QUANTIFYING ICE-SHIP INTERACTIONS FROM AN OPTICAL PERSPECTIVE

Fall 2023 Semester Closeout and Roundup

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Agenda

1) Mask-RCNN
2) Local Region Ice-Statistics Extraction
3) Force Prediction (WIP)
    a) RNN: LSTM
4) Future Works Proposals

Mask-RCNN

- Mask-RCNN Def: Mask - Region Convolution Neural Network
- Built to extend capabilities of Faster-RCNN, adding only small computational overhead in comparison [1]. The ‘extension’ specifically is a branch to predict an object’s mask in parallel to the bounding box prediction.
- 2016 COCO challenge winners (pre-trained weights available @matterport Github)

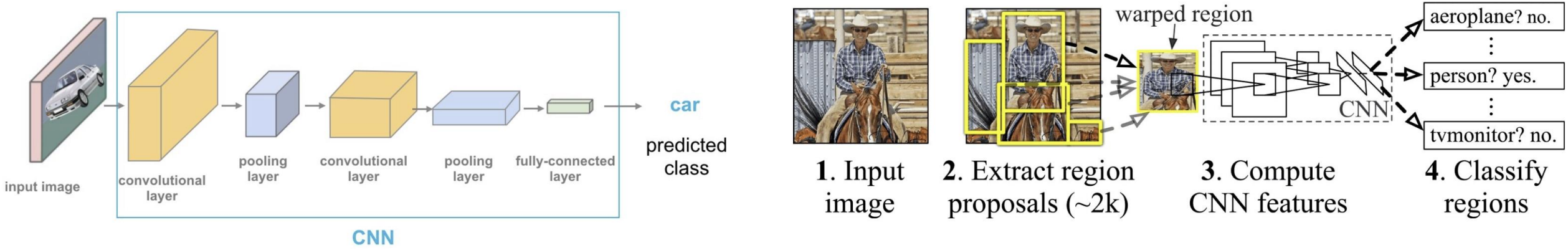
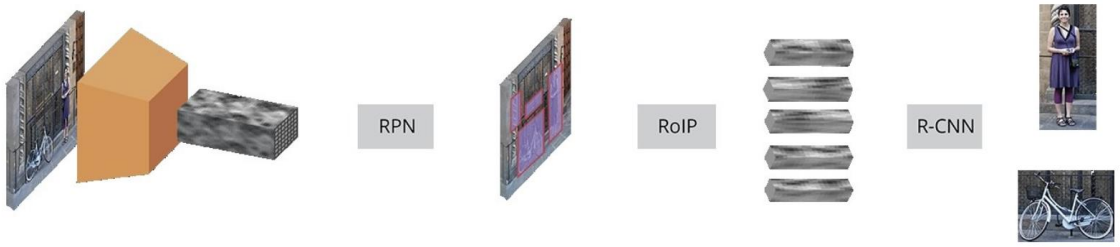


Figure: CNN & RNN Architectures [2]

[1] K. He, G. Gkioxari, P. Dollár, and R. Girshick, Mask R-CNN, https://arxiv.org/abs/1703.06870 (accessed Dec. 4, 2023).
[2] E. Odemakinde, “Everything about mask R-CNN: A beginner’s guide,” viso.ai, https://viso.ai/deep-learning/mask-r-cnn/ (accessed Dec. 4, 2023).

Mask-RCNN

Fast-RCNN opposed to faster RCNN (shown here), uses selective search rather than RPN layer



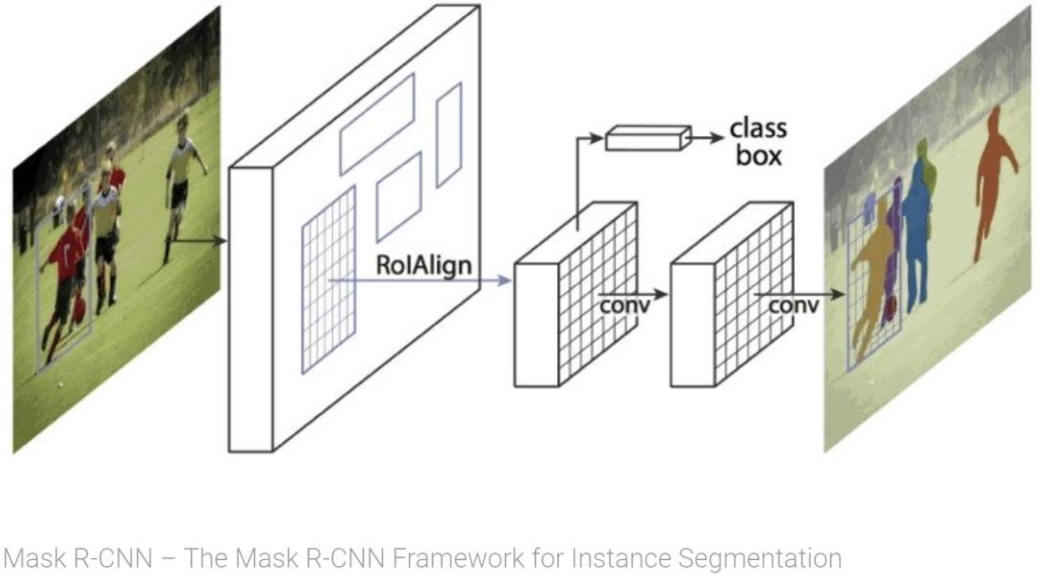


Figure: Faster-RCNN & MRNN Architectures [2]

[2] E. Odemakinde, “Everything about mask R-CNN: A beginner’s guide,” viso.ai, https://viso.ai/deep-learning/mask-r-cnn/ (accessed Dec. 4, 2023).

