Remote Beehive Health Analysis using Embedded System and Relevant Audio Features

Oct. 2021 - Sep. 2024

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keywords: Audio analysis, smart beehive monitoring, deep learning, precision beekeeping, feature selection, embedded system

Abstract: Bees are very important pollinating insects contributing to preserve natural ecosystems. However, they are also sensitive to various external factors such as weather, diseases, predators or pollution which can have severe impacts on their health. This explain the recent researches based on IA to develop smart beehive monitoring systems to assist beekeepers [17]. The audio analysis approach for precision beekeeping gained interest due to the capability of audio signal to convey accurate information about the health state of a beehive using a simple microphone (e.g. the number of bees, stress factors, the absence of the queen, etc.). Hence, estimating relevant information from audio signals requires robust acoustic features and the adequate preprocessing (e.g. signal separation and denoising) which could lead to promising result when combined with a deep learning approach. Moreover, the usage of an embedded system introduces constraints about the computational cost and the amount of transmitted data that should be optimized to be as low as possible.

The goal of this PhD thesis is to design a complete method based on deep learning allowing to collect data and to efficiently predict the state of a beehive using an embedded measurement system in a real-world field recording scenario.

Scientific problem

Information retrieval from an audio signal is an interdisciplinary problem which remains intensively investigated by researchers since decades, especially for music by the MIR community [5]. To be efficiently addressed, this problem first requires to compute efficient signal representations allowing to separate the relevant components from the irrelevant part often associated to undesired noise. As audio recordings are multicomponent non-stationary signals, they can contain harmonic components modeled by a set of parameterized sinusoids, transients that can be modeled by impulse components and a stochastic part that is related to possibly colored noises. Hence, the high-level analysis of the audio content requires to compute the signal features and signal parameters such as the predominant fundamental frequencies (F_0) which can be related to physics-based harmonic models allowing to estimate the characteristics of the source which produced the analyzed audio signal. From another hand, audio signals analysis may require an efficient preprocessing such as source separation and denoising to reduce the irrelevant noise and to adapt the required frequency bandwidth and sampling rate of the captured data. This step is eased when the properties of the signal of interest are known, such as its spectral envelope or the spectral distribution of its signal components. Finally, this thesis aims at developing a complete solution for precision beekeeping that can operate with a smart embedded measurement system which can predict the health state of the monitored beehive. The implementation step will also require to deal with the possible hardware limitations related to the computation complexity and dimension of the transmitted data that should be optimized.

Goals

The objectives of this thesis can be summarized as follows.

- Identifying the most efficient and robust audio features for supervised, and non-supervised audio classification scenarios.
- Development and comparative assessment of new deep learning methods for identifying a beehive health state from recorded audio signals.
- Optimal pre-processing and denoising to enhance the audio signal of interest (e.g. audio segmentation and event classification).
- Design of a complete solution based on an embedded system allowing to capture signal and to predict the state of a beehive.

Proposed methodology

This thesis focuses on information retrieval from acoustic signal with an application to beehive health prediction which recently gained of interest [14, 3, 19, 1, 4, 9, 15, 16, 18]. The PhD candidate will first investigate the state-of-the-art methods and attempt to contribute to the (Detection and Classification Acoustic Scenes and Event) DCASE Challenge [12]. To this end, an experimental protocol will be developed to comparatively assess with baselines the future new proposed methods applied to the actual and future new proposed datasets built from the data provided by the company Starling Partners through their project "Des Abeilles & Nous". The future developed methods will pay attention to compute efficient data representation and to select the most relevant audio features allowing to use supervised, semi- and non-supervised machine learning frameworks. This work could benefit of the recent advances in the field of time-frequency analysis based on synchrosqueezed transforms [8, 7, 6] which opens new perspectives of real-world applications.

This research work will focuses on deep neural networks [10] which actually provides the best state-of-the-art results when combined with a suitable signal representation [14]. Our work will attempt to propose new neural architectures with a efforts to optimally reduce the dimension (from a information theory point of view) of the required input features leading to the best prediction accuracy. Moreover, we also expect to adopt new strategies to deal with the lack of training data such as deep transfer learning[20], adversarial training[13], and promising data augmentation techniques such as Curriculum Learning [2]. For this work, an effort is expected for analyzing and understanding the meaning of the learned features and representations allowing to detect non-labeled beehive states. Hence, the final step of this thesis will be to design a measurement system based on a low-cost embedded circuit such as Arduino uno or Raspberry pi, allowing the real-time monitoring of one or several connected beehives. To this end, new sensors such as temperature, hygrometry, or atmospheric pressure, could also be investigated to improve the robustness of the future beehive smart system by merging all the available information using a multimodal approach [11].

Related works

- Master thesis of **Agnieszka Orlowska** (supervised by D. Fourer), (Feb. 2021 - Sept. 2021).
- Master internship of Leila Khellouf (supervised by D. Fourer), "Audio Signal Processing for Remote Beehive Health Analysis". IBISC Lab, Univ. Evry, Apr. 2020 - Sept. 2020.

Required profile

- good machine learning and signal processing knowledge
- mathematical understanding of the formal background
- excellent programming skills (Python, Matlab, C++)
- good motivation, high productivity and methodical works
- an interest for AI and new technologies

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