# 7R－4 Incorporation of Connection Constraints into the Generation Process of Allophone-Based LR Table

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## 1 Introduction

The combination of phoneme context dependent(allophone) models and a GLR parser has been used to improve the recognition accuracy in continuous speech recognition systems. The GLR parser is guided by an LR parsing table automatically created from context-free grammar.

We have proposed an algorithm to incorporate the phoneme-context-dependence into the LR table through constraints propagation[2]. In this method, the generation of an allophone-based LR table is realized by two steps: From a set of syntactic, lexical and allophonic(CFG) rules, an initial LR table is constructed at first, and then, this initial LR table is modified on the basis of an allophone connection matrix. This method have the problem of explosion of initial LR table as the CFG rules increase.

In order to rectify this problem, in this paper, we describe an approach to incorporate the connection constraints into the generation process of the LR table. Using this method, the explosion of the initial LR table size can be avoided, and the time for generating an allophone-based LR table decreased greatly.

## 2 Incorporation of connection constraints into the generation process of LR table

This section presents an approach to incorporate the allophone connection constraints into an allophone-based canonical LR table.

Consider the extended context-free grammar including syntactic(rule 1), lexical(rule 2 to 3) and allophonic rules(rule 4 to 9):

| | |
|---|---|
| (1) S → N P | (6) i → i1 |
| (2) N → a n1 i (brother) | (7) i → i2 |
| (3) P → g a | (8) g → g1 |
| (4) a → a1 | (9) g → g2 |
| (5) a → a2 | |

Fig. 1 *An example of CFG rules*

In Fig. 1, "n1", "a1", "a2", "i1", "i2", "g1" and "g2" are the the allophones.

The canonical collection of sets of LR(1) items for this extended CFG grammar can be generated using the algorithm in[1]. A part canonical collection of sets of LR(1) items is shown in Fig 2.

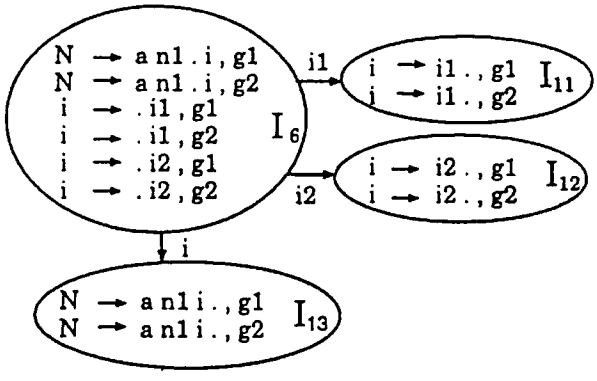


Fig. 2 *Part LR(1) collection for grammar in Fig. 1*

In Fig 2, $I_{11}$ is transferred from $I_6$ by shifting i1, $I_{12}$ is transferred from $I_6$ by shifting i2, and $I_{13}$ is transferred from $I_6$ by shifting i.

Consider that for the allophones in Fig. 1, there exists a connection matrix shown in Fig. 3 giving the connectabilities between adjacent allophones.

| | a1 | a2 | i1 | i2 | g1 | g2 | n1 |
|---|---|---|---|---|---|---|---|
| a1 | | | | | | | 1 |
| a2 | | | | | | | 0 |
| i1 | | | | | 0 | 1 | |
| i2 | | | | | 0 | 1 | |
| g1 | 0 | 0 | | | | | |
| g2 | 1 | 1 | | | | | |
| n1 | | | 1 | 0 | | | |

Fig. 3 *An example of connection matrix*

Now we show how to incorporate the allophone connection constraints into the generation process of the LR table by using the LR(1) collection in Fig. 2 and the connection matrix in Fig. 3,

(1). The following two items of $I_6$ in Fig. 2

i → · i2, g1
i → · i2, g2

are due to the closure "{[N → a n1 · i, g1/g2]}", but according to the connection matrix in Fig. 3,

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$Connect[n1, i2] = 0$, so these two items should be removed from $I_6$. Since these two items were removed, $I_{12}$ will vanish automatically.

(2). According to Fig. 3, $Connect[i1, g1] = 0$, so the following item of $I_6$

i→ · i1, g1

can be removed. Since this item was removed, the item of $I_{11}$

i→ · i1, g1

will vanish automatically too.

(3). Further, consider the item of $I_6$

N→ a n1 · i, g1

for the two allophones "i1" and "i2" of phone "i", by step (1), only "i1" is valid, and by step (2), "g1" can not succeed "i1", so this item should also be removed, and then the item of $I_{13}$

N→ a n1 i ·, g1

will vanish automatically too.

After incorporating the connection constraints into the generation process of LR(1) item collection, three LR(1) item collections in Fig. 2 decreased to two, as in Fig. 4. This means the decrease in states of canonical LR table.

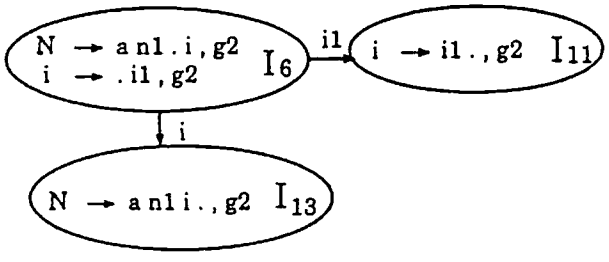


Fig. 4 *Collection LR(1) after incorporation of the connection constraints*

The explosion of initial LR table in [2] can be avoided through this processing.

# 3 The effects of proposed method

An extended CFG rule set with 1208 rules, which includes 64 syntactic rules, 120 lexical rules and 1024 allophone rules, is used to test the effects of proposed method.

The size of canonical LR tables and the CPU time for generating LR table are compared between incorporating and not incorporating the allophone connection constraints into the generation process of LR table.

### 1) The size of LR table

Table 1 shows the comparisons of LR table size, where CLR and MCLR mean not incorporating and incorporating the allophone connection constraints into the generation process of LR table, respectively.

Table 1 Comparisons of LR table size

| Table type | state | shift | reduce | goto |
|---|---|---|---|---|
| CLR | 11157 | 21057 | 701370 | 425 |
| MCLR | 1179 | 1005 | 1474 | 425 |

Through incorporating the allophone connection constraints into the generation process of LR table, the number of states, shift actions, and reduce actions decreases to 11%, 4.8%, and 0.2% of the CLR table.

### 2) CPU time for generating LR table

Table 2 shows the CPU time for generating CLR and MCLR table.

Table 2 CPU time for generating LR table

| Table type | CPU time (second) |
|---|---|
| CLR | 1422 |
| MCLR | 34 |

Compared with the CLR table, the CPU time required for the proposed method deceased to 2.4%.

# 4 Conclusion

We have described a method to incorporate the allophone connection constraints into the generation process of allophone-based LR table, and the effect of the proposed method has been tested with a generation experiment of LR table.

The proposed method can also be used to incorporating other connection constraints represented in the form of connection matrix (for example, morphological constraints) into an LR table.

The future works will be incorporating the morphological connection constraints into the generation process of LR table in addition to allophonic connection constraints.

# References

[1] A.V. Aho, S. Ravi, and J.D. Ullman. *Compilers: Principle, Techniques, and Tools*. Addision Wesely, 1986.

[2] H. Tanaka, H. Li, and T. Tokunaga. Incorporation of phoneme-context-dependence into LR table through constraints propagation method. In *Proc. AAAI-94 Workshop on Integration of Natural Language and Speech Processing*, pages 15–22, Seattle, 1994.