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Wavegrams

A new technique for visualizing vocal fold dynamics noninvasively using electroglottographic signals

INTRODUCTION

Electroglottography (EGG) is a non-invasive and relatively inexpensive technique to monitor vocal fold vibration. The EGG signal correlates with the time-varying relative vocal fold contact area.

Here, we present new method for analyzing and displaying EGG signals and their first derivative (DEGG), which:

(a) **allows monitoring the EGG (or DEGG) signal over time within a single image; and**

(b) **provides an intuitive means for studying the time-varying vocal fold contact phase.**

METHOD

Firstly, the time-varying fundamental frequency is measured, and consecutive individual glottal cycles are identified within the EGG signal. Then, each cycle is locally normalized in duration and amplitude, and the signal values are encoded by color intensity. Finally, the cycles are concatenated to display the entire voice sample in a single image, similar as in sound spectrography.

Wavegrams can also be created based on the first mathematical derivative (DEGG) of the EGG signal. In such a display, the phases of vocal fold contacting and de-contacting are usually indicated by a horizontal dark and light line, respectively (see Figure 1).

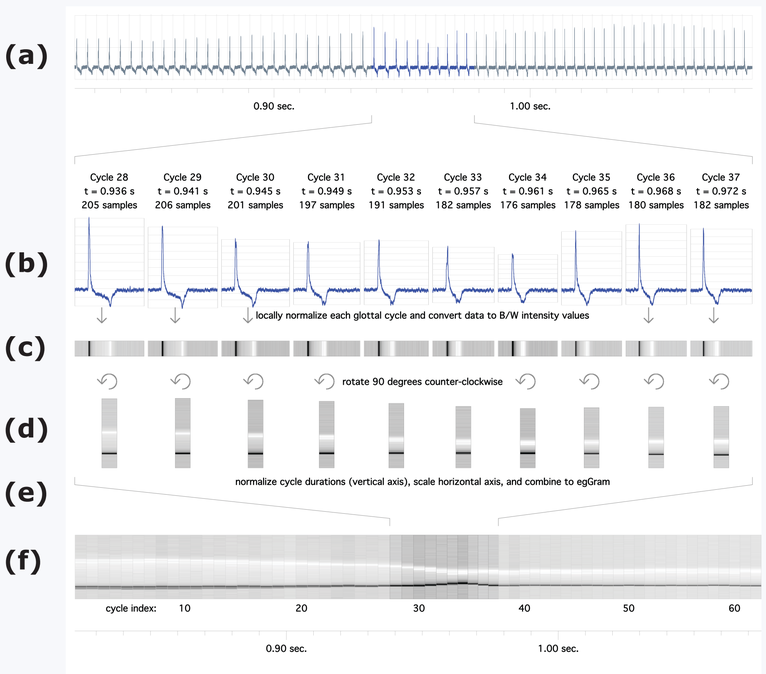

Figure 1: Basic processing steps to create a DEGG wavegram: (a) DEGG signal; (b) extraction of consecutive glottal cycles; (c) locally normalized data values are converted into monochrome color information strips; (d) strips are rotated 90 degrees counter-clockwise; (e) glottal cycle duration is normalized: strips are scaled to equal height; (f) the resulting graphs are combined to form the final display, the EGG wavegram.

RESULTS

Typical landmarks for EGG and DEGG wavegrams are shown in Figure 2.

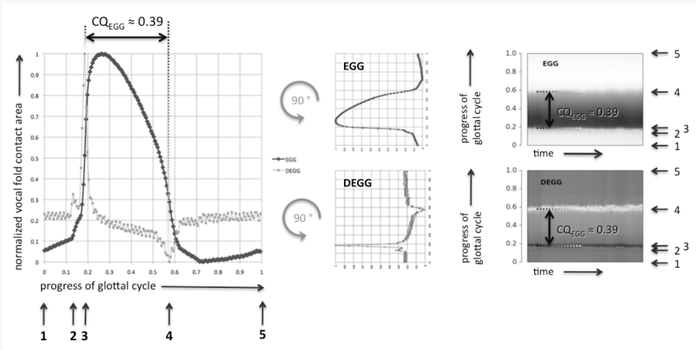

Figure 2: Typical wavegram landmarks, as related to the EGG signal of a single glottal cycle and its first derivative:

(1) beginning of glottal cycle

(2) initiation of vocal fold closure

(3) maximum rate of increase of vocal fold contact

(4) maximum rate of decrease of vocal fold contact

(5) end of glottal cycle

In Figure 3, phonation with increasing fundamental frequency is illustrated in a wavegram (female amateur singer). Analysis data revealed an involuntary transition from chest to falsetto register, indicated by a sudden change of vocal fold contact duration around t ≈ 0.95 s.

