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Open World Recognition Of Ship Radars

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Introduction

- Protecting the security of a maritime area is an important defensive activity.
- Many ships have radar transmitters, with a typical signature.
- This radar can be identified for protection against hostile ships.

Goals

- Classify ships by their radar transmitted signals, using Rafael's dataset.
- Detect unknown ships not in the training dataset.
- Cognize the new ships and add them to the dataset.

Challenges

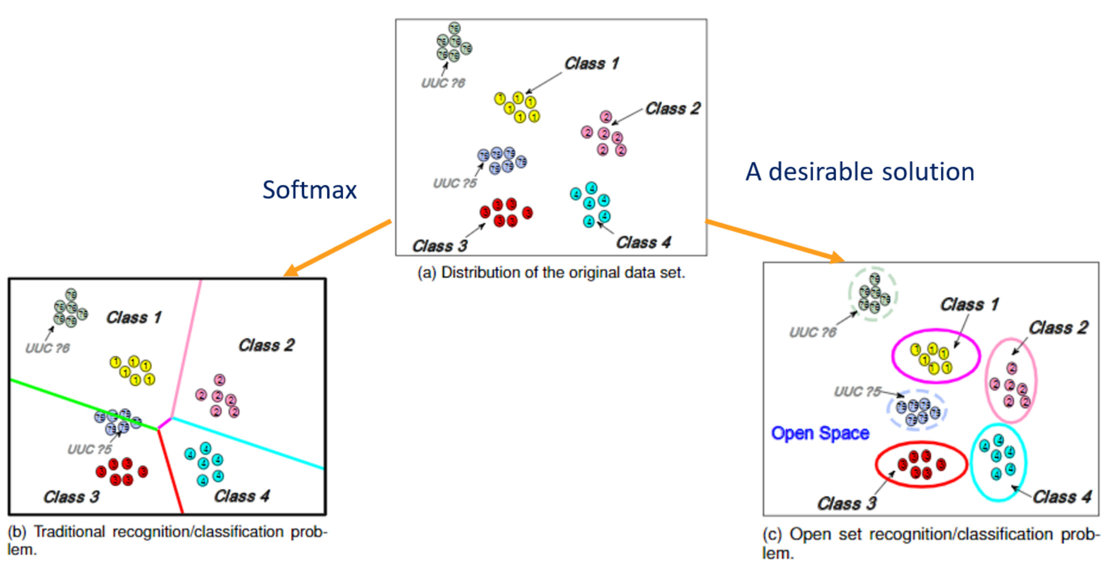
- Many ships have a similar radar signal and only a typical fingerprint distinguishes between them.
- Representing the data efficiently.
- The problem of detecting and cognizing unknown classes is at the forefront of research.

Problem Definition

(Chuanxing Geng et al., 2020)

Task	training	Testing	Goal
Traditional classification	Known known classes	Known known classes	Classifying known known classes
Open Set Recognition (Out Of Distribution Detection)	Known known classes	Known known classes &unknown unknown classes	Identifying known known classes &rejecting unknown unknown classes
Generalized Open Set Recognition (Open World Recognition)	Known known classes &side-information	Known known classes &Unknown unknown classes	Identifying known known classes & cognizing unknown unknown classes

- Regular deep learning neural networks can only classify a limited number of classes, because of their Softmax layer.



