Birdcall Identification Project

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Online:
< http://cnx.org/content/col10616/1.2/ >

C O N N E X I O N S

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Collection structure revised: December 17, 2008
PDF generated: February 5, 2011
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Chapter 1

Birdcall Identification: Introduction[1]

1.1 Birdcall Identification Project

1.1.1 Motivation

Birdwatchers around the world have struggled with the arduous task of remembering and identifying the many birdcalls native to their area. As an added struggle, those who live in an urban environment are challenged to pull the sound of a birdcall out of the background noise present in the city. Our birdcall identification program attempts to computationally identify birdcalls. With a computational identifier, many problems associated with birdcall identification are mitigated: there is no need to remember birdcalls, the program can algorithmically separate the birdcall from the background, and the sound file can be automatically saved to the computer.

1.1.2 Method

Previous attempts to identify bird sounds relied solely on spectrograms. Our process focuses on using a time-domain matched filter and frequency analysis in tandem to achieve accurate results. The matched filter identifies the similarities between two sounds as a function of time. Frequency analysis differs two sounds based on the energy in the frequency spectrum. The matched filter in conjunction with frequency analysis provide accuracy far surpassing that of lone spectrograms.

[1] This content is available online at <http://cnx.org/content/m18950/1.3/>.

Chapter 2

Birdcall Identification: Bird Choice[1]

2.1 Bird Choice

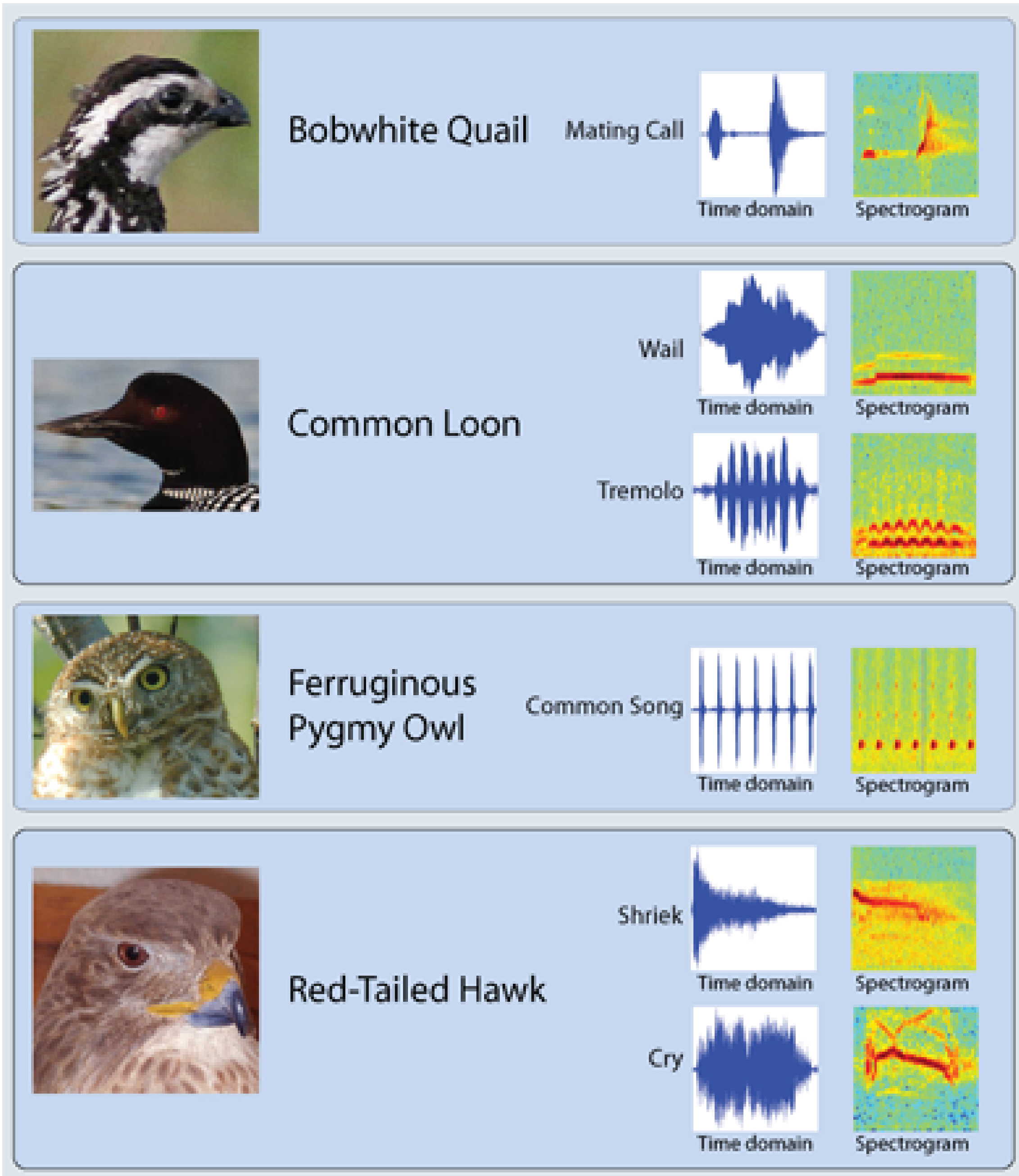
We elected to use six different birdcalls in our project: the common loon wail; the common loon tremolo; the red-tailed hawk cry; the red-tailed hawk shriek; the bobwhite quail mating-call; and the ferruginous pygmy-owl hoot. The group selected these calls based upon two major criteria. Each call needed to be available from multiple sources, and each call had to be audibly different from the other calls selected.

