A LEXICON-DRIVEN ANALYSIS OF CHINESE SERIAL VERB CONSTRUCTIONS

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ABSTRACT

Serial verb constructions (SVCs), a series of VPs juxtaposed without any marker between them, is a specific structure in Chinese, which can not be treated as ordinary VPs. Structural ambiguity is the most serious problem for analyzing SVCs. In this paper, we investigate resolution of structural ambiguities of SVCs as well as the related problem, determinism during the course of parsing. We show that some types of SVCs, such as pivotal constructions, sentential subjects and sentential objects, can be dealt with as ordinary VPs through their lexical representations. In addition, we use a reconstructive phrase structure rule for describing the remaining SVCs, two more separate events and descriptive clauses. This reconstructive rule plays the role of eliminating nondeterminism during the course of parsing. At first, these types of SVCs are temporarily analyzed as an S followed by a VP; then after completion of the right-hand side of this rule, reconstruction rules are consulted to build the actual structure of the SVC sentence. The parsing results of SVC sentences are naturally expressed in conventional head-complement structure in HPSG, without inventing any new structure.

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I. INTRODUCTION

A Chinese declarative sentence, like an English sentence, is basically composed of an NP and a VP. Generally, a Chinese NP is composed of a head noun and some preceding modifiers;a Chinese VP consists of a head verb, one or two complement NPs and some adjuncts [1-3]. Some kinds of Chinese VPs have different structures. For example, the VP, 有 一本書 很 有趣, in sentence (1) consists of a head verb, 有, a complement NP, 一本書, and another VP, 很 有趣. In the corresponding English sentence, "He has a book which is very interesting", a marker, *which*, is used to denote the beginning of a relative clause. In such manner, it is easy to divide these two VPs because of the marker. However, there is no such marker in Chinese, which will make parsing difficult. In addition to sentence (1), there are other types of sentences having similar structure, as in sentences (2) to (6). In general, these types of sentences contain two or more verb phrases juxtaposed without any marker between them, termed serial verb constructions (SVCs) [2,3].

(1) 他 有 一本書 很 有趣.

He has a book which is very interesting.

(2) 他 去 學校 打 籃球.

He went to school to play basketball.

(3) 我 求 他 代表 我.

I begged him/her to represent me.

(4) 他 有 一本書 我 很 喜歡.

He has a book which I like very much.

(5) 他 說 他 要 去 台北.

He said he want to go to Taipei.

(6) 五個人 坐 一輛摩托車 很 危險.

It is very dangerous that five people ride on a motorcycle.

All of the above sentences have the same form,

(NP) V1 (NP) (NP) V2 (NP),

where the NPs in parenthesis are optional and V1 and V2 represent the first and the second verbs, respectively [2]. These sentences have different syntactic structures because of different types of verbs and relationship between them. Generally there are the following types of SVCs shown in Table I [2]. The syntactic structure in head-complement tree form of each type of SVCs are shown Fig.1. The labels C and H adjacent to arcs in the trees denote complement and head, respectively.

There are two main approaches for analysis of SVCs: one is based on phrase structure rules (PSRs) [4-7] and the other is based on Case Grammar [8-9]. It is difficult to obtain a

uniquely correct result by merely using simple syntactic types because an SVC sentence can be any structure in Table I. Therefore additional information is required to rule out structures not preferred. Subcategorization structure of verbs is a useful clue to guide the construction of an appropriate syntactic structure [4,5]. For example, a pivotal verb, such as 勸 (suggest), subcategorizes an NP and a VP as its direct and indirect objects, respectively; the verb 說(say) needs a saturated sentence as its object.

Table I. Types of Serial Verb Constructions.

Types	Descriptions	Examples
(i)	Two more separate events	他 上樓 睡覺 (He went upstairs to sleep). 他 拿 一雙筷子 吃飯 (He uses a pair of chopsticks to eat rice).
(ii)	Pivotal constructions	我 要 她 代表 我 (I asked her to represent me). 我 勸 他 學 醫 (I suggested him to study medicine).
(iii)	Descriptive clauses	我 有 一個妹妹 喜歡 游泳 (I have a sister who likes to swim). 他 有 一本書 很 有趣 (He has a book which is very interesting).
(iv)	Sentential subjects	五個人 坐 一輛摩托車 很 危險 (It is very dangerous that five people ride a motorcycle). 機器 翻譯 一個 句子 要 五分鐘 (It needs five minutes for machine to translate a sentence).
(v)	Sentential objects	他 說 妳 很 漂亮 (He said you are very beautiful). 他 否認 他 做錯 了 (He denied that he was wrong).

