Conversational Telephone Speech Recognition for Lithuanian

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Introduction

Goal: develop a conversational telephone speech recognition system for the low-resourced Lithuanian language

Questions

- Phoneme-based system better than grapheme-based system?
- How can additional resources improve system performance?
  1. Web texts
  2. Untranscribed audio

Outline

- Conversational telephone speech
- Description of Lithuanian language
- Speech-to-text and Keyword spotting systems
- Data set
- Baseline recognition systems
- Experiments
- Conclusions

Conversational Telephone Speech

Transcribing conversational telephone speech is a complex task

- Silence can be inserted between words
- High variability of speaking rates and styles
- Grammar rules of written language not strictly followed
- Hesitations: *ah, uhs, ums*
- Filler words and phrases: *yeah, you know*
- False starts, aborted or stuttered words: *let's meet mon- no tuesday*
- Non verbal sounds: *breathing, tongue clicks*
- Limited frequency bandwidth, noisy audio channels

iARPA Babel Project

www.language-service.co.nz

Apply lingustic, machine learning, and speech processing methods to enable speech recognition for keyword search (Harper, ASRU 2013, Coling 2014)
http://www.iarpa.gov/index.php/research-programs/babel

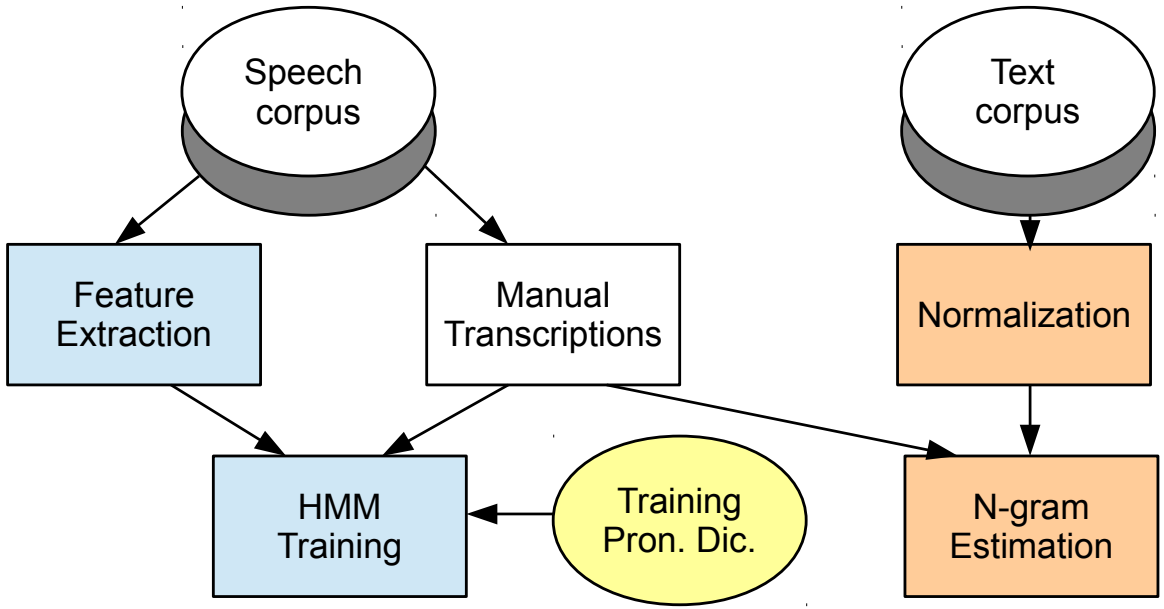
Lithuanian language

- 3.5 million speakers
- Baltic subgroup of Indo-European languages
- 2 dialects - Aukštaitian and Samogitian

Lithuanian language

- Based on Latin alphabet, 32 letters
- Some letters occur in recent loanwords
  1. *f* - filmas 'film', *ch* - chaosas 'chaos', *h* - humoras 'humor'
- Inflected language
  1. 5 of 11 parts of speech are inflective: noun, verb, adjective, numeral, and pronoun
  2. Words composed of root, stem, prefix, suffix, and ending
- Flexible word order in sentence
- 3 types of stresses, meaning of some words can be distinguished by stress

System training resources



- Acoustic model: telephone speech recordings with transcriptions
- Language model: written text
- Pronunciation dictionary
  1. Graphemes - easily derived
  2. Phonemes - linguistic skills, better represent speech production

Low resourced language

- Little acoustic data with corresponding transcriptions
- Text and untranscribed audio can be found on the Internet

Lithuanian phonemic inventory

Vowels	
a, ą	/a/, /ɑ/
e, ę, ė	/ɛ/, /æ/, /e:/
i, į, y	/i/, /i:/, /i:/
o	/o:/, /ɔ/
u, ų, ū	/ʊ/, /u:/, /u:/