The project group contains no bird experts, so we used only prerecorded birdcall clips as samples. Such audio clips saved us the necessity of making field recordings. Also, the clips' creators, who presumably possess more ornithological expertise than we, had already identified the birds present in each recording. For formatting reasons, we chose only audio clips saved as wav files. However, with this constraint, relatively few bird types suited our needs. Adults of each bird species have up to fourteen or fifteen call types. Of these types, frequently only one or two are available as recordings, and of recorded types, almost none exist in multiple, wav-file examples on the internet, or in libraries. This significantly reduced our pool of candidate birds.

Our second major criterion was that the chosen birdcalls be audibly and spectrographically distinctive. Although spectrographic analysis can easily reveal differences between signals in the frequency domain, human error is less likely when group members can tell the difference between time-domain calls by ear. Having a variety of birdcalls, some similar, some radically different, also produces a more interesting analysis than the use of entirely alike, or entirely dislike calls.

The application of both criteria resulted in the final selection of birds.

[1] This content is available online at <http://cnx.org/content/m18933/1.6/>.


Bobwhite Quail
Mating Call
Time domain
Spectrogram
Common Loon
Wail
Time domain
Spectrogram
Tremolo
Time domain
Spectrogram
Ferruginous Pygmy Owl
Common Song
Time domain
Spectrogram
Red-Tailed Hawk
Shriek
Time domain
Spectrogram
Cry
Time domain
Spectrogram

Chapter 3

Birdcall Identification: Matched Filter Implementation[1]

3.1 Matched Filter Implementation

3.1.1 Matched Filter

Matched filters do an excellent job of identifying sound samples, so we decided to apply the method here to identify birdcall audio files. A matched filter searches for a sample clip, the filter, within a longer audio recording. Convolution compares the filter to the longer signal at each possible offset. The greater the maximum amplitude of the convolution result, the stronger the match. By having a different filter for each birdcall, we can search an audio file to identify which birdcall it contains.

The matched filter algorithm is as follows:

1. Reverse the filters in the time-domain.
2. Normalize the energy of each of the filters.
3. Convolve each filter with the input signal and take the maximum amplitude of the resulting convolution signals.
4. The filter that gives us the greatest maximum value indicates which birdcall the signal contains.

[1] This content is available online at <http://cnx.org/content/m18917/1.3/>.

