EcoSonics - Psychoacoustic Diversity Modeling for Environmental Management

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Can psychoacoustic measures be used to predict impact of environmental change on species diversity? *We hypothesize that modeling correlation between an ecosystem's psychoacoustic properties and local weather data can expedite current prediction methods for climate impact on an ecosystem and suggest robust management strategies.*

Background

- EcoSonic models the correlation between Mel-frequency cepstral coefficients (articulation entropy) and weather data to predict impacts of weather variation on the acoustic properties of ecosystems. Sound is powerful and critical in defining ecosystem makeup. Environmental sound qualities change with weather variation and climate patterns. Rocks provides reverberation, amplifying animal calls, while shrub and trees may dampen sound propagation.

We ask if Mel-frequency cepstral coefficients (articulation entropy) are a robust measure of climate impact on acoustic properties of ecosystems (Acoustic Diversity Measure) with the aim of developing a comprehensive approach to road noise mitigation on Mule Dear population.

Methods:

1) Sound recordings - 4 days in length, every 2 weeks.
2) Using an array of sound recorders on 6 transects north and south of E. Rio Verde Drive. Recorders placed along a distance matrix away from Rio Verde Drive every 300m for 1.2 km north-south, to capture the distance from road effect (See Map 1).
3) MFCC – Mel Frequency Cepstral Coefficients, represent the short-term power spectrum of the sound. These are calculated over very small-time windows. These basically provide the dynamics of the sound and how it changes over time. The following visual shows a representation of MFCCs. As the image shows, the MFCC features attempt to capture the timbre of the audio signal on a small scale.
4) Machine Learning: A process of taking historical data, creating mathematical models out of it and then attempting to predict the data for the future/or for a set of inputs for which the input is unknown. In this context, we try to create a model that learns a locations acoustic diversity of a over a period of time and then try to predict the same for different data set of a future date.

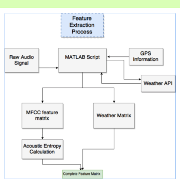


Figure 1 - Feature Extraction Method

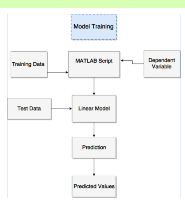
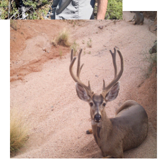


Figure 2 - Model Training Method

Results

- The correlation of weather data and entropy of psychoacoustic measures proved robust in representing an Acoustic Diversity Measure.

The resulting model provided representative trends in psychoacoustic measures when fed the weather data of one day and asked to predict the psychoacoustic measures for the following day (see Figure 3).



The MFCC's equate to an Acoustic Diversity Measure, representing the number of distinct sounds in each recorded sample. Increased entropy in such a measure would represent reduced Acoustic Diversity and therefore a reduction in species present in the ecosystem.

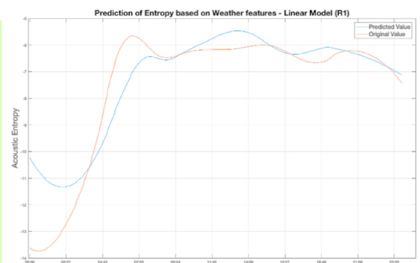


Figure 3 - Predicted acoustic entropy based on previous days weather data plotted against actual data.

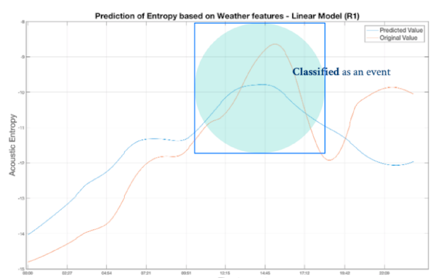


Figure 4 - Predicted acoustic entropy plot demonstrating an event

Furthermore, events appear are clearly indicated in data plots (see Figure 4), opening the way to using this method for auto segmentation and classification

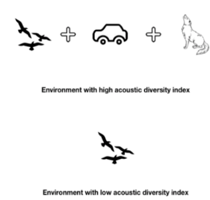
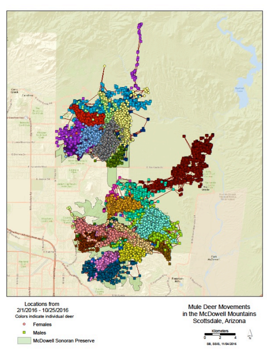


Figure 5 - Acoustic Diversity Measure



- *Map 1. Mule deer movements in the McDowell Mountains, Scottsdale, Arizona as measured by radio collars for the dates of: 2/1/2016 to 5/9/2017.*

The first application of the Acoustic Diversity Measure supports a study of the movement of mule deer through a wildlife linkage in the McDowell Sonoran Preserve. In 2012, AZGFD conducted a road mortality and wildlife track study and recommended wildlife crossing structures and long-term monitoring presence farther away from the road. Preliminary results from a joint AZGFD/ MSC Field Institute mule deer telemetry project substantiated that the road acts as a significant barrier to mule deer movement and reduces wildlife occupancy.

The Acoustic Diversity Measure assists in developing a robust approach to road noise mitigation and wildlife crossing by considering how sound quality varies relative to road distance, elevation and patterns of vegetation in addition to variation of these patterns relative to weather conditions. The additional data provides site specific optimization of site and form of mitigation and prediction capacity for future management.

- Table 1 represents a multivariate linear regression model that predicts the Acoustic Diversity Measure from the collected weather parameters

Features	Estimate	SE	tStat	pValue
dewPoint	-0.21029047	0.04309618	-4.87956163	1.18E-06
windSpeed	0.137373321	0.033727356	4.073053367	4.88E-05
cloudCover	4.636317405	1.956748781	2.369398386	0.017942285
temperature	0.073488801	0.033632723	2.185038703	0.029039365
visibility	-0.65807317	0.321714443	-2.04551949	0.040976756
humidity	9.666408614	6.962762307	1.388300819	0.16525037
windBearing	0.002787038	0.002063029	1.350944914	0.176915603
precipIntensity,	0	0	NaN	NaN
precipProbability	0	0	NaN	NaN
apparentTemperature	0	0	NaN	NaN

Table. 1 - Correlation between weather data and entropy

- The results show that there is a positive, statistically significant relationship between the acoustic diversity measure and cloud cover, wind speed, and temperature; and an inverse statistically significant relationship between acoustic diversity and dewPoint and visibility

pValue - are these statistically valuable in predicting entropy in the multi-variant linear regression model

Future Directions

1. Validation of findings: We will also examine how this technique performs on data sets from different times of the year under different weather conditions for the same location in order the strengthen the model.
2. Dig Deeper: Expand our understanding of how the weather parameters affect entropy (Acoustic Diversity Measure) and further analyze the cause of these relationships. This would not only help us validate the hypothesis of a relationship between the two factors but may also help in understanding the effect of climate change on ecological diversity.
3. Classifying Events: It would be an interesting and important extension of this work to be able to classify events using machine learning techniques. Initial classification will focus on broad categories like, human activities, bird calls, animal sounds, natural sounds like, waterfall, rainfall, storms etc

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