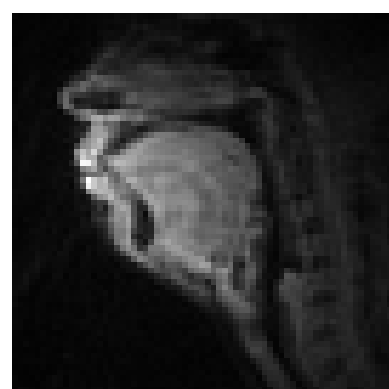
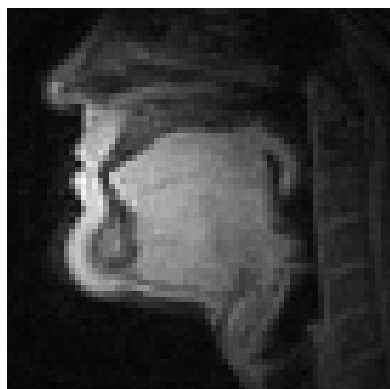
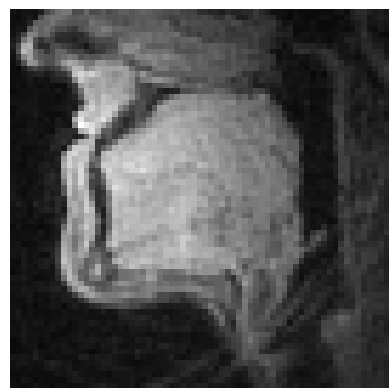
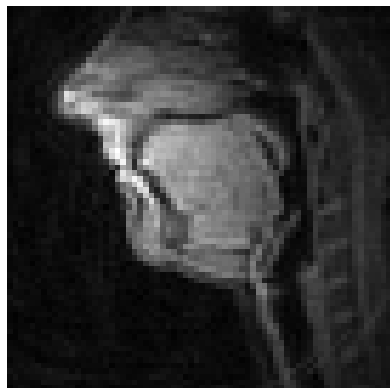


# Morphological Variation in the Adult Vocal Tract

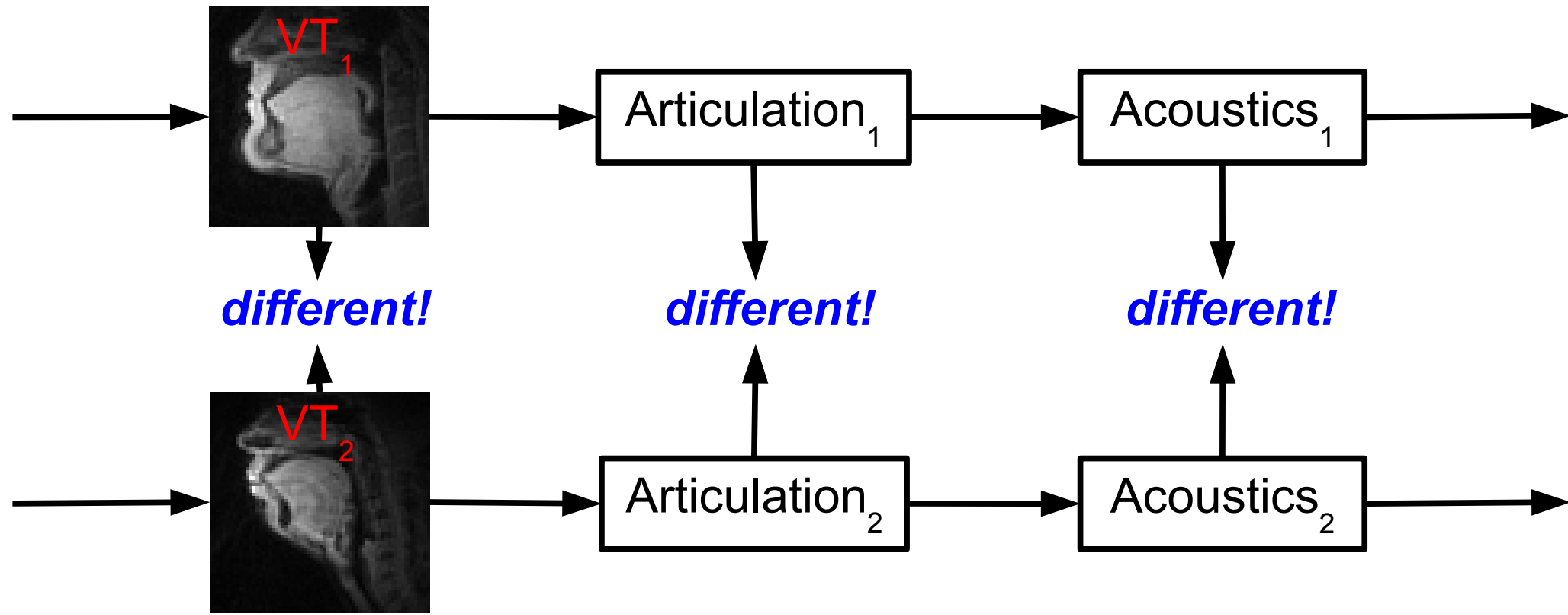
Adam Lammert, Michael Proctor & Shrikanth Narayanan  
University of Southern California



