AUTOMATIC CHINESE TEXT GENERATION BASED ON INFERENCE TREES

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Abstract

This paper describes a method for the generation of a coherent and continuous Chinese text from an inference tree. We argue that it is important to include information of rhetorical relations as part of the knowledge representation scheme in a rule-based expert system shell, in order to facilitate text generation of the inferred relationships. Applying the Rhetorical Structure Theory(RST) defined by Mann and Thompson[5,6], a set of rhetorical relations for Chinese rule-based inferencing is proposed. We observe that the rhetorical structure for an inference tree will be transformed after the inference tree is reasoned(or proved) by an expert system. Rules governing such transformation are derived. We also give an algorithm that can systematically generate multiple sentences of coherent Chinese text on the basis of the transformed rhetorical structure involving conjunctively and disjunctively conjoined constituents in Chinese.

1. Introduction

Natural language text generation (NLTG) can be viewed as a decision process, which determines what information to communicate, when to do it, and which syntactic structures and words might best express the author's intent. Generally speaking, NLTG can be divided into two stages, the strategic stage and the tactical stage [7]. Given a set of communicative goals, the strategic stage determines the content and structure of the discourse. At this stage, relevant information to be included in a text is determined, discourse strategy to control of the order information in the text is selected, and focus mechanism isused to monitor the progress of succeeding utterances so that the text can be easily understood.

On the other hand, the tactical stage uses a grammar and dictionary to realize in some natural language a single utterance produced by the strategic stage. An utterance can consist of one or more related propositions, which, in turn, corresponds to one or more simple sentences(or clauses) in the text. It is recognised that generating multiple sentences for a text is far more difficult than that of a single sentence, as the text generator must tackle such problems as pronominal reference and the use of conjunctions in order to produce a coherent and rhetorically sound text.

This paper addresses the tactical problem in Chinese text generation, where an utterance is represented by a proof tree of a rule-based expert system, as defined below.

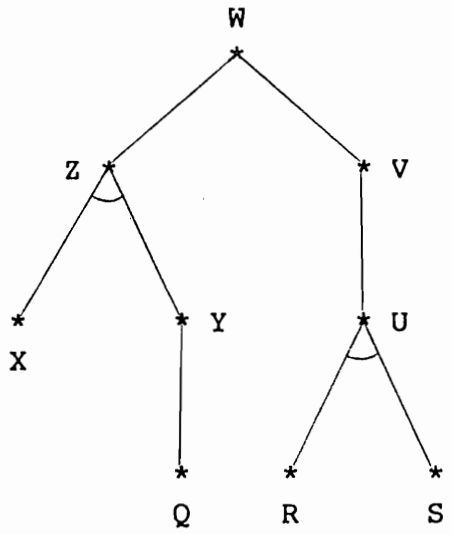
Generally speaking, an expert system is a computer program that is capable of reasoning and arriving at conclusions based on the knowledge it possesses. A rule-based expert system represents knowledge in terms of facts and rules. Facts are permanent or temporary knowledge that is unconditionally true. On the other hand, rules represent knowledge in a form that can be used for inference. Specifically, in a rule-based system, knowledge is represented as a series of "If-Then" rules based on propositional or predicate logic. In this paper, we are interested in two types of rules, namely, the AND rules (Conjunction) and the OR rules(Disjunction) as shown below.

Q :- P_1 AND P_2

Q :- P_1 OR P_2

Rules can be combined with facts to deduce new facts or arrive at conclusions. This process is known as inference. We can view an inference as a process of constructing a tree structure whose nodes are the clauses used in rules and whose branches are arrows connecting the clauses. When an AND rule is encountered, we have an "AND node". Otherwise, we have an "OR node". The branching in such a tree reflects the structure of a set of rules used in an inference. The tree so constructed is referred to be an AND/OR inference tree.

Fig. 1 shows an AND/OR inference tree (IT) for a set of rules in a knowledge base of some expert system.



W :- Z OR V
Z :- X AND Y
Y :- Q
V :- U
U :- R AND S

Figure 1

A proof P is an association of either the value True (T) or False (F) with each node of IT in such a way that all the rules in IT are not violated. A proof tree is an inference tree with an associated proof.

Our problem is to derive an algorithm that generates a paragraph of coherent and rhetorically sound Chinese text for a given proof tree. Our concern in this paper is not on how to generate an isolated Chinese sentence[2]. Instead, we are mainly concerned with clause concatenation, conjunctions and related issues of form and function in generating multiple-sentence Chinese text [1,6].