- 32 letters
- 56 phonemes, 45 consonants and 11 vowels
- Consonants soft (palatalized) or hard (not palatalized)
- 8 diphthongs /ai/, /aʊ/, /ei/, /ʊi/, /oʊ/, /o:i/, /iɛ/, /ʊo:/
- 4 affricates /ts/, /ʧ/, /dz/, /dʒ/

Lithuanian phonemic inventory

	Consonants		
p	/p/,/p^{j}/	dz	/dz/,/dz^{j}/
b	/b/,/b^{j}/	č	/ʧ/,/ʧ^{j}/
t	/t/,/t^{j}/	dž	/dʒ/,/dʒ^{j}/
d	/d/,/d^{j}/	m	/m/,/m^{j}/
k	/k/,/k^{j}/	n	/n/,/n^{j}/
g	/g/,/g^{j}/	l	/ɫ/,/l^{j}/
v	/v/,/v^{j}/	r	/r/,/r^{j}/
s	/s/,/s^{j}/	j	/j/
z	/z/,/z^{j}/	f	/f/,/f^{j}/
š	/ʃ/,/ʃ^{j}/	ch	/x/,/x^{j}/
ž	/ʒ/,/ʒ^{j}/	h	/ɣ/,/ɣ^{j}/
c	/ts/,/ts^{j}/		

- Consonants are soft before the vowels /ɛ/, /æ/, /ė:/, /i/, /i:/
- Classes of sounds
  1. Voiced /b/, /d/, /g/, /z/, / ʒ/, /ɣ/, /dz/, /dʒ/, /v/, /j/, /m/, /n/, /ɫ/, /r/
  2. Voiceless /p/, /t/, /k/, /f/, /s/, /ʃ/, /x/, /ts/, /ʧ/

Grapheme to phoneme rules

Lithuanian has quite strong dependency between orthographic transcription and phonetic form

- *ia*, *iau*, *iai* pronounced *e*, *eu*, *ei*
  lauk**ia** /ɫaʊkɛ/ (waits)

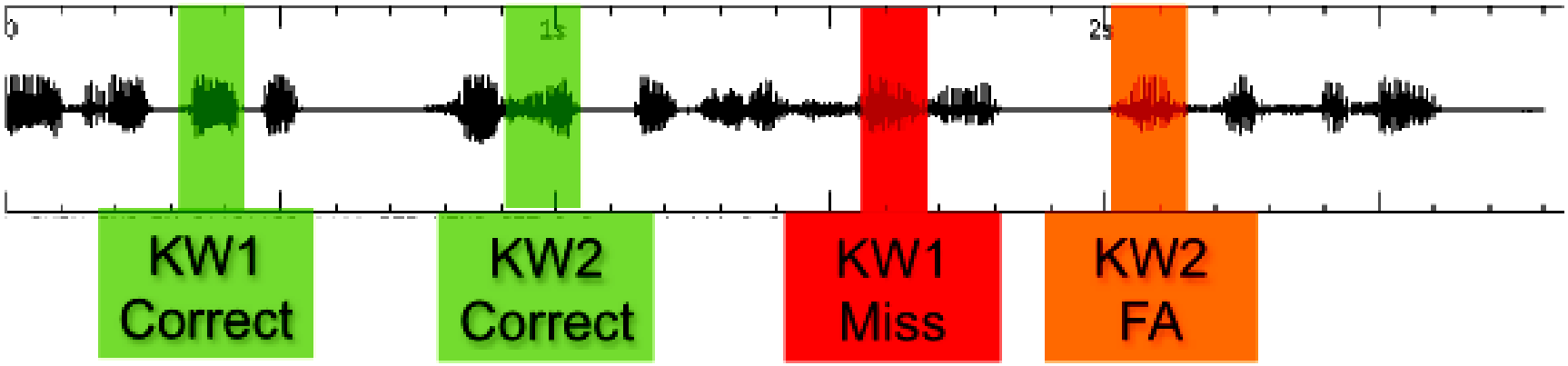
- voiceless consonants *p*, *t*, *k*, *s*, *š* before voiced *b*, *d*, *g*, *z*, *ž* are pronounced like voiced (anticipatory coarticulation)
  su**k**damas /sʊgdamas/ (turning)

- voiced consonants *b*, *d*, *g*, *z*, *ž* before voiceless *p*, *t*, *k*, *s*, *š* are pronounced like voiceless
  dir**b**ti /dirpti/ (to work)

- voiced consonants *b*, *d*, *g* at the end of word are pronounced like voiceless
  ka**d** /kat/ (that)

- ....