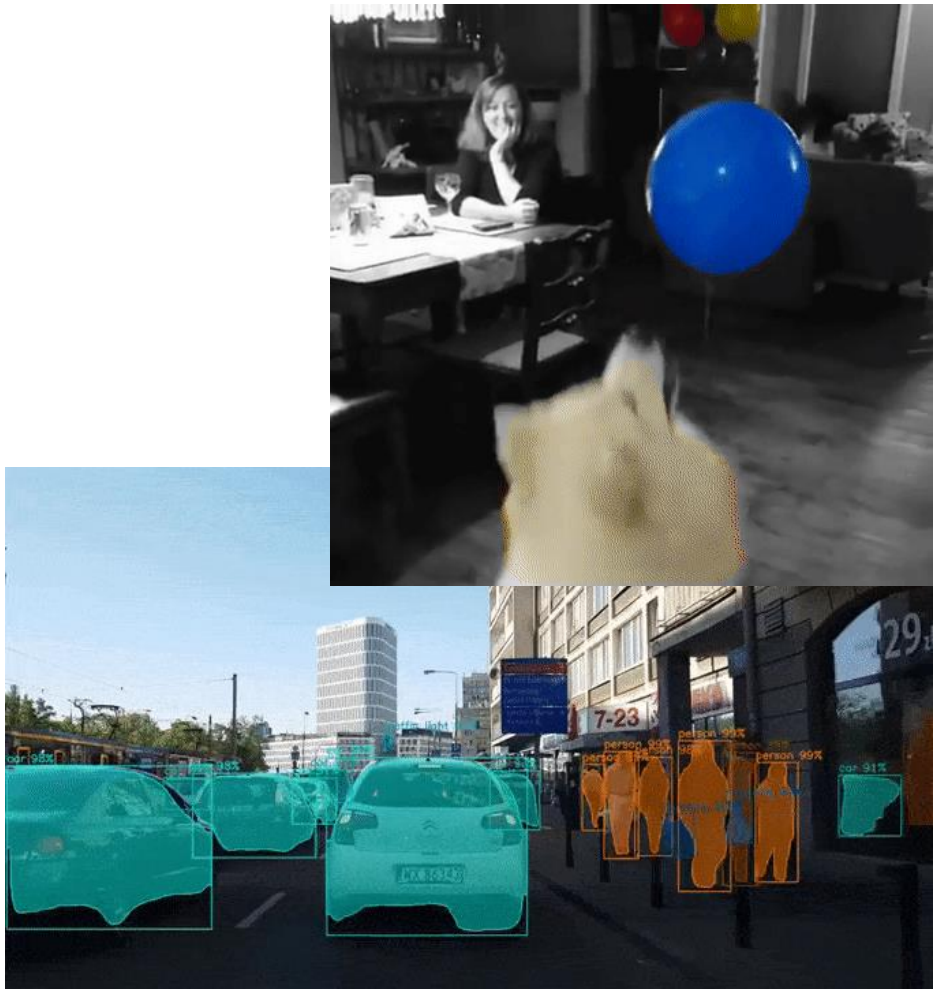
Mask-RCNN

Matterport Mask-RCNN implementation using Python [3]

Lot of good samples & pre-trained weights to get started from. Majority of samples are built in Jupyter notebooks, so it makes it easy to understand.

Some examples of implementations;

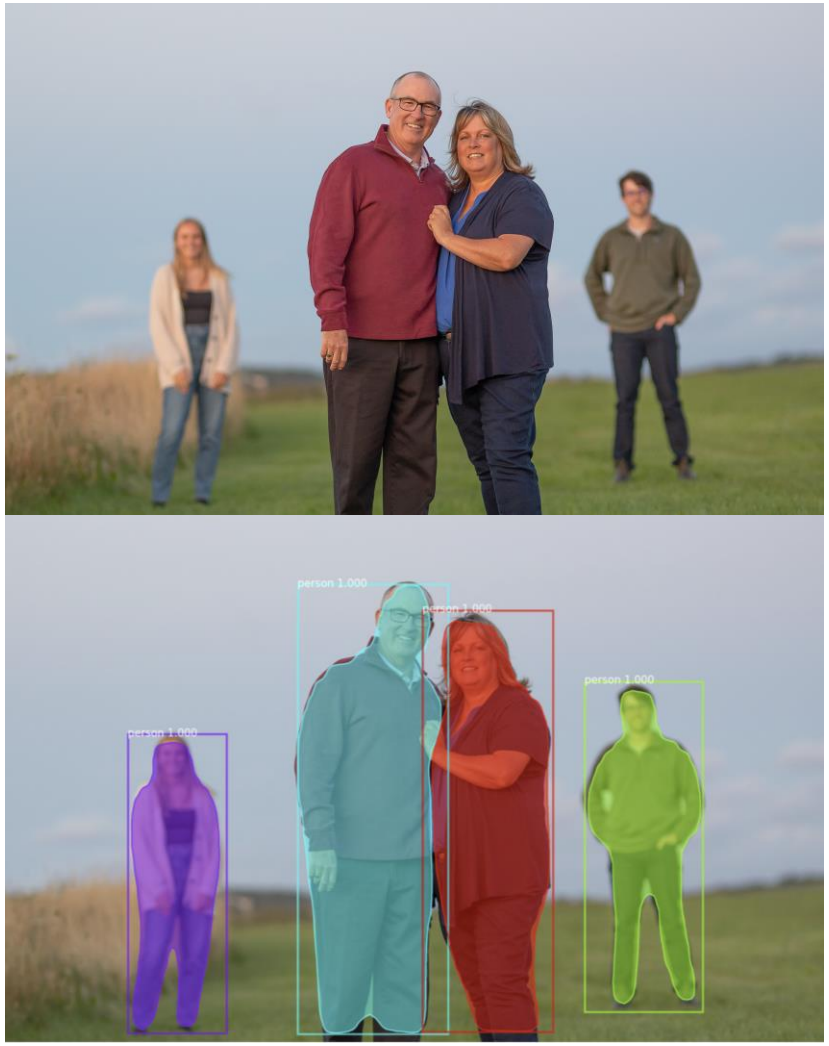
a) Splash of color; merges predicted mask in colour with greyscale background (Top RHS)
b) Generic full colour video implementation from dash cam footage on busy street (Bottom RHS).

