Title
Vocal Individual Recognition of Acorn Woodpecker (Melanerpes formicivorus)

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**Vocal Individual Recognition of Acorn Woodpecker**

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**Introduction**

**Acorn Woodpecker (Melanerpes formicivorus)**

- Nonmigratory, group-living pidid
- Common residents in the oak woodlands of California
- Acorn storage habit
- Acorns are stored in the holes drilled on the granary trees (Fig. 1)
- Extreme sociality
- Each group contains 1-4 breeding males, 1-2 breeding females, and 0-10 nonbreeding helpers. Group members are engaged in social activities every day. (Fig. 2)

**Vocalizations in Acorn Woodpecker**

- Sociality drives the evolution of communicative complexity
- A complex vocal communication system is expected in the acorn woodpecker due to its high level of sociality
- Each individual should be able to recognize other individuals during their vocal communication.
- Variation in the vocalization should exist in the acorn woodpecker and different individuals should have their unique vocal patterns, which is called vocal individuality.

**Problem Description**

- **Step 1:** Examine the existence of vocal individuality in acorn woodpecker
- **Step 2:** Develop efficient methods for individual recognition by acoustic sensor network

**Method and Result**

**Data acquisition**

- Calls were recorded from acorn woodpeckers in Hastings Reserve, Carmel Valley, California. The ID of the calling bird was identified through color bands on both legs during recording.
- Calls were digitalized from the recordings. Waveforms and Spectrograms were made by RAVEN 1.2.
- Waka calls and Karri-cut calls: most common and may encode the individual information.

**Feature Characterization**

- Features characterized include two parts: temporal and spectral
- Temporal features measured are showed in Fig3(top). Analysis of temporal features indicate that differences between individuals exist. But temporal features are not enough for individual discrimination. (Fig.4)
- Spectral features interested include two parts: features related to fundamental frequency and features related to dominant frequency. (Fig.3)
- The preliminary study shows that there is no significant difference in Fmax, but the difference may exist in Fstart, Fmax, FMdesc, FMasc.

**Individual recognition based on HMM**

- **Hidden Markov Model (HMM):** popular, efficient method for speech recognition.
- **Data preparation:** Each waka call in a bout of calls is cut out and saved as different files. One part of data are used for training HMMs, the other part are used for testing those HMMs.
- **HMMs are built for 5 individuals:** M2056, M2428, M3982, M3284.
- **HMMs are tested using testing calls from 4 individuals:** M2056, M2428, M3982, M3284.
- M3284 does not have enough data for testing.

- **Results showed that individual acorn woodpecker can be recognized by HMMs with high accuracy. This indicates that vocal individuality does exist in acorn woodpecker and that HMM is an efficient tool for vocal individual recognition.**
- **Result could be improved when more data are used for training models.** F3983 has lowest recognition accuracy because of its limited training data set.
- Because woodpeckers give a bout of calls, not isolated calls. If most calls in a bout of calls can be recognized correctly, the ID of the caller still can be recognized regardless of several incorrectly recognized calls in the bout. This will also improve the result. (eg. M2428 can be recognized with 100% accuracy with this method)

**Future work:**

1. Develop HMMs for recognizing calls from continuous recording with background noise.
2. Apply HMM to acoustic sensor network and finally use the network to monitor birds in the field.

**Table 1:** Result of HMM recognition of 4 individual acorn woodpecker

<table>
<thead>
<tr>
<th>Acorn ID</th>
<th>Training no. of calls</th>
<th>Testing no. of calls</th>
<th>% of correctly recognized calls</th>
<th>Recognition accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>M2328</td>
<td>18</td>
<td>11</td>
<td>79.3%</td>
<td>99.7%</td>
</tr>
<tr>
<td>M2329</td>
<td>40</td>
<td>19</td>
<td>69.7%</td>
<td>85.3%</td>
</tr>
<tr>
<td>M2392</td>
<td>28</td>
<td>24</td>
<td>80.7%</td>
<td>95.5%</td>
</tr>
<tr>
<td>F3983</td>
<td>20</td>
<td>12</td>
<td>75.5%</td>
<td>80.5%</td>
</tr>
</tbody>
</table>