Acoustic Ship Classification

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Maritime Security Domain

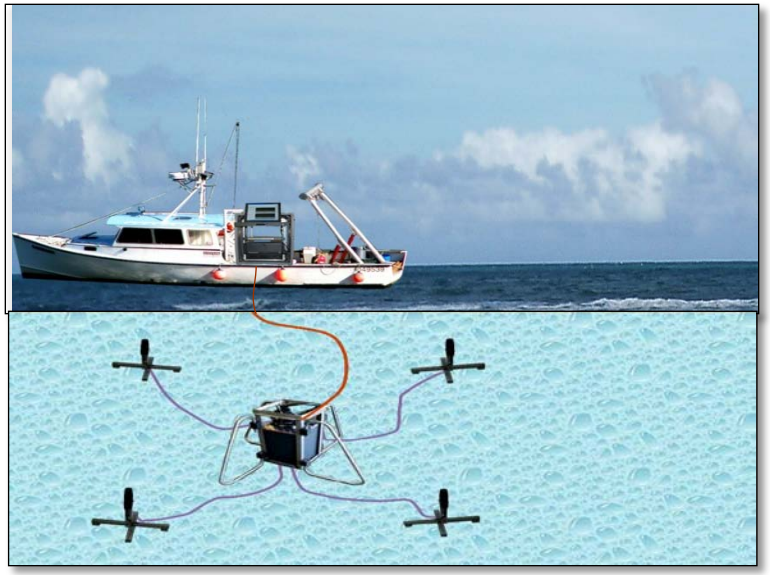
USS Cole bombing in 2000 – Killed 17 US Navy sailors

outline

- *The acoustic system*
- *The acoustic signature processing*
  - *Cross correlation*
  - *Noise modulation*
- *The acoustic signature analysis*
  - *ship classification*
- *The decision making automated algorithm*
  - *Decision Tree*
- *conclusion*

Passive Acoustic system

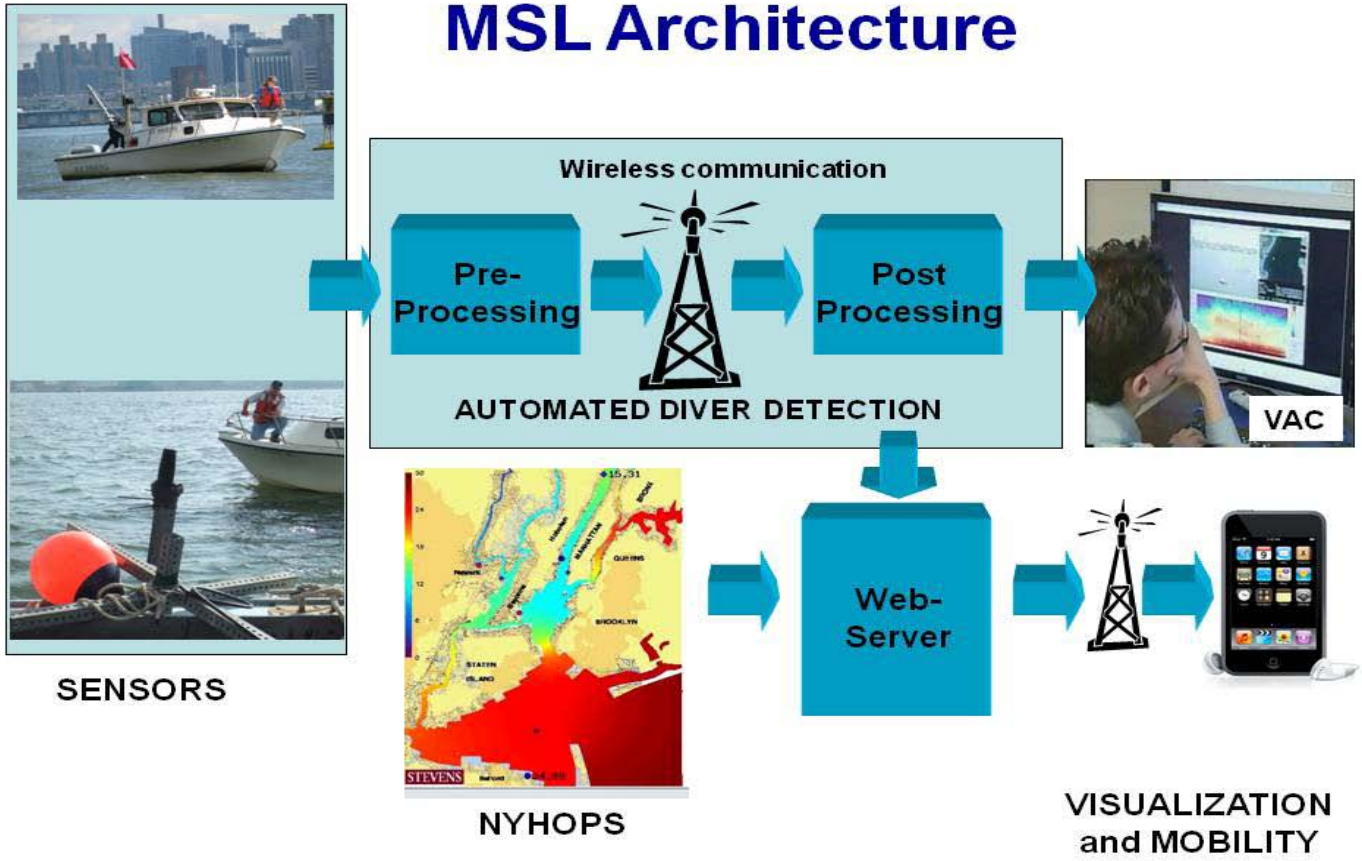
An acoustic system simply listens to its immediate environment



