Benefits of using polar coordinates for working with ultrasound midsagittal tongue contours

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Introduction

Midsagittal tongue contours averaged via Smoothing-Spline Analysis of Variance (SSANOVA with 95% confidence bounds) (Gu, 2002; Wang, 2011; Davidson, 2006; applied in Chen & Lin, 2011; Kochetov, Sreedevi, Kasim & Manjula, 2014; Lee-Kim, Kawahara, & Lee, 2014; etc…)

Problem 1

- Cartesian plane standard
- Creates errors in non-horizontal:
  - Curves
  - Confidence bounds
- Generates statistical errors
  - At tongue tip & root

Solution 1

- Polar coordinates (cf. Mielke, 2015)
  - See Figures 1 and 2

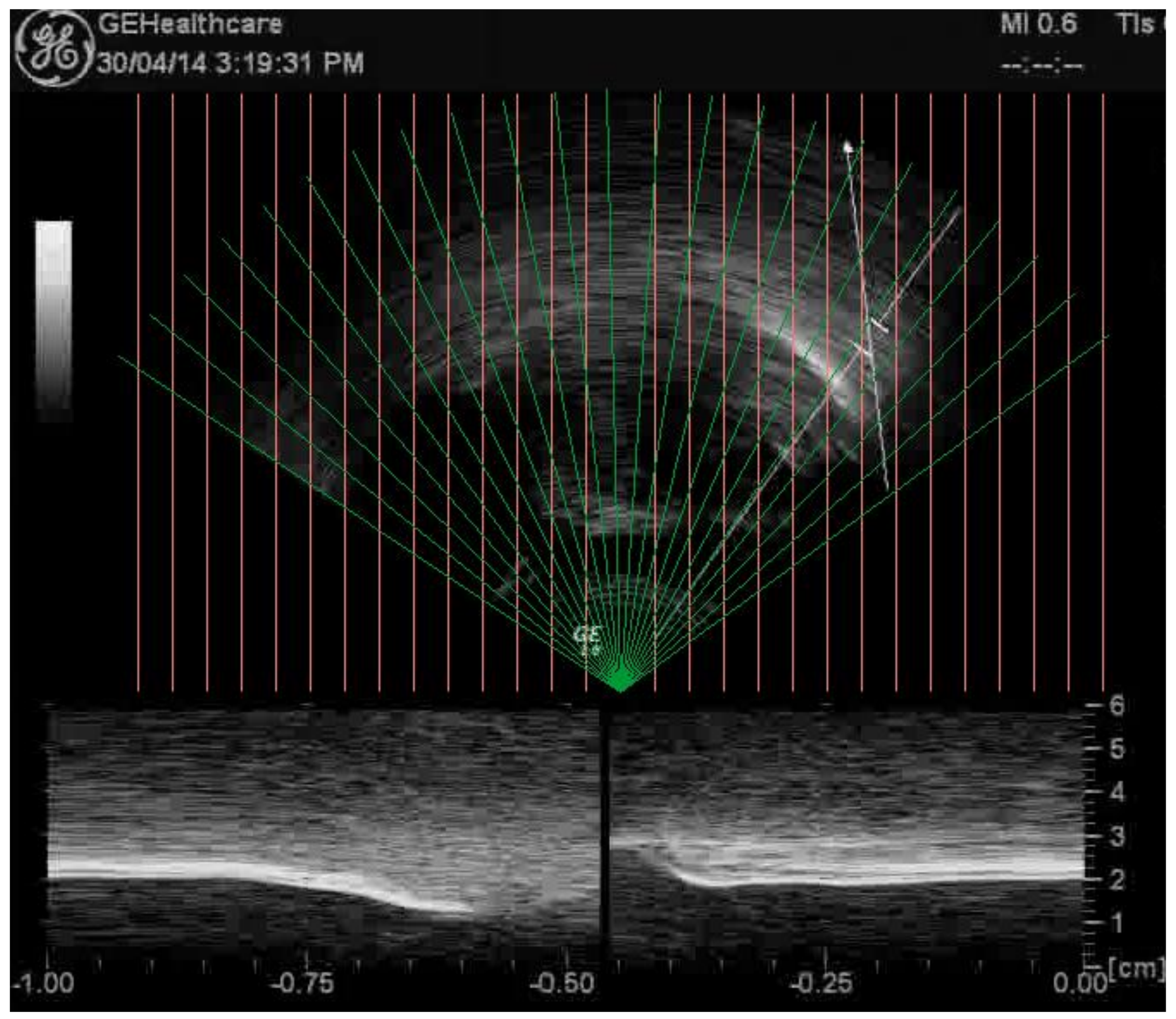

Figure 1: Cartesian plane averaging (vertical red lines) vs. polar coordinates (green, fan shaped lines)