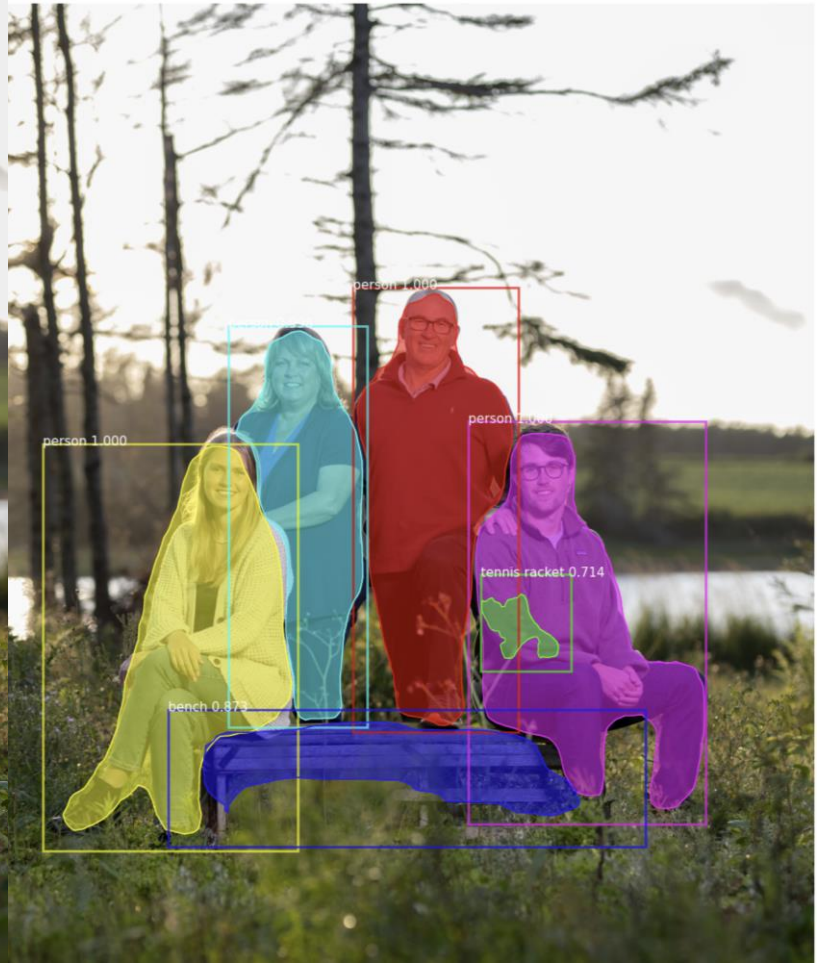


MRCNN video examples [3].

[3] W. Abdulla, "Mask R-CNN for Object Detection and Instance Segmentation on Keras and TensorFlow," GitHub, 2017. [Online]. Available: https://github.com/matterport/Mask_RCNN

Mask-RCNN





Figures: MRCNN pre-trained on COCO capability examples.

Mask-RCNN

- Applying this to Ice-Ship Force Prediction
  - Transfer learning from pretrained weights based on COCO 2016 dataset, to keep training time under control [3].
- Annotation Style
  - COCO – need to input the ground truth mask

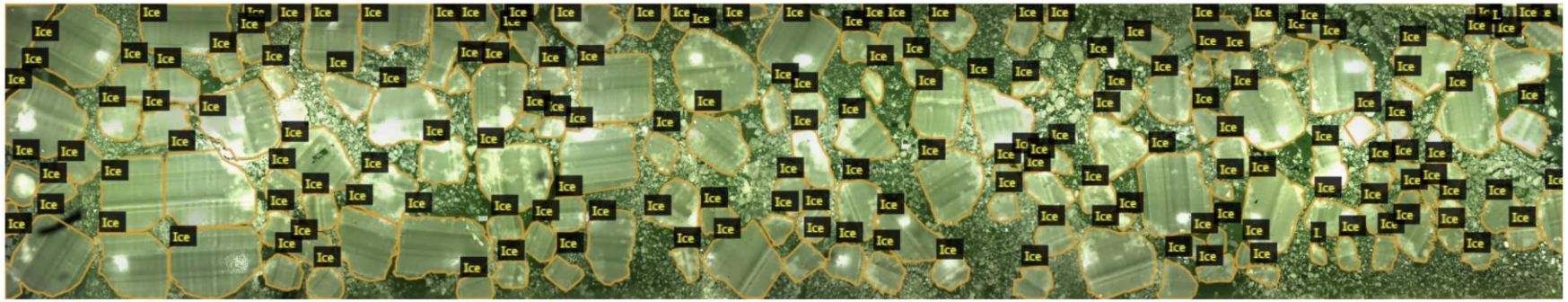


Figure: VIA Image Annotation Tool Showing Mask Annotations and COCO Annotation Format

[3] W. Abdulla, "Mask R-CNN for Object Detection and Instance Segmentation on Keras and TensorFlow," GitHub, 2017. [Online]. Available: https://github.com/matterport/Mask_RCNN

Mask-RCNN

- Annotation overhead
  - Non-annotated regions are assigned region attribute: “Background” (BG)
  - Everything in the image must be annotated.
  - We chose to allow brash ice to be considered “background” **Future works**

