

# VowSpace: A vowel formant analysis application for phonetic research

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## Software

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## Summary

Vowel formant frequencies, which vary by vowel and speaker, are crucial in phonetic and sociolinguistic studies. These frequencies reveal language- and speaker-specific traits (Clopper et al., 2005). F1 and F2 relate to vowel height and backness, aiding in vowel distinction, while F3, F4, and F5 provide more detailed speaker information (Fant, 1960; K. N. Stevens, 1998). Measuring these frequencies is key across phonetics, sociolinguistics, dialectology, speech technology, and language learning.

Formant values are affected by a speaker's vocal tract length, gender, and age, making comparisons difficult. To address this, researchers have developed various vowel normalization techniques to reduce physiological differences while preserving phonetic contrasts (Adank et al., 2004; Disner, 1980; Lobanov, 1971).

Visualization of formant values through F1-F2 scatterplots facilitates the analysis of vowel inventories, regional and diachronic differences, and speech perception experiments. However, these processes often require complex scripting or software, limiting access for non-specialists or students.

## Statement of need

In phonetic and sociophonetic research, analyzing vowel formants is essential for understanding language variation, speaker physiology, and vowel space. Researchers often use general-purpose software, such as R (R Core Team, 2021) or Praat (Boersma & Weenink, 2025), which require advanced skills and time for custom visualizations. VowSpace is an open-source tool for vowel space plotting, combining raw and normalized data. While R packages like phonR (McCloy, 2016) and vowels (Kendall & Thomas, 2018), as well as Praat, offer similar functions, they either assume programming expertise or lack accessible GUI features for normalization and visualization.

VowSpace was developed to fill this gap by providing an offline desktop application for acquiring, handling, normalizing, and visualizing vowel formant data within a single environment. It was designed to minimize the level of technical expertise required to work with vowel formants, thereby making this area of research more accessible to newcomers. Considering the lack of a dedicated application for vowel formant analysis and the requirements of fields such as forensic phonetics, which necessitate offline platforms, VowSpace can serve as a primary tool for a wide range of phonetic analyses.

## State of the field

Besides R packages like phonR and vowels, and the widely used desktop application Praat, there are two web-based tools for vowel formant data normalization and visualization. NORM

(Thomas & Kendall, 2007) supports multiple normalization algorithms, including Lobanov, Nearey, Watt & Fabricius, and Bark difference, and allows for vowel space plotting and data export for cross-speaker and dialect comparisons. Visible Vowels (Heeringa & Van de Velde, 2018) offers an interactive platform for uploading formant data, creating vowel plots, and conducting exploratory analyses such as clustering and multidimensional scaling, focusing on visual analytics for phonetic and sociolinguistic research.

VowSpace offers advantages over web-based tools like NORM and Visible Vowels, making it suitable for large-scale or advanced phonetic research. As a desktop application, it avoids browser and internet limitations, offline data security, and offers comprehensive normalization and visualization options. It integrates normalization methods, along with interactive plotting features like zoomable vowel charts, customizable colors, and high-quality exports. Additionally, VowSpace provides simple data reading and writing, graphical plotting with speaker metadata, exportable figures suitable for publication, and audio analysis tools for vowel formant acquisition through spectrograms and formant lines. These capabilities make VowSpace a flexible, precise, and user-friendly alternative for research and teaching across phonetics, phonology, sociolinguistics, and language teaching and acquisition.

## Software design

VowSpace's design heavily focuses on ease of use for students and professionals focusing on vowel formants in acquiring, visualizing, normalizing, comparing, and analyzing vowel formant frequencies from audio files and/or datasets. To this end, it features an intuitive graphical user interface for exploring vowel space across speakers and groups, with normalization methods including Bark Difference (Traunmüller, 1990), Lobanov (Lobanov, 1971; Ramirez, 2022), Nearey 1 and 2 (Nearey, 1978), Bark (Traunmüller, 1990), Log, Mel (S. S. Stevens & Volkman, 1940), and Erb (Moore & Glasberg, 1983) applicable by buttons. VowSpace enables researchers to load, normalize, and visualize formant data, providing publication-ready results across platforms that support interactive, reproducible workflows.

