

Adaptation of Morpheme-based Speech Recognition for Foreign Entity Names

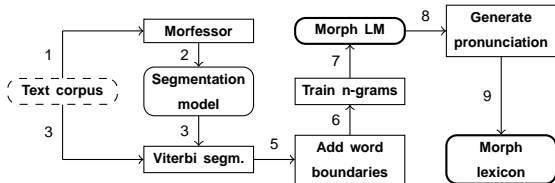
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Introduction

Statistical morph-based language models



Morph n-gram examples:

- <w> expect ing <w> un expect ed ness <w>
- <w> oli <w> oikea staan <w> yllättävä n <w> hyvä <w>

Introduction

- **Morph-based language models for ASR**
 - Statistical morph segmentation successfully used to tackle OOV problem in speech recognition for morphologically rich languages (Finnish, Turkish, Estonian) [1]
 - High recognition error rate still remains for foreign entity names (FENs) [2]

[1] M. Creutz, T. Hirsimäki, M. Kurimo, A. Puurula, J. Pykkönen, V. Siivola, M. Varjokallio, E. Arisoy, M. Saraçlar, and A. Stolcke, Morph-based speech recognition and modeling of out-of-vocabulary words across languages, *ACM Trans. Speech Lang. Process.*, vol. 5, no. 1, pp. 1-29, 2007.

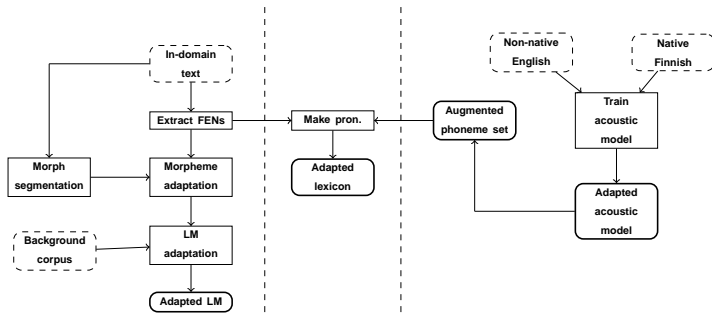
[2] T. Hirsimäki and M. Kurimo, Analysing Recognition Errors in Unlimited-Vocabulary Speech Recognition, *Proc. NAACL-2009*, pp. 193-196, 2009.

Introduction

- **Causes of high FEN error rate in morph-based ASR**
 - Erroneous pronunciation models
 - Out-of-domain or out-of-date background LM
 - Oversegmentation of foreign words (specific for statistical morph-based models)
 - Examples: mcafee \rightarrow m + cafe + e, reading \rightarrow re + a + ding
 - Makes pronunciation modeling difficult and unreliable

Introduction

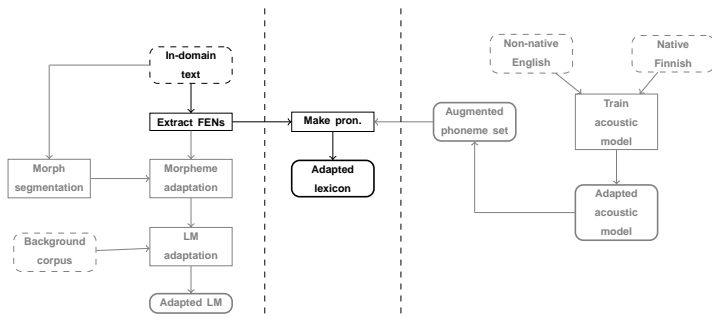
- Adaptation environment for improving FEN recognition



Methods

• Lexicon adaptation

- Extract foreign words from in-domain text
- Generate pronunciation rule
- Add to lexicon



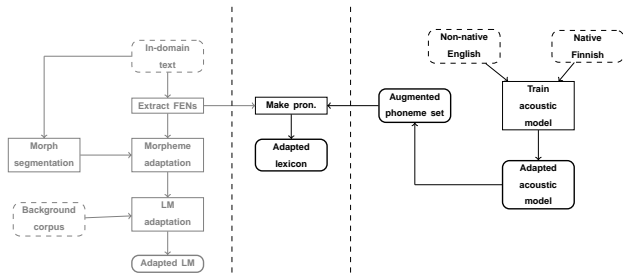
Methods

Acoustic model adaptation

- Train acoustic model with English sentences spoken by Finnish speakers
- Augment native phoneme set with most common non-native phonemes