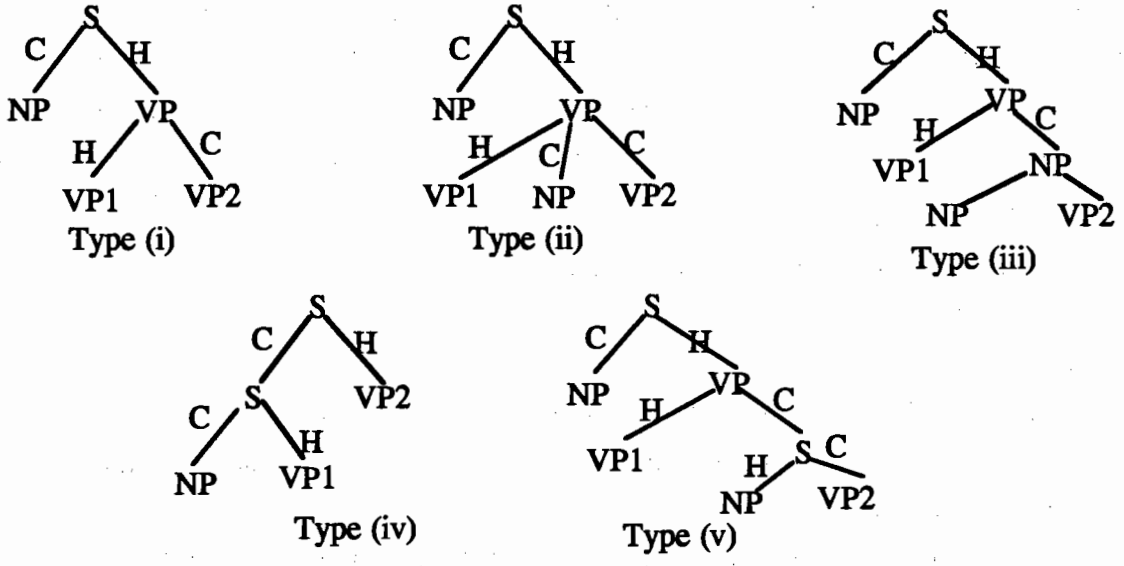

Fig. 1 Types of syntactic structures of SVCs in head-complement tree form.

Classification of verbs based on their meaning is another effective method to help determine the types of SVCs. Yang [8] divided verbs into seven groups according to their semantic categories: causative, emotional, possessive, narrative, special-1, special-2, and normal. Chang [4,5] divided stative verbs into three classes: (1) NP-statives which describe the properties of individuals; (2) VP-statives which modify the verb phrases; and (3) S-statives whose subjects are propositions. Pun [9], based on the theory of Case Grammar, nominated fourteen verb classes, where each one has different basic slots.

Preference rules make up the deficiency of the above methods to choose a preferred structure. Chang [4,5] used a preference rule that argument readings are preferred adjunct readings. That is, pivotal constructions and sentential objects are preferred over descriptive clauses, two more separate events, and sentential subjects. If there are alternative reading survived, Chang applies the last rule to choose a preferred structure in the order of descriptive clauses, two separate events, and sentential subjects.

From the above discussions, subcategorization structures and classification of verbs are essential means for structural disambiguation in SVCs even if they are treated in different manners. In this paper, we investigate the analysis of SVCs in our HPSG-based parser by utilizing subcategorization information and classification of verbs. The former works on SVC analysis focused on the resolution of structural ambiguities[4-7]. We will focus on determinism of parsing in addition to structural disambiguation in SVCs.

Our parser is basically a unification-based, lexicon-driven left-corner parser [10]. Certain types of SVCs can be analyzed by relying on the specific subcategorization structures of the verbs [3]. The lexical entries of verbs in remaining types of SVCs have the same subcategorization frame as ordinary verbs [11]. Classification of verbs is thus used to disambiguate these types of SVCs. There are exceptions in descriptive clauses which can not be disambiguated according to verb classification, as in sentences (7) and (8) [2].

(7) 他 做 了 一道菜 我 很 喜歡.

He cooked a dish which I like very much.

(8) 我們 種 那種菜 吃.

We raised that kind of vegetable to eat.

In these types of SVCs, the second VPs are either an object-missing sentence, S/NP[Obj] or an object-missing verb phrase, VP/NP[Obj]. Both of these structural features can be used to guide the constructions of SVCs.

Our unification-based left-corner parser scans the input sentences from left to right. In such manner, each the prefixes of SVC sentences will form a subconstituent which is itself a saturated sentence. The remaining of the sentence will form a phrasal verb, which plays the

decisive role to build up the syntactic structure of an SVC sentence. We thus do not give a PSR for each kind of SVCs, which will result in nondeterminism. Instead, we use a general PSR with loose conditions on the subconstituents in the rule. The PSR only confines that the subconstituents is a saturated sentence followed by a phrasal verb and, temporarily, it does not state how the target constituent is configured. Then, after the second verb phrase is actually constructed, a set of reconstruction rules which defines the relationships between the subconstituents in SVCs and how the complete structure is constructed is consulted to build up the actual structure of the SVC sentence.

In the following section, structural ambiguities and their resolution in SVCs are demonstrated by examples. In Section III, we show a method to eliminate nondeterminism in the course of parsing SVC sentences. In Section IV, we show the implementation of SVC analysis in our HSPG parser. Finally, concluding remarks are made in Section V.

II. STRUCTURAL AMBIGUITIES AND THEIR RESOLUTION

In this section, we show the situations of structural ambiguities in SVCs and their resolution. According to the structures of SVCs shown in Fig. 1, SVCs can be described by the partial set of PSRs shown in Fig. 2.

