ASR inspired syllable stress detection for pronunciation evaluation without using a supervised classifier and syllable level features

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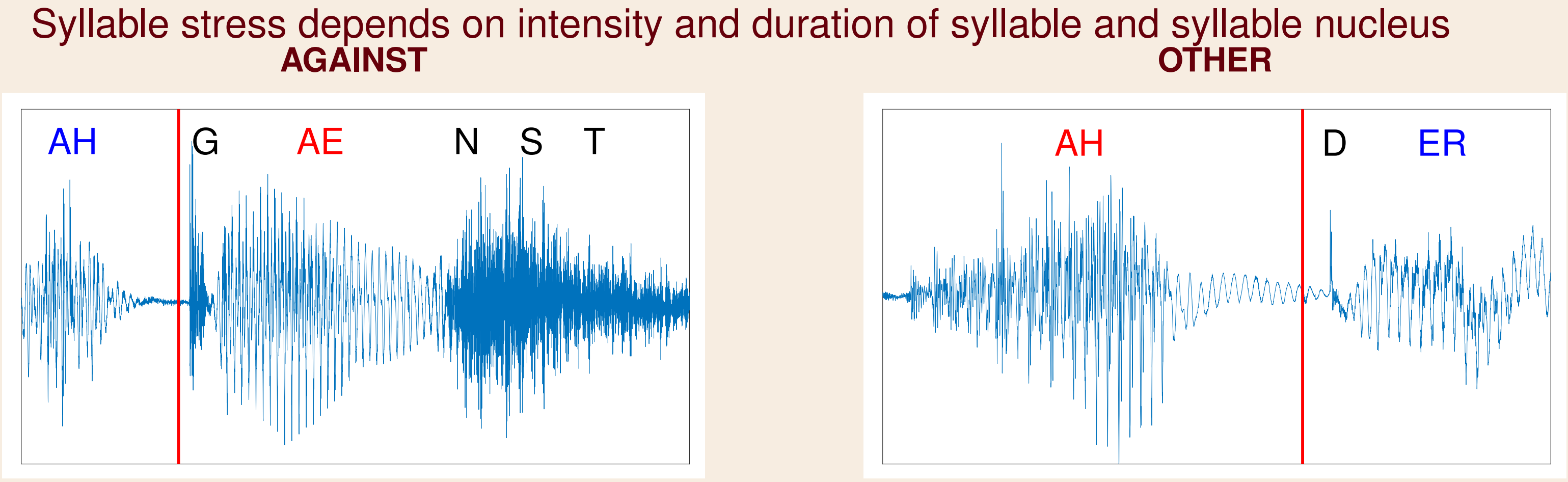
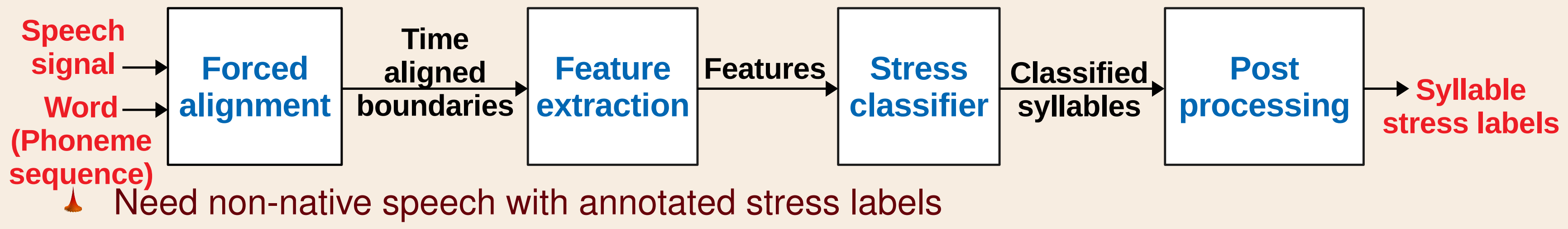
PROBLEM STATEMENT

- **Task:** To detect syllable stress in polysyllabic words spoken by non-native English speakers
- Syllable stress depends on intensity and duration of syllable and syllable nucleus