No two vocal tracts  
are exactly alike:

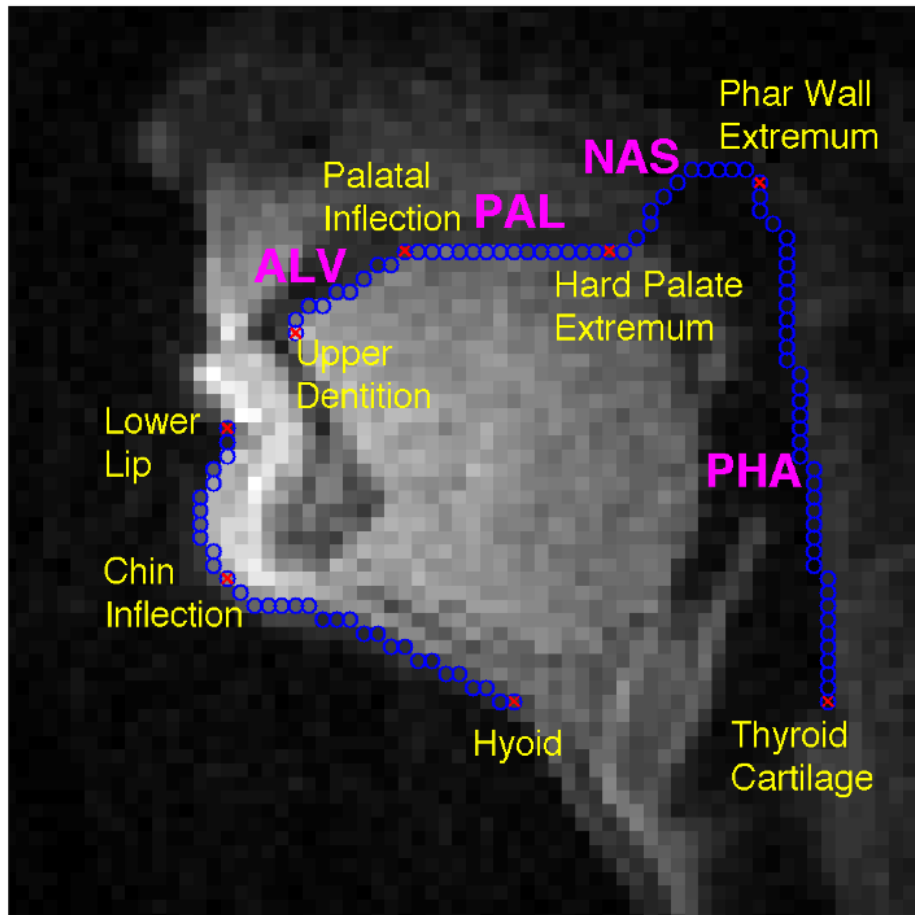
- Proportions
- Structural shapes
- Structural orientations