Omni-directional hydrophone

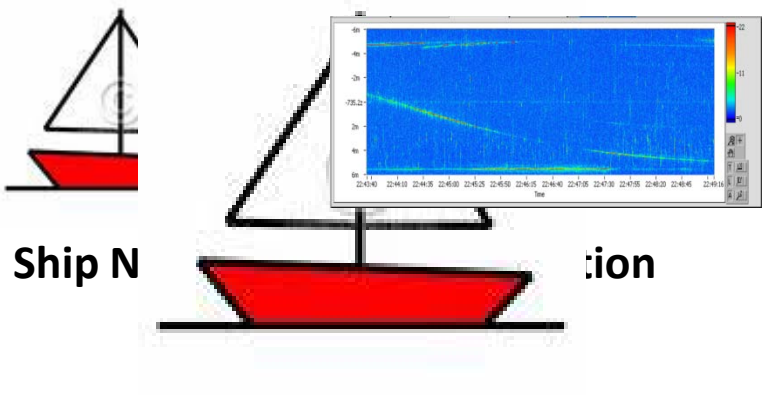
- A pressure sensor designed to sense acoustic pressure
- Equally in every direction

Acoustic Methodology – Maritime Security Lab Architecture



Source: Sutin, A. B., B (2009). Acoustic research for port protection at the Stevens Maritime Security Laboratory. 3rd International Conference and Exhibition on Underwater Acoustic Measurements: Technologies & Results. Nafplion, Greece.