Phoneme	Word
CH	cheese
JH	george
SH	she
TH	theta

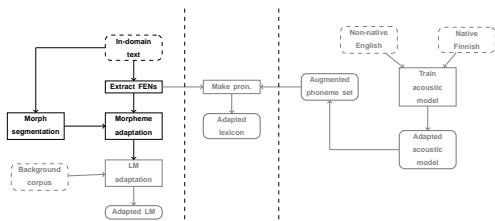
- Use augmented phoneme set to generate pronunciation rules for foreign words



Methods

• Morpheme adaptation

- Oversegmented foreign words in in-domain text restored back in to their base forms
- *sta dium* → *stadium*
com mon we al th → *commonwealth*
- Enables easier pronunciation modeling



• Alternative is morph-aligned pronunciation (morph pron.)

- Align pronunciation rule of a whole word on to separate morphs using maximum-likelihood alignment

stadium
 Stadium **ST EY D I H U W M**

com mon we al th
 Commonwealth **K A H M A O N V E H L I T H**

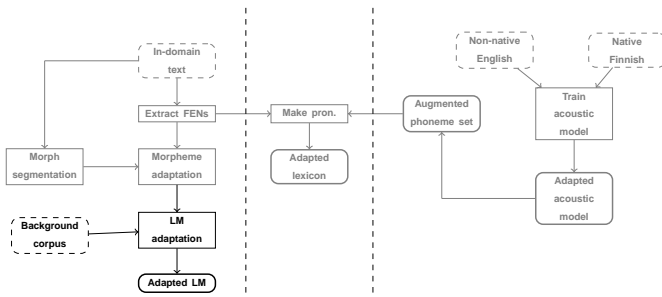
Methods

• Language model adaptation

- Linear interpolation used to adapt background LM $P_B(w|h)$ with in-domain LM $P_i(w|h)$

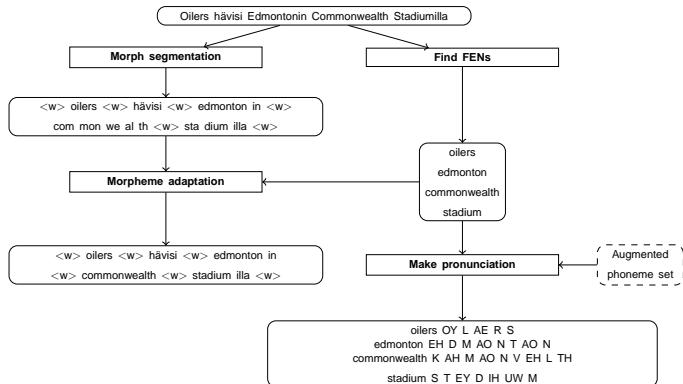
$$P_{adapt_i}(w|h) = \lambda P_i(w|h) + (1 - \lambda) P_B(w|h) \quad (1)$$

- Value of adaptation weight λ determined beforehand



Methods

Example



Experiments

• System&Models

- Aalto speech recognizer [5]
- Background text corpus of 70 million words
 - Morph segmentation model
 - Background LM (n=12, 30k morph vocabulary) trained on segmented corpus with variKN toolkit [6]
- Audio corpus with 20h of speech (Finnish)
 - Baseline acoustic model

• Evaluation data

- Finnish radio news segments in 16kHz audio
 - General news set: 32 segments, 8271 words, 4.8% FENs
 - Sports news set: 43 segments, 6466 words, 7.9% FENs
- Spoken document retrieval set
 - General news: 1609 sentences, 4.0% FENs
 - 171 queries

[5] T. Hirsimäki, J. Pytköinen, and M. Kurimo, Importance of High-order N-gram Models in Morph-based Speech Recognition, *IEEE Trans. Audio, Speech and Lang.*, pp. 724-732, vol. 17, 2009.

[6] V. Siivola, T. Hirsimäki and S. Virpioja, On Growing and Pruning Kneser-Ney Smoothed N-Gram Models, *IEEE Trans. Audio, Speech and Lang.*, Vol. 15, No. 5, 2007.