# Morphology is Part of Speech Production



- Morphology is:
  - variable
  - a potential source of variability
- Do subjects maximize articulatory or acoustical similarity?
- A window into speech production goals

# Subject Pool & Morphological Features



## 30 Adult Subjects

- Sex:
 

19 male	11 female
---------	-----------
- Race:
 

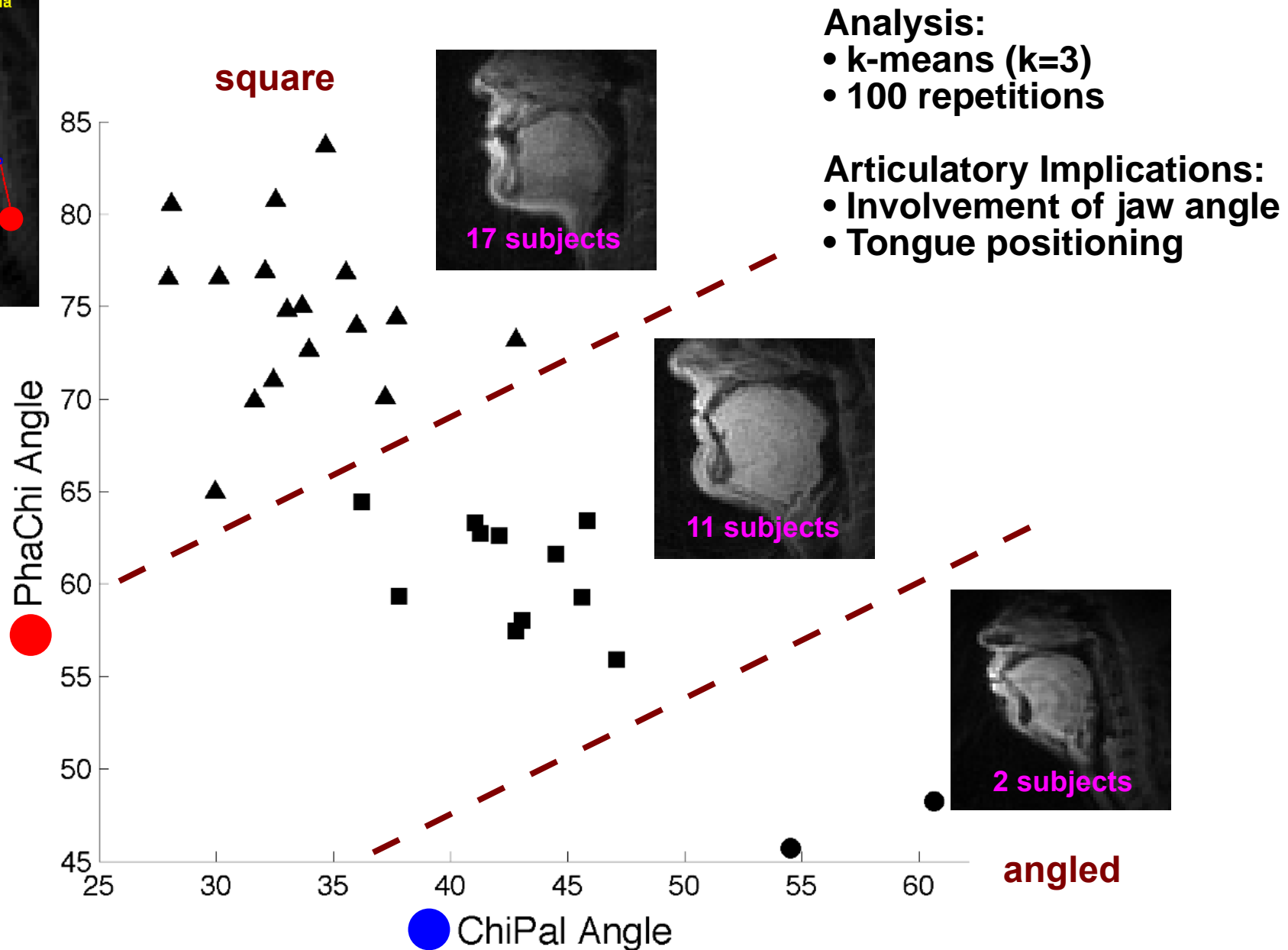
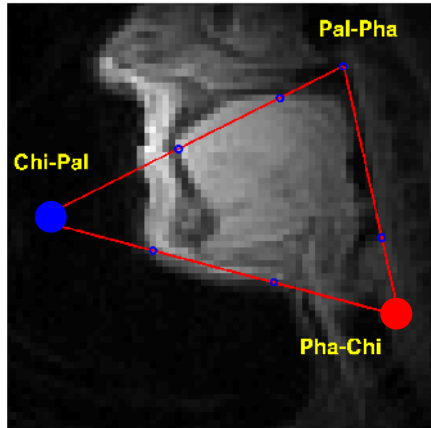
24 caucasian	6 asian
--------------	---------
- Language Background:
 

