Marine Mammal Adviser for Test and Evaluation

Presented by:

Kathleen Hodgdon (ARL/PSU)

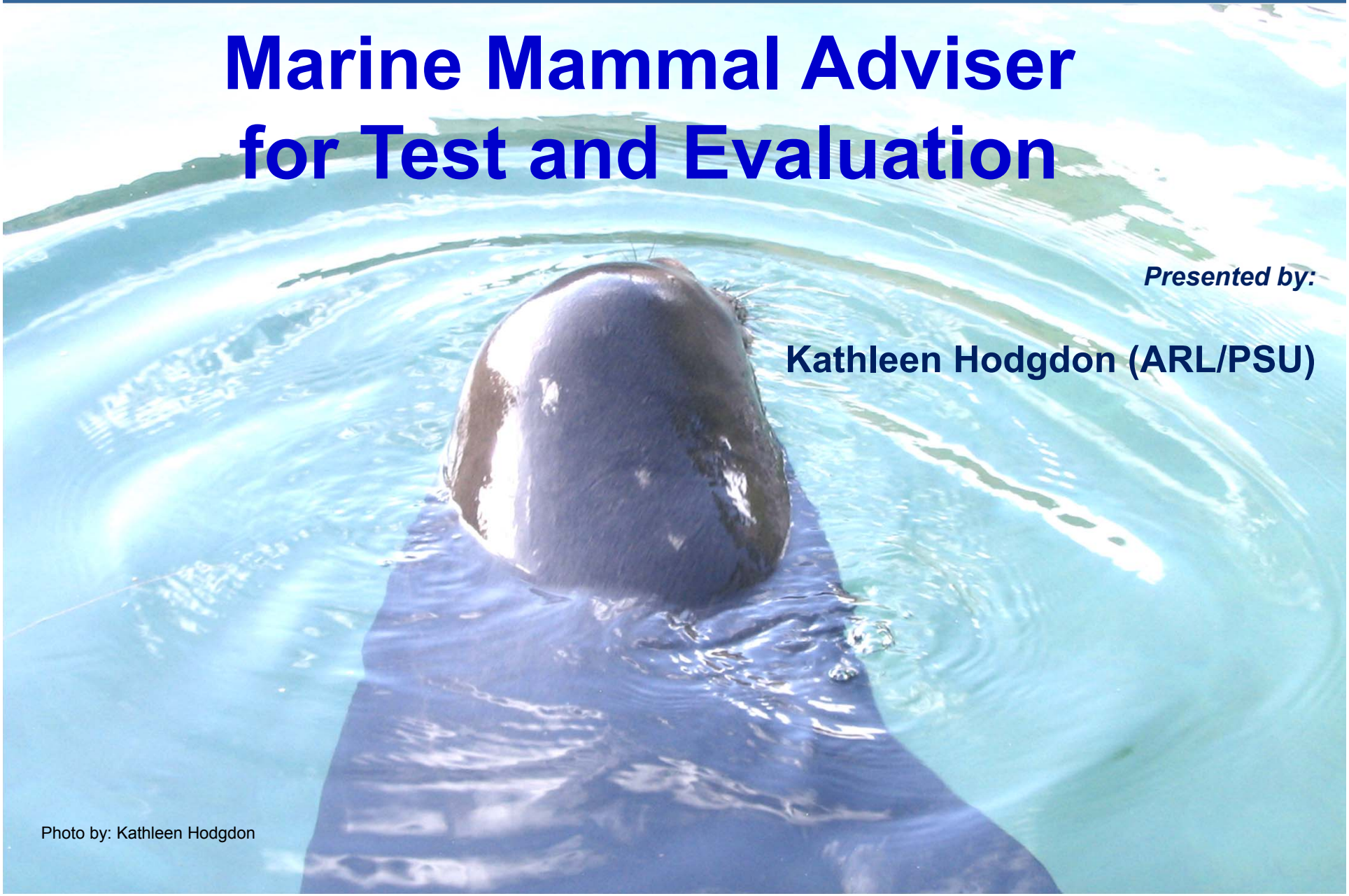


Photo by: Kathleen Hodgdon

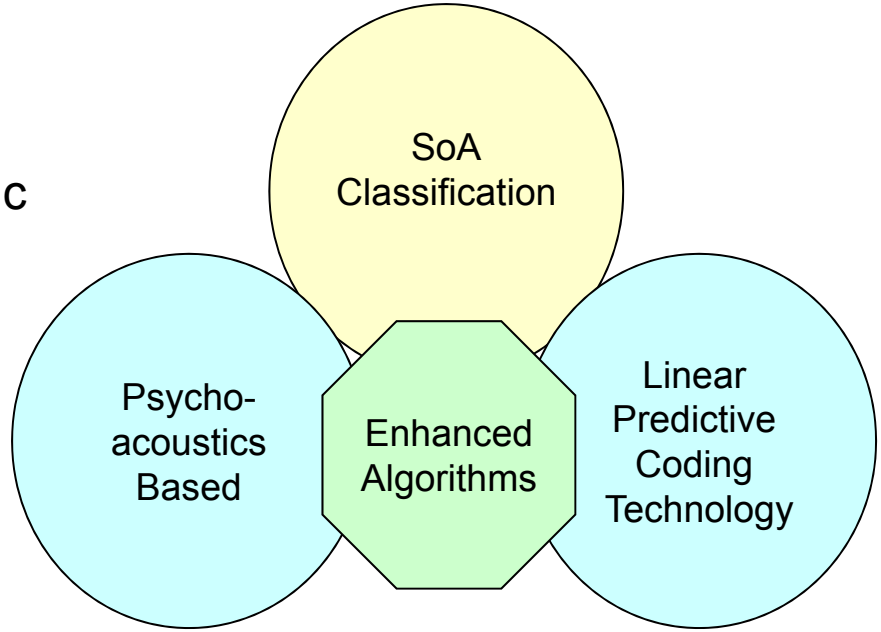
Human Perception-based Approach

- 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.

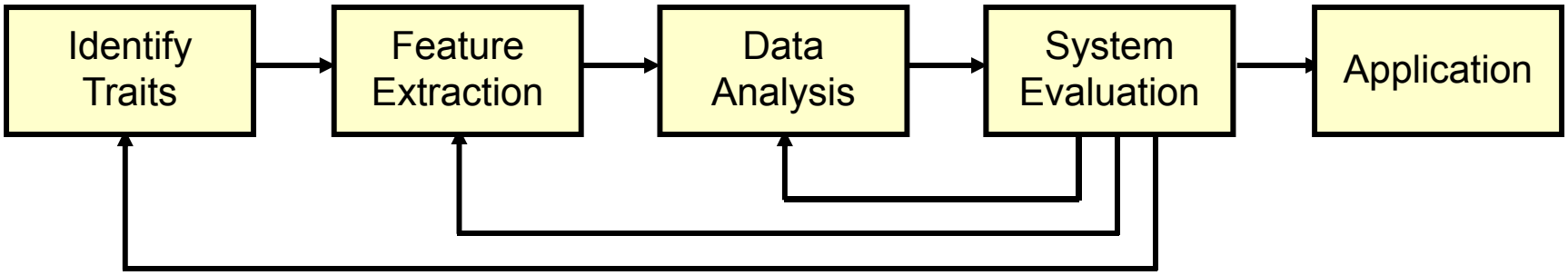
