Comparing Spectral Bands for Object Detection at Sea using Convolutional Neural Networks

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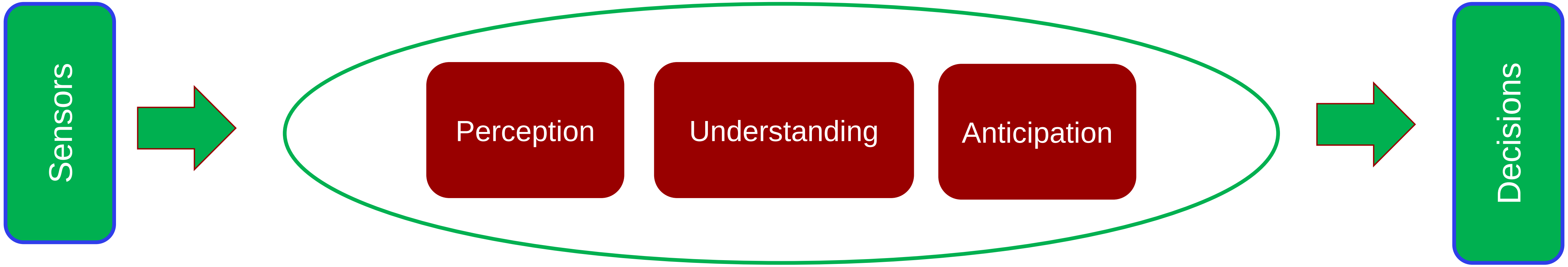
Motivation – Autonomous navigation at sea

Overall goal:

- To realize autonomous or assisted navigation at sea.

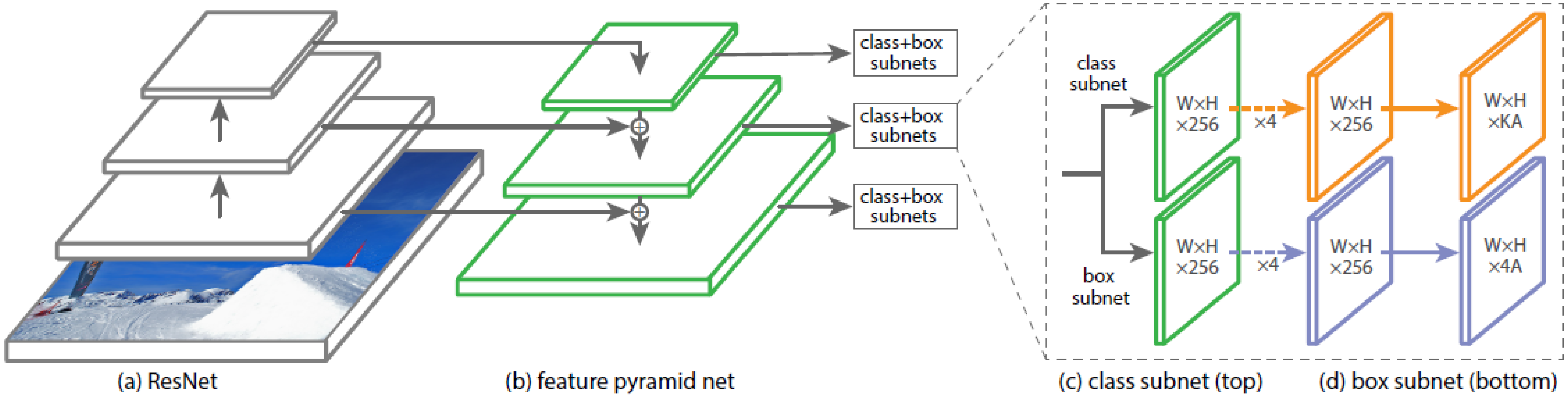
Steps to goal:

- Detect and classify nearby objects.
- Determine position and anticipate future behavior.
- Decide upon maneuvering based on object behavior and COLREGs.



