AMBIGUITY RESOLUTION OF SERIAL NOUN CONSTRUCTIONS IN CHINESE SENTENCES

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ABSTRACT – We present a rule–based approach to resolve ambiguities of a series of noun constructions in Chinese sentences. According to our statistics, serial noun constructions occur 12.6% in our testing articles. The relationship between two adjacent nouns in a Chinese sentence can be a modification, possession, apposition, conjunction, or two separate noun phrases. We employ both syntactic and semantic features to resolve the possible ambiguities via rules, which take into account the situations that (1) the genitive marker, *de5*, in NP schema is omitted and (2) there is zero pause in coordinated constructions and appositions. The syntactic structure of a series of nouns with length exceeding two depends on the association of different types of combinations. We find that the conjunctions have the strongest association, then modification, possession and finally apposition. This scheme of ambiguity resolution is integrated into our unificationbased chart parser. Experimental results show its applicability.

I. INTRODUCTION

A substantive in Chinese is a word which normally functions as the subject or the object of the sentence[1, 2]. According to the conventions of syntactic categories in GPSG[3], substantives are denoted by the feature specifications, $[N +]$ and $[V -]$, which correspond to nominals in English. Hereafter, we use N to denote substantives in Chinese. To further distinguish words, each substantive is featured with a syntactic type. For example, the partial feature specification of *ban4gong1shi4* (office) is $[[N +], [V -], [type place]]$, while the common noun *ren2* (person) is featured with $[[N +], [V -], [type common]]$.

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Li and Thompson [4] formulated Chinese noun phrases (NPs) as follows:

associative phrase + {classifier/measure phrase, relative clause} + adjective + N,

where all the elements except the head noun *N* are optional. An associative phrase (AP) is an NP followed by a genitive marker, *de5*, such as *wo3 de5* (my). A classifier/measure phrase, termed DM hereafter, is composed of a demonstrative followed by a measure, such as *zhe4 ben3 (shu1)*(this (book)) and *yi1 bei1 (ka1fei1)*(a cup (of coffee)). A relative clause (RC) is simply a nominalized clause placed before a head noun, such as *zhang1san1 mai3 de5 (qi4che1)* ((the car) that Zhangsan bought). In this situation, *de5* can not be omitted. However, under certain situations, the genitive marker can be omitted, such as *wo3 (de5) mei4mei5*(my sister) in (1). A noun can also be used as a modifier of another noun, such as *you4ji4yuan2 lao3shi1* (a teacher in a kindergarten) in (1), where *lao3shi1* (teacher) is the head noun modified by *you4ji4yuan2* (kindergarten). Both *wo3 mei4mei5* and *you4ji4yuan2 lao3shi1* are NPs composed of two adjacent nouns without any marker between them.

(1) *wo3 mei4mei5 shi4 yi1 wei4 you4zhi4yuan2 lao3shi1.*

(My sister is a teacher in a kindergarten.)

Hereafter, adjacent nouns or pronouns are called NNs or serial noun constructions (SNC).

Though the above two NNs are NPs, the first one is a possessive phrase and the second is a modifer–head structure. In addition to the above two cases, there are other types of NNs. The NN in (2), *peng2you3 tong2xue2* (friends and classmates) is a conjunction; *mi4shu1 li3xiao3zhu* (the secretary, Li Xiaozhu) in (3) is an apposition. Topicalization also results in a kind of NN, such as *shu1 wo3* (book I) in (4). The NN *wo3 zhong1guo2ren2* (I (am) a Chinese) in (5) is a subject–predicate construction with copula, *shi4*, omitted. A special kind of NP, such as *ka1fei1 wu3bei1* (five cup of coffee) in (6), is of the structure *N + DM*. The subject in double subject sentences is another kind of NNs, such as *wo3 yi1fu2* (my clothes, or I, clothes) in (7).

(2) *ta1 ji4 he4ka3 gei3 peng2you3 tong2xue2.*

(He sent congratulatory cards to his friends and classmates.)

(3) *mi4shu1 li3xiao3zhu1 chu1qu4 le5.*

(The secretary, Li Xiaozhu, went out.)

(4) *zhe4 ben3 shu1 wo3 xi3huan1.*

(This book I like.)

(5) *wo3 (shi4) zhong1guo2ren2.*

(I am a Chinese.)

(6) *ta1men5 jiao4 ka1fei1 wu3bei3.*

(They order five cups of coffee.)

