Geospatial Modeling Techniques for the Analysis of Geographic Variations in Animal Vocalizations

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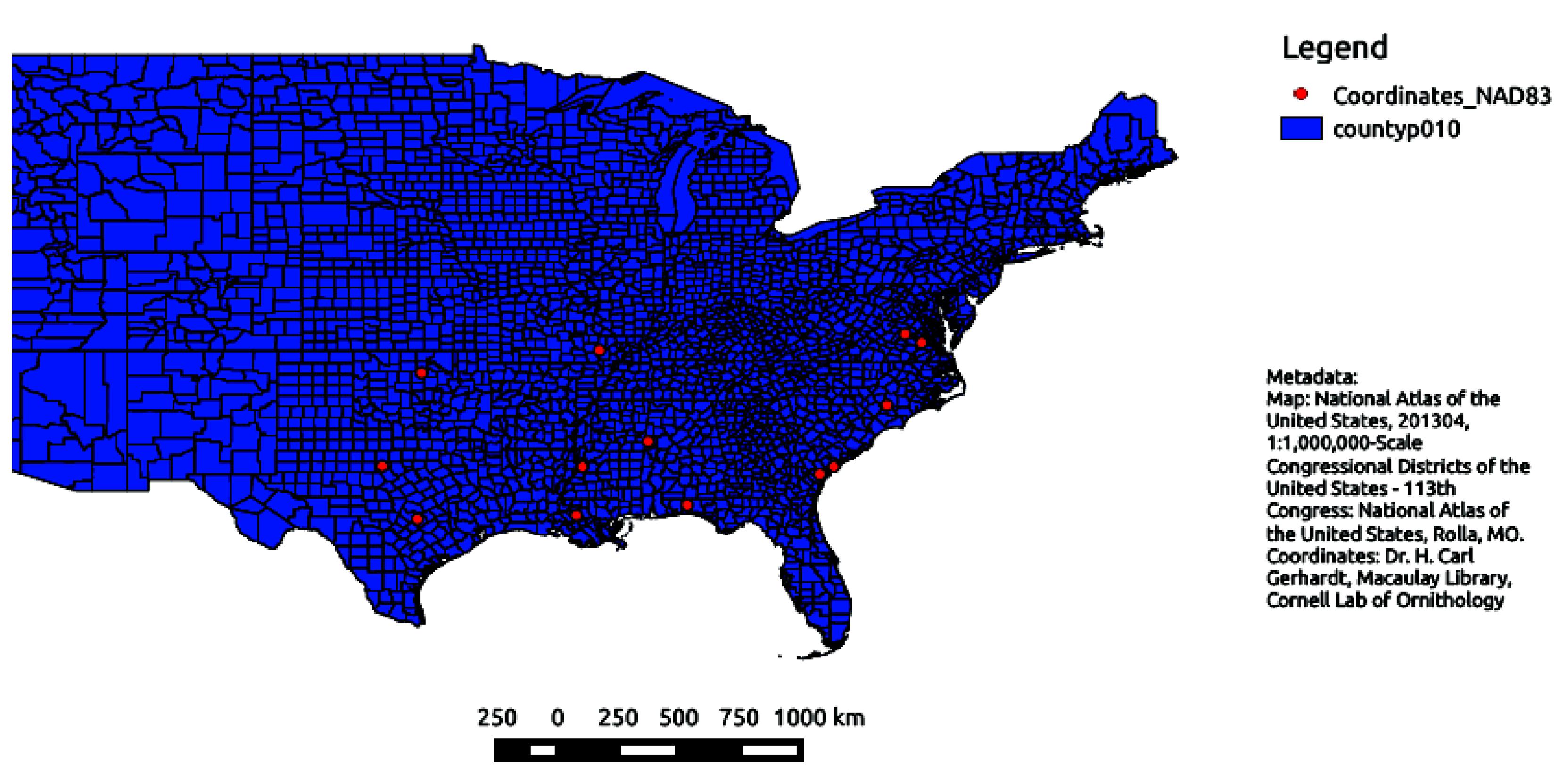
Abstract