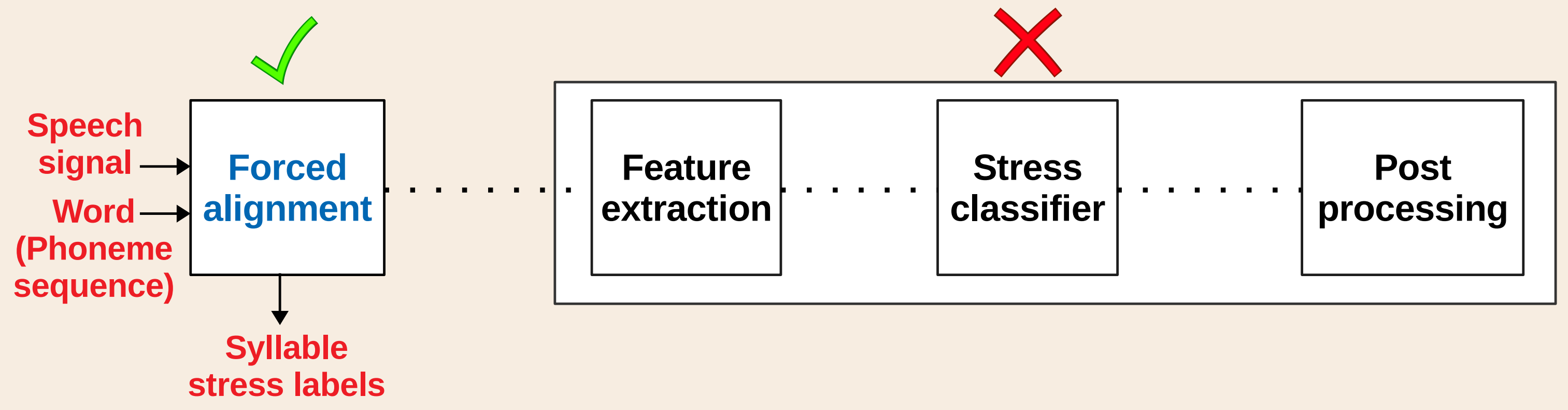


Typical approach:

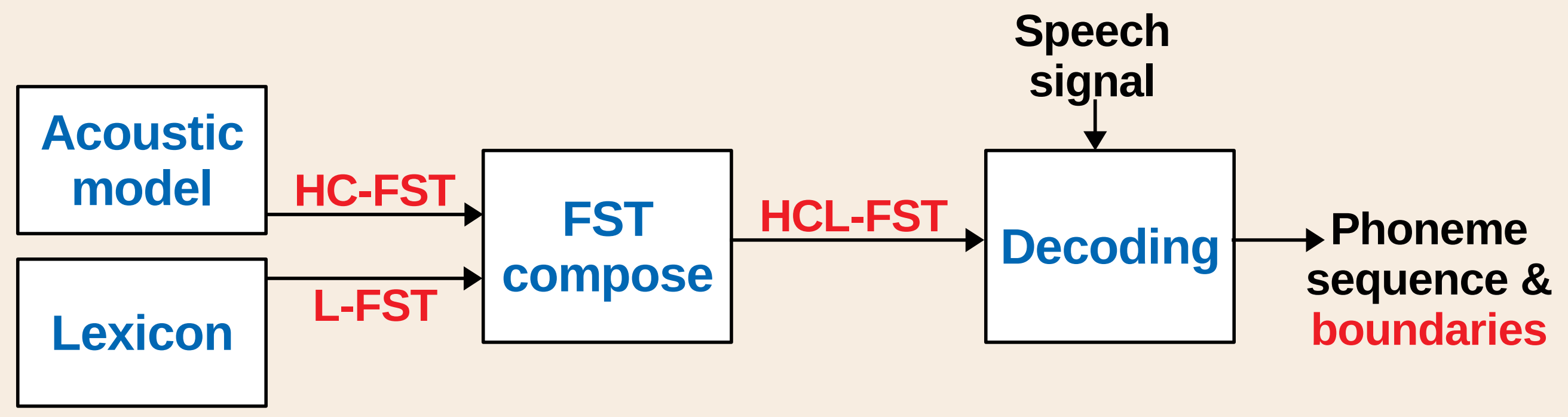


- Need non-native speech with annotated stress labels
- Inaccurate syllable/syllable nuclei boundaries due to typical forced alignment

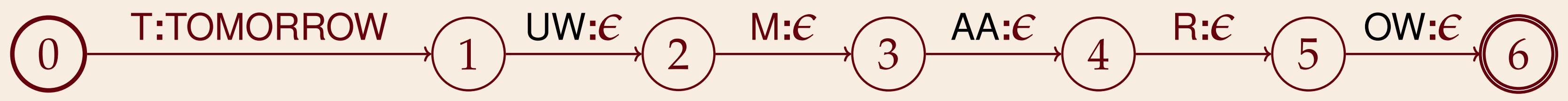
Our approach:



