# Computer-Assisted Pronunciation Training

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# Outline

- Introduction
- Mispronunciation patterns of non-native speakers
- Research approaches
- Challenges and research opportunities

# Introduction

- With increasing globalization, there has also been a significant increase in the demand for foreign language learning

分时共用的教师资源

# Introduction

- CAPT特点
  - 方便学生进行大量发音练习和测试
  - 个性化学习进度
  - 方便教师掌握学生发音情况
  - 提升发音评测的客观性

# Introduction

- Applications of CAPT can be divided into two areas:
  - Pronunciation assessment
  - Pronunciation learning/teaching
    - Segmental (phonetic)
    - Subsegmental (e.g., place of articulation, manner of speech)
    - Suprasegmental (prosodic)

# Mispronunciation patterns of non-native speakers

- Pronunciation errors are usually characterized at the phonetic(segmental) or prosodic (suprasegmental) level
  - Phonetic Errors
    - Substitutions
    - Insertions
    - Deletions

# Mispronunciation patterns of non-native speakers

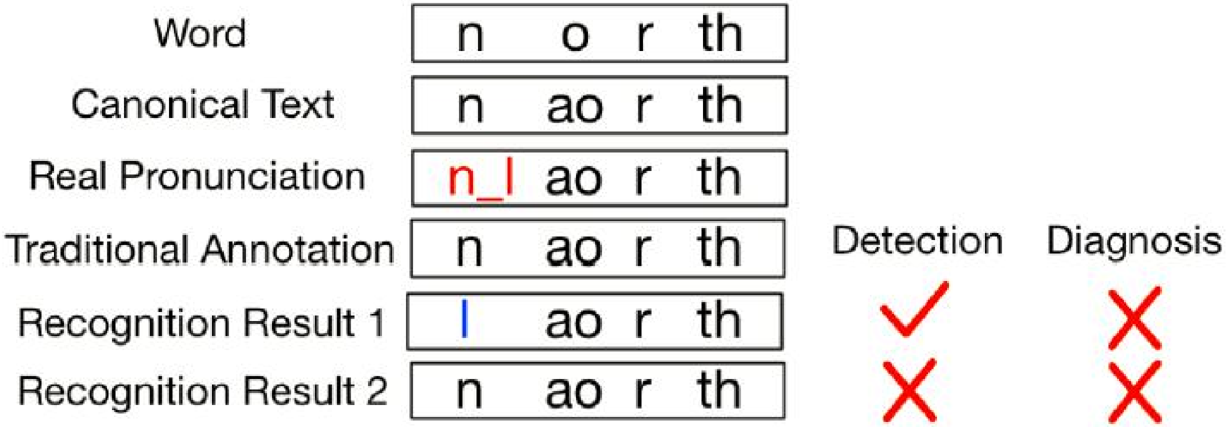
- Different phontactic constraints across languages might result in deletion and insertion errors
    - Only certain consonants are allowed at syllable final positions
        - “face” might be pronounced as “fay”
    - Consonant clusters are not allowed in Vietnamese either
        - Vowels might be inserted in between consonants when Vietnamese speakers learn English

# Mispronunciation patterns of non-native speakers

- Phonetic substitutions occur because of approximating L2 phonemes with L1 phonemes
    - In Mandarin and Spanish, there are no short vowels
        - Words like “eat” and “it” might sound similar
- Sometimes the non-native phone is neither in L1 or L2. It could be in between

# Mispronunciation patterns of non-native speakers

- Most existing approaches to modeling L2 speech can only target categorical phoneme error types based on the native phoneme set



|  |  |  |  |  | Detection | Diagnosis |
|---|---|---|---|---|---|---|
| Word | n | o | r | th |  |  |
| Canonical Text | n | ao | r | th |  |  |
| Real Pronunciation | n_l | ao | r | th |  |  |
| Traditional Annotation | n | ao | r | th |  |  |
| Recognition Result 1 | l | ao | r | th | ✓ | ✗ |
| Recognition Result 2 | n | ao | r | th | ✗ | ✗ |

**Fig. 1.** An example for how non-categorical mispronunciations are wrongly treated in traditional MDD

# Mispronunciation patterns of non-native speakers

- In terms of intelligibility, prosody is as important as phonetic accuracy
  - Prosodic Errors
    - Stress
    - Rhythm
    - Intonation

# Mispronunciation patterns of non-native speakers

- Stress: the specific emphasis given to a particular syllable or word
  - Acoustic： greater loudness, higher pitch, and longer duration
  - The stress placed on syllables within words are called lexical stress or word stress
  - Stress placed on words within sentences are called sentence stress or prosodic stress

# Mispronunciation patterns of non-native speakers

- In Bengali（孟加拉语） is fixed (restricted to the initial syllable of a word)

