Development of video processing algorithm (YOLO) in autonomous vessels operations

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