Convolutional Neural Nets for object detection: RetinaNet

- One-stage detector
  - Backbone feature extractor
  - Feature map extracted using feature pyramid net
  - Predetermined anchor sizes assigned at each layer using stride
  - Anchors sent to classifier



Lin et al: Focal Loss for Dense Object Detection 2017

Challenges with vision system

Challenges:

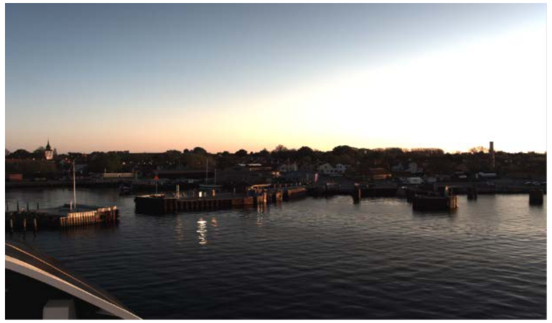
- Variation in visibility due to changing weather
- Reflections from water
- Day and night operation

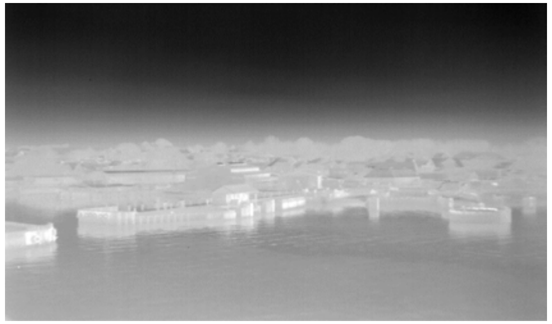
Objectives:

- A vision system effective in multiple spectral bands for image based object detection.
- Test platform outputting the same image in different spectral ranges.

Implemented vision system

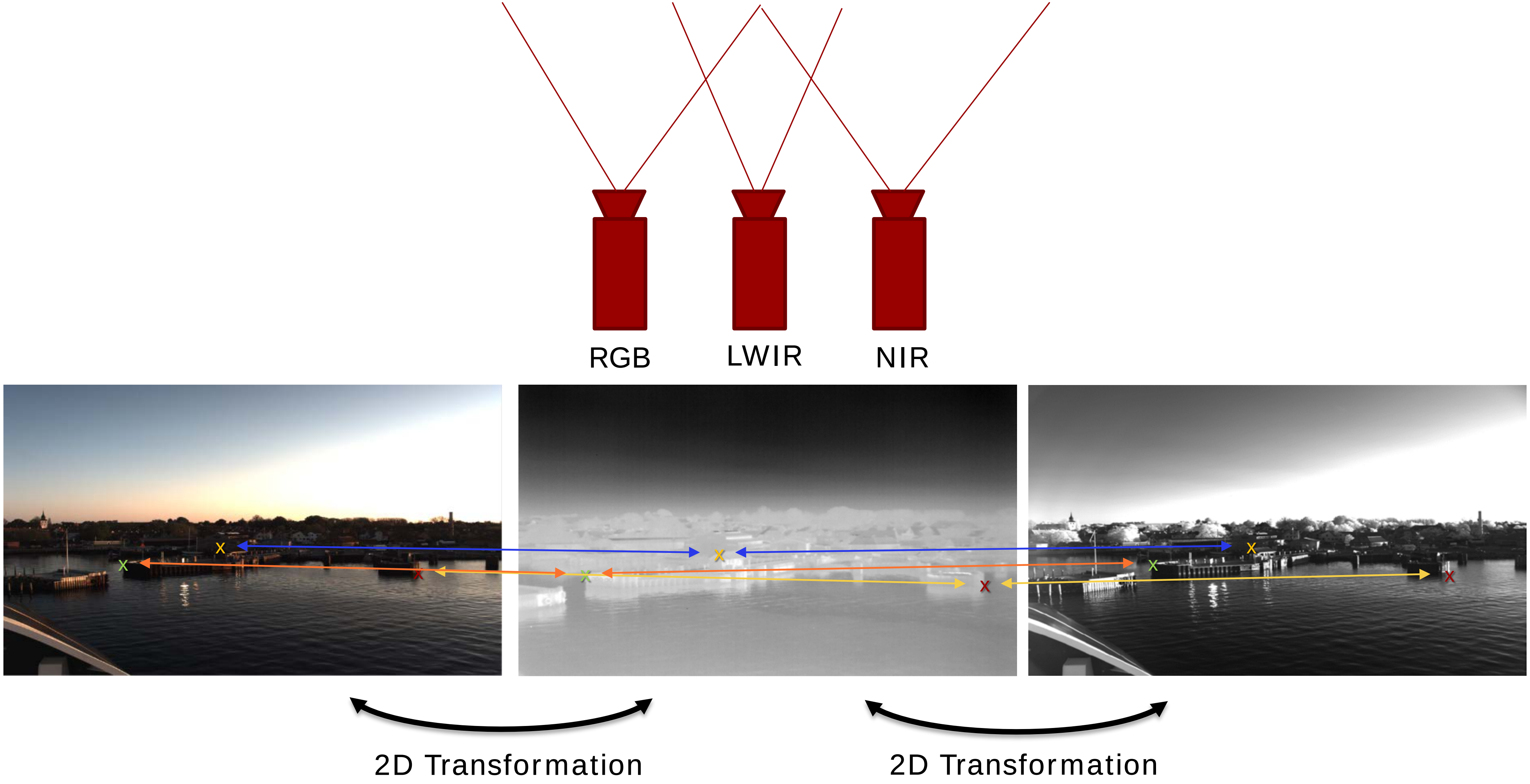
Camera Model	Wavelength	Resolution	Bit depth	HFOV
JAI GO-5000C	Visible range	2560x2048px	12 bit	55º
JAI GO-5000M	NIR 800-1000nm	2560x2048px	12 bit	55º
Teledyne Dalsa Calibir 640	LWIR 8000-14000nm	640x480px	14bit	42.5º





