Who Are You (I Really Wanna Know)? Detecting Audio DeepFakes Through Vocal Tract Reconstruction

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DeepFakes

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September 05, 2019

DeepFakes

The Deepfake problem is not just about authentication, fundamentally, it's about

"Is this speaker even human?"

Hypothesis

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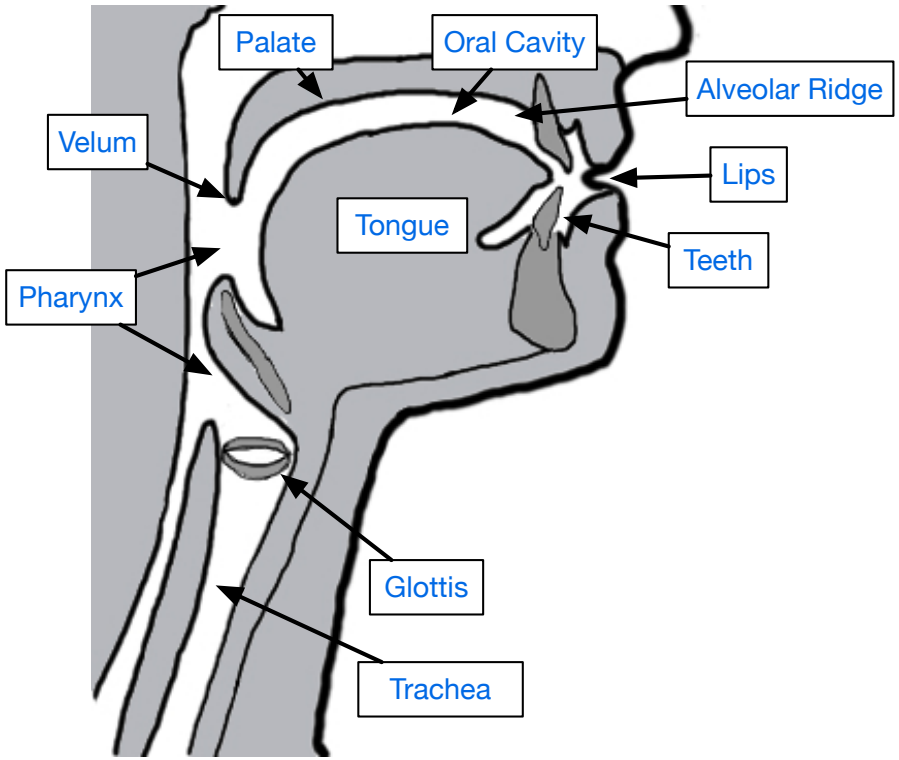
- **Hypothesis:** We can apply techniques from fluid-dynamics *to extract biological structure from audio.*
  - Humans have limited configurations of their vocal tract.
  - ML does not necessarily abide by these same constraints.

Organic Voice Creation



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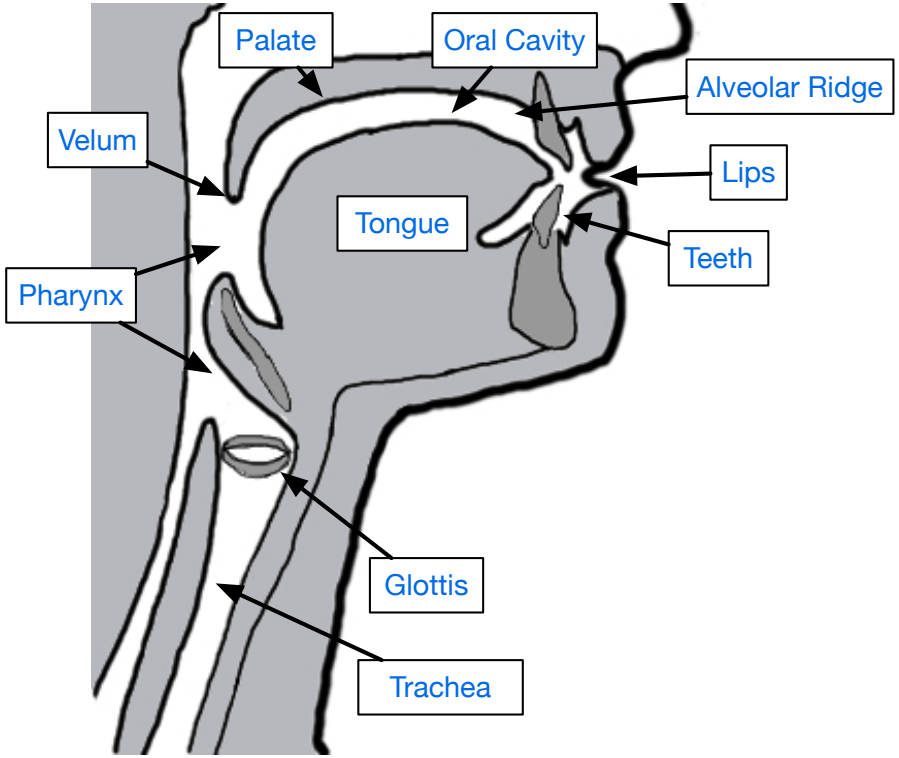

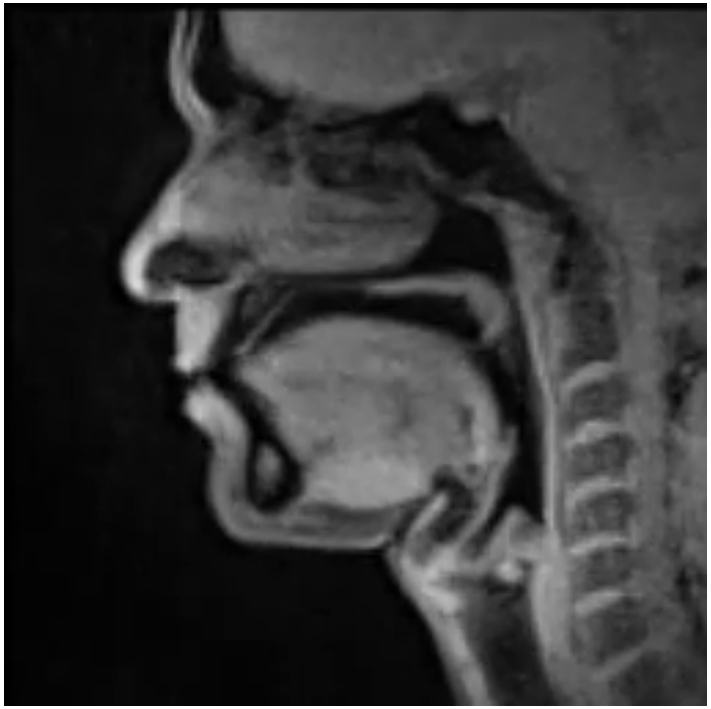

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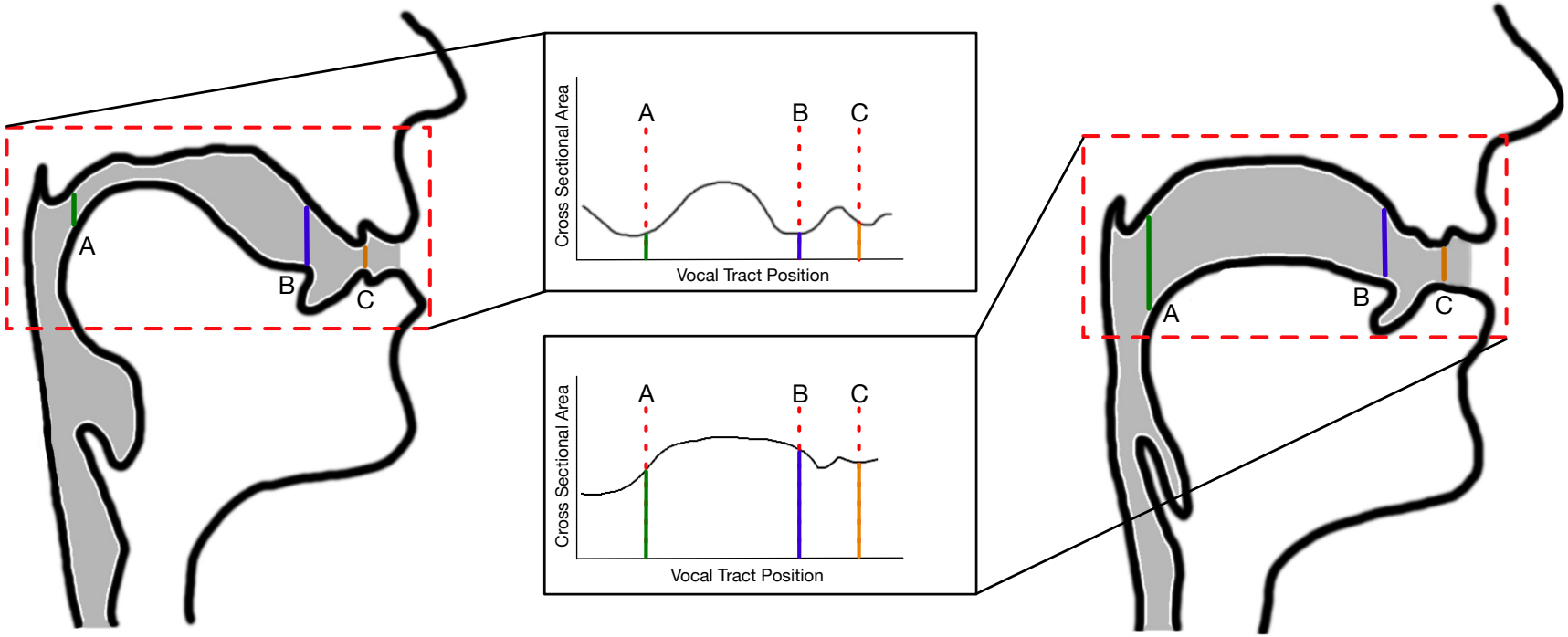

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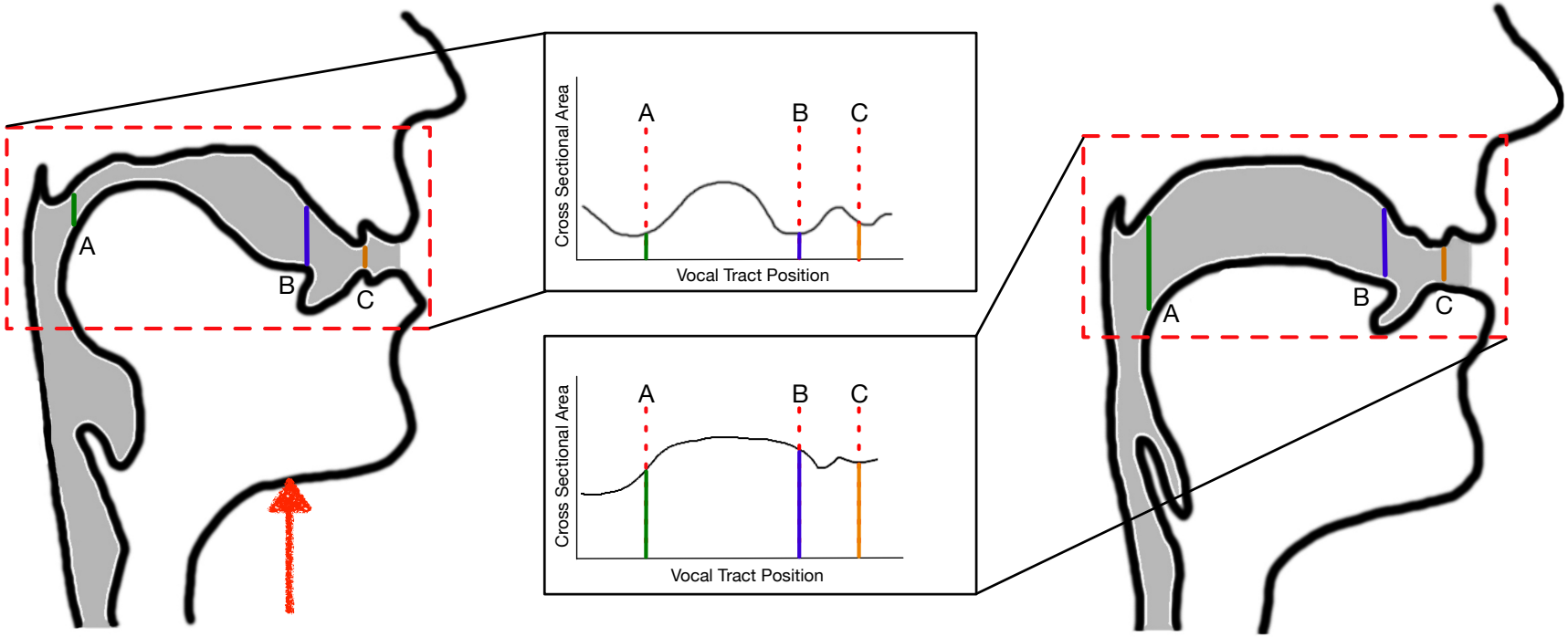

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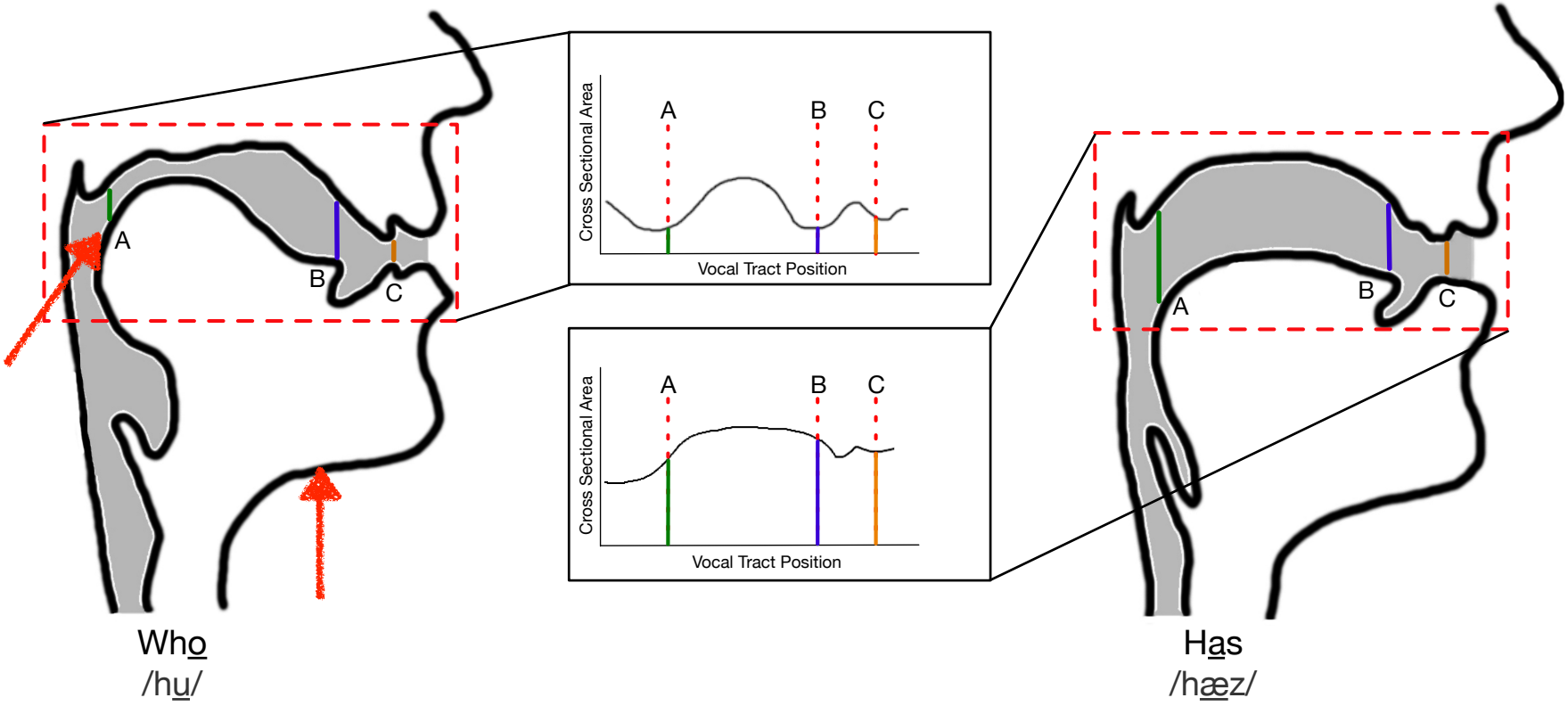