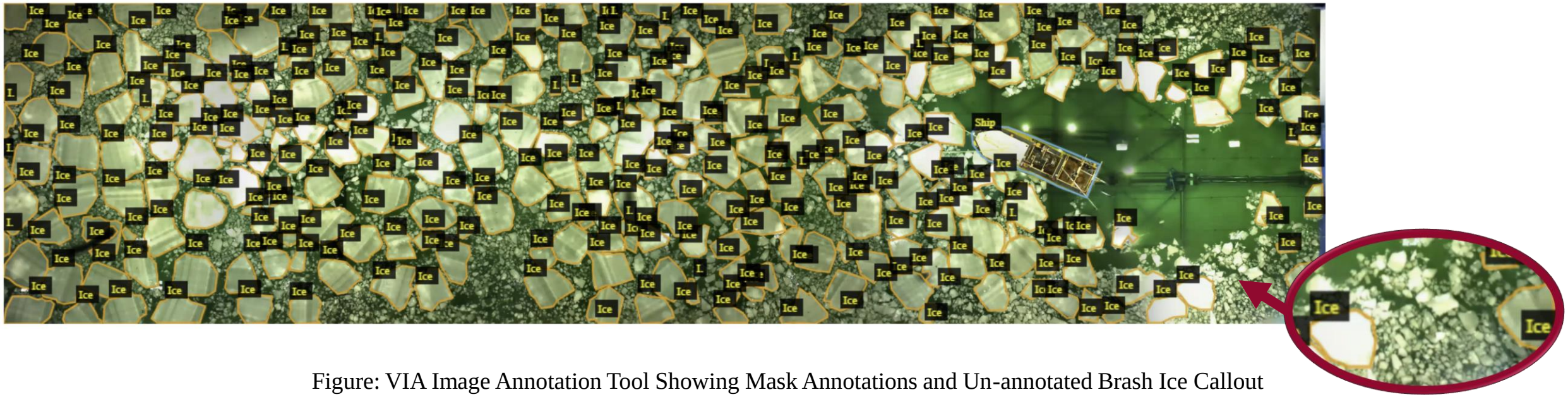


Figure: VIA Image Annotation Tool Showing Mask Annotations and Un-annotated Brash Ice Callout

Ice-Statistics Extraction

What kind of statistics?

- Total Pixel Area Future Works – convert to *real* measurement
- Mean floe size
- Standard Deviation of floe size

Ice beyond 2SL forward, and 0.5SL behind have no effect on the ship per Dr. Shameem [4]

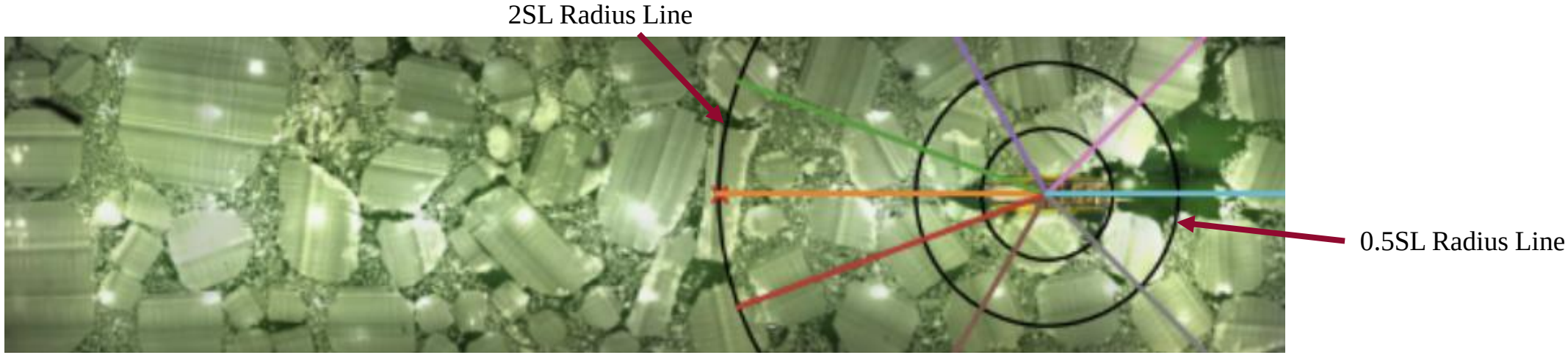
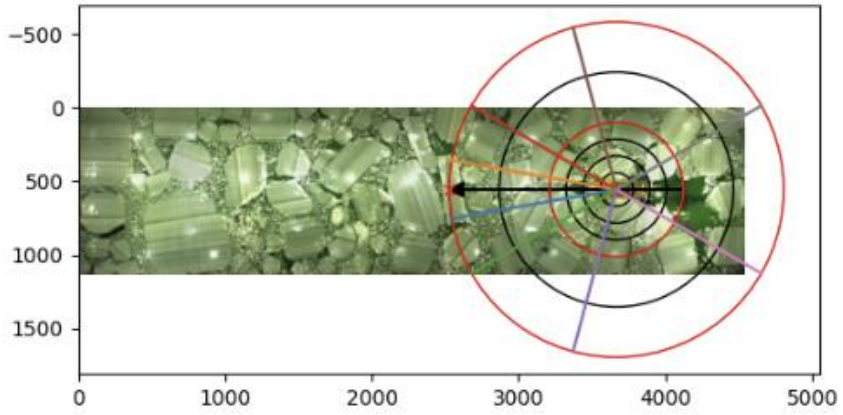


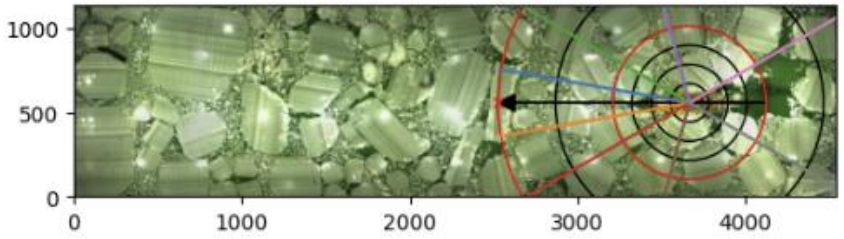
Figure: 2SL (2.5SL) and 0.5SL (1SL) Region Proposal Callout

[4] S. Islam et al., "Physical Model Testing for Supporting Ice Force Model Development of DP Vessels in Managed Ice," in OTC Arctic Technology Conference, 2018.