(7) *wo3 yi1fu2 xi3 de5 hen3 gan1jing4.*

(My clothes is washed cleanly, or I wash my clothes cleanly.)

There are no such problems in English[5], since possessive, conjunctive, punctuation, and structural evidence can help distinguish the mutual relations between different nouns. The NNs in (5)–(7) can be processed as appositions, ordinary NPs, and possession, respectively, which will be clear later.

From our experiments, serial noun constructions occur very frequently in Chinese sentences[6]. For 1545 sentences, 9.25 characters per sentence in average, there are 327 NNs appearing in 195 sentences. Thus the frequency of serial noun constructions in the testing samples is 12.6% (195/1545).

The researchers on Chinese syntactic analysis and semantic interpretation paid less attention on the problem of NN combinations [7, 8], or even did not touch the problems [9–13]. In our Chinese–to–English machine translation system (CEMAT) [10], we propose a rule–based approach for processing NN combinations, which can be integrated into the existing parser [9,10] and semantic interpreter [8].

In general, it is very difficult to distinguish the types of NN combinations through syntactic analysis since they are of the same structure: a noun followed by another noun. In our approach, we employ various syntactic and semantic feature to determine the combinations of NNs. The association of nouns in serial noun construction with length exceeding two are not trivially from left to right. For example, in the long NN, *wo3 tong3xue2 zhang1san3* (my classmate, ZhangSan), the association is ((*wo3 tong3xue2*) *zhang1san1*). The association of *wo3 ba4ba5 ma1ma5* (my father and mother) is (*wo3 (ba4ba5 ma1ma5*)). The different kinds of association rely on the different combination types. In this paper we establish a rule base to determine the hierarchical structure of long NNs.

In Section II, we will show the combination rules for a pair of adjacent nouns. Then in Section III, we will discuss the association of nouns for serial noun constructions with length exceeding two. In Section IV, the implementation is briefly introduced. Concluding remarks are made finally.

II. NN COMBINATION RULES

Let N_1 and N_2 be two adjacent nouns in a sentence. The general form of NN combination rules is

LHS: S_1, S_2

RHS: Combinationtype

where S_1 and S_2 denote syntactic and semantic information encoded in the form of frame–type feature structures. For example, if N_1 is a personal pronoun and N_2 is a noun in the domain hierarchy *role*, then N_1N_2 is a possessive type combination. Encoded in the feature structure form, the rule becomes as follows.

LHS: [phon α,
    syn   [head [n +,
                    v ,
                    type   pronoun]],
    sem [var [hier person]]].
    [phon β,
    sem [var [hier role]]].
RHS: [phon $\alpha\beta$,
    syn   [nn_type possession].

This rule states that if two input nouns N_1 and N_2 can unify successfully with the two components in the LHS, respectively, then an additional syntactic feature, *nn_type*, is augmented in the resulting feature structure of N_1N_2. For example, *wo3* (I) and *mei4mei5* (sister) in sentence, *wo3 mei4mei5 shi4 ge5 xiao3xue2 lao3shi1* (My sister is a teacher of a primary school), unify successfully with the two components of the LHS of the above rule; therefore, it is referred as a possessive combination.

In the following, we will discuss the combination rules of possession, conjunction, apposition, separate constituents, and modification, respectively. The rules together with the corresponding examples will be shown in the tabular form. For convenience, we only show the terminal values of the components of the LHS.

A. Possession type

The possession type of NNs happens between two human relatives with *de5* omitted. The first noun is a personal pronoun, and the second noun is either in the domain hierarchy *role*, *component*, or *a_corporate_person*, which means the social individual sentient, components of human body, and the social collective sentient, respectively [14]. The possessive personal pronoun in English corresponds to a personal pronoun followed by an optional genitive marker *de5* in Chinese.

An NP of the structure $DM + N$ commonly represents a definite object, such as *na4 ben3 shu1* (that book) and *zhe4 duei4 jia1ju4* (this pair of furniture). Such kind of NP preceeded by a personal pronoun or a personal proper noun strongly imply that the succeeding NP is owned by the preceeding noun. We summarize the rules for possessive NNs in the following table.