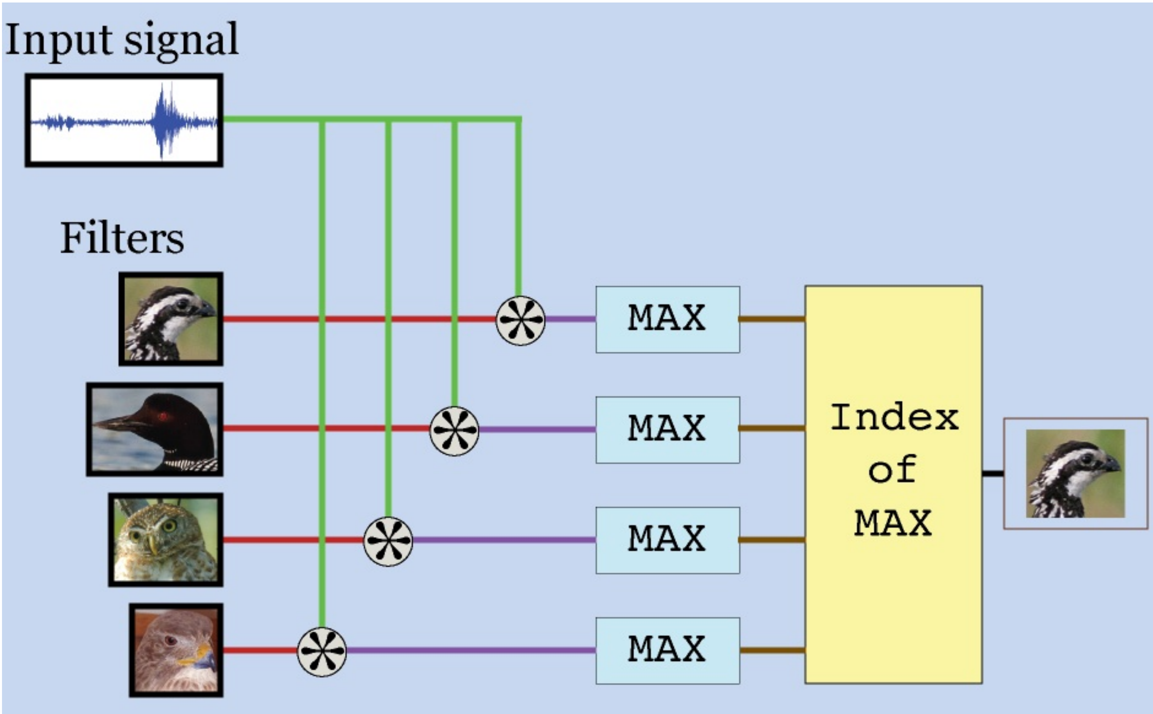


Figure 3.1

3.1.2 Filter Library Creation

Our first step in implementing the matched filter algorithm was to create a library of birdcall filters. To do this, we looked at the spectrograms of a few sample audio files of the same birdcall and selected a portion that looked representative of the call.