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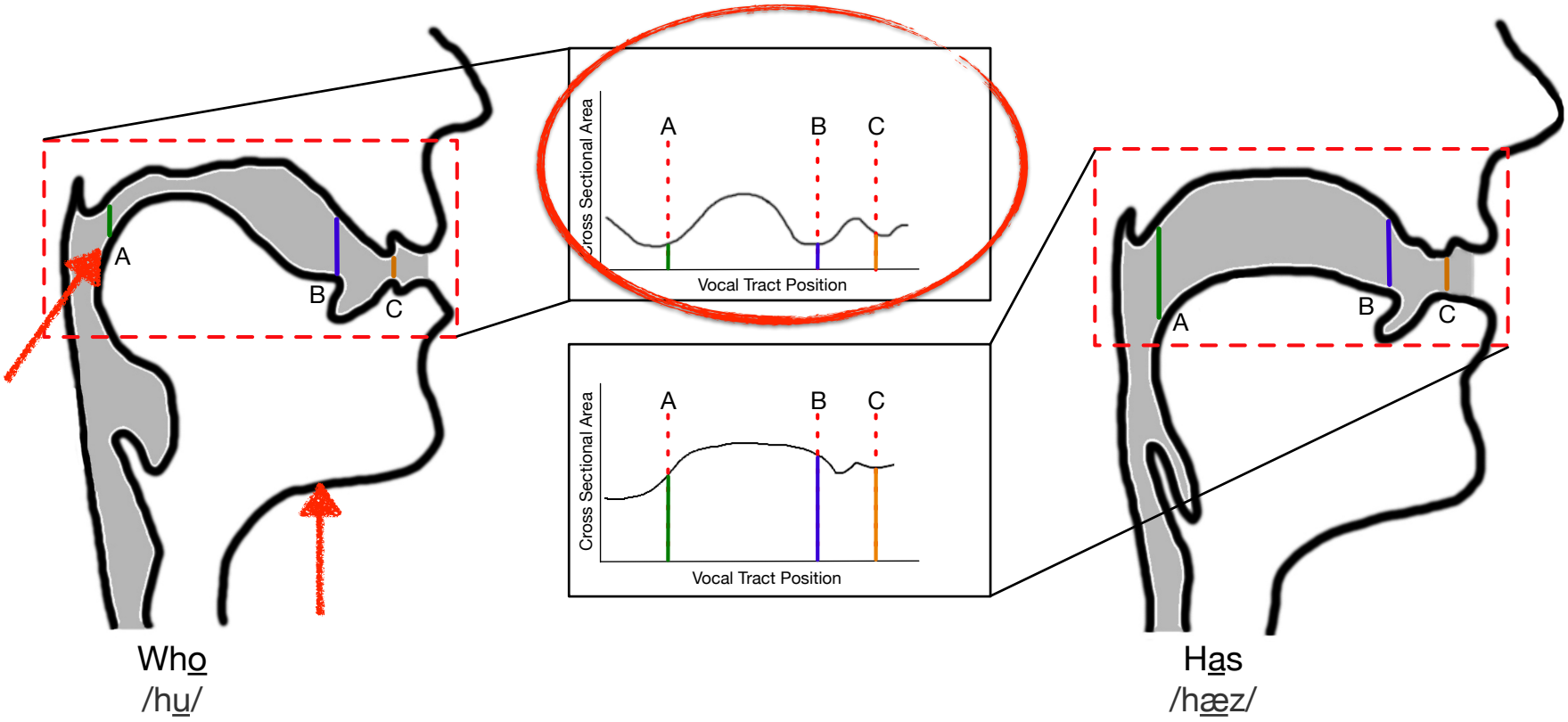

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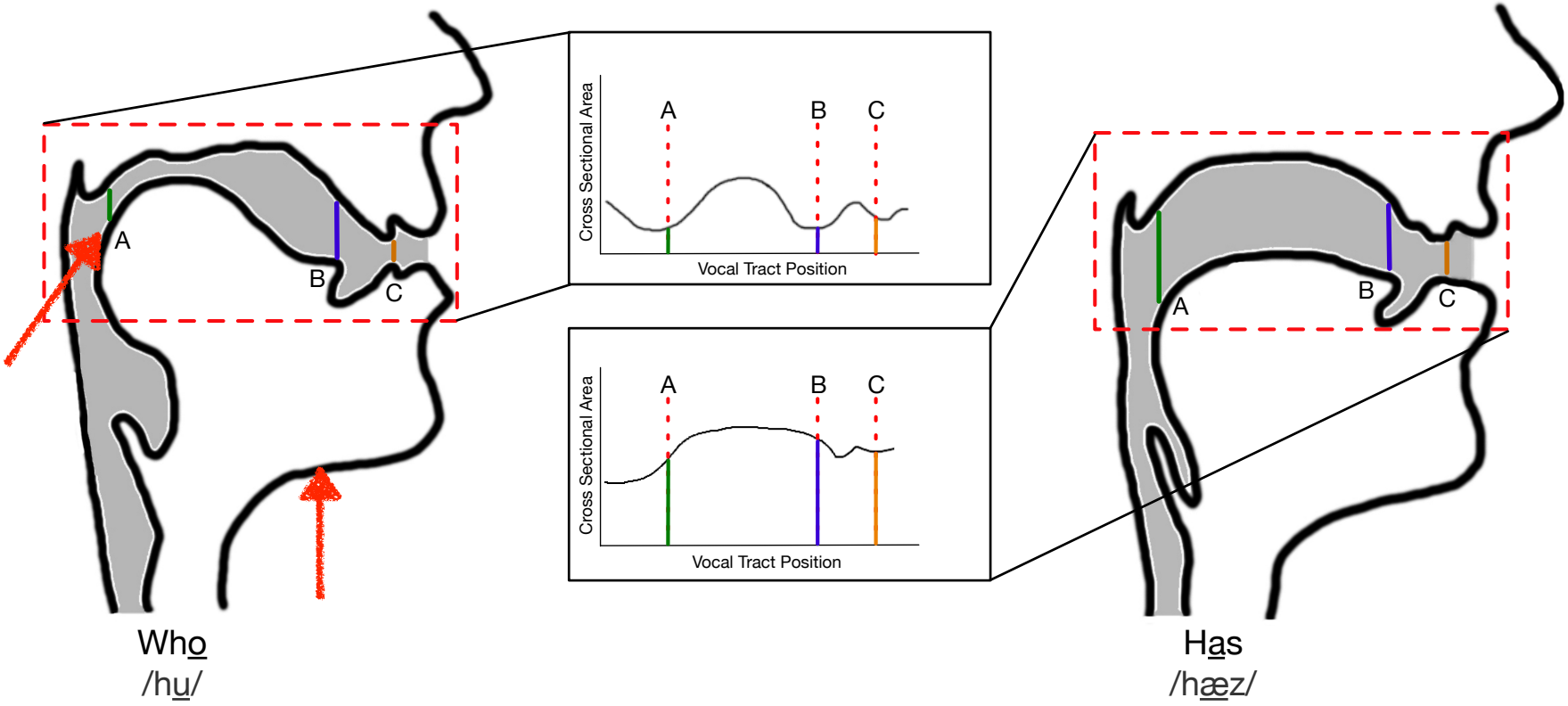

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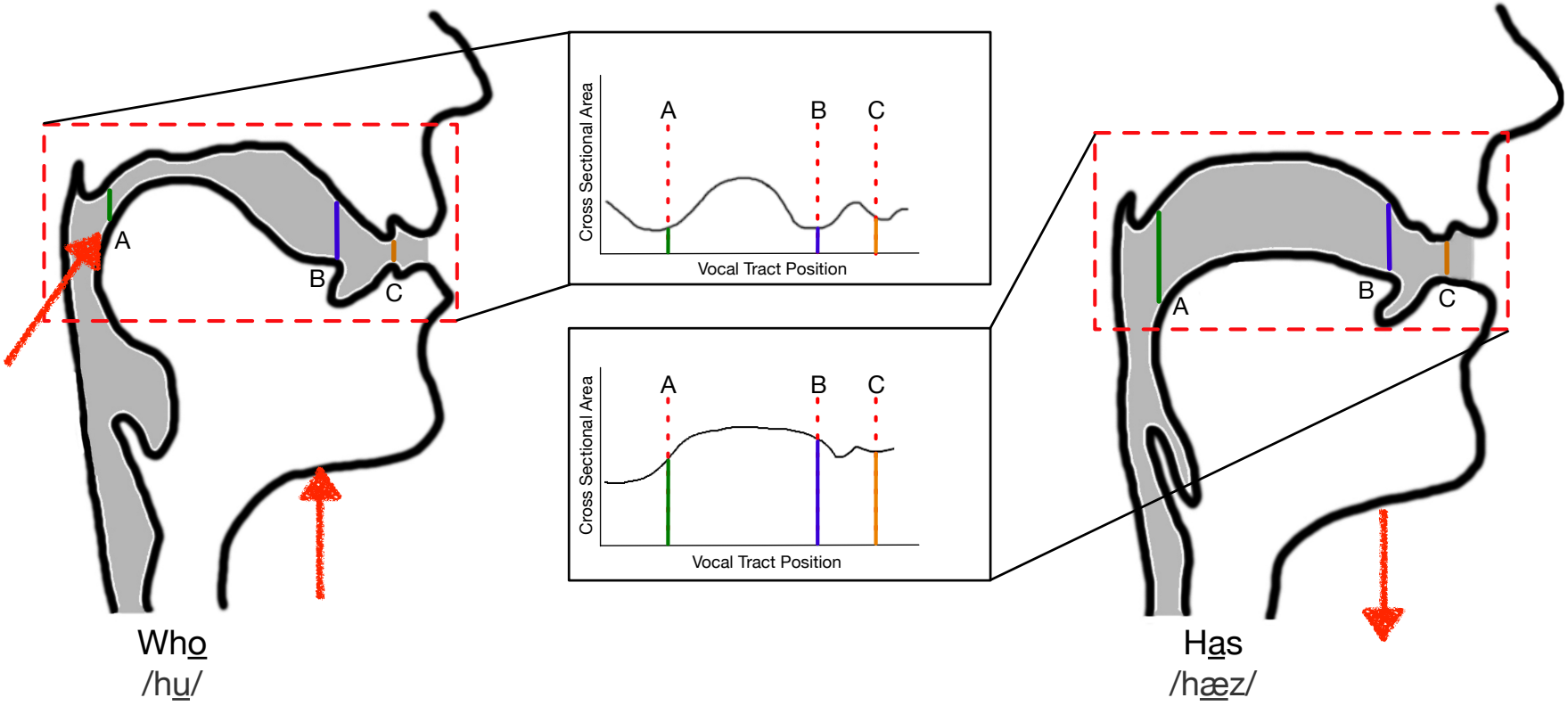

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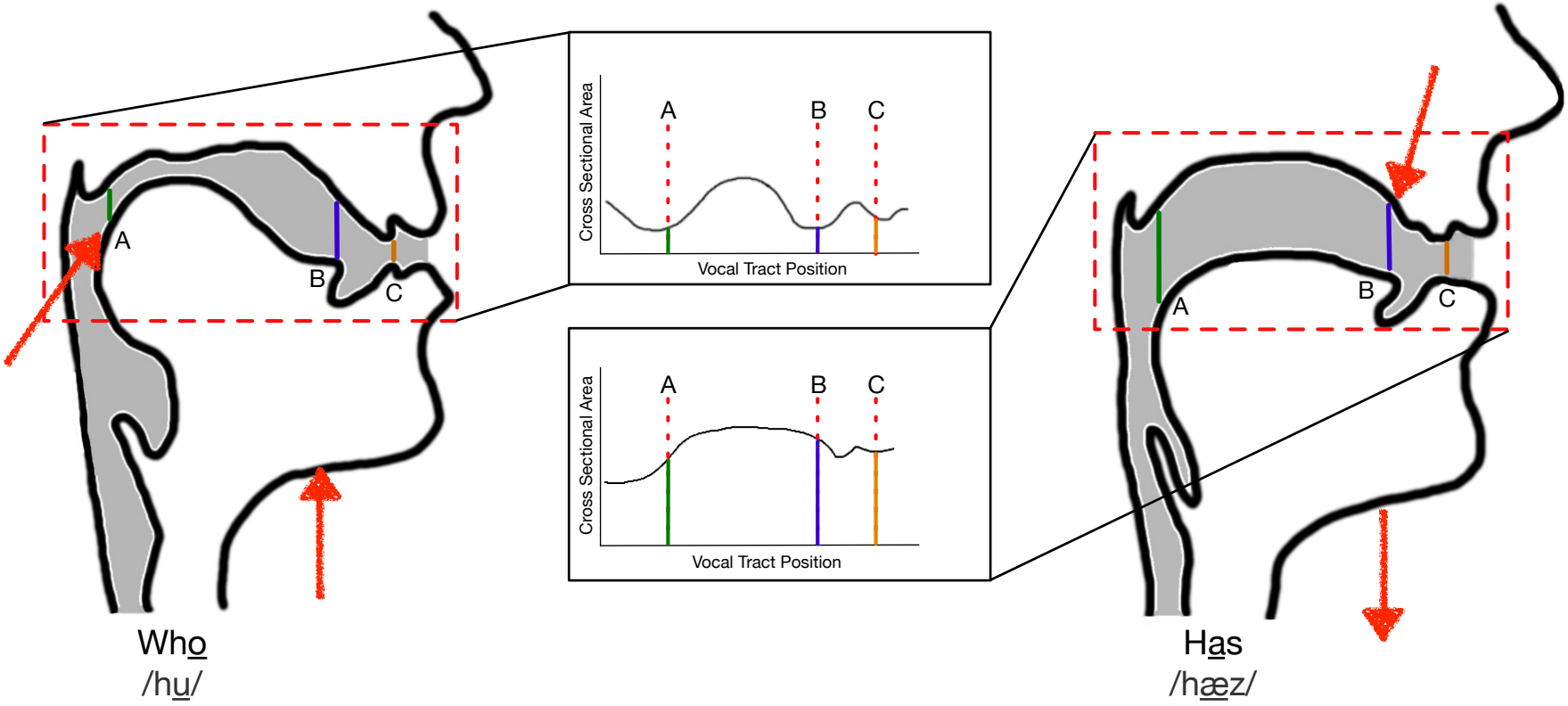