Rule #	S_1	S_2	Examples
1	personal_ pronoun	role	*wo3 ba4ba5* (my father), *ni3 lao3shi* (your teacher)
2	personal_ pronoun	component	*wo3 wei4* (*tong4*) (my stomach (pain)), *ta1 to2* (*tong4*) (his head (pain))
3	personal_ pronoun	a_corporate_person	*wo3 xue2xiao4* (my school), *wo3men5 gong1si1* (our company)
4	personal_ proper_noun	DM + N	*zhang1san1 na4ben3 shu1* (that book of Zhangsan's)
5	personal_ pronoun	DM + N	*wo3 zhe4dui1 jia1ju4* (these furniture of mine)

Ambiguity occurs in a DM followed by two nouns because they can be the structure $(DM + N_1) + N_2$ or $DM + (N_1 + N_2)$. The former structure is a possessive relation, N_2 belonging to $(DM + N_1)$, such as *zhe4jia1 can1ting1 (de5) cai4* (the food of this resturant) in (8). The latter one is that a DM modifies a modification type of NN, such as *zhe4ge5 you4zhi4yuan2 lao3shi1* (this teacher in a kindergarten) in (9). The cooccurrence relation between a DM and its following noun provides an effective clue to resolve this ambiguity [15].

(8) *zhe4jia1 can1ting1 cai4 hen3 hao3 chi1.*

(The dish of the resturant tastes good.)

(9) *zhe4ge5 you4zhi4yuan2 lao3shi1 jiao1 de5 hen3 hao3.*

(This teacher in a kindergarten teaches students well.)

The subject of a double–subject sentence can also be interpreted as a possessive relation, such as the first meaning of *wo3 yi1fu2* (my clothes) in (10). However, (10) can be interpreted alternatively as *I washed clothes cleanly*. The resolution of the meaning ambiguity depends on the context of the sentence.

(10) *wo3 yi1fu2 xi3 de5 hen3 gan1jing4.*

(My cloth is washed cleanly, orI wash my cloth cleanly.)

B. Conjunction type

A conjunctive NN is a coordinative construction with zero marker between two nouns, where each noun of the NN has approximately the same function as the whole construc-

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tion[1]. Fragments *ba4 ma1* (father and mother) and *zhuo1zi5 yi3zi5* (tables and chairs) are instances of conjunctive NNs. In English, it is illegal that there is no conjunctive in a conjunction. In the following table we use variables, as those used in Prolog, to catch this notion.

Rule #	S_1	S_2	Examples
1	X	X	*ba4 ma1* (father and mother) *zhuo1zi5 yi3zi5* (tables and chairs)

C. Apposition type

When two expressions in succession refer to the same thing, the relation is one of apposition. They are further classified into close apposition, loose apposition, and interpolated apposition[1]. The examples of close apposition are *wang2-jia1*(Wang family, the Wangs), *li3 dai4fu1* (Doctor Li), and *ke1xue2 zha2zhi4* (The magazine Science). As a rule, close appositions are subordinate phrases or compounds such that the first part modifies the second. In this paper, they are classified as modification type of NNs. In loose apposition, the expressions are in coordination without pause, as in *wo3 peng3you3 zhang1san1* (my friend, Zhangsan) and *zhong3tong3 li3deng1hui1* (the President, Li Denghui). An interpolated apposition is an inserted phrase with a pause marker ",". The omission of the interpolated apposition does not affect the completeness of sentence, such as *zhang1san1, wo3 de5 yi1 ge5 peng2you3, ming2 tian1 yao4 lai2* (Zhangsan, one of my friend, will be here tomorrow). Since the expressions are identified by commas, they are not considered as NNs here.

Human–related appositions occur frequently because we generallly need to point out the very person we talk about. Thus we obtain a rule that a *role* noun followed by a personal proper noun or personal pronoun is an appositive NN. For the cases of nonhuman related appositions, the first noun is a proper noun and the second one is used to describe the property of the first one.

The Chinese reflexive morpheme, *zi4ji3* (self), may optionally be preceded by a pronoun that is coreferential with the subject of the sentence [4], as in (11). A personal pronoun followed by a DM is also a kind of appositive NN, where the DM mentions the members of the personal pronoun. For example, *ta1men4 san1wei4* (they, three) in (12) is an appositive NN, where the DM *san1wei4* (three) indicates that there are three members in their group.

(11) *zhi3 you3 di4di5 ta1 yao4 shang4xue2.*

(Only my brother, he, needs to go to school.)

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(12) *wo3 zhi4ji3 yao4 qu4 mei3guo2.*

(I myself want to go to the U.S.A.)

