





Presentation to Kasher Contest Committee

Detection of Unknown Ship Radars

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In collaboration with: RAFAEL



Background

- Many ships transmit radar signal as the sail across ports
- Ships identification ability is important





Radar

- A detection system which uses radio waves for:
 - Navigation
 - Tracking Objects & Threats



- Each radar transmitter has its own special characteristics:
 - Frequency & Pulse Width
 - Non-linear effects

Open World Recognition





Open World Recognition – Applications

• A challenging open task in Machine Learning

Computer Vision

Natural Language Processing







Quality Measures

- False positive (FP) = known ship labeled as unknown
- True positive (TP) = unknown ship labeled as unknown

Low FP is more important than high TP



Project Goal

Online recognition of known and unknown ships





Dataset

- 500,000 radar signals from 76 ships (classes)
- Real data received from Rafael





Dataset



SIPL SIBAL AND IMAGE PROCESSING LAB

Prior Work

- **Classification** using deep learning (ResNet-18)
 - Net inputs Spectrograms
 - 89.8% accuracy



samples

Rejection algorithm based on Deep Open Classification (DOC):
TP = 66%, FP = 35%

Not a full Open-World solution





- Open-world recognition and learning of unknown ships



Closed World Classification





Pre-processing – Bispectrum

- 2nd order autocorrelation of the DFT
- Emphasizes 2nd order non-linear properties
- Example applications:
 - Distinguishing between musical instruments
 - EEG signals monitoring







Pre-processing – Bispectrum

$$B(k_1, k_2) = X^f(k_1) X^f(k_2) \overline{X^f(k_1 + k_2)}$$





Dimensionality Reduction

• K_1, K_2 plane reduced to one dimension





time [samples]

[Hao et al., 2020]



Network Inputs

Merged 4 channels: Spectrogram + Bispectrum





Datasets – Closed World

- Dataset #1 'Standard'
 - 40 training classes

- Dataset #2 'Hard-To-Separate'
 - 10 training classes
 - Classes share same classic features





Results – Closed World

Input Type	Standard Dataset	Hard-to- Separate Dataset
Spectrogram	89.8%	72.9%
Bispectrum + Spectrogram	90.1%	75.5%



Rejection Algorithm





Rejection – Proposed Solution

- Previous project (DOC) algorithm:
 - -Set reject threshold for each class **separately**

- Our solution's main idea:
 - -Use all neural network output combined
 - -Anomaly detection to recognize unknown ships





Anomaly Detection – Based on k-NN

• For each training sample:

Calculate mean distance from k-nearest neighbors

• Threshold = top X% of mean distances





Anomaly Detection – Based on k-NN

• For each test set sample:

Calculate mean distance from k-neighbors from the train set

mean dist > *threshold* \Rightarrow **Unknown**, Else \Rightarrow **Known**





Rejection – Results and Conclusions



- Significantly improved results compared to DOC
- Controllable FP rate



Open World Recognition





Open World Recognition

• Main idea:

Use neural network output vector to cluster unknown samples





Number of Clusters

Used 3 techniques for determining the number of clusters:

- Elbow Method
- Silhouette Analysis
- Davies-Bouldin index

• Choose k by majority vote



Results - Realistic Simulation





Realistic Simulation – Assumptions

- Radar receiver is directional
- We continuously receive signals from the same ship
- Batch size = 100 samples
- Batch is unknown if: *#rejected samples > const*(= 65)





Known Class #1

Successful known detection:

Rejected Data:





Unknown Class #1

Successful unknown detection: Successful clustering (1 class):







Unknown Class #1

Successful unknown detection: Successful clustering (1 class):







Unknown Class #2

Successful unknown detection: Successful clustering (2 classes):







Unknown Class #3

Successful unknown detection: Successful clustering (3 classes):





Unknown Class #4

Successful unknown detection: Successful clustering (4 classes):







Known Class #2

Successful known detection:



Successful clustering (4 classes):



Conclusion

- Improved Closed World Classification
- New and better Rejection using anomaly detection
- Novel Online Learning based on clustering





- Open-world recognition for ship radar data
 - Generic solution, suitable for many applications



Thanks!





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Questions?



References

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