

Lecture 8: Vocal Tract Physiology

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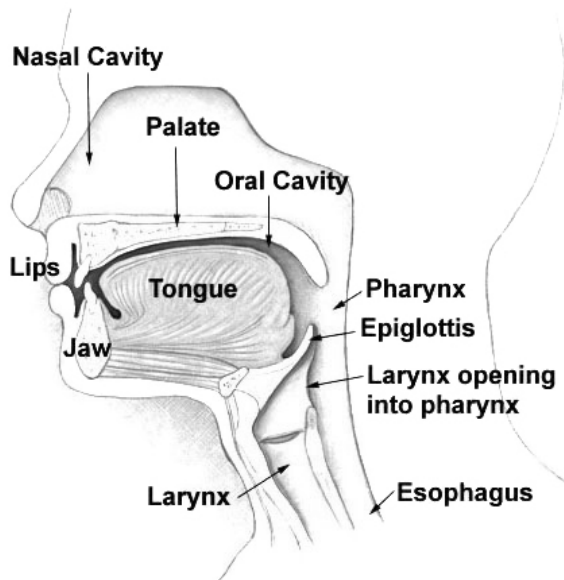
ECE 537: Speech Processing

- 1 Anatomy of the vocal tract
- 2 Technologies for imaging speech production
- 3 Examples of parameterizations that are useful for research
- 4 Example
- 5 Summary

Outline

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Anatomy of the vocal tract



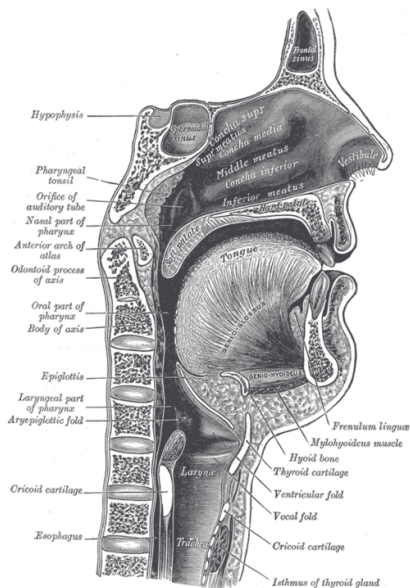
Structures you need to know

- Cavities: oral, nasal, pharyngeal
- Muscular hydrostats: tongue, lips
- Boundaries: hard palate, soft palate, larynx
- Bones: mandible (jaw)

Naming of muscles

- Most muscles have two-part names, specifying their two endpoints. Example endpoints are:
 - “glossus” = tongue
 - “hyo-” = hyoid
 - “genio-” = mandible near chin
 - “mylo-” = mandible near molars
 - “stylo-” = styloid process of temporal bone
- Intrinsic muscles of the tongue are named by direction: longitudinalis, verticalis, transversus.