Ice-Statistics Extraction



(a) Uncropped



(b) Cropped

Figure: Initial Region Proposals

Divisions
- Angles:
  - ± [10,30,75,150]
- Distance (Radius from ship center)
  - ± [0.25,0.5,0.75,1,1.75, 2.5]

Divisions
- Angles:
  - ± [0, 20, 60, 135, 180]
- Distance (Radius from ship center)
  - ± [0.5, 1, 2.5]

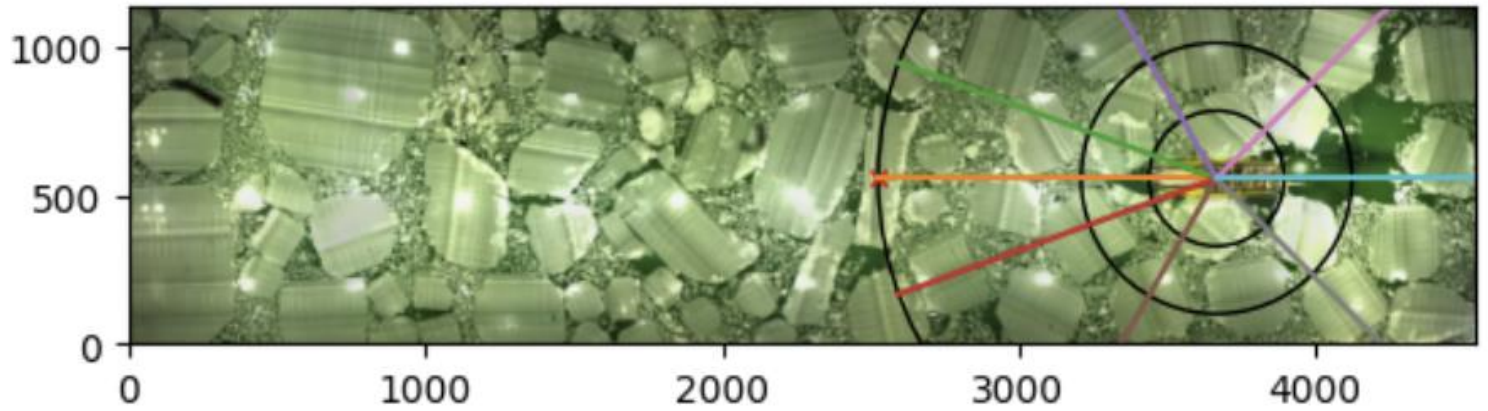
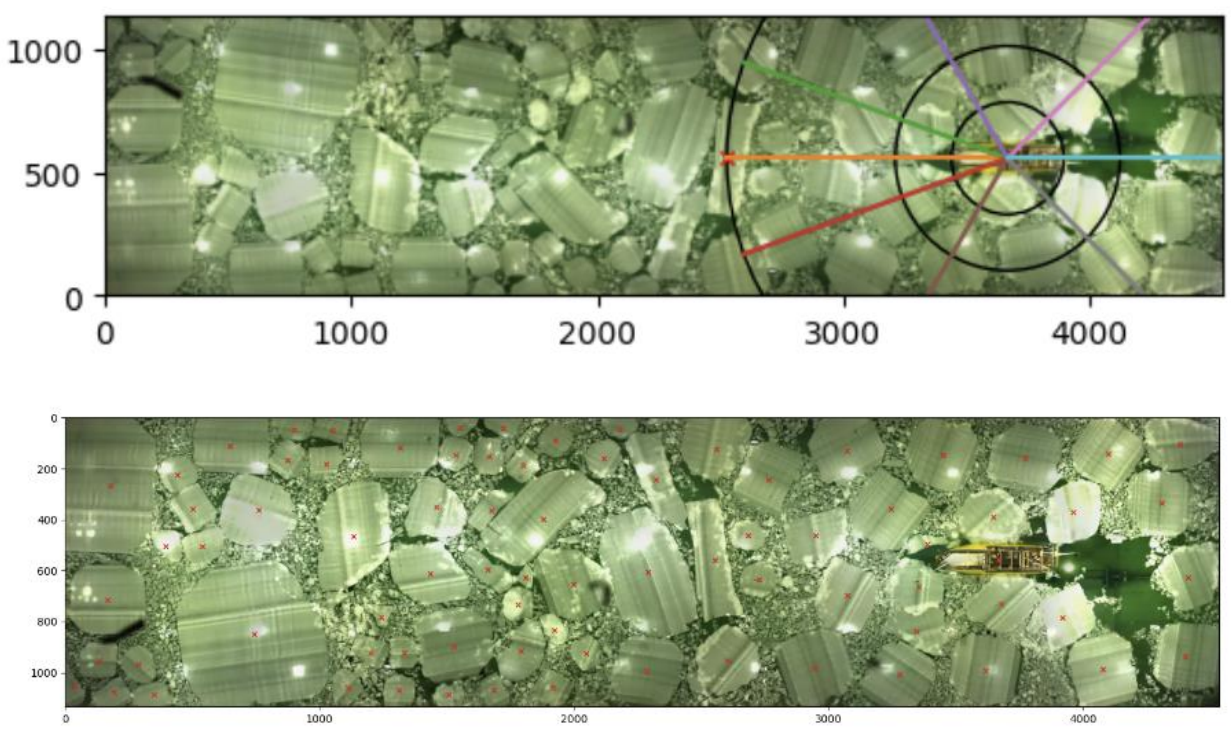
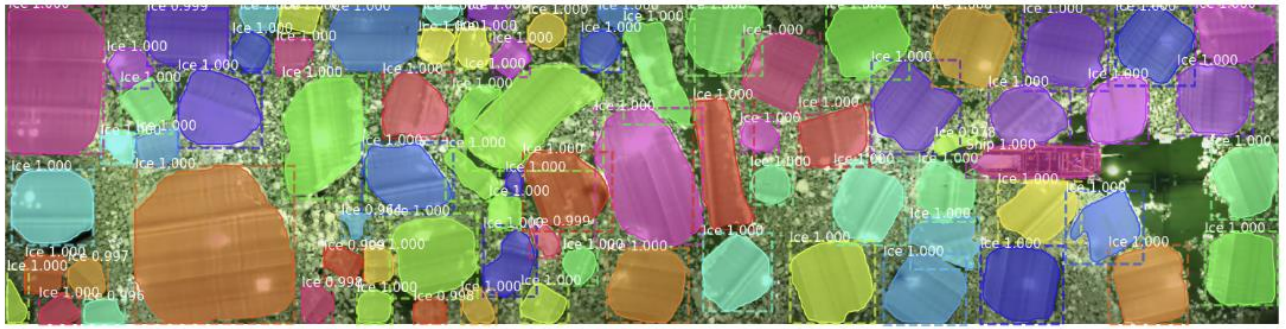


