Title: A Consideration on Inter-Phoneme Distance via Sino-Japanese Morpheme Recognition.

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A Consideration on Inter-Phoneme Distance via Sino-Japanese Morpheme Recognition

Shigeyoshi KITAZAWA, Masaaki ISHIKAWA
and Shuji DOSHITA

1. INTRODUCTION

For speaker-dependent isolated word recognition, a method of pattern matching using the characteristics over a whole word sound as a template has been usually chosen. The method works best when the wordset is not too large, and consists of words with low acoustic inter-word similarity, i.e., redundant as a series of sounds.

But among words frequently met in applications, there are many minimal pairs, that is, words that differ by only a phoneme. Such words have high inter-word acoustic similarity as well as phonetic similarity. Presence of such pairs in a wordset is bound to affect performance. So in evaluating the performance of word recognition system, not only the wordset size but also the acoustic similarity of the wordset should be quantitatively evaluated.

In this study a set of 346 Sino-Japanese morphemes (jion) which constitutes an isolated class in Japanese from the point of view of phonology, was chosen as an example of recognition object. We show the list of 346 “jion”s in Appendix 1. We believe the set of 346 “jion”s might constitute a good evaluation measure of word recognition systems. We used the dynamic programming time warping matching (DP-matching) technique which is a common method of isolated word recognition.

2. PHONOLOGICAL STRUCTURE OF “jion”

“Jion” consist of from two to four phonemes, forming one or two syllables. When the first phoneme is a vowel, it is assumed that it is actually preceded by a glottal stop [ʔ].

The first segment is thus a non-vowel /C/ including /ʔ/, and the second is a vowel /V/. The second and third segments of three segment “jion”s are either a vowel /V/ and a mora-nasal /N/, or one of /ai/, /ei/, /ou/, /uu/, /ui/ and /ii/. The third and fourth segments of the four segment “jion”s are one of /ki/, /ku/, /tʃi/ and /tsu/.

In brief the phonological structure of “jion” is confined to the following four types:

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Shuji DOSHITA (堂下 赦參) : Professor, Department of Information Science, Kyoto University.
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Appendix. 1 346 "jion"s.

<table>
<thead>
<tr>
<th>1) a</th>
<th>2) ai</th>
<th>3) aku</th>
<th>4) atu</th>
<th>5) an</th>
<th>6) i</th>
<th>7) iki</th>
<th>8) iku</th>
<th>9) i'</th>
<th>10) itu</th>
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<td>kotu</td>
<td>kon</td>
<td>kya</td>
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<td>kyo</td>
<td>kyou</td>
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<tr>
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<td>tai</td>
<td>taku</td>
<td>tatu</td>
<td>tan</td>
<td>ti</td>
<td>tiku</td>
<td>titu</td>
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<td>7) iki</td>
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<td>9) i'</td>
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</table>
So the phonological structure of "jion" has the following characteristics:

a) the number of segments is limited;

b) there are only 33 kinds of phonological structures if one excepts the difference of the initial phoneme;

c) there are many minimal pairs, (for example, /baku/ and /daku/).

Table 1 shows the 33 kinds of phonological structures of "jion" excepted the difference of the initial phoneme.
A Consideration on Inter-Phoneme Distance via Sino-Japanese Morpheme Recognition

Table 1. Phonological structures of “jion” excepted the difference of the initial phoneme

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<tr>
<th>group</th>
<th>number of kinds</th>
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<th>number of kinds</th>
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<td>total</td>
<td>56</td>
<td>total</td>
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Table 2. Classification of recognition errors.

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<th>group</th>
<th>errors (%)</th>
<th>examples</th>
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<td>initial consonant only</td>
<td>164 (84.5)</td>
<td>a-ma, etu-hetu, ke-te, hei-gei, ran-nan, ta-a, mei-rei, satu-zatu, zyuku-syuku, den-gen, bi-ri, batu-matu, bo-go, etc.</td>
</tr>
<tr>
<td>vowel in initial syllable</td>
<td>7 (3.61)</td>
<td>kotu-katu, sun-son, sei-sai, sen-san, sya-syu, syaku-syoku, dan-don</td>
</tr>
<tr>
<td>consonant &amp; vowel in initial syllable</td>
<td>14 (7.22)</td>
<td>katu-hatu, kan-ton, sii-tui, siti-keti, sui-zai, seti-zati, sotzati, nai-riu, nan-mon, ratu-botu, bati-oti, bitu-metu, ban-don, bun-gan</td>
</tr>
<tr>
<td>others</td>
<td>9 (4.64)</td>
<td>so-son, syuu-syu, syun-tyuu, tyu-tyuu, hu-huu, me-men, yu-yuu, ru-ryuu, ryu-gyuu</td>
</tr>
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</table>

3. EXPERIMENT OF RECOGNITION OF 346 “jion”s

One male speaker produced the set of 346 “jion”s twice. We made the first set of them the templates and the second set the object of recognition. Waveforms were first low-pass filtered at 8.9-kHz and then sampled at 18.5-kHz. The parameterization, a 20th-order LPC analysis, was carried out over 20.8-ms hamming windows shifted every 6.92-ms.

