisfy grammar rules, so constraint rules are designed to specify the true temporal expressions according to the context. These constraint rules are developed by analyzing thedata set.

A constraint rule will be triggered after the right part of the corresponding grammar rule is satisfied. If the constraint rule is satisfied, then the grammar rule can be applied; otherwise, it cannot be applied. Examples of constraint rules are shown in Table 2 and the following two examples show the constraint checking procedure step by step.

Table 2. Examples of constraint rules

Grammar rule 3:	Time_Base -> Time_Temp +
Constraint rule 3:	IF There is only one constituent of the type "Time_Temp", THEN the constituent "Time_Unit" which is contained in "Time_Temp", should not be "分/ minute".
Grammar rule 4:	Time_Temp -> Integer Time_Unit
Constraint rule 4:	The constituent "Integer" can not end up with "个 (a quanti fier)".

(1) 这家新闻机构十分迅速地报道了这次事件。
   (This news agency reported the event very quickly.)
      Step 1. Look up dictionary.
          [十/Digit] [分/Time_Unit]
      Step 2. Apply the grammar rule No.5.
          [十 /Integer] [分/Time_Unit]
      Step 3. Check constraint rule No.4.
          Pass.
      Step 4. Apply grammar rule No.4.
          [十分/Time_Temp]
      Step 5. Check constraint rule No.3.
          Fail and then terminate parsing.

(2) 晚上7时30分西弗吉尼亚州和俄亥俄州投票结束。

    (The ballot ended at 7:30 p.m. in Western Virginia and Ohio.)

        Step 1. Look up dictionary.

               [7/Digit] [时/Time_Unit][3/Digit] [0/Digit][分/Time_Unit]

        Step 2. Apply the grammar rule No.5.

               [7/Integer] [时/Time_Unit] [30/Integer][分/Time_Unit]

        Step 3. Check constraint rule No.4.

               Pass.

        Step 4. Apply grammar rule No.4.

               [7时/Time_Temp] [30分/Time_Temp]

        Step 5. Check constraint rule No.3.

               Pass.

        Step 6. Apply grammar rule No.3.

               [7时30分/Time_Base]

        Step 7. Apply grammar rule No.2.

               [7时30分/Time_Of_Day]

        Step 8. Apply grammar rule No.1.

               [7时30分/Exp]

        Step 9. Recognize the temporal expression successfully.

In the first example "十分/very" is an adverb and has no temporal meaning. However the character "十/ten" and "分/minute" can be looked up and satisfy the grammar rule. Constraint rules are necessary to filter the pseudo expression.

4.3 Combination of Temporal Expressions

Because each possible substring in a sentence is tried, multiple nested, overlap or adjacent temporal expressions may exist in the sentence. However, some of these expressions are just parts of the optimal answers. So combination is necessary to get the integrated temporal expression. After applying grammar rules, if any two temporal expressions are nested, overlapped or adjacent, our system will combine them and keep the final result. This procedure is shown by the following examples.

(3) 这次列车将于次日早上到达南昌。

    (This train will arrive at Nan Chang next morning.)

    First recognized temporal expressions are [次日/tomorrow] and [早上/morning].

    After the combination, the correct answer [次日早上/next morning] will appear.

(4) 晚上8时篮球比赛开始。

    (The basketball game starts at 8:00 p.m.)

    First recognized expressions are [晚上/night], [8时/8:00], [晚上8时/8:00 p.m.].

    The final result is [晚上8时/ 8:00 p.m.].

4.4 Temporal/Non-temporal Disambiguation

Some strings of characters are temporal expressions in given contexts, but in other contexts they are not. The context should be browsed to extract the true temporal expressions. Some constraint rules are designed to check the context and fulfill disambiguation. Three kinds of ambiguities are founded. The first kind is the ambiguities

caused by numbers, such as example 5. In this case, the expression "15：10" contains temporal information, but in sports news messages it may be a score of a game. The second kind is the ambiguities caused by the combination of numbers and time units, such as "十号". In example 6, the expression "十号" just refers to a football team member. However, in many news messages it is a date. The third kind is the ambiguities caused by Chinese words, such as "前". In example 7, the expression means "former" and its explanations in other contexts may be "in front of".

(5) 本次列车将于15：10到达终点站。

(6) 然而6分钟后，10号宿茂臻冲顶即将比分扳平。

(7) 俄罗斯前总统叶利钦等政府首脑为人类和平欣然提笔。

There are multiple explanations for the same one phrase or word, so ambiguities may be caused. To discriminate these expressions, heuristics for disambiguation are embedded in corresponding constraint rules.

5   Normalizer Based on Mapping Procedure

The goal of normalizer is to represent the temporal information of contained in temporal expressions, according to some standard. The normalizer is based on the mapping procedure, in which temporal expressions are explained and represented by values of temporal attributes. In this procedure, the objects number, unit, time and duration are employed to store and represent temporal information.

5.1   Introduction to Normalization

TERN 2004 evaluation [14] is a public evaluation on the extraction and normalization of temporal expressions. To evaluate our temporal parser in a real task, we express temporal information according to the standard of TERN 2004 evaluation. Any temporal expression will be explained by a possible combination of the values of the six attributes. These attributes are described in table 3.