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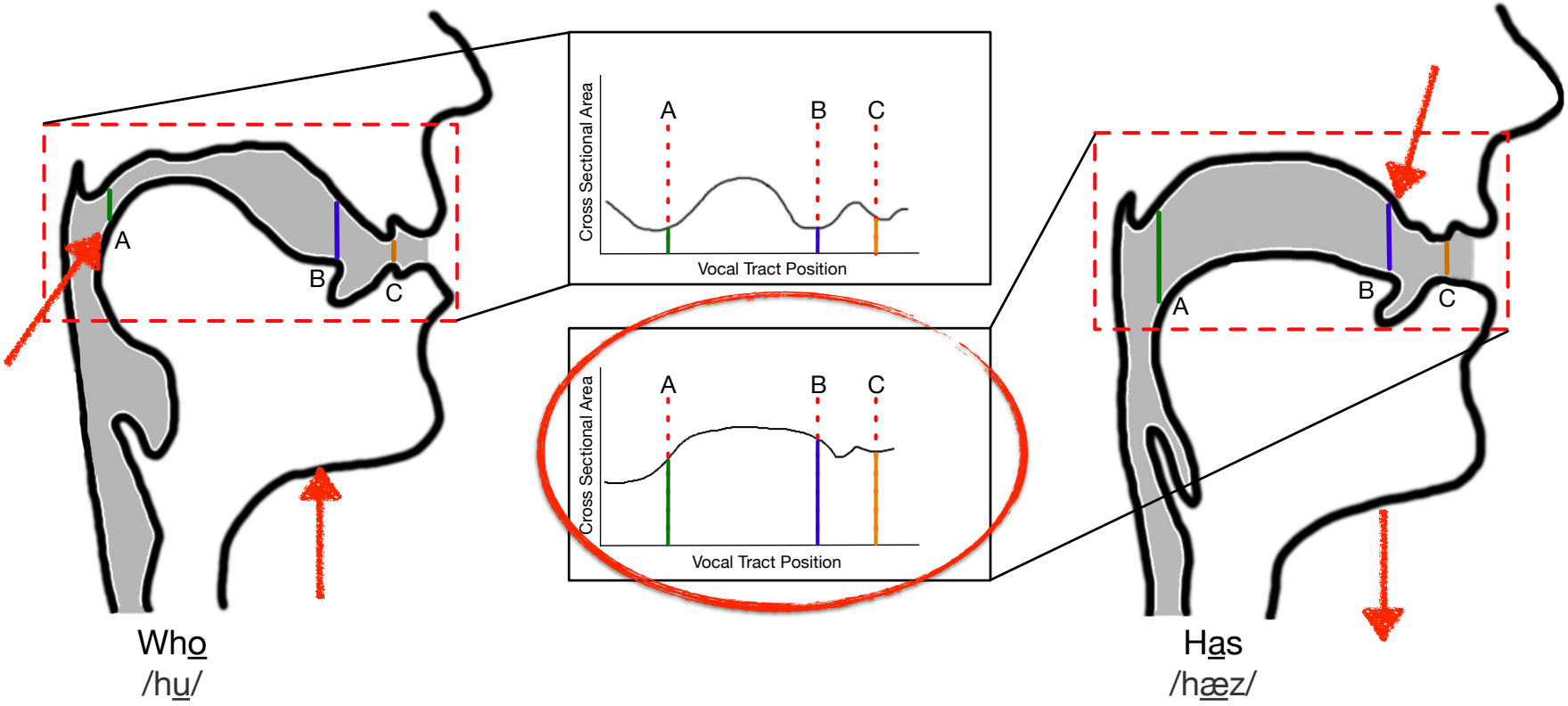
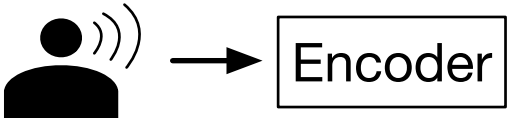


DeepFake Creation



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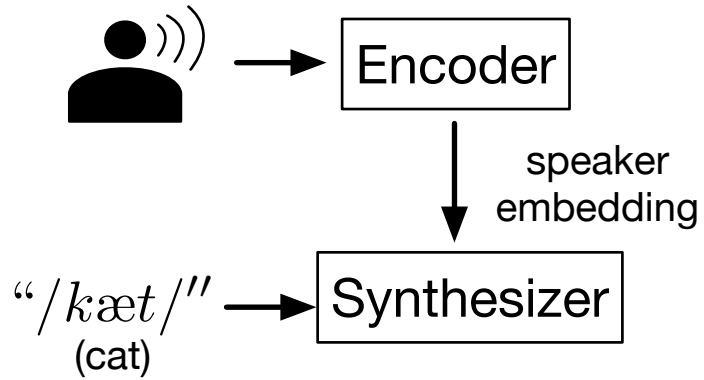

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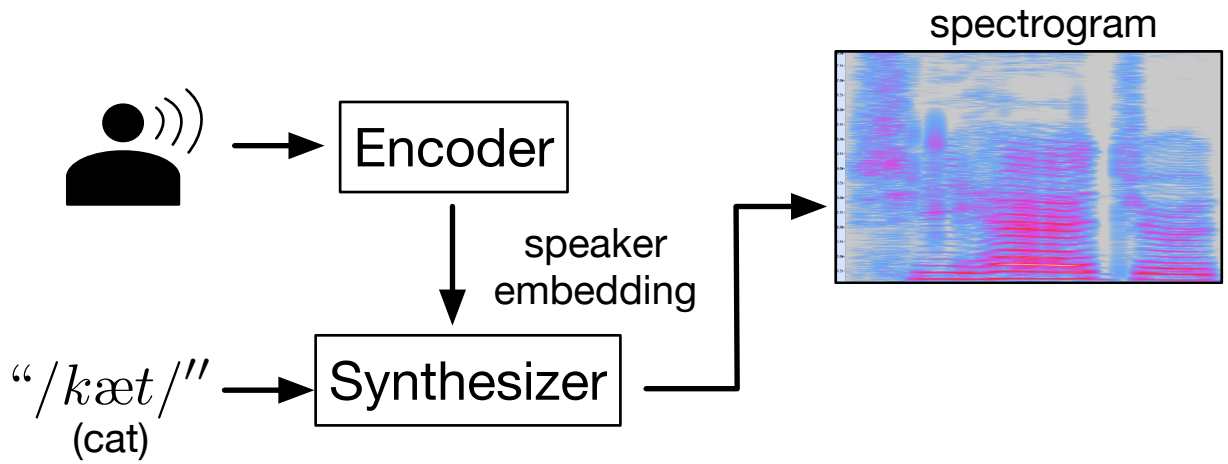

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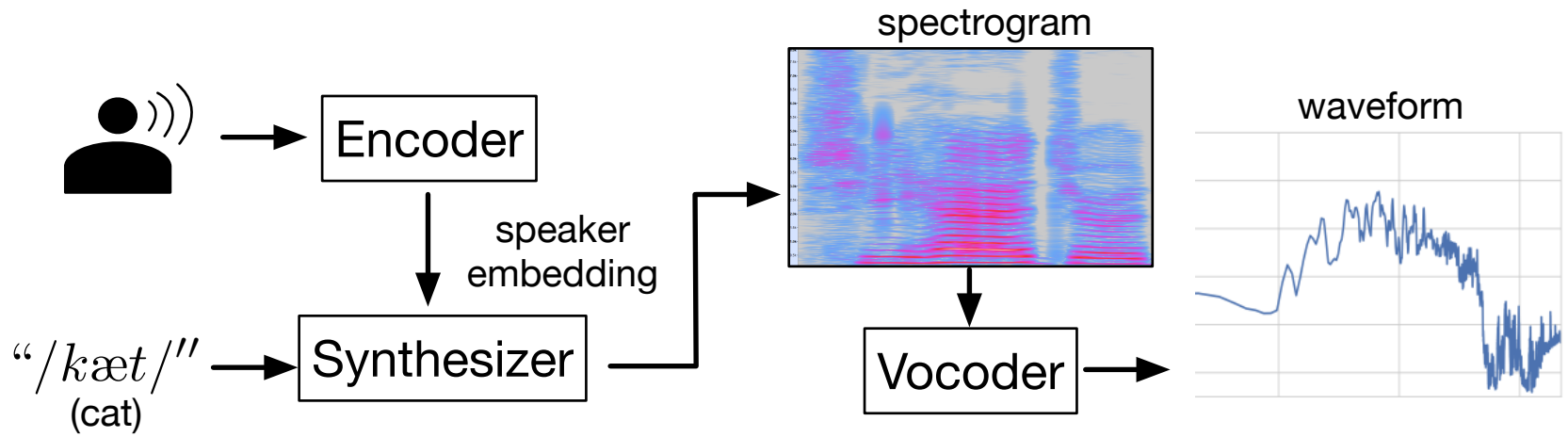

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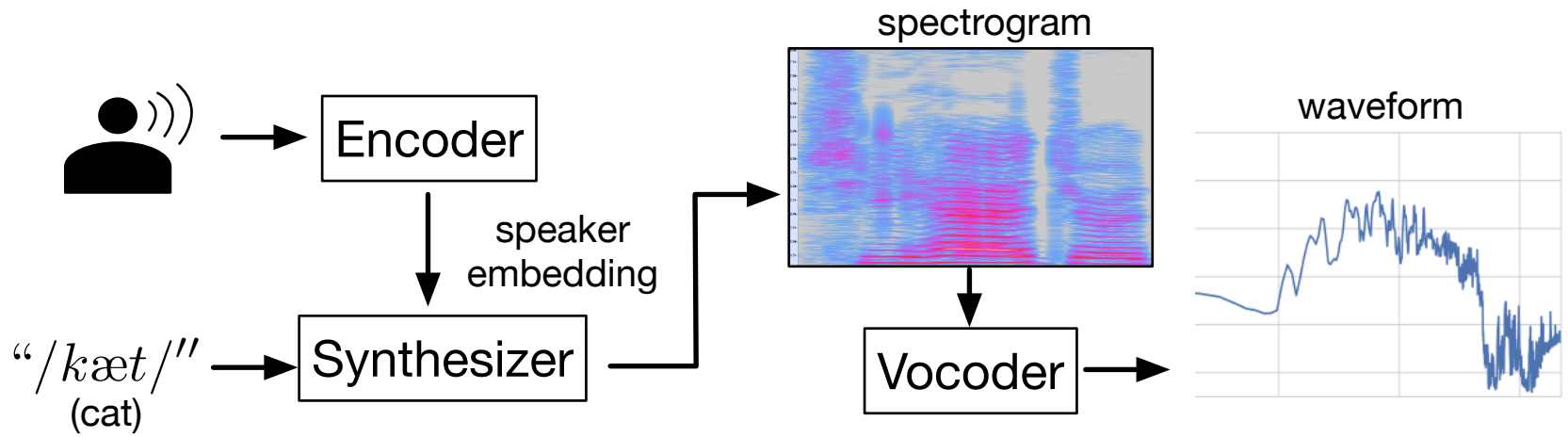

- Fundamentally not capturing the fluid dynamic behavior of the vocal tract

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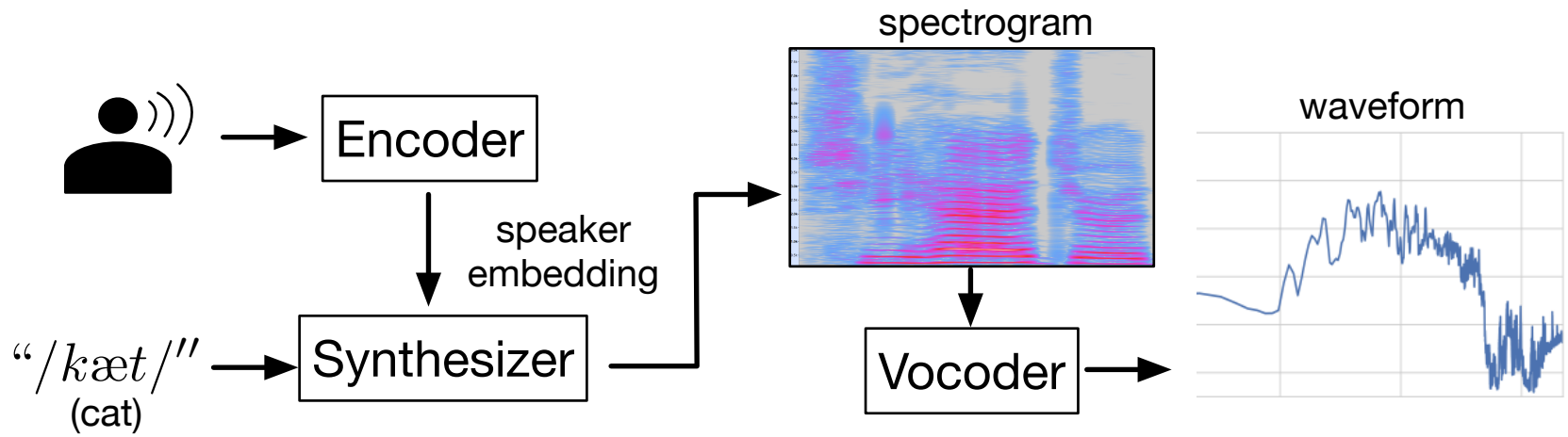
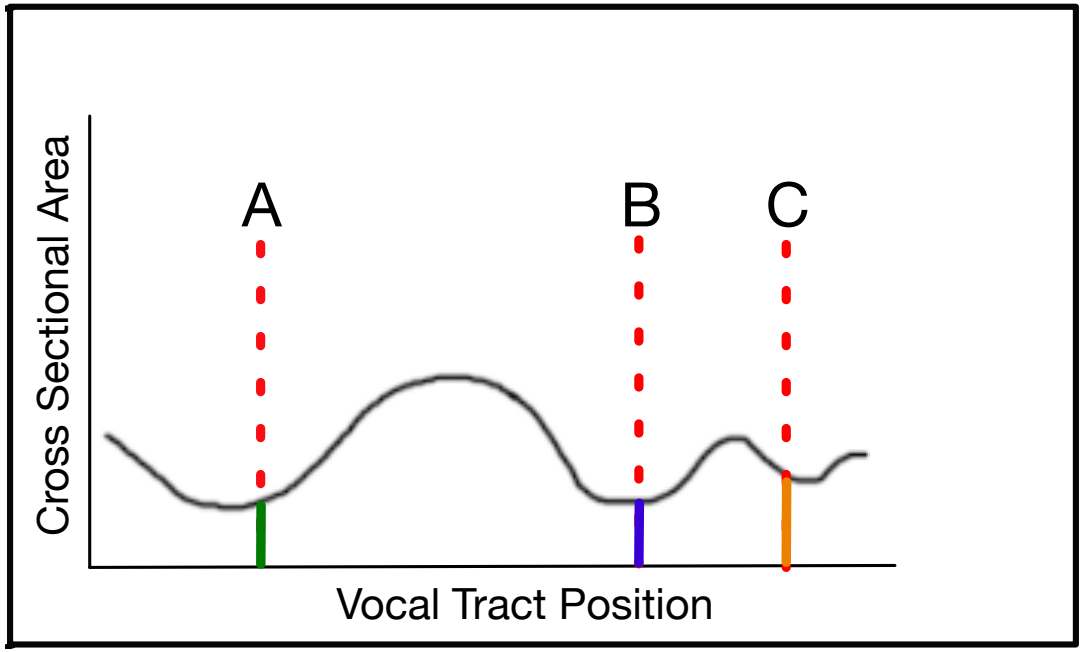


- Fundamentally not capturing the fluid dynamic behavior of the vocal tract
- Relying on ML to learn the fluid dynamics