Same scene obtained in different spectral ranges

Image Alignment



Dataset

	Images	Buoy	Ship
Visible range	9229	13894	6256
NIR	9229	13889	6256
LWIR	9229	13845	6219
Validation set	923	1431	624

Example image from the Dataset.

Results - performance metrics

$$precision = \frac{TP}{TP + FP}$$

$$recall = \frac{TP}{TP + FN}$$

$$AP(q) = \int_0^1 p(r|q)dr, \; mAP = \frac{1}{Q}\sum_{q=1}^{Q} AP(q)$$

	Visible range	NIR	LWIR
Precision	**0.96**	**0.96**	0.95
Recall	0.9	**0.94**	0.86
mAP @0.25 IoU	**0.98**	**0.98**	0.96
mAP @0.50 IoU	0.95	**0.96**	0.89
mAP @0.75 IoU	**0.45**	0.42	0.37

What is there

What CNN says

True Positive

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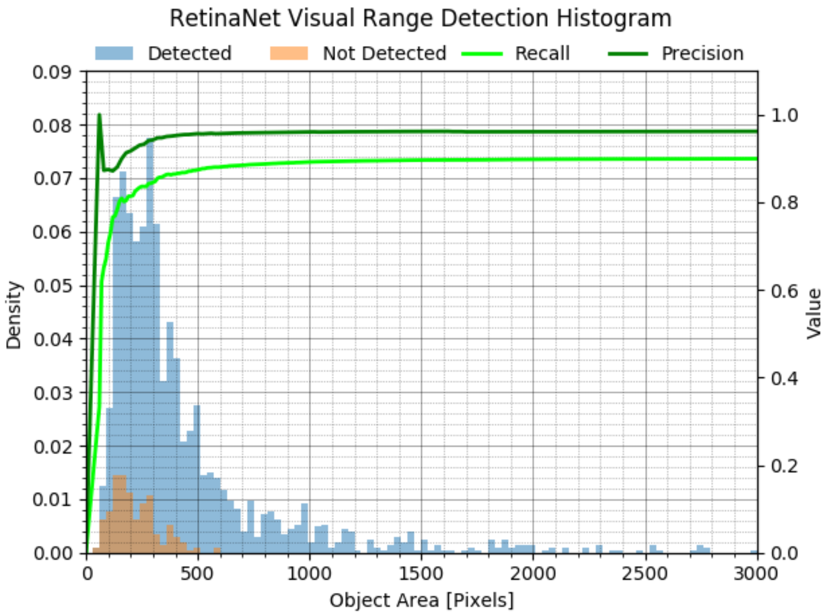
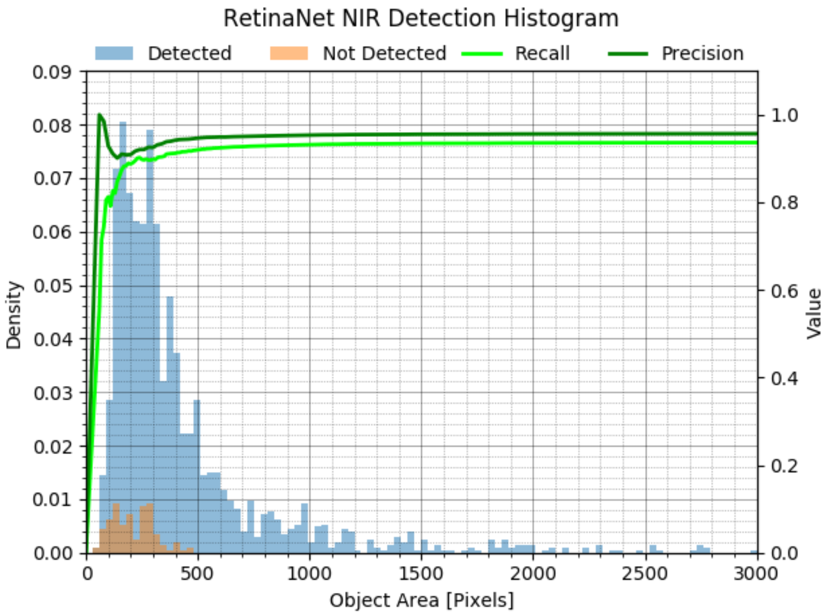
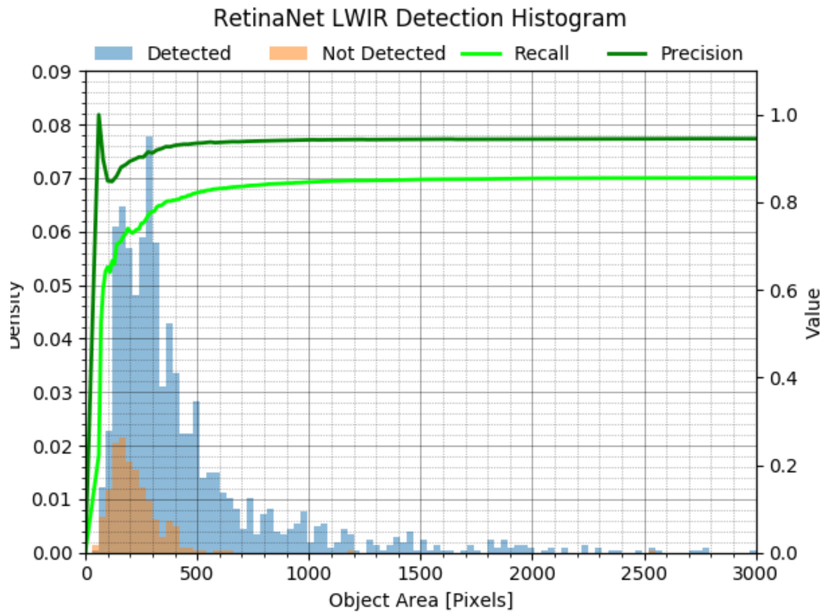
False Negative

