A Phonological Knowledge Base System Using Unification-based Formalism - A Case Study of Korean Phonology -

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Abstract

This paper describes the framework of a Korean phonological knowledge base system using the unification-based grammar formalism : Korean Phonology Structure Grammar (KPSG). The approach of KPSG provides an explicit development model for constructing a computational phonological system : speech recognition and synthesis system. We show that the proposed approach is more describable than other approaches such as those employing a traditional generative phonological approach.

1. Introduction

This paper has two main goals: one is to investigate the phonological knowledge base system for constructing a Korean speech recognition and synthesis system, the other is to show that our formalism is more describable than other systems employing the traditional phonological approaches[1] [2].

A language has its own sound patterns. By sound pattens we mean (1) set of sounds that occur is a language, (2) the permissible arrangement of the sounds in words and (3) the processing for adding, deleting, or changing sound [3].

A speech recognition/synthesis system also needs a phonological knowledge base system (data base), and the rules which govern the sound sequences and the phonological processes.

Traditinoally, a computational phonological systems have been described and classified in terms of 'Generative Phonology[4]', However most of those approaches are not sufficient to describe the various knowledge of a computational speech system.

In this paper, we show the feasibility of phonological knowledge base system with a unification-based formalism, and illustrate the flexibility of implementation and representation.

2. Syllable Structure of Korean Language

A spoken language is not only a linear of sound segments, but is a group of vowels and consonants to form large units of a sound such as syllables, words and utterance.

In this section we present the nature and properties of the Korean phonetic structure : Korean syllable. The Korean syllable structure has two types: one is the type of consonant and vowel group(CV type : 가 : ga), and the other is the type of consonant, vowel and consonant group(CVC type : 갂 : gak). The Korean language, however, has a predominant writing system : HANGUL which is based on sound segments and syllables. Especially, a HANGUL syllable corresponds to one character which is a combination of two or three sound symbols. In other words, a spoken syllable corresponds to a written syllable as a one-to-one fashion.

Structurally, a syllable may be divided in to three parts : oneset, necleus and coda. The most prominent part of a syllable consists of all the segments that precede the necleus and are tautosyllabic segments that follow the necleus. A syllable that has no coda is called "open syllable" : one with a coda is called "closed syllable". According to the above definitions of a syllable structure, the Korean syllable can be described as follows :

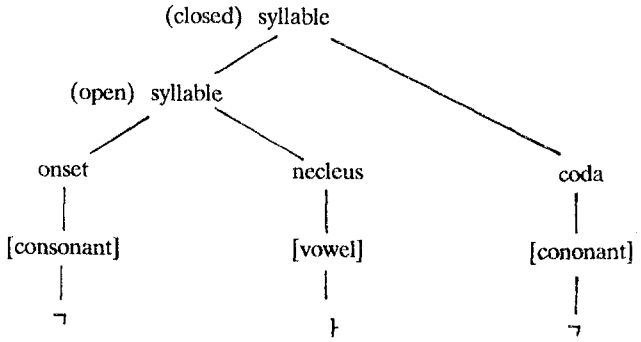


Fig. 1 Korean syllable structure

3. Korean Phonology Structure Grammar

As mentioned above, KLSG[5] is a new grammar theory for the Korean language and follows a unification-based grammar such as GPSG[6] and HPSG[7]. An outstanding characteristic of the KLSG, which has its descriptive capability, can be described in syntatic and morphological knowledges as well as knowledge of writting system, phonological and semantic knowledge with a unified grammar theory. In this paper we are only concerned with the phonological structure of the Korean language.

3-1. The phonological feature system in KPSG

All the Korean phonological categories of KPSG are presented by the sets of feature and they consist of feature and their values. In the following, we briefly described the phonological feature structure of KPSG.

SYL(Syllable) <--- {Consonant-Onset,
Vowel Consonant-Coda};

This feature presents the consonant and vowel according to the articulatory properties of phoneme.

PDF(Phoneme Distinctive Feature)
<--- {Nasal, Voiced,...};

This feature presents the practical phonetic values of the Korean language.

FOLL(FOLlow) ; This feature can take a set of categories as its values : the value corresponds to a list of categories.