Human Perception-based Approach (Cont.)

- 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 Basics

- 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

Perception Based Features

Analysis in the Cochlea and Auditory Cortex

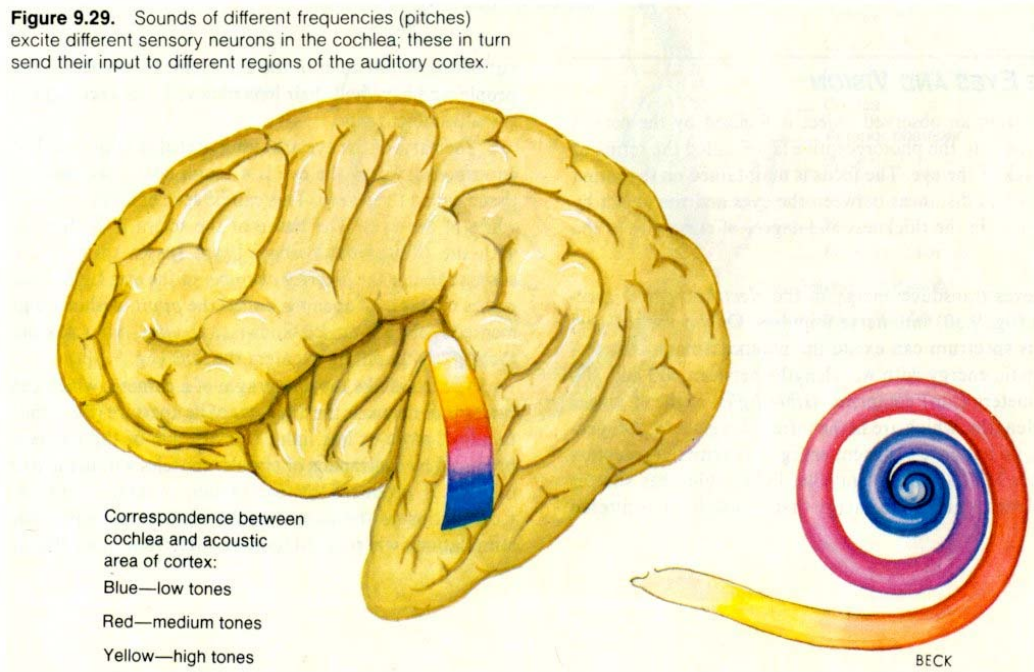
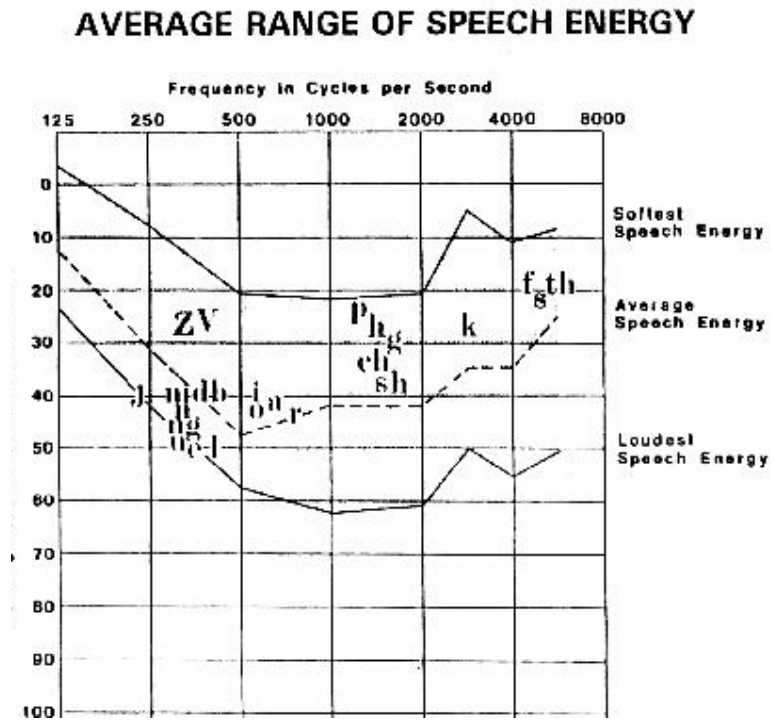


