Quantifying the shape of the vowel space: a geometric morphometric approach

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The vowel space is a two-dimensional shape within a first-formant, second-formant data space. The shape, size, and position of the vowel space are described by the absolute and relative positions of different vowels within the data space. Vowel spaces vary between individuals and groups of speakers, and therefore provide useful information for speaker discrimination. A number of measures exist to describe the vowel space, but as yet there is no reliable measure of vowel space *shape* that retains information about the relative positions of vowels within the space using a small number of parameters. Such a measure would be a useful feature for speaker discrimination as well as providing information to help study or categorise groups of speakers.

Geometric morphometrics [1] is a technique for quantifying shape within a rigorous statistical framework. The procedure makes use of generalised Procrustes analysis (GPA), which normalises size, position and rotation, to describe each shape as a single point in shape space. Shape is defined on the basis of landmarks, i.e. corresponding locations across different shape observations. Vowel positions might therefore be considered landmarks that define the shape of a speaker's vowel space.

To determine how useful geometric morphometrics is for quantifying the vowel space shape, we used GPA to align the vowel spaces for adults from Peterson and Barney's 1952 study [2]. Shapes were compared using a linear model, revealing a significant difference in vowel space shape between males and females, $p < 0.01$. This suggests that vowel space shape may be useful for discriminating between groups of speakers.

The proposed technique offers a new parameter to describe the vowel space, which may prove useful in the fields of speaker, dialect, and language comparison. The GPA technique may also have some applicability to the long-standing issue of normalising formant values in order to compare them across subjects [3]. Future work will seek to address how to select appropriate vowels as landmarks across languages, how many vowels are sufficient to appropriately describe the shape of the vowel space, and whether vowel space shape parameters add useful information to the forensic speaker comparison process.

References

[1] D. C. Adams, F. J. Rohlf and D. E. Slice, "A field comes of age: Geometric morphometrics in the 21st century", *Hystrix*, vol. 24, no. 1, 2013, pp. 7-14.
[2] G. E. Peterson and H. L. Barney, "Control methods used in a study of the vowels," *J. Acoust. Soc. Am.*, vol. 25, no. 2, Mar. 1952, pp. 175-184.
[3] N. Flynn and P. Foulkes, "Comparing vowel formant normalisation methods," in *Proc. ICPhS 2011*, Hong Kong, 2011, pp. 683-686.