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ENTROPY APPROACH FOR BIOACOUSTICS SIGNAL ANALYSIS OF REPETITIVE NOTES

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***Abstract*—This paper discusses a method for analyzing animal sound by using information theory namely the Shannon entropy. The basic principle of the theory is first presented, together with the spectral centroid. The well known spectral centroid is used as a reference for result comparison. To assess the performance and suitability of the proposed method, sound from 15 Australian frog species are used as test samples. The sound from these animal species are first segmented into syllables. The Shannon entropy value of the syllables are then determined, and compared to spectral centroid value. It is found that the syllables of the frogs sound have entropy that is different from one to another even from the same species. On the other hand, from the spectral centroid analysis, it is found that almost all of the syllables of frogs sound (from the same species) have a unique frequency value which implies that their sounds are highly consistent with repetitive note.**

Keywords-Bioacoustics signal, Shannon entropy, frogs sound analysis

I. INTRODUCTION

Recently, several studies have suggested the potential application of information theory as feature for characterizing animal sounds. Doyle *et al.* [1] and Suzuki *et al.* [2] for example have discussed the application of information theory to quantify the responses of humpback whale to the external stimuli and also for understanding of the structure in their songs. Earlier on, Hanser *et al.* [3] has carried out some analysis on the communication complexity of several animals sounds using the same theory.

Study by Da Silva and Vielliard [4] is of particular interest in this paper. The paper used entropy approach to characterize Brazilian hummingbirds based on the sequence of the notes of their songs. This is possible because animal species like the Brazilian hummingbirds produce several sequences of notes in their calls. Therefore, the bird species can be characterized based on the entropy of the sequence of these notes.

Unfortunately, not all animal can produce such a beautiful sequence of song. Some animals like frog and cicada produce a repeated single note throughout their calls. Thus, the entropy value of their calls will be the same regardless of their species.

In this paper, similar concept by [4] is used to analyze the syllables of sound from several species of Australian frogs. It is shown in this paper that similar concept can be used to analyze repeated single note of sound by performing the study on the time-history (time-domain) of the syllables rather than on the variability of their song's structure.

II. THEORETICAL BACKGROUND AND EXPERIMENTAL PROCEDURE

Spectral centroid is the center point of the spectral distribution of a particular signal. This is the most common method used to analyze a sound signal. The spectral centroid, f_c of a sound power spectrum distribution is defined as the weighted mean of the frequencies presents in the signal and is given by [5]

$$f_c = \frac{\sum_{s=0}^{N-1} f_s P_s}{\sum_{s=0}^{N-1} P_s}. \quad (1)$$

P_s is the magnitude of the spectrum of bin number s, and f_s represents the center frequency of the respective bin.

Given a sequence of amplitude of sound x_i in a signal of length n from an animal species, the Shannon entropy H of the signal can be obtained as [6]

$$H = \sum_{i=1}^{n} p(x_i) I(x_i) = -\sum_{i=1}^{n} p(x_i) \log_2 p(x_i). \quad (2)$$

$p(x_i)$ denotes the probability function of the i-th data points, which can be determined according to the frequency of occurrence of that particular sequence in the signal.

As previously discussed, the aim of this paper is to use Shannon entropy to analyze animal sound of several syllables with single frequency or notes. To assess the performance and the suitability of the method, 15 Australian frog species are used as test samples. It is well known that most frog species produce several syllables in a single calls but with similar notes. The sound sample from each species is first segmented into syllables. The spectral centroid of each syllable is then determined using Eq. (1) and then plotted on a box plot describing the distribution of the spectral centroid of all the syllables in a sound signal from a species.

Similarly, the Shannon entropy for each syllable of sound from particular species is also determined by using Eq. (2). The distribution of the entropy values of all the syllables of the sound from a species is then presented in a box plot for analysis and for comparison with the result from the frequency centroid.

III. EXPERIMENTAL RESULTS AND DISCUSSIONS

15 Australian frog species used in this paper are listed in Table 1. The sound of these frogs were obtained from Frogs Australia Network (http://www.Frogsaustralia.net.au/frogs). The background information regarding the sound from these species is also given in Table 1. It can be seen that each species has their own number of syllables in a call, the time interval between syllable and the duration of the each syllable. The last column in the table shows the number of syllables available in a sound recording of the respective species.

The distribution of the spectral centroid of the syllables of the frog sound are shown in Figure 1. It can be seen that the spectral centroid has a very short range of frequency. Twelve species show an almost unique value, which implies that the frequency of the syllables produced by these species are consistent (single note). In other words, these species produce syllables of sound with the same pattern throughout their calls. Therefore, it is expected that method employed by [4] could be difficult to be used to study their sounds.

An alternative method could be used that is by looking into the entropy of the time-domain signal of the syllables. Figure 2 shows the result of the distribution of the entropy value of all syllables in the sound signal of the frog. It can be seen that the Shannon entropy value of most of the frog species are not as unique as the spectral centroid (refer to Figure 1), where their values are in a certain range of bits. The result implies that although the syllables of frog calls have the same pattern, each syllable may have different information contents.

TABLE 1 INFORMATION BACKGROUND OF 15 FROG SPECIES CALL AND NUMBER OF TEST SAMPLES FOR THIS STUDY.