2. RST Analysis of AND/OR Rules

2.1 Review of Rhetorical Structure Theory

Rhetorical Structure Theory (RST) provides a theoretical basis for computational text planning and generation [5,6]. RST describes a text by assigning a rhetorical structure to it. Specifically, a

rhetorical structure represents a text as a tree, whose terminal nodes represent independent clauses appearing in the text, and non-terminal nodes represent instances of rhetorical relations, also called "schemas", which indicate how a particular unit of text structure is decomposed into other smaller units. Fig. 2 shows a generic rhetorical relation.

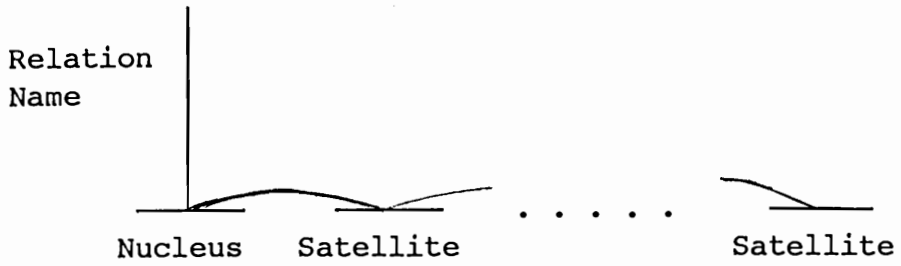


Figure 2

There are two or more text spans covered by a rhetorical relation. The text span pointed by a vertical line labeled with the relation name is called the nucleus, while the other spans are called satellites. A rhetorical relation can be symmetric or asymmetric. In a symmetric relation, functions of all the spans are of equal importance, but in an asymmetric relation, one span is more essential to the text than the other. The prominent and essential core span is the nucleus, and the other spans the satellites. The identity of the nucleus is part of therelation definition.

As pointed out by Mann and Thompson [6], the set of rhetorical relations is reasonably stable for any particular purpose, and they are, to certain extent, language-specific and culture-specific.

2.2 Rhetorical Relations for Rule-based Inferencing

As pointed out in Section 1, we are interested in two kinds of rules in a rule-based expert system, i.e. the AND rules and the OR rules. Without loss of generality, we assume that the rule body of an AND/OR rule consists of no more than two predicates.

To define a set of rhetorical relations for AND/OR rules, we propose that each rule should be represented as a two-level

rhetorical structure as shown in Fig. 3.

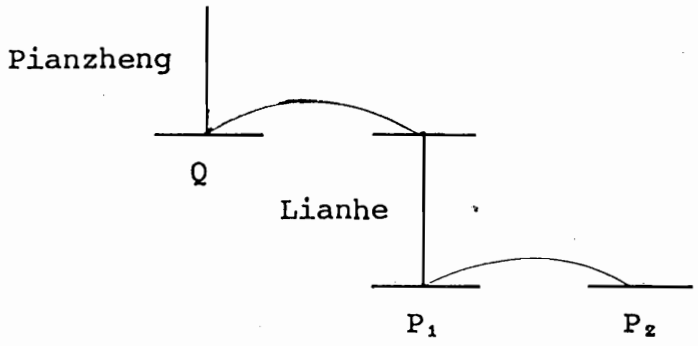


Figure 3

In Fig. 3, the upper rhetorical relation corresponds to the logical implication in a rule, and the lower rhetorical relation corresponds to the conjunction or disjunction of the two predicates that constitute the rule body. The set of rhetorical relations that can be used in the former shall be called Pianzheng relationship (偏正關係) and those used in the latter Lianhe relationship (聯合關係) .

Pianzheng relationship for a rule can be one of the following rhetorical relations:

1. Sufficient condition (假設關係) : This rhetorical relation applies to a rule whose body is the sufficient condition of its head. In Chinese, this relation is indicated by a pair of discontinuous constituents in a conjunction, e.g." 如果 ..... 那末 .....".

2. Necessary and sufficient condition (條件關係) : This rhetorical relation applies to a rule whose body is both the necessary and sufficient condition of its head. In Chinese, this relation is indicated by the discontinuous conjunction, e.g. " 只有 ..... 才 .....".

Both of the above rhetorical relations are asymmetric relations, where the text span corresponding to the head of a rule is the nucleus, while the other span corresponding to the body of a rule is the satellite.

On the other hand, Lianhe relationship for a rule includes the following rhetorical relations:

1. Disjunction (選擇關係) : This rhetorical relation applies to the rule body of any OR rule. This is a symmetric relation. In Chinese, this relation is indicated by the discontinuous conjunction, e.g. "或者 ..... 或者 .....".

2. Conjunction (並列關係) : This rhetorical relation applies to the rule body of an AND rule, where the two constituent predicates are semantically related. This is also a symmetric relation. In Chinese, this relation is indicated by the discontinuous conjunction, e.g. "一方面 ..... 一方面 .....".