VowSpace has a main interface and two tools: Audio Analysis and DataFrame Editor. The Audio Analysis window allows users to load audio files, view, and extract features such as intensity, pitch, and vowel formants (F1–F4) using a spectrogram using the Parselmouth library (Jadoul et al., 2018). Users can also add formant values to the visualizer.

The built-in DataFrame Editor allows in-app data editing with instant scatterplot updates upon saving. Data can be exported as a spreadsheet. VowSpace supports a minimal input format:

```
vowel f1 f2 speaker
/æ/ 123 1234 Özlem
```

Supported columns include 'bark\_f1' for Bark, logarithmic 'log\_f1', and z-scores 'zsc\_f1', which can be plotted.

## Research impact statement

VowSpace was first developed in order to acquire and plot vowels in R without relying on a number of applications. Since then, it has grown to be a full-suite application that was used in independent research as the main analysis tool. Initially, it included only an interface for visualization. Later in its development; normalization methods, dedicated windows for spectrogram analysis and data handling, and an IPA keyboard were added.

VowSpace has also been proven to be a useful tool for phonetic research. VowSpace has been utilized in Turkish vowel acoustics research, including the TÜBİTAK 2209-A project Vowel Space of Standard Turkish, which studies formant distributions across speakers. It is also part of the ongoing study titled Acoustic Analysis of Turkish Vowel Formants: A

Methodological Perspective, which focuses on normalization techniques and methods for cross-speaker comparison in Turkish. The tool's features, like vowel plotting, normalization, and data editing, aid these studies. Considering its capabilities and ease of use, VowSpace will help researchers by offering an efficient, user-friendly way of doing phonetics.