- English has variable stress

# Mispronunciation patterns of non-native speakers

- Rhythm: the temporal pattern of how a language is spoken
  - English and German are stress-timed
    - Some syllables are long while others (unstressed syllables) are short
  - French and Spanish are syllable-based
    - Each syllable is spoken at a regular interval

# Mispronunciation patterns of non-native speakers

- Intonation: the variation in pitch
  - Intonation helps the listener parse the boundaries in speech
  - Intonation also helps convey the speaker’s attitude and emotions
- tonal languages such as Mandarin Chinese and Vietnamese
  - Variation in pitch can result in words with different meanings

# Research approaches

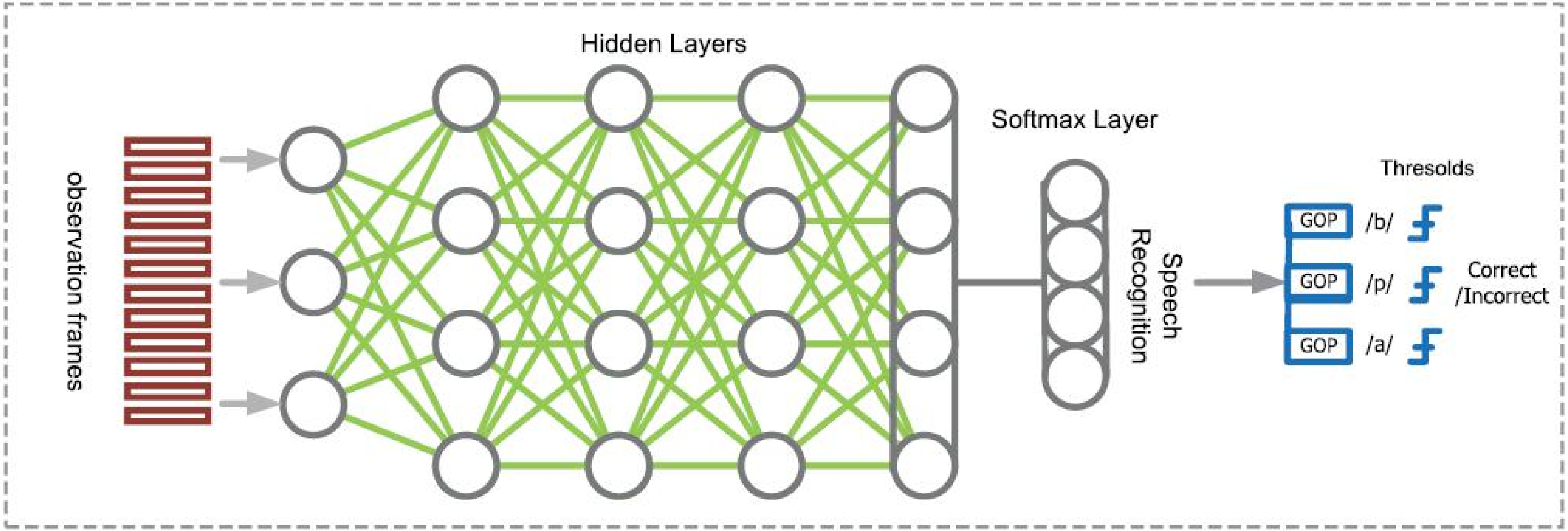
- Frameworks for Detecting Phonetic Errors：
  - ASR is often a natural component in a CAPT system
  - The ASR system can be trained with just native speech or with both non-native speech and native speech

# Research approaches

- Frameworks for Detecting Phonetic Errors：
  - Likelihood-Based Scoring（GOP）
  - Classifier-Based Scoring
  - Extended Recognition Network（ERN）
  - Unsupervised Error Discovery

# Research approaches

- Likelihood-Based Scoring（GOP）



# Research approaches

- Likelihood-Based Scoring（GOP）

$$\mathrm{GOP}(\mathrm{p}) = \log \frac{\mathrm{P}(\mathrm{O} \mid \mathrm{p})}{\max_{\mathrm{q}\in\mathrm{Q}} \mathrm{P}(\mathrm{O} \mid \mathrm{q})}$$

Q为所有音素的集合，p标准phone，O为声学特征
q后验概率最大的phone

$$\mathrm{GOP}(\mathcal{O}_n, q_n) > b \begin{cases} \text{yes,} & \text{correct pronunciation,} \\ \text{no,} & \text{mispronunciation.} \end{cases}$$

# Research approaches

- Classifier-Based Scoring
  - Truong et.al used acoustic phonetic features to train binary classifiers to distinguish confusion pairs
  - Acoustic phonetic，MFCC, GOP