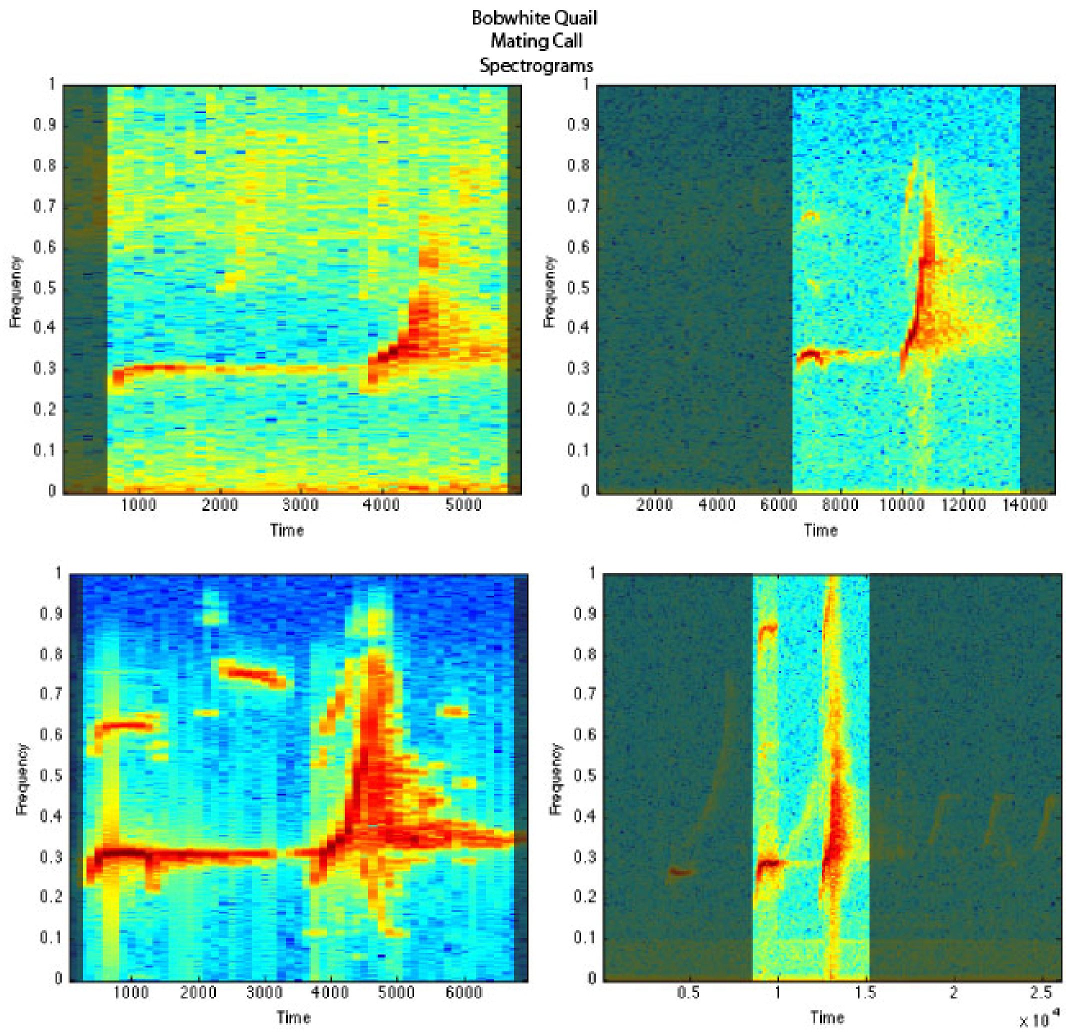


Figure 3.2

For each birdcall, one of the representative audio segments was saved as a filter. Because the first two steps of the above matched filter algorithm affect only the filter library and are independent of the input signal, we reversed the filters and normalized their energy before saving them to wave files.

3.1.3 Matlab Implementation

The following MATLAB script performed our matched filter algorithm. When given a wave file as input, it would tell us how well the audio sample matched against each of the 6 birdcall filters.

> NOTE: We used circular convolution instead of linear convolution because it computed much faster. MATLAB's built-in cconv function zero-pads the two signals before multiplying their FFTs, generating the convolution result we are looking for.

```
function result = birdcheck(file)
```

```
    [sig, fs, nbits] = wavread(file);
    signal=sig(:,1);
    signal=signal/max(abs(signal));
    filters{1}=wavread('filters/bob.wav');
    filters{2}=wavread('filters/lt.wav');
    filters{3}=wavread('filters/lw.wav');
    filters{4}=wavread('filters/pygmy.wav');
    filters{5}=wavread('filters/red.wav');
    filters{6}=wavread('filters/redcry.wav');
    for i=1:6
      filter=filters{i};
      result(i) = max(abs(cconv(signal,filter(end:-1:1))));
    end
  end
```

The script was able to correctly identify several birdcalls. It did fail to correctly identify four cases in two categories:

1. Two of our loon tremolo files registered as pygmy owl common songs.
2. Two of our red-tailed hawk shriek files registered as red-tailed hawk cries.

Chapter 4

Birdcall Identification: Method Refinement[1]

Need for Improvement
The matched filter implementation gave the right result in most cases, but occasionally reported a fairly good correlation between an input signal and a filter that were clearly quite distinct from one another. The matched filter often doesn't recognize a strong difference between two signals if one has power in a particular frequency range that the other lacks. For instance, a loon tremolo has a wide spectrum compared to a ferruginous pygmy owl, but the matched filter often reported a good match because the owl's pitch was in the loon's range.

Frequency-domain Analysis
We hoped to adjust the matched filter results by taking into account the frequency-domain error between the signal and the filter. The convolution step of the matched filter showed not only the strongest match between the signal and the filter, but also the time of that match in the input signal. We windowed out the chunk of the input signal that matched best. We then used the mean-squared error between the magnitudes of that chunk's FFT and the filter's FFT to obtain a number indicating how well the frequency content of the two signals matched.