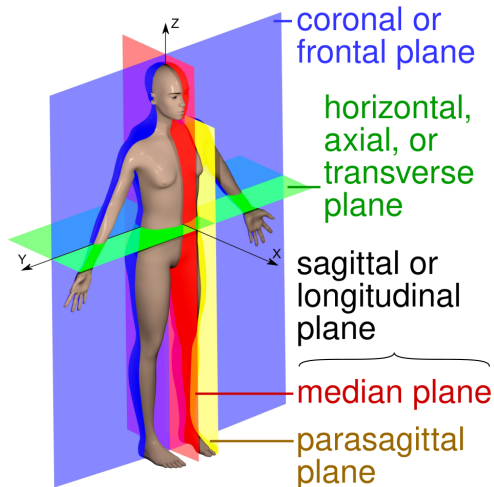
Anatomy of the vocal tract



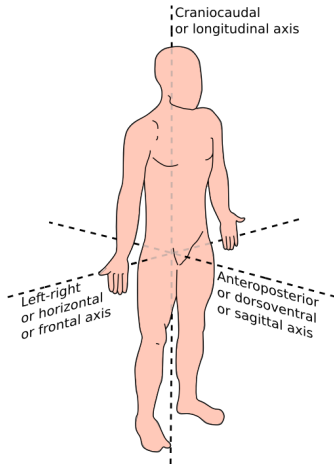
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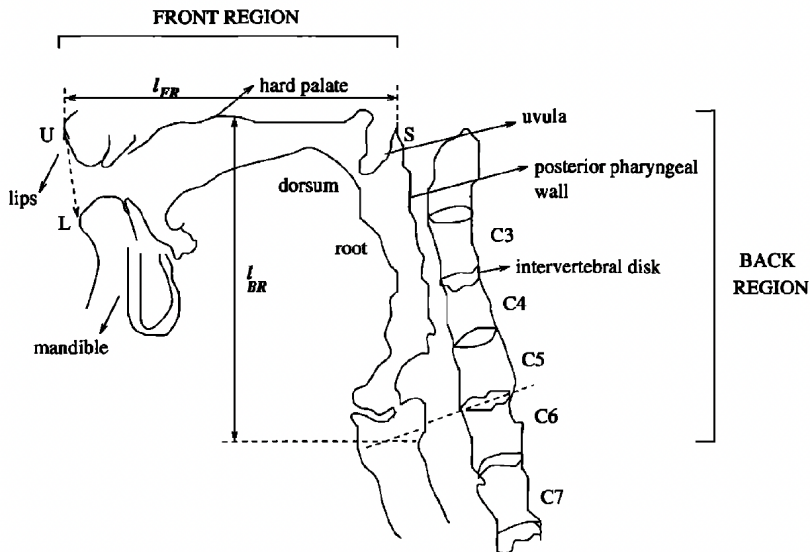
Terminology: Imaging planes



Terminology: Directions



Dorsoventral and Anteroposterior in Midsagittal plane



Technologies for imaging speech production

- Cineradiography/Flourosocopy
- X-ray microbeam
- Electromagnetic articulography (EMA)
- Ultrasound
- Electropalatography
- Real-time MRI
- Volumetric MRI

Cineradiography

`https://linguistics.berkeley.edu/acip/appendix/vocal\_tracts/KNS.html`

X-ray microbeam

- Millimeter-radius, low-power beams are linked to a real-time tracking system to track the locations of 10 gold pellets attached to the tongue, lips, and jaw.
- X-ray dosage was safe, but the system was very expensive: The longest-running was at U. Wisconsin for 10 years, and data is now public
- https://github.com/rsprouse/xray_microbeam_database
- https://www.researchgate.net/figure/Typical-pellet-placements-for-X-ray-microbeam-data-array_fig1_9041667

Electromagnetic articulography

- Tiny radio antennae are taped to your tongue
- They measure $\text{power} = 1/\text{distance}$ from 3+ radio receivers, and infer position in real time
- https://en.wikipedia.org/wiki/Electromagnetic_articulography
- <https://www.articulograph.de/>

Ultrasound

<https://www.youtube.com/watch?v=hf87zmPMa4U>

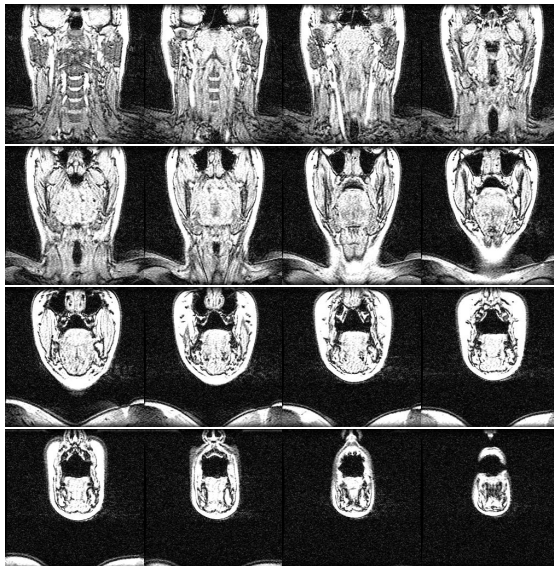
Electropalatography

<https://en.wikipedia.org/wiki/Electropalatography>

Real-time MRI

`https://en.wikipedia.org/wiki/File:
Real-time_MRI_-_Speaking_\(English\).ogv`

Volumetric MRI



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Area functions from volumetric MRI