TYPICAL FORCED ALIGNMENT



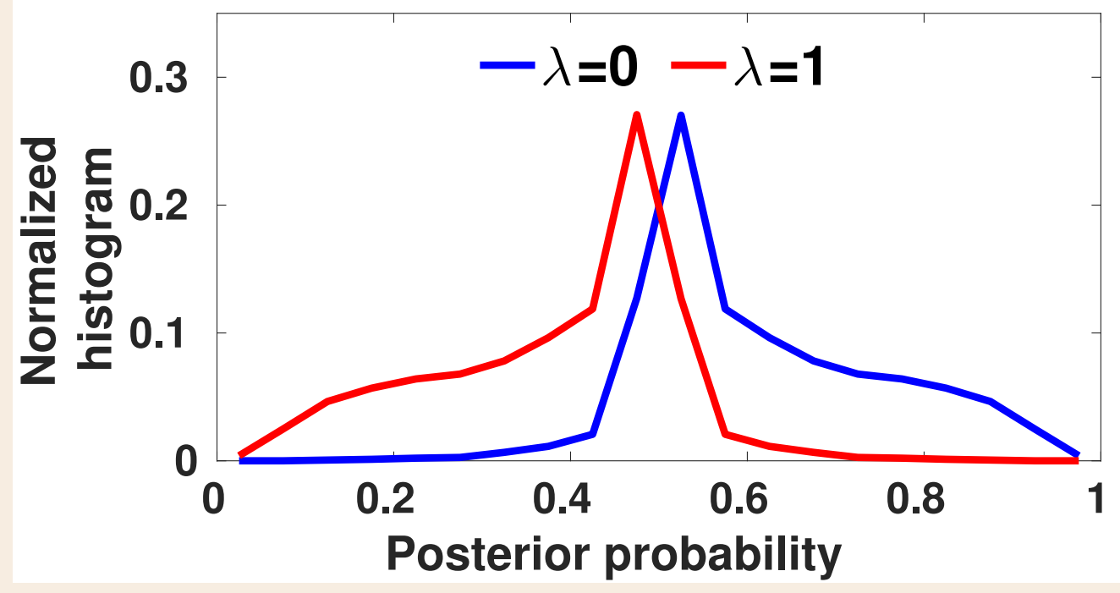
- Forced alignment is done through decoding using acoustic model and lexicon
- Acoustic model and lexicon are represented through finite state transducers (FSTs)
- Exemplary L-FST for the word **TOMORROW** (**T UW M AA R OW**)



MOTIVATION

- p - syllable nucleus phoneme (e.g., UW), λ - stress label (0,1), **O** - acoustic segment of p
- $\mathcal{P}(\lambda)$ - prior, $\mathcal{P}(\mathbf{O}|p,\lambda)$ - likelihood, $\mathcal{P}(\lambda|\mathbf{O},p)$ - posterior probability

$$\mathcal{P}(\lambda|\mathbf{O},p) = \frac{\mathcal{P}(\mathbf{O}|p,\lambda)\mathcal{P}(\lambda)}{\sum_{\lambda\in\{0,1\}} \mathcal{P}(\mathbf{O}|p,\lambda)\mathcal{P}(\lambda)}$$