Keyword spotting system



- Keyword Spotting (KWS) - find only certain words
- Two types of errors - miss and false alarm
- Keywords
  1. Out-of-vocabulary (OOV) are missing keywords from the ASR system vocabulary
  2. In-vocabulary (INV)
- Performance metrics
  1. Actual term-weighted value (ATWV)
  2. Maximum term-weighted value (MTWV)

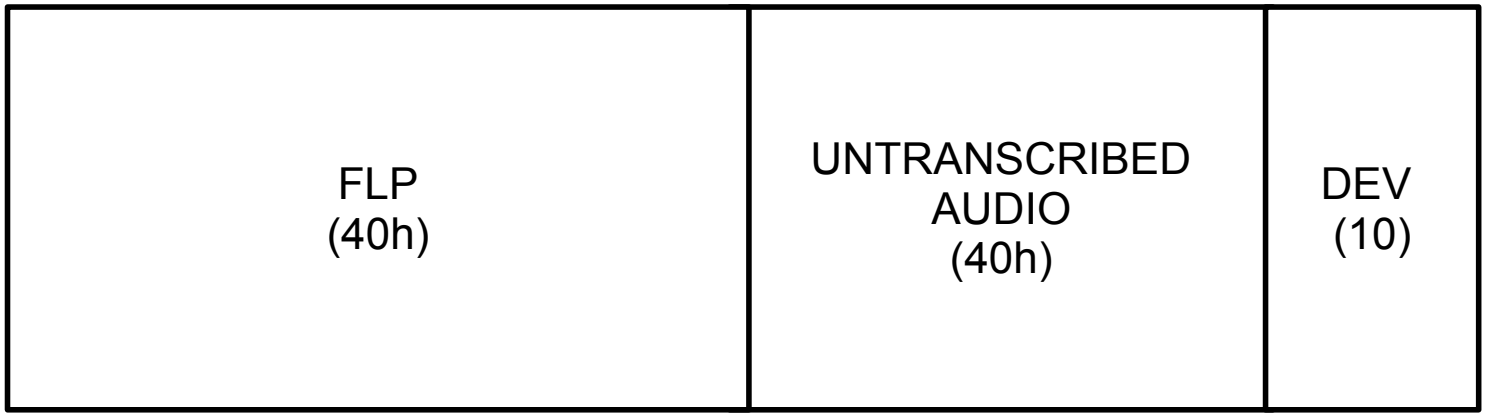
Data set

- 40 h with transcripts (+40 untranscribed) (Full Language Pack (FLP))
  1. IARPA-babel304b-v1.0b dataset
- 3 h trans (+77 untranscribed) (Very Limited Language Pack (VLLP))
- Web text corpora 26M word tokens
- Results reported
  1. Speech-to-text (STT) system on 10 hour dev set
  2. KWS on 4079 keywords for FLP condition, 10% OOV

Baseline recognition systems

- Speech-to-text system
  1. Left-to-right 3-state HMMs with Gaussian Mixtures
  2. Word position-dependent triphone-based models, tied-state
  3. Stacked bottleneck features, provided by Brno University of Technology [Grézl et al, 2013]
  4. Semi-supervised training (SST)
  5. 3-gram backoff LMs with Kneser-Ney smoothing
- Keyword spotting system
  1. Lattices converted to confusion networks
  2. Exact matches considered, though case and whitespace ignored
  3. Word and sub-word (character 7-gram) units [Hartmann et al, 2014]