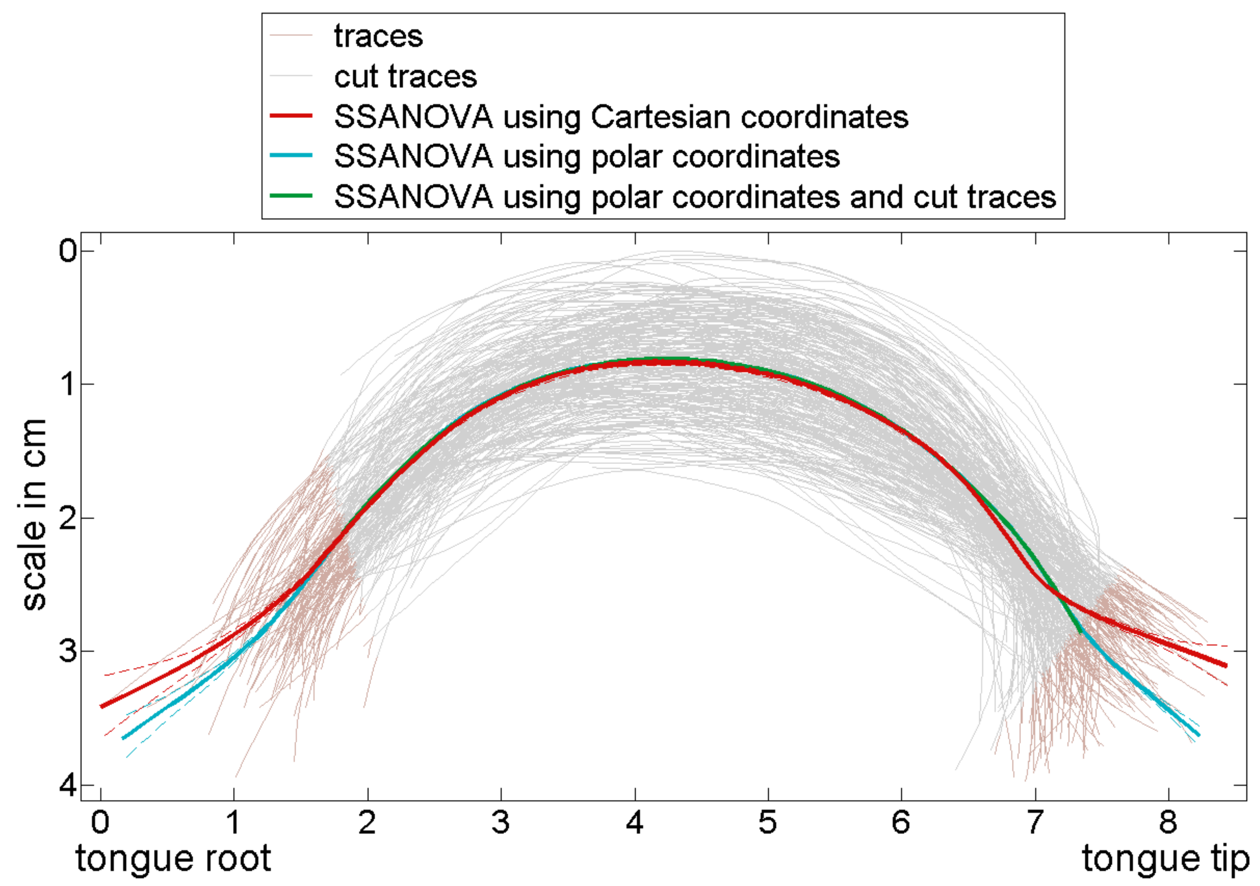

Figure 2: Tongue traces (faint lines), Cartesian SSANOVA (red), Polar SSANOVA (cyan), Polar SSANOVA based on cut traces (green)