For several decades now, there has been a steady stream of publications on methods to analyze the geographic variations in the vocalizations of various animal species. A few of these analysis methods have become well known and widely used. The classical papers relied heavily on the use of spectrograms to decompose vocalizations into their fundamental frequencies for study. Various methods and statistical techniques were developed in order to better utilize these spectrograms to understand the workings of animal vocalizations. In this paper, we present a new method to generate statistical models to study these vocalizations using the mating calls of the Cope's Gray Treefrog. The Cope's Gray Treefrog *(Hyla versicolor)* was chosen because it is very well studied due to its status as a model organism for studies on polyploidic speciation and mate discrimination and therefore there is a wealth of recordings of its mating call. This study focuses on how the Cope's Gray Treefrog's mating calls vary over the majority of their geographic range with the end goal of producing a geostatistical model of these variations which may provide a tool for future research in studying spatial variations in animal vocalization. Samples were selected from all over the southeast from Missouri to Virginia and from Texas to Florida and several states in between.

Introduction

Recently, signal processing has become a very large part of field biology with the advent of techniques such as Spectrographic Cross-Correlation (SPCC) and Principal Coordinates Analysis (PCO) often abbreviated together as SPCC-PCO by Cortopassi and Bradbury (2000) [1]. This project attempts a different method based not on the spectrograms but on the original signals. Here we align the original WAV files, generate distance matrices, and then construct a geospatial model for how the calls change across geographic space.

Map 1: Map of Recording Locations



Map 1: This map displays the geographic locations of all of the recording sites from which samples were taken. These samples were collected between 1969 and 1990 by Dr. H. Carl Gerhardt and were licensed to this project and downloaded from the Macaulay Library of the Cornell Lab of Ornithology. The points in red are the coordinate locations while the map itself is from the U.S. National Atlas. It is in the Public Domain as it is a publication of a part of the USDOI.