Figure 9.29. Sounds of different frequencies (pitches) excite different sensory neurons in the cochlea; these in turn send their input to different regions of the auditory cortex.

Fox, S. I., Human Physiology, Third Edition, Wm. C. Brown Publishers, Dubuque, IA, 1990.



Northern, J. L., Downs, M. P. Hearing in Children, Williams & Wilkins, Baltimore MD, 1984.

- Time Domain Analysis
  - Intensity
  - Duration
  - Amplitude Modulation

- Frequency Domain Analysis
  - Center Frequency
  - Frequency Modulation
  - Amplitude-Frequency Interaction

Perception Based Features (Cont.)

- 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

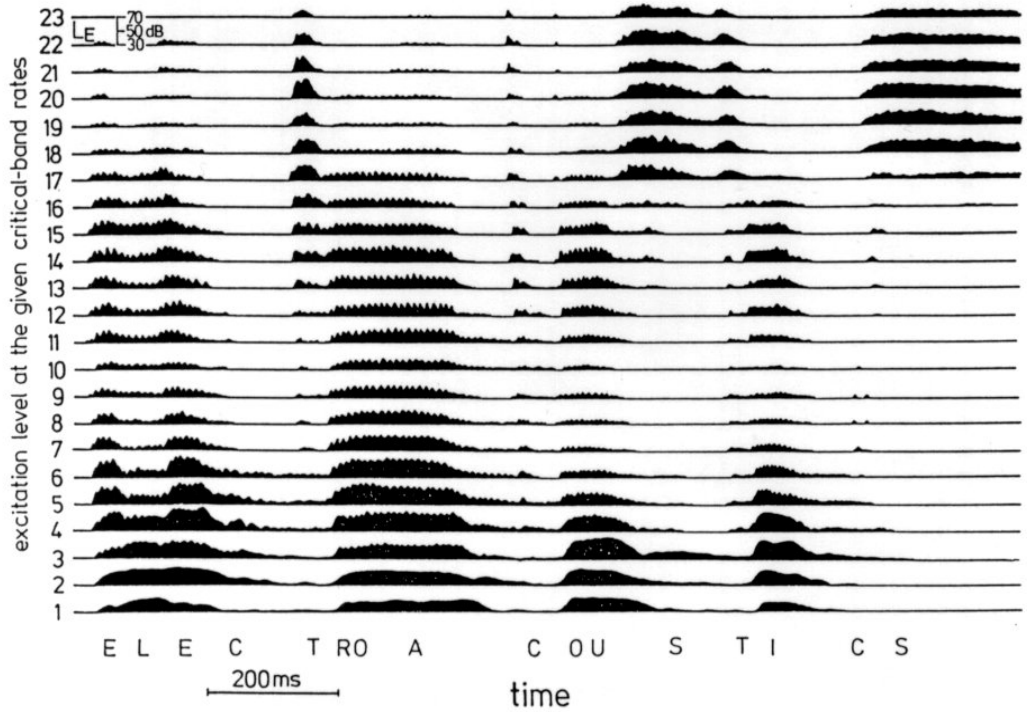


Fig. 6.18. Excitation level versus critical-band rate versus time pattern of the spoken word "electroacoustics". The excitation level is indicated for 23 discrete critical-band rates from 1 to 23 Bark

