Marine Mammal Adviser for Test and Evaluation

Presented by:

Kathleen Hodgdon (ARL/PSU)
• Rationale for Perception-based Marine Mammal (MM) Adviser Approach

• For identification of marine mammals at test ranges, current methods rely on:
  – Traditional signal processing methods
  – Expert human listeners

• This approach applies aspects of human perception to classification algorithms.

• Speech production and psychoacoustic-based metrics may afford a classification algorithm that more closely approximates human perception.

• This enhanced algorithm should afford improvements in automated marine mammal classification prior to the conduct of testing at sea ranges.
• Technical Issues to Address
  – Identify optimal configuration for marine mammal vocalizations datasets
  – Identify optimal dynamic range and frequency range to facilitate analysis
  – Obtain recordings of ambient levels at multiple locations
  – Identify novel features and algorithms that enhance detection capabilities
  – Mesh novel and existing algorithms
  – Refine signal detection and classification algorithms and models
  – Implement models to process, detect and identify noise events in archived data

• Potential Novel Processes
  – Speech perception and psychoacoustic based algorithms
  – Linear predictive coding for speech
  – Loudness and level based metrics
  – Modulation metrics
  – Frequency based metrics
Classifier Design Process

- **Traits** are intrinsic properties that might distinguish objects from members of other classes
- **Feature extraction** is the process of characterizing a candidate target as a vector of numerical values
- **Data analysis** extracts information from labeled training data and determines which features/classifiers should be used for classification
- **System evaluation** is the process of testing the overall classification performance; if the performance is unsatisfactory, other properties, features, or classifiers are sought
• Classification feature considerations
  – Features should be intuitive
  – Features should be easy to calculate to support real-time operations
  – Feature dimensionality should be as low as possible
  – Features should be robust to propagation environment
Analysis in the Cochlea and Auditory Cortex

Time Domain Analysis
- Intensity
- Duration
- Amplitude Modulation

Frequency Domain Analysis
- Center Frequency
- Frequency Modulation
- Amplitude-Frequency Interaction
Human Perception of “Electroacoustics”
- Range: 20 Hz to 20 kHz
- Broad Bands:
  - 24 Critical Bands in “Bark”
  - Approx. 100 Hz wide < 500 Hz
  - 20% Center Frequency
- Finer Frequency Resolution
- Intensity Level Analysis
- Duration
- Modulation
  - Amplitude
  - Frequency

---

Fig. 6.18. Excitation level versus critical-band rate versus time pattern of the spoken word “electroacoustics”. The excitation level is indicated for 23 discrete critical-band rates from 1 to 23 Bark

• A literature search was conducted to identify features currently used to classify marine mammals

• The features discussed in published journals were included for consideration in the classification process (Mellinger & Fristrup):
• Time Domain Feature Categories
  – Intensity
  – Duration
  – Amplitude Modulation

• Frequency Domain Feature Categories
  – Center Frequency
  – Frequency Modulation
  – Short-term Bandwidth
  – Aggregate Bandwidth
  – Amplitude-Frequency Interaction
Linear Predictive Coding Features

- Linear Predictive Coding (LPC) is a compression technique used for digital communication.
- LPC was refined based on speech production and fundamentals of human perception.
- Speech analysis is based on formant frequencies and the addition of sibilants or plosives.
- LPC technology is used here to extract features from marine mammal vocalizations.
- For marine vocalizations, the formants can be viewed as fundamental frequencies and the addition of consonants likened to the addition of chirps or clicks.
- The analysis may use the spectral envelope as well as the finer aspects of the signal.
- The envelope and the modulation depth, along with temporal and frequency based features also underlie psychoacoustic algorithms.
Classifier Design: SEPARĀT

• Existing Classification Software
  - Shell Enhanced PAttern Recognition Advanced Toolbox (SEPARĀT)

• MATLAB-based software package developed at ARL
• Interpret signals to assist in decision making
• Statistical characterization of data
• Feature analysis and evaluation
• Rapid design and evaluation of many classifiers
• Decision rule generation
• Error estimation
• Imported marine mammal .WAV files from www.mobysound.org
• Developed basic marine mammal library to train and test classifier
  – Employed hold-out data splitting for testing purposes
  – Entire classes also held out of training to demonstrate no-match capability

<table>
<thead>
<tr>
<th>Blue Whale</th>
<th>Bowhead Whale</th>
<th>Humpback Whale</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Blue Whale" /></td>
<td><img src="image2" alt="Bowhead Whale" /></td>
<td><img src="image3" alt="Humpback Whale" /></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Minke Whale</th>
<th>N. Pacific Right Whale</th>
<th>Southern Right Whale</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image4" alt="Minke Whale" /></td>
<td><img src="image5" alt="N. Pacific Right Whale" /></td>
<td><img src="image6" alt="Southern Right Whale" /></td>
</tr>
</tbody>
</table>

Marine mammal images are part of public domain downloaded from www.wikipedia.com and www.noaa.gov
• Limited datasets available:
  − Used Distinct signals
  − Single vocalization each file

• Full implementation requires:
  − More expansive datasets
  ▪ Varying ambient conditions
  ▪ Different calls per group
  ▪ Different individuals
  ▪ Diverse interactional states
• Marine Mammal Adviser GUI developed by ARL/PSU
• Generate training and testing libraries by loading .WAV files from multiple sources
• Rank sources in test library against classes in training library and report results
### Marine Mammal Adviser (Cont.)

#### Adviser - Ranking Table

<table>
<thead>
<tr>
<th>Unknown Source</th>
<th>Confidence</th>
<th>Best Match From Library</th>
</tr>
</thead>
<tbody>
<tr>
<td>Source1</td>
<td>100</td>
<td>No Match</td>
</tr>
<tr>
<td>Source2</td>
<td>80</td>
<td>BowheadWhale</td>
</tr>
<tr>
<td>Source3</td>
<td>72</td>
<td>HumpbackWhale</td>
</tr>
<tr>
<td>Source4</td>
<td>100</td>
<td>MinkeWhale</td>
</tr>
<tr>
<td>Source5</td>
<td>95</td>
<td>No Match</td>
</tr>
<tr>
<td>Source6</td>
<td>100</td>
<td>No Match</td>
</tr>
</tbody>
</table>

**Options:**
- Weight Editor
- Save
- Close
- Help
• Expansion and Enhancement of Capabilities

- LPC features are used in speech analysis and recognition.
- Psychoacoustic metrics exist that evaluate signals based on aspects of perception.
- Human perception based analysis can be applied to marine mammal vocalizations.
- The Marine Mammal Advisor can separate distinct groups of vocalizations.
• Marine Mammal Adviser

• Speech production and psychoacoustic-based metrics may afford a classification algorithm that more closely approximates human perception.

• The Marine Mammal Adviser can afford improvements in consistent, automated marine mammal classification prior to the conduct of testing at sea ranges.
• Acknowledgements
  – This work was conducted by members of the ARL Special Projects Division’s Pattern Recognition Group.
  – Special thanks to Greg Babich, Nick Mascola, Kathy McClintic, and Cory Smith.