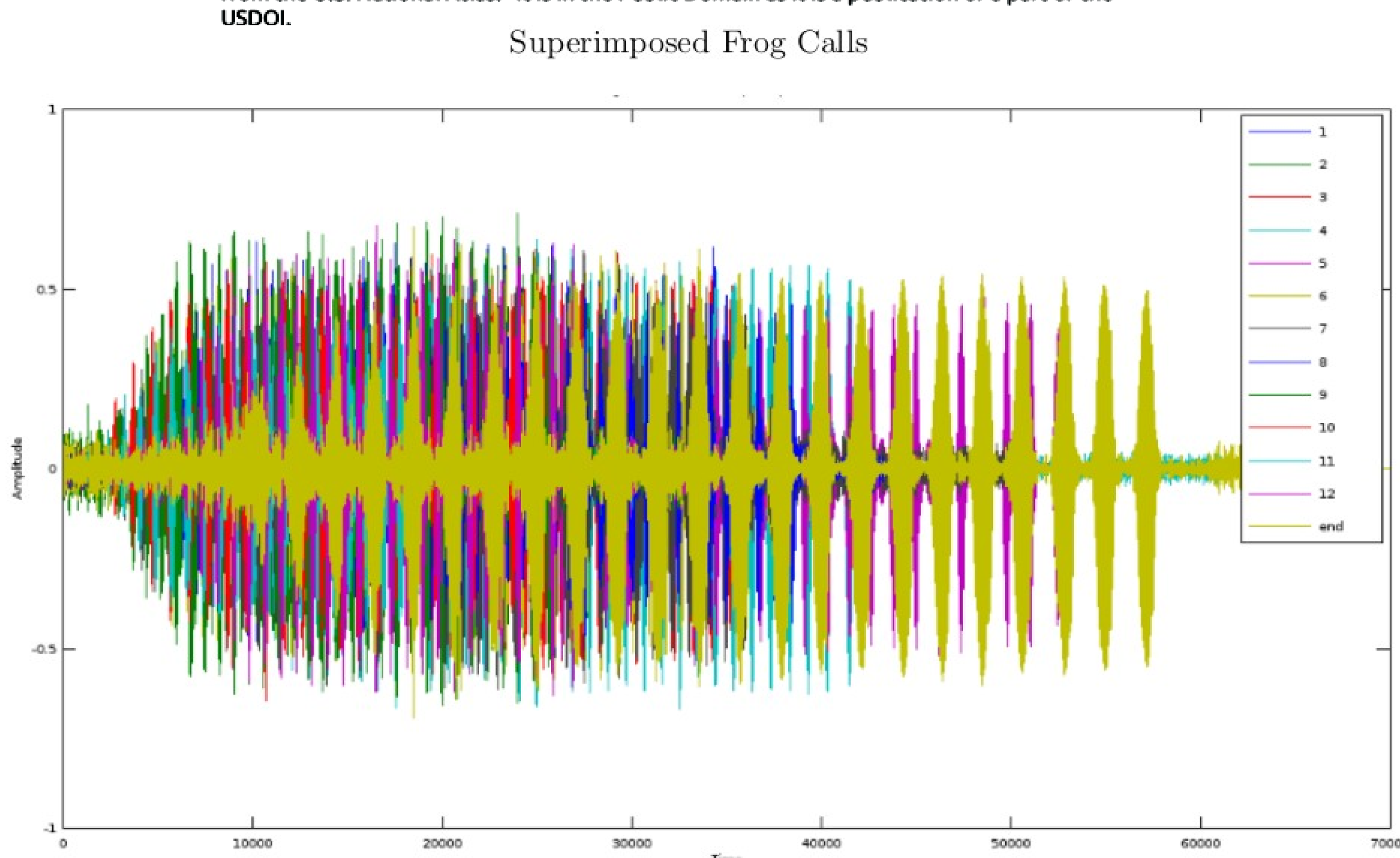


Figure 1: This figure shows a simultaneously plotted sample of 13 calls (one from each location) superimposed using a 1D Generalized Procrustes Analysis leaving in scale. The image was generated using MATLAB and a short 1D GPA custom program.