PSRs	Descriptions
VP –> VP VP	Two more separate events.
VP –> VP NP VP	Pivotal constructions.
VP –> VP NP1 NP1 –> NP VP	Descriptive clauses.
VP –> VP S	Sentential objects.
S –> S VP	Sentential subjects.
VP –> V VP –> V NP	VP-forming rules

Fig. 2 Partial set of PSRs for SVCs.

Based on the above PSRs, an SVC sentence such as 我 勸 他 學 醫 (I suggested him to study medicine) can be analyzed as any one of the structures in Fig. 1, which results in ambiguity. However, there is only one is correct among these structures. We first employ the subcategorization structure of the main verb 勸. Since the pivotal verb, 勸, subcategorizes an NP as its first object and a VP as the second object. Thus, by this information, a structure of Type (ii) is selected. Similarly, the main verbs in SVCs of sentential subjects and sentential objects have their specific subcategorization; thus these types of SVCs can also be identified by subcategorization information. Table II is a summary of the specific subcategorizations.

Other types of SVCs, descriptive clauses and two more separate events, do not have specific subcategorization for disambiguation. A method based on classification of verbs can be useful. If the class of verbs in the second VPs of these two types of SVCs can be distinguished, then the ambiguity of these two types of SVCs can be removed. Chang's classification is effective for this purpose [4,5]. In Chang's classification, (1) NP-statives describe the properties of individuals, such as 聰明 (clever); (2) VP-statives modify verb phrases, such as 專心 (engrossed); and (3) S-statives whose subjects are propositions, such as 危險 (dangerous). Preference rules of SVCs indicate that the second VPs in SVCs of descriptive clauses, two separate events and sentential subjects are NP-statives, VP-statives and S-statives, respectively. In the sentence, 他 上樓 睡覺, the second VP is a VP-stative in Chang's classification and the first verb,上樓, does not subcategorize a VP object; therefore, it is identified as an SVC of two separate events. The second VP in sentence (1) is used to modified an NP which is NP-stative; thus a structure of descriptive clauses is established. The classification of verbs is finer in the Case Grammar approach [8,9], which will not be discussed here.

Table II. Subcategorization structures of some verbs of SVCs.

Types	Subjects	Object1	Object2
Pivotal	NP	NP	VP
Sentential subjects	S	NP	null
Sentential objects	NP	S	null

There are still cases in descriptive clauses which can not be identified by the above methods, such as sentences in (7) and (8). These sentences have structural evidence in the second VPs. The second VP is an object-missing sentence or S/NP[Obj] in sentence (7), and an object-missing VP, or VP/NP[Obj] in sentence (8). Thus the parser can analyze these sentences by taking advantage of these structural evidence.

III. ELIMINATION OF NONDETERMINISM IN PARSING SVC SENTENCES

Efforts of parsing SVCs mostly focus on resolving structural ambiguities [4-7]. The related problem concerning nondeterminism during the course of parsing are not addressed at all. In the following, we investigate the elimination of nondeterminism, which will further promote the efficiency of parsing SVCs.

In the bottom-up parsing, based on the partial set of PSRs listed in Fig. 2, nondeterminism occurs when a VP subconstituent is constructed because all VP rules of SVCs in Fig. 2 are candidates in the next rule activation. From the observation of syntactic structures shown in Fig. 1, the leaves in all SVC sentences are of the same linear form: an S followed by a VP, each of which is shown in shaded areas in Fig. 3.

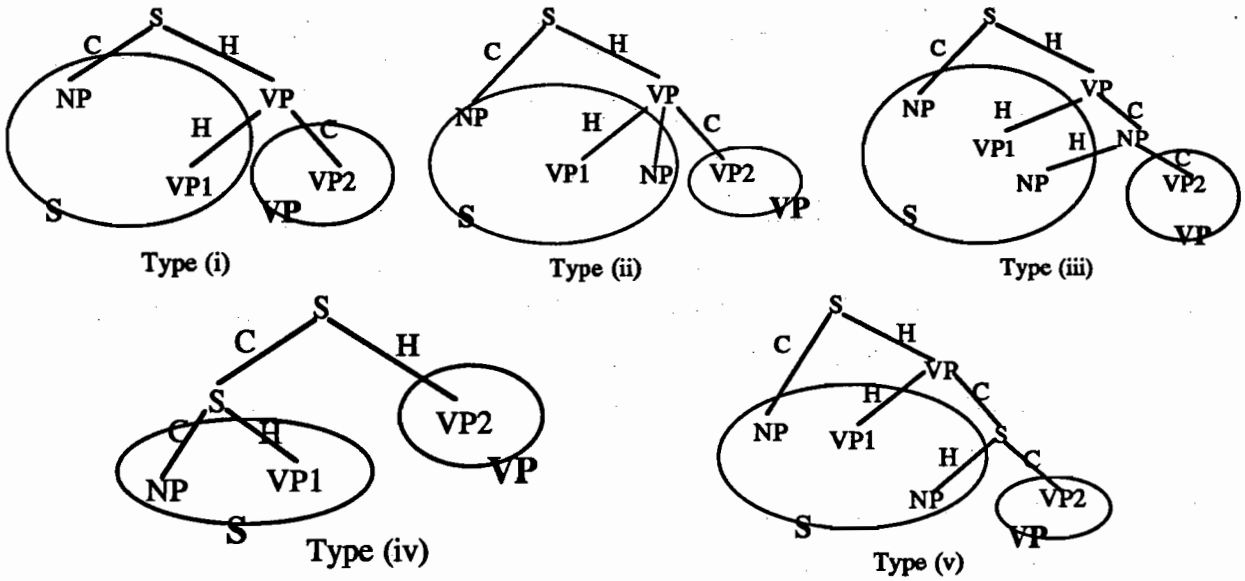

Fig. 3 All types of syntactic structures of SVCs redrawn in S-VP form.