3. Progression (遞進關係) : This rhetorical relation applies to the rule body of an AND rule, where the two constituent predicates are semantically related but one is more prominent and essential than the other. This is an asymmetric relation. In Chinese, this relation is indicated by the discontinuous conjunction,
e.g. "不但 ..... 而且 .....".

To facilitate text generation, each AND/OR rule in the knowledge base will be associated with two tags, denoted as {TAG1, TAG2}, where TAG1 indicates Pianzheng relationship and TAG2 indicates Lianhe relationship. If the rule body has only one predicate, TAG2 will be left blank.

2.3 Rhetorical Structure for Inference Tree

It is a straightforward procedure to construct a rhetorical structure for an inference tree. Every node of an inference tree always corresponds to some AND/OR rule with an associated rhetorical relationtags, {TAG1, TAG2}, as discussed in Subsection 2.2.

Starting at the root node N of an inference tree, we replace N by the two-level rhetorical structure shown in Fig. 3. The upper vertical line is labeled with TAG1 and the lower vertical line TAG2 of the rule corresponding to N. The nucleus span of the upper rhetorical relation is labeled with the head of the rule, which is the same as the predicate associated with N. The two spans of the lower rhetorical relations are connected to the left daughter and

the right daughter of N. The rhetorical relation indicated by TAG2 must be used to determine which daughter of N is connected to the nucleus span and which to the satellite span. Then, consider the left subtree of N, followed by the right subtree of N, using the same procedure above to replace their root nodes by the appropriate rhetorical structures. This procedure continues until all the nodes of the inference tree are exhausted.

3. Rhetorical Structure Transformation

Given the following rule with the associated rhetorical relations:

$Q(X)$:- $P_1(X)$ AND $P_2(X)$ { Sufficient condition , Progression }

Let P_1 stands for the clause " 投入更多的人力 " ,
P_2 stands for the clause " 提高機械化程度 " ,
Q stands for the clause " 農業現代化就會成功 " .

Furthermore, assume that X stands for some country.

Using the proper Chinese conjunctions for the associated rhetorical relation, we can generate the following text from the above rule. Note that in all the texts followed, conjunctions that are used to link clauses within a single sentence or across multiple sentences are underlined. How the texts are generated will be discussed in Section 4.

如果一個國家不但投入更多的人力，而且提高機械化程度，那末該國農業現代化就會成功。

It is known that P_1 and P_2 for country A are both true. After inferencing, it is deduced that Q is also true. This inferred result can be stated by the following text:

因爲A國家不但投入更多的人力，而且提高機械化程度，所以A國農業現代化就會成功。

The rhetorical relations associated with the above text stated in the same format as a rule should be { cause and effect (因果關係), progression }.

On the other hand, if it is proved that P_1 is true while P_2 is false for country B, we can no longer use the previous rhetorical relations to generate an easily understood text. Instead, the inferred result should be generated using another rhetorical relation combination{ possible effect(或然因果關係), concession(讓步關係)} so that proper Chinese conjunctions and order of clauses can be determined. Note that since the premise of the rule is found to be false, we can infer that the conclusion is probably false. The generated text is:

因爲B國家没有提高機械化程度，所以，縱然投入更多的人力，B國農業現代化大概仍然不會成功。

From the above discussion, we observe that : (1) Rhetorical relations are essential to select different conjunctions for clause linking and to determine the order of clauses in the text generated, and (2) the rhetorical relations associated with a rule can be changed after that rule is reasoned by an expert system.

3.1 Transformation of Rhetorical Relations

In the previous subsection, we have observed that the rhetorical relations associated with a rule will be transformed after that rule is reasoned by an expert system. The rules governing such transformationare described in Table 1 and 2.

after / before	Satellite is true	Satellite is false
sufficient condition	cause and effect	possible effect
necessary and sufficient condition	premise and condition	premise and condition

Table 1 Transformation rules for Pianzheng relationship

after / before	If P_1 and P_2 are both true or both false	If one is true and the other is false
disjunction	conjunction	adversativity / concession
conjunction	conjunction	adversativity / concession
progression	progression	adversativity / concession

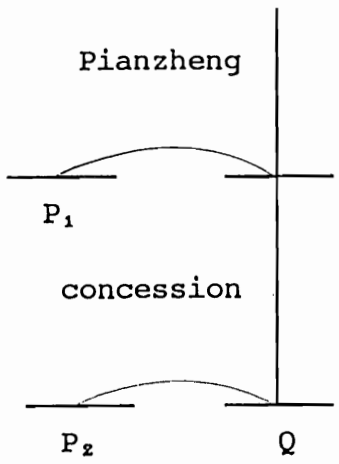
Table 2 Transformation rules for Lianhe relationship

In Table 2, if the truth values of P_1 and P_2 are different, the transformed rhetorical relations, namely, adversativity (轉折關係) or concession is applied to the whole rhetorical structure of a rule, not only the rule body. Furthermore, there is a mutual duality property between this pair of rhetorical relations as discussed in the following subsection.