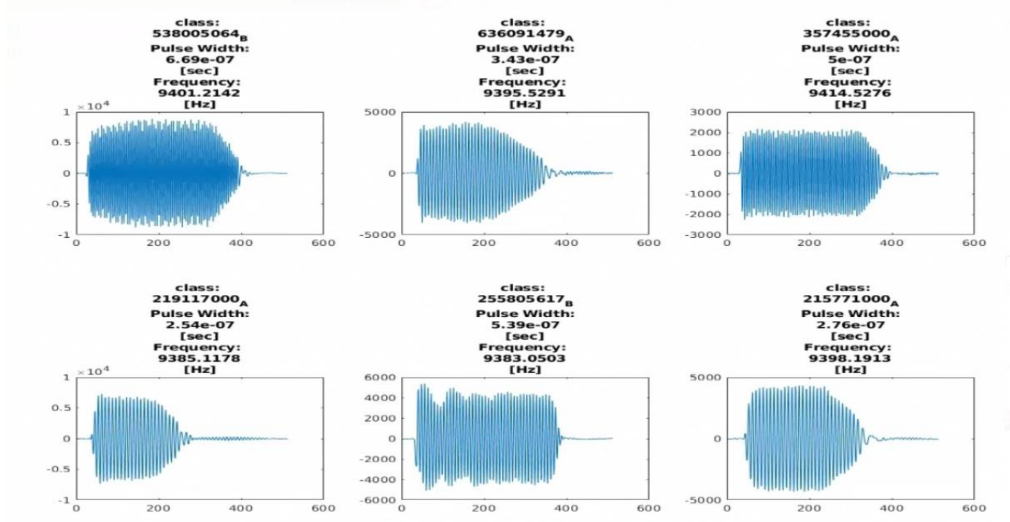
(a) Distribution of the original data set.

(b) Traditional recognition/classification problem.

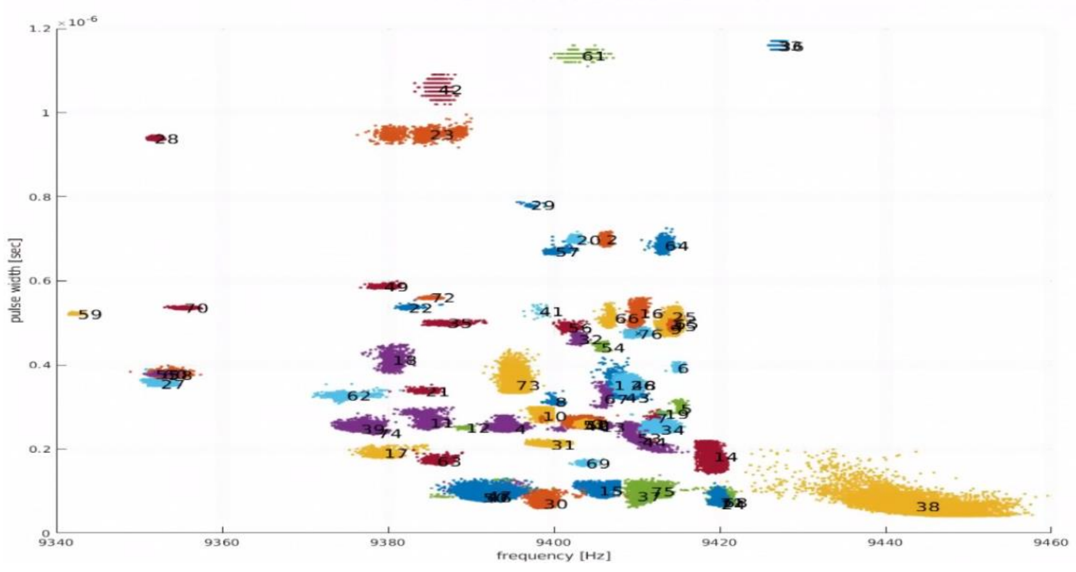
(c) Open set recognition/classification problem.