Thus if we use a PS rule, S_SVC --> S VP, to describe SVC sentences, then nondeterminism just described can be eliminated. All SVC sentences are temporarily treated as a sentence composed of an S and a VP. Then after the right-hand side of this S_SVC rule is completed, a set of reconstruction rules are needed to reorganize the subconstituents in S and VP to establish the actual structure of the SVC sentence. In fact, the reconstruction rules play the role of structural disambiguation of SVCs.

According to the discussion in the previous section, we adopt subcategorization information of verbs to identify pivotal construction, sentential subjects and sentential object. We use the verb classification of Chang [4,5] to distinguish SVCs of two more separate events and descriptive clauses. In the following, we show in order the reconstruction rules for these two classes of SVCs in Table III. Note that S and VP in the table are the right-hand side of the S rule, S --> S VP, and S/NP[Obj] and VP/NP[Obj] denote an object-missing sentence and an object-missing verb phrase, respectively.

Table III. Reconstruction rules for SVCs.

Rule #	Descriptions	Conditions	Actions
1	For pivotal constructions	head_verb(S)=pivotal	Construct a Type (ii) structure.
2	For sentential subject	subj(head_verb(S))= sentence obj(head_verb(S))=NP	Construct a Type (iv) structure.
3	For Sentential object	subj(head_verb(S))=NP obj(head_verb(S))=sentence	Construct a Type (v) structure.
4	For two separate events	head_verb(VP)=VP-stative	Construct a Type (i) structure.

5	For descriptive clauses	head_verb(VP)=NP-stative	Construct a Type (iii) structure.
6	For descriptive clauses	VP=S/NP[Obj]	Construct a Type (iii) structure.
7	For descriptive clauses	VP=VP/NP[Obj]	Construct a Type (iii) structure.

IV. IMPLEMENTATION AND RESULTS

In this section, we show the implementation of the S-rule and reconstruction rules for analyzing SVCs in our HPSG parser without altering the existing structure of the parser. In addition, we will show a prominent merit of our parser in dealing with SVCs; that is, pivotal constructions and sentential objects can be treated as ordinary sentences by our lexicon-driven method.

A. Overview of an HPSG parser

HPSG (Head-driven Phrase Structure Grammar) is a lexicon-driven grammar formalism [12]. It reduces PSRs of its predecessor, GPSG [13], by enriching the content of lexical entries. An HPSG consists of a list of universal principles, lexical entries, and language-specific grammar rules. The most often used universal principles are the head feature principle (HFP), the subcategorization principle (SP), and the adjuncts principle (AP). The HFP declares that a phrase shares the same head 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 specification that remain to be satisfied; and the AP states that any adjunct daughter must be unifiable with some member of the head daughter's adjuncts specification.

The structure of our HPSG can be depicted schematically as shown in Fig. 3, where each component is described in the following.

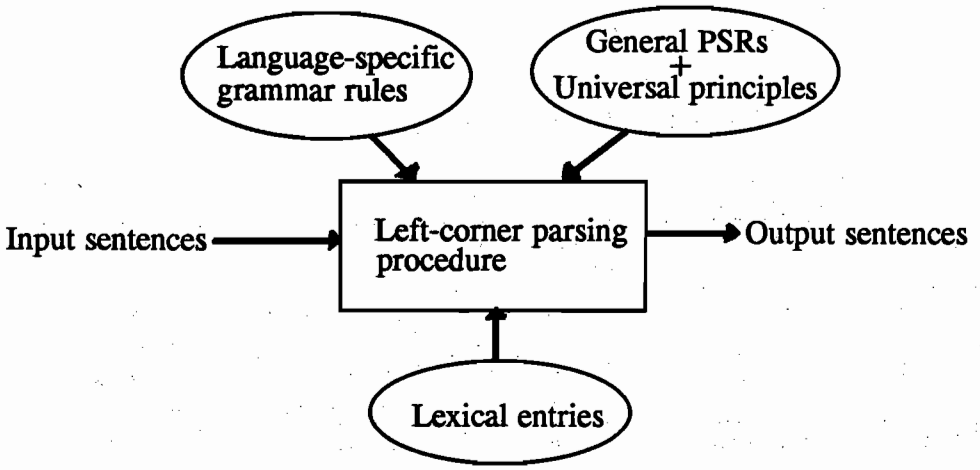

Fig. 4 Schematic diagram of the HPSG parser.