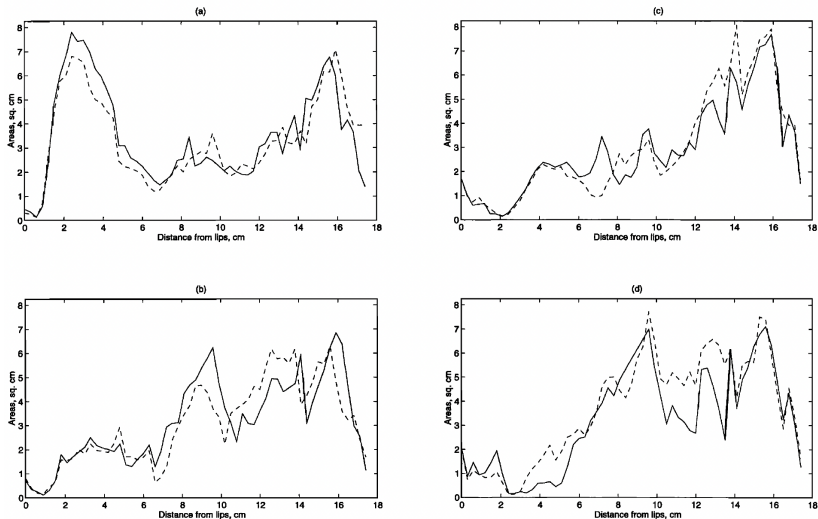
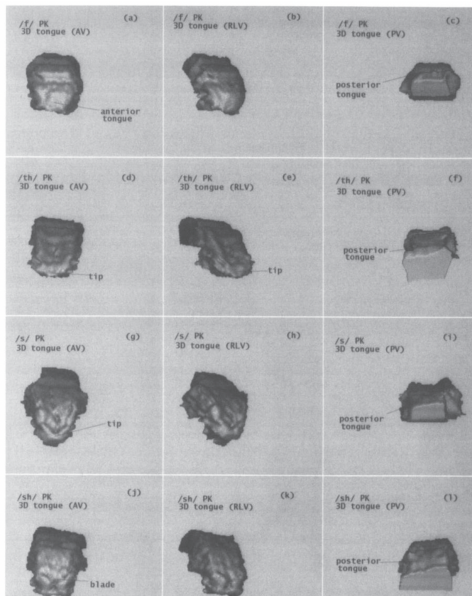


FIG. 15. Complete area functions for unvoiced (solid) and voiced (dashed) fricative pairs for subject MI: (a) $/f-v/$, (b) $/θ-ð/$, (c) $/s-z/$, and (d) $/ʃ-ʒ/$.

3D tongue shape



Factor analysis of 3D tongue shape

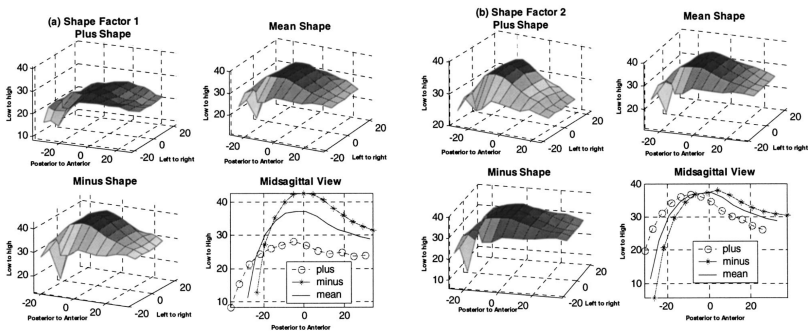


FIG. 5. Shape factors of 3D Analysis. (a) Shape factor 1. (b) Shape factor 2.

Zheng et al., "Analysis of the three-dimensional tongue shape using a three-index factor analysis model," 2003

Factor analysis of 3D tongue shape

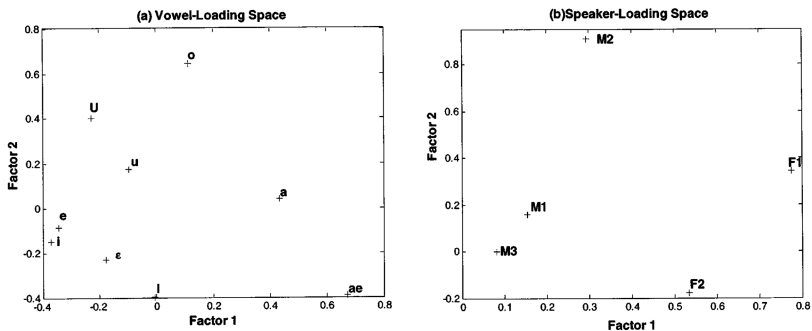


FIG. 6. Vowel and speaker loading spaces of 3D Analysis. (a) Vowel loading space. (b) Speaker loading space.

Zheng et al., "Analysis of the three-dimensional tongue shape using a three-index factor analysis model," 2003

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Example

Sketch a midsagittal view of the vocal tract. Label the tongue tip, tongue dorsum, lips, jaw, larynx, pharynx, hard and soft palate.

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Summary

- Articulators:
 - Muscular hydrostats: Tongue, lips
 - Bones: jaw, hard palate
 - Cavities: oral, nasal, pharyngeal, laryngeal
- Image planes: sagittal, coronal, axial
- Image directions: dorsoventral, anteroposterior, left-right
- Imaging modalities: Cineradiography, X-ray microbeam, EMA, Ultrasound, Electropalatography, Real-time MRI, Volumetric MRI