Figure: Current Region Proposals

Ice-Statistics Extraction





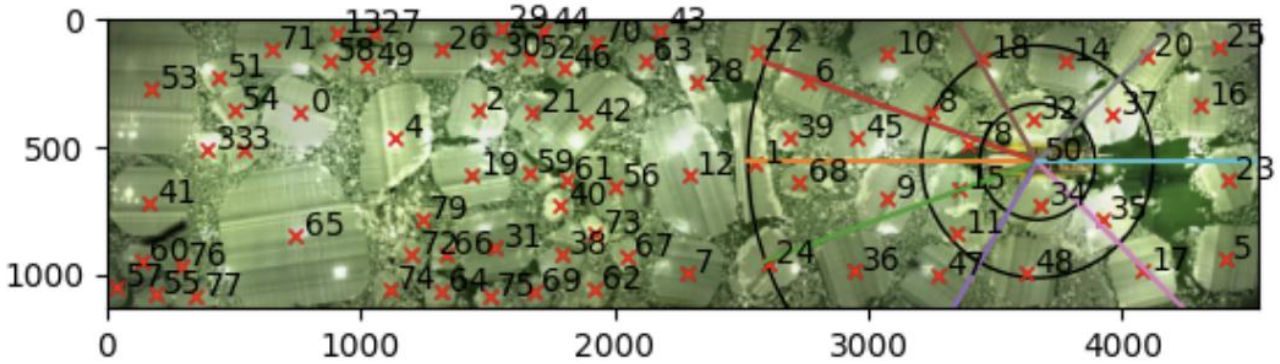
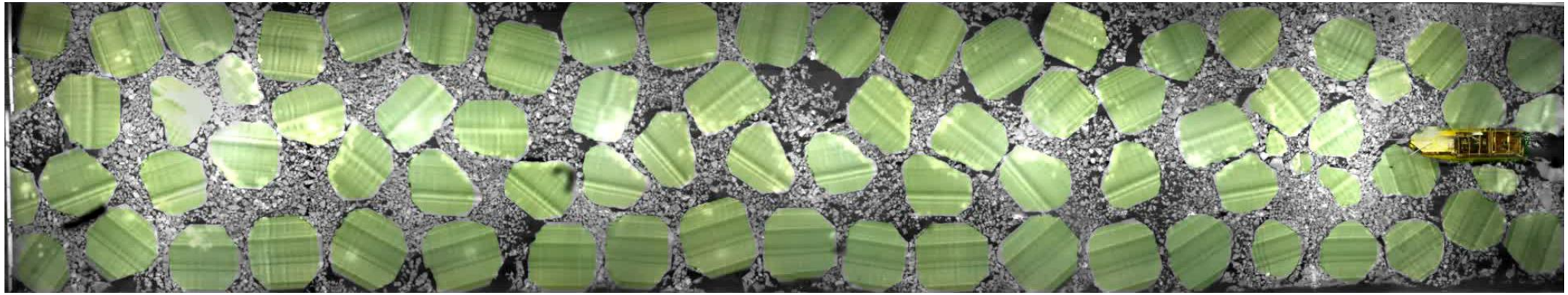
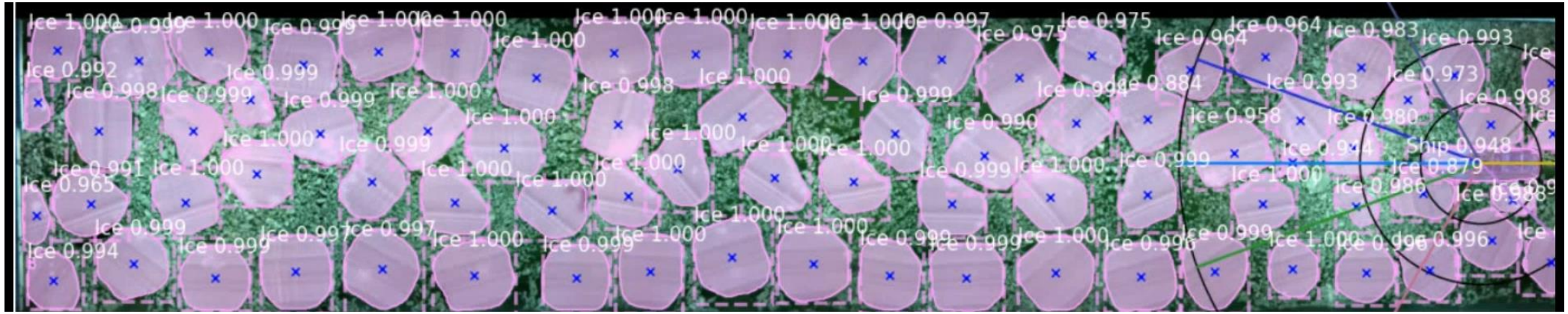


Figure: a) Proposed regions, b) proposed masks, c) proposed mask centroids, d) proposed mask centroids and overlayed proposed regions.

