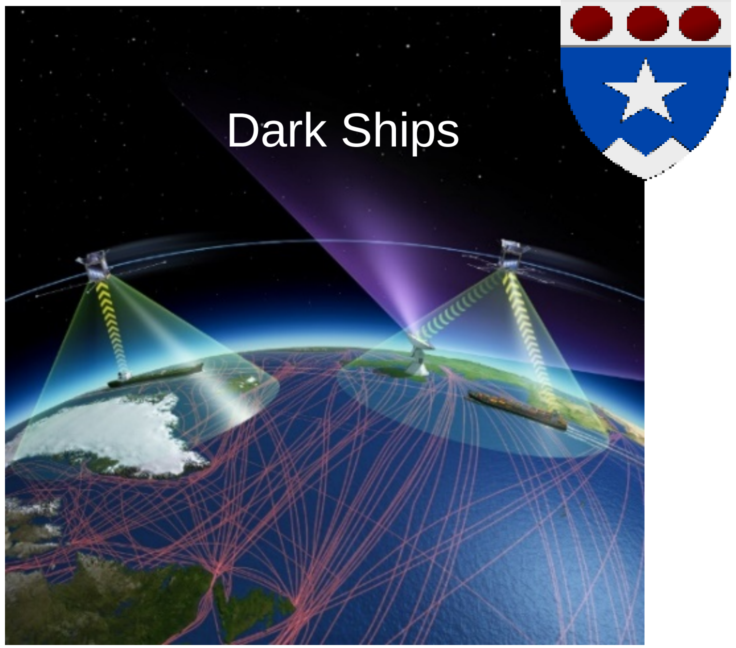
Ship-ID: Identification of dark ships from satellites

on behalf of Peder Heiselberg, DTU Space



We can detect and classify ships
and distinguish from icebergs, skerries, etc.

Q: How do we identify (ID) dark ships?

A: By face recognition or fingerprint algorithms

Method: build databases and use AI

Dark ship ID - examples

Easy: large ships with a dark background are easy to label correctly.

Difficult: Small white ships with a bright background are hard to distinguish from i.e., sea, clouds, and large wakes.

H.B. Pedersen et al., *Ship-ID in Sentinel-2 MSI using deep neural networks*, proc. Am. Graph.Soc. meeting, Chicago, dec. 2022. And in progress.

Ship-ID method

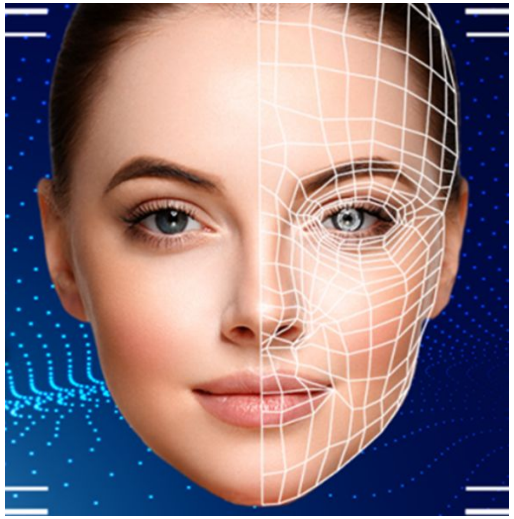
1. Build SHIP-ID database from satellite images, AIS and other available data sources

    - starting with Sentinel-2 images of 4200 (different) ships around DK

    - several images of each for variation (22000 in total)

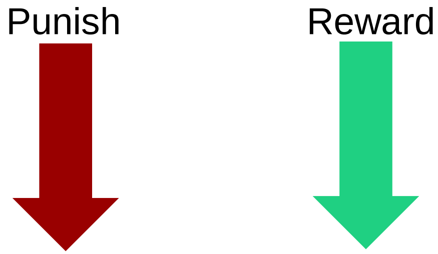
    - 13 multispectral bands w. down to 10m resolution

2. Develope AI algorithms for optimal ID and discrimination of dark ships
3. Methods like face recognition or fingerprints