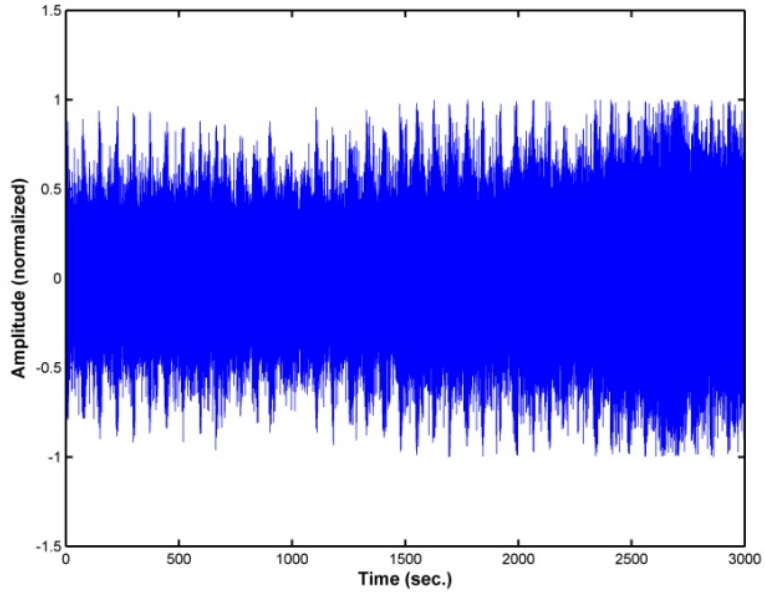
Zwicker, E. , Fastl H., Psychoacoustics: Facts and Models, Springer-Verlag 1999.

State-of-the-Art (SoA) Features

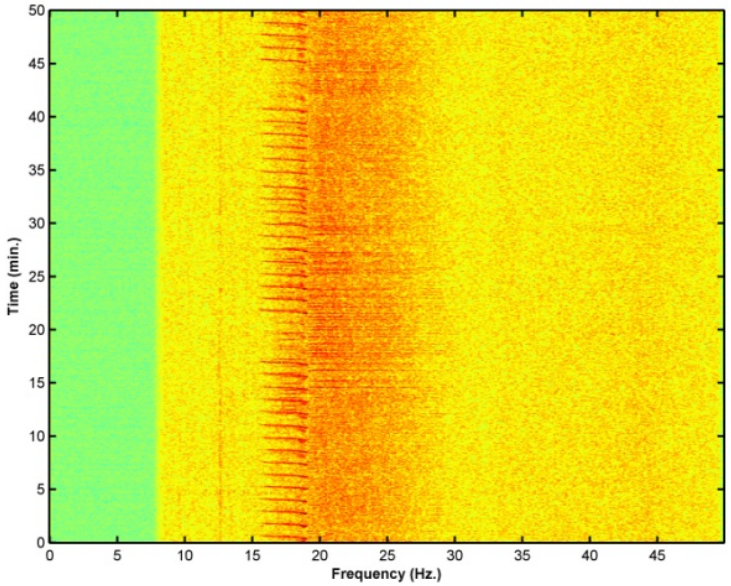
- A literature search was conducted to identify features currently used to classify marine mammals
- The features discussed in published journals were included for consideration in the classification process (Mellinger & Fristrup):
  - Mellinger, D.K., Bradbury, J.W. *Acoustic Measurement of Marine Mammal Sounds in Noisy Environments*. Proc. Second International Conference on Underwater Acoustic Measurements: Technologies and Results. Heraklion, Greece, 25-29 June 2007
  - Fristrup, K.M., Watkins, W.A. *Characterizing Acoustic Features of Marine Animal Sounds* Technical Report WHOI-92-04, Woods Hole

SoA Features (Cont.)

- Time Domain Feature Categories
  - Intensity
  - Duration
  - Amplitude Modulation



- Frequency Domain Feature Categories
  - Center Frequency
  - Frequency Modulation
  - Short-term Bandwidth
  - Aggregate Bandwidth
  - Amplitude-Frequency Interaction



