A Constrained Finite-State Morphotactics for Korean

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Abstract

In this paper, we propose a constrained finite-state model, named cfsm, for Korean morphotactics and attempt to show how it can successfully treat some major morphological problems in Korean. As a preliminary descriptive framework, this model adopts the Korean morphological system Komor by Lee (1999) to lay out some basic problems in Korean morphotactics and describe linear approaches to their possible solutions. This descriptive step is then followed by various testing steps executed by using Xerox’s finite-state development tools, namely xfst for creating finite-state networks and lexc specifying natural language lexicons. With Komor’s constraints represented in feature structures and appropriately implemented into xfst and by making Komor run on xfst, the proposed cfsm is expected to fully benefit from the descriptive groundwork of Komor and the finite-state processing power of xfst.

1. Aim and Approach

This work aims at developing a constraint-based finite-state model named cfsm for Korean morphology. For this purpose, it re-implements Lee’s (1999) Korean morphology system Komor, which had been implemented with a C-augmented grammar tools named MALAGA1, by using Xerox’s finite-state development tools, namely xfst for creating finite-state networks and lexc specifying natural language lexicons. With Komor’s constraints represented in feature structures and appropriately implemented into xfst and by making Komor run on xfst, the proposed cfsm is expected to fully benefit from the descriptive groundwork of Komor and the finite-state processing power of xfst.

In designing and implementing our proposed model cfsm, we strictly adhere to the principle of possible continuation that has been advocated by Hausser (1989) and Beesley and Karttunen (2003) in recent years. The main operation in executing cfsm is concatenation (without backtracking), but strictly constrained by some requirement conditions on feature-value matching. In Korean, for instance, noun and verbal stems concatenate with a sequence of their suffixal particles or endings to form well-formed word forms. But this concatenation is often constrained by their particular syllable structure or degree of regularity. For example, a verbal stem ‘먹’ mek’ may simply concatenate with a tense marker to form another stem, but its syllable structure may restrict the choice of its ending, thus allowing the stem ‘먹었’ mek.ess’ only. This linear approach with necessary constraints is, however, considered adequate especially in treating the morphology of agglutinative languages like Korean.

1 MALAGA is an acronym for “Malaga accepts left-associative grammars with attributes”, developed by Bjoern Beutel and others at Department of Computational Linguistics, Erlangen-Nuernberg University.
2. Design and Representation

The proposed model cfsm consists of three main modules: (1) Lexicon, (2) Grammar, and (3) Output.

2.1. Lexicon

The Lexicon again consists of three sub-lexicons: (1) Basic Lexicon, (2) Extended Lexicon with allomorphic variations, and (3) Enlarged Lexicon augmented with syllable-complete surface forms. These sub-lexicons are constructed semi-automatically by a preprocessing engine implemented preferably by Java that provides a list of multi-character symbols, a set of lexical definitions and concatenation rules for the execution of Xerox’s morphotactic engines.

Each lexical item listed in these sub-lexicons is associated with an appropriate feature structure which is represented in a feature-value matrix or an equivalent XML format. For illustration, consider a list of well-formed word forms in Korean like:

(1) a. 쪼다 chwup.ta, (be cold)
    b. 추웠다 chwu.wess.ta, (was/were cold)

The feature structure associated with each of these word forms can be represented in a matrix form as follows:

(2) a. \[
\begin{array}{c}
\text{SURF} \ '뎁다' \\
\text{SEM} \ [\text{CONTENT} \ <\text{state},'being_cold'>]
\end{array}
\]

b. \[
\begin{array}{c}
\text{SURF} \ '추웠다' \\
\text{SEM} \ [\text{CONTENT} \ <\text{state},'being_cold'>] \\
\text{TENSE} \ past
\end{array}
\]

2.1.1. Basic Lexicon

The Basic Lexicon lists basic lexical units, or morphemes, for instance like verbal stems and their suffixal endings with minimally necessary information.

(3) a. \[
\begin{array}{c}
\text{SURF} \ '뎁'
\text{POS} \ \text{adjective}
\text{FORM} \ p-class
\text{SEM} \ [\text{CONTENT} \ <\text{state},'being_cold'>]
\end{array}
\]

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2 We use the non-commercial version of the Xerox engines that are provided with Beesley and Karttunen (2003).

3 The Yale romanization of Hangul is adopted as is done by most Korean linguists. See Lee (1994).
2.1.1. Extended Lexicon for Allomorphic Variations and Constraints

By a set of allomorphic rules, the Basic Lexicon is then automatically extended to the Extended Lexicon that is designed to contain all of the possible allomorphic forms. Since the adjectival stem ‘ зрз chwup’ belongs to the p-variation class of semi-irregularity, the Extended Lexicon should contain the following two items:

1. Allomorphic Extension: Adjectival Stems

   (4) a. [SURF ' зрз chwup'
   POS adjective
   BASEFORM ' зрз chwup'
   SYLLABLE closed & dark
   SEM [CONTENT <state, 'being_cold'>]
   b. [SURF ' 추우 chwu.wu'
   POS verb
   BASEFORM ' 추우 chwu.wu'
   BRIDGE e
   SYLLABLE open & dark
   SEM [CONTENT <state, 'being_cold'>]

Note above that each allomorph contains information about its syllable features: the syllable analysis of the stem ‘ зрз chwup’ shows that its (final) syllable is closed, thus ending in a consonant, and is classed as dark because its vowel is neither ‘a’ or ‘o’. On the other hand, the final syllable of the stem ‘ 추우 chwu.wu’ is analyzed as open and dark.