The processing

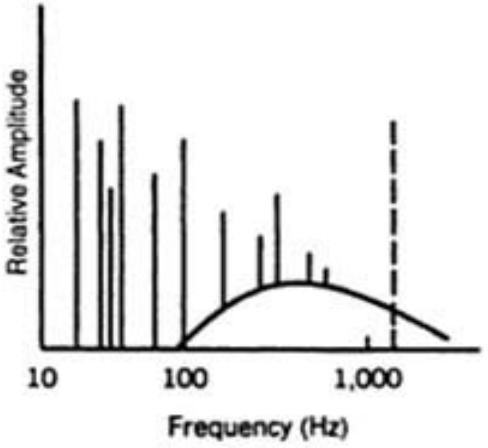


Ship Classification

Automated Decision Making

Ship Noise

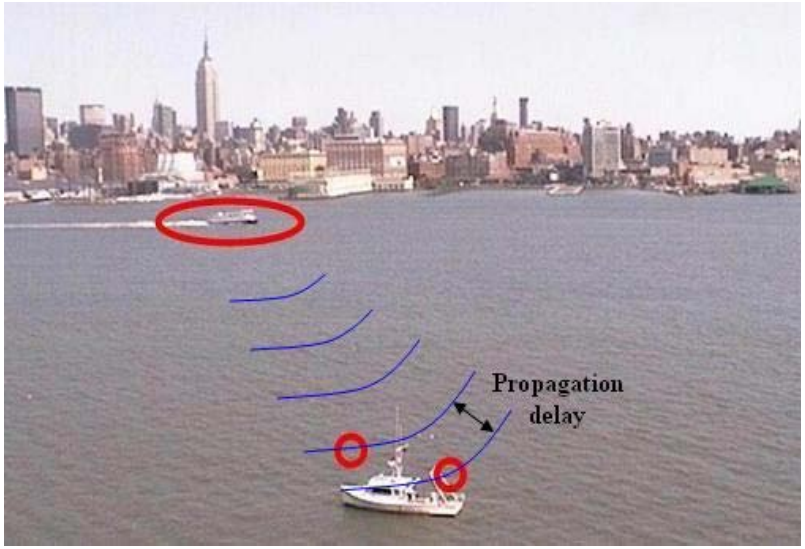
1) mechanical noise of the main engine and auxiliary machine
2) propeller cavitations noise
3) Hydrodynamic noise of the moving vessel.



Ship Detection

Cross-correlation

- The noise radiated by a ship propagates underwater and reaches the hydrophones at different times due to different propagation distances.
- This delay depends on the direction of the ship.



Video: F:\Ship Detection computer Screen.avi

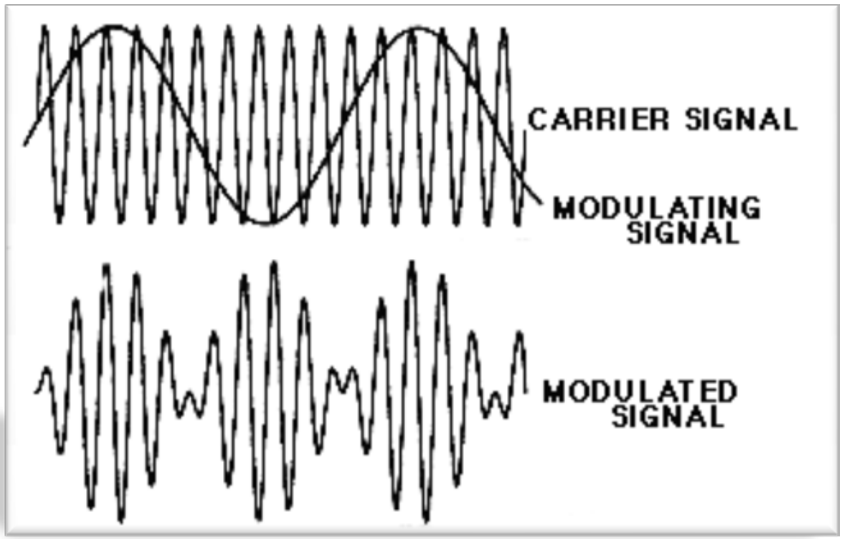
Noise Modulation

Modulation is the process of taking a signal (voice, ship noise etc) and converting it into some aspect of a sine wave. Then transmitting the sine wave leaving the actual signal behind.