# Research approaches

- Extended Recognition Networks(ERN)
  - 在解码网格中加入先验知识的约束(Kenworthy, 1987; A. M. Harrison, 2008;Gao, 2015)

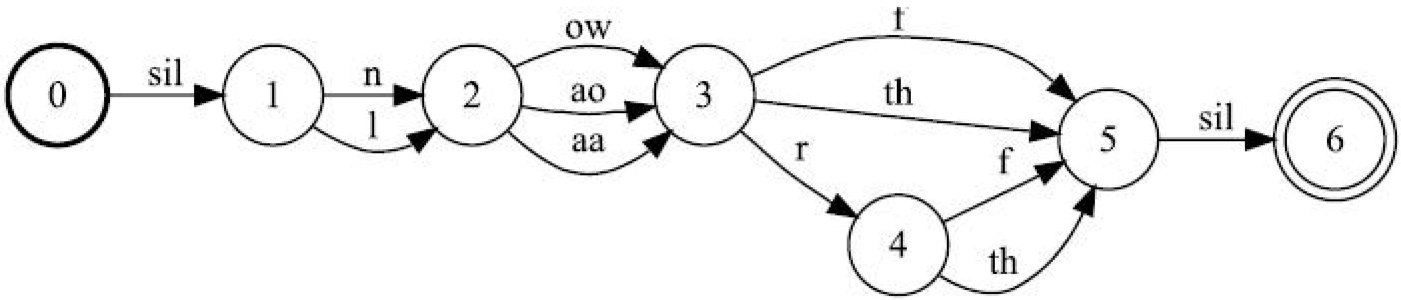


Figure 3: *Extended recognition network of "north"*

# Research ap

- Unsupervised
  - Need larg annotatio