3-2. The Korean syllable structure rule

We can describe the Korean syllable struture of Fig 1 using the value of FOLL features as follow :

(1-1) open syllables -->
Consonant-Onset+Vowel

(1-2) closed syllables -->
Consonant-Onset+Vowel+Consonant-Coda

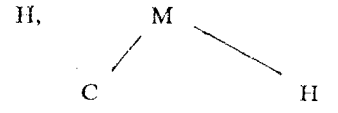
(1-1') [SYL v ; FOLL { }] -->
[SYL c-o ; FOLL { }]
[SYL v ; FOLL {c-o}].

(1-2') {SYL c-c ; FOLL { }] ->
[SYL v ; FOLL { }]
[SYL c-c ; FOLL {v}].

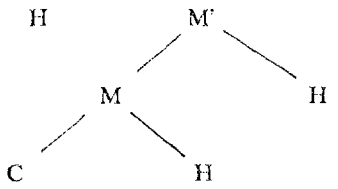
A careful look at the features specified in (1-1') and (1-2') will reveal that the ocurrences of the syllabic feature are predictable with the form of the rules; the syllabic feature appears on the set of feature similar to the left hand side among the right hand side in the rules.

In the KPSG, we assume the syllable structure rule as the general rule as follow :

(1-3) M --> C H,



M' --> M H



where M and M' are the mother categories, C and H are the daughter categories, in which C is the complement category, and H is the head category, respectively. Since (1-3) is a binary tree, we use (1-1') to get a syllable structure for (1-2'). its content is determined by the principles discussed later. The head in a rule plays the role of a primitive in the knowledge processing of KPSG, and the feature of head is applied by the following principle.

A. Head Feature Principle(HFP)

The values of the idividual HEAD features of the mother are indentical to the values of the HEAD features corresponding to its head.

This principle guarantees that the values of these head features at the M(M') node and those at H node in the (1-3). The general idea behind the formulations is to state certain constraints regarding the head features. The head features include SYL and PV.

But the HFP does not give necessary assignment of the values to the syllable's element. The rules for the sound sequence and the phonological processes are handled by another principle called subcat feature principle.

B. Subcat Feature Principle(SFP)

The value of the FOLL feature of a head is indentical to the FOLL feature of its mother except for the category which is identical to its daughter.

The subcat feature principle states the relationship that holds between the FOLL value of the mother and that of the head in a given local phonology tree.

C. Binding Frature Principle(BFP)

This principle states the distribution of binding features over a given syllabic tree. A binding feature is a feature whose value is determined with respect to a category possibly seperated by a number of syllable boundaries. This feature plays a crucial role in describing the phonological process: vowel harmony and so on.

These principles are the constraints to select the adequate local syllabic tree among the inadequate local syllabic trees generated by the above phonological rules: M ---> C H and M' ---> M H. The information of the basic feature values is prepared as the concrete phoneme entry, and is propagated a local tree to another local tree during the phonological processing. The operation which determines the structure of feature and the sets of feature is called unification.

The feature system in phonological knowledge base system plays a role of the declarative feature knowledge and the unification applied by the principles correspond to the procedural knowdedge which specify the rules governing the sound sequence and phonological process. From the viewpoint of sound inventories, each rule is described declaratively as a constraint condition which is settled among the features. The equality and partiality among the feature are defined by the concept of unification.

4. Pratical examples

In this section we illustrate how the phonological rules in KPSG are operated. The processes of sound change vary in the degree of naturalness. There are various types of assimilations such as (1) nasalization, (2) palatalization, (3) assimilation and (4) vowel assimilation and so on. Among those various types of assimilation, we investigate the most common type of the nasal assimilation in the Korean language.