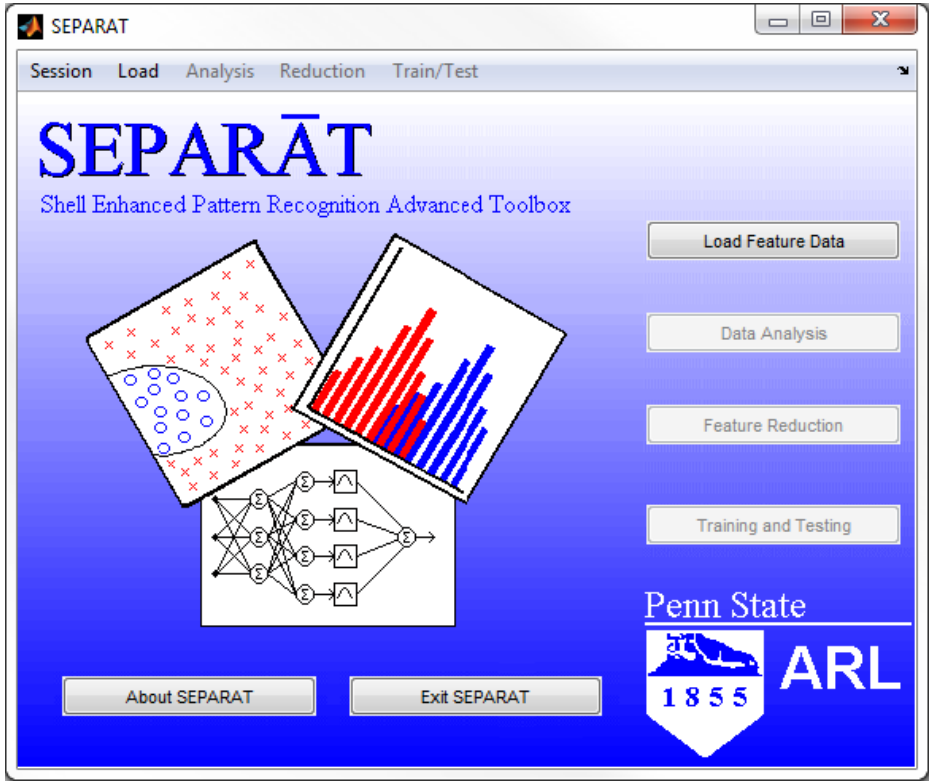
Linear Predictive Coding Features

- 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
  - **S**hell **E**nhanced **PA**ttern **R**ecognition **A**dvanced **T**oolbox (**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



Example Vocalization Dataset

- 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

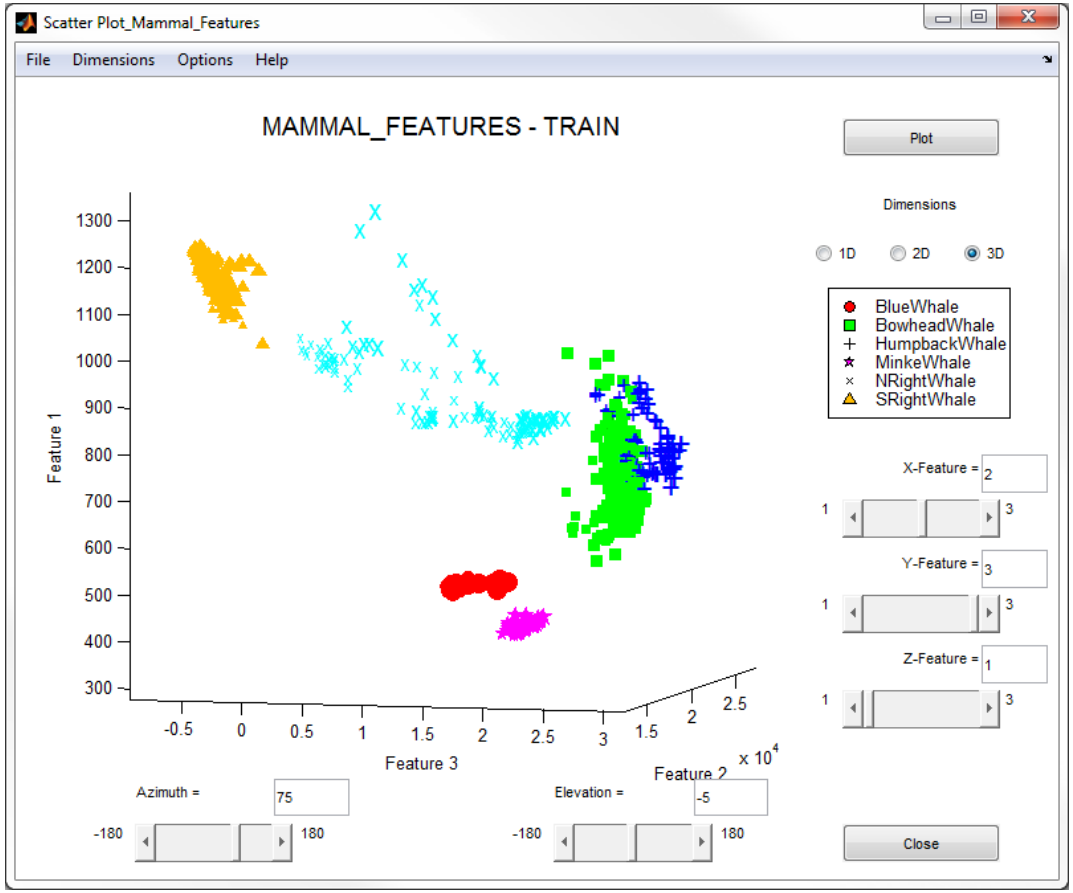
Blue Whale	Bowhead Whale	Humpback Whale
		
Minke Whale	**N. Pacific Right Whale**	**Southern Right Whale**
		

Marine mammal images are part of public domain downloaded from www.wikipedia.com and www.noaa.gov