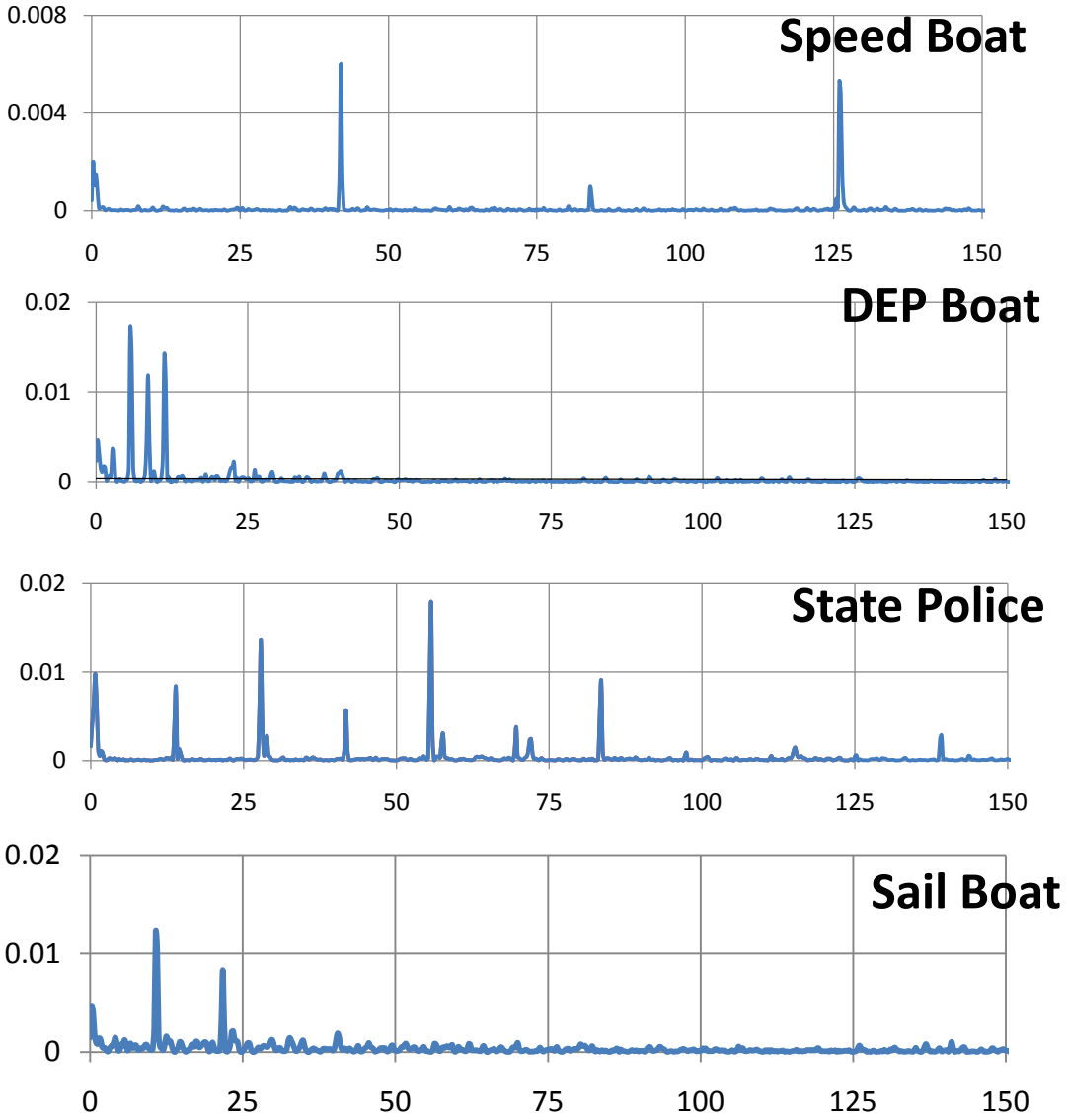
- Ship noise = information signal
- Water = medium
- Sine wave = carrier

Amplitude modulation:

We allow the amplitude of the carrier to change in respond to the information signal But everything else is kept fixed!