As an example, a comparison of a hawk shriek versus a filter for a hawk cry shows that their frequency ranges don't match very well:

[1] This content is available online at <http://cnx.org/content/m18919/1.2/>.

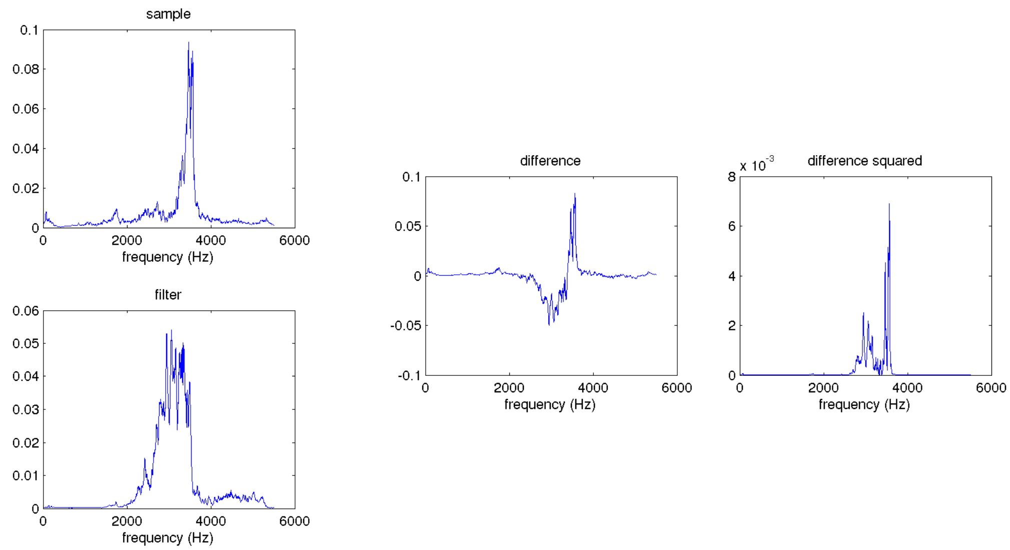


Figure 4.1

In contrast, the same shriek versus a filter for a shriek shows a lower mean-squared error (0.4637 compared to 0.9257, after scaling):

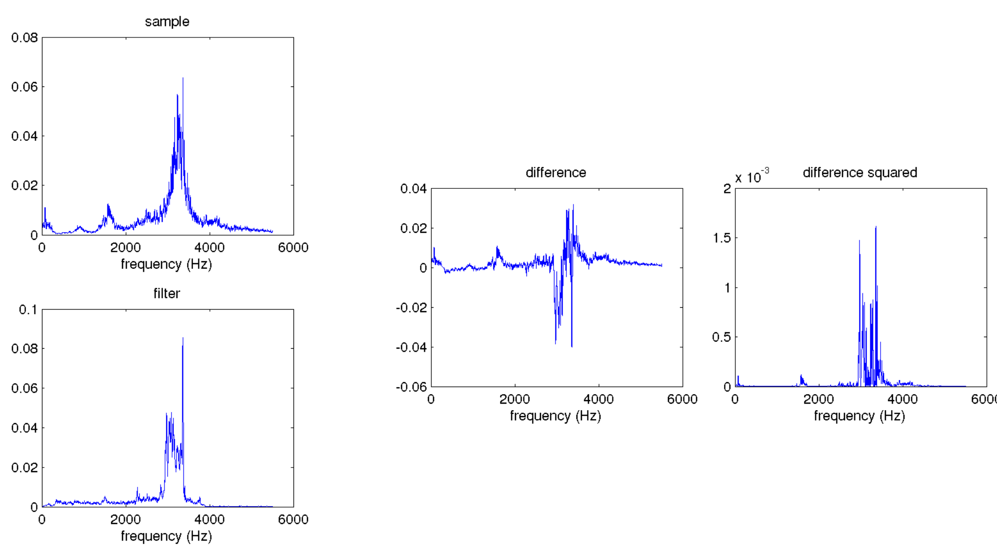


Figure 4.2

Correction Algorithm

The mean-squared FFT error by itself was a good predictor of which filter matched best with an input signal, despite ignoring phase information to focus only on magnitudes. We divided the matched filter output by the mean-squared error to arrive at a final result value.