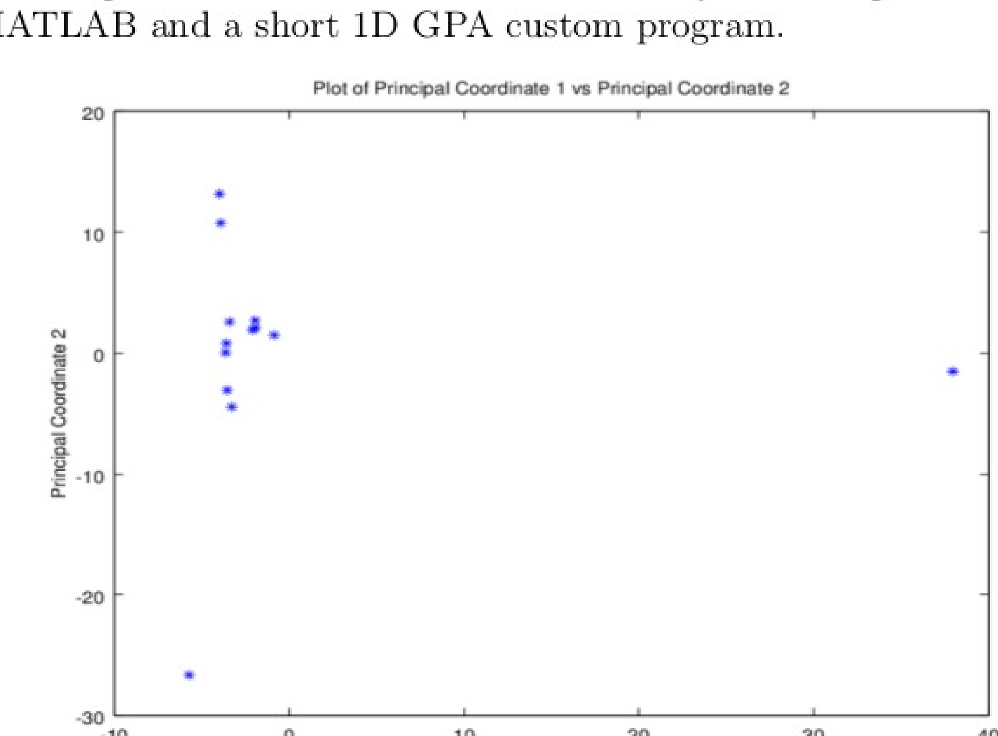


Figure 2: This figure shows a simple plot of the first two principal coordinate axes of the sampled 13 frog calls.

Hypothesis

It is intended that this project will result in a useful computational model of how the structure of animal vocalizations change depending upon their geographic location.

Methods

For this project, frog call files were licensed from the Macaulay Library which is owned and operated by the Cornell Lab of Ornithology [3]. All of the recordings were done by Dr. Gerhardt over the years 1969 to 1990 [3]. The individual calls from each of these files were then extracted for further analysis. In total, the full data set consists of 186 individual calls. Though only a subset of 13 calls. 1 from each population, were analyzed due to current constraints on computational resources. An extension of the initial programs that were used are in the works for the full data set. The analysis used a custom program written in MATLAB which read in all 13 files and a csv file with the geographic location at which each call was recorded. Geographic locations were recorded in North American Datum 1983 (NAD1983) Latitude-Longitude coordinates. The Lati-Long coordinates were transformed into UTM coordinates. The calls were then aligned using 1-Dimensional Generalized Procrustes Analysis. The 1D GPA code was run along with an older maximum cross-correlation alignment code and both were timed to determine if there was a computational cost advantage to using GPA over cross-correlation [5]. The UTM coordinates were then used to generate a Euclidean distance matrix. The matrix of frog calls was then subjected to a Principal Coordinates Analysis using the method put forth by Gower (1966) [4]. The resulting Principal Coordinates and Distance Matrices will be used to compute estimated principal coordinate values using the Simple Kriging regression-interpolation Geostatistical Method based on Delhomme (1978) which estimates intermediate values as a spatially-dependent weighted combination of the known values [2].

Results

Alignment Method	Computation Time	Speedup Factor	% Improvement
Maximum Cross-Correlation	0.58377 seconds	1.0000	0.00%
1D Generalized Procrustes Analysis	0.49342 seconds	1.1831	18.31%

Figure 3: This table shows a comparison of the implementations of alignment methodologies: Maximum Cross-Correlation Alignment and 1-Dimensional Generalized Procrustes Analysis. The Computation Times shown are the average of 1000 timed runs of the alignment programs. Each of the alignment programs are custom-written functions in MATLAB. Note that the 1D GPA method is much faster on average than the Maximum Cross-Correlation Method which was used last year for signal alignment. The method for calculating the speedup is $\frac{t_{cross-correlation}}{t_{1D-GPA}}$ and $(1 - speedup) * 100$ for the % improvement [5].

Conclusion

The results clearly show that the 1-Dimensional Generalized Procrustes Analysis is superior to the Maximum Cross-Correlation Alignment method and provides a speedup of more than 18% from the cross-correlation method. The geospatial model itself, which will be based on Kriging estimates calculated from known Principal Coordinate values (shown in Figure 2), is still in progress, though the initial trials are promising. This work is primarily to showcase one advantage of using Generalized Procrustes Analysis to align calls over pairwise alignment by Maximum Cross-Correlation.

Acknowledgements

The authors would like to thank Thomas Campbell Arnold and the members of the Morphometrics Lab at FSU for the generous contribution of their knowledgeas well as Dr. H Carl Gerhardt and The Macaulay Library at the Cornell Laboratory of Ornithology for graciously providing us with the recordings of the frog calls.

References

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