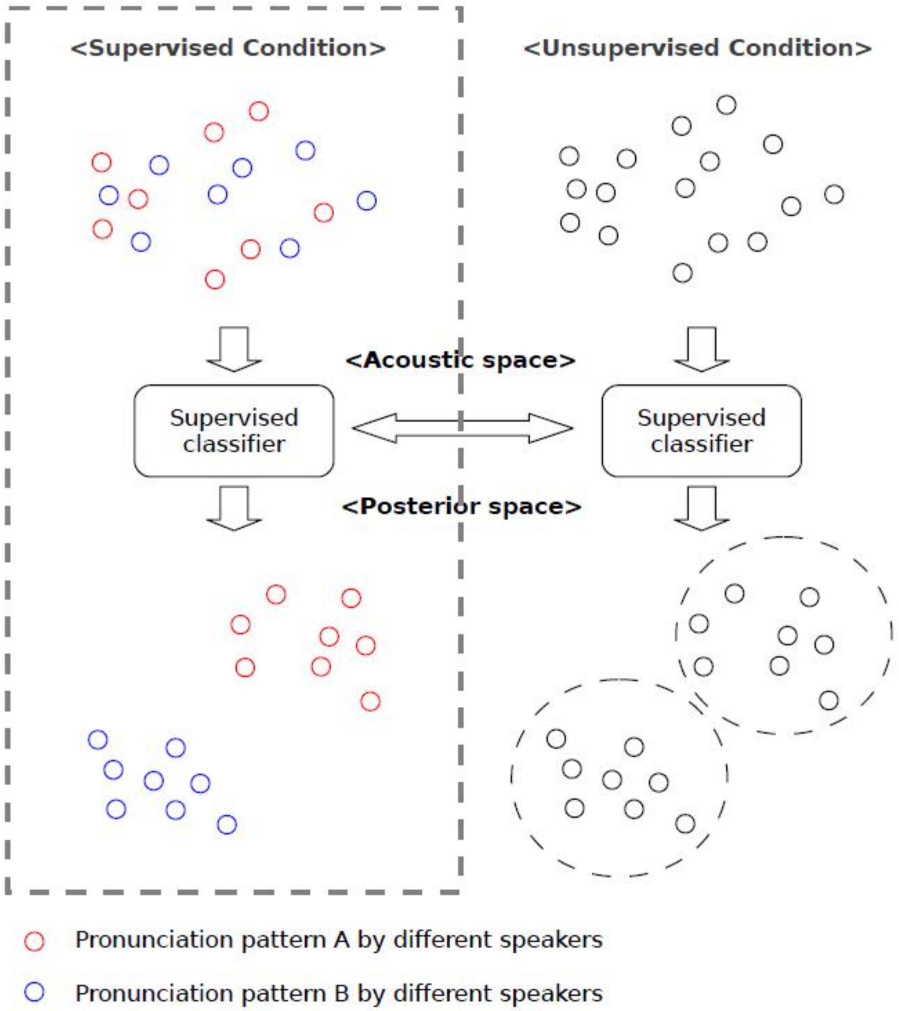


**Fig. 2**. *The effect of mapping from acoustic space to posterior space in supervised and unsupervised learning.*

# Research approaches

- Unsupervised Error Discovery

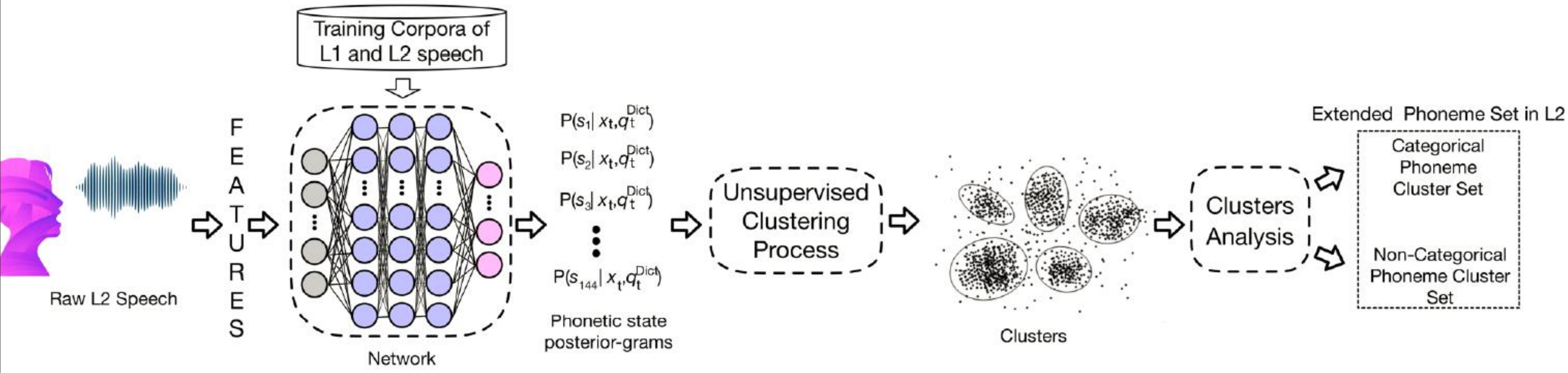
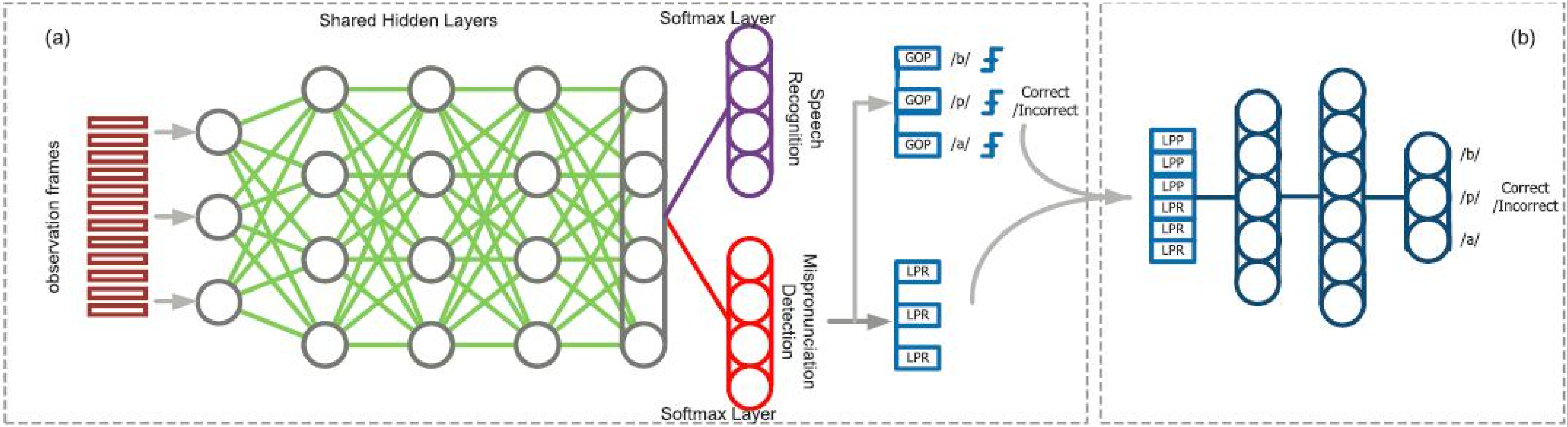