Data Pre-Processing

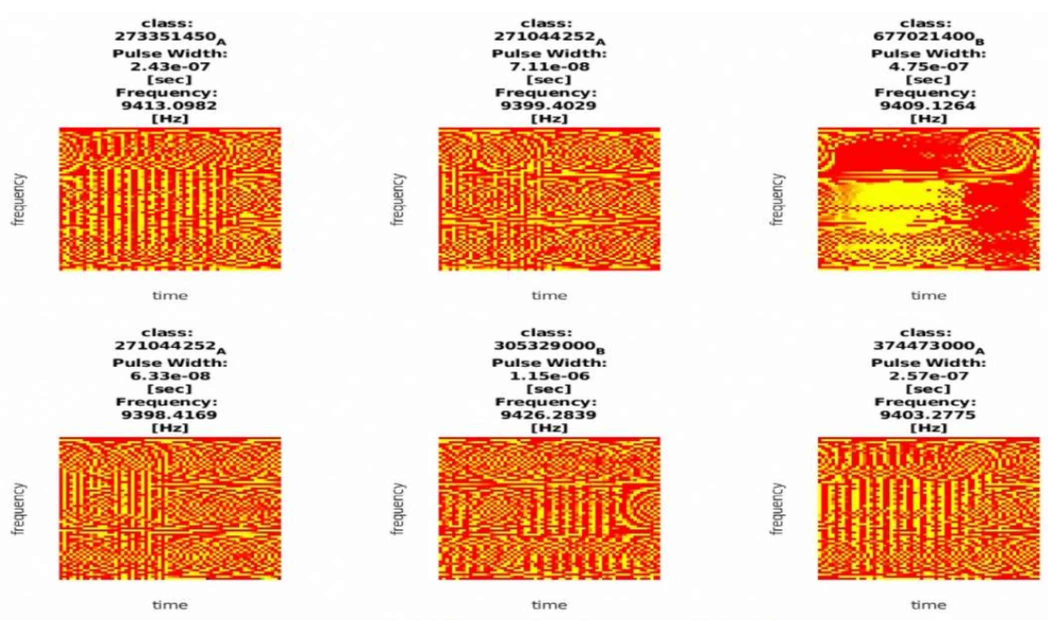
- Our dataset includes tagged radar signals:



- Classes frequency and pulse-width:

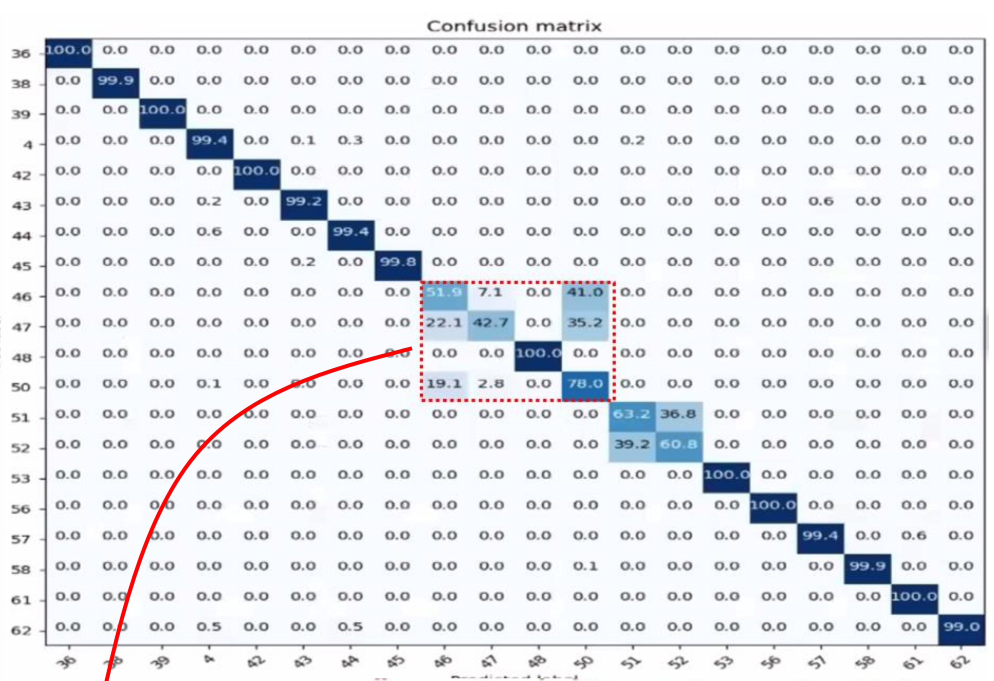


- Transforming to spectrogram images (R = phase, G = amplitude, B = 0):