Psycho-acoustic Feature Analysis

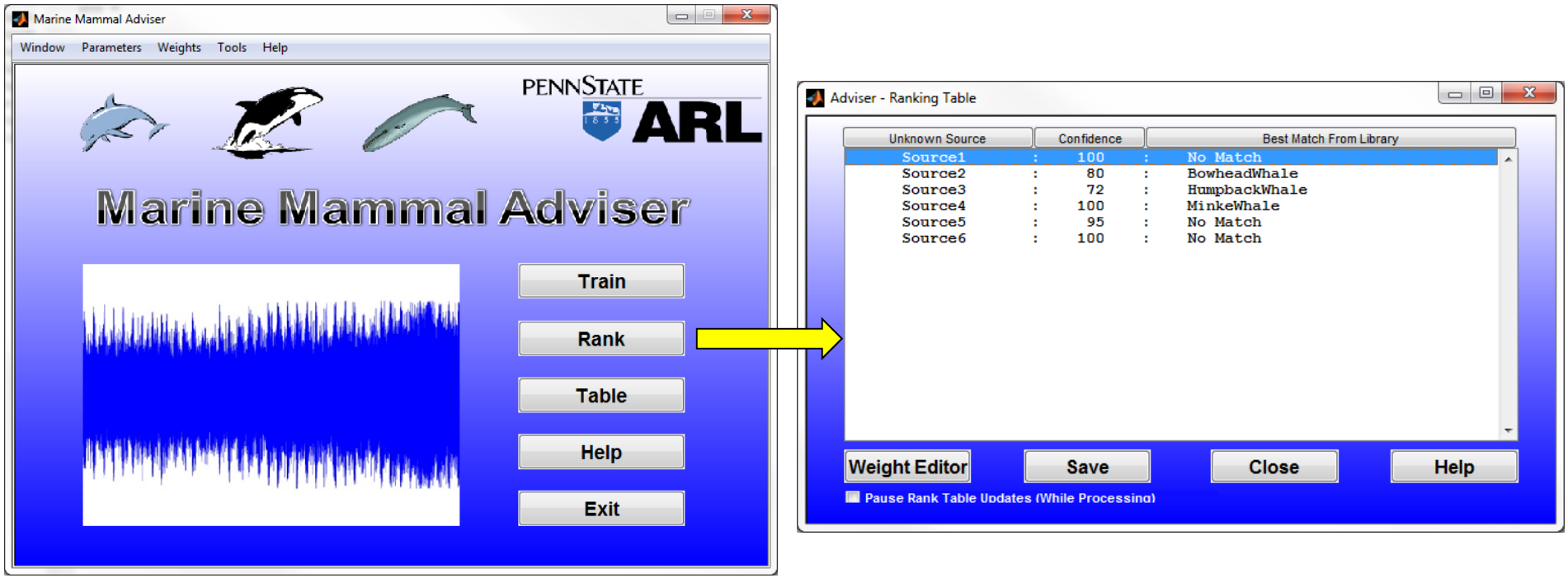
- Limited datasets available:
  - Used Distinct signals
  - Single vocalization each file

- Full implementation requires:
  - More expansive datasets
    - Varying ambient conditions
    - Different calls per group
    - Different individuals
    - Diverse interactional states