LPC cepstrum distance is used as inter-frame distance. Using these local distances, the distance between the input pattern and the reference pattern is calculated by means of a dynamic programming time warping technique. As a
Appendix. 2 641 city names.

<p>| | | |</p>
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147) hon-jo: 196) abiko 245) nagaoka
148) higashimatsuyama 197) kamogawa 246) san-jo:
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150) kasukabe 199) kimizu 248) shibata
151) sayama 200) futtsu 249) nitsu
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153) konosu 202) tachikawa 251) kamo
154) fukaya 203) musashino 252) to:kamachi
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156) yono 205) ome 254) murakami
157) sokka 206) fuchu: 255) tsubame
158) koshigaya 207) akishima 256) tochio
159) warabi 208) chofu: 257) itoigawa
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161) iruma 210) koganei 259) gosen
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163) asaka 212) hino 261) shirone
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result 43.9% recognition rate was achieved. Table 2 shows the classification of recognition errors. Errors in the initial syllable accounted for 95.4% of all errors, of which 88.6% were errors in the initial consonant only. Table 4 shows the confusion matrix of the initial consonant. The recognition rate is low compared to the rate currently achieved on sets of city names, but this is precisely attributable to the low redundancy of “jion”. To illustrate this point, consider a system that can recognize only the vowel parts of a word. When we input the sounds of 346 “jion”s and those of 641 city names into this system and accept an output symbol, the average number of input symbols that are confused (recognized as the same word) are respectively 19.8 and 2.75. This shows that the set of 346 “jion”s has lower redundancy than the set of 641 city names. We show the list of 641 city names in Appendix 2.

Table 3. Recognition rate of distinctive-features in morpheme-initial consonant.

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Table 4. Confusion matrix of morpheme-initial consonant.

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Table 3 shows the recognition rates of distinctive features in the morpheme-initial consonant. The recognition rate of "strident" was 100%, and that of "sharp" and "flat" were comparatively good. That of "compact" 81.3% was the worst. However, this result is not necessarily caused only by the characteristics of the morpheme-initial consonant, but also by opposition of the succeeding vowel. For example "strident" is a feature which opposes affricates /ts/ and /dz/ to simple stops.
Fig. 1. Two-dimensional plot of a group of morphemes /Caku/.

/t/ and /d/. But /ts/ and /dz/ can precede only vowel /u/, and /t/ and /d/ only one of vowels /a/, /e/ and /o/.

4. Distance Between the Sound Patterns of “jion”

By means of Multi-Dimensional Scaling, we obtained a two-dimensional plot of the sound patterns of “jion” from the distance calculated by the DP-matching process. In the recognition experiment only the minimum distance was used, but here the whole distance matrix is evaluated and the relation of the sound patterns of “jion” is shown. However if we show the relation of all 346 “jion”s at once, it is difficult to interpret the result because of the numerous factors involved.

So we showed the relation of the “jion”s contained in one of the 33 groups which differ only in the initial consonant. Fig. 1 shows the two-dimensional plot of a group of morphemes /Caku/ as an example. Roughly speaking the first factor of the horizontal axis corresponds to the length of time for which the speech sound continues. The feature “strident” is contained in this factor. The second factor of the vertical axis corresponds to the feature “voiced” of the initial consonant.

5. Experiment of Discrimination of the Initial Plosive of “jion”

In the recognition of 346 “jion”s using DP-matching, the part excluding the
initial consonant was almost recognizable. So, for only plosives of the initial consonants of 346 "jion"s we made a discrimination experiment by the method in Reference 2, and obtained for unknown speaker discrimination rate 82.0% for unvoiced plosives and 88.0% for voiced plosives. At the experiment using DP-matching, the detection rate of plosive 54.6% and the discrimination rate in the group which was regarded as plosive 64.6% were obtained.

6. CONCLUSION
1) The set of 346 "jion"s, which generates an important subset of Japanese, has high inter-word acoustic similarity, and should constitute a good evaluation measure of word recognition systems.
2) The main cause of error in the set was confusion of the initial consonant. This emphasizes the need for high precision initial consonant recognition.

REFERENCES

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