



STATISTICAL PHRASE-BASED SPEECH TRANSLATION

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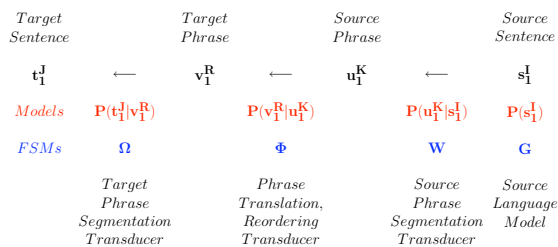


Introduction

- Objective: Tight integration of Automatic Speech Recognition (ASR) and phrase-based Statistical Machine Translation (SMT) systems.
 - ASR word lattices as input to the SMT system
 - Lattices encode a larger search space
 - Exploit sub-sentential information
- Modeling issues:
 - Propagation of ASR information to the SMT component
 - Correct disfluencies, hesitations, spontaneous speech effects...
 - Efficient phrase extraction
- Previous work:
 - (E. Matusov et al 2005) reported translation gains using word lattices
 - (Bertoldi et al 2005) used confusion networks for integration with the SMT system
- We present: Generative source-channel model of speech to text translation.
 - Tight coupling of the ASR and SMT system using word lattices
 - Implemented using weighted finite state machines (WFSMs)
- So what's new?
 - Conditional models vs joint models of target-source generation
 - Unified modeling framework
 - No need for extensive reformulation of underlying ASR and SMT models
 - Simpler decoding and estimation procedures
 - Lattice translation is a direct extension of our text translation systems

Generative Model of Text Translation

- Noisy channel model for text translation



- Translation system translates phrase sequences and not word sequences
 - Target phrase sequence acceptor $Q = \text{project_input}[\Omega \circ T]$
 - T is an acceptor for target word sequence t_1^J
 - A phrase sequence is a sequence of words to be translated
 - Different phrase sequences lead to different translations
 - Phrase sequence acceptor is unweighted

- The final translation is given by

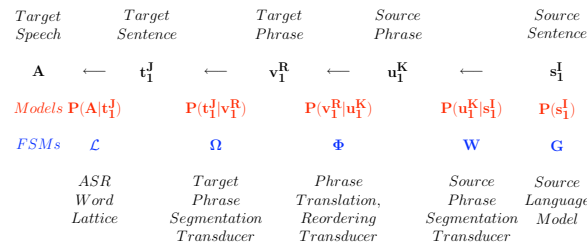
$$\hat{s}_1^I = \text{argmax}_{s_1^I} \{ \max_{v_1^R, u_1^K} P(t_1^J, v_1^R, u_1^K, s_1^I) \}$$

- Implemented as a best-path search through the translation FSM T

$$T = G \circ W \circ \Phi \circ Q$$

Generative Model of Speech Translation

- Noisy channel model for speech translation



- The ASR word lattice is one of the components in the noisy channel model
- The translation system translates the lattice of phrase sequences
 - Q is obtained by applying Ω to the ASR lattice L
 - Unlike the text translation case, Q is a weighted acceptor with scores from the acoustic word lattice attached to it.
- The final translation is given by

$$\hat{s}_1^I = \text{argmax}_{s_1^I} \left\{ \max_{t_1^J, v_1^R, u_1^K} P(A, t_1^J, v_1^R, u_1^K, s_1^I) \right\}$$

- Implemented as a best-path search through the translation FSM T

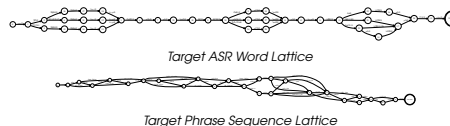
$$T = G \circ W \circ \Phi \circ Q$$

Transforming ASR Word Lattices into Phrase Lattices

- Reformulate speech translation as a modeling problem
 - Efficient extraction of phrases from ASR word lattice
- ASR lattice pre-processing
 - Map unspoken tokens to NULL
 - Standard FSM operations: epsilon removal, determinization and minimization
- Controlling ambiguity in the ASR word lattice
 - Path based likelihood pruning of ASR word lattices
 - Extracting phrases under the posterior distribution

$$Q = P(v_1^R | A) = \frac{\sum_{t_1^J} P(v_1^R | t_1^J) P(A | t_1^J) P(t_1^J)}{P(A)}$$

- What about the target LM $P(t_1^J)$?
 - Shown to improve translation
 - Doesn't show up in the noisy channel model
 - Need to reformulate the SMT models to properly incorporate the target LM.
- Phrase extraction from ASR word lattice
 - Lattice subsequences of limited length
 - GRM Library tools for counting subsequences in a WFSM



Speech to Text Translation Performance

- 2005 TC-STAR Mandarin Broadcast News Translation Task

- 6 Mandarin news broadcasts, manually segmented and transcribed into Chinese sentences (525 for DEV set, 495 for EVAL set)
- 2 English reference translations per sentence for translation.
- Mandarin ASR lattices generated by LIMSI, corresponding to 231 segments for DEV set and 181 segments for EVAL set.

- Translation system: similar to 2005 JHU/CU NIST Chinese-English SMT system.

- Document level BLEU for evaluating translation performance.

- Mandarin Broadcast News Translation Performance

	Mandarin Source	DEV	EVAL
Monotone	Ref. Transcription	16.1	18.8
Phrase Order	ASR 1-Best	14.8	13.6
	ASR lattice	15.0	13.8
MJ-1 VT Phrase Reordering	Ref. Transcription	16.1	19.3
	ASR 1-Best	15.0	13.8
	ASR lattice	15.1	14.0

- How many new foreign phrases does speech translation introduce?

	DEV transcriptions	ASR Lattice
#Chinese phrases	44744	58395

- How many new foreign phrases were found in bitext?

	DEV transcriptions	ASR Lattice
#Chinese phrases	11617	12983
# English phrases	59589	60574

- Extracting phrases from ASR lattice doesn't result in a larger phrase inventory
 - Disfluencies in speech - different modeling approaches for phrase extraction
 - Mismatch in tokenization for the Chinese ASR lattices

Conclusion

- Presented a modeling framework for statistical speech-to-text translation

- Extension of the phrase-based TTM text translation model
- Tight coupling of the ASR and SMT subsystems using lattices both as
 - * Statistical models
 - * WFSM based implementation
- Demonstrated feasibility of the above approach.

- Future Work

- Initial formulation and implementation has weaknesses
 - * Proper integration of the target language model
 - * Phrase extraction under the posterior distribution
 - * Improved pruning strategies for word lattices
 - * Improved phrase coverage
- Integrated development of the component ASR and SMT systems.