The HPSG rules translated in PATR-II formalism [14], implemented in Prolog, are shown in Fig. 4, where each one actually is a rule-of-rule. That is, a translated HPSG rule is the sole argument of the functor *rule_sel* (rule selection), which is selected according to the conditions listed in the body of the corresponding *rule_sel*. The body of a *rule_sel* plays the role of deterministic selection of an HPSG rule.

```
% Head pre-complement structures.
rule_sel( (R ule X ---> [X1, X2]:-
        X1:syn:loc  ===  X2:syn:loc:subcat:first:syn:loc,  %
    SP
        X2:syn:loc:subcat:rest === end, % SP
        X:syn:loc:subcat === X2:syn:loc:subcat:rest, % Sp
        X:syn:loc:head === X2:syn:loc:head, % HFP.
        X:syn:loc:lex === '-',
        X:head_dtr === X2,
        X:cmp_dtr === X1)):-
    current_dag(C),
    rem_sen([Next_word|_]),N ord Next_word,
    (subcat_feature(C);
     C isa_vp, N isa_nominalization_particle).
```

```
% Head post-complement structures.
rule_sel((R ule X ---> [X1,X2]:-
        X1:syn:loc:subcat:first:syn === X2:syn, % SP
        X:syn:loc:subcat === X1:syn:loc:subcat:rest, % SP
        X:syn:loc:head === X1:syn:loc:head, % HFP,
        X:syn:loc:lex === '-',
        X:head_dtr === X1,
        X:cmp_dtr === X2)):-
    current_dag(C),
    (C isa_preposition;
     C isa_vp2). % C is a VP with subcat length >1.
```

```
% A lexical X is changed to a phrasal X.
rul_sel( (R ule X ---> [X1]:-
        X:syn:loc:subcat === X1:syn:loc:subcat, % SP
        X:syn:loc:head === X1:syn:loc:head, % HFP.
        X:syn:loc:lex === '-',
        X:head_dtr === X1)):-
    current_dag(C),
    (C isa_lexical_v;
     C isa_lexical_n;
     C isa_genitive_marker;
     C isa_nominalization_particle).
```

```
% Head pre-adjunct structures.
rule_sel((R ule X ---> [X1,X2]:-
        X:syn:loc:subcat === X2:syn:loc:subcat, % SP
        X:syn:loc:head === X2:syn:loc:head, % HFP
        X2:syn:loc:head:adjuncts === X1:syn:loc:head,
        X:syn:loc:lex === '-',
        X:head_dtr === X1,
        X:syn:loc:adj_dtr_type === pre,
        X:adj_dtr === X1)):-
    current_dag(C),
    C isa_pre_adjunct_category.
```

```
% Head post-adjunct structures.
rule_sel((R ule X ---> [X1,X2]:-
        X:syn:loc:subcat === X1:syn:loc:subcat, % SP
        X:syn:loc:head === X1:syn:loc:head, % HFP
        X1:syn:loc:head:adjuncts === X2:syn:loc:head,
        X:syn:loc:lex === '-',
        X:head_dtr === X1,
        X:syn:loc:adj_dtr_type === post,
        X:adj_dtr === X2)):-
    current_dag(C),
    C isa_phrase,
    (rem_sen([Next_word|_]);rem_sen([Next_word])),
    N ord Next_word,
    N isa_post_adjunct_category.
```

Note:

(i) The symbols X, X1 and X2 are variables denoting the feature structures of constituents.

(ii) The symbols concatenated by colons are path names of the corresponding feature structure.

(iii) The identity symbol, ===, represents the destructional unification.

Fig. 4: HPSG rules translated into PATR-II form.

The HPSG lexical entry, expressed in feature structure form, is shown below.

(12)
```
phon:
syn:    loc:    head:
                subcat:
                lex:
        bind
```

Lexical entries for Chinese verb 賣 (sell) and noun 西瓜 (water melon) represented in PATR-II form are shown below.

(13)W ord '賣':-

W:phon === '賣',

W:syn:loc:head:maj === v,

W:syn:loc:subcat:first:syn:loc:head:maj === n,

W:syn:loc:subcat:rest:first:syn:loc:head:maj === n,

W:syn:loc:subcat:rest:rest:first:syn:loc:head:maj===n,

W:syn:loc:subcat:rest:rest:rest === end.

(14)W ord '西瓜':-

W:phon === '西瓜',

W:syn:loc:head:maj === n,

W:syn:loc:head:type === common,

W:syn:loc:head:hier === fruit.

Note that the *adjuncts* features of lexical entries are inserted by using a meta-lexicon procedure, which adds the *adjuncts* feature to the corresponding lexical entries automatically.

The parsing procedure is a left-corner one [14], as shown below.

(15)
```
recognize(Dag1,B,C) :- leaf(Dag0,B,E), left_corner(Dag0,Dag1,E,C).
left_corner(Dag1,Dag2,C,C):-unify(Dag1,Dag2).
left_corner(Dag1,Dag2, C,D) :-
        rule_sel((_ ule Dag0 -- [Dag1|Dags]:- XXX)),call(XXX),
        recognize_rest(Dags,C,H),left_corner(Dag0,Dag2,H,D)
leaf(Dag, [Word|C],C):- Dag ord Word.
recognize_rest([],A,A).
recognize_rest([Dag|Dags],C,D):- recognize(Dag,C,E), recognize_rest(Dags,E,D).
```

The first rule, *recognize*, states that a sentence is recognized as category Dag1 if it proves that a leaf of category Dag0 constitutes a left-corner of Dag1. Detailed descriptions of the rest clauses can be obtained from [10,14].

