Wildlife Monitoring through Acoustics: The Case of Woodpeckers

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Content

- Introduction: why monitoring birds?
- Recent advances in ecoacoustics
  - Existing acoustic monitoring projects
  - How do people deal with the deluge of data?
  - Best species identification work
- Own results with woodpeckers
  - Detection of drumming, identification of species
  - Building an autonomous recording station
How and why do we monitor wildlife?

- Wildlife monitoring is a pillar of environmental impact studies, biodiversity management
- The EU environmental protection policies are based on birds (birds & habitats directive)
- Ornithological work is field work, but acoustics + mass data processing offer new avenues for insight
  - Audio recording stations
  - Automated data screening

Birds are
- Excellent bio-indicators
- Easy to track because they sing
Wildlife acoustic monitoring

Used in: archives of nature sounds, ecosystem conservation, bird conservation

AmiBio (Greece, 10 TB)  QUT (Australia, 100 TB)  Arbimon (Puerto Rico and Costa Rica, permanent)

⇒ Objective: automated inventory of species
  - Recognition algorithms lag behind
  - First need to browse through the sound archives

+ pilot studies in other megadiverse countries
Color-composite spectrograms

- 2-hour window around dawn
- Proper « music score » appearance
- Evolution of bird community? Towsey et al have month, year images


**Acoustic Complexity Index (ACI)**

ACI = \[ \frac{\sum_{k=1}^{n} |I_k - I_{k+1}|}{\sum_{k=1}^{n} I_k} \]

At frame \( k \)  \hspace{3cm} At frame \( k+1 \)

- Sum over blocks of 30secs

- ACI = average change in intensity OVER average intensity
- Result is frequency dependent
- Bird songs are rapidly varying signal \( \Rightarrow \) high ACI = high bird activity

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Structure of a recognition scheme

Sound files

Frames

Acoustic indicators (MFCC..)  \( \Rightarrow \) feature vector

Training set

Test set

Classifier

It’s a goshawk

+ Noise treatments
Literature on Bird Species Automated Recognition

- Somervuo et al, 2006
  - MFCC / HMM
  - 70 % of correct identifications of passerines

- Potamitis, 2014
  - Image processing, cross-correlation, bag of words, random forest, multi-label
  - 91.7% ROC AUC* on nips4b

- Stowell & Plumbley, 2014
  - Full spectrum (projected), random forest, multi-label
  - 85.4% ROC AUC* on lifeclef2014, 89.8% on nips4b

* Area under the ‘Receiver Operating Characteristic’ curve
From there to... woodpeckers

- How to cope with the variety of bird songs using *one-fits-all* acoustic features?
- Acoustic features to describe the songs are species-specific, or specific to a group of species (family)
  → We need more biologically meaningful information, using ornithological knowledge
- Data mining is an achievable goal

- **Research orientation:**
  ⇒ Full identification of 10 (11) EU woodpecker species from their sounds
## European Woodpeckers

<table>
<thead>
<tr>
<th>Latin Name</th>
<th>Drumming</th>
<th>Song</th>
<th>Sound Files</th>
<th>Drumming Rolls</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Dendrocopos leucotos</em></td>
<td>✓</td>
<td>✗</td>
<td>43</td>
<td>248</td>
</tr>
<tr>
<td><em>Dendrocopos major</em></td>
<td>✓</td>
<td>✗</td>
<td>115</td>
<td>818</td>
</tr>
<tr>
<td><em>Dryocopus martius</em></td>
<td>✓</td>
<td>✓</td>
<td>27</td>
<td>84</td>
</tr>
<tr>
<td><em>Dendrocopos medius</em></td>
<td>✗ (rare)</td>
<td>✓</td>
<td>3</td>
<td>8</td>
</tr>
<tr>
<td><em>Dendrocopos minor</em></td>
<td>✓</td>
<td>✓</td>
<td>67</td>
<td>832</td>
</tr>
<tr>
<td><em>Dendrocopos syriacus</em></td>
<td>✓</td>
<td>✗</td>
<td>3</td>
<td>8</td>
</tr>
<tr>
<td><em>Picus canus</em></td>
<td>✓</td>
<td>✓</td>
<td>29</td>
<td>104</td>
</tr>
<tr>
<td><em>Picoides tridactylus</em></td>
<td>✓</td>
<td>✗</td>
<td>68</td>
<td>547</td>
</tr>
<tr>
<td><em>Picus viridis</em> **</td>
<td>✗ (rare)</td>
<td>✓</td>
<td>6</td>
<td>16</td>
</tr>
<tr>
<td><em>Jynx torquilla</em></td>
<td>✗</td>
<td>✓</td>
<td>✗</td>
<td>✗</td>
</tr>
</tbody>
</table>

**TOTAL** 361 2665

+ Peculiar calls

** Data Sources:**


**Now split from *Picus sharpei* (Gorman, 2014)**

Drawing from R.T. Peterson (2008)
Woodpecker drumming

Drumming roll (DR)

Time interval between rolls

Characteristic LF content

DR duration

Time between strokes

0 Hz

5000 Hz

1500 Hz

Time interval between rolls

Initial Interval

Time structure

Delta Interval (~slope)

Time intervals between strokes (sec)

Initial Interval

Delta Interval (~slope)

Time intervals between strokes (sec)

Time (sec)
Long Audio Records
Looking for drumming using the ACI

Candidate Segments or Xeno-Canto Files (~minutes)

Kmeans unsupervised clustering, using spectral profile

Calculation of other DR Parameters

DR Extraction
Clustering in one bird / one tree groups

Time interval between DR calculation

Feature Matrix Assembly and Classification
Results: Time Structure

- The large datasets have numerous outliers
- All delta interval outliers were checked manually
- Acceleration is more common
Results: DR Duration / Spectral

- Strong correlation DR duration / number of strokes
- All *D. major* outliers were checked manually
- Twin species (e.g. *D. major* and *syriacus*) have identical time structures but differ in duration

- Peaks above 2000 Hz only found in the largest datasets
- Strong correlation spectral centroid / spectral peak
- Justification for characteristic LF content
Quality of Features

- Time parameters in agreement with Zabka
- The time structure parameters have the least variation and the most discriminating power
- The large variation in time interval between rolls is confirmed
**t-SNE maps – k-NN Classification**

![t-SNE map with class labels]

**k-NN Classification**
- Training database is 20% of the total, unevenly spread between the classes (from 60% for the small classes to 13% for the largest)
- Overall recognition rate $86.4\% \pm 0.8\%$ (200 trials) – ROC AUC $93.5\% - 99.5\%$
Building our own recording station

12 V Car Battery

Raspberry Pi2
Debian (Linux)

Microphone
Røde omnidirectional

Preprocess. Octave (ACI)
12 kHz, 16 bits

Flash Drive
~64 GB
15 hours/day for 50 days

Steinberg UR12
Sound card

Phantom

176.4 kHz
16 bits

Although Wildlife Acs sells a good ready-made module...
Outlook

- Onward with the chase for the last of the Belgian grey-headed woodpeckers... (partnership with AVES)
- Will then try to decipher the songs
- Ecoacoustics is a field in explosion, with a lot of creativity
- Unimagined insight into the wild, if we can focus the questions or further develop the processing capacity
Woodpecker songs

P. viridis XC76373
3.4 sec

D. martius XC110355 (song)
6 sec (total song 21 sec)

P. canus XC133208
2.5 sec
Thank you

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(1) Theoretical Mechanics, Dynamics and Vibration
(2) Circuit Theory and Signal Processing
(3) Physics
(4) Zoology

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