A method for automatically detecting problematic tongue traces

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Current work

- ***Background***: Fasel and Berry [1] introduced a deep belief network approach to automated labeling of tongue contours
- ***Problem***: Errors along the anterior and root edges of the tongue are common [2, 3]

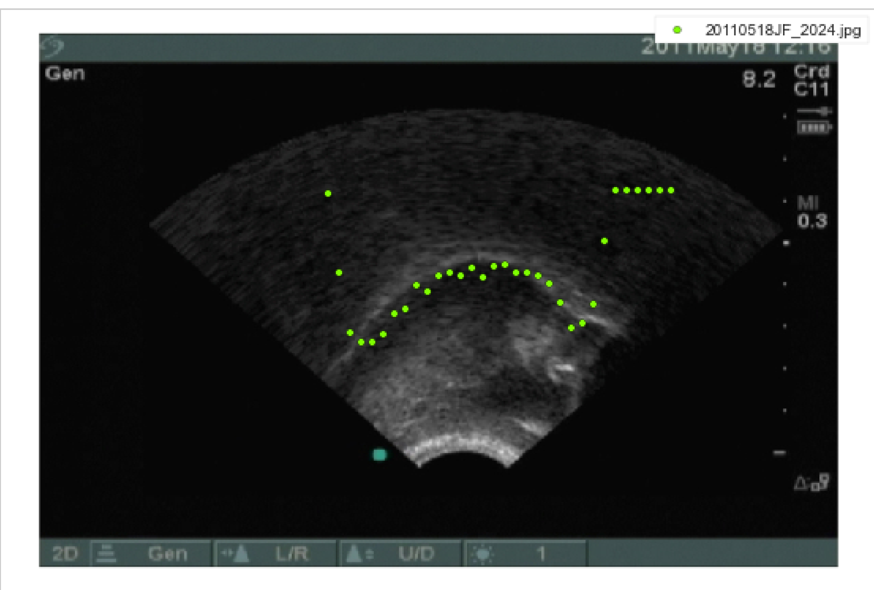


Figure 1: A common error

- ***Goal***: Reduce errors by modifying *training* and *post-processing* procedures

Training data

- 850 images from the Harvard Sentences [4]
  - selected **800** most + **50** least diverse

Why Harvard Sentences?

- **Large dataset**
  - Image pool of 33K+
- **Diverse**
  - Phonetically balanced dataset
    - 1906 distinct words
  - 11 speakers
  - Many tongue configurations