B. Lexicon-driven parsing of SVCs

SVCs of pivotal constructions and sentential objects can be analyzed as ordinary sentences by using our lexicon-driven parser. The lexicon-driven parser relies heavily on the subcategorization frame of verbs to construct the head-complement structures. The combination of the head and the adjuncts depends on the *adjuncts* features of the head. To deal with the verb of pivotal constructions, 勸 (suggest), for instance, a lexical entry is given below.

(16) W ord '勸' :-

W:phon === '勸',

W:syn:loc:head:maj === v,

W:syn:loc:lex === '+',

W:syn:loc:subcat:first:syn:loc:head === n, % The first obj. is an NP.

W:syn:loc:subcat:first:syn:loc:lex === '-',

W:syn:loc:subcat:rest:first:syn:loc:head:maj === v, % The second obj. is a VP (a

W:syn:loc:subcat:rest:first:syn:loc:lex === '-', % subject-missing sentence).

W:syn:loc:subcat:rest:first:syn:loc:subcat:rest === end,

W:syn:loc:subcat:rest:rest:first:syn:loc:head:maj === n, % The subj. is an NP.

W:syn:loc:subcat:rest:rest:first:syn:loc:lex === '-',

W:syn:loc:subcat:rest:rest:rest === end. % End marker of subcat frame.

For the case of sentential objects, 說 (say), for example, a lexical entry is shown in (17).

(17) W ord '說':-

W:phon === '說',

W:syn:loc:head:maj === v,

W:syn:loc:lex === '+',

W:syn:loc:subcat:first:syn:loc:head:maj === v, % The obj. is a saturated sentence.

W:syn:loc:subcat:first:syn:loc:subcat === end,

W:syn:loc:subcat:rest:first:syn:loc:head:maj === n, % The subj. is an NP.

W:syn:loc:subcat:rest:first:syn:loc:lex === '-',

W:syn:loc:subcat:rest:rest === end. % End of subcat frame.

In the following steps, we show how the pivotal construction sentence, 我 勸 他 學 醫 (I suggested him to study medicine), is constructed according to the lexical entry of the verb 勸 and the HPSG rules in Fig. 4. In the following demonstration, for convenience, we only list the main part procedure of rule invocation.

Step 1: Current Word: 我.

The NP 我 first activates the *head pre-complement rule,* and require a VP (S/NP[subj]) to form a complete sentence.

Step 2: Current Word: 勸,

The verb 勸 activates the *head post-complement rule*, and an NP (the first object of 勸) is required by the rule to form a larger VP which in turn leaves over a VP to form a saturated VP.

Step 3: Current Word: 他.

The NP 他 unifies successfully the remaining part in Step 2. Again this resulting VP activates the *head post-complement rule*, and a VP (the second object of 勸) is required to form a complete VP.

Step 4: Current Word: 學.

The verb 學, a transitive verb, activates the *head post-complement rule*, and an NP (the object of) is required.

Step 5: Current Word: 醫.

The NP, 醫, satisfies the remaining part in Step 4; thus a complete VP, 學 醫, is constructed, which in turn unifies successfully the remaining part of Step 3. A complete pivotal construction is thus constructed.

C. The S-rule for SVCs and reconstruction of SVC structures

In Section III, we use an S –> S VP rule to describe some SVC sentences in order to remove nondeterminism on PSRs selection. Then a set of reconstruction rules are applied on the right-hand side of this S-rule to reorganize the real structure of the SVC sentence. In the HPSG parser, this S-rule is thus expressed as the following form.

(18)
```
rule_sel((R ule X ---> [X1,X2]:-
                    X1:syn:loc:head:maj ===v, % A sentence.
                    X1:syn:loc:subcat === end,
                    X1:syn:loc:lex === '-',
                    X2:syn:loc:head:maj === v, % A phrasal verb.
                    X2:syn:loc:lex === '-',
                    assert(svc(X,X1,X2)) )):-
          current_dag(C), C isa_saturated_sentence.
```

Note that in this rule we only confine loose restrictions for X1 and X2, i.e. the S and the VP in the right-hand side, respectively. At the end of the list of identities, an *svc(X1,X2,X3)* is asserted into the database, which is used for latter reconstruction. The reconstruction rules are represented as follows.