(1-4) nasal assimilation(nassalization)
a. k - - > ŋ / - - - - - [+nasal]
b. p - - > m/ - - - - - [+nasal]
c. t - - > n/ - - - - - [+nasal]

(1-4) is the formal descriptions of the phonological rules based on the theory of generative phonology. The notation k - > / - - - [+nasal] is to be read as "k is re-written as if nasal phonetics is immediately to its right". These rules correpond to the procedural knowledge of phonological process. In comparison with this, unification based formalism is declarative knowledge representation. For example,

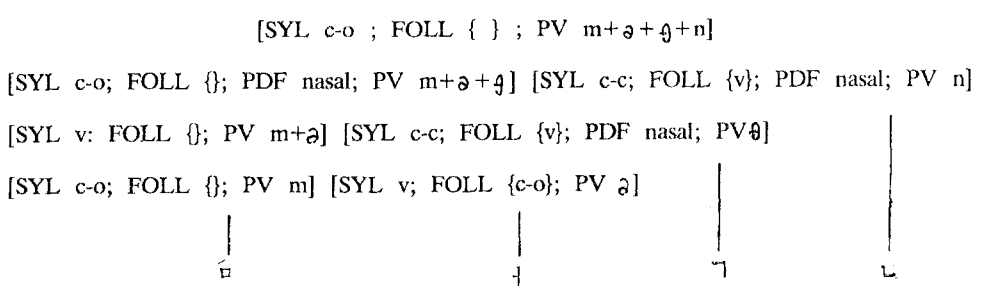
(1-5) [SYL c-o ; FOLL { } ; PV α+β]

{SYL c-c; FOLL {}; PDF nasal; PVα]
|
α [SYL c-o; FOLL {SYL c-c; PDF nasal}: PVβ)]
|
β

(1-5) presents the general rule form for nasal assimulation and here PVα+β means that phonetic values are composed according to the compositional phonology. Now, we show the scheme of the rule form (1-5) with a practial example in the case of rule (1-4a)

In the (1-6), the feature's values such as c-or v, nasal, and m or n, etc. correspond to feature, SYL, PDF and PV respectively. At each node, the feature's values of the mother are passed to the head according to the head feature principle, the syllable's boundaries and agreement between the fea tures are recognized and sound's value is synthesized by the feature principle.

(1-6) 먹-는 (m ㅓk-nun) ....> 멍-는 (m ㅓ -nun)



Finally, we present briefly a Korean sound inventories (symbolic databases of phonetics) of the phoneme used in the allophone rule.

(1-7)

ㄱ (k) : {SYL c-o ; FOLL { } ; PDF *;...; PV k}

ㄱ (k) : {SYL c-c ; FOLL {v} ; PDF *;...; PV k}

ㄱ (ㅇ) : {SYL c-c ; FOLL {v}; PDF nasal ;....; PV ㅇ }

ㅂ (p) : {SYL c-o ; FOLL { } ; PDF *;...; PV p}

ㅂ (p) : {SYL c-o ; FOLL{v} ; PDF nasal ;....; PV p}

ㅂ (m) : {SYL c-o, FOLL{v} ; PDF nasal ;....; PV m}

ㄷ (t) : {SYL c-o ; FOLL { } ; PDF *;....; PV t}

ㄷ (t) : {SYL c-c ; FOLL {v} ; PDF *;....; PV t}

ㄷ (n) : {SYL c-c ; FOLL {v} ; PDF nasal ;....; PV n}

ㄷ (n) : {SYL c-c ; FOLL { } ; PDF *;....; PV n}

ㄷ (n) : {SYL c-c ; FOLL {v} ; PDF *;....; PV n}

ㄷ (n) : {SYL c-c ; FOLL {SYLL c-c ;
PDF nasal} ; PDF *; ....; PV n}

In the (1-7), the feature set shows the phonological constraints of each phoneme respectivly.

5. Feature Works

At present it is not clear just how to classify and integrate all the knowledge we have accumulated about the natural phonological processes into the grammars of individual languages. We introduced a unification-based grammar formalism for phonology. We verify that unification-based grammar formalism is a very useful theory for constructing the computational speech processing system, similar to a syntactical system.

In order to construct speech recognition and synthesis system, we need a number of various knowledge sources : acoustic, phonetics, phonology, prosody, morphology, syntax, semantics, and pragmatics. The problem is how to represent and use those knowledges. The knowledge representation must keep the transparency among the knowledges with a unified way. Unification-based grammar formalism satisfy the above requirements.

We also attemp to describe the English phonological knowledge base system with a unification-based formalism, and are implementing the Korean speech recognition /synthesis system[8] with the KPSG.

6. References

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