Modeling Human Voice Creation



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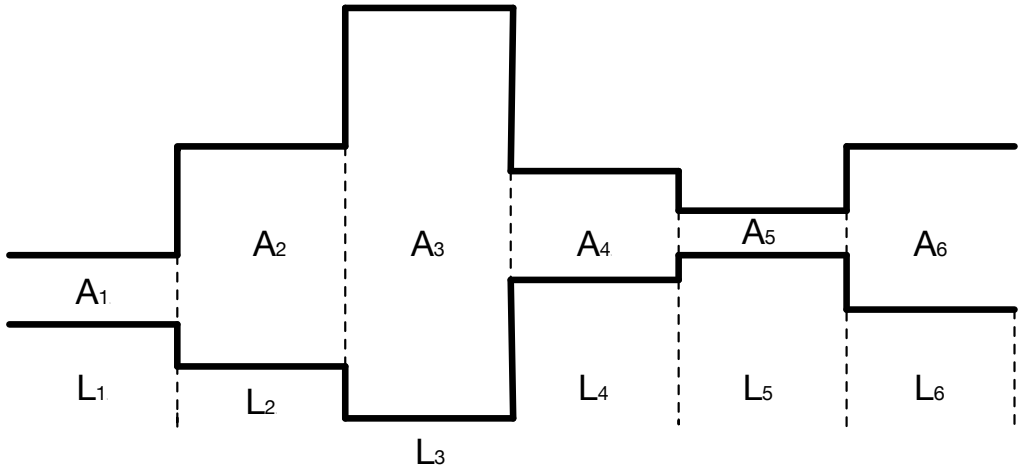

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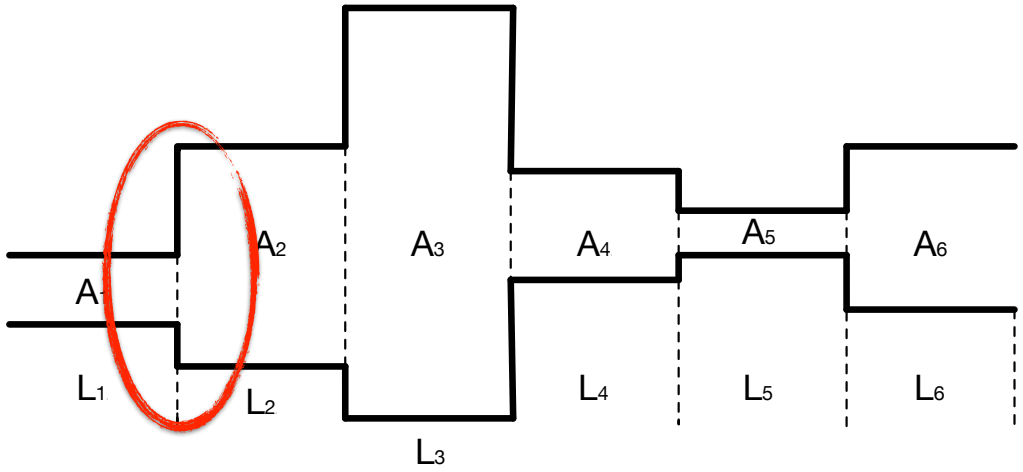

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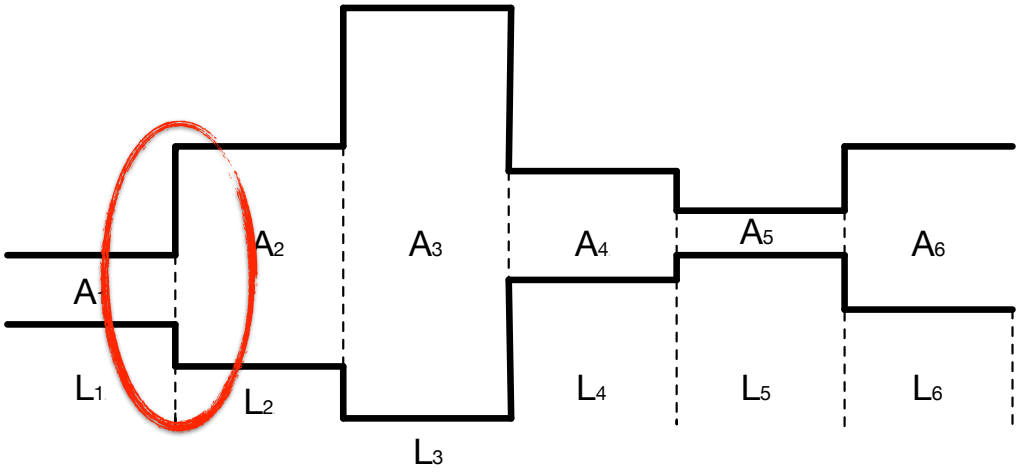

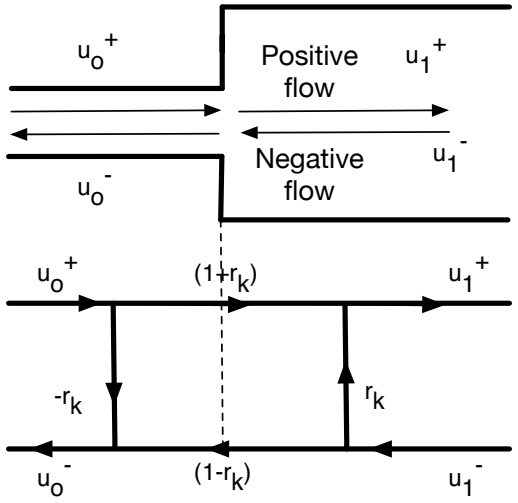

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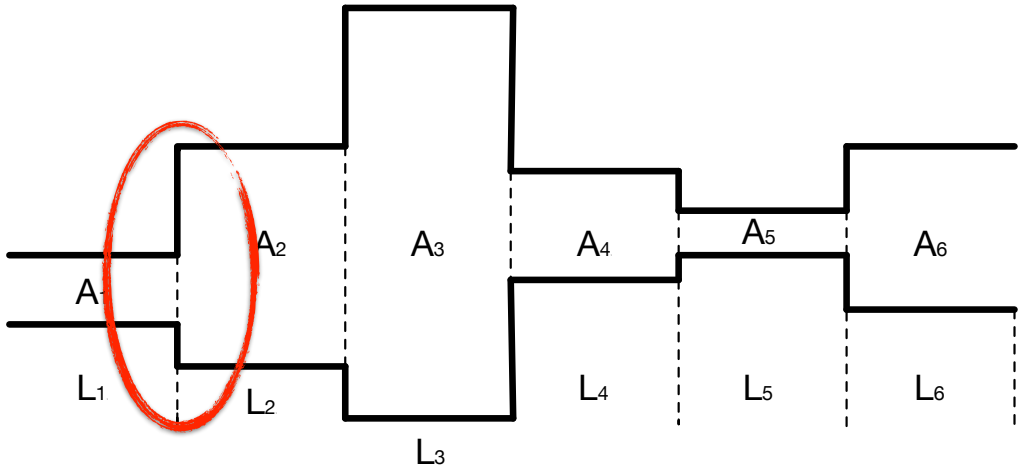
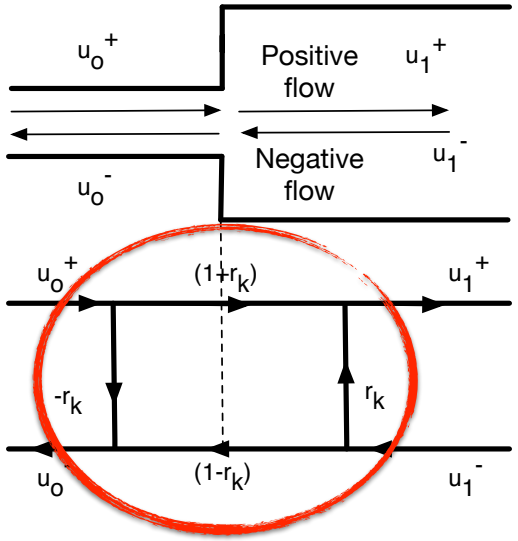


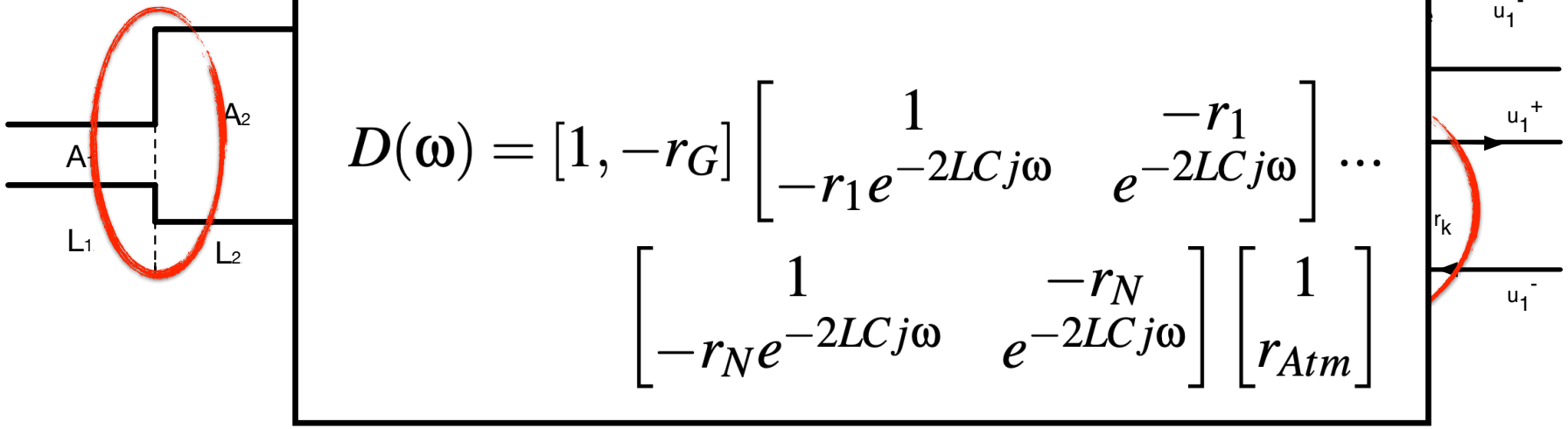


Modeling Human Voice Creation

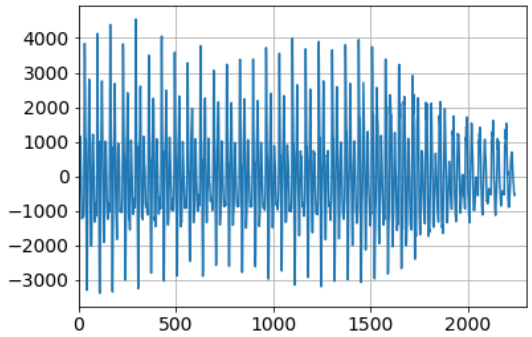
$$V(\omega) = \frac{0.5(1+r_G)\prod_{k=1}^{N}(1+r_k)e^{-LCNj\omega}}{D(\omega)}$$

$$D(\omega) = [1, -r_G]\begin{bmatrix} 1 & -r_1 \\ -r_1 e^{-2LCj\omega} & e^{-2LCj\omega} \end{bmatrix}\cdots$$

$$\begin{bmatrix} 1 & -r_N \\ -r_N e^{-2LCj\omega} & e^{-2LCj\omega} \end{bmatrix}\begin{bmatrix} 1 \\ r_{Atm} \end{bmatrix}$$



Audio to Biology



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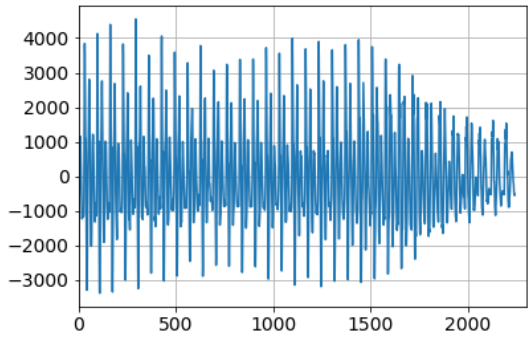

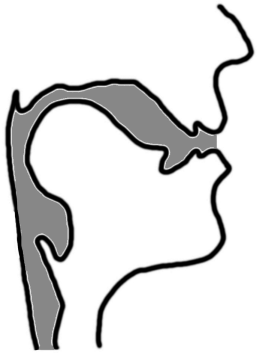

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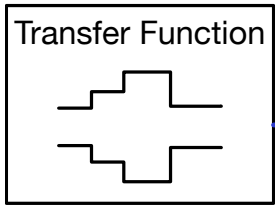

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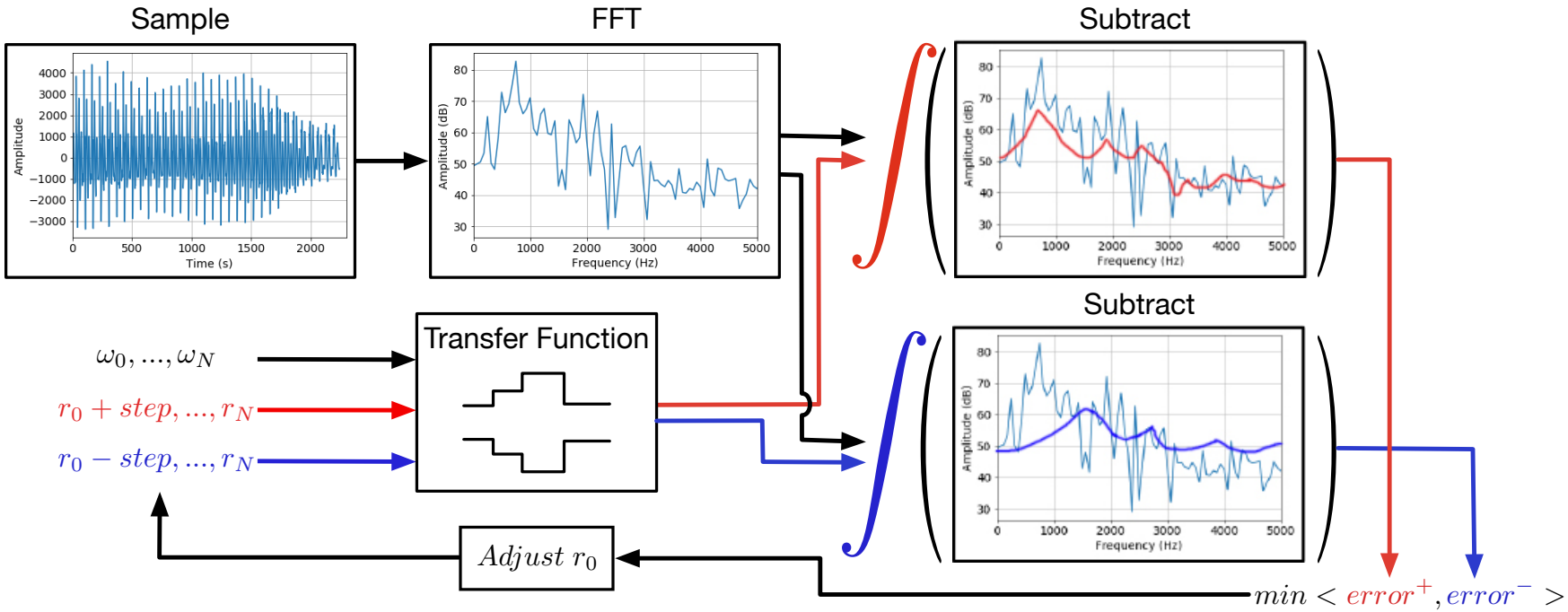