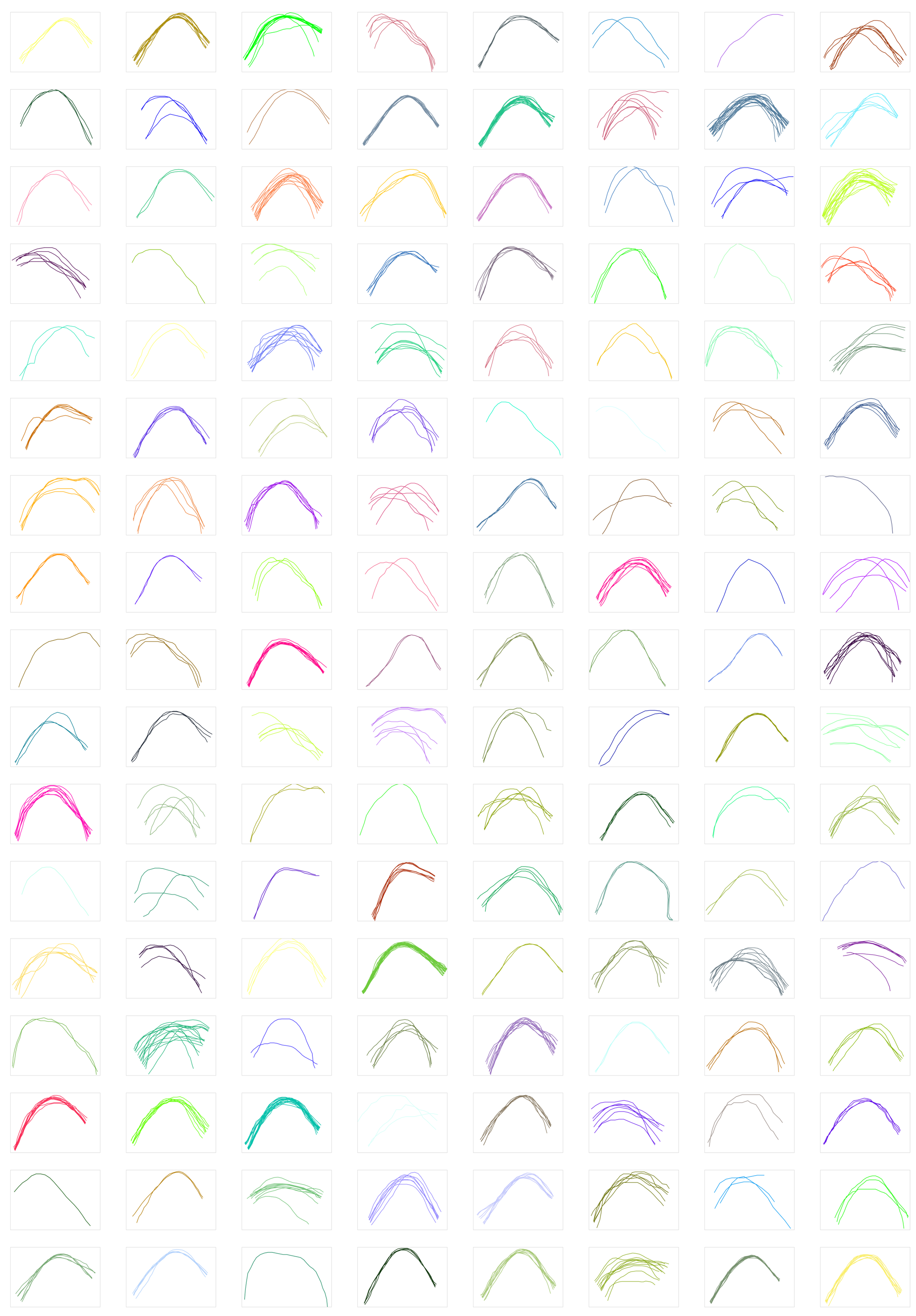


Figure 2: 180 k-means clusters of tongue contours in the training data

Network architecture

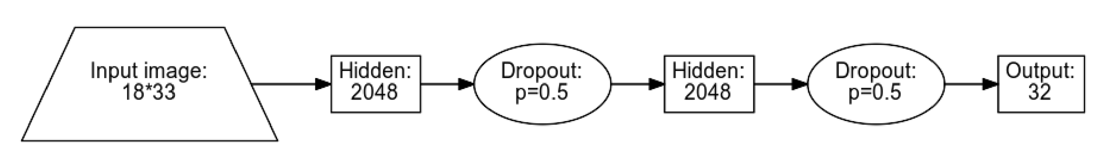


Figure 3: Autotres architecture comprised of two hidden layers with 2048 units each and dropout with probability 0.5.

Training modifications

Preprocessing images

- Add Gaussian blur to reduce image noise

Scaling images

- Decrease image size to simplify training
  - fewer pixels = fewer units

Regularization

- Add ℓ^1 and ℓ^2 regularization [5] to avoid overfitting

$$\mathbf{R}_{\ell^p}(\theta) = \|\theta\|_p = \left(\sum_{j=0}^{|\theta|} \left|\theta_j\right|^p\right)^{\frac{1}{p}}$$