(19)
```
reconstruction(Dag0,Dag1,Dag2):-
        retract(svc(Dag0,Dag1,Dag2)),
        (
% Case 1. Two more separate events. E.g., [他]i 唱歌 ei 跳舞.
        Dag2:syn:loc:head:type === vp_stative,
```

```
        Dag2:syn:loc:subcat:rest === end, % S/NP[Subj]
        Dag2:syn:loc:subcat:first:syn:loc:head === % Dag2's null NP ===
          Dag1:cmp_dtr:syn:loc:head,          % Dag1's subject.
        Dag0:syn:loc:head === Dag1:syn:loc:head, % HFP
        Dag0:syn:loc:subcat === Dag1:syn:loc:subcat, % SP
        Dag0:cmp_dtr === Dag1:cmp_dtr,
        Dag0:head_dtr:head_dtr === Dag1:head_dtr,
        Dag0:head_dtr:head_dtr === Dag1:head_dtr,
        Dag0:head_dtr:cmp_dtr === Dag2;
% Case 2. Descriptive clauses. E.g., 他 有 [一本書]i ei 很 漂亮.
        Dag2:syn:loc:head:type === np_stative,
        Dag2:syn:loc:subcat:rest === end, % S/NP[Subj]
        Dag2:syn:loc:subcat:first:syn:loc:head === % Dag2's null NP ===
          Dag1:head_dtr:cmp_dtr:syn:loc:head,   % Dag1's object.
        Dag0:syn:loc:head === Dag1:syn:loc:head, % HFP
        Dag0:syn:loc:subcat === Dag1:syn:loc:subcat, % SP
        Dag0:cmp_dtr === Dag1:cmp_dtr,
        Dag0:head_dtr:head_dtr === Dag1:head_dtr,
        Dag0:head_dtr:cmp_dtr === Dag2;
% Case 3. Descriptive clauses. E.g., 他 有 [一本書]i 我 很 喜歡 ei.
        Dag2:syn:loc:head:maj === v,
        Dag2:syn:loc:subcat === end,
        Dag2:head_dtr:cmp_dtr:syn:loc:head:maj === n ,   % S[Obj:null]
        Dag2:head_dtr:cmp_dtr:syn:loc:null === '+', % S[Obj:null]
        Dag2:head_dtr:cmp_dtr:syn:loc:head ===      % X2's null NP ===
          Dag1:head_dtr:cmp_dtr:syn:loc:head, % X1's object.
        Dag0:syn:loc:head === Dag1:syn:loc:head, % HFP
        Dag0:syn:loc:subcat === Dag1:syn:loc:subcat, % SP
        Dag0:cmp_dtr === Dag1:cmp_dtr,
        Dag0:head_dtr:head_dtr === Dag1:head_dtr,
        Dag0:head_dtr:cmp_dtr === Dag2;
% Case 4. Descriptive clauses. E.g., [我們]i 種 [菜]j ei 吃 ej.
        Dag2:cmp_dtr:syn:loc:head:maj === n ,   % VP[Obj:null]
        Dag2:cmp_dtr:syn:loc:head:type === null , % VP[Obj:null]
        Dag2:cmp_dtr:syn:loc:head ===       % X2's null NP ===
          Dag1:head_dtr:cmp_dtr:syn:loc:head, % X1's object.
        Dag2:syn:loc:subcat:first:syn:loc:head === % X2's subject ===
          Dag1:head_dtr:cmp_dtr:syn:loc:head,   % X1's subject.
        Dag0:syn:loc:head === Dag1:syn:loc:head, % HFP
        Dag0:syn:loc:subcat === Dag1:syn:loc:subcat, % SP
        Dag0:cmp_dtr === Dag1:cmp_dtr,
        Dag0:head_dtr:head_dtr === Dag1:head_dtr,
        Dag0:head_dtr:cmp_dtr === Dag2;
% Case 5. Sentential subjects. E.g., 五 個 人 坐 一 輛 摩拖車 很 危險.
        Dag2:syn:loc:head:type === s_stative,
        Dag2:syn:loc:subcat:rest === end, % S/NP[Subj]
        Dag2:syn:loc:subcat:first:syn:loc:head:maj === v, % X2 subcats an S.
        Dag2:syn:loc:subcat:first:syn:loc:subcat === end, %
        Dag0:syn:loc:head === Dag2:syn:loc:head, % HFP
        Dag0:syn:loc:subcat === Dag2:syn:loc:subcat, % SP
        Dag0:cmp_dtr === Dag1,
        Dag0:head_dtr === Dag2).
```

Recall that *reconstruction* is activated after the right-hand side of S –> S VP rule is completed. Thus the activation of *reconstruction* is inserted after the *recognize_rest* procedure in the seconds *left_corner* rule, which becomes the following.

(20)
```
left_corner(Dag1,Dag2, C,D) :-
        rule_sel((_ ule Dag0 -- [Dag1|Dags]:- XXX)),call(XXX),
        recognize_rest(Dags,C,H),
        case([svc(_,_,_) -> reconstruction(Dag0,Dag1,Dag2)]),
        left_corner(Dag0,Dag2,H,D)
```

In the following, we show, in brief steps, the process of parsing a sample sentence, 他 有 一本書 很 有趣.

Step 1: Current word: 他.
The NP headed by this noun activates the head-pre-complement rule and a VP is required to form a complete sentence.

Step 2: Current word: 有.
This verb is first changed to phrasal verb which in turn activates the head-post-complement rule. An NP is required to form a VP headed by 有.

Step 3: Current words: 一 本 書.
An NP headed by 書 is formed, which satisfies the requirement of Step 2. A sentence is thus established; the S --> S VP rule is activated according to this sentence. To complete this S-rule, a VP is required.

Step 4: Current word: 很.
This adverb activates the head-pre-adjunct rule and a VP is required.

Step 5: Current word: 有趣.
This is an intransitive verb. It is first changed into a phrasal verb, which meets the requirement of Step 5. A VP, 很 有趣, is formed, and then it satisfies the remaining VP in Step 3. Before the completion of the S-rule a *svc(X0,X1,X2)* is asserted into the database.