16 English	8 German
5 Mandarin	1 Hindi

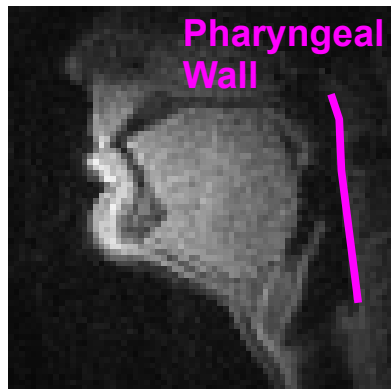
## Traces

- Rest position (respiration)
- Hard structures only
- Anatomical landmarks

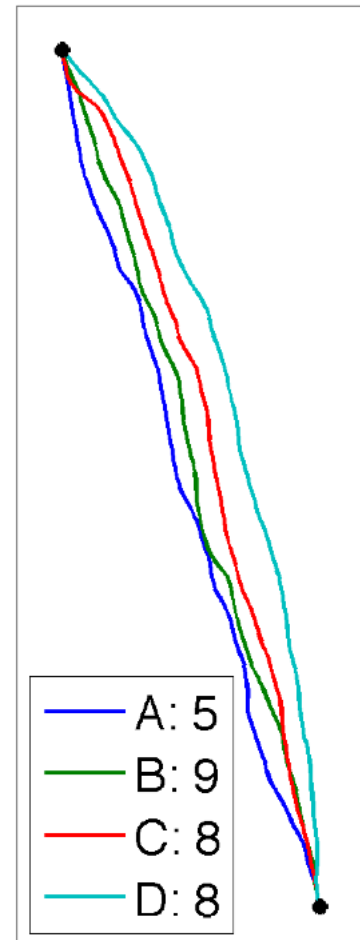
# Orientation of Key VT Structures



# Variations in Pharyngeal Wall Shape



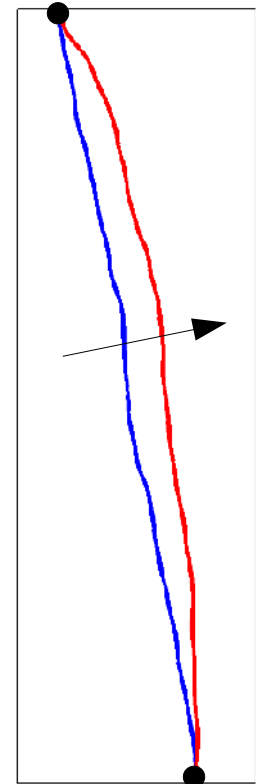
- Degree of concavity is the major variation
- Implications VT resonances for vowels/approximants