Other lexical items also contain information about their syllable structure through syllable analysis, as shown in the following:
Six variants are listed as past tense markers in the Extended Lexicon. Each has its own SYLLABLE and REQUIRES conditions for combining with an appropriate stem: the last ‘ㅣㅆ iss’, for instance, combines with ‘하 하’ to produce ‘됬 hayss’(do+past).

4. Allomorphic Extension: Past Adnominal Endings

```plaintext
[surf 'ㄱ ss'
pos verbalEnding
form wordFinal
syllable incomplete
requires [syllable open]
results [pos adnoun]
]  
(7) a.
```
2.1.3. Enlarged Lexicon

This Extended Lexicon is then further augmented to the Enlarged Lexicon in two ways: (1) syllable completion and (2) minimal ordering. Since Hangul characters, say ‘사랑 sa.rang’, can be analyzed into phonemic units, ‘ㅅ s’, ‘ㅏ a’, ‘ㄹ r’, ‘ㅏ a’, and ‘ㅗ ng’, or into syllables, ‘사 sa’ and ‘랑 rang’, a choice is necessary between phonemic and syllabic analysis for morphological processing. The komor system by Lee (1999) chose the phonemic analysis, thus analyzing ‘추웠다 chwu.wess.ta’ into ‘추우/ㅓ/ㅆ 다 chwu.wu/e/ss/ta’. As in Shim and Yang (2002, 2004), on the other hand, the present work has taken the alternative way of analyzing characters into complete syllables, thus resulting in a morphological analysis as in: ‘추웠/다 chwu.wess/ta’ instead of ‘추우/ㅓ/ㅆ 다 chwu.wu/e/ss/ta’.

The second approach reduces the number of the steps of morphological processing. In the given example, that number reduces from three to one. This process, however, requires the pre-processing of surface forms like ‘추웠 chwu.wess’ that combines any syllable-incomplete forms like ‘ㅓㅆ ess’ into syllable-complete forms like ‘쨌 wess’. In our case, the Intermediate Lexicon must thus contain both the forms ‘추웠 chwu.wess’ and ‘추운 chwu.wun’, since both the verbal endings ‘ㅓㅆ ess’ and ‘ㄴ n’ are syllable-incomplete.

The Enlarged Lexicon can further be enlarged by containing complex nominal particles like ‘에서부터라도 ey.se.pwu.te.ra.to’ (even from) or complex verbal endings like ‘으시었겠 u.si.ess.keyss) (Bridge+Honorific+Past+Conjunctured). These complex particles or endings are found to occur with very low frequency in a very large corpus and to be not worth of being generated by a set of rules. Hence, they can be preprocessed and included in the Enlarged Lexicon. Such a decision reduces the load of ordering rules to a great extent.

2.2. Grammar

By Grammar here is meant a set of morphotactic rules based on the Enlarged Lexicon. The basic, perhaps sole operation in cfsm for Korean is concatenation and this operation applies linearly in a left-associative manner to a pair of input surface forms to generate a well-formed new string and eventually a well-formed word form through repeated applications. On the basis of the Enlarged Lexicon devised here, our cfsm should be able to analyze or generate the following word forms:

(8) a. 췄다 chwup.ta, (state of being cold)
   b. 췄겠다 chwup.keyss.ta (conjectured state of being cold)
   c. 추웠다 chwu.wess.ta (past state of being cold)
   d. 추웠겠다 chwu.wess.keyss.ta (past conjectured state of being cold)
   e. 추운 (cold)chwu.wun (Adnoun, past state of being cold)

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4 Shim and Yang (2002) and Shim and Yang (2004) proposed (1) and Kang (2002) (2), also through personal communication.
5 See Lee (1994).
6 This observation was communicated to us by Seung-Shik Kang through personal communication and also in Kang (2002).
2.2.1. Preprocessing Complex Verbal Endings

In komor the word form ‘추웠겠다 chwu.wess.keyss.ta’ is analyzed as a series of concatenation as in:

(9) 추우 stem + ㅓ bridge + ㅆ past + 켓 conjecture + 다 sfinal

But cfsm analyzes it as:

(10) a. Either 추웠 stem,past + 켓 conjecture + 다 sfinal
     b. or 추웠겠 stem,past,conjecture + 다 sfinal

Here we have an option to choose either (a) or (b). Consider the following:

(11) a. 먹었다 mek.ess.ta (eat/Verb+Past)
     b. 먹겠다 mek.keyss.ta (eat/Verb+Conjectured)
     c. 먹었겠다 mek.keyss.ta (eat/Verb+Past+Conjectured)
     d. *먹겠었다 mek.keyss.ess.ta

But this list contains an ill-formed word-form, namely ‘먹겠었다 mek.keyss.ess.ta’. To eliminate it, komor uses an ordering constraint so that the past tense verbal ending ‘었 ess’ should precede the conjectural ending ‘겠 keyss’.