> NOTE: We added a small number to the error before dividing, to avoid dividing by zero in the case where the signal perfectly matches the filter.

In all cases where the matched filter had selected the correct bird as the strongest match, this adjustment increased the ratio between the strong match and the others. It corrected the errors between different red-tailed hawk vocalizations, but wasn't sufficient to recognize the loon tremolo.

Chapter 5

Birdcall Identification: Matlab GUI[1]

5.1 Matlab Bird Call Identification Program

5.1.1 Matlab GUI

The group created a MATLAB Graphical User Interface (GUI) to implement the birdcall identification algorithms.

[1] This content is available online at <http://cnx.org/content/m18918/1.2/>.

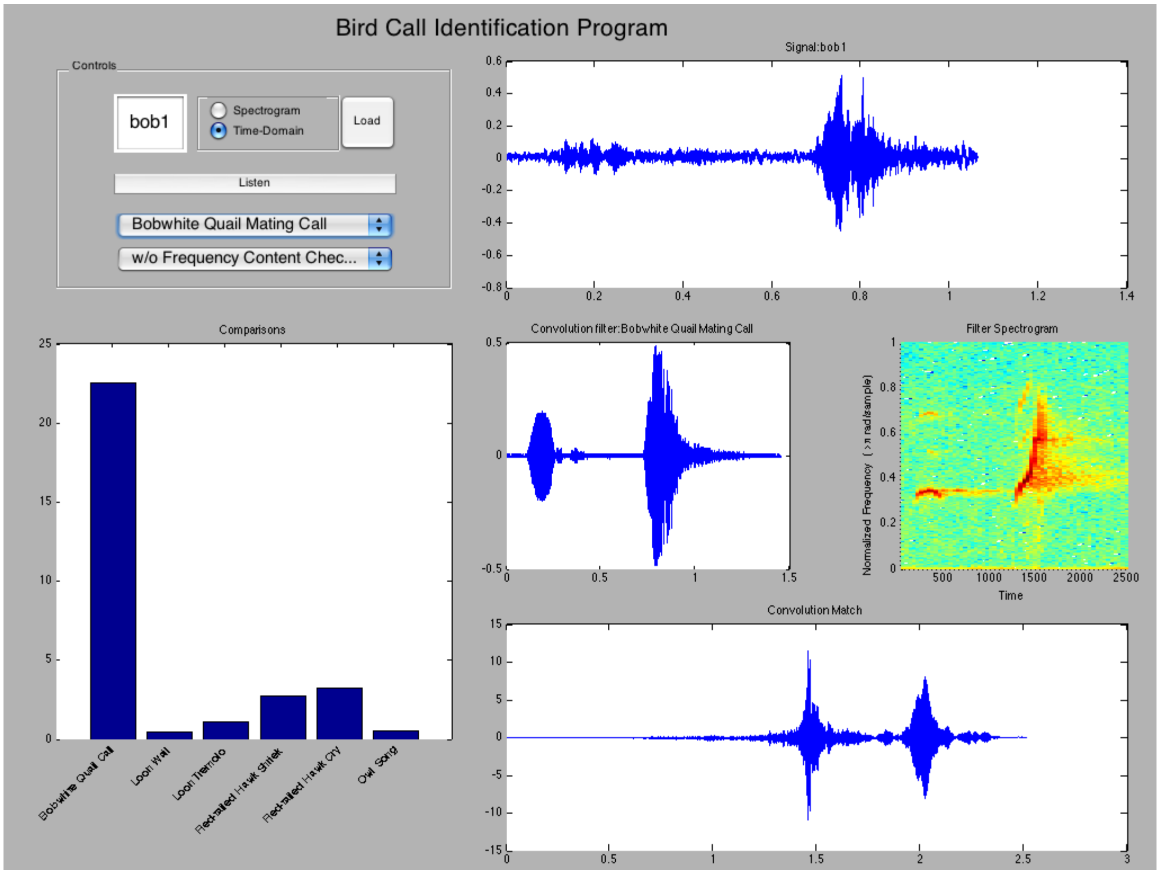


Figure 5.1

Our GUI was able to load in audio files, play them, and display the result of convolving the audio signal with a specific filter. It also produced a bar graph of the maximum of the convolution result for each filter. This would graphically show us not only which birdcall the audio signal contained, but also how confidently the program was reporting one birdcall over another.