Translation to polar coordinates necessitates choosing origin of polar coordinate system

Option 1

- Choose "an origin that is close to the center of an imaginary circle corresponding to the arc approximated by the collected tongue traces" (Mielke, 2015)
  - Not based on ultrasound hardware
  - Invalidates cross-comparison of sounds

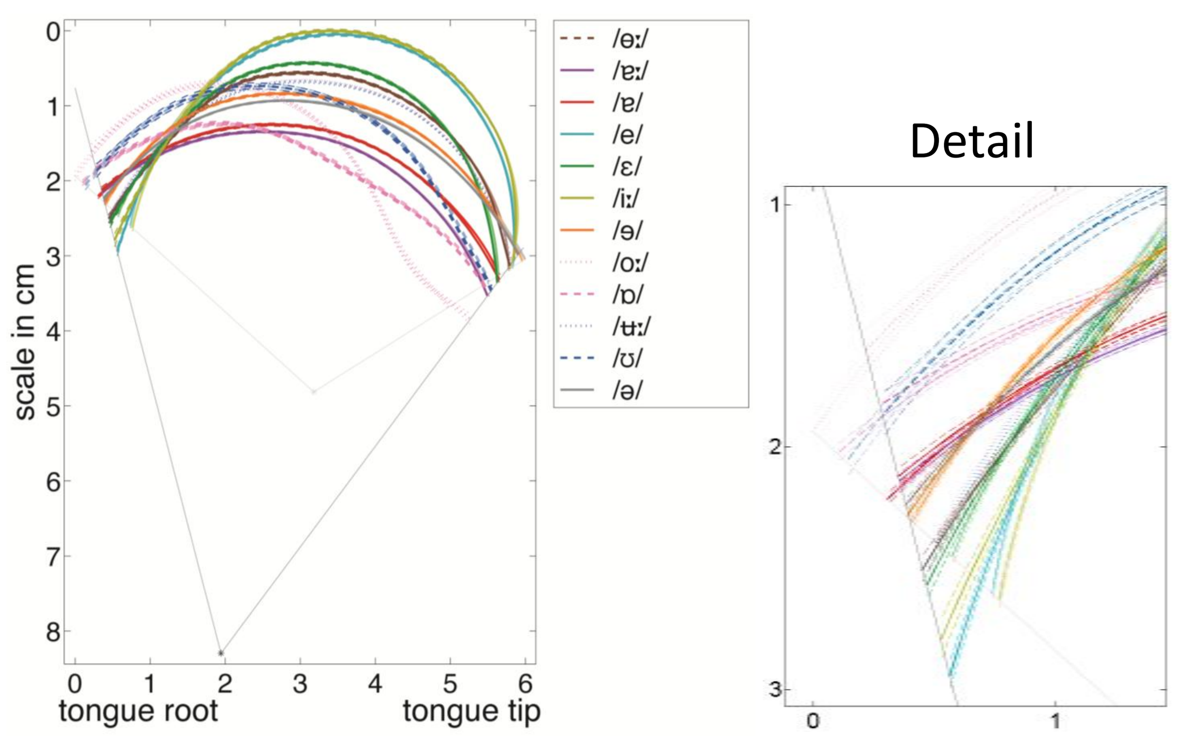

Figure 3: SSANOVA vowel curves for New Zealand English (NZE). Faint lines (Mielke's method – Option 1), Dark lines (estimated transducer origin – Option 2), Detail (highlights differences)

Option 2

- Estimate transducer location from ultrasound image
  - Plot angled lines on image
  - Set equations equal
- See Figure 3 for comparison of both options