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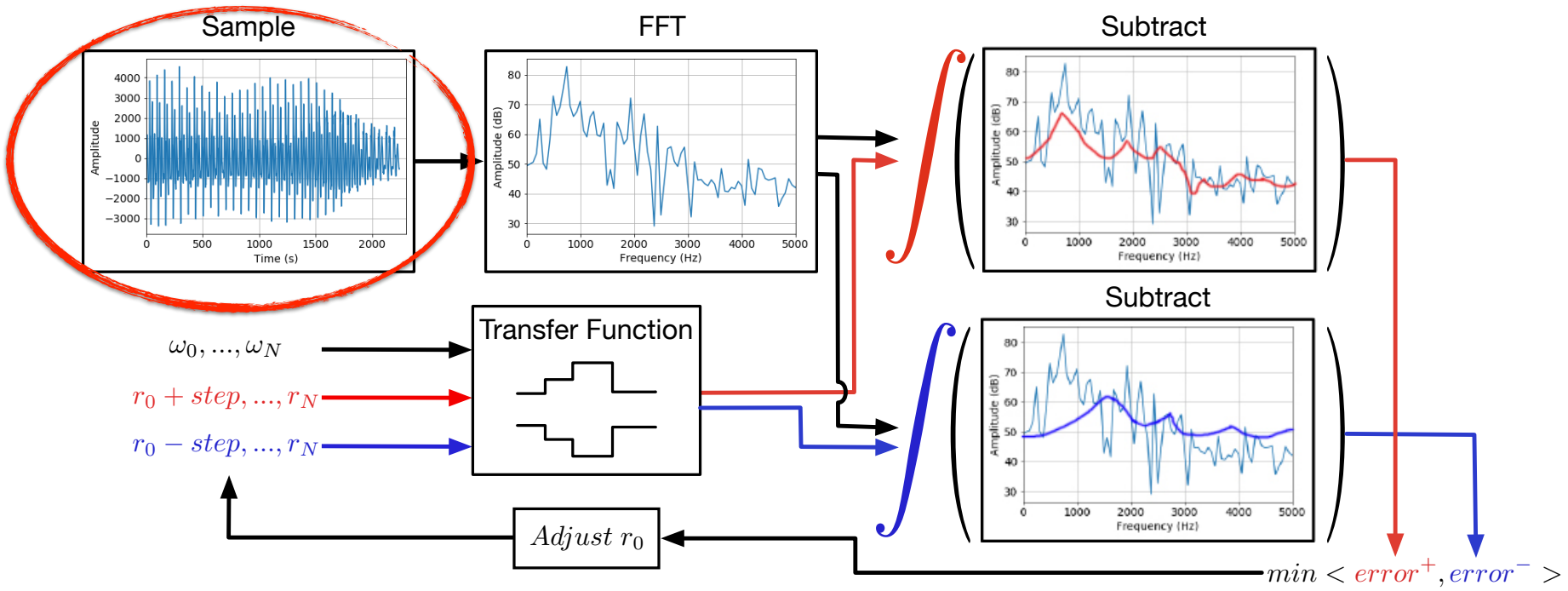

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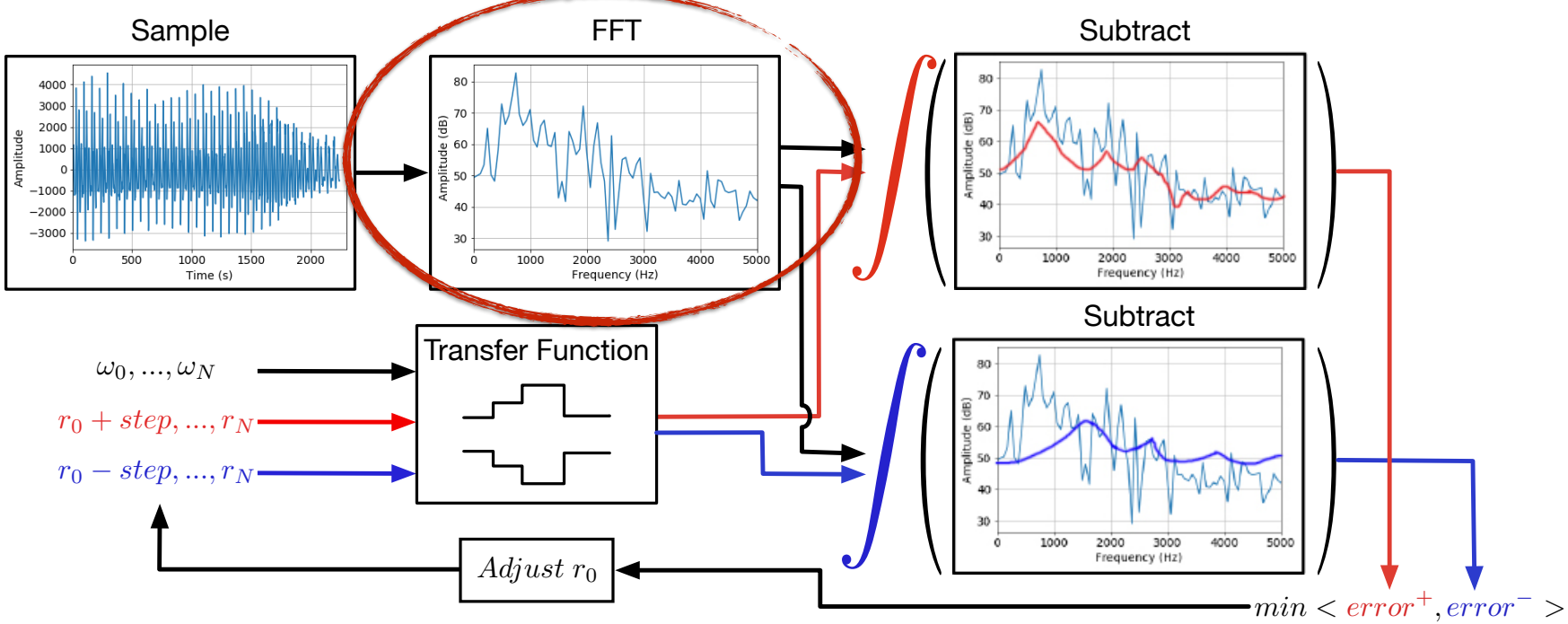

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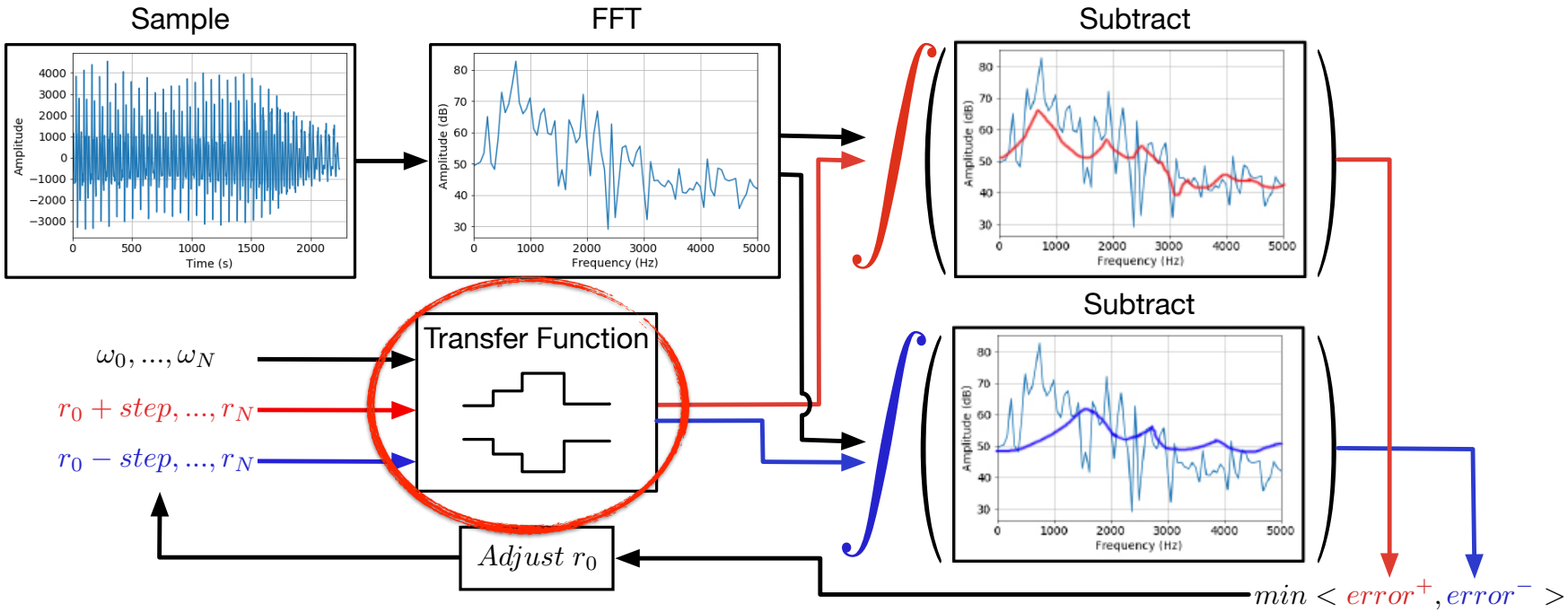

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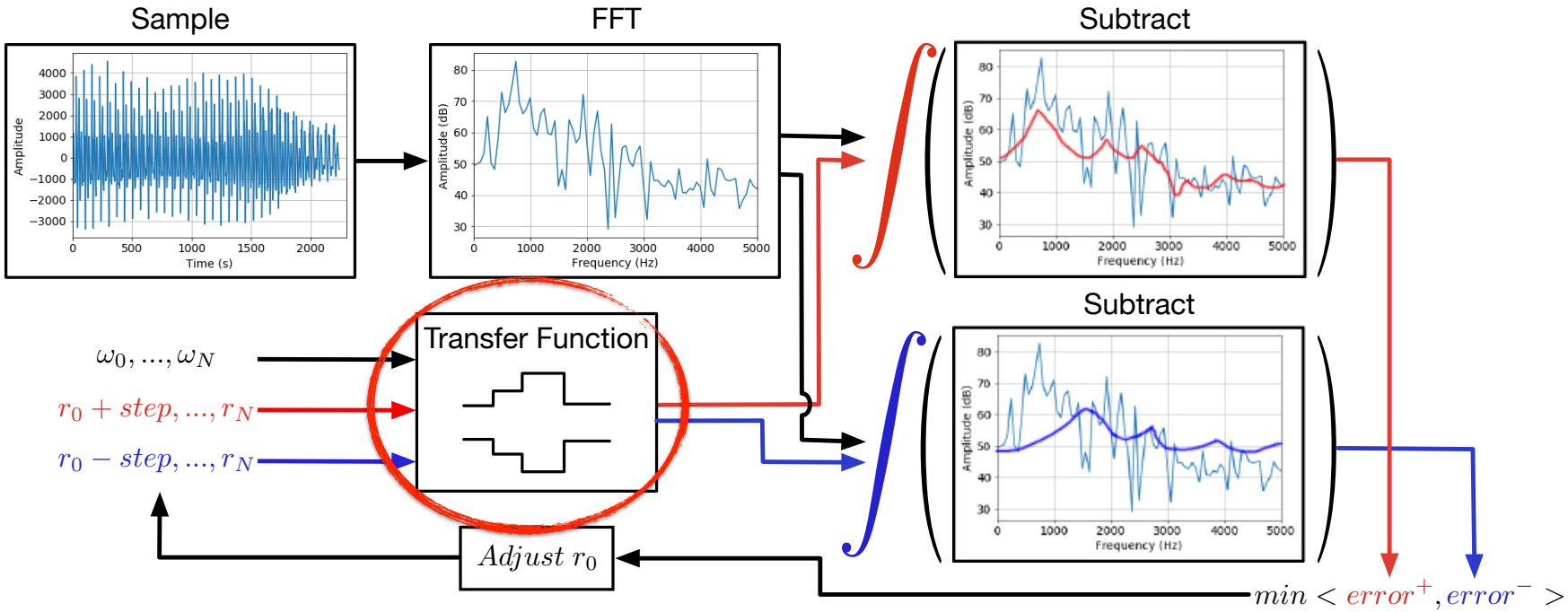

- Transfer Function - 15th order differential equations that models the anatomy
  - Without knowing appropriate boundary conditions, there exists an infinite number of possible solutions

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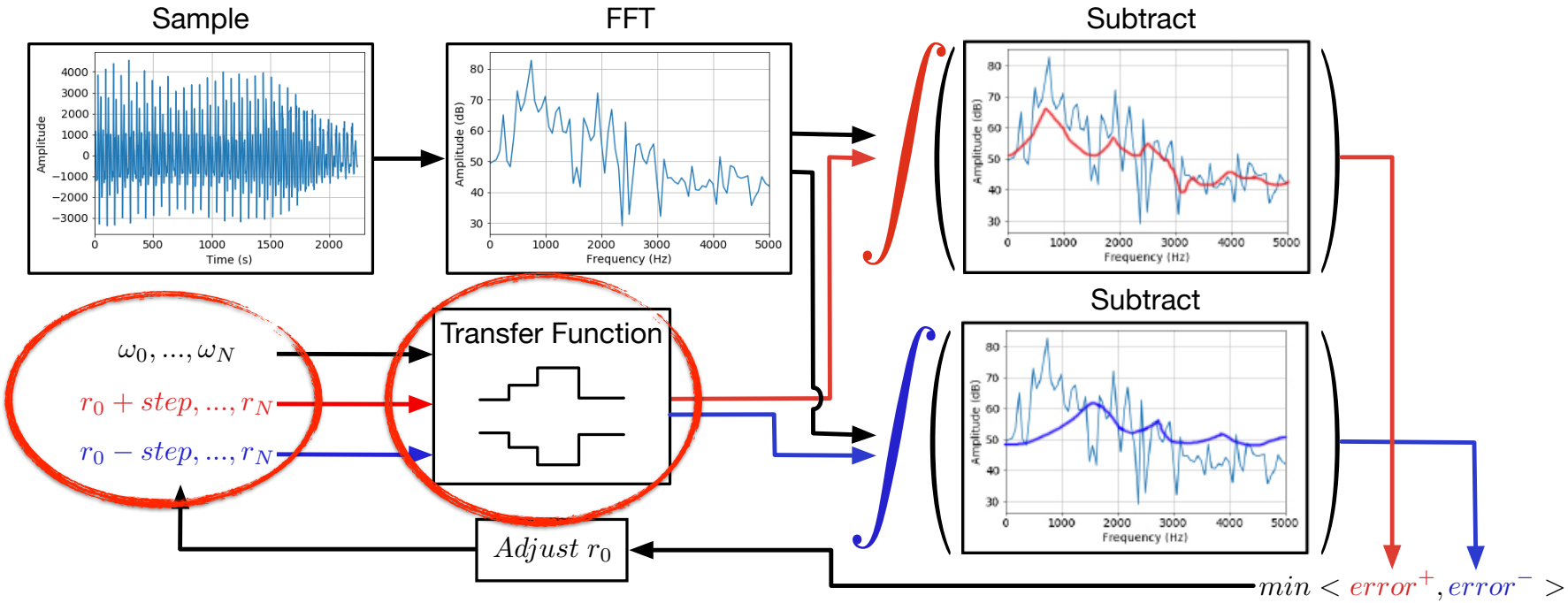