Pixel size of objects needed for detection: Detection Histograms







Detected Object

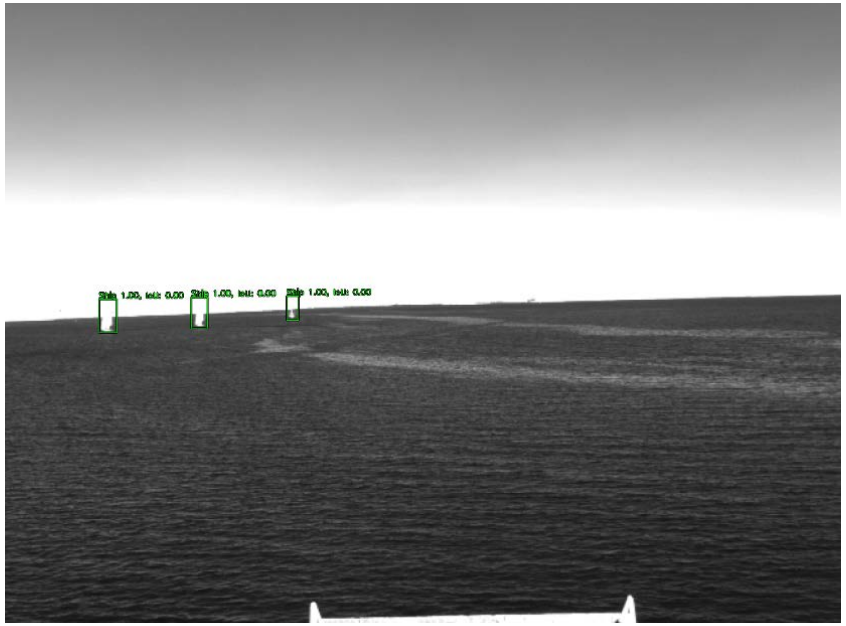
Missed Object

Precision

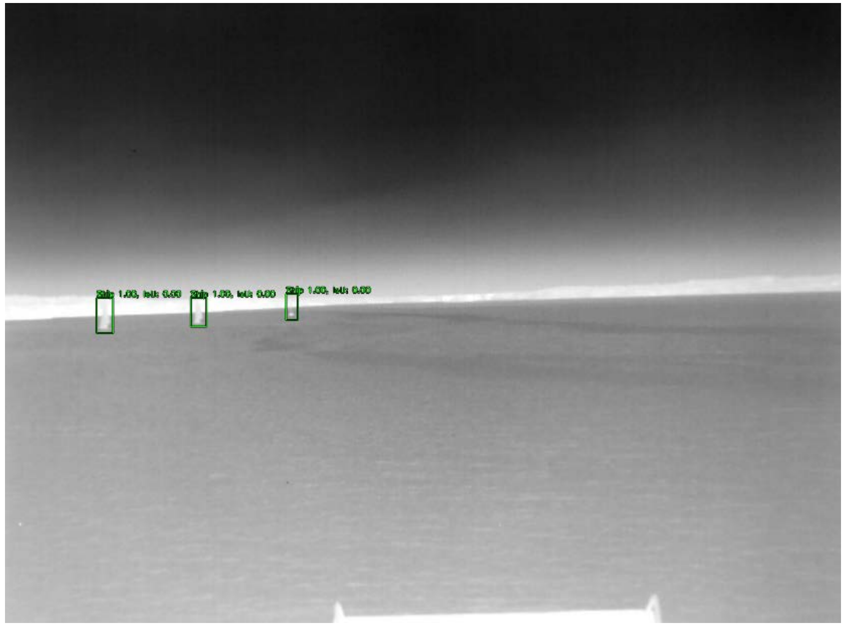
Recall

Examples – Daytime

Visible Range



NIR

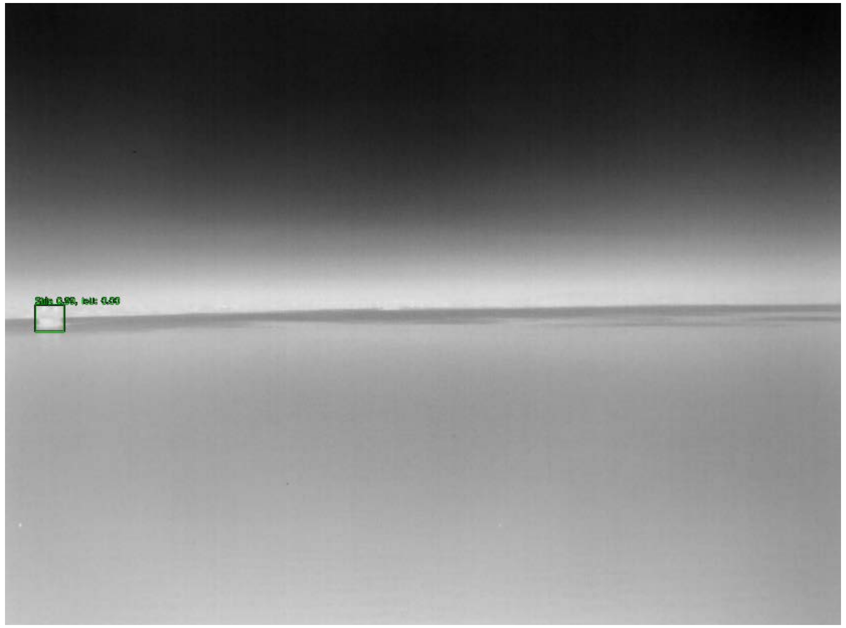


LWIR

Examples – Dusk

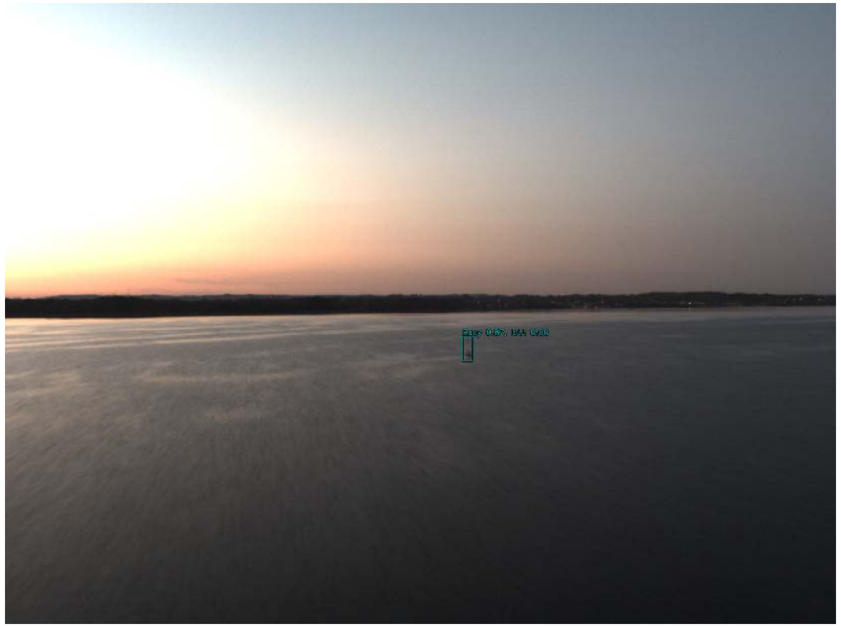
Visible Range

NIR



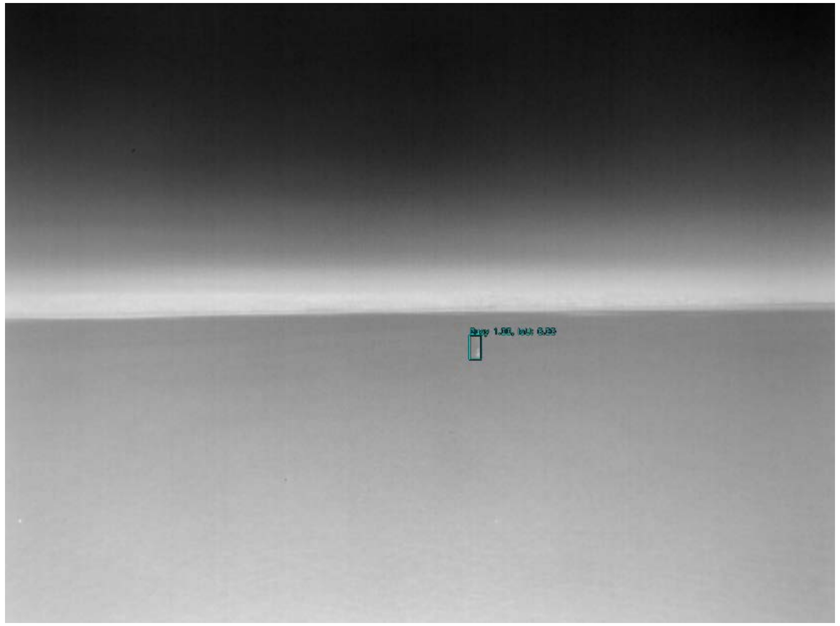
LWIR

Examples – Dusk



Visible Range

NIR



LWIR

Navigation perspective

M/F Marstal Ferry: 5.45 nmi away