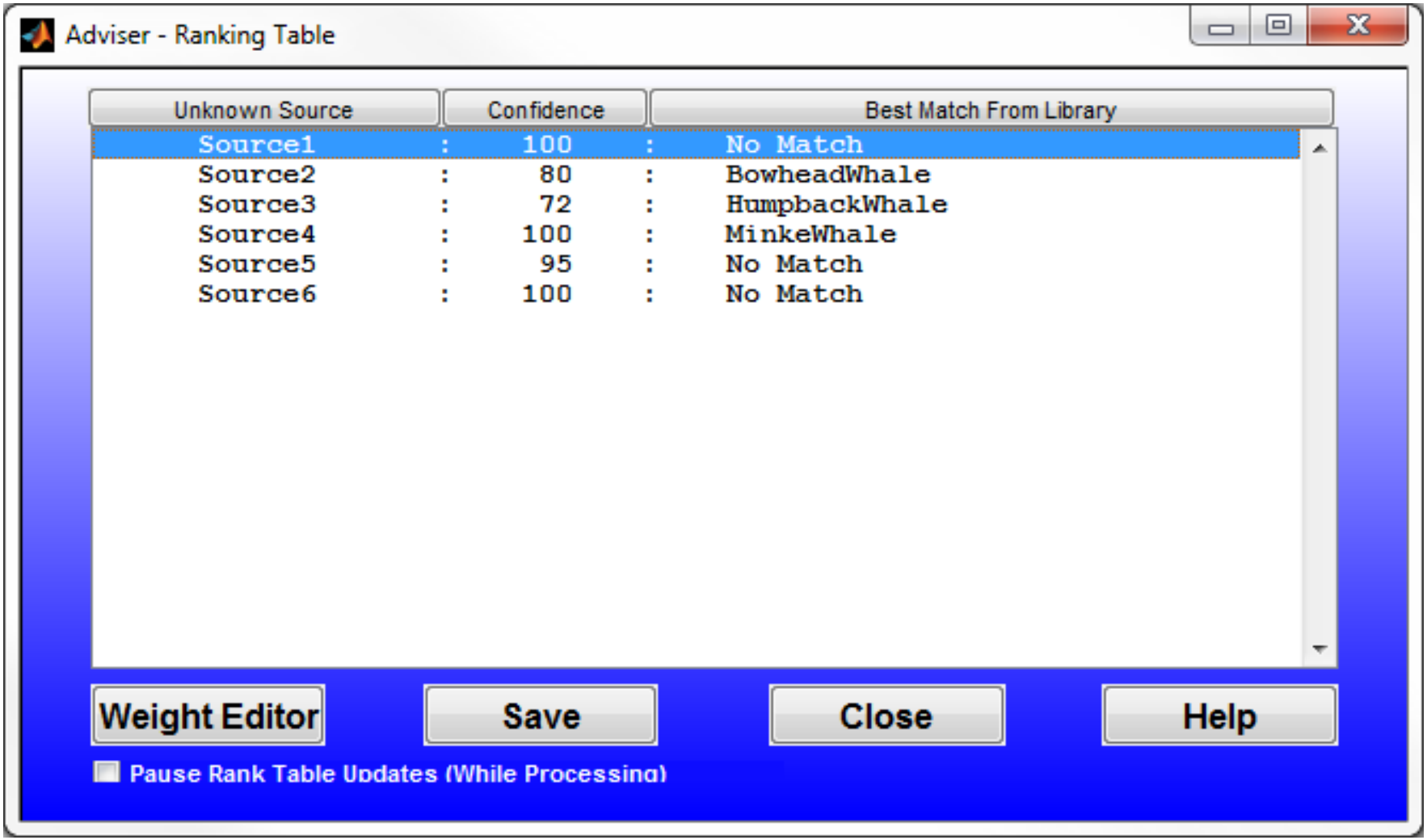


Marine Mammal Adviser

- 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

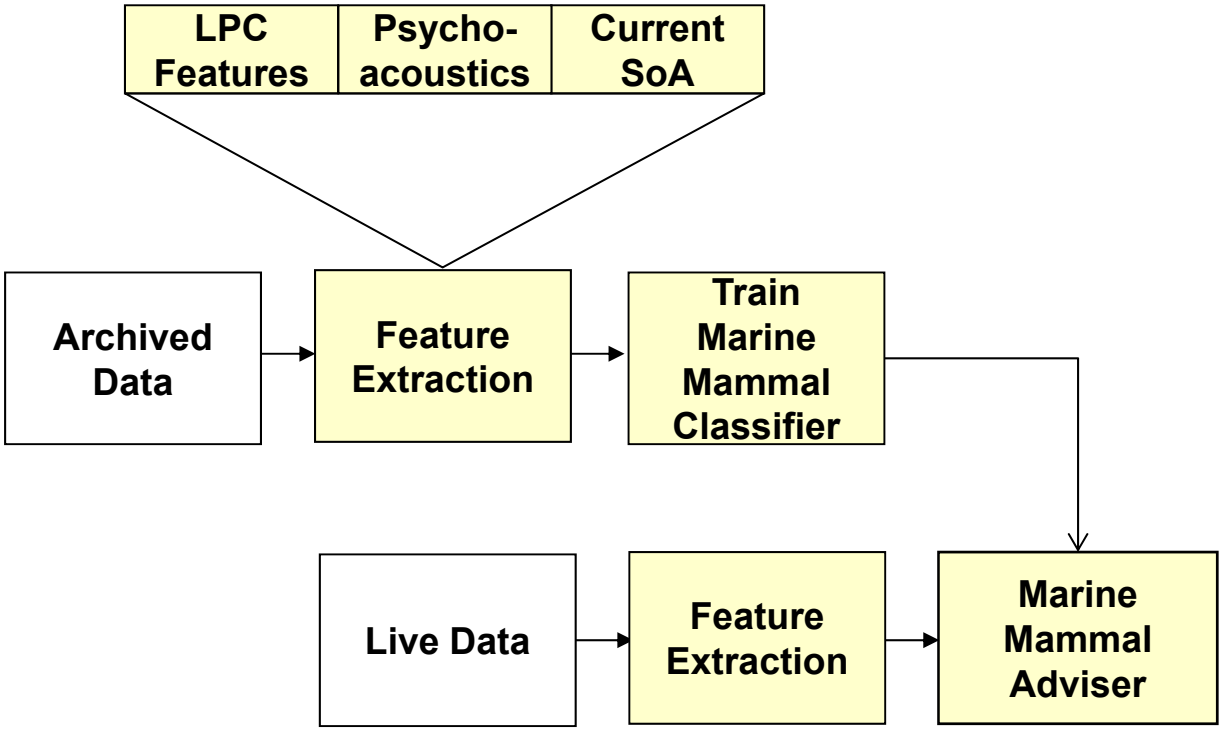


Marine Mammal Adviser (Cont.)