The GUI has the ability to choose whether or not to use our frequency content checking algorithm.

Chapter 6

Birdcall Identification: Results[1]

6.1 Results

These results show how strongly the different audio samples matched up to the different filters.

The number outside of the parentheses indicates the results with frequency content checking turned on. The number inside the parentheses indicates the results with frequency content checking turned off.

All numbers are relative to the greatest match found for a given sample.

Bobwhite Quail mating call samples against different filters (4 sample audio files):

Bobwhite Quail Mating Call	Loon Tremolo	Loon Wail	Pygmy Owl Common Song	Red-tailed Hawk Shriek	Red-tailed Hawk Cry
1.0000 (1.0000)	0.0195 (0.0492)	0.0076 (0.0200)	0.0092 (0.0241)	0.0661 (0.1210)	0.0648 (0.1444)
1.0000 (1.0000)	0.0002 (0.0050)	0.0001 (0.0019)	0.0002 (0.0044)	0.0050 (0.0651)	0.0055 (0.0681)
1.0000 (1.0000)	0.5229 (0.7098)	0.0312 (0.0555)	0.0194 (0.0343)	0.1808 (0.2484)	0.5020 (0.5506)
1.0000 (1.0000)	0.3218 (0.4168)	0.0252 (0.0372)	0.0735 (0.1055)	0.1417 (0.1777)	0.1406 (0.1810)

Table 6.1

Loon tremolo samples against different filters (5 sample audio files):

Bobwhite Quail Mating Call	Loon Tremolo	Loon Wail	Pygmy Owl Common Song	Red-tailed Hawk Shriek	Red-tailed Hawk Cry
0.1415 (0.1839)	0.5374 (0.5355)	0.1321 (0.1692)	1.0000 (1.0000)	0.1288 (0.1597)	0.1314 (0.1729)
0.0687 (0.0858)	1.0000 (1.0000)	0.7520 (0.8008)	0.3405 (0.4000)	0.2189 (0.2581)	0.0478 (0.0604)

continued on next page

[1]This content is available online at <http://cnx.org/content/m18952/1.1/>.

0.0145 (0.0432)	0.1217 (0.2971)	0.0138 (0.0415)	1.0000 (1.0000)	0.0227 (0.0651)	0.0058 (0.0176)
0.0004 (0.0077)	1.0000 (1.0000)	0.0079 (0.1194)	0.0045 (0.0758)	0.0011 (0.0197)	0.0002 (0.0032)
0.0142 (0.0417)	1.0000 (1.0000)	0.2819 (0.5282)	0.0375 (0.1053)	0.0363 (0.0966)	0.0305 (0.0884)

Table 6.2

Loon wail samples against different filters (5 sample audio files):

Bobwhite Quail Mating Call	Loon Tremolo	Loon Wail	Pygmy Owl Common Song	Red-tailed Hawk Shriek	Red-tailed Hawk Cry
0.0027 (0.0084)	0.2130 (0.3991)	1.0000 (1.0000)	0.0137 (0.0406)	0.0109 (0.0327)	0.0011 (0.0035)
0.0058 (0.0109)	0.3337 (0.4185)	1.0000 (1.0000)	0.0221 (0.0393)	0.0278 (0.0503)	0.0025 (0.0047)
0.0123 (0.0245)	0.1891 (0.2551)	1.0000 (1.0000)	0.1412 (0.2133)	0.0222 (0.0436)	0.0120 (0.0239)
0.0633 (0.1744)	0.1927 (0.3783)	1.0000 (1.0000)	0.0870 (0.2364)	0.1453 (0.3819)	0.0072 (0.0198)
0.0001 (0.0030)	0.0039 (0.0598)	1.0000 (1.0000)	0.0004 (0.0072)	0.0005 (0.0099)	0.0001 (0.0015)

Table 6.3

Pygmy owl common song samples against different filters (3 sample audio files):

