Title
Vocal Individual Recognition of Acorn Woodpecker (Melanerpes formicivorus)

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Introduction

Acorn Woodpecker (*Melanerpes formicivorus*)

- **Nonmigratory, group-living picid**
- **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)

Fig 1 An Acorn Woodpecker

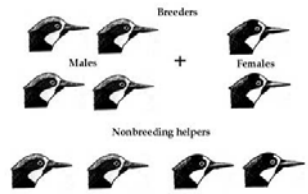

Fig 2 Mating system of the Acorn Woodpecker

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.**

Vocal individuality monitored by Sensors

- **Acoustic sensor network**
  - Receive acoustic signals from animals passively.
  - A non-intrusive way to observe animal behavior in the wild.
- **Information contained in acoustic signals:**
  - *Where are you*: Location of individual
  - *Who are you*: Individual information: age, sex, size, social status, *etc.*; Individual identity
  - *What are you doing*: Movement pattern of individual; any behavior related to vocal signal(eg. Alarm call & anti-predator behavior)
- **If acoustic sensors can recognize individual acorn woodpecker, it will be much easier for biologists to track individual and to study their activities.**

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 *Karrit-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 exit in Fstart, Fmax, FMdesc, FMasc.

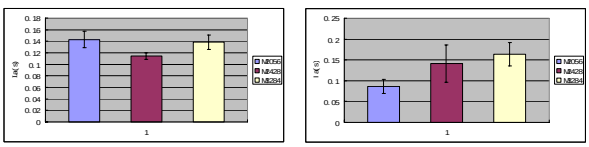

Fig 4. Comparison of temporal features among three birds: M2056, M2428, M3284 . Left: comparison of La. Right: comparison of Ia. M2056 and M2428 show significant difference in these two features.

Table 1 Result of HMM recognition of 4 individual acorn woodpecker

ACWO ID	Training data(# of calls)	Testing data(# of calls)	# of Correctly recognized calls	Recognition accuracy
M2428	71	31	29	93.5%
M2056	60	79	69	87.3%
M3982	28	34	30	88.2%
F3983	20	12	9	75%

• **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

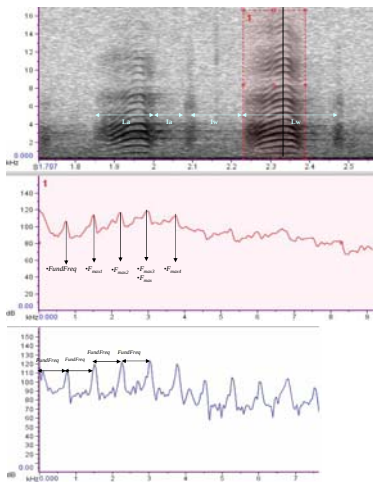

Fig. 3 Spectrogram of Waka calls from the bird M2056 (generated by RAVEN, Hamming window, window size=1024 samples, overlap = 95%). Top. temporal features used in analysis: Lw(duration of the waka call), Iw(interval between two calls), La(duration of the first note in the call), and I1(interval between the two notes in the call.) Middle. Power density curve of the selected call (mark by red square). *FundFreq* is Fundamental frequency. *Fmax1-4* is the first four harmonics with peak amplitude. *Fmax3* is the highest peak, which also gives the value of *Fmax*. Bottom. Estimation of Fundamental Frequency using the frequencies of first, second, third….harmonics. The blue curve is the spectrogram slice view at the position of the black line. In this graph, the black line is placed on the maximum frequency of the fundamental frequency.

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,F3983 and M3284.

• **HMMs are tested using testing calls from 4 individuals:** M2056, M2428, M3982, F3983. 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)