Algorithm training

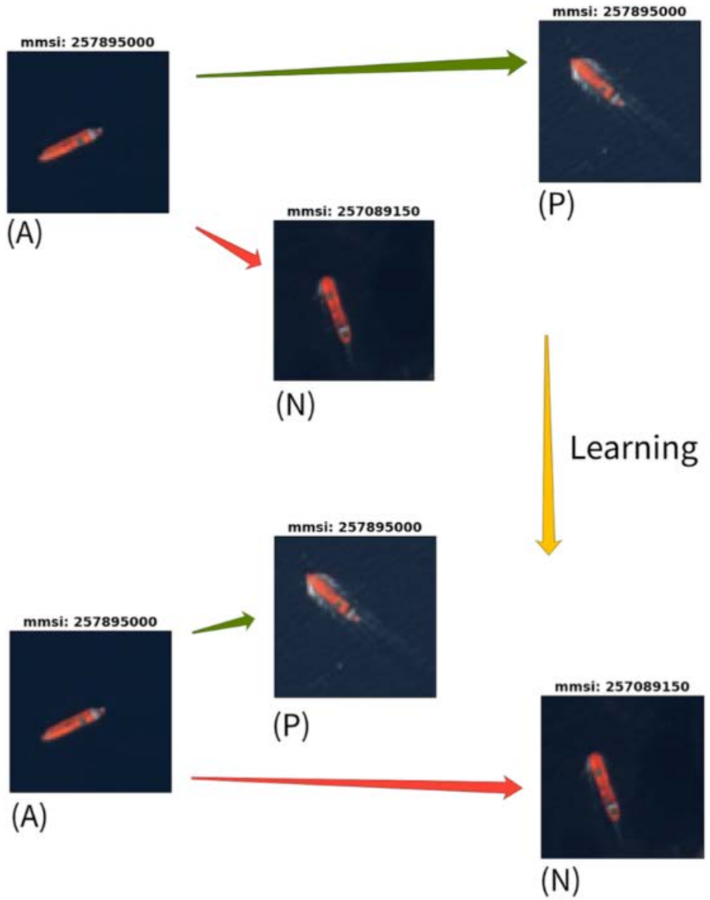
Triplet Loss Function The triplet loss function compares three images at a time. An anchor image (A), a positive image (P), which is another image of the same ship as the anchor image, and a negative image (N), which is an image of a different ship than the anchor image.



$$\mathcal{L}(A, P, N) = ||\mathrm{f}(A) - \mathrm{f}(N)||^1 - ||\mathrm{f}(A) - \mathrm{f}(P)||^1 \geq \alpha$$

Where f(A), f(P) and f(N) are the feature vectors of the image and α is a margin parameter. The margin parameter ensures that the difference be- tween the two pairs is at least α big, where the value of α is a hyperparameter that can be optimized.