FLP available data



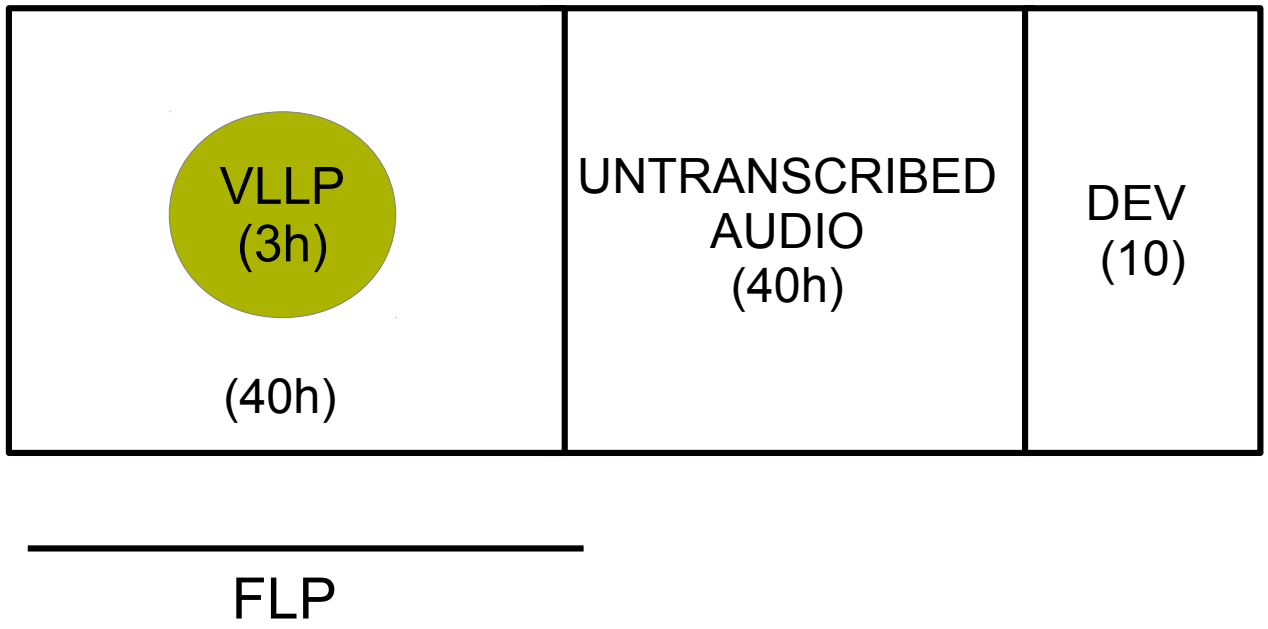
STT and KWS results for FLP systems

System	#Units	Modification from baseline
FLP graph-baseline	35	graphs
FLP phone-baseline	32	phones
FLP phone	36	affricates
FLP phone	38	diphthongs [except ou, oi]
FLP phone	48	soft consonants [except soft ch]

System	#Units	%WER	MTWV(all/inv/oov)
graph-baseline	35	44.6	0.579/0.592/0.472
phone-baseline	32	44.7	0.576/0.591/0.476
phone	36	44.6	**0.580/0.593/0.487**
phone	38	**44.4**	0.576/0.591/0.460
phone	48	44.6	0.573/0.587/0.472

- Affricates separate unit, slight improvement in MTWV (36 phones)
- Diphthongs separate units, 0.3% decrease in WER (38 vs 32 phones)
- Best phone-system 0.2% absolute lower WER than graph-system

VLLP available data



WER results for VLLP systems

System	#Units	Modification from baseline
VLLP graph-baseline	33	graphs, c→ts, f→v
VLLP graph	29	z→s, ch→ɣ, ę→ɛ, į,y→i:, ū,ų→u:
VLLP phone-baseline	31	phones, f→v
VLLP phone	29	z→s, ch→ɣ, ę→ɛ, į,y→i:, ū,ų→u:

System	#Units	%WER
graph-baseline	33	52.6
graph	29	**52.2**
phone-baseline	31	52.3
phone	29	**52.0**

- Results slightly better when number of units reduced
- Best phonemic system about 0.2% lower WER than best graphemic system

WEB and SST

- In our experiments
  1. FLP→ manual transcriptions for LM
  2. VLLP → manual and WEB texts for LM, untranscribed data for AM
- WEB texts and SST help to reduce gap between FLP and VLLP
- What is impact of WEB texts and SST for both FLP and VLLP systems?

WER results for different conditions

Set	Hours	AM	LM	Lexicon	%OOV	%WER
FLP	40	trn	trn	30k	7.6	44.4
FLP	73	trn + SST	trn	30k	7.6	44.8
FLP	40	trn	trn + web	60k	5.2	**42.4**
FLP	73	trn + SST	trn + web	60k	5.2	42.4
VLLP	3	trn	trn	5.7k	16.7	59.3
VLLP	41	trn + SST	trn	5.7k	16.7	59.0
VLLP	3	trn	trn + web	60k	6.0	53.3
VLLP	41	trn + SST	trn + web	60k	6.0	**52.0**

- FLP 40 vs VLLP 3: reduces absolute WER by 15%
- Web texts: for VLLP the WER is reduced by 6%, under 2% for FLP
- SST improves VLLP both with and without Web data
- Best VLLP WER remains 10% behind of FLP

Conclusions

- Developed conversational telephone speech recognition system for Lithuanian, a low-resourced language
- Compared phoneme-based and grapheme-based systems
  1. Phonemes give only a slight improvement for two training conditions (3 or 40 hours of transcribed audio data)
  2. Strong relationship between the orthographic and phonemic forms in Lithuanian
- Explored impact of Web texts for training language models, and untranscribed data for semi-supervised training of acoustic models
  1. Adding Web texts to FLP system gave an improvement of about 2%
  2. VLLP system was improved more 7% absolute using both Web data and semi-supervised training

Thank you for your attention!

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