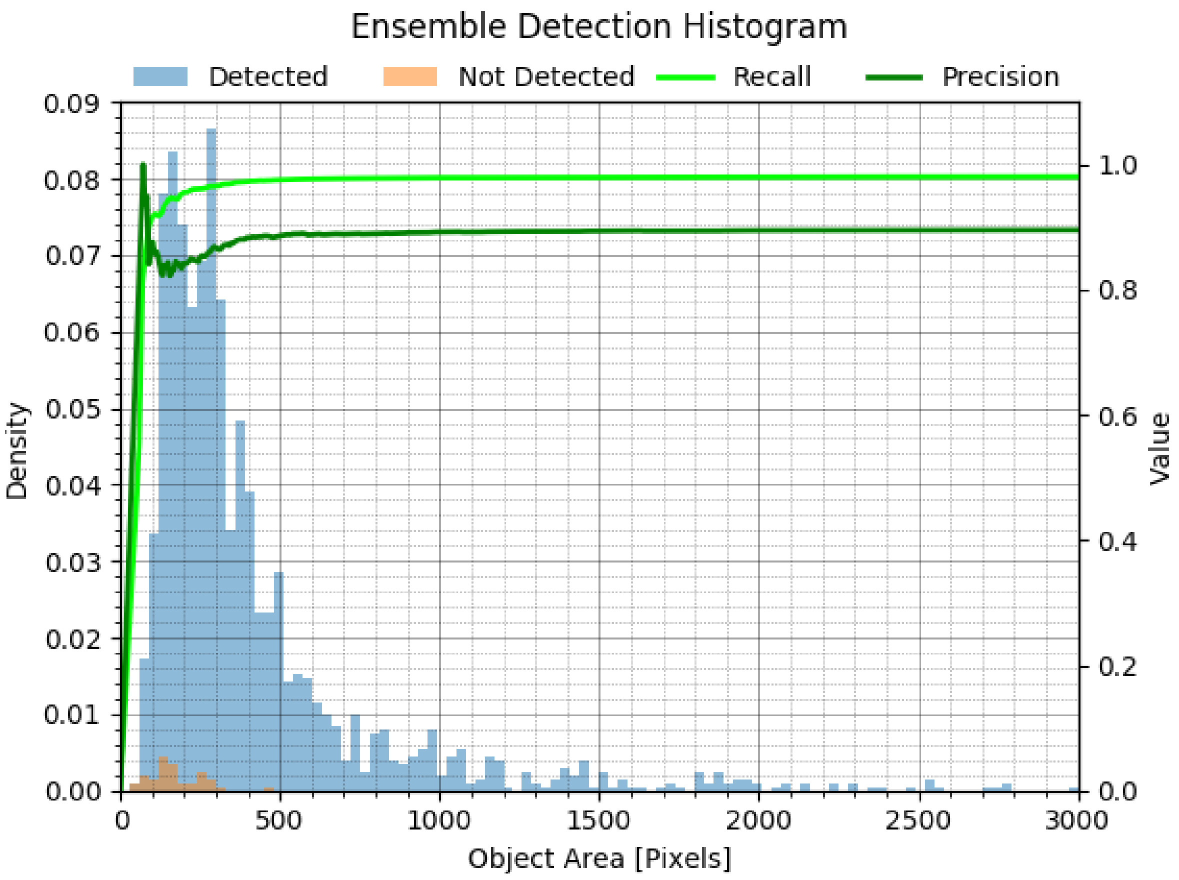
	Visible	NIR	LWIR
Pixels Area (recall 0.5)	70	60	70
Minimum Detection Distance (recall 0.5)	1.06 nmi	1.27 nmi	1.06 nmi

Conclusions

- 3 Spectral ranges assessed for object detection in maritime images.
- Possible to detect with high probability, detecting up to 94% of objects in single image.
  - Missed objects are far away and will be detected as they approach.
  - Object tracking will improve detection
- Each spectral range has its advantages.
  - Visible range includes the color of navigational lights.
  - NIR best for detection in day time.
  - LWIR best for detection during low light.

Recent and Future work

- Ensemble modeling



	Visible range	NIR	LWIR	Ensemble
Precision	0.94	**0.942**	0.938	0.904
Recall	0.92	0.949	0.86	**0.984**

Manuscript submitted: Frederik E. T. Schöller, Martin K. Plenge-Feidenhans'l, Jonathan D. Stets, Mogens Blanke: Object Detection Performance for Marine Autonomous Crafts using Ensemble Models.

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