Training Corpora of L1 and L2 speech
Raw L2 Speech
FEATURES
Network
$P(s_1| x_t, q_t^{Dict})$
$P(s_2| x_t, q_t^{Dict})$
$P(s_3| x_t, q_t^{Dict})$
$P(s_{144}| x_t, q_t^{Dict})$
Phonetic state posterior-grams
Unsupervised Clustering Process
Clusters
Clusters Analysis
Extended Phoneme Set in L2
Categorical Phoneme Cluster Set
Non-Categorical Phoneme Cluster Set

**Fig. 2.** The framework of the proposed approach

# Research approaches

- Strategies for Improving Phonetic Error Detection
  - Verification/Rescoring



# Research approaches

- Strategies for Improving Phonetic Error Detection
  - Deep learning
    - DNN-HMM acoustic model better than GMM-HMM baseline
    - Convolutional neural networks were used in to automatically extract features

# Research approaches

- Strategies for Improving Phonetic Error Detection
  - Articulatory or Acoustic Phonetic Knowledge
    - Landmark-based SVM classifiers for detecting possible English pronunciation

# Research approaches

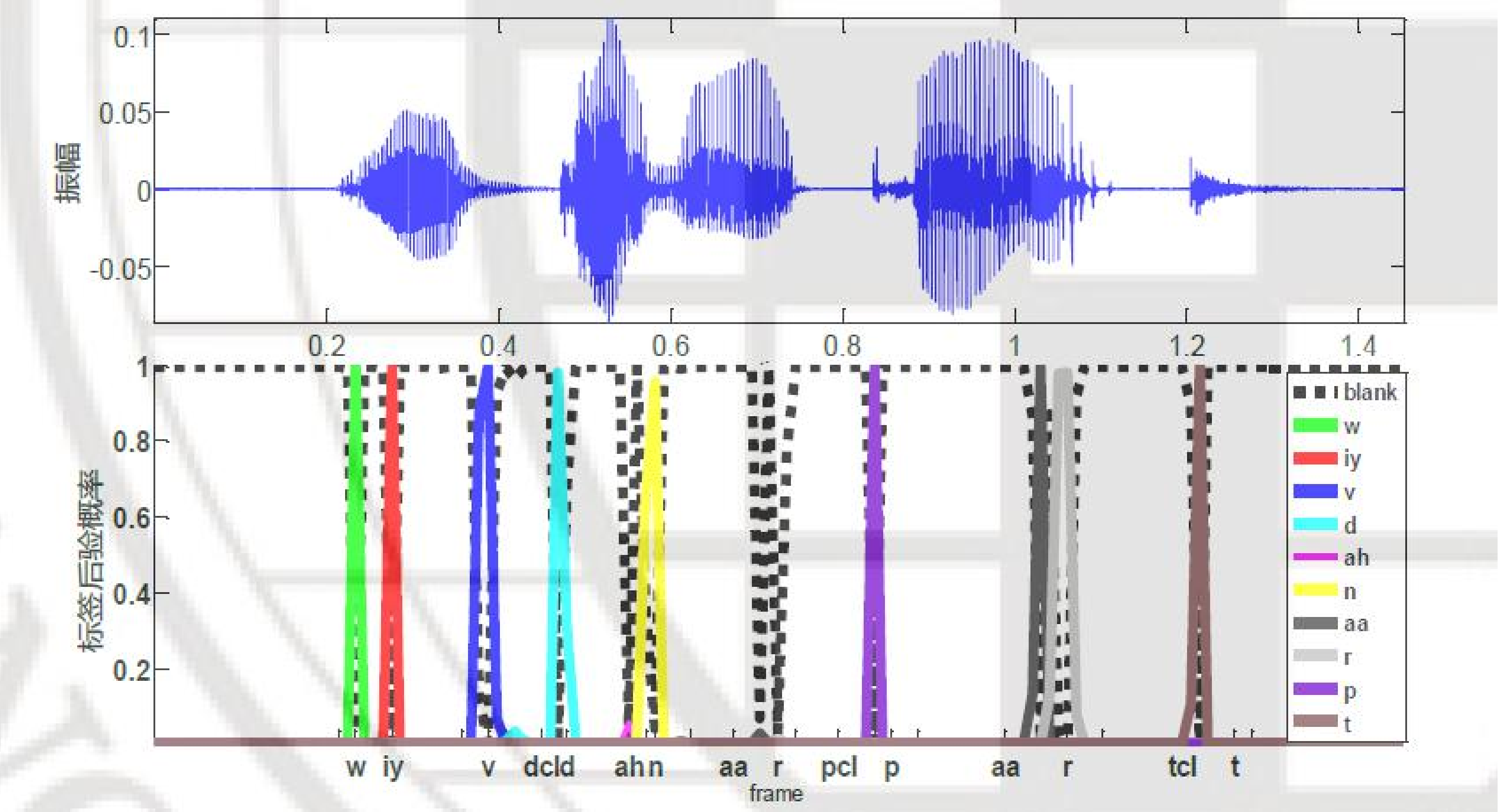


图 15 CTC 的尖峰现象，以“We’ ve done our part”为例

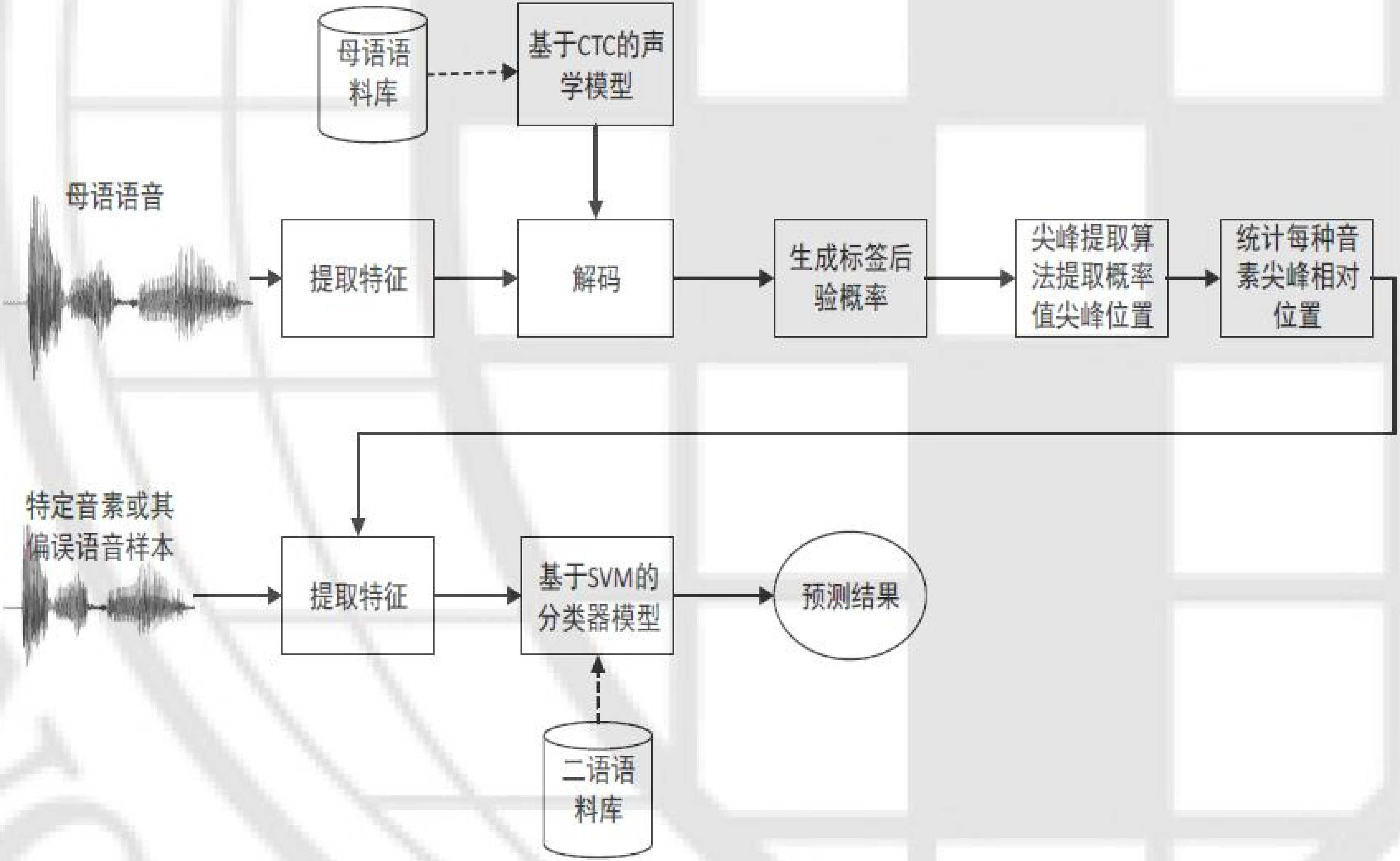


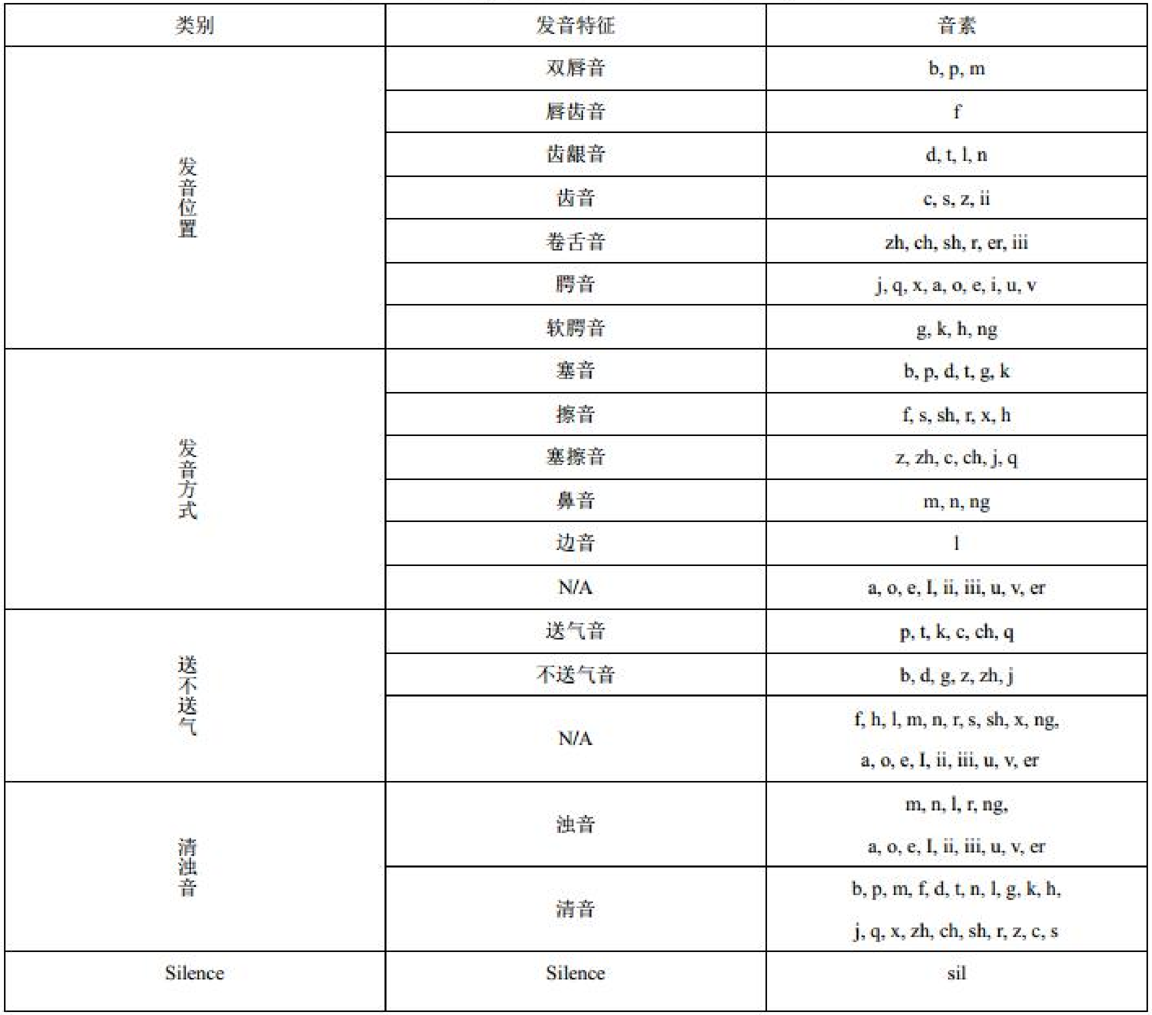
图 17 基于 CTC 的 landmark 检测及其发音偏误检测框架

# Research approaches

- St n

ossible

res(the place



| 类别 | 发音特征 | 音素 |
|---|---|---|
| 发音位置 | 双唇音 | b, p, m |
| | 唇齿音 | f |
| | 齿龈音 | d, t, l, n |
| | 齿音 | c, s, z, ii |
| | 卷舌音 | zh, ch, sh, r, er, iii |
| | 腭音 | j, q, x, a, o, e, i, u, v |
| | 软腭音 | g, k, h, ng |
| 发音方式 | 塞音 | b, p, d, t, g, k |
| | 擦音 | f, s, sh, r, x, h |
| | 塞擦音 | z, zh, c, ch, j, q |
| | 鼻音 | m, n, ng |
| | 边音 | l |
| | N/A | a, o, e, I, ii, iii, u, v, er |
| 送不送气 | 送气音 | p, t, k, c, ch, q |
| | 不送气音 | b, d, g, z, zh, j |
| | N/A | f, h, l, m, n, r, s, sh, x, ng,<br>a, o, e, I, ii, iii, u, v, er |
| 清浊音 | 浊音 | m, n, l, r, ng,<br>a, o, e, I, ii, iii, u, v, er |
| | 清音 | b, p, m, f, d, t, n, l, g, k, h,<br>j, q, x, zh, ch, sh, r, z, c, s |
| Silence | Silence | sil |

