Detection and identification of beehive piping audio signals

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Motivation

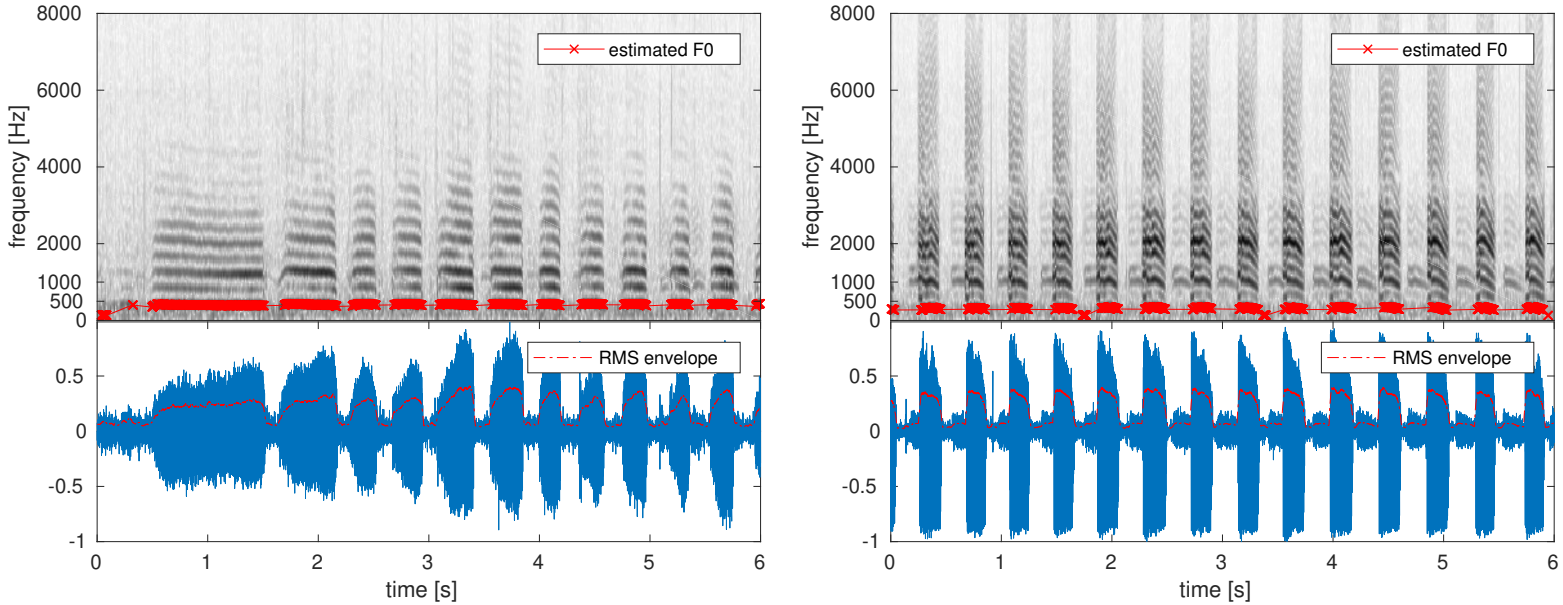
Piping signals are the most noticeable signs of swarming.

- Piping signals are specific short signals emitted by queen and workers bees
- Full of interest for a better understanding of the bees behavior
- Can be useful for improving smart beekeeping

Contributions

- A new annotated beehive dataset for smart beekeeping focusing on quacking and tooting bee signals
- The first machine learning-based study designed for bee piping signals
- A comparative evaluation of several proposed detection and audio classification methods
- Python codes and dataset are freely available: `https://fourer.fr/dcase22`