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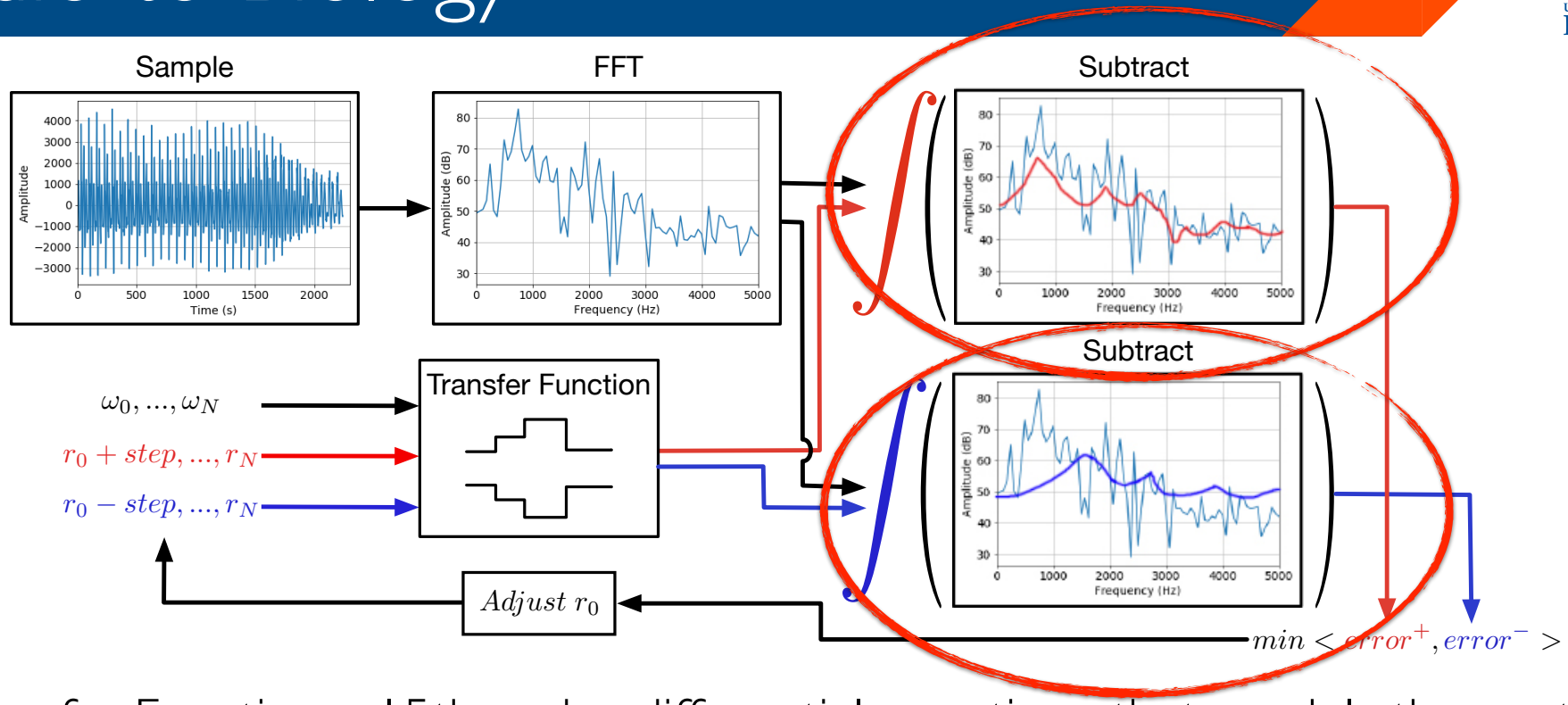

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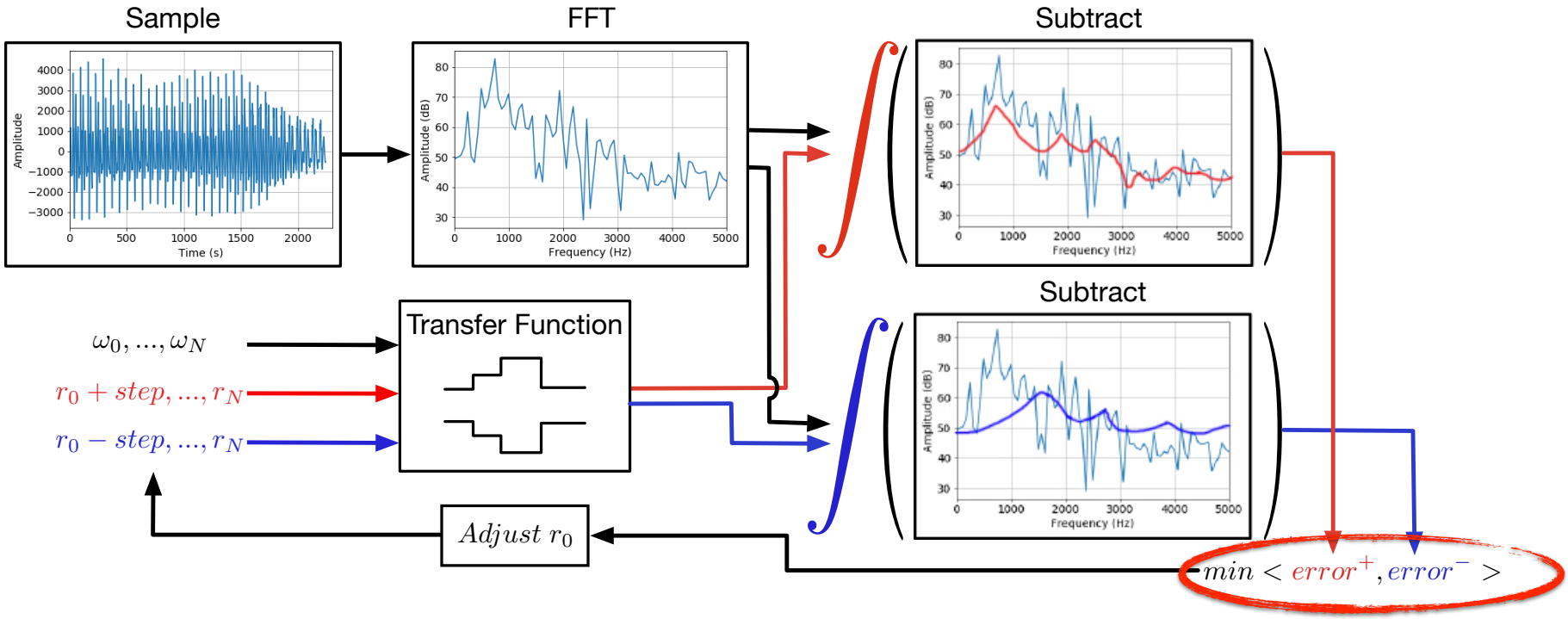

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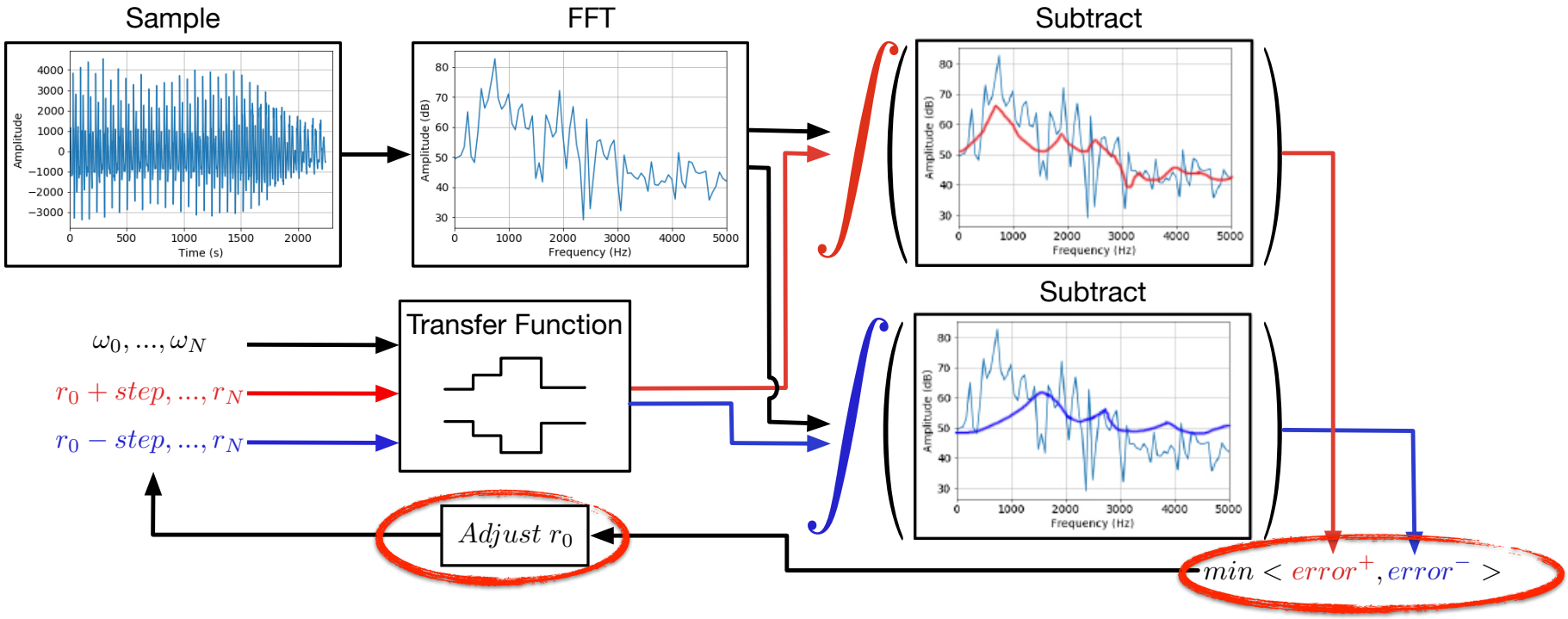

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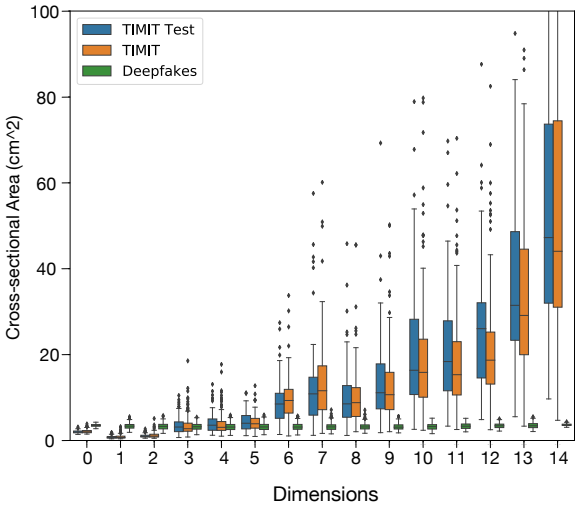
The Straw-man



a)

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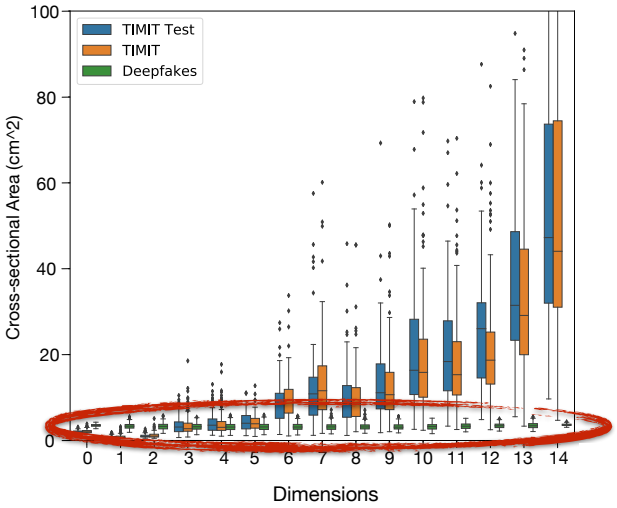

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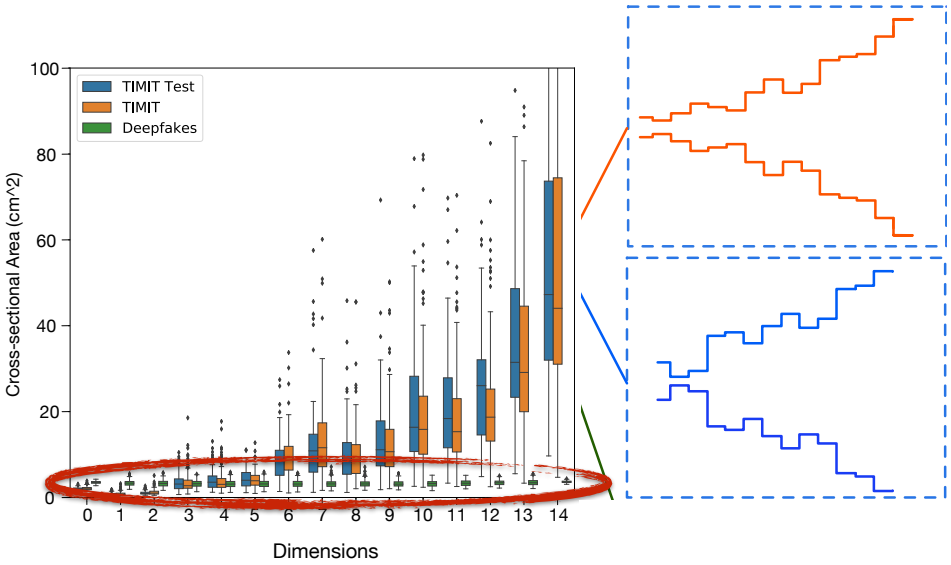
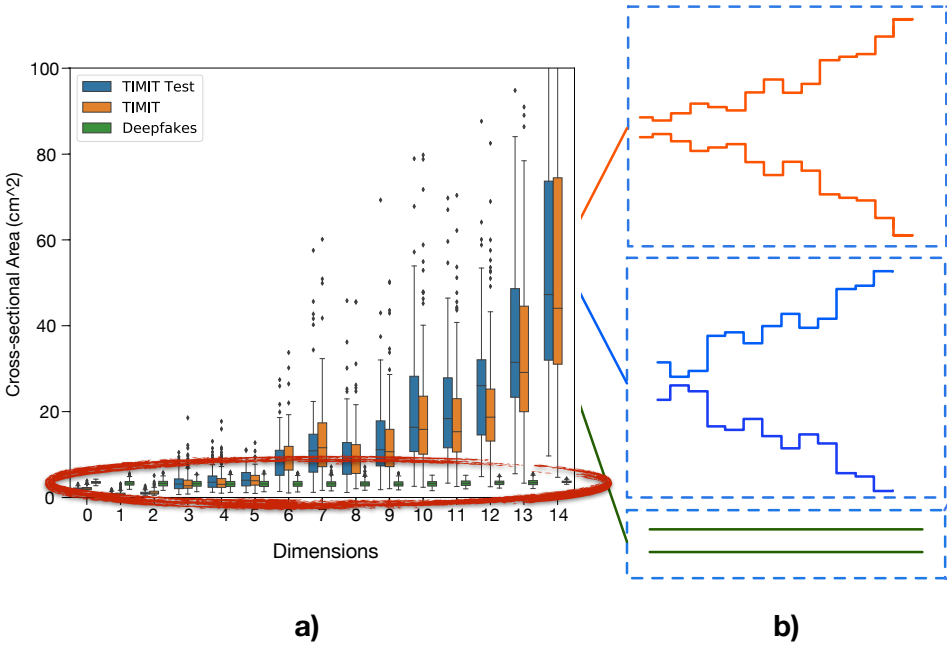