Species name	**No. syllables in a call**		**Syllables time interval (s)**	**Syllable range (s)**	**No. of syllables of test samples**
	Min	**Max**			
Austrochaperina robusta	2	2	0.041 - 0.042	0.064	31
Cophixalus monticola	21	22	0.006 - 0.040	0.140	59
Cophixalus saxatilis	8	12	0.124 - 0.202	0.050	41
Crinia remota	12	14	0.060 - 0.088	0.026	74
Cyclorana novaehollandiae	1	1	-	0.255	29
Geocrinia rosea	1	1	-	0.074	84
Heleioporus albopunctatus	1	1	-	0.281	18
Heleioporus australiacus	4	5	0.023 - 0.041	0.059	60
Limnodynastes convexiusculus	1	1	-	0.110	20
Limnodynastes dorsalis	1	1	-	0.232	6
Limnodynastes ornatus	1	1	-	0.079	21
Limnodynastes peronii	1	1	-	0.070	3
Limnodynastes salmini	1	1	-	0.227	17
Limnodynastes tasmaniensis	4	8	0.019 - 0.020	0.047	22
Neobatrachus pictus	48	51	0.013 - 0.028	0.010	51
Neobatrachus sutor	1	1	-	0.041	64

IV. CONCLUSION

In this paper, a different way of using entropy theory for animal sound analysis was presented. The approach is by applying Shannon entropy directly into the time domain of the syllables of the animal sound rather than into the sequence of the pattern of the syllables. It is proven that by comparing with the spectral centroid, Shannon entropy reveals the diversity of the syllables although their frequency characteristics are similar. This has opened additional possibility in animal sound analysis using entropy approach.

V. CONCLUSION

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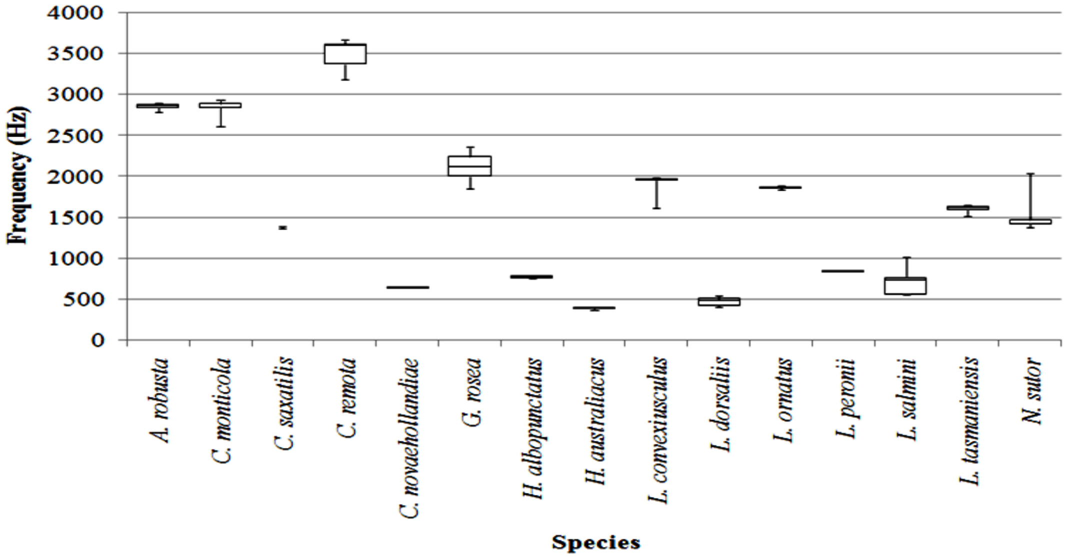

Figure 1 Box plot of spectral centroid of frog calls from 15 Australian frogs.

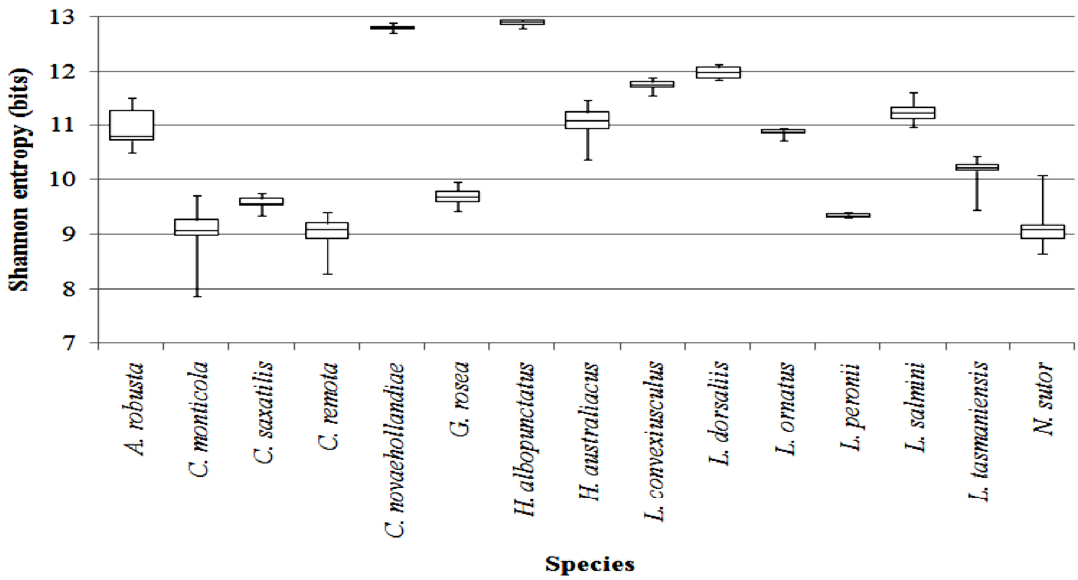

Figure 2 Box plot of Shannon entropy of frog calls from 15 Australian frogs.