Klaus Miesenberger
Christian Bühler
Petr Penaz (Eds.)

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Optimizing Vocabulary Modeling for Dysarthric Speech Recognition

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Abstract. Imperfection in articulation of dysarthric speech results in the deterioration on the performance of speech recognition. In this paper, the effect of the articulating class of phonemes in the dysarthric speech recognition results is analyzed using generalized linear mixed models (GLMMs). The model with the features categorized according to the manner of articulation and the place of tongue is selected as the best one by the analysis. Recognition accuracy score for each word is predicted based on its pronunciation and the GLMM. The vocabulary optimized by selecting words with the maximum score shows a 16.4 % relative error reduction in dysarthric speech recognition.

Keywords: Dysarthria · Vocabulary modeling · Speech recognition

1 Introduction

Dysarthria is a motor speech disorder caused by damage to the central or peripheral nervous system. As the error rate of recognition is significantly higher when dysarthric speakers use an ASR system developed for non-dysarthric speakers, researchers have focused on improving the models for recognition. The speech recognizer is composed of models such as acoustic model, pronunciation model, vocabulary and language model. The acoustic characteristic of dysarthric speech is analyzed and dysarthric speech is converted to be heard as normal speech [1]. The acoustic model is improved by using speaker adaptation or by using DNN [2]. Confusions in pronunciation are modeled as pronunciation variants or embedded to the search network [3]. In ASR-based applications developed for dysarthric speakers, recognition errors are reduced not only by improving the models but also by defining problems in the application of ASR with small vocabulary and simple-patterned utterances for lowering perplexity [4–6]. The voice keyboard [5] is an interface for inputting the mapped key by recognizing an isolated word utterance, which is a method for text input using small vocabulary isolated word recognition. A phonetic alphabet is set as the default vocabulary for the interface [5, 6]. Customizing the vocabulary leads to a decrease in the errors in recognition [6], however, the customization is performed by trial and error. One of the characteristics of dysarthric speech is imperfection in articulation. The frequencies of articulation errors of phoneme and of class of phoneme are observed in

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dysarthric speech [7, 8]. For consonants, fricatives and affricates show higher error rates when classified by manner of articulation and alveolars show higher rates when classified by place of articulation and the error rate for monophthongs at extreme positions such as /i, ae, a/ is higher [7]. The difference between recognition accuracy by ASR system and score of intelligibility test by human rater is observed [9].

From previous researches, we assume that error rates in recognition depend on the class of the phoneme and the effect of the articulating the classes in recognition result rather than in the judgement of human raters is analyzed in order to estimate the recognition performance of each word based on its phoneme-level pronunciation. We analyze the effect of the articulating class of phoneme in dysarthric speech recognition result using the generalized linear mixed model (GLMM) and define the recognition score based on the analysis of optimizing the vocabulary for improving the ASR performance.

2 Method

In our voice keyboard, users enter text into the application by repeatedly uttering a recognition word for a target alphabet. Korean graphemes are composed of 19 consonants, 8 monophthongs, and 13 diphthongs. We exclude 5 consonants for fortis and 9 less frequent diphthongs from arrangement of the keys in the voice keyboard due to lack of data, which results in the keyboard having a total of 47 keys for 14 consonantal graphemes, 12 vowel graphemes and 21 control functions.

Two sets of isolated word corpus of Korean dysarthric speakers are used for analysis and evaluation [10]. The vocabulary of one corpus is composed of 173 words and the other is 500 words. Recording the word utterances is repeated at least twice for 13 speakers. One set among two sets of the utterance is used for the acoustic model adaptation, and the other is used for recognition test. The GMM-HMM models are trained and adapted by applying fMLLR and MAP methods [11]. The isolated word grammar for a total of 47 words in a vocabulary is made to define the search network. The number of phonemes for each class in the canonical pronunciation of the word for an utterance in the speech corpus is counted. Severity of the speaker and four types of counts according to criteria of classification of consonants and vowels are written to form the fixed effects of the generalized linear mixed model (GLMM). Speaker ID and word ID are also included as the random effects in the model. As a result, four GLMMs are built to predict the recognition accuracy: Place-Frontness model, Place-Height model, Manner-Frontness model and Manner-Height model. Among the models, the Manner-Frontness model minimizes the negative of log likelihood and the model size. The estimates of the model are shown in Table 1.

Fricative, Nasal, Front, Central, Back and Severity are significant ($p < 0.05$). Accuracy decreases as Severity and the number of Fricative and Lateral increases. Accuracy increases as the number of Nasal, Plosive, Affricate, Diphthongs and monophthongs increases.

The word set of the speech corpus includes three types of alphabet word lists whose words are selected based on their ease of articulation. Words in each alphabet word lists and 1-best words among control candidate set are combined to yield three kinds of

Table 1. Estimate of the Manner-Frontness model.

Effects	Intercept	Plosive	Fricative	Affricate	Nasal	Lateral
Estimate	3.96	0.04	−0.26	0.03	0.20	−0.04
Sign.	***		*		*	
Effects	Front	Central	Back	Severity	Diphthong	
Estimate	0.36	0.80	0.44	−1.57	0.08	
Sign.	***	***	***	***		

*** p<0.001,
* p<0.05

baseline word lists. The recognition score of each word is defined as a weighted sum of the number of phonemes in each phoneme class counted from canonical pronunciation and the estimates of the Manner-Frontness model. The word error rate (WER) is the rate of the number of substitution and deletion errors from the total recognition number.

As shown in Table 2, the average WER of 100 trials of the random selection is 17.2 %. WERs using three alphabet word lists are 16.5 ~ 18.2 %. Using the maximum of the number of phonemes as criterion for selecting words shows a 16.8 % rate and using the minimum criterion shows a 21.1 % rate. The differences between the WERs of baselines are not significant.

Table 2. Recognition results

WER, %	Baseline						Recognition Score
	Phonetic Alphabet			Minimum	Maximum	RandomSelection	
	Set 1	Set 2	Set 3				
	18.2	16.5	17.8	21.1	16.8	17.2	13.8

Using the word list with the highest recognition score, a 13.8 % WER is obtained, which is a 16.4 % relative improvement compared to the baseline. The improvement is statistically significant ($p < 0.05$).

3 Conclusions

In this paper, four sets of the articulation features for each word are defined and the relationship between the features and WERs is analyzed using a GLMM. Among the models, the Manner-Frontness model is selected as the best one by the analysis. Estimates of the GLMM are observed and applied to calculate the recognition score. The results from Table 1 that increasing the number of Fricative increases the recognition error rates and the number of Nasal increases the accuracy are consistent with the analysis of the articulation errors of the English dysarthric speech. The difference between monophthong and diphthong is also consistent. The fortis phonemes which are complex to articulate seem to lower the estimate of Plosive. The vocabulary is optimized with words having the maximum recognition score for voice keyboard interface and, as a result, the WER decreases by 16.4 %, relatively. The results would be extended to other language by the mapping between the class of the phoneme in Korean and other language.

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