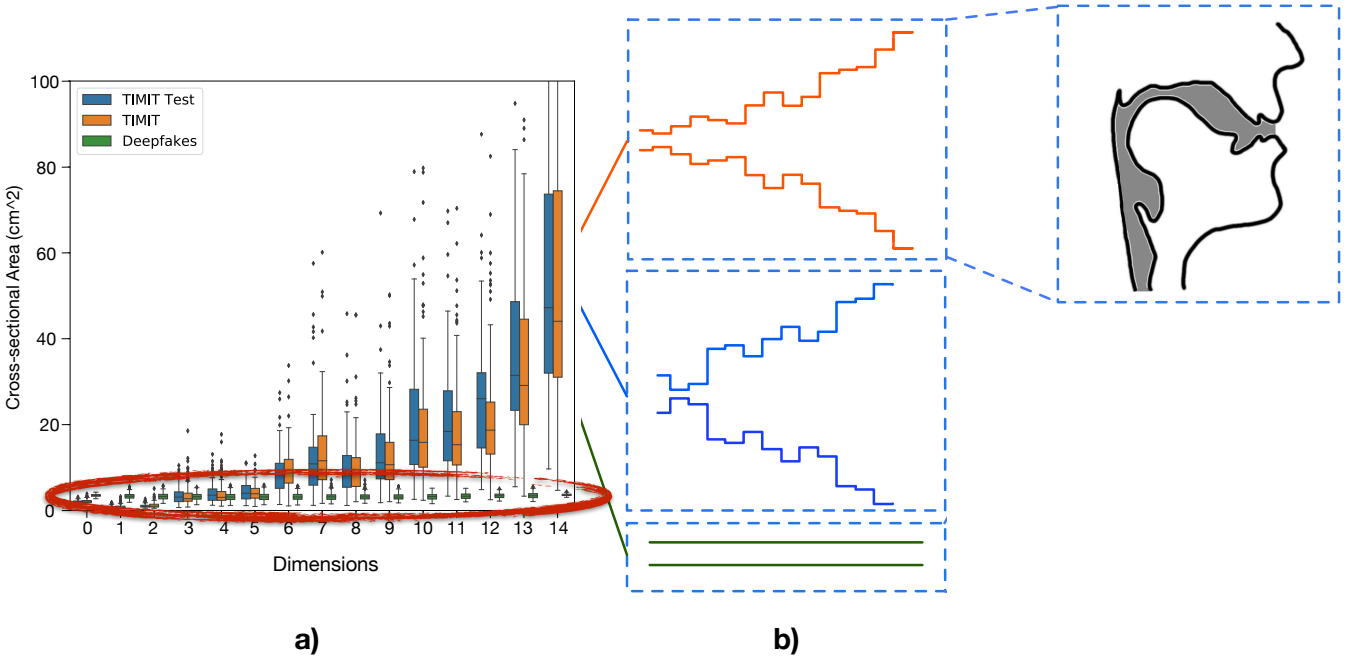
a)

The Straw-man



a) b)

The Straw-man



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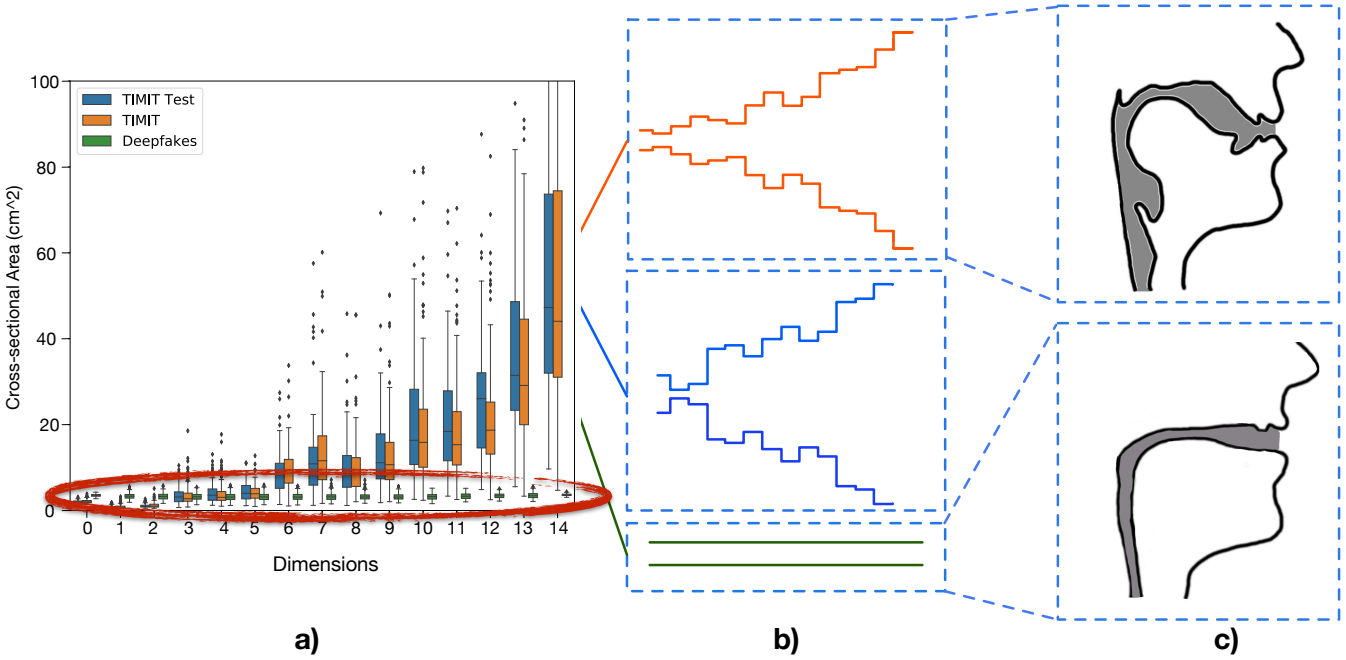

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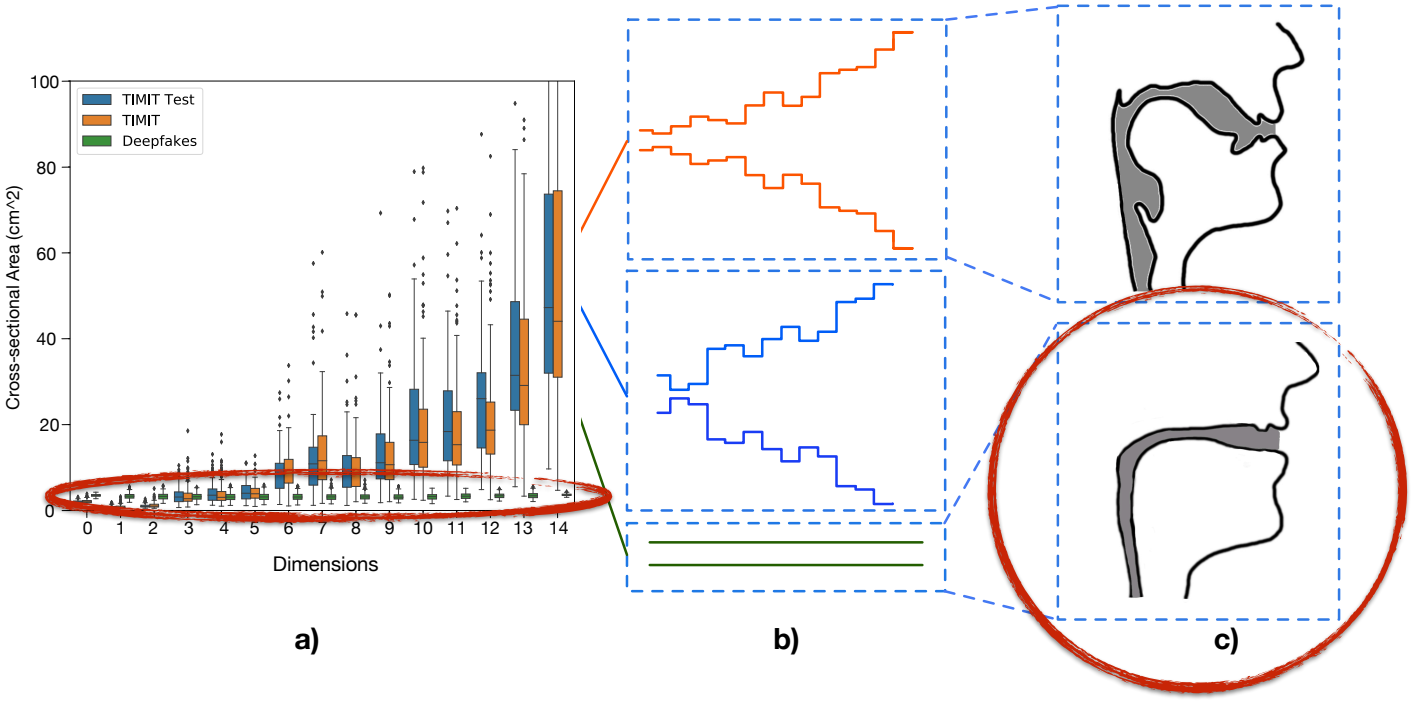

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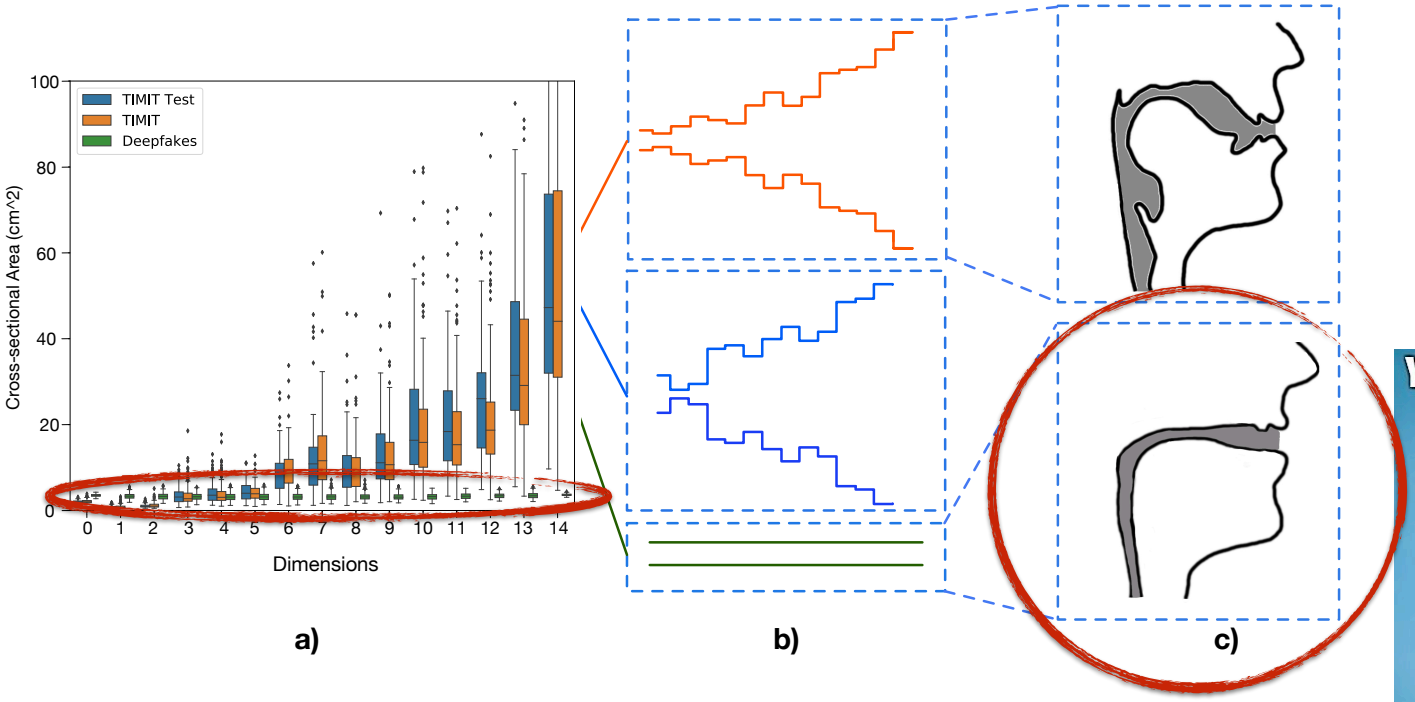

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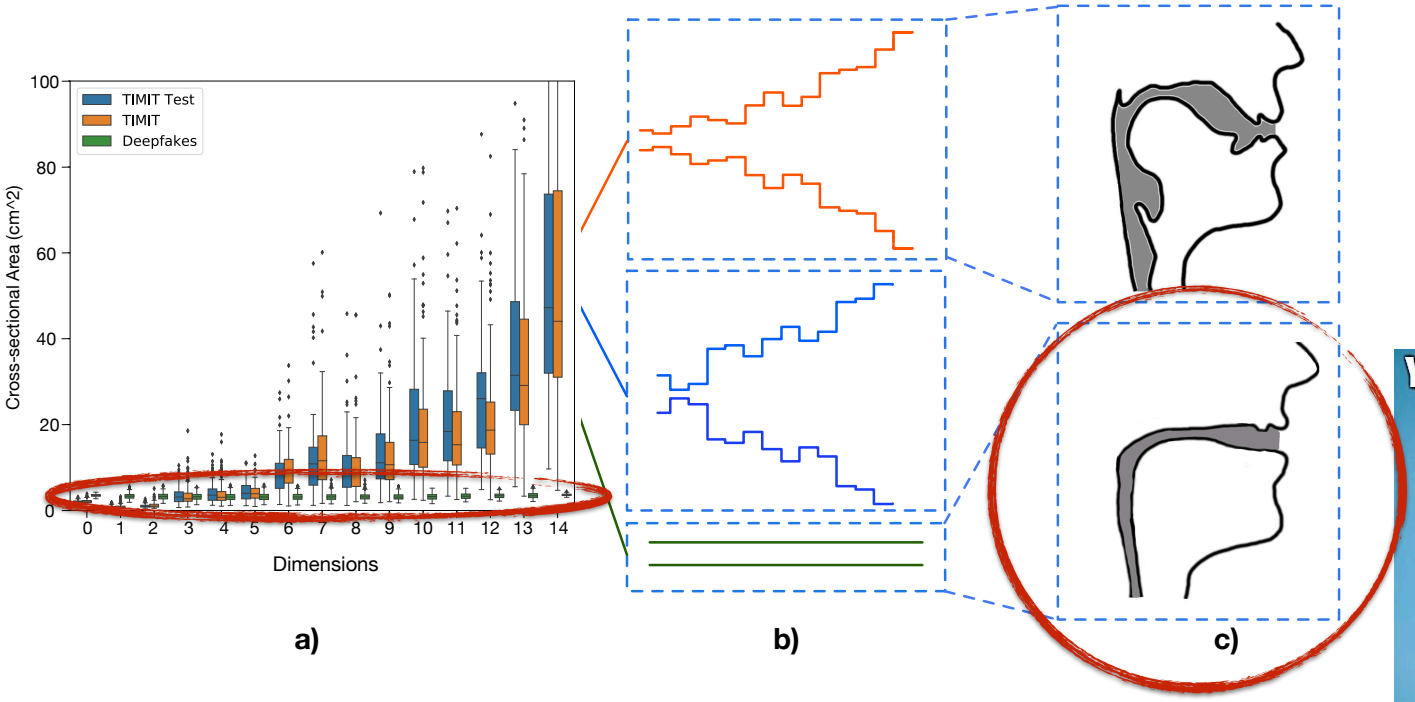
- Impossible vocal tract