A noun followed by a DM commonly serves as the object of a verb, which is equal to an ordinary NP, *DM + N*. For example, *zhan4dou4ji1 wu3bai3 jia4* (fighter plane, five hundred) is equal to *wu3bai3jia4 zhan4dou4ji1* (five hundred fighter planes). When parsing, it is transformed to be the form *DM + N* in order to process them as ordinary NPs.

(13) *ta1men4 san1wei4 dian3 le5 wu5bei1 ka1fei1.*

(They three ordered five cups of coffee.)

In summary, we have the following rules of apposition.

	S_1	S_2	Examples
1	hier = role	personal_ proper_noun	*wo3 peng2you3 zhang1san1* (my friend, Zhangsan)
2	hier = role	personal_ pronoun	*di4di5 ta1* (my brother, he)
3	hier = X, proper_name	hier = X	*san1guo2yan3yi4 zhe4 ben3 shu3* (the book "The Romance of the Three Kingdoms")
4	personal_ pronoun	reflexive	*wo3 zi4ji3* (I myself)
5	personal_ pronoun	DM	*ta1men4 san1 wei4* (they three)

The subject–predicate constructions NP_1 NP_2 and NP_1 NP_2 NP_3 are analyzed as the omission of the copuls, *shi4,* to take advantage of the general sentence pattern: NP + VP. For example, see sentences (14) and (15).

(14) *ta1 (shi4) zhong1guo2ren2.*

(He is a Chinese.)

(15) *ka1fei1 yi1bei1 (shi4) wu3shi2yuan2.*

(The price of a cup of coffee is fifty dollars.)

The above consecutive NPs are rather similar as appositive NNs, except that appositive NNs are subjects or objects of verbs.

D. Separate constituent type

Two neighboring nouns may play two different syntactic roles. In order to determine this type of NNs, we first consider which kinds of nouns can not be modified by other nouns. From [1, 4], it is obvious that proper nouns and pronouns can not be modified by other nouns. When such a situation occurs, the two nouns are taken to be two phrases. This class of NNs is mainly from topicalization, such as *shu1 wo3* in (16) and *bao4zhi3 ni3* in (17), and so on.

(16) *zhe1 ben3 shu1 wo3 xi3huan1*

(This book I like it.)

(17) *jin1tian1 de5 bao4zhi3 ni3 kan4guo4 le5 ma5?*

(Have you read today's paper yet?)

In general, topics must occur in sentence–initial position[4]. Time phrases and locative phrases occuring in sentence–initial positions are considered as topics as well [4], as shown below.

(18) *zuo2tian1 yu3 xia4 de5 hen3 da4.*

(It rained heavily yesterday.)

(19) *tai2bei3 yu3 xia4 de5 hen3 da4.*

(It rained heavily in Taipei.)

A time word may be preceded by another noun. If this noun is a time word, then they form a modification type of NN. For example, both *zho2tian1* (yesterday) and *xia4wu3* (afternoon) in (20) are time word; they form a modification type of NN. However, in *wo3 ming2tian1* of (21), *ming2tian1* (tomorrow) is a time word but *wo3* (I) is not; thus they form an NN of separate constituents.

(20) *wo3 zho2tian1 xia4wu3 qu4 tu2shu1guan3.*

(I went to the library yesterday afternoon.)

(21) *wo3 ming2tian1 qu4 tai2bei3.*

(I will go to Taipei tomorrow.)

Rule #	S_1	S_2	Examples
1	X	pronoun	*shu1 wo3(book, I)*
2	X	proper_noun	*bao4zhi3 ni3* (paper, you)
3	time	X	*zuo2tian1 yu3* (yesterday, rain)
4	place	X	*tai2bei3 yu3* (Taipei, rain)
5	time	X {time}	*wo3 ming2tian1* (I, tomorrow)

The NNs identified by Rule 1 and 2 of the above table are mostly resulted from movement of object to the sentence–initial position. In our parser, when such NNs are identified, two NPs are established for each noun. The verb is then established as a VP with a missing object, i.e., *VP/NP* in GPSG.

The direct and indirect object of a ditransitive verb is also an NN of this type. However, we do not include the case here because the verb needs two NPs to make the VP saturated.

E. Modification type

In a modification type NN, the second noun is the head noun and the first one is an adjective. For example, in *xiao3xue2 lao2shi1* (a teacher of a primary school), *xiao3xue2* (primary school) modifies the head noun *lao2shi1*. It is quite difficult to obtain rules for determining the modification type of NNs because there are less grammatical evidence [16]. We use a catch–all rule to solve this problem. That is, if an NN can not trigger any of possession, conjunction, apposition, and modification types of rules, it is taken as a modification type of NNs.