Figure 4 shows conversion of cm scale to pixels

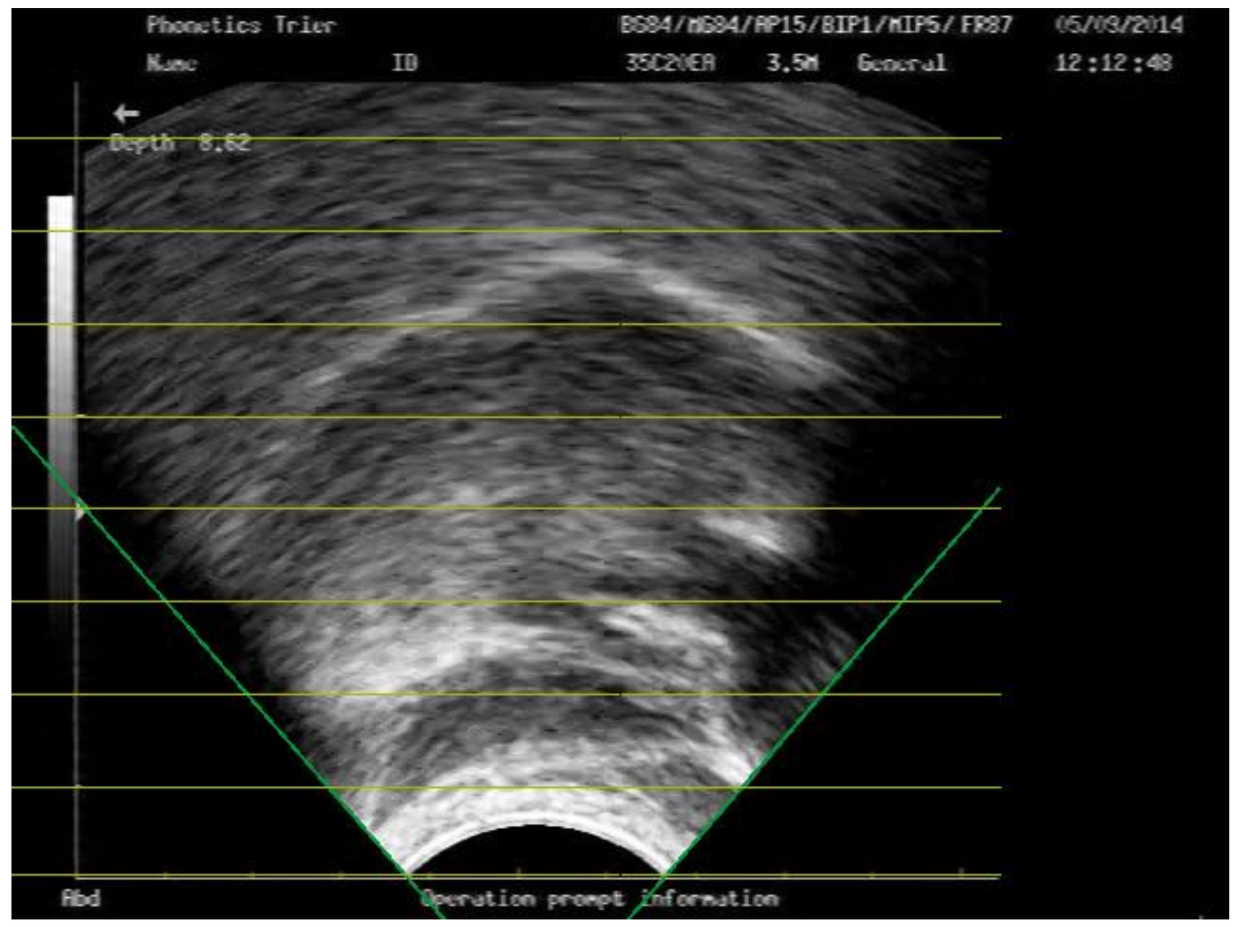

Figure 4:
Horizontal lines (conversion from cm to pixels)

Option 2 also provides solutions for:

Problem 2

Varying lengths of traces

- Single trace may affect average curve at edges
- Reflected in increasing error estimates

Solution 2

- Cut traces along radial lines
- Group vowels together
- Eliminate data points with 5% highest & lowest angle values
- Results: See Figure 1 (green line; gray vs. brown traces indicate cut-off)

Problem 3

Rotate/translate complete data set

- To fix gross misalignments
  - Visually
  - Co-collected/co-registered data (cf. Derrick, Best, & Fiasson, In Press)
  - See Figure 5