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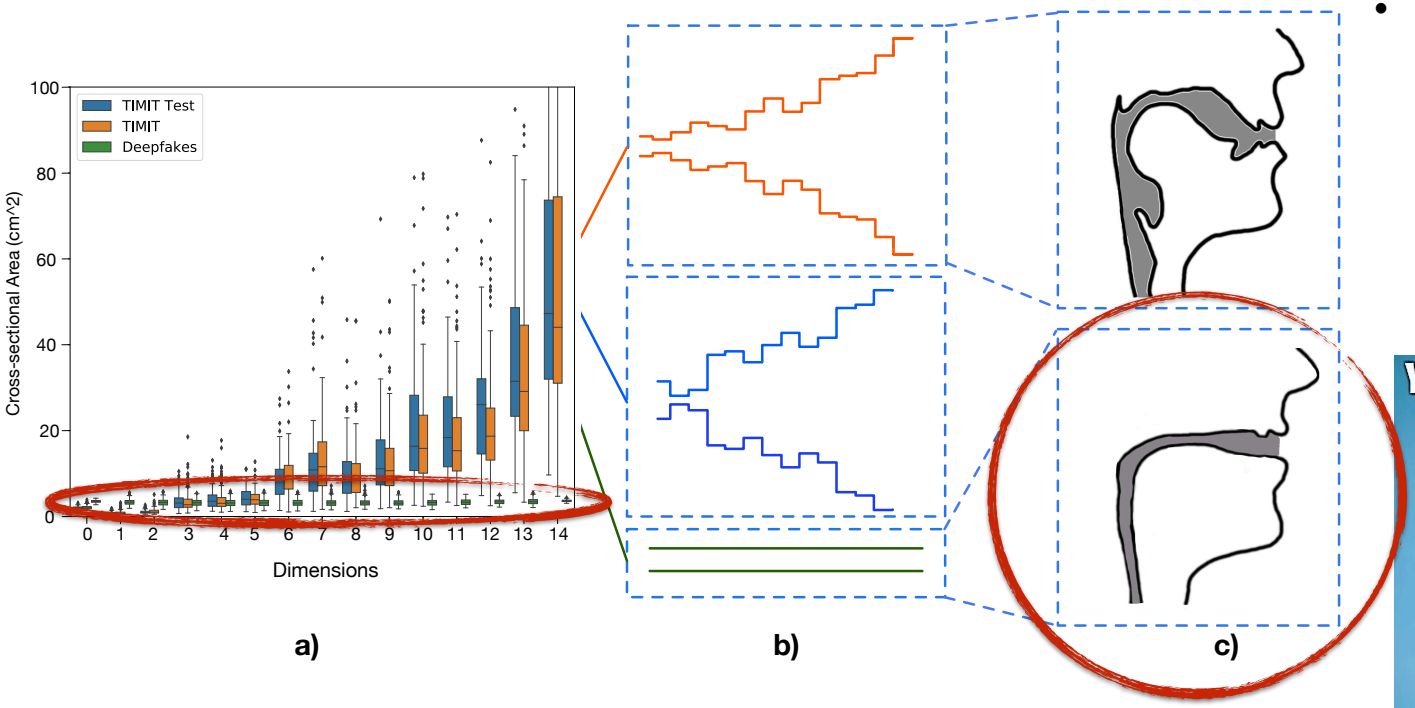

- Impossible vocal tract
- Model correctly mimics macro-acoustical features

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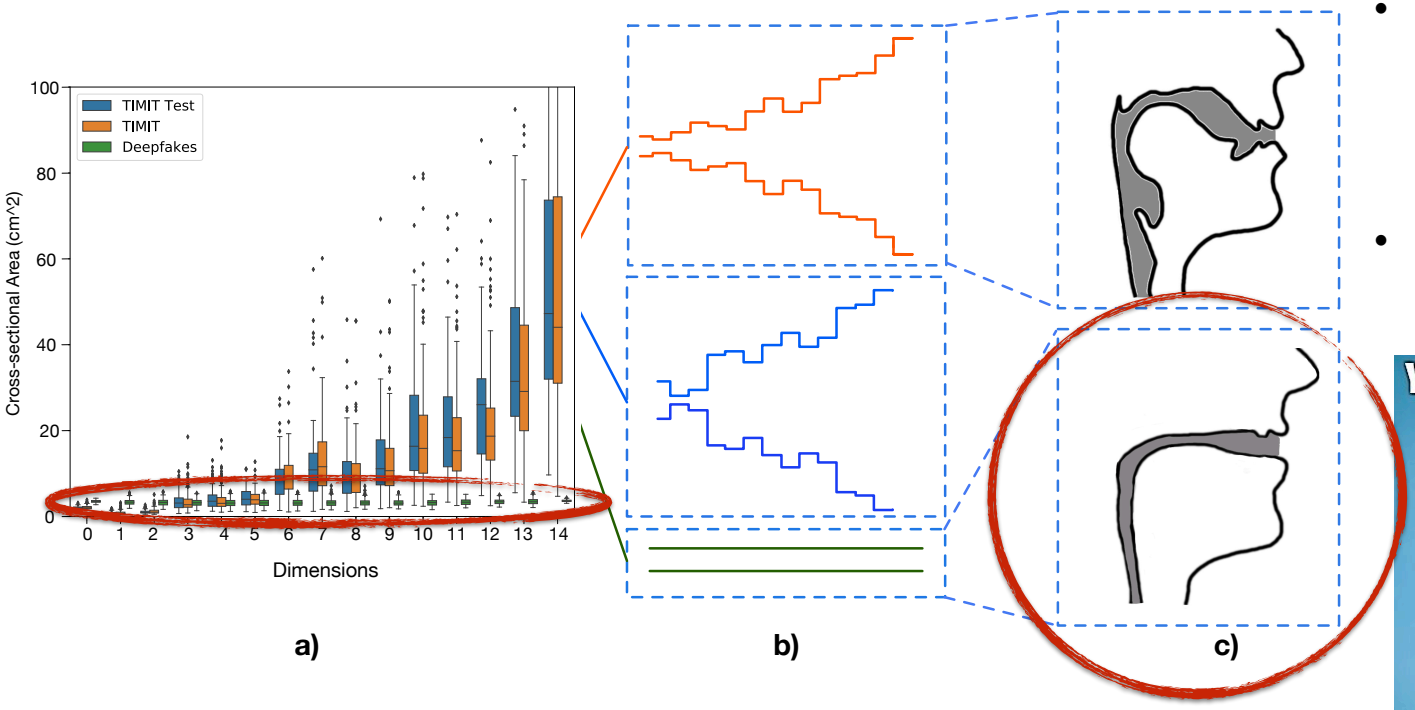

- Impossible vocal tract
- Model correctly mimics macro-acoustical features
- Model fails to mimic micro-acoustical features

Detection Results

- Full sentence evaluation

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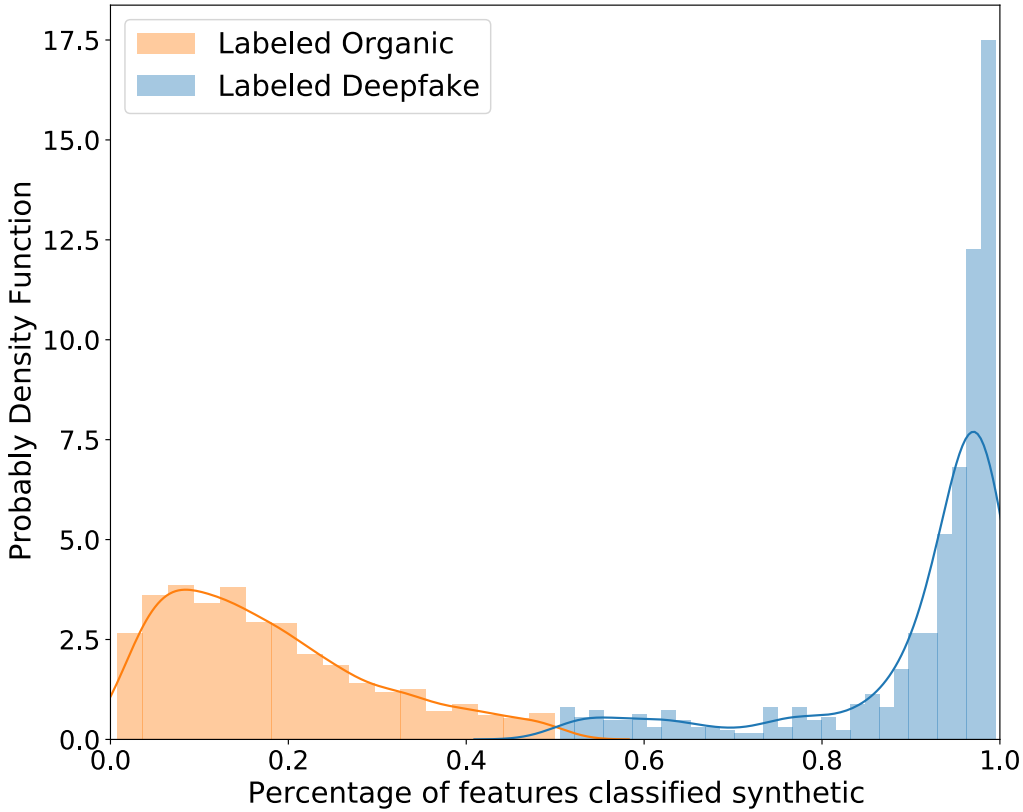

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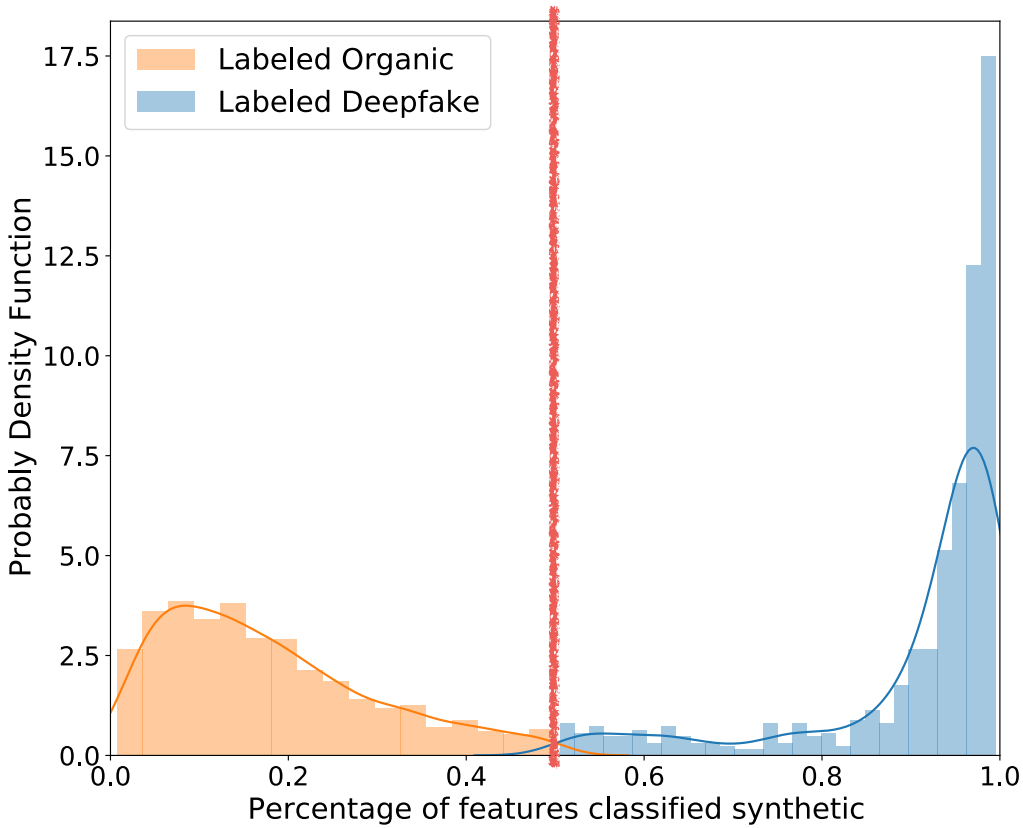
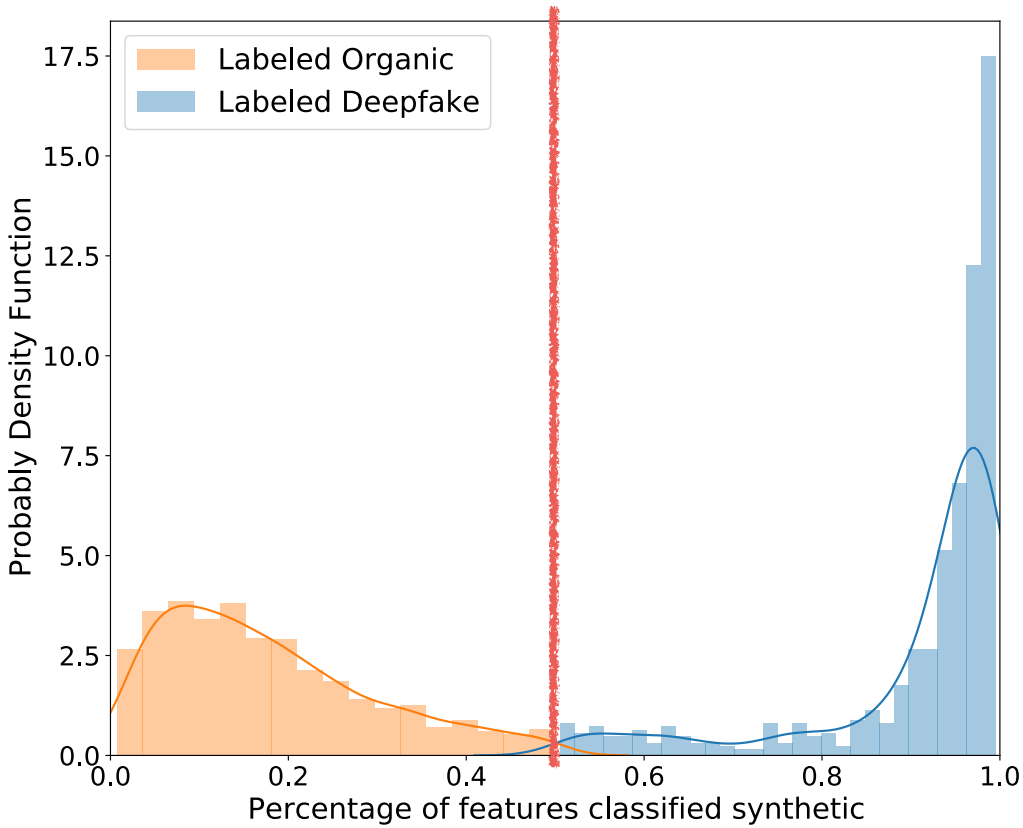


Detection Results

- Full sentence evaluation
  - 4,966 sentences examined
  - 12,525 Bigram-Feature examined
  - Precision: 99.9%
  - Recall: 99.5%



Take Away

- Fluid dynamics can be used to accurately recreate biology from audio
- Reconstruction of anatomical features can allow a defender to differentiate human generated audio from DeepFake audio
  - Are we even listening to a human? We can measure that!

Questions

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