Another way to solve this problem is to treat a sequence of verbal endings like ‘었겠’ as a complex verbal ending and list them in the Enlarged Lexicon. Such a decision is statistically motivated, as Kang (2002) claims that the preprocessing of such complex verbal endings must increase the efficiency of morphological processing.

Our proposed Enlarged Lexicon will then contain the following complex verbal endings:

Enlarged Lexicon: Complex Verbal Endings

(12) a. SURF ‘었겠 ess.keyss'
     POS verbalEnding
     REQUIRES [SYLLABLE closed&dark]
     SEM [TENSE past
          MODALITY conjectured]

Since there is no longer a process of concatenating of ‘었 ess’ and ‘겠 keyss’ in our system, it is necessary to pre-generate verbal stems like ‘추웠겠 chwu.wess.keyss’ in the Enlarged Lexicon to obtain well-formed word-forms like ‘추웠겠다 chwu.wess.keyss.ta’.

2.2.2. Conforming to the Xerox engines

Our engine cfsm automatically converts the Enlarged Lexicon to the rule format suitable for executing Xerox’s xfst and lexc. Besides a list of multi-character symbols that are used in defining the rules, it consists of a set of definitions and a sequence of rules called LEXICON. Here is a portion of it obtained from our sample Enlarged Lexicon:
Definitions

adjective =
[ 추
  "@P.SURF.'추 chuwup'@"
  "@P.POS.adjective8"
  "@P.TYPE.stem"
  "@P.BASEFORM.'추 chuwup'@
  "@P.SYLLABLE.closed"
  "@P.SEM.[CONTENT <state,'cold'>]@"
 ]
추웠
  "@P.SURF.'추웠 chwu wess'@"
  "@P.POS.adjective8"
  "@P.BASEFORM.'추웠 chwu wess'@
  "@P.SYLLABLE.closed&dark";
  "@P.SEM.[CONTENT <state,'cold'> TENSE past]@"
 ]

verbalEnding =
[ 았
  ! Check constraint
  "@R.SYLLABLE.closed&clear"
  "@R.TYPE.stem"
  "@P.SURF.'있다 ass'@"
  "@P.POS.verbalEnding8"
  "@P.SYLLABLE.closed"
  "@P.SEM.[TENSE past]@"
  ]

adnoun =
[ 추운
  "@P.SURF.'추운 chwu wun'@"
  "@P.POS.adnoun8"
  "@P.SYLLABLE.closed"
  "@P.SEM.[CONTENT <state,'cold'>]@"
  ]

verbEnding =
[ D.FORM.wordFinal@ ! D = Disallow
  
  니다
  "@P.SURF.'다 ta'@
  "@P.POS.verbEnding8"
  "@P.SYLLABLE.close&dark"
  "@P.SEM.[SENTENCETYPE declarative]@"
  ]

!! the end of Definitions

LEXICON Root
adjective;
verb;
adnoun;
LEXICON adjective
<adjective> verbalEnding;
<adjective> verbEnding;
LEXICON verb
<verb> verbalEnding;
<verb> verbEnding;
LEXICON adnoun
<adnoun> #;
LEXICON verbalEnding
<verbalEnding> #;
LEXICON verbEnding
<verbEnding> #;

Table 1: Sample Enlarged Lexicon

2.2.3. Compilation
By giving a command apply up or simply up on xfst for '추웠다', we can get the following analysis:

Figure 2: Analyzing for '추웠다' in Xerox Finite-State Tool (xfst) / Command Mode
In order to display the results of analysis or generation, \texttt{cfsm} runs an interface that represents each lexical item in a matrix form, showing how they are processed and concatenated step by step. Here is an example.

![Figure 3: Analyzing for '추웠다' in Constraint-based Finite-State Morphotactics (cfsm) UI](image)

3. Concluding Remarks

Our proposed \texttt{cfsm} is a newborn baby, although its theoretical conception dates back to the beginning of \texttt{Komor}. In this paper we have attempted to find automatic ways of converting \texttt{Komor} into \texttt{cfsm}, thus allowing the use of finite-state tools for morphotactics like Xerox’s \texttt{xfst} and \texttt{lexc}. The primary benefit of this conversion is that the comparatively complete description of the Korean morphology in the rule-based \texttt{Komor} can directly be imported into the proposed \texttt{cfsm}.

4. References

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