**Bat Calls Classification**

**About the project:**

Bats use echolocation for orientation and prey detection and emit “sounds” at unique frequencies. Most bat species have evolved species-specific echolocation calls but they also show great interspecific variation and flexibility caused by habitat, geography, sex, age, etc. In other cases, there is a great overlap of call structures between species which makes identification to species level complicated. Through extensive field work I have recorded ultrasonic bat calls in Mexico with specific labels that allow us to relate species to call characteristics. The main objective is to develop a classifier using reference echolocation calls using Random Forest methods. However, so far Random Forest trained to classify directly to species has not been accurate enough for those species with high overlapping call characteristics.

There are two main tasks:

a) Extract the variables that best discriminate the species.

b) Cluster the 8 species into <8 clusters (groups) with similar call characteristics with the condition that a single species cannot be in two different groups.

**Data Format:**

The data is in txt tab delimited. Missing values are coded with NA. Columns represent the variables and rows the species. There are 8 different species, some with unique calls and others with highly overlapping calls. The species are labelled as Spp1, Spp2, etc. I cannot give the species name for confidentiality reasons but there is no need to know the particular name of the species for the analysis.

**Variables:**

I used the specialized program Sonobat to extract different bat calls parameters that represent sound measurements. There are 73 variables in different units. You can see the units used highlighted in yellow in the next table. There is no need to read the whole explanation of each variable, only if you want to get into more technical details of the specific sound characteristic measured.