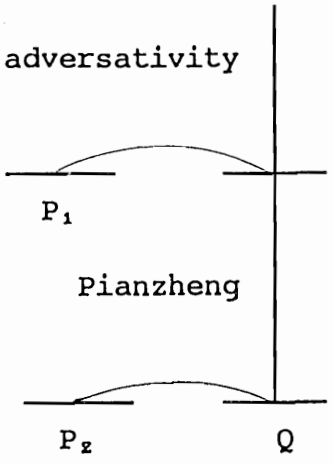
3.2 Transformation Rules for concession and adversativity

Concession and adversativity are good examples that different text can be generated for the same piece of information. These two rhetorical relations occur when, after reasoning, the truth value of P_1 and P_2 are found to be different for an AND/OR rule. The rhetorical structure of the inferred result can be represented in one of the two forms shown in Fig. 4.

Choosing which rhetorical structure of Fig. 4 depends on whether the rule is an AND rule or an OR rule, as well as the truth values of P_1 and P_2, as shown in Table 3.



(a) Rhetorical structure with concession



(b) Rhetorical structure with adversativity

Figure 4

Rule Type	P_1	P_2	Q	Rhetorical Structure
AND	F	T	F	Use Fig. 4(a)
AND	T	F	F	Use Fig. 4(b)
OR	T	F	T	Use Fig. 4(a)
OR	F	T	T	Use Fig. 4(b)

Table 3

Example 3.1

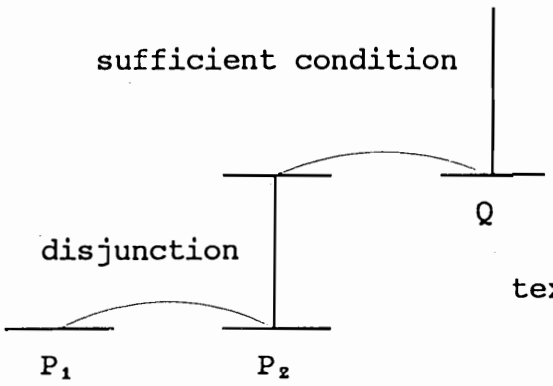
Given the following rule with the associated rhetorical relations:

Q(X) :- P_1(X) OR P_2(X) { sufficient condition, disjunction}

Let P_1 stands for the clause " 工資高 "
P_2 stands for the clause " 物價低 "
Q stands for the clause " 生活水準可以維持高水平 "

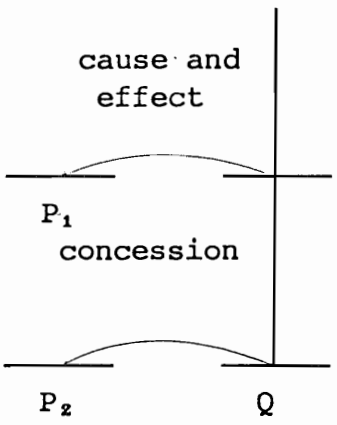
Fig. 5(a) shows the rhetorical structure for this rule, and the corresponding text generated using the appropriate conjunctions.

After this rule is reasoned by an expert system, it is discovered that P_1 is true and P_2 is false. Using Table 3, we can transform the rhetorical structure of Fig. 5(a) to that shown in Fig. 5(b) or 5(c).The texts for Fig. 5(b) and 5(c) are also given.



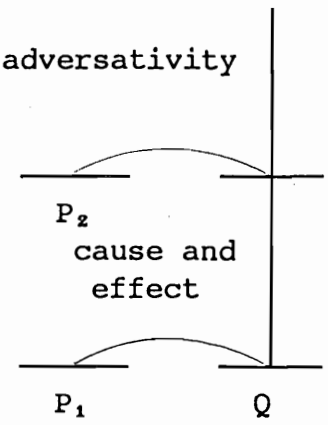
text: 如果或者工資高，或者物價低，那末生活水準可以維持高水平。

(a) Rhetorical structure for an OR rule with text



text: 因爲工資高，所以即使物價不低，生活水準仍然可以維持高水平。

(b) Transformed rhetorical structure with concession



text: 雖然物價不低，但是工資高，所以生活水準仍然可以維持高水平。

(c) Transformed rhetorical structure with adversativity

Figure 5

3.3 Rhetorical Structure for Proof Tree

Using the transformation rules developed above, we can generate many different rhetorical structures (accordingly, generate different texts) for the same inference tree, each corresponding to a different proof. Further, even for the same proof, the rhetorical structure generated is not unique. This non-uniqueness property is due to the followings. Firstly, for any symmetric rhetorical relation, we can randomly select one clause to be the nucleus and the other to be the satellite. The resulting rhetorical structure will be different.