Bee piping signals



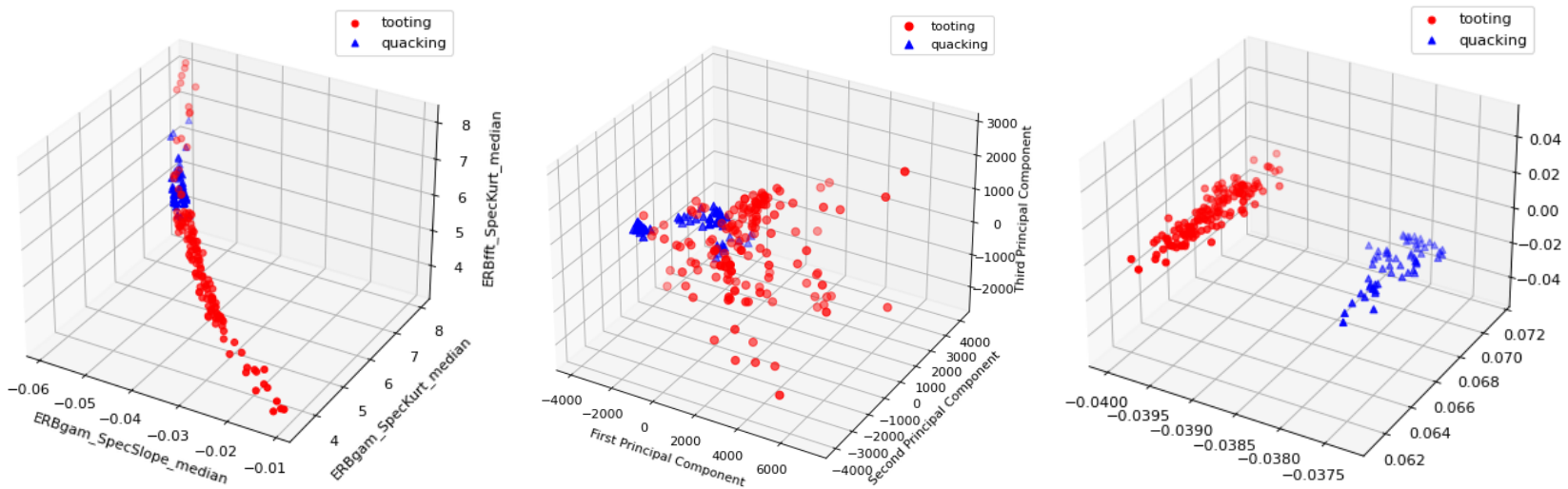
(a) Tooting

(b) Quacking

Figure : Spectrograms with highlighted F_0 and waveforms with RMS envelope of two distinct piping signals.

- **Tooting** corresponds to the sound emitted by a virgin queen bee who announces her presence by releasing pheromones and by tooting. Tooting corresponds to a series of pulsed, high-pitched sounds produced by pressing her thorax and operating her wing-beating mechanism without spreading her wings.
- **Quacking** is a distinct piping sound emitted by mature queens still confined within their queen cells answering the tooting. A chorus of synchronized quacking follows each tooting, and those specific swarming sounds are broadcasting in the bee nest as vibrations received by the workers.

Timbre features analysis



(a) Top-3 most relevant (b) PCA (c) LDA

Figure : Fig. 2: 3D projections of our proposed piping dataset where each point corresponds to a one-second-long excerpt.

- Signal acoustic analysis based on timbre features first proposed by Peeters et al. 2011
- Temporal, spectral, harmonic and perceptual descriptors
- A total of 164 timbre features summarized by median and Inter Quartile Range (IQR) statistics related to the signal acoustic parameters.

Detection and classification results

Table : Experiment 3: Simultaneously detection and classification comparative results.

Method	Feat. dimension	Label	Recall	Precision	F - score	Accuracy
TTB+SVM	164	Tooting	0.88	0.78	0.83	0.82
		Quacking	0.03	0.12	0.05	
		Non-piping	0.99	0.89	0.94	
1D-CNN	11,025	Tooting	0.93	0.84	0.88	0.85
		Quacking	0.10	0.54	0.16	
		Non-piping	0.99	0.86	0.92	
MFCC+CNN	17×47	Tooting	0.88	0.81	0.84	0.84
		Quacking	0.18	0.45	0.26	
		Non-piping	**0.99**	**0.90**	**0.95**	
STFT+CNN	512×42	Tooting	**0.94**	**0.97**	**0.95**	**0.91**
		Quacking	**0.50**	**0.76**	**0.60**	
		Non-piping	**0.99**	0.89	0.94	

- 4 classification and 2 specific detection methods are proposed
- Beehive-independent 3-fold cross-validation comparative evaluation
- Additional non-piping signals are randomly chosen from the OSBH dataset