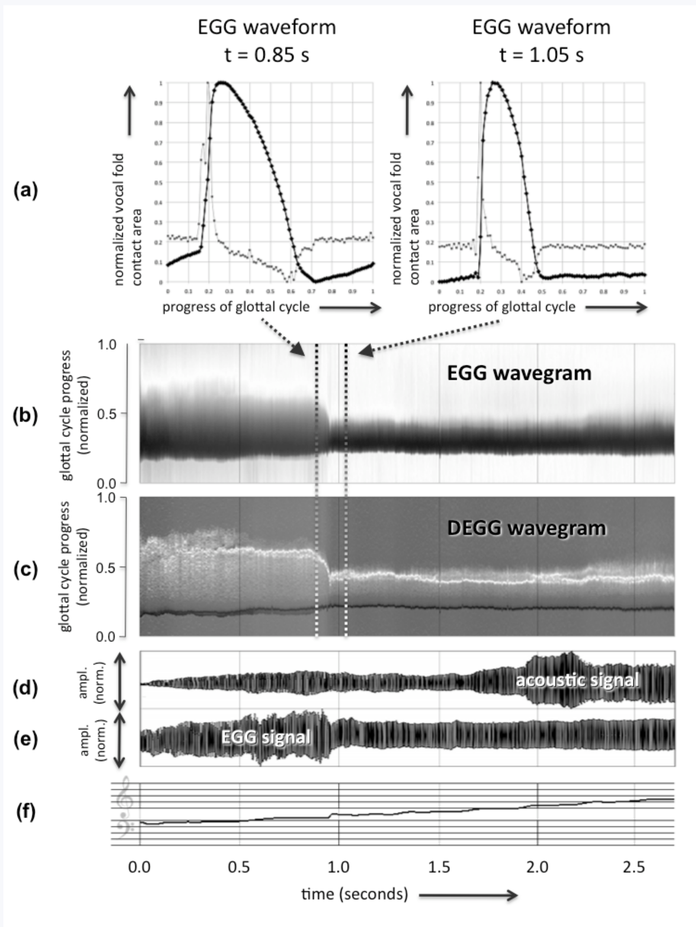

Figure 3: Female phonation with increasing fundamental frequency. (a) EGG (black) and DEGG (grey) waveforms representing glottal cycles extracted at t = 0.85 s and t = 1.05 s, respectively; (b) EGG wavegram; (c) DEGG wavegram; (d) and (e) amplitude plot of audio and EGG signal; (f) fundamental frequency displayed in musical notation (ca. 208 Hz – 415 Hz).

Phonation involving increasing and decreasing vocal intensity produced at a stable pitch (F#3, ca. 185 Hz) by an untrained male amateur singer is shown in Figure 4. The DEGG wavegram reveals a steady change of vocal fold contact phase, correlating with acoustic intensity. Please note the presence of multiple converging DEGG peaks in the contacting phase of vocal fold vibration at lower intensity levels (Figure 4c). After the converging DEGG peaks have fully merged, a sudden increase of vocal fold contact phase occurred. A reversed phenomenon was seen around t ≈ 7.5 s. (see ellipses in Figure 4).

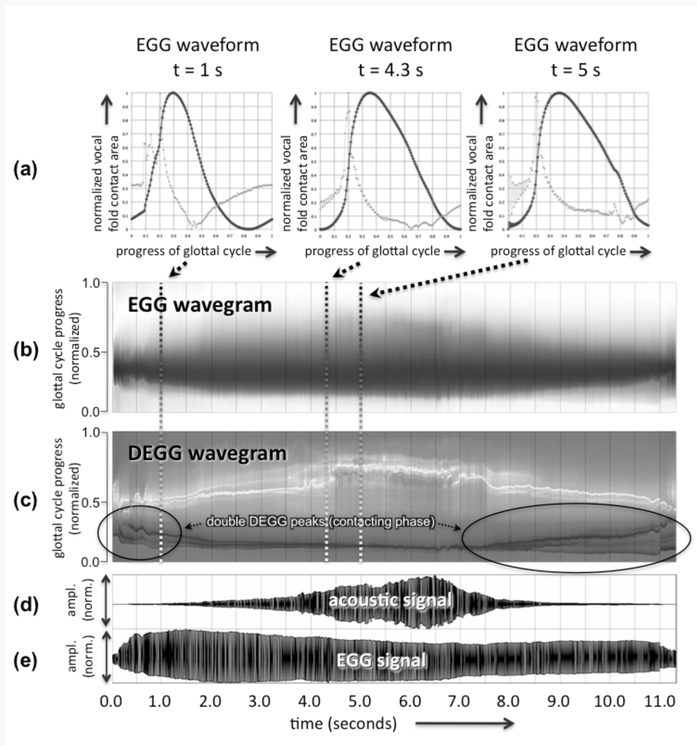

Figure 4: Male phonation with increasing and decreasing vocal intensity. (a) EGG (black) and DEGG (grey) waveforms representing glottal cycles, extracted at t = 1 s, t = 4.3 s and t = 5 s, respectively. (b) EGG wavegram; (c) DEGG wavegram; (d) and (e) amplitude plot of audio and EGG signal.

DISCUSSION AND CONCLUSION

(1) The wavegram technique provides a new and potentially powerful **method for displaying entire electroglottographic signals**, or parts thereof.

(2) It is an **intuitive tool to quickly assess vocal fold contact phenomena** and their variation over time.

(3) EGG wavegrams promise to **reveal more information on the physiologic behavior of vocal fold vibration**.

Multiple converging/diverging DEGG peaks in the contacting/decontacting phase, respectively, appear as a systematic phenomenon, seen in a considerable proportion of subjects. It can be speculated that they are related to phase differences in the superior-inferior as well as the anterior-posterior vocal folds dimension ("zipper-like" vocal fold opening or closure).

REFERENCE: Christian T. Herbst, W. T. S. Fitch, Jan G. Švec (**2010**). "Electroglottographic wavegrams: a technique for visualizing vocal fold dynamics noninvasively." **J. Acoust. Soc. Am.**, *in press*

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