Secondly, as discussed in Subsection 3.2, we can select either concession or adversativity to express an inferred rule. This non-uniqueness property of text generation allows us to select a text to be generated according to designated optimization criteria, or writing styles. Text selection and optimization will not be addressed in this paper.

We adopt the following deterministic top-down procedure to transform a rhetorical structure for an inference tree, given a proof. Starting at the root of the rhetorical structure, every step of the transformation takes a two-level rhetorical structure, corresponding to a rule in the original inference tree, and applies to it the transformation rules presented in Subsections 3.1 and 3.2. The transformation should preserve the structure of the original rhetorical structure as follows: (1) If the transformed rhetorical structure includes the concession or adversativity, then the satellite span in the bottom level of the original rhetorical structure will become the satellite span in the top level of the transformed rhetorical structure. (2) For the other rhetorical structures, the transformation should preserve the original identity of nucleus and satellite spans. See Fig. 6(a) to 6(c) for an example.

4. Chinese Text Generation for Rhetorical Structure

4.1 Rhetorical Relations and Chinese Conjunctions

Two or more simple sentences (or clauses) can be linked to form a compound or complex sentence by means of suitable conjunctions. Let x and y be a pair of discontinuous constituents in a conjunction, and

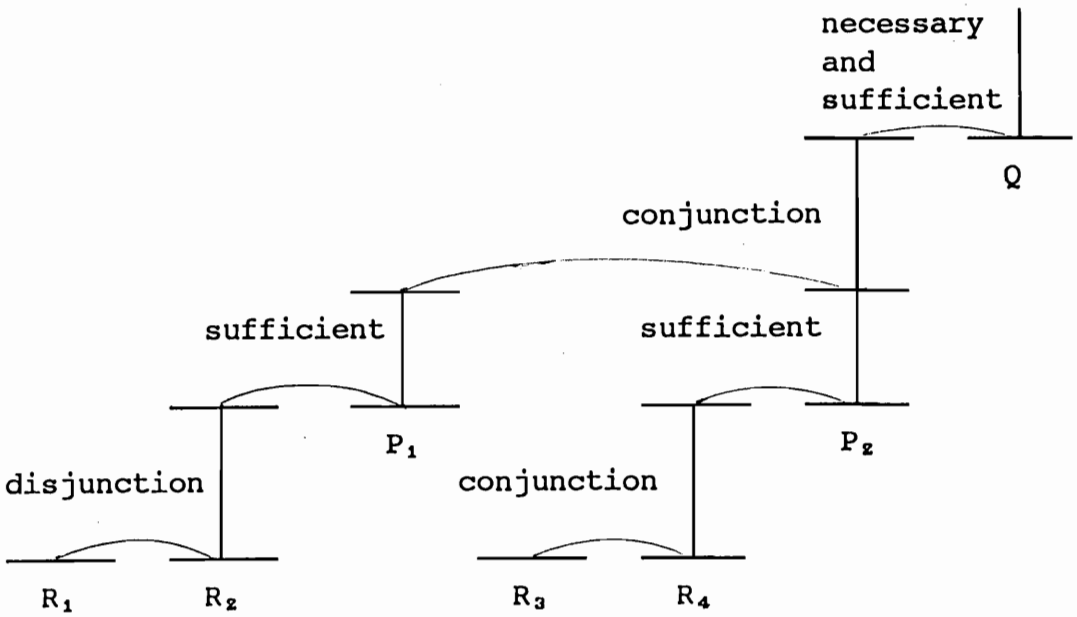


Figure 6(a) Rhetorical structure for an inference tree

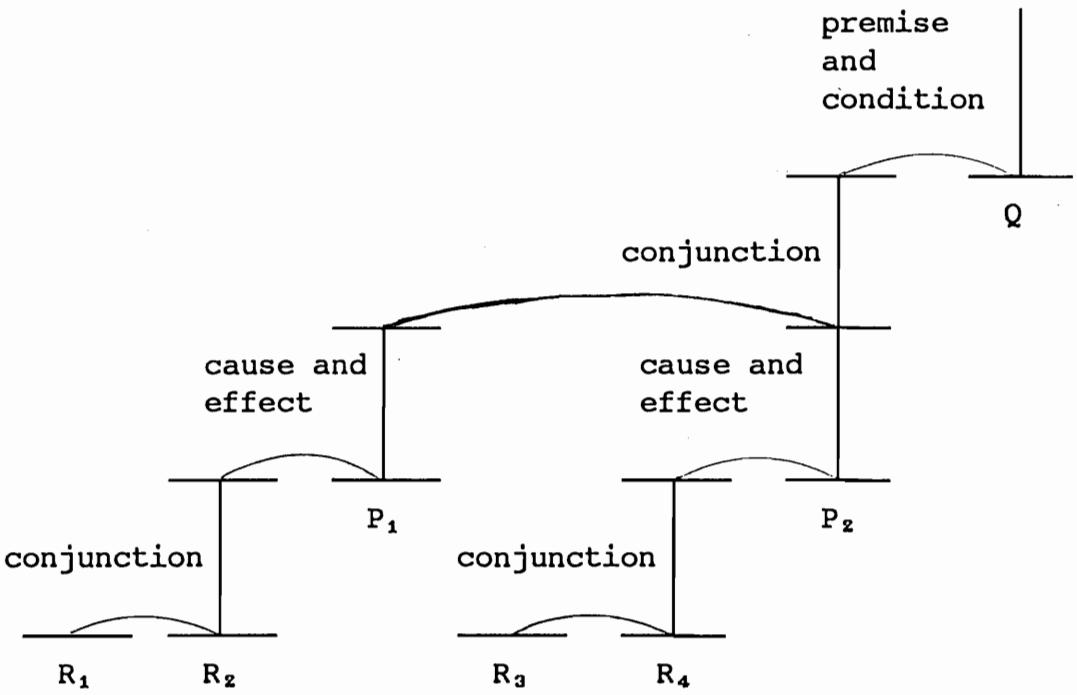


Figure 6(b) Rhetorical structure for the inference tree shown in Fig. 6(a) with an associated proof = {(R_1,T), (R_2,T), (R_3,T), (R_4,T), (P_1,T), (P_2,T), (Q,T)}

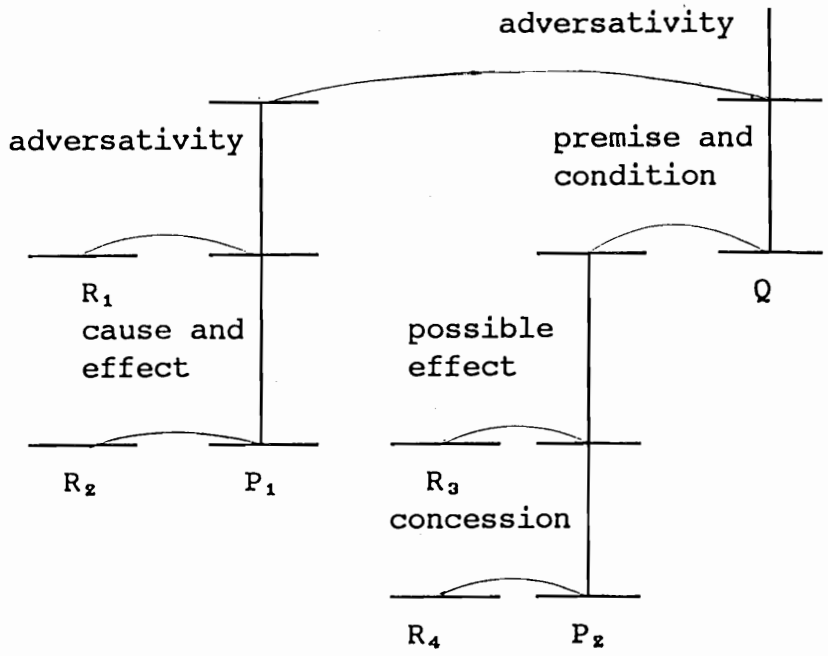


Figure 6(c) Rhetorical structure for the inference tree shown in Fig. 6(a) with an associated proof = {(R_1,F), (R_2,T), (R_3,F), (R_4,T), (P_1,T), (P_2,F), (Q,F)}

A and B be two clauses. Then, to join A and B together, we can use either one of the following two formats:

Format 1: xA, yB
Format 2: A, yB

In Format 2, there is the omission of the first discontinuous constituent in the conjunction, associated with the first clause (which is usually the satellite span in an asymmetric rhetorical relation). Generally speaking, with few exceptions, it is grammatically incorrect in Chinese to omit the constituent associated with the second clause (which is usually the nucleus span). Omitting both constituents will usually make the meaning of the resulting sentence logically ambiguous.

Mapping from the rhetorical relations discussed in Section 3 to their corresponding Format 1 or 2 of the generally paired conjunctions are given in Appendix A. Note that this mapping is a one to many mapping.

4.2 A Chinese Text Generation Algorithm for Rhetorical Structure

A rhetorical relation (RR) can be represented by:

RR_Name (Satellite, Nucleus).