Distribution of posterior probability of unstressed acoustic segments

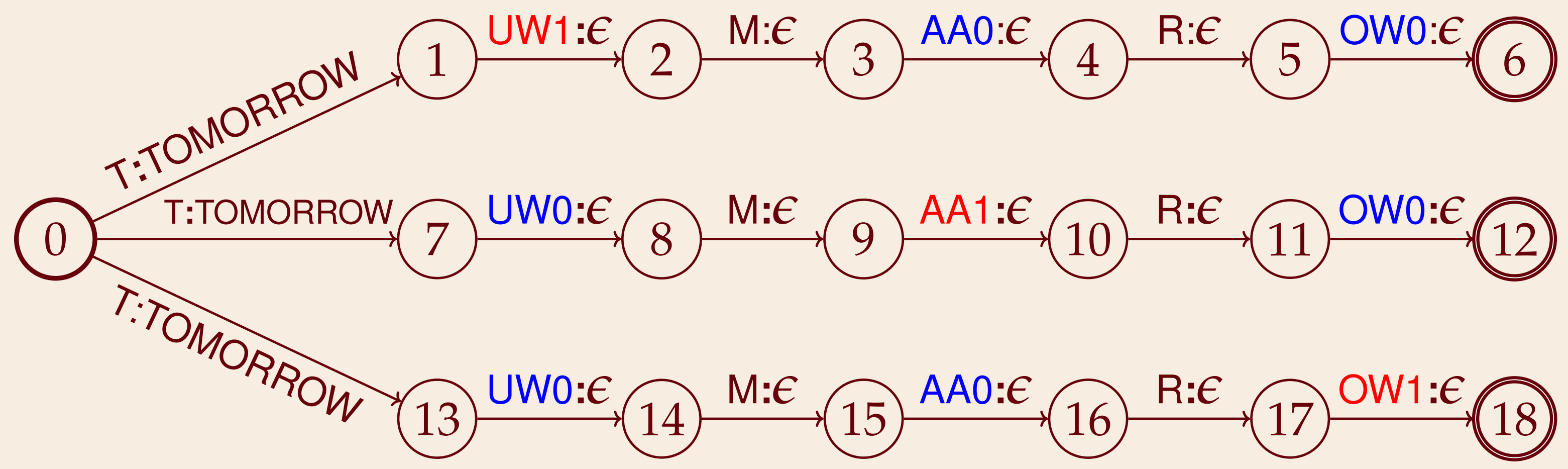
PROPOSED APPROACH

Modified forced alignment:

- Acoustic model with phoneme set containing stressed and unstressed vowel phonemes (syllable nuclei)
- Lexicon with **Stress Encoded Syllable Nuclei** (**SESN**): label 0 for no stress ⟹ UW0 for unstressed UW; label 1 for stress ⟹ UW1 for stressed UW

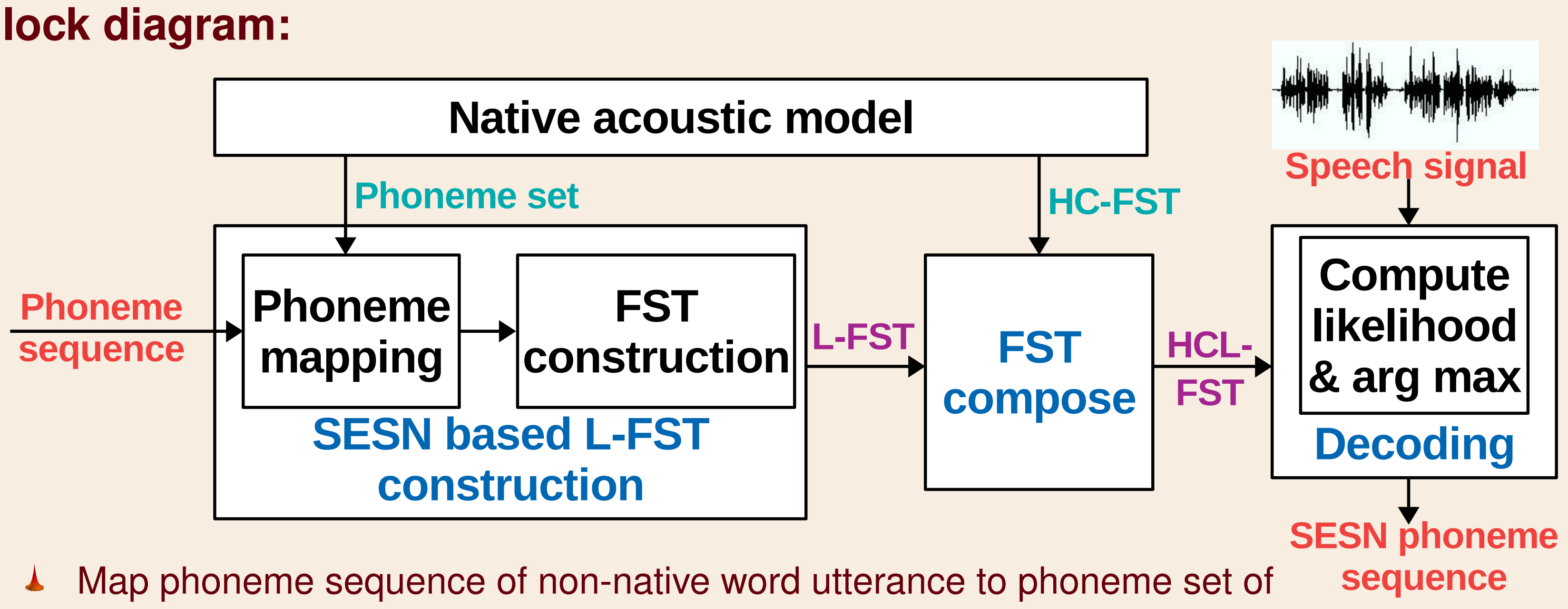
T UW1 M AA0 R OW0
T UW0 M AA1 R OW0
T UW0 M AA0 R OW1

SESN based L-FST:



- Phoneme sequence with *N* syllable nuclei has *N* stress variant pronunciations and hence *N* paths in SESN based L-FST

Block diagram:



- Map phoneme sequence of non-native word utterance to phoneme set of native acoustic model
- Construct SESN based L-FST
- Compose HC-FST of acoustic model and constructed L-FST
- Decode the maximum likely SESN based phoneme sequence

EXPERIMENTAL SETUP

Native acoustic model data:

- 960 hours of LibriSpeech (**Libri**)
- 30 hours of LibriSpeech (**Libri-S**)
- 30 hours of Wall Street Journal (**WSJ**)

Non-native stress detection data:

- **ISLE** corpus[1] - English utterances by 10 Italians (**ITA**) and 11 Germans (**GER**)
- Manually annotated stress labels for polysyllabic words
- Distribution of bisyllabic (**B**), trisyllabic (**T**) and quadrisyllabic (**Q**) words which form overall (**O**) words across **ITA** and **GER**:

	B	T	Q	O
ITA	1873	433	82	2388
GER	2360	578	99	3037

- **Metric**: syllable stress detection accuracy

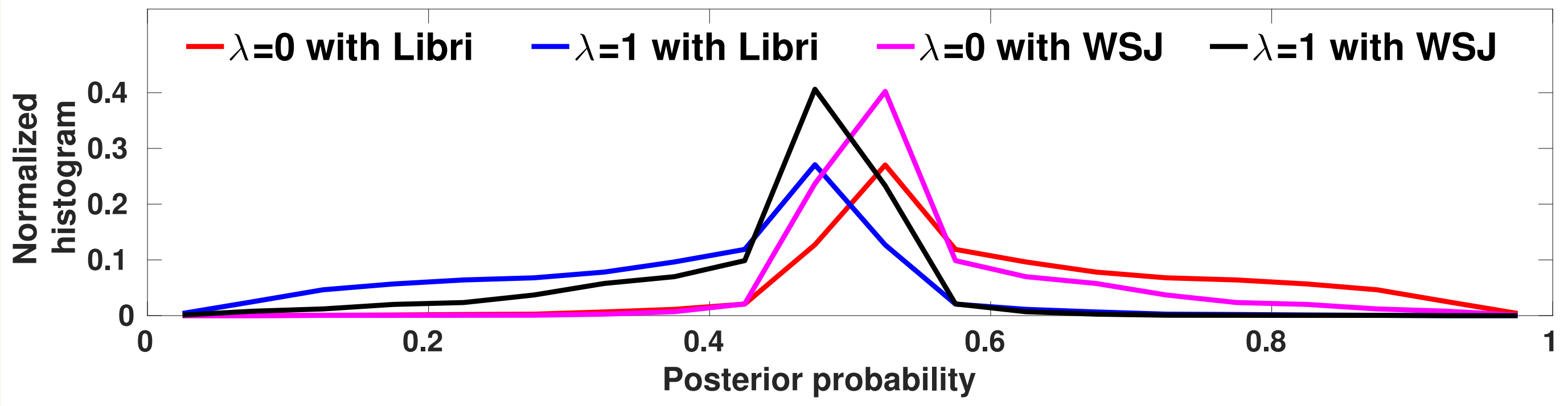
RESULTS & DISCUSSION

Comparison of proposed approach (PA) with baselines:

- Supervised baseline approaches - **BL-1**[2], **BL-2**[3]

	BL-1	BL-2	PA		
			Libri	Libri-S	WSJ
ITA	83.17	86.26	**85.24**	75.39	72.05
GER	85.81	87.53	**87.00**	79.32	75.33

- Although unsupervised, proposed approach performs on par with supervised baselines
- Sensitive to the amount of training data of acoustic models
- Number of syllable nuclei with posterior probability < 0.5 for $\lambda = 0$ is higher for WSJ than Libri



Performance across word lengths:

		ITA			GER		
		B	T	Q	B	T	Q
BL-2		88.85	86.97	77.21	89.13	84.31	73.58
PA	Libri	86.92	83.37	76.83	87.02	**89.27**	**74.24**
	Libri-S	76.13	72.13	**79.88**	78.22	81.43	**83.33**
	WSJ	71.70	72.90	72.56	75.04	76.93	**75.25**

- Performs better than BL-2 on words with more than two syllables

CONCLUSION

- Syllable stress detection in ASR framework performs on par with supervised baselines
- Train native acoustic model with phoneme set containing both stressed and unstressed syllable nuclei and construct lexicon with multiple phoneme sequences containing SESN

Future work:

- Methods for stress detection when the input phoneme sequence is unavailable
- Analysis of first language specific tendencies for mis-placing syllable stress

ACKNOWLEDGEMENT

Authors thank the **Department of Science & Technology, Government of India** and the **Pratiksha Trust** for their support

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