# Research approaches

- Detecting Prosodic Errors
  - Lexical Stress
    - Gaussian mixture models perform the best compared to decision trees and neural networks
    - Duration and pitch estimates are the most important features

# Research approaches

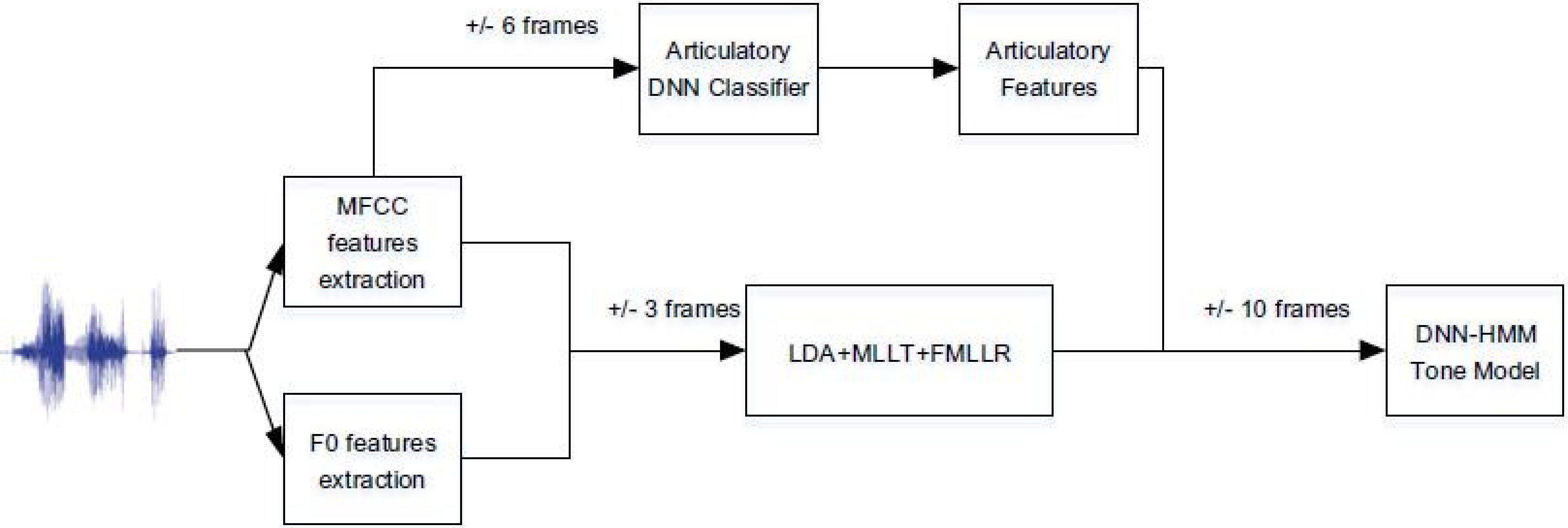
- Detecting Prosodic Errors
  - Lexical Tones
    - Lexical tones are primarily characterized by the pitch contour (e.g., Mandarin), sometimes the pitch height (e.g., Cantonese)
    - ASR framework for Tones Recognition
    - Syllable boundaries+classifier

# Research approaches

- Detecting Prosodic Errors
  - Lexical Tones
    - Segment the F0 contour to tone nucleus
    - Goodness of Tone (GOT)
    - The GOT features were modeled by an SVM classifier
    - Pitch related features could be inferred from a DNN system trained by 40-dimension MFCC features

# Research approaches

- Detecting Prosodic Errors
  - Lexical Tones



# Research approaches

- Automatic Fluency Scoring
  - Cucchiarini et.al found that rate of speech correlates highest with perceptual fluency
  - The number of silent pauses and the rate of articulation

# Challenges And Research Opportunities

- Scarcity of Large-Scale Linguistic Resources
  - Lack of Non-Native Speech Data
    - Substitution phonemic errors by artificially introducing them in a native corpus
  - Lack of Human Annotations
    - Phonetic transcriptions require lots of cost, time, and labor (linguistic expertise)
    - Prosody labeling and fluency scoring can be much more subjective and harder to achieve inter-rater agreement

# Challenges And Research Opportunities

- Common Modeling Assumptions
  - Text dependence
    - The even higher cost of human annotation of datasets if a CAPT system is text-independent
  - Mispronunciations are Categorical
    - Nonnative pronunciations might frequently fall out of the native phonemic or lexical tone categories

# Challenges And Research Opportunities

- Metrics for Evaluation
  - Information retrieval task
    - Precision
    - Recall
  - Mispronunciation detection error
    - False acceptance rate
    - False rejection rate

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谢谢

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