|  |  |
| --- | --- |
| **Variable** | **Explanation** |
| Spp  **categorical** | The bat species |
| CallDuration  **milliseconds** | Duration of the call (milliseconds). |
| Fc  **kHz** | Characteristic frequency of the call. Determined by finding the point in the final 40% of the call having the lowest slope or exhibiting the end of the main trend of the body of the call (kHz). |
| HiFreq  **kHz** | Highest apparent frequency of the call (kHz). |
| LowFreq  **kHz** | Lowest apparent frequency of the call (kHz). |
| Bndwdth  **kHz** | Total frequency spread of the call. Calculated from the difference between the highest and lowest frequency (kHz). |
| FreqMaxPwr  **kHz** | The frequency of the maximum amplitude of the call (kHz). |
| PrcntMaxAmpDur  **%** | Percentage of the entire call duration at which the maximum amplitude occurs. |
| TimeFromMaxToFc  **milliseconds** | Time from the point at which the maximum amplitude occurs to the point in the call of the characteristic frequency (ms). |
| FreqKnee  **kHz** | Frequency at which the initial slope of the call most abruptly transitions to the slope of the body of the call (kHz). |
| PrcntKneeDur  **%** | Percentage of the entire call duration at which the knee occurs, i.e., the point at which the initial slope of the call most abruptly transitions to the slope of the body of the call. |
| StartF  **kHz** | Frequency of the start of the call. Typically the same point as the highest frequency, but different if the call initially rises in frequency (kHz). |
| EndF  **kHz** | Frequency of the end of the call. Typically the same point as the lowest frequency, but different if the call ends with a rise in frequency (kHz). |
| DominantSlope  **kHz/ms** | Slope of the longest sustained trend in slope of the call. Determined by finding the segment of the call having the minimum residue for a linear regression of a segment of the call of 20% the duration of the call (kHz/ms). |
| SlopeAtFc  **kHz/ms** | Instantaneous slope at the point of the characteristic frequency (kHz/ms). |
| StartSlope  **kHz/ms** | Slope at the start of the call, calculated from the first 5% of the call duration (kHz/ms). |
| EndSlope  **kHz/ms** | Slope at the end of the call, calculated from the final 5% of the call duration (kHz/ms). | |
| SteepestSlope  **kHz/ms** | Steepest slope of the call, calculated from a linear regression of a segment of 10% the duration of the call (kHz/ms). | |
| LowestSlope  **kHz/ms** | Lowest slope of the call, calculated from a linear regression of a segment of 10% the duration of the call (kHz/ms). | |
| TotalSlope  **kHz/ms** | Total slope of the call, calculated from the difference in frequency and time from the point of highest frequency to the point of the characteristic frequency (kHz/ms). | |
| HiFtoKnSlope  **kHz/ms** | Slope of the call calculated from the difference in frequency and time from the point of highest frequency to the point of the knee (kHz/ms). | |
| KneeToFcSlope  **kHz/ms** | Slope of the call calculated from the difference in frequency and time from the point of the knee to the point of the characteristic frequency (kHz/ms). | |
| CummNmlzdSlp  **kHz/ms** | Average of the instantaneous slopes of the call (kHz/ms). | |
| HiFtoFcExpAmp  **relative units** | Amplitude parameter of an exponential fit of the call from the point of high frequency to the point if the characteristic frequency. | |
| HiFtoFcDmp  **relative units** | Damping parameter of an exponential fit of the call from the point of high frequency to the point if the characteristic frequency. | |
| KnToFcExpAmp  **relative units** | Amplitude parameter of an exponential fit of the call from the point of the knee to the point if the characteristic frequency. | |
| KnToFcDmp  **relative units** | Damping parameter of an exponential fit of the call from the point of the knee to the point if the characteristic frequency. | |
| HiFtoKnExpAmp  **relative units** | Amplitude parameter of an exponential fit of the call from the point of the high frequency to the point if the characteristic frequency. | |
| HiFtoKnDmp  **relative units** | Damping parameter of an exponential fit of the call from the point of the high frequency to the point if the characteristic frequency. | |
| FreqLedge  **kHz** | Frequency of the ledge, i.e., the most abrupt transition to the most extended flattest slope section of the body of the call preceding the characteristic frequency, also referred to as the “ledge” of the call (kHz). | |
| LedgeDuration  **kHz** | Duration of the ledge, i.e., the most extended flattest slope section of the body of the call preceding the characteristic frequency (ms). | |
| FreqCtr  **kHz** | Frequency at the center of the duration of the call (kHz). | |
| Fbak32dB  **kHz** | Frequency of the call 32 dB below the point of maximum amplitude of the call, and preceding the point of maximum amplitude of the call (kHz). | |
| FFwd32dB  **kHz** | Frequency of the call 32 dB below the point of maximum amplitude of the call, and after the point of maximum amplitude of the call (kHz). | |
| Fbak20dB  **kHz** | Frequency of the call 20 dB below the point of maximum amplitude of the call, and preceding the point of maximum amplitude of the call (kHz). | |
| FFwd20dB  **kHz** | Frequency of the call 20 dB below the point of maximum amplitude of the call, and after the point of maximum amplitude of the call (kHz). | |
| Fbak15dB  **kHz** | Frequency of the call 15 dB below the point of maximum amplitude of the call, and preceding the point of maximum amplitude of the call (kHz). | |
| FFwd15dB  **kHz** | Frequency of the call 15 dB below the point of maximum amplitude of the call, and after the point of maximum amplitude of the call (kHz). | |
| Fbak5dB  **kHz** | Frequency of the call 5 dB below the point of maximum amplitude of the call, and preceding the point of maximum amplitude of the call (kHz). | |
| FFwd5dB  **kHz** | Frequency of the call 5 dB below the point of maximum amplitude of the call, and after the point of maximum amplitude of the call (kHz). | |
| Bndw32dB  **kHz** | The total bandwidth covered from the point of the call 32 dB below and before the point of maximum amplitude and the point of the call 32 dB below and after the point of maximum amplitude of the call (kHz). | |