Table 3. Temporal attributes

Attribute	Function
VAL	Contains the value of a time or duration
MOD	Captures temporal modifications
SET	Designates set-denoting expressions
ANCHOR_VAL	Contains a normalized form of the reference time
ANCHOR_DIR	Capture the relative direction/orientation between VAL and ANCHOR_VAL
NON_SPECIFIC	Designates a generic, essensially nonreferencial expression

5.2   Normalization of Temporal Expressions

After the procedure of extraction, the chart parser keeps all the applied grammar rules and recognized intermediate constituents. Semantic meanings of temporal expressions

can be achieved by the explanation of these grammar rules. In this procedure, some basic objects, such as "number", "unit", "time" and "duration", can be employed to store and convey temporal information. Applying grammar rules means creations or updates of basic temporal objects. Based on our temporal framework, we explain how to normalize the temporal expression extracted, i.e. mapping the expressions to the values of six attributes. The mapping procedure is different for different kinds of temporal expressions. A general description about the mapping procedure is shown in Fig. 3.
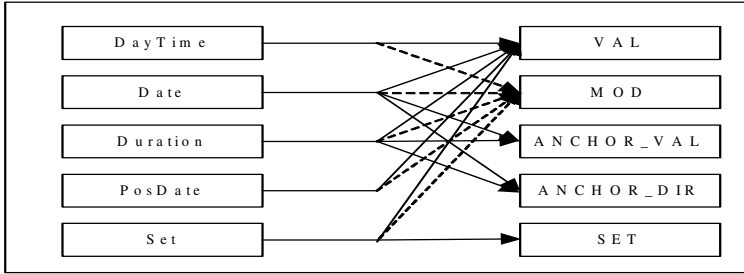

Fig. 3. Mapping temporal expressions to attributes

According to the classification scheme in Section 3.3, all temporal expressions can be mapped to the six attributes. The mapping procedures are complicated and selected examples are shown in Table 4. It is difficult to tell whether a temporal expression is "specific" or not, and few expressions are set a value at this attribute, we do not map expression to the attribute "NON_SPECIFIC".

Table 4. Examples of normalization

Expressions	Attributes
目前/now	val="PRESENT_REF" anchor_val="2000-10-05" anchor_dir="AS_OF"
晚上8时20分/20: 20 p.m.	val="1999-04-26 T20:20"
后两年/the next two years	val="P2Y" anchor_val="2000" anchor_dir="STARTING"
每两天/every two days	val="P2D" set="YES"
明天下午/ next afternoon	val="2000-10-07TAF"

"MOD" attribute of temporal expressions may be set as "YES" if there are some modifying descriptions about the expressions, such as "将近/about", "早于/before" and so on. So any kind of temporal expressions may be mapped on this attribute. "Set" expressions can be explained as set of times, such as "每年/each year", or set of durations, such as "每两年/every two years", so the attributes "VAL" and "SET" will be filled. "ANCHOR_VAL" and "ANCHOR_DIR" refer to reference times and we

adopt the publishing times of news articles as the default reference times. Event expressions are relevant with a specific event and it is hard to represent the exact meaning of them. In our system event expressions are not normalized.

5.3 Time/Duration Disambiguation

Sometimes people omit a part of a full temporal expression for convenience in Chinese texts. For example, "4月/April" and "97年/ '97" are used to instead "2000年4月 /April, 2000" and "1997年/the year 1997". However, "4月/four months" and "97年 /97 years" are also legal temporal expressions. These temporal expressions are combinations of numbers and common time units. The first kind of explanations means these expressions are times and the second kind of explanations means they are durations. To get the correct values of temporal attributes for these temporal expressions, disambiguation is necessary. Heuristic rules are employed for disambiguation, which are shown in Table 5.

Table 5. Some heuristic rules for disambiguation

IF a 3-digit or four-digit number is combined with the unit "年/year", THEN this expression is time;

IF a 2-digit number is combined with the unit "年/year" and the number is bigger that 70, THEN this expression is time.

IF a 1-digit number is combined with the unit "年/year", THEN this expression is duration.

6 Evaluation and Analysis

In this section we report the results about evaluating our temporal parser on a manually annotated corpus, which consist of 457 Chinese news articles. The data collection contains 285,746 characters/142,872 words and 4,290 manually annotated temporal expressions. We will evaluate the boundaries of expressions and the values of the six temporal attributes.

Table 6. Experiment configuration

Experiment No.	Conditions
1	No constraints, combination of nested expressions
2	No constraints, combination of nested, overlapped and adjacent expressions
3	Constraints, combination of nested expressions
4	Constraints, combination of nested, overlapped and adjacent expressions

In our temporal parser, we embedded constraints to restrict grammar rules. In addition, we combine the nested, overlapped and adjacent temporal expressions. In Chinese, many temporal expressions contain nested temporal expressions. If we do not

combine these nested components into the optimal answer, there will be so many mismatched expressions. So the combination of nested temporal expressions is necessary. In the experiments, we try to evaluate two factors: the constraint rules, and the combination of overlapped and adjacent temporal expressions. Four experiments are set up, which are described in Table 6. Given these conditions, the results of the experiments are shown in Table 7.