Equation 1: Generalized equation for the ℓ^p-norm

Post-processing

Constraining regional change

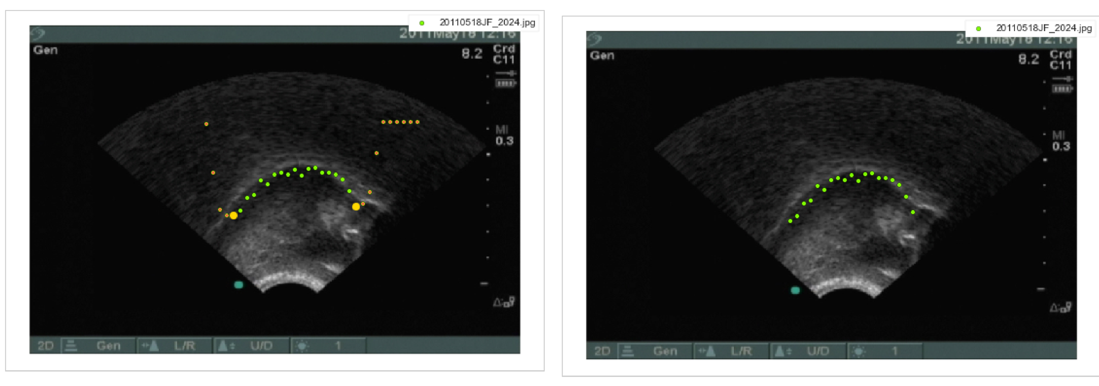
- Detect physiological impossiblities

Figure 4: Use the expected average positional change between adjacent points in three tongue regions [6] to detect and constrain erroneous coordinates.

Figure 5: Corrected through derivative-based constraint

Trimming from local minima

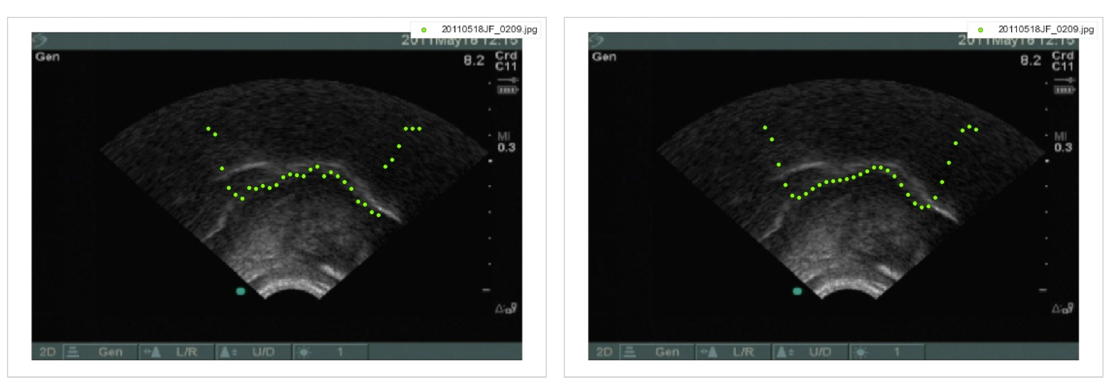
- Find regional y-axis minima



(a) Highlighted regional minima **(b)** Trimmed from local minima

Smoothing via polynomial fit

- Use Savitzky-Golay filtering [7, 8]



(a) Autotres output **(b)** Smoothed

Figure 7: 9^{th} order polynomial fit

Results

$$MSD(U,V) = \frac{1}{2n}\left(\sum_{i=1}^{n} \min_j \left|v_i - u_j\right| + \sum_{i=1}^{n} \min_j \left|u_i - v_j\right|\right)$$

Equation 2: Mean Sum of Distances (MSD) method of Li et al. [9]

Method	MSD
AutoTrace (original)	
Default settings	29.4
(S-G + *minima*)	25.19
Autotres (new)	
.1 scaling	42.6
Regularization	42.5
Savitzky-Golay smoothing	42.9
Constrained regions	40
Trimming minima	16.64
(*Regularization* + S-G + *minima*)	**15.71**

Future work

- New architectures
  - convolutions
  - multiple networks for tongue regions
  - layer modeling whether or not a point should be produced
    - some images don't have a contour
- Unsupervised pretraining

Code

`Autotres`

- third-generation software
- Python 3
- fast training on the GPU
- open source and freely available
- includes utilities for training, tracing, visualization, and evaluation

`https://github.com/arizona-phonological-imaging-lab/autotres`

Acknowledgements

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