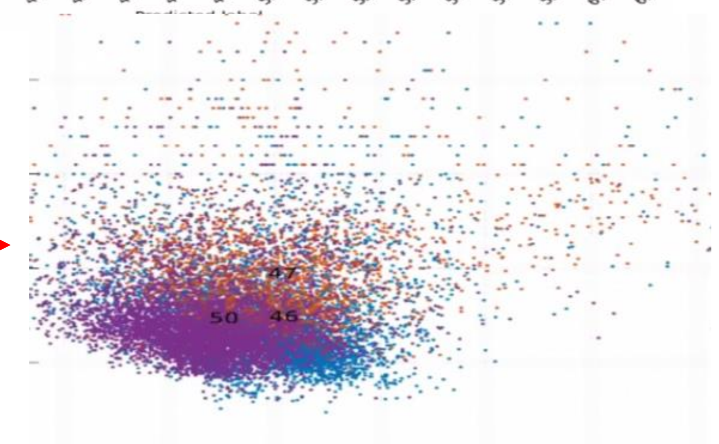


Traditional Classification

- Classify between only known classes.
- Using ResNet architecture.
- Good results: 91% accuracy!



Difficulty in separating classes with overlap in frequency and pulse width



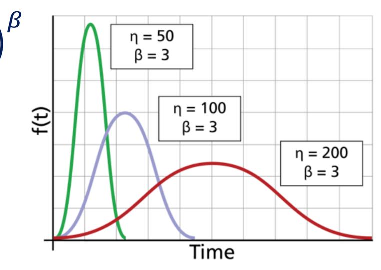
Open Set Recognition

- Detect "unknown" signals that were not part of the original dataset.
- Three possible solutions:

1. **Naïve solution**
   - Set a threshold on Softmax layer probabilities.
   - If the maximal probability is below the threshold, predict "unknown".
   - Too simple.
   - Difficult to adjust the threshold.
2. **Openmax** (Abhijit & Boult, 2016)
   - Extract the last fully-connected output for each signal and use it as a feature vector.
   - Fit a Weibull distribution of the feature vectors for each class:

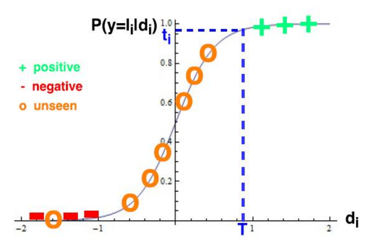
$$f_{weibull}(x)=\frac{\beta}{\eta}\left(\frac{x-\gamma}{\eta}\right)^{\beta-1} * e^{-\left(\frac{x-\gamma}{\eta}\right)^{\beta}}$$

β – shape
η – scale
γ – location



   - Calculate the probability to belong to the distribution of each class.
   - Predict "known" or "unknown" according to the probability.
3. **DOC** (Lei Shu et al., 2017)
   - Train a network with a sigmoid layer as output and fit a distribution with standard deviation σ_i for every class.
   - Use a threshold and a hyper-parameter α:

$$t_i = max(0.5, 1 - \alpha * \sigma_i)$$



   - And the prediction is:

$$\hat{y} = \begin{cases} reject, & sigmoid\left(fc[i]\right) < t_i, \forall i \\ argmax\left(sigmoid\left(fc[i]\right)\right), & else \end{cases}$$

Results

Method	Accuracy known	Accuracy unknown
Naïve solution	87%	57%
Openmax with threshold	91%	56%
DOC	90%	66%

Conclusions

- We implemented ship radar signal classification in an open set configuration.
- Improved results compared with a naïve solution.
- Future work: open world configuration.

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