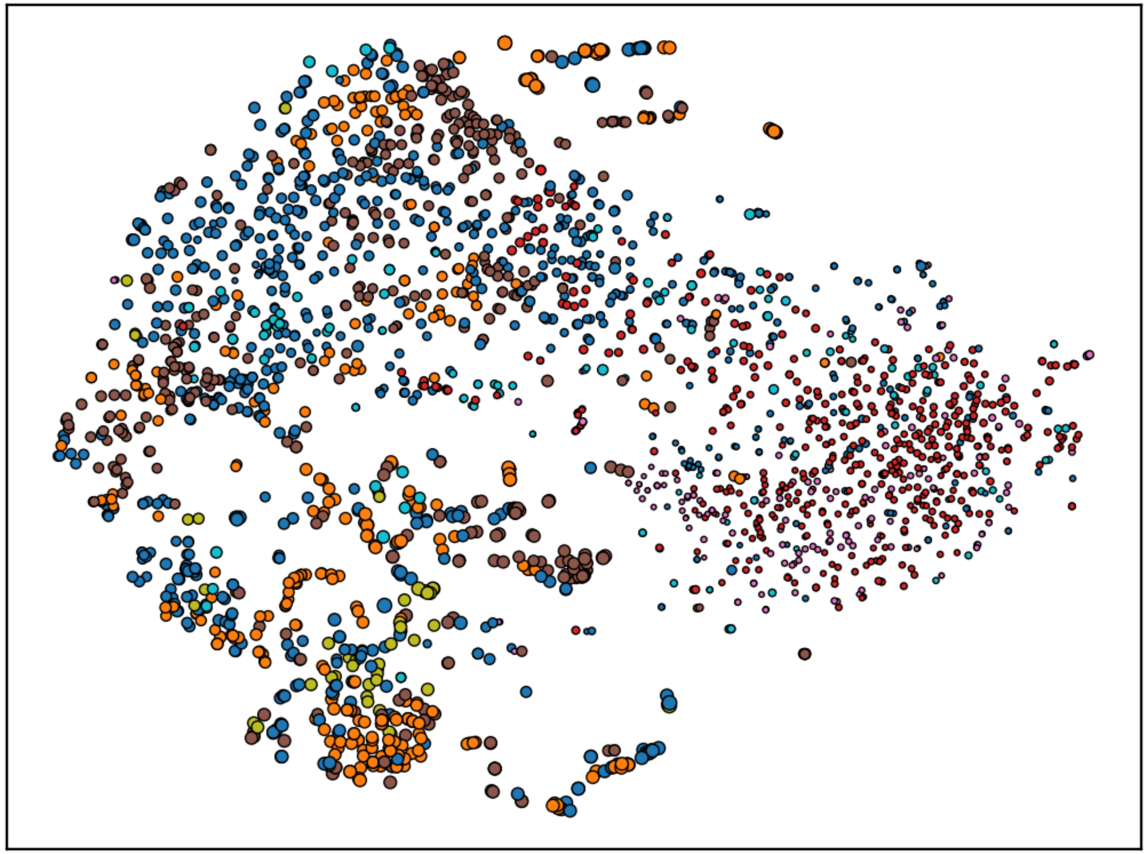
More advanced neural network algorithms than machine learning (k-means, etc.)



CNN’s generate feature vectors for each image.

Database plotted vs. two best features (~principal components)