Ice-Statistics Extraction



Video: Masked Detections (splash of color)



Video: Masked Detections (overlayed masks, scores and regions)

Ice-Statistics Extraction

Current Assumptions (limitations)

- 0° yaw
  - Can maintain this with selective datasets from NRC testing. Future works: Difficult challenge mathematically to robustly determine heading within 5 degrees.

- Consistent pixel density
  - OK for this implementation. Other cameras/datasets will need to re-define distance Future works: based on known distance in the image.

- No processing of NRC provided data
  - Ship speed data is measured as carriage speed not instantaneous ship speed Future works

Ice-Statistics Extraction

Output to CSV (one row per frame, one file per video)

1. FrameN (int)
2. Carriage_Speed_DP (float)
3. Global_FX (float)
4. Global_FY (float)
5. Global_FT (float)
6. Global_MZ (float)
7. Floe_Size (string)
8. Drift_Speed (float)
9. Ice_Thick (float)
10. Drift_Angle (float)

} Directly from NRC DAQ (CSV input)

11. Region_0:228.0_0:20 - Ice Conc
12. Region_0:228.0_0:20 - Mean
13. Region_0:228.0_0:20 - StdDev

} Repeated for each region (pre-defined, easily changed)

Ice-Statistics Extraction

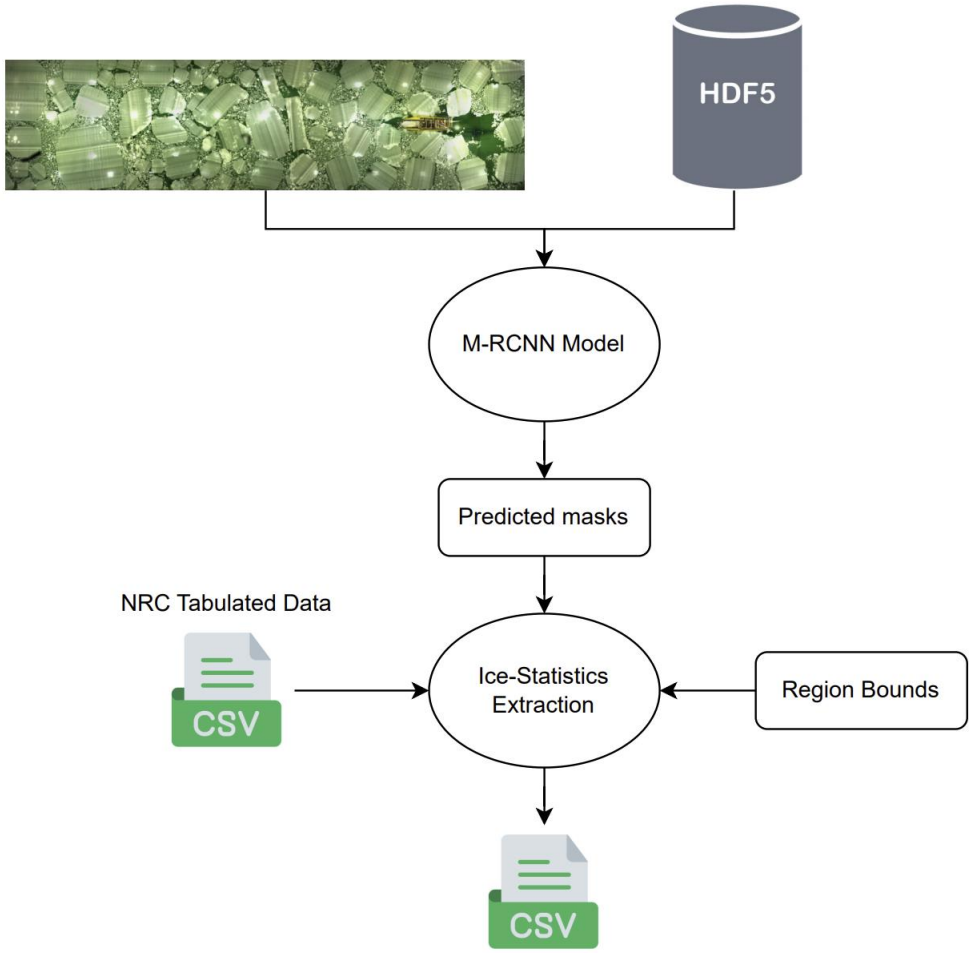


Figure: Summary Flowchart of Ice-Statistics Extraction

Force Prediction

Using output of ice-extraction (CSV), train LSTM RNN model using several of the videos available from NRC Ice testing in 2022.

- I want to try to show the correlation between a high concentration of ice in front of the vessel, indicates a likely collision a few time steps later.
  - Would be nice to be able to make some correlations here between size of the ice and which region it is in relative to the ship.