Table 7. Experiment results

Attributes		NO. 1.	NO. 2.	NO. 3.	NO. 4.
TEXT	P	0.717	0.758	0.810	0.856
	R	0.838	0.850	0.830	0.843
	F	0.773	0.801	0.820	0.849
VAL	P	0.730	0.750	0.787	0.807
	R	0.693	0.681	0.742	0.732
	F	0.711	0.714	0.764	0.768
MOD	P	0.563	0.565	0.629	0.626
	R	0.586	0.550	0.616	0.574
	F	0.574	0.557	0.622	0.599
SET	P	0.698	0.662	0.879	0.867
	R	0.606	0.589	0.611	0.598
	F	0.649	0.624	0.720	0.707
ANCHOR_VAL	P	0.680	0.750	0.681	0.687
	R	0.658	0.681	0.662	0.652
	F	0.669	0.714	0.672	0.669
ANCHOR_DIR	P	0.724	0.727	0.733	0.737
	R	0.682	0.669	0.694	0.682
	F	0.702	0.697	0.713	0.708

Several related works are designed to extract and normalize temporal expressions, however they are about English, Spanish, French, Korea and so on. We take part in TERN 2004 evaluation on Chinese temporal expression extraction and achieve the highest performance in this task. There is no public result on Chinese temporal expression normalization, for reference we compare our normalization result of Experiment NO. 4 with the English normalization result in TERN 2004. Our performance is medium among their results.

Table 7 compares the Precision, Recall and F-measure for different attributes in different experiments. "TEXT" means the performance of exact boundaries of temporal expressions and other attributes are explained in Section 5.1. For attributes "TEXT" and "VAL", we achieve the highest performance in Experiment 4. The F-scores are 0.849 and 0.768, respectively. For other attributes, we also achieved nearly highest score in Experiment 4. From the trend of performance on these two attributes, we can see the constraints and the procedure of combination have positive effects to performance of the temporal parser, especially on "TEXT" and "VAL". At the same time, the procedure of combination is not significant to other attributes. Based on the assumption that two adjacent or overlapped temporal expressions refer to the same temporal concept, we combined them. However, the procedure of combination can not help to explain the meaning of the expressions.

After the evaluation we collect the errors of Experiment NO. 4 and try to summary the reasons. Wrong attribute values include missed, incorrect and spurious cases. The reason for errors on the attributes "ANCHOR_VAL" and "ANCHOR_DIR" is that the system did not give correct reference times. Table 8 gives the error distributions according to different attributes. From this table, it can be seen that temporal Chinese words and events are difficult to extract and normalize.

Table 8. Error distributions

Attributes	Reasons	Number	Percentage
TEXT	Boundaries of temporal Chinese words	366	37.4%
	Boundaries of events	193	19.7%
	Grammar rules	161	16.4%
	Boundaries of temporal noun phrase	89	9.1%
	Combination procedure	76	7.8%
	Annotation inconsistence	75	7.7%
	Temporal/non-temporal ambiguities	19	1.9%
VAL	Explained semantics	299	27.6%
	Explanation of temporal Chinese word	180	16.6%
	Errors introduced by extraction	177	16.3%
	Specification/generalization characteristic	148	13.7%
	Wrong reference times	122	11.3%
	Annotation inconsistence	80	7.4%
	Point/duration ambiguities	63	5.8%
	Explanation of events or noun phrase	14	1.3%
MOD	Errors introduced by extraction	44	33.3%
	Annotation inconsistence	35	26.5%
	Explanation of temporal Chinese word	27	20.5%
	Explained semantics	23	17.4%
	Ambiguities	3	2.1%
SET	Explained semantics	35	81.4%
	Errors introduced by extraction	3	7.0%
	Annotation inconsistence	5	11.6%

7   Conclusion

In this paper, we present the temporal parser that extract and normalize comprehensive temporal expressions from Chinese texts. We also propose a temporal framework, which include basic temporal objects and relations, the measurement and classification of temporal expressions. To cope with kinds of temporal expressions, constraint rules are employed to retrieve genuine expressions and resolve ambiguities. The temporal parser CTEMP is fully implemented, which is based on the chart parsing and constraint checking scheme. We have evaluated the temporal parser on a manually annotated corpus and achieved promising results of F-measures of 85.6% on extent and 76.8% on value. We took part in TERN-2004 Chinese temporal expression extraction with this parser and achieved the highest performance in that track.

In our experiments the temporal parser is also evaluated with/without constraints, combination of nested and overlapped temporal expressions. We find that constraints are significant to the task extraction and normalization. At the same time, combination has positive influence on the task extraction. Error analysis shows that temporal Chinese words and events are more difficult to extract and normalize. To improve the performance of extraction, we plan to decide whether to keep any temporal Chinese words as a genuine temporal expression automatically according to the contribution of the word. We also plan to improve the performance of normalization by more precise semantic explanation.

Acknowledgement

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