## Figures

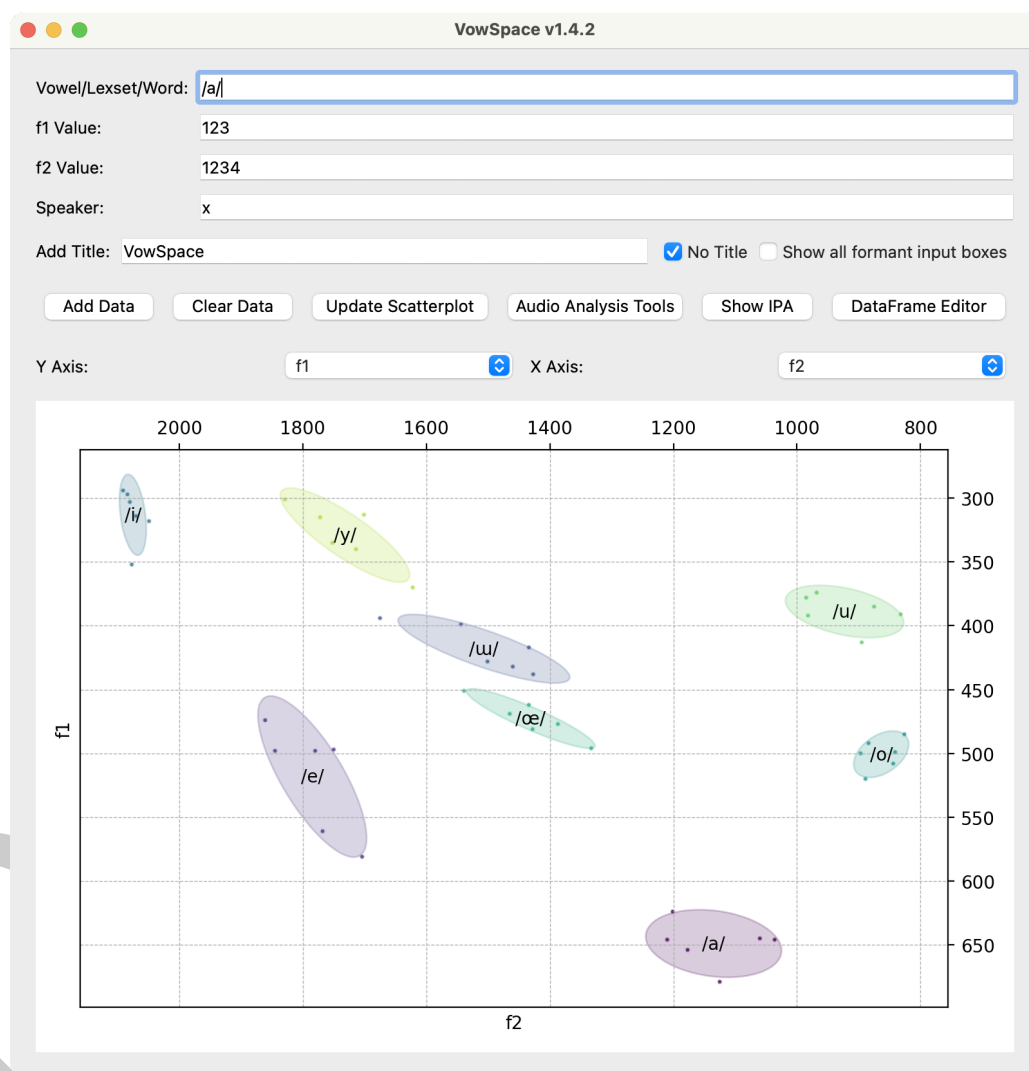


Figure 1: VowSpace's main user interface

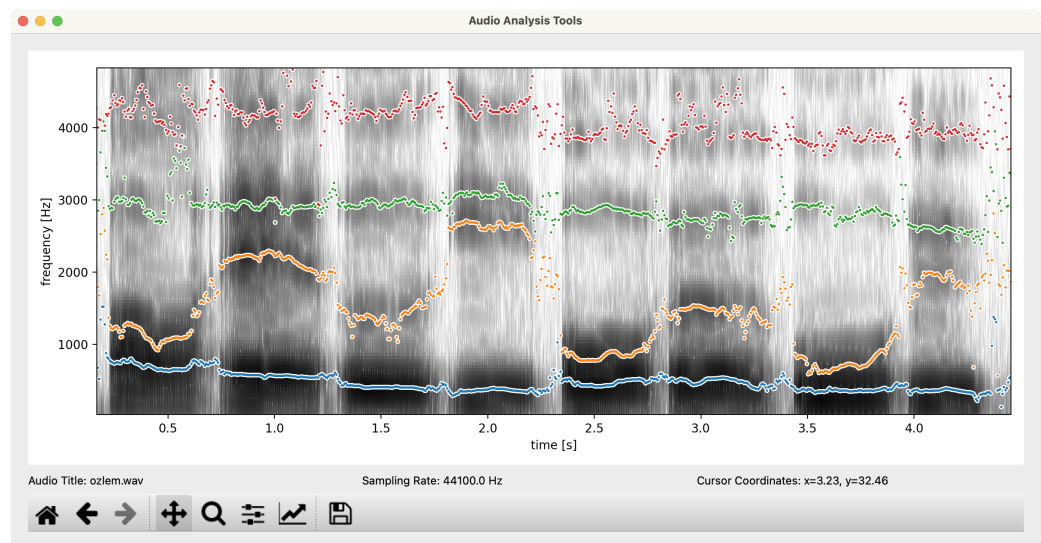


Figure 2: Audio Analysis Tools UI

## AI usage disclosure

Generative AI tools were used during the development of this application to assist with problem solving and code refactoring. All generated content was reviewed, tested, and validated by the author. No generative AI tools were used in the writing of this manuscript, or the preparation of supporting materials.

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