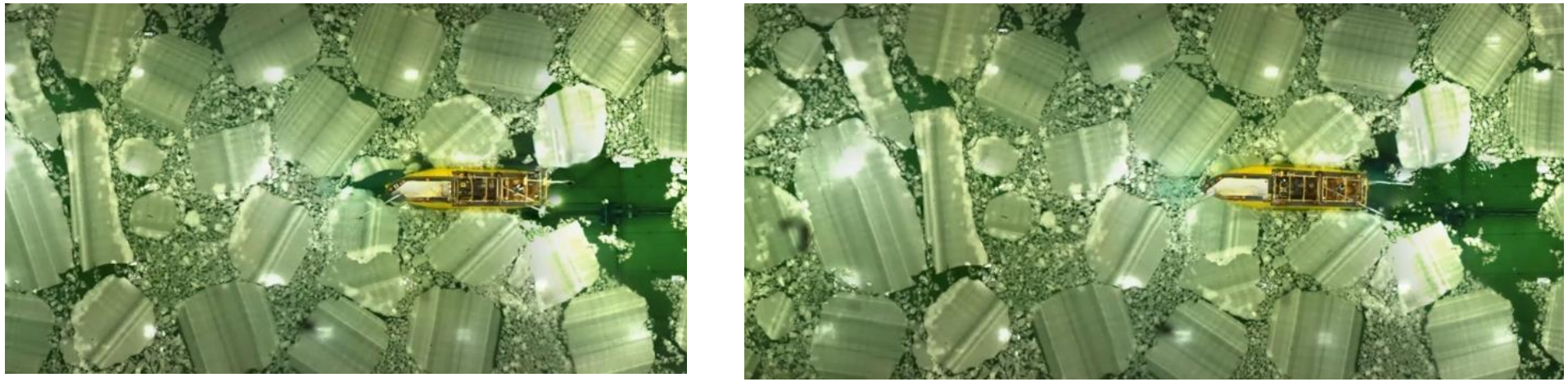


Figure: Two Different Collision Type Instances (Rubbing/Oblique Collision)

Future Works Proposals

Proposed future works in terms of experimental setup for the next 5 semesters, in order of importance (to me).

1. Direct form of collision force measurement
   a) Tactile sensor sheet [5]
   b) Strain gauges on hull
2. Sensor Mounting Location
   a) Ship mounted
3. CCG Live Webcam footage
   a) Outfitting live hull with strain gauges, tactile sensor sheet?
4. Using Wayne Pearson's Ice Simulator Model
   a) Infinite data source
5. Alternative sensors
   a) SAR, LiDAR, etc.

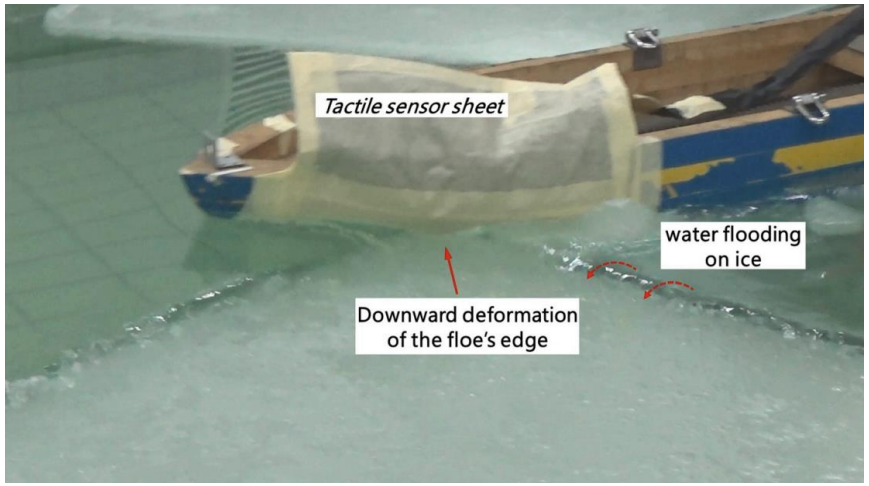


Figure: Tactile Sensor Sheet [5]

[5] Sun and Y. Huang, "Investigations on the ship-ice impact: Part 1. experimental methodologies," Marine Structures, vol. 72, p. 102772, 2020

Future Works Proposals

Proposed future contribution direction

1. Add brash/slush ice considerations, similar to B.Dowden [4]
   a) Generally expanding ice type capabilities
2. Decrease reliance on ice types provided by NRC; consideration of ice thickness/density/age/inertia without this being an external input.
3. Considering/identifying/tracking individual ice collision events.
4. Expanding prediction time horizon to all ice pieces in a decent region around the ship
   a) POC that this could be used for trajectory planning/tracking operations
5. Reinforcement learning focusing on generalizing architecture across different vessels

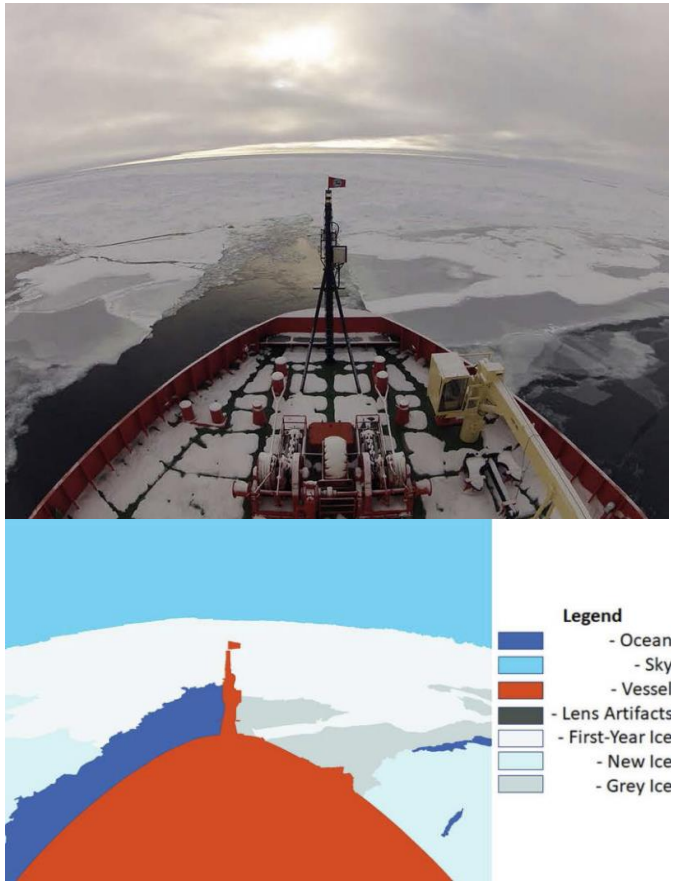


Figure: Semantic Segmentation including brash ice [6]

[6] B. Dowden, O. De Silva, W. Huang, and D. Oldford, “Sea ice classification via deep neural network semantic segmentation,” IEEE Sensors Journal

Thank-you all for the help & support this semester!