**Analysis:**

- k-means (k=4)
- 100 repetitions

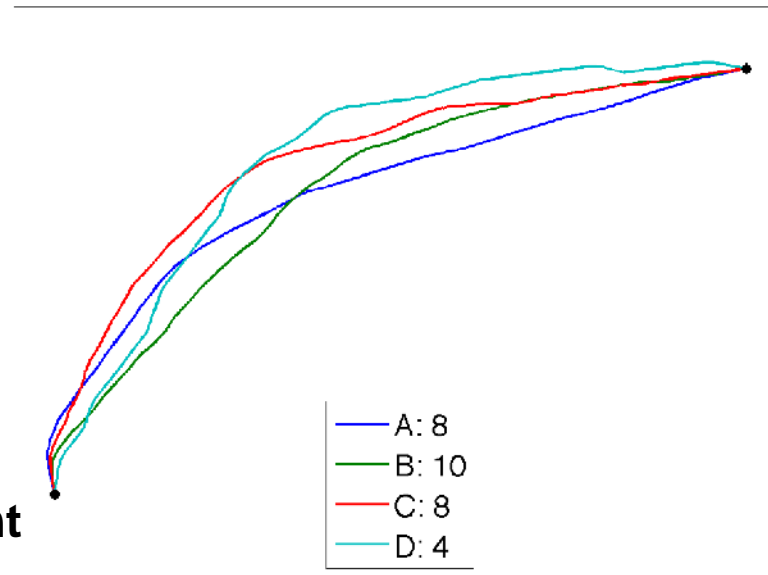
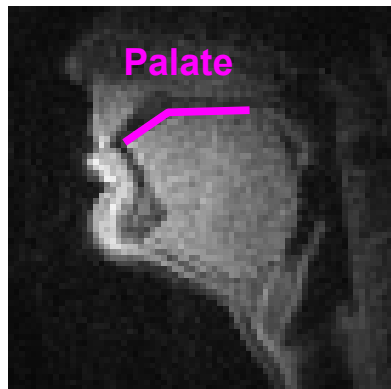
78% of Variance



**Analysis:**

- PCA
- 1<sup>st</sup> comp.

# Variations in Palate Shape



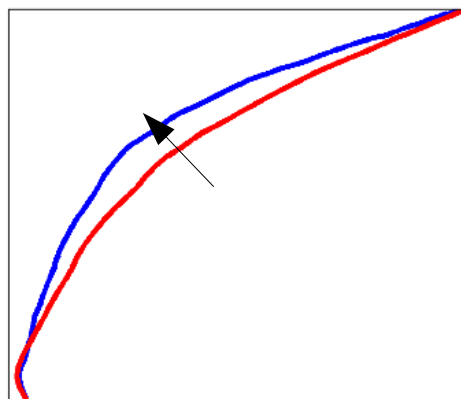
**Analysis:**

- k-means (k=4)
- 100 repetitions

**Implications:**

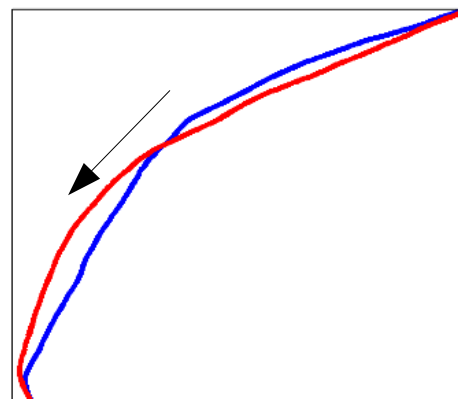
- VT resonances for vowels/approximants
- Tongue shaping for sibilant fricatives

