Listening to the ecosystem: the integration of machine learning and a long-term soundscape monitoring network

Tzu-Hao Harry Lin\textsuperscript{1*}, Yu-Huang Wang\textsuperscript{2}, Han-Wei Yen\textsuperscript{3}, Yu Tsao\textsuperscript{1}

\textsuperscript{1}Research Center for Information Technology Innovation, Academia Sinica
\textsuperscript{2}Taiwan Biodiversity Information Facility, Academia Sinica
\textsuperscript{3}Acadia Sinica Grid Computing
Long-term monitoring of ecosystem

• Essential for conservation management
  • Field surveys of wildlife
  • Biodiversity monitoring

• Labor intensive work, require automatic sensing techniques
Remote sensing of ecosystem

**Large scale**

**Satellite sensing**
- Entire landscape

**RADAR, LIDAR**
- Detail of landscape, wildlife community

**Small scale**

**Camera trap**
- Individual animal

*Image courtesy of SCIENCE*
Soundscape

- **Geophony** (Nature sounds...)
- **Biophony** (Animal vocalizations...)
- **Anthrophony** (Human made noise...)

https://www.nps.gov/yose/learn/nature/soundscape.htm
Listening to biodiversity

• Passive acoustic monitoring
  – Identify an animal by detecting its acoustic signals
  – Classify the species based on acoustic features

Biodiversity

Calling species

Detection and classification

Composition of calling species

Estimation of biodiversity

The proportion can be estimated by using other methods
Challenge of soundscape monitoring

• Data storage
  – Large amount of data
  – Unlabeled data

• Analysis
  – Various types of animal vocalizations
  – Most users are not familiar with signal processing
  – Noise interference, multiple sound sources

• Performance
  – Sensitivity of recording devices
  – Uncertainty of detectors and classifiers
Objectives

- Open acoustic data
- Interactive visualization
- Identify questions
- Ecoacoustics research
- Conservation management
- Machine learning
- Modeling and prediction
- Soundscape monitoring
- Citizen science
- Data mining
- Distributed computing infrastructure
- Interactive visualization
- Open acoustic data
Soundscape monitoring network

Missions:

• Evaluate the dynamics of soundscape and biodiversity

• Study the interactions between wildlife, habitat, and human activities
Missions:

- Open data
- Service for ecological and environmental researches, citizen science, education

Detection and classification

Researchers

Cloud data center
Academia Sinica Grid Computing

Web-based management system (Pumilio)
Villanueva-Rivera & Pijanowski (2012)

Visualization and interactive interface
Tools for analyzing field recordings (unlabeled data)

- Visualization of long-term acoustic data
- Unsupervised detection of biological chorus
- Clustering of soundscape scenes and events
Marine soundscape
Indo-Pacific humpback dolphins & marine soundscape

3. Chunggang river estuary

Data collected by Institute of Ecology and Evolutionary Biology, National Taiwan University

5. Waipu artificial reefs

Distribution of dolphins’ core habitat

Miaoli County
Analysis procedures

Unsupervised separation of different sound sources

- Fish chorus
- Snapping shrimp sounds
- Ambient & shipping noise

Biosonar detector
Tonal sound detector

Modeling by GAM
- SPL of soundscape
- Clicking rate
- Whistle complexity

✓ Sampling by 1 day interval
Behavior response to different sound sources

- Prey associated sound: +
- Competitor of acoustic space: + -
- Environmental and anthropogenic noise: -

![Diagram showing detection rate of humpback dolphins with Estimated mean SPL (dB re 1 μPa)]
Forest soundscape
Forestry biodiversity

Sanyi (A) (500 m)

Lienhuachih (B) (800 m)

Taiping Mt. (C) (1900 m)

Data collected by Taiwan Forestry Research Institute
Analysis procedures

Long duration recordings

Unsupervised classification of soundscape scenes and events

Measuring and modeling the change of diversity
Visualization of soundscape change

Sanyi (A), 500m
Lienhuachih (B), 800m
Taiping Mt. (C), 1900m
From soundscape to biodiversity
Machine learning facilitates acoustics-based biodiversity monitoring

• Supervised detection and classification
  • Search for specific targets
  • Behavior and population size of keystone species

• Unsupervised separation and classification
  • Labeling and evaluate the change of data structure
  • Spatial and temporal change of biodiversity
  • Interactions between habitats, climates, human activities, and wildlife

• Require large scale computing resources
Future platform

Open science:

- Evaluating classification results and labeling by publics
- Conducting ecoacoustics experiences through DCI

Detection and classification

Cloud data center

Distributed computing infrastructure

Visualization and interactive interface

Citizen science
International collaborations on the remote sensing of biodiversity

• Sensor network of terrestrial and marine ecosystems
• Distributed data computing and services
  • Open data, open tools, open science
Acknowledgement

- Jason Mai, Dr. Sheng-Shan Lu
- Ministry of Science and Technology
  - Independent postdoctoral research fellowship
Thanks for your attention!
schonkopf@gmail.com