| Bndw20dB  **kHz** | The total bandwidth covered from the point of the call 20 dB below and before the point of maximum amplitude and the point of the call 32 dB below and after the point of maximum amplitude of the call (kHz). | |
| Bndw15dB  **kHz** | The total bandwidth covered from the point of the call 15 dB below and before the point of maximum amplitude and the point of the call 32 dB below and after the point of maximum amplitude of the call (kHz). | |
| Bndw5dB  **kHz** | The total bandwidth covered from the point of the call 5 dB below and before the point of maximum amplitude and the point of the call 32 dB below and after the point of maximum amplitude of the call (kHz). | |
| DurOf32dB  **milliseconds** | The duration of the call from the point of the call 32 dB below and before the point of maximum amplitude and the point of the call 32 dB below and after the point of maximum amplitude of the call (ms). | |
| DurOf20dB  **milliseconds** | The duration of the call from the point of the call 20 dB below and before the point of maximum amplitude and the point of the call 32 dB below and after the point of maximum amplitude of the call (ms). | |
| DurOf15dB  **milliseconds** | The duration of the call from the point of the call 15 dB below and before the point of maximum amplitude and the point of the call 32 dB below and after the point of maximum amplitude of the call (ms). | |
| DurOf5dB  **milliseconds** | The duration of the call from the point of the call 5 dB below and before the point of maximum amplitude and the point of the call 32 dB below and after the point of maximum amplitude of the call (ms). | |
| Amp1stQrtl  **relative units** | Total amplitude of the first quartile of the call (relative units). | |
| Amp2ndQrtl  **relative units** | Total amplitude of the second quartile of the call (relative units). | |
| Amp3rdQrtl  **relative units** | Total amplitude of the third quartile of the call (relative units). | |
| Amp4thQrtl  **relative units** | Total amplitude of the fourth quartile of the call (relative units). | |
| Amp1stMean  **relative units** | Mean of the first quartile amplitude (relative units). | |
| Amp2ndMean  **relative units** | Mean of the second quartile amplitude (relative units). | |
| Amp3rdMean  **relative units** | Mean of the third quartile amplitude (relative units). | |
| Amp4thMean  **relative units** | Mean of the fourth quartile amplitude (relative units). | |
| LnExpA\_StartAmp  **relative units** | Amplitude parameter of an exponential fit of the time-amplitude trend of the call from the start of the call to the point of maximum amplitude. | |
| LnExpB\_StartAmp  **relative units** | Damping parameter of an exponential fit of the time-amplitude trend of the call from the start of the call to the point of maximum amplitude. | |
| AmpStartLn60ExpC  **relative units** | Time parameter of an exponential fit of the time-amplitude trend of the call from the start of the call to the point of maximum amplitude. | |
| LnExpA\_EndAmp  **relative units** | Amplitude parameter of an exponential fit of the time-amplitude trend of the call from the point of maximum amplitude to the end of the call. | |
| LnExpB\_EndAmp  **relative units** | Damping parameter of an exponential fit of the time-amplitude trend of the call from the point of maximum amplitude to the end of the call. | |
| AmpEndLn60ExpC  **relative units** | Time parameter of an exponential fit of the time-amplitude trend of the call from the point of maximum amplitude to the end of the call. | |
| AmpK@start  **kHz/ms** | Slope of a logarithmic plot of the time-amplitude trend of the call from the start of the call to the point of maximum amplitude (kHz/ms). | |
| AmpK@end  **kHz/ms** | Slope of a logarithmic plot of the time-amplitude trend of the call from the point of maximum amplitude to the end of the call (kHz/ms). | |
| AmpKurtosis  **relative units** | Kurtosis of the time-amplitude trend. | |
| AmpSkew  **relative units** | Skew of the time-amplitude trend. | |
| AmpVariance  **relative units** | Variance of the time-amplitude trend. | |
| AmpMoment  **relative units** | Moment of the time-amplitude trend. | |
| AmpGausR2  **relative units** | R-squared of a Gaussian fit of the time amplitude trend. | |
| HiFminusStartF  **kHz** | High frequency minus start frequency. This measure may be used as a quality control check to sort and reject improperly trended calls. For typical frequency modulated calls, a value greater than zero (i.e., start frequency less than high frequency) may indicate an improperly trended call (kHz). | |
| FcMinusEndF  **kHz** | Characteristic frequency minus start frequency. This measure may be used as a quality control check to sort and reject improperly trended calls. Use as appropriate for different types of calls. For example, most calls from the genus Myotis should have a positive value for this measure indicating the end frequency is less than the characteristic frequency. A negative value might indicate an improper trend as the result of a poor signal or excessive echo obscuring the end of the call (kHz). | |
| RelPwr2ndTo1st  **relative units** | Ratio of the strength of the harmonic that SonoBat trended (typically the first or primary harmonic) to the strength of the next higher harmonic (typically the second harmonic). A ratio of the 3rd harmonic that exceeds the 2nd harmonic’s ratio typically indicates a saturated or “clipped” signal. Such calls will render inaccurate assessments of power distribution through the call, although the time-frequency trend will remain reliable. | |
| RelPwr3rdTo1st  **relative units** | Ratio of the strength of the harmonic that SonoBat trended (typically the first or primary harmonic) to the strength of the second higher harmonic (typically the third harmonic). A ratio of the 3rd harmonic that exceeds the 2nd harmonic’s ratio typically indicates a saturated or “clipped” signal. Such calls will render inaccurate assessments of power distribution through the call, although the time-frequency trend will remain reliable. | |