Experiments

● **LM adaptation data**

- Collected manually from the Web
- On average 2-3 articles per topic featured in the news segments
 - 120 000 words of text gathered for general news set
 - 60 000 words of text gathered for sports news set
 - 60 000 words of text gathered for spoken document retrieval set

● **AM adaptation data**

- English sentences spoken by native Finnish speakers, 70 minutes of 16 kHz audio

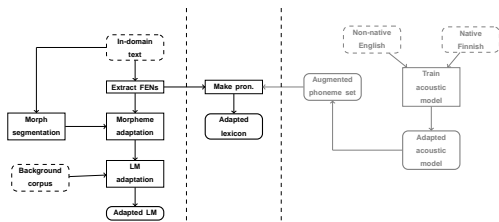
Results - Speech recognition task

- Lexicon, LM, and morpheme adaptation

Baseline acoustic model					
Adaptation method		Results			
		General News		Sports News	
Primary	Additional	WER[%]	FENER[%]	WER[%]	FENER[%]
-	-	21.7	76.8	34.1	80.9
-	Lexicon	21.7	76.6	34.0	80.7
LIN ($\lambda = 0.1$)	-	20.5	68.0	32.1	70.0
	Lexicon	20.4	67.8	32.1	70.4
	Morpheme + Lexicon	19.9	55.7	30.1	52.9
	Lexicon (morph pron.)	20.7	57.9	31.6	54.2

WER = Word error rate

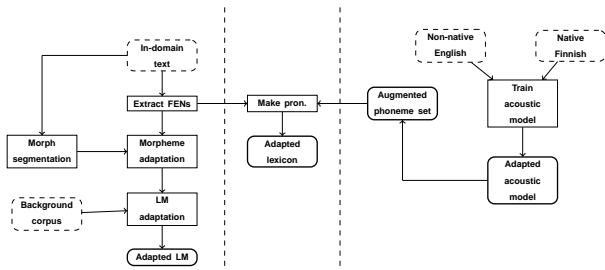
FENER = Foreign entity name error rate



Results - Speech recognition task

- AM adaptation with augmented phoneme set

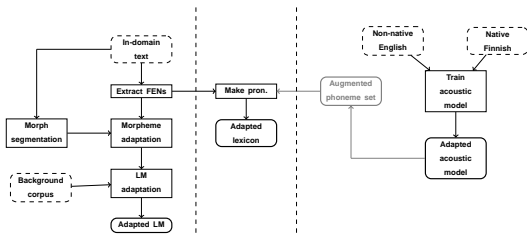
Adapted acoustic model with augmented phoneme set (CH,JH,SH,TH)					
Adaptation method		Results			
		General News		Sports News	
Primary	Additional	WER[%]	FENER[%]	WER[%]	FENER[%]
	-	23.0	77.8	34.7	81.5
LIN ($\lambda = 0.1$)	Lexicon	22.0	64.5	31.3	61.7
	Morpheme + Lexicon	21.6	56.9	30.6	53.8



Results - Speech recognition task

- **AM adaptation with native phoneme set**
- **Non-native phonemes mapped to closest native diphone or triphone context**
 - "S" → "sh", "C" → "tsh", "D" → "dj", "T" → "th"

Adapted acoustic model with native phoneme set					
Adaptation method		Results			
		General News		Sports News	
Primary	Additional	WER[%]	FENER[%]	WER[%]	FENER[%]
	-	21.6	77.3	33.5	80.5
LIN ($\lambda = 0.1$)	Lexicon	20.0	59.4	29.9	60.7
	Morpheme + Lexicon	19.5	51.6	29.1	52.1



Results - Speech retrieval task

ASR results

Baseline acoustic model			
Adaptation method		Results	
		SDR eval. set	
Primary	Additional	WER[%]	FENER[%]
-		29.9	64.4
LIN ($\lambda = 0.1$)	Lexicon	29.2	50.4
	Morpheme + Lexicon	29.3	51.7

Ranked Utterance Retrieval results

- Mean Average Precision (MAP)

System	Indexing		
	Baseform	Morph	Combined
Baseline	0.4643	0.6296	0.6861
LIN + Lexicon	0.4651	0.6317	0.6915

Conclusions

- **Adaptation framework improves recognition of foreign words**
- **Positive effect on FEN recognition**
 - LM adaptation
 - Lexicon + Morpheme adaptation
 - Morph-aligned pronunciation
 - AM adaptation (native phoneme set)
- **Future work**
 - Fully unsupervised adaptation framework (partially implemented [7])
 - Adaptation of acronyms

[7] André Mansikkaniemi and Mikko Kurimo. Unsupervised vocabulary adaptation for morph-based language models. In Proceedings of the NAACL 2012 Workshop on the Future of Language Modeling for HLT. ACL, June 2012.