F. Conflict resolution

The conditions of previous rules are not mutually independent. We adopt the specificity ordering strategy to resolve the conflicts when more than one rule are triggered. This strategy states that the rule with the most specific conditions is fired first. When the parser fails to produce a result by the fired rule, the rule with the less specific conditions is fired. This procedure proceeds until the parser completes the analysis. For example, in sentence (2), since the NN *peng2you3 zhang1san1* is a *role* noun followed by a personal pronoun, it can trigger both Rule *1* of appositive type and *Rule* 1 of separate constituent type. According to the specificity, the former one is fired and a correct result is obtained.

III. ASSOCIATION OF NOUNS IN SERIAL NOUN CONSTRUCTIONS

The association of nouns is nontrivial for a serial noun construction with length exceeding two. For example, let $N_1N_2N_3$ be three successive nouns in a sentence. There are two possible structures:

$$(N_1N_2)N_3 \text{ and } N1(N_2N_3)$$

As mentioned in Section I, the phrase *wo3 peng2you3 zhang1san1* should be of the former structure, while the phrase *wo3 ba4ba5 ma1ma1* the structure of the latter one.

Thus to design a parser, we must consider the association of nouns in serial noun constructions. The above examples illustrate the association of N_2 with N_1 and N_3, respectively. It can be reformulated as the problem of comparing the precedence between the combination types of N_1N_2 and N_2N_3. For the phrase *wo3 peng2you3 zhang1san1, wo3 peng2you3* and

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peng2you3 zhang1san1 are possession and apposition, respectively. Since each of the nouns in an appositive NN refers to the same thing, omission one of the phrases does not change the meaning of the phrase. Thus, an apposition has the least precedence. In other words, the possessive relation P precedes the appositive relation A, represented as $P > A$. Accordingly, *wo3* first associates with *peng2you3* and then *wo3 peng2you3* with *zhang1san1*.

For a possessive NN, the preceding noun is an associative phrase with omitted *de5* such as *wo3*(I) in the fragment *wo3 (de5) ge1ge5* (my brother). From observations, a NN combination of the modification type M has higher precedence than that of the possession type P, denoted as $M > P$. It results in the following structure:

wo3 zhong1xue2 lao3shi1
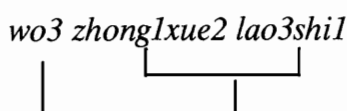
A conjunctive NN is a unit acting, as a whole, like the subject or the object of a verb; they are covered under the scope of an adjective or a modifying noun. In sentence (22), the noun *xue2xiao4* (school) modifies the succeeding nouns *lao3shi1* (teachers) and *xue2sheng1* (students).

(22) *xue2xiao4 lao3shi1 xue2sheng1 dou1 can1jia1 lu3xing2*

(All of the teachers and students in the school participated in the tour)

Thus we obtain that the conjunctive combination C precedes the possessive combination P, denoted as $C > P$.

When a possessive combination and a modification combination appear together with an appositive combination, the possession P and modification M precedes apposition A. That is,

$$M > P > A,$$

For example, in sentence (23), *wo3 zhong1xue2 lao3shi1* and *wang2xiao3zhu1* refer to the same person. After these two NPs are combined together, they form an appositive NP.

(23) *wo3 zhong1xue2 lao3shi1 wang2xiao3zhu1 jie2hun1 le5*

(My high school teacher, Ms. Wang XiaoZhu, got married)

From the above discussion, we conclude

$$C > M > P > A.$$

The above discussions consider the precedence relations for serial noun constructions containing different types of combination. For a sequence of the same type of combinations, the precedence is from left to right. For sentence (24),

(24) *ji4suan4ji1 yan2jiu4suo3 suo3zhang3 chen2zen3 jiao4shou4 chu1guo2 le5*

(The head of the Institute of Computer, Prof. Chen Zen, went abraod.)

the combination types and the resulting structure of the serial noun construction is shown below.