SHIP CLASSIFICATION – final signatures

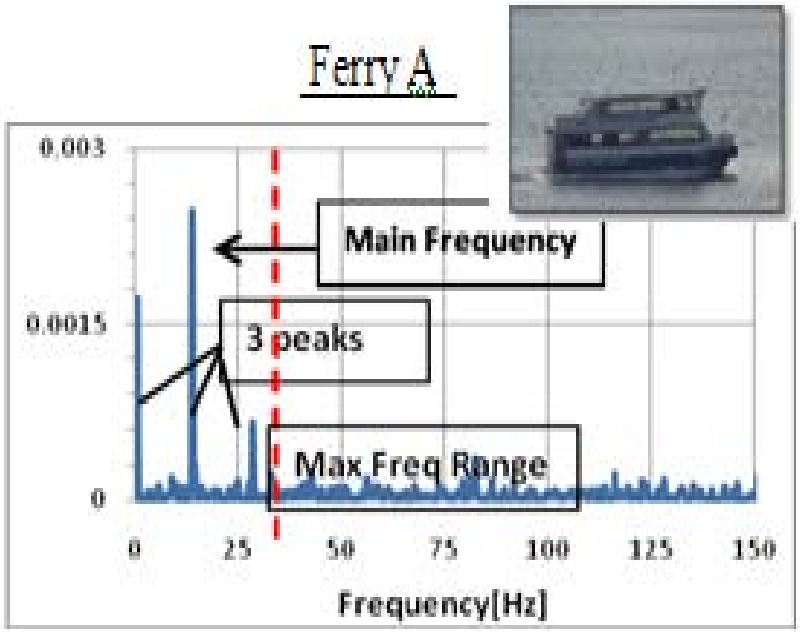


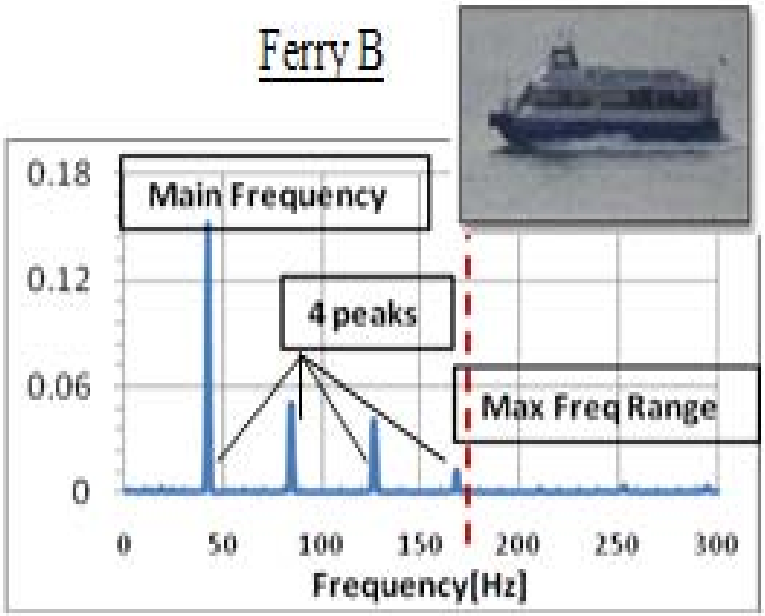
Ship Classification-Using Attributes

- The general process of classification is placing individual vessels into groups labels based on quantitative information of its attributes.
- Attributes are: well described categories that are usually denoted by a numerical or alphabetic code.

Attributes	Attributes subpopulations
Number of Peaks	2-3 peaks
	4 peaks
	other
Main Frequency	10-14 Hz
	41-46 Hz
	Other
Maximum Frequency	14-41 Hz
	Above 130 Hz
	Other
Amplitude Ratio	2-4
	other

Ferries on the Hudson River





Type	# peaks	Main Freq	Max Frequency range	Amp Ratio first/sec
Ferry_A	3	~11Hz	20-40 Hz	2<x<4
Ferry_B	4	~41 Hz	<130 Hz	2≤x≤4

Classification algorithms

- Objective: automate the process of searching for patterns in the data

- The data set consists of information x and y for each vessel.
  ***X*-** denotes a vector of each attribute
  - denotes the group label (ferry, not ferry, speed boat etc).
  ϕ-a rule used to evaluate all ***x***, that will then declare a range $\hat{y}_j$ that is as close as possible to the real y_j (group label).

- It is the responsibility of the classification algorithm to approximate as closely as possible to the true group labels Such that:

$$\hat{y}_j = \Phi(\mathbf{x}_j) \approx y_j$$

Decision Tree algorithm

The process: At each node the algorithm chooses one attribute of the data that most effectively splits its set of samples into subsets.