46% of Variance



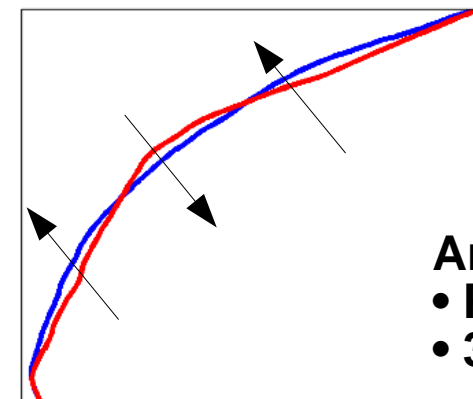
**concavity**

30% of Variance



**inflection location**

10% of Variance

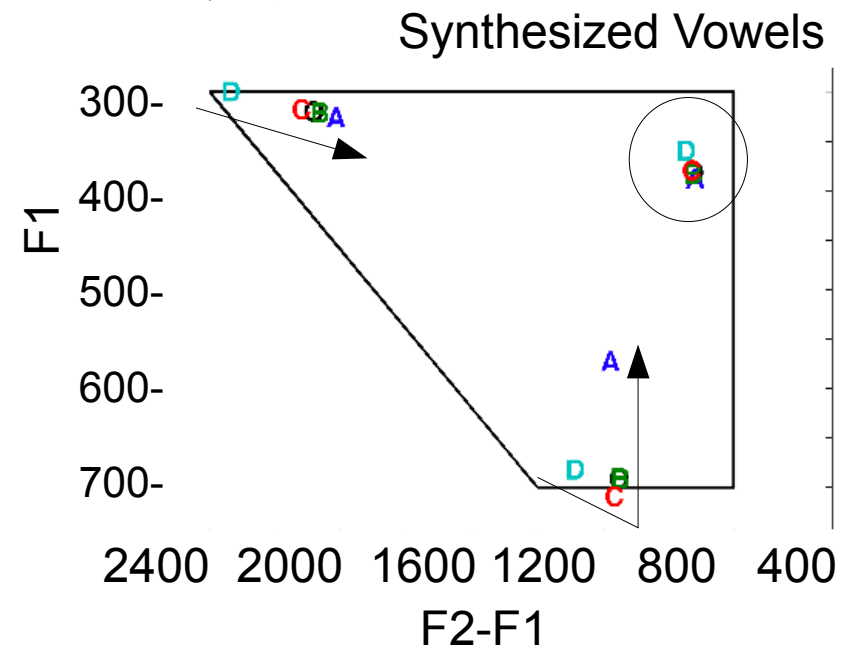