ji4suan4ji1 yan2jiu4suo3 suo3zhang3 chen2ren3 jiao4shou4
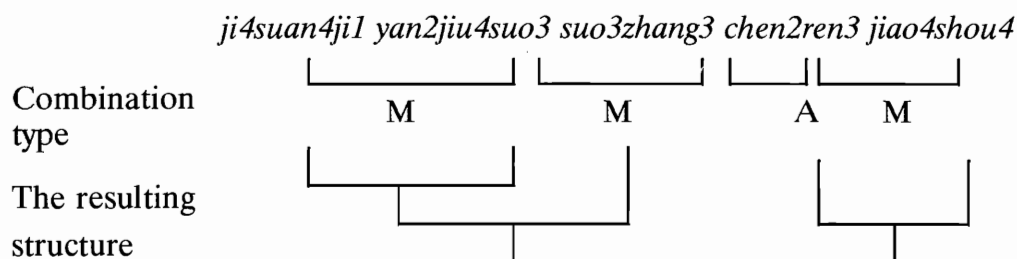
IV. IMPLEMENTATIONS

We present in this section how to employ NN combination rules and NN association in our parser to disambiguate serial noun constructions. HPSG (Head–driven Phrase Structure Grammar) [17], a lexicon–driven unification–based grammar formalism, constructs constituent structures of sentences in accordance with the Head Feature Principle (HFP), Subcategorization Principle (SP), and Adjunct Principle (AP). The HFP declares that a phrase shares the same features with its head daughter. The SP states that in any phrase, each complement daughter must be unifiable with a member of the head daughter's subcat–list, a list of subcategorization specifications, that remains to be satisfied. The AP states that any adjunct daughters must be unifiable with some member of the head daughter's adjunct specifications.

Our original parser employed the above principles to parse Chinese declarative sentences [9]. However, in our further studies, we find that the principles are not enough to replace all the ID (immediate dominant) rules in GPSG[3], especially in handling the nominalizations of Chinese sentences. The new version of the parser thus adds a rule–based mechanism for handling nominalizations.

The association of nouns in serial noun constructions can not be reflected from the adjunct feature. We use rules to determine the combination of nouns. The resulting feature structures of NN combination are head–adjunct structures, except the conjunctive combination, which is represented as a coordinate structure. Considering sentence *ta1 mei4mei5 zhang1xiao3zhu1 shi4 ge5 xiao3xu2 lao3shi* (His sister, Ms. Zhang XiaoZhu, is a teacher in a primary school), the resulting feature structure of *ta1 mei4mei5 zhang1xiao3zhu1* is shown partially as follows.

[phon [ta1, mei4mei5, zhang1xiao3zhu1]],

head_dtr   /* head–daughter */

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                [phon  [zhang1xiao3zhu1],
adjuncts_dtr                                    /* adjunct–daughter */
        [phon  [ta1, mei4mei4],
        head_dtr  [phon  [[mei4,mei4]],
        adjuncts_dtr    ,
                [phon  [[ta1]],
                nn_type  possession],
        nn_type  apposition].
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where the additional feature *nn_type* indicates the type of NN combination.

When two consecutive nouns are detected during the course of parsing, the parser looks forwards the following constituents to determine the maximal coverage of the serial noun construction. Then the parser consults the NN combination rules to determine the type of the combination and to form the resulting feature structure. NN association rules are consulted to determine the structure if there are more than two nouns in the serial noun construction.

V. CONCLUDING REMARKS

We have presented a rule–based approach to resolve ambiguities of serial noun constructions. The combination types of neighboring nouns have been examined and determined by a set of rules. They can be applied in a syntactic parser to determine the correct role of each noun. The association of NN combinations have also been analyzed to construct the correct structures.

In our experiments, 23 out of 327 cases, 7.1% approximately, are misidentified by consulting the NN combination rules and the association rules. The types of misidentification are summarized as follows.

1. The genitive marker, *de5*, are occasionally omitted. There are 7 cases of this type of misidentification, which are identified as modification type of NNs.

2. The conjunctive, *he2*, or the conjunctive punctuation mark are omitted. There are two cases of this type of misidentification.

3. One case of the conjunction structure is misidentified as *(N₁ N₂) he2 N₃,* while it should be *N₁ (N₂ he2 N₃).*

4. The remaining misidentifications are related to the apposition type of NN due to the incomplete of the apposition rules.

To solve the first two types of misidentification, a commonsense knowledge base is required. Actually, it is very difficult to built such a knowledge base. Acquiring new rules from

the generalization of misidentified patterns can reduce these types of error. This is left for further researches. The last two types of misidentification needs more studies in conjunctive and appositive constructions.

The goal attempting to resolve syntactic ambiguities of serial noun constructions has partially been reached. Our next step in the processing of noun phrases is to work toward lexical selection in English and to order the selected constructions in an appropriate order.

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