Each color represents a ship



Here with ship images

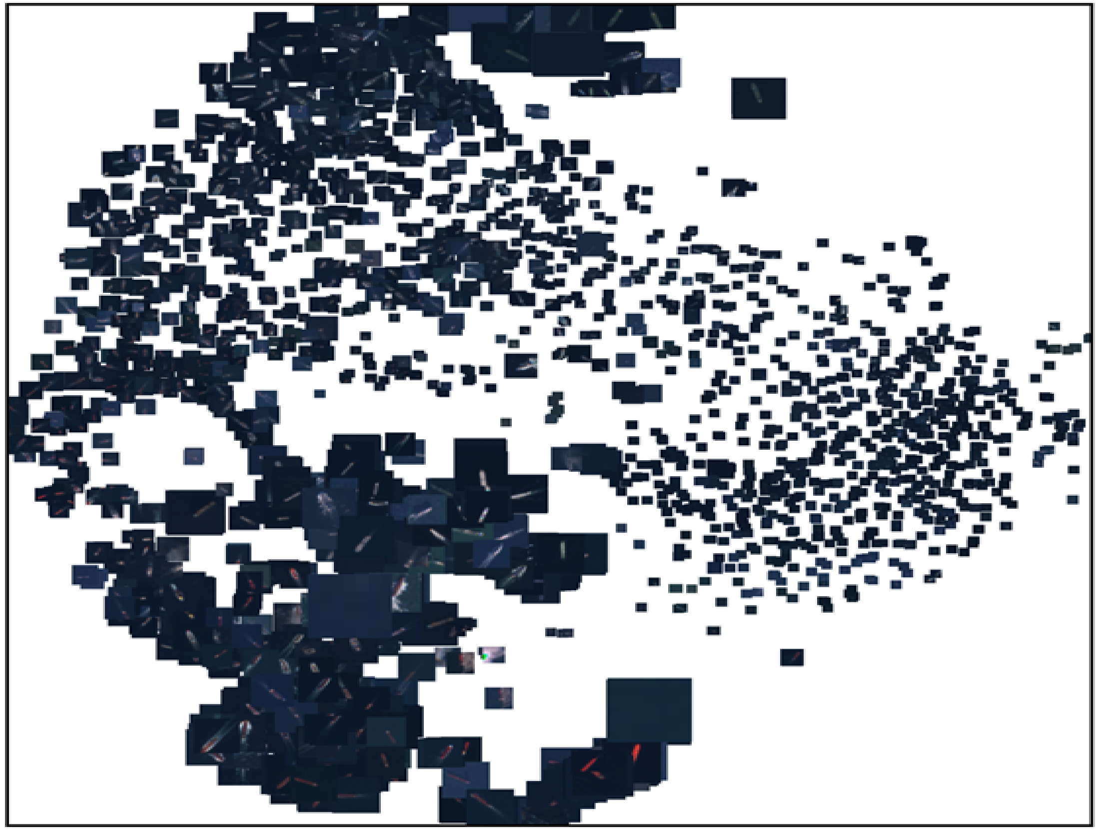
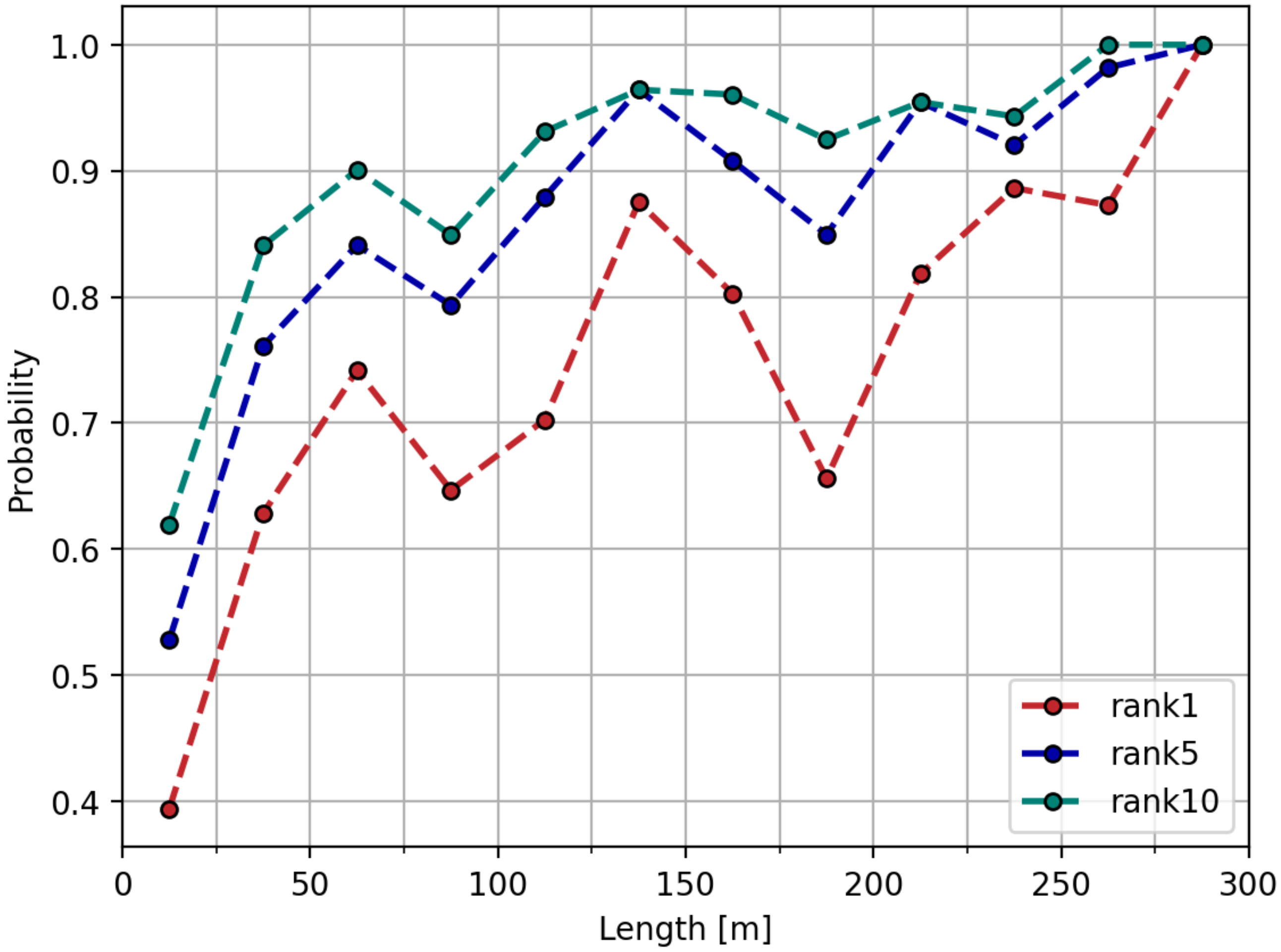