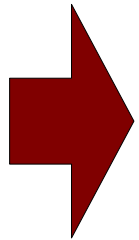
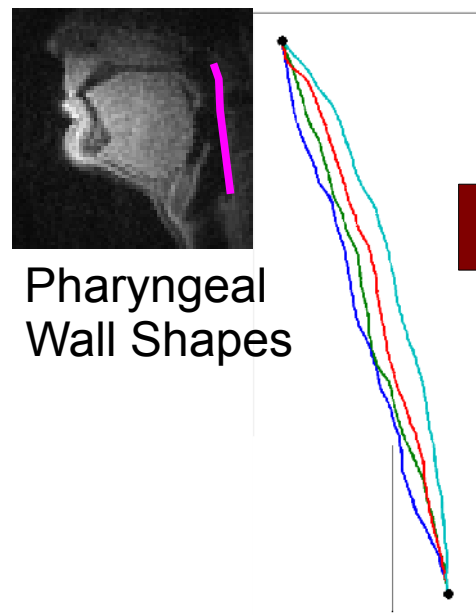
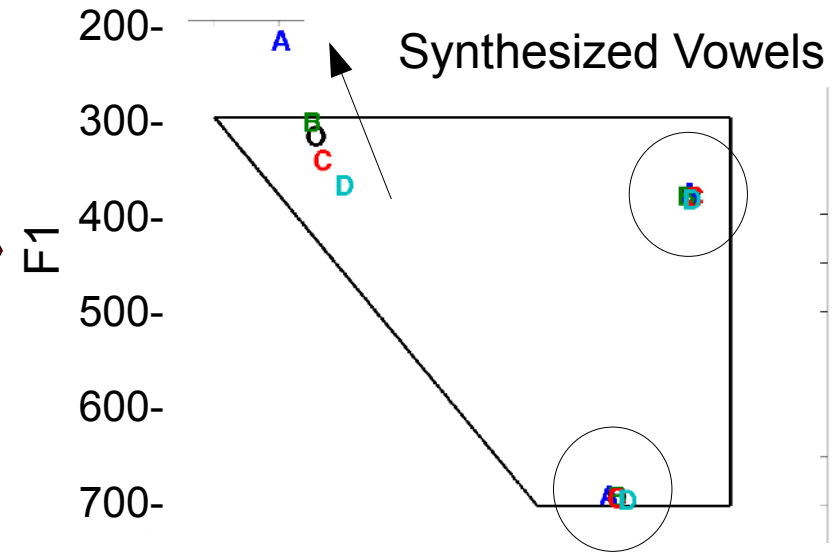
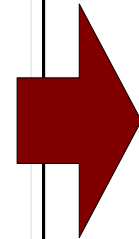
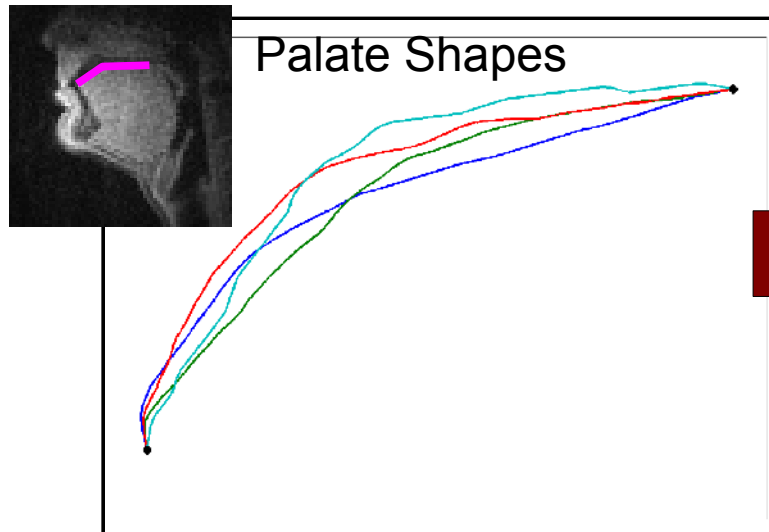