A rhetorical structure (RS) can be defined by its root rhetorical relation, whose two spans are themselve s rhetorical structures. We denote the rhetorical structures connected to the satellite and the nucleus RS_Satellite and RS_Nucleus respectively. Therefore,

RS = Root_RR_Name (RS_Satellite, RS_Nucleus)

This definition of rhetorical relation can be applied recursively until a terminal node is reached. In that case, the RS is set to be the clause p associated with that node. Furthermore, if p is assigned a truth value according to a given proof, then the RS is set to be p (for True) or -p (for False) accordingly. For example, the transformed rhetorical structure shown in Fig. 6(c) can be represented by:

RS1 = adversativity(adversativity(-R_1,cause and effect(R_2,P_1)),
premise and condition(possible effect(-R_3,concession(R_4,-P_2)),
-Q))

The above list representation for a rhetorical structure will be the basis of the following text generation algorithm.

1. The list representation is processed in a left-to-right order. Scanning from the left,when the first relation is encountered, its relation name is used to search the conjunction table shown in Appendix A. If the first argument of this relation is a simple predicate, then a Format 1 conjunction pair is selected, otherwise, a Format 2 conjunction pair is selected. Note that the first constituent of a Format 2 conjunction pair is always absent.

2. Drop the relation name and the corresponding parentheses. Append the first conjunction to the first argument(i.e. the satellite) of this relation, and the second conjunction to the second argument (i.e. the nucleus).

3. Punctuations are assigned according to the following rules:

a. If the first argument is a clause, then insert a comma after the first argument.

b. If the second argument is not a clause, then insert a comma after the second conjunction.

c. Insert a fullstop after the second argument, if no punctuation has been assigned to this position.

4. Repeat Steps 1 to 3 until there is no more relation name and parentheses left in the generated text.

Using this algorithm, we obtain the following text for RS1.

雖然 $-R_1$，但是，因爲 R_2，所以仍然 P_1。然而，由於 $-R_3$，因此，即使 R_4，大抵仍然 $-P_2$。由此推論 $-Q$。

5. A Method for Chinese Text Generation for Inference Tree

To generate a coherent and rhetorically sound Chinese text for a given proof tree (i.e. an inference tree with an associated proof), we have to carry out the following steps:

1. Generate the rhetorical structure for the inference tree.

2. For each terminal node (corresponding to a predicate of the inference tree) of the generated rhetorical structure, associate its corresponding truth value from the given proof.

3. Transform the rhetorical structure with the associated truth values to a new rhetorical structure using the transformation rules discussed in Section 3.

4. Generate a Chinese text for the transformed rhetorical structure using the algorithm presented in Section 4.2.

We use the following example to illustrate the above method for Chinese text generation:

Example 5.1

Given the following three rules and their corresponding rule texts.

rule_0: Q :- P_1 AND P_2 { necessary and sufficient condition, conjunction }
只有當一個人身體弱，加上經濟差，他才需要別人救濟。

rule_1: P_1 :- R_1 OR R_2 { sufficient condition, disjunction}
如果一個人或者患病，或者年紀老邁，那末他身體弱。

rule_2: P_2 :- R_3 AND R_4 { sufficient condition, conjunction}
如果一個人沒有積蓄，加上失業，那末他經濟差。

Fig. 7 shows the inference tree for the above rules. We are required to generate a paragraph of Chinese text for the following purpose.

已知張三患病，年紀老邁，沒有積蓄，失業，請説明張三的現況。

To generate the required text, we have to carry out the 4 steps shown above.

1. The inference tree is replace by its corresponding rhetorical structure shown in Fig. 6(a).

2. According to the requirement stated above, the inference tree is reasoned by the expert system and the following proof is obtained.

