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When Bees Speak: Acoustic Monitoring for Colony Health Using Deep Learning

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Beekeeping plays a crucial role in maintaining healthy ecosystems through pollination and supporting biodiversity. Monitoring the health of bee colonies is essential for beekeepers, but traditional methods may miss early signs of stress within hives. In this study, we present a novel approach using artificial intelligence (AI) to analyze hive sounds and detect early warning signs of stress.

Our method employs semi-supervised learning, enabling the model to learn from both labelled (clearly identified) and unlabeled audio data. At the core of our system is a Transformer model—a state-of-the-art AI technique adept at recognising patterns in sequential data such as sound. The model analyzes audio features including tone and energy to classify different hive conditions.

We utilized a dataset of 5,336 bee sound samples sourced from research projects and public repositories. Our AI identifies three primary hive states: normal activity, absence of a queen bee (NoQueen), and swarming behaviour, as well as detecting stress indicators. We applied “pseudo-labelling,” where the model assigns labels to unlabeled audio to effectively expand its training data.

The system achieved 99% accuracy on labelled data and successfully pseudo-labelled the majority of unlabeled recordings by comparing them to known examples. These results demonstrate that AI-driven acoustic monitoring can assist beekeepers in maintaining healthy colonies and contribute to ecosystem conservation efforts.

Keywords
Machine Learning, Transformer, Acoustic analysis, Beehive health monitoring, Semi-supervised learning, Sustainable beekeeping

References

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