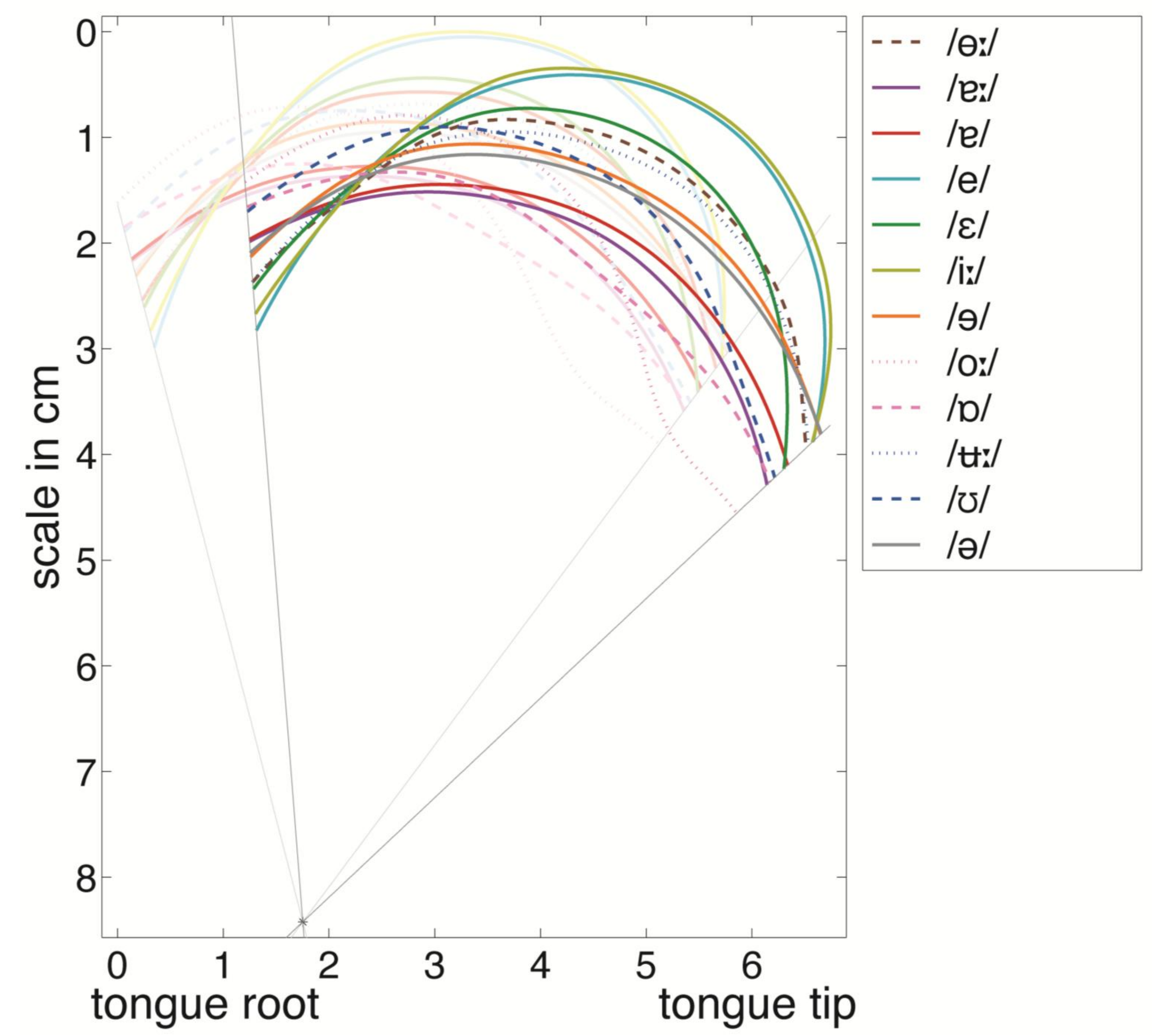

Figure 5: Rotation performed on New Zealand English vowel data to facilitate visual comparison with other participants' data

Conclusion

- Polar coordinates significantly improve average curves at edges
  - Tongue tip/root
- Our approach also allows
  - Between sound/articulation comparison
  - Between subject comparison
  - Rotation/translation correction

References:

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