Bobwhite Quail Mating Call	Loon Tremolo	Loon Wail	Pygmy Owl Common Song	Red-tailed Hawk Shriek	Red-tailed Hawk Cry
0.1991 (0.2862)	0.1992 (0.2607)	0.0325 (0.0482)	1.0000 (1.0000)	0.3698 (0.5210)	0.0497 (0.0689)
0.0002 (0.0044)	0.0023 (0.0390)	0.0003 (0.0051)	1.0000 (1.0000)	0.0004 (0.0080)	0.0001 (0.0014)
0.0056 (0.0432)	0.0340 (0.2394)	0.0054 (0.0451)	1.0000 (1.0000)	0.0086 (0.0654)	0.0071 (0.0560)

Table 6.4

Red-tailed hawk shriek samples against different filters (3 sample audio files):

Bobwhite Quail Mating Call	Loon Tremolo	Loon Wail	Pygmy Owl Common Song	Red-tailed Hawk Shriek	Red-tailed Hawk Cry
0.1069 (0.3132)	0.0156 (0.0641)	0.0149 (0.0646)	0.0083 (0.0356)	1.0000 (0.9954)	0.5033 (1.0000)
0.4171 (0.5852)	0.0650 (0.1608)	0.0245 (0.0643)	0.0328 (0.0844)	1.0000 (0.8354)	0.9876 (1.0000)

continued on next page

0.0050 (0.0650)	0.0005 (0.0085)	0.0004 (0.0071)	0.0004 (0.0074)	1.0000 (1.0000)	0.0337 (0.1755)

Table 6.5

Red-tailed cry samples against different filters (2 sample audio files):

Bobwhite Quail Mating Call	Loon Tremolo	Loon Wail	Pygmy Owl Common Song	Red-tailed Hawk Shriek	Red-tailed Hawk Cry
0.0082 (0.0734)	0.0001 (0.0025)	0.0001 (0.0016)	0.0001 (0.0027)	0.0377 (0.2092)	1.0000 (1.0000)
0.0933 (0.3682)	0.0028 (0.0204)	0.0012 (0.0089)	0.0019 (0.0145)	0.4080 (0.5496)	1.0000 (1.0000)

Table 6.6

Chapter 7

Birdcall Identification: Conclusion[1]

7.1 Birdcall Identification Project

7.1.1 Conclusion

The combination of the matched filter process with the frequency content analysis proved to be a fairly robust tool in identifying birdcalls. The matched filter tells us which birdcall is found in the time-domain, while the frequency analysis confirms the proper frequency content at the site of the match.

Our MATLAB GUI implementation gave a simple interface to identify birdcalls within a wave file. The interface gives a visual confidence reading regarding which birdcalls are within a sound sample. With more time, the program could easily be translated to a web application or mobile interface for use in the field.

7.1.2 Future Work

Our implementation was simply a test of concept. If we wished to take the project further, the first step would be to increase the filter library size. If made mobile, we could create a filter library that would mold itself to the species of birds in the specific geographic location, giving our algorithm less to check against.

Though our program can be made faster, the project as a whole was highly successful. Further work needs to be done to ensure the reliability of the program, especially as birdcalls are added. In the end, a venture into a marketing plan could prove to be lucrative.

7.1.3 Acknowledgments :

Special Thanks to:

- Our instructor, Rich Baraniuk
- Our TA, Matthew Moravec
- Our Mentor, Marcos Duarte

Sound files from:

- www.dovehunt.org
- wildspace.ec.gc.ca
- www.michiganloons.org
- www.wildernessbay.com
- www.sylvialake.org
- www.avians.net

[1] This content is available online at <http://cnx.org/content/m18954/1.1/>.

- www.birding.com.br
- www.owling.com

Index of Keywords and Terms

Keywords are listed by the section with that keyword (page numbers are in parentheses). Keywords do not necessarily appear in the text of the page. They are merely associated with that section. *Ex.* apples, § 1.1 (1) **Terms** are referenced by the page they appear on. *Ex.* apples, 1

B Bird, § 2(3)
Birdcall, § 5(13)
birdcall identification, § 1(1), § 7(19)
birdcalls, § 3(5)
birds, § 3(5)

E Elec 301, § 1(1)

F Filter, § 2(3)
filters, § 3(5)

M matched filter, § 3(5), § 5(13)
MATLAB, § 5(13)

S Signal Processing, § 5(13)
signals, § 3(5), § 5(13)
Spectrograph, § 2(3)

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