**angularity**

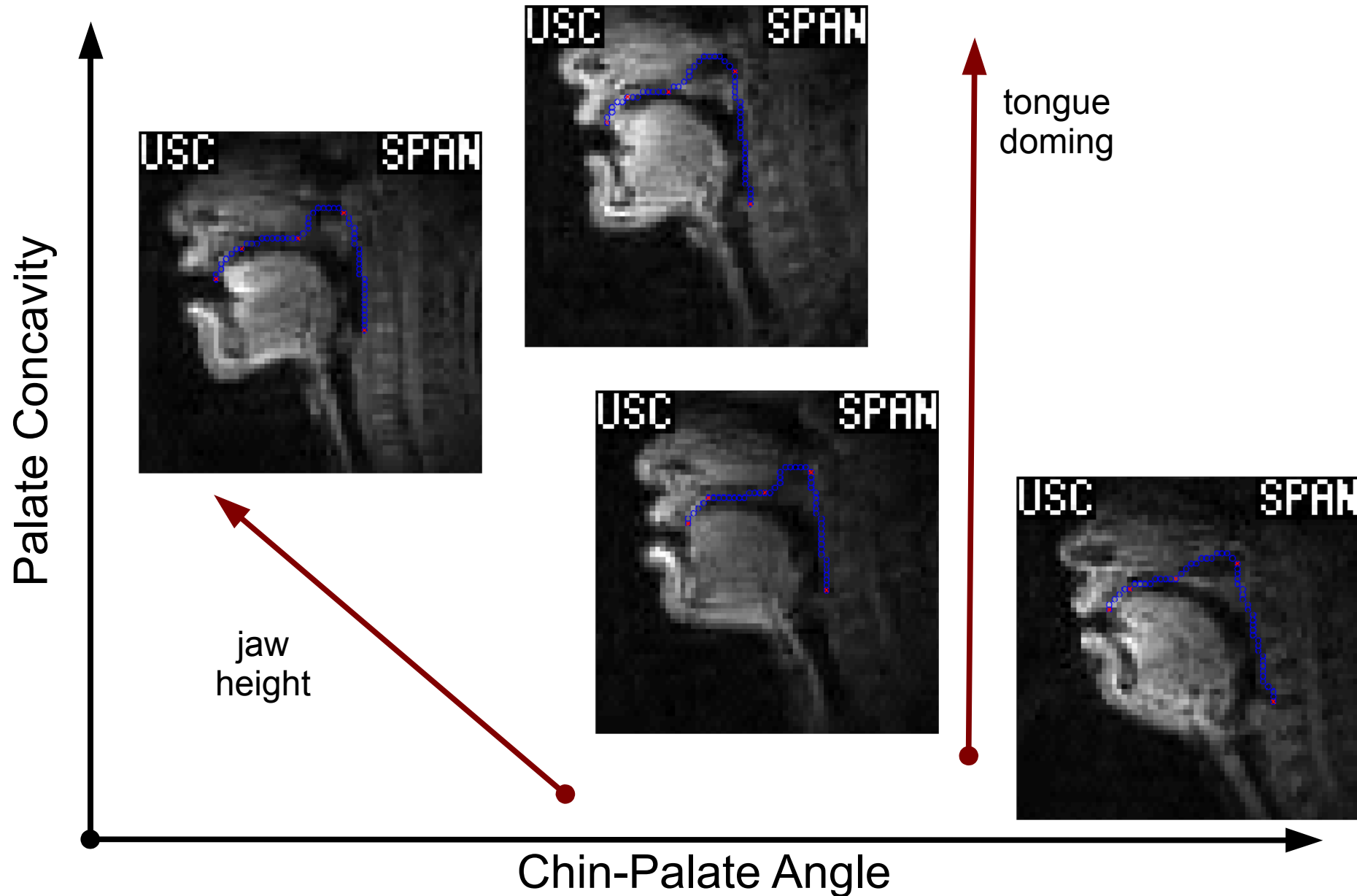
**Analysis:**

- PCA
- 3 comp's.

# Theoretical Impact of Morphology: Acoustic Modeling



# Morphological Impact on Articulation: A Case Study of 4 Mandarin /afa/





# Summary and Future Work

- Substantial differences between adult VTs
  - Should not be ignored
- Potential for explaining inter-speaker variability
  - One cause variability in acou. and artic.
  - Large potential impact on vowel formants
- A window into speech production goals
- Many kinds of variability remain unstudied
  - Tongue size and shape (place, shaping)
  - Velum size and shape (nasals)
- Ongoing studies of impact on acou. and artic.
  - Sibilant fricatives vs. palate shape
  - Sounds with several articulations (e.g., / /)
  - Place of articulation

# Acknowledgements

- Shri Narayanan (co-author, advisor)
- Michael Proctor (co-author, mentor)
- SAIL and SPAN Group



- National Institutes of Health
- Northern Digital Inc.