↓

By measure of homogeneity of the data

↓

Entropy

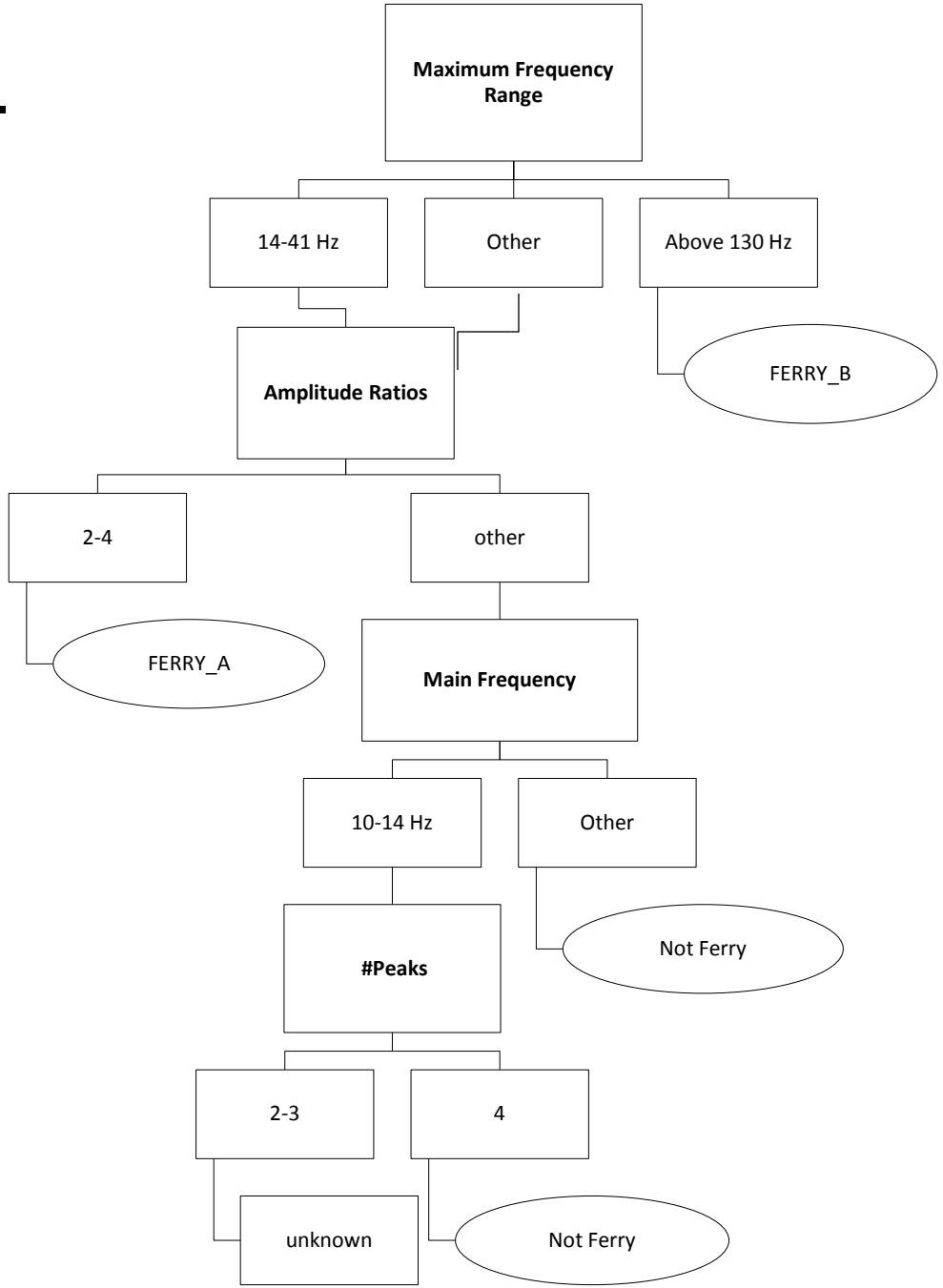
Information Gain [using entropy]

Information Gain =	Entropy of parent table	–	Sum (entropy of each subset Si)

Entropy= $\sum$-Pj $\log_2$Pj

Probability= (# positive instances)/(# total instances)

Final Decision Tree



Conclusion

This case study has demonstrated the effectiveness of utilizing DEMON acoustic signatures for boat identification. Attributes for classification were extracted from the boat signatures and the simplified decision tree was built. Future work is needed in maintaining a catalog for acoustic signatures; developing a library of few hundred boats signatures will allow for more accurate classification of vessels.

Acknowledgment

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Questions?