Proof = {(R_1,T), (R_2,T), (R_3,T), (R_4,T), (P_1,T), (P_2,T), (Q,T)}

3. The rhetorical structure of Fig. 6(a) is transformed to a new rhetorical structure shown in Fig. 6(b).

4. The Chinese text generated for the transformed rhetorical structure is as follows.

張三除了患病，兼之年紀老邁，因此身體弱。同時，他一方面沒有積蓄，一方面失業，從而他經濟差。由此推論他需要別人救濟。

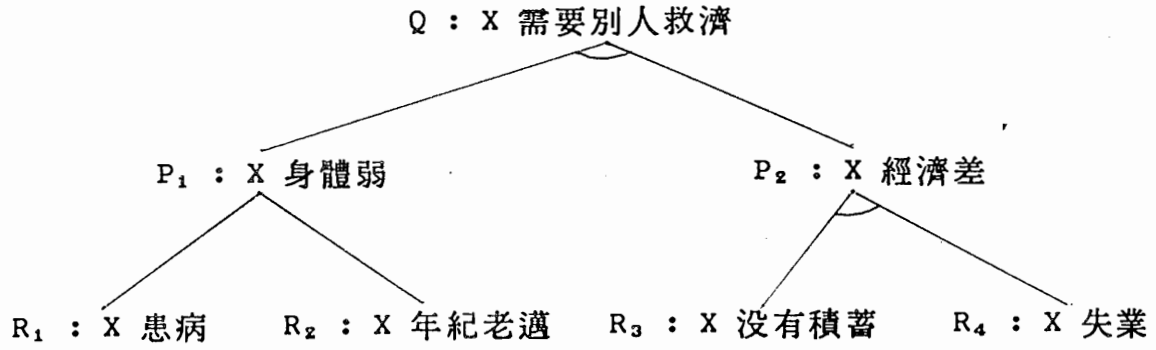


Figure 7

Example 5.2

For the same inference tree shown in Fig. 7, we are required to generate another paragraph of Chinese text to describe the followings.

已知李四没有患病，年紀老邁，有積蓄，失業，請説明李四的現況。

To generate the required text, we carry out the 4 steps as before.

1. The rhetorical structure of the inference tree is the same as before.

2. According to the requirement stated above, the inference tree is reasoned by the expert system and the following proof is obtained.

Proof = {(R_1,F), (R_2,T), (R_3,F), (R_4,T), (P_1,T), (P_2,F), (Q,F)}

3. The rhetorical structure of Fig. 6(a) is transformed to a new rhetorical structure shown in Fig. 6(c).

4. The Chinese text generated for the transformed rhetorical structure is as follows.

雖然李四没有患病，但是，因爲年紀老邁，所以身體仍然弱。然而，由於他有積蓄， 因此，即使他失業，經濟大抵仍然不差。自然他還不需要別人救濟。

6. Conclusions

Traditional study of knowledge representation emphasizes the impact of a representation on the process of inferencing, and disregards its effect on text generation. However, as pointed out by Mann and Thompson, "the relations of RST reflect a set of distinct kinds of knowledge that are given special treatment in text generation. It is therefore essential to represent these in the knowledge notations underlying a general text comprehender or generator." [6] Therefore, we propose in this paper a way of including information on rhetorical relations as part of the knowledge representation scheme in a rule-based expert system shell. By means of this rhetorical knowledge, this paper describes a method to generate Chinese text for proof trees which are the results of inferencing carried out by a rule-based expert system.

This study is the outgrowth of a research project which attempts to design and develop an automated Chinese text abstraction system (ACTAS) using a human-machine co-operative approach [8]. Inshort, ACTAS operates according to the followings. Information concerning a designated text is first digested by ahuman informant, who will then interact with ACTAS by means ofanswering a series ofquestions, which ACTAS automatically generated, with the assistance of a domain knowledge base and an inference engine, in order to acquire knowledge on the significant facts and the flow of argumentation in the original text. This acquired knowledge, or the abstract of the original text, is represented in the form of a proof tree in ACTAS. This proof tree is then transformed into a paragraph of rhetorically sound and easily understood Chinese text using the method presented in this paper.

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Appendix

A. Conjunction Table

Note that only selected conjunction-pairs are included for each rhetorical relation in the following table. This is not an exhaustive listing.

Rhetorical Relation	Format	Conjunction-pair		Remarks
		1	2	
sufficient condition	1	如果	那末	(a)
		倘若	那末	
		要是	就	
necessary and sufficient condition	1	只有	才	(a)
		惟有	才	
		但凡	總	
cause and effect	1	因爲	所以	(b)
		由於	因此	
	2	----	因此	
		----	從而	
		----	以致	
premise and condition	1	既然	那麼	
	2	----	由此推論	
		----	可見	
		----	自然	
adversat-ivity	1	雖然	但是	(c)
		雖然	然而	
	2	----	但是	
		----	然而	
		----	不過	

Rhetorical Relation	Format	Conjunction-pair		Remarks
		1	2	
concession	1	即使	仍然	
		縱然	也	
		盡管	還	
		就算	仍然	
		誠然	可是	
conjunction	1	除了	兼之	
		一方面	另一方面	
		一來	二來	
	2	----	同時	
		----	加上	
disjunction	1	或者	或者	
	2	----	或者	
progression	1	不但	而且	
		不只	甚至	
	2	----	進而	
		----	甚至於	
		----	乃至於	

Remark

(a) This rhetorical relation will not appear in any transformed rhetorical structure.

(b) Possible effect will use the same conjunction pair, except that the clause of its nucleus span should include such adverbs as 大概, 大抵, 可能, 多半 etc.

(c) The clause of the nucleus span of the Pianzheng relationship that is coupled with this rhetorical relation should include such adverbs as 仍然, 還 etc.