Potential Future Development

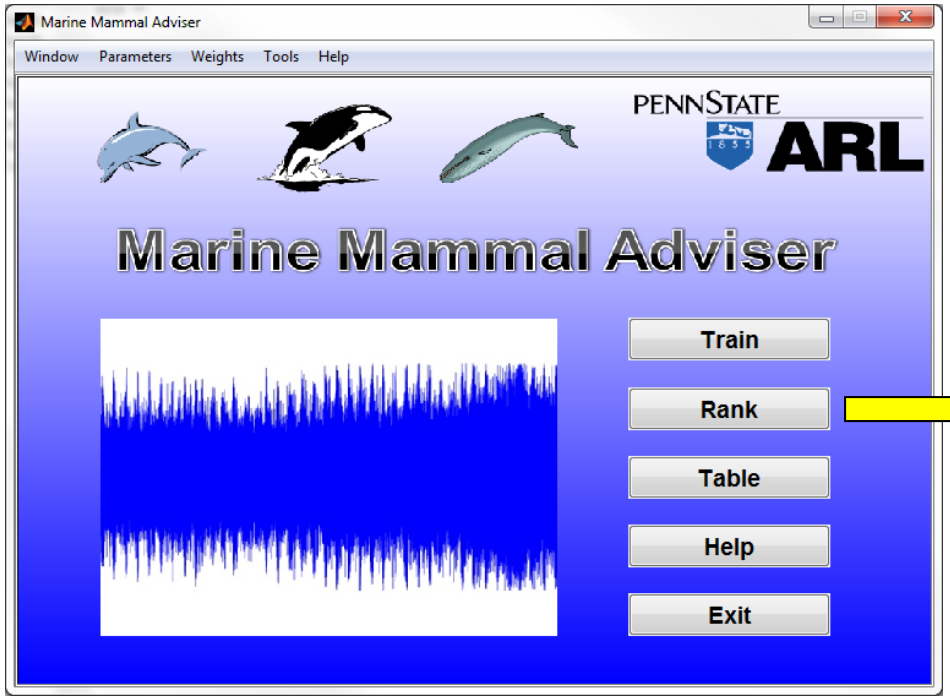
- Expansion and Enhancement of Capabilities

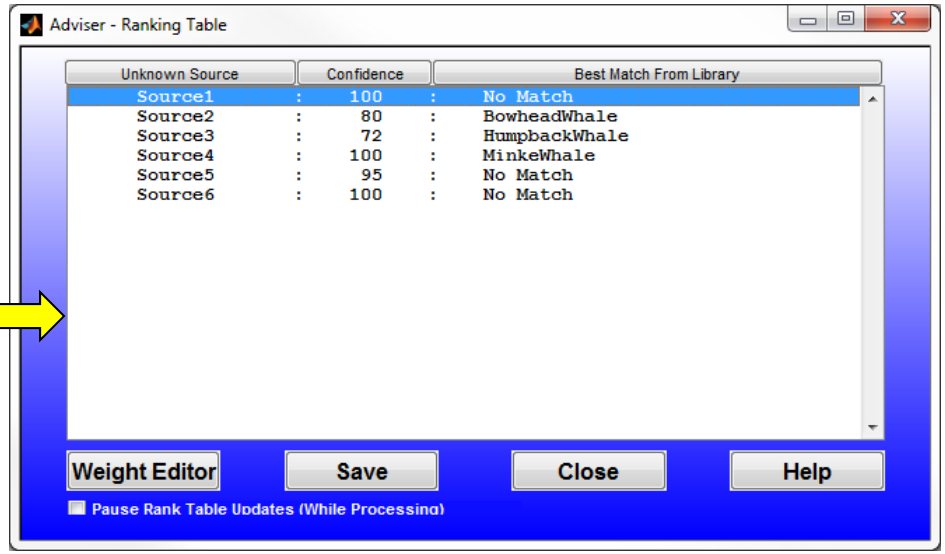


- LPC features are used in speech analysis and recognition.
- Psychoacoustic metrics exist that evaluate signals based on aspects of perception.
- Human perception based analysis can be applied to marine mammal vocalizations.
- The Marine Mammal Advisor can separate distinct groups of vocalizations.

Questions?

- 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.





Thank You!

- 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.