Image analysis by Convolutional Neural Networks



ID probability increases w. ship length

Also increase with rank, where
e.g. rank5 is top 5 suspects

~90% chance for larger ships

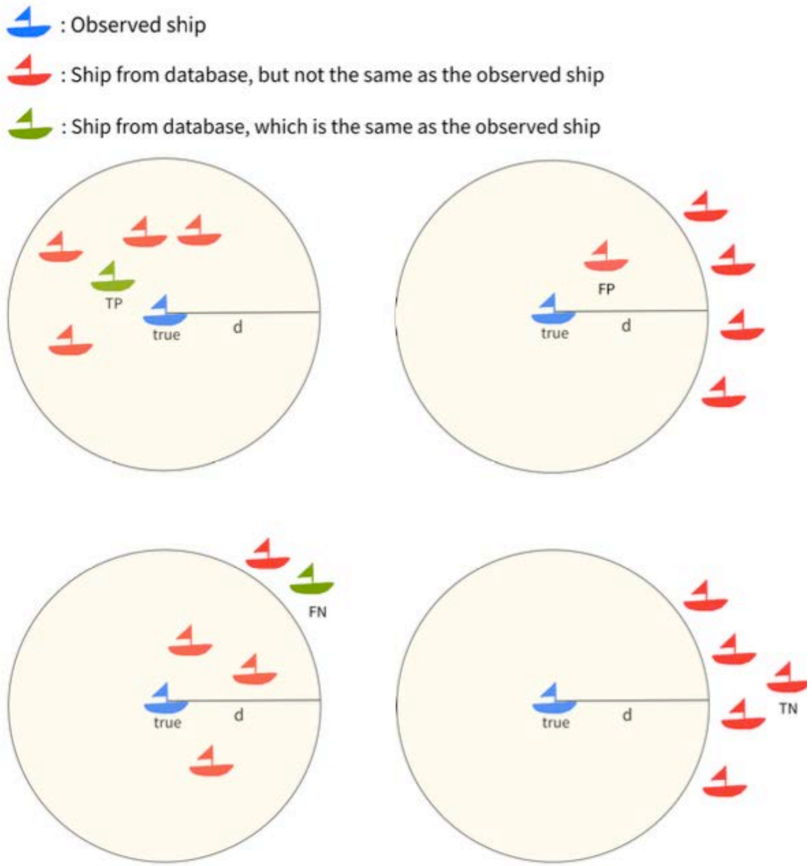
It works: you can fingerprint (larger) ships from 800km up in space!

Algorithm training - maximising accuracy

Accuracy

d-distance is used as a measure of accuracy, where the mean-absolute- error between different feature vectors is used. The d-distance is then based on the mean d-distance of all the distances between each ship group, where a ship group is the group of all images that contains the same ship.

TopN is used as a measure of accuracy, where it is said that if the true ship is within top N of the prediction, then it is labelled as correct. The N value depends on the usage, but has been varied between 1 and 10 for this problem



Results:

- Promising accuracy for larger ships including military vessels
- Small ships difficult
- Large/small is relative to sensor resolution eg 10m for Sentinel-2
- Optical better than SAR due to higher resolution and more spectral bands

Next step:

- More ships in databases
- Separate regions: Arctic, North+Baltic+Barents+Black Seas
- Add other data sources as AIS gaps & anomalies
- Add track record and ”criminal” record
- Top list of suspects - Check for alibis
- Sensor data fusion: RF, RFI, coastal radar, fiber,..

Applications:

- ID dark ships – or provide list of suspects
- Arctic surveillance and critical infrastructure monitoring
- Deterrance