Step 6: After the completion of the right-hand side of the S-rule, i.e., execution of *recognize_rest* in *left_corner*, a check on *svc(_,_,_)* is true, which activates *reconstruction* to establish the actual SVC structure. In this situation, Case (ii) in *reconstruction* is fired.

D. Sample results of parsing SVC sentence

In the following we show the parsing results of two sample sentences, in abbreviated feature structure form.

SVC Type: Two more separate events.

Sentence: 他 讀書 很 專心.

```
syn:  loc:  head: ...
            subcat: ...
cmp_dtr:  syn:  loc:  head: ...
                      lex:-
          head_dtr:  phon:他
                     syn:  loc:  head: ...
                                 lex:+
                           bind:-
head_dtr:  head_dtr:  syn:  loc:  subcat: ...
                            head: ...
                            lex:-
                      head_dtr:  phon:讀書
                                 syn:  loc:  head: ...
                                             subcat: ...
                                             lex:+
                      cmp_dtr:  syn:  loc:  head: ...
           cmp_dtr:  syn:  loc:  head: ...
                                 subcat: ...
                                 lex:-
                                 adj_dtr_type:pre
                           lex:-
                      head_dtr:  syn:  loc:  head: ...
                                             subcat: ...
                                             lex:-
                                 head_dtr:  phon:專心
                                            syn:  loc:  head: ...
                                                        subcat: ...
                                                        lex:+
                      adj_dtr:  phon:很
                                syn:  loc:  head: ...
                                            lex:+
                                      bind:-
```

SVC Type: Descriptive clauses.

Sentence: 他 有 一 本 書 我 很 喜歡.

```
syn:  loc:  head: ...
            subcat: ...
cmp_dtr:  syn:  loc:  head: ...
                      lex:-
          head_dtr:  phon:他
                     syn:  loc:  head: ...
                                 lex:+
                           bind:-
head_dtr:  head_dtr:  syn:  loc:  subcat: ...
                            head: ...
                            lex:-
                      head_dtr:  syn:  loc:  subcat: ...
                                             head: ...
                                             lex:-
                                 head_dtr:  phon:有
```

syn: loc: head: ...
subcat: ...
lex:+
cmp_dtr: syn: loc: head: ...
subcat: ...
lex:-
adj_dtr_type:pre
head_dtr: syn: loc: head: ...
subcat: ...
lex:-
adj_dtr_type:pre
head_dtr: syn: loc: head: ...
subcat: ...
lex:-
head_dtr: phon:書
syn: loc: head: ...
lex:+
bind:-
adj_dtr: phon:本
syn: loc: head: ...
subcat: ...
lex:+
bind:-
adj_dtr: phon:一
syn: loc: head: ...
lex:+
bind:-
cmp_dtr: syn: loc: head: ...
subcat: ...
lex:-
lex:-
head_dtr: syn: loc: subcat: ...
head: ...
lex:-
head_dtr: syn: loc: head: ...
subcat: ...
lex:-
adj_dtr_type:pre
head_dtr: syn: loc: head: ...
subcat: ...
lex:-
head_dtr: phon:喜歡
syn: loc: head: ...
subcat: ...
lex:+
adj_dtr: phon:很
syn: loc: head: ...
lex:+
bind:-
cmp_dtr: syn: loc: head: ...
lex:-
null:+
bind:-

```
cmp_dtr:   syn:   loc:   head: ...
                        lex:-
           head_dtr:   phon:我
                       syn:   loc:   head: ...
                                     lex:+
                                   bind:-
```

V. CONCLUDING REMARKS

We have shown a reconstructive method for parsing Chinese SVC sentences by using a lexicon-driven parser. In this work, only one phrase structure rule is added into the parser for SVCs. The lexicon-driven mechanism shows promising in processing SVCs of pivotal constructions, sentential subjects and sentential objects for the head verbs in these types of SVCs have their specific subcategorization. They are handled as ordinary VPs by using the existing parser without adding any phrase structure rule. The only phrase structure rule for SVCs is used to describe SVCs of descriptive clauses and two more separate events. Nondeterminism during the course of parsing SVCs does not occur because there is only one phrase structure rule for SVCs. The phrase structure rule is attached with a set of reconstruction rule which is used to build the actual structures of SVCs and resolve structural ambiguities. We have tested every type of SVCs in our parser, and performance is similar as processing ordinary declarative sentences. The resulting structures fit the conventional HPSG format, so that it can be treated as ordinary declarative sentences in latter phases, such as semantic interpretation, structural transfer in MT, etc. At present, the parser performs well for every SVCs consisting of two VPs. However, there are still further work for long SVCs. Consider the SVCs containing more than two VPs, as in sentences (21) and (22).

(21) 他 去 學校 找 同學 打 籃球.

He went to school to find classmates to play basketball.

(22) 我 有 一個 妹妹 喜歡 去 學校 找 同學 打 籃球.

I have a sister who likes to go to school to find classmates to play basketball.

At present, the reconstructive approach for SVCs can not parse these sentences. By observations, the troublesome VP series in these sentences are mostly in conjunctive structures. Consequently, the cases of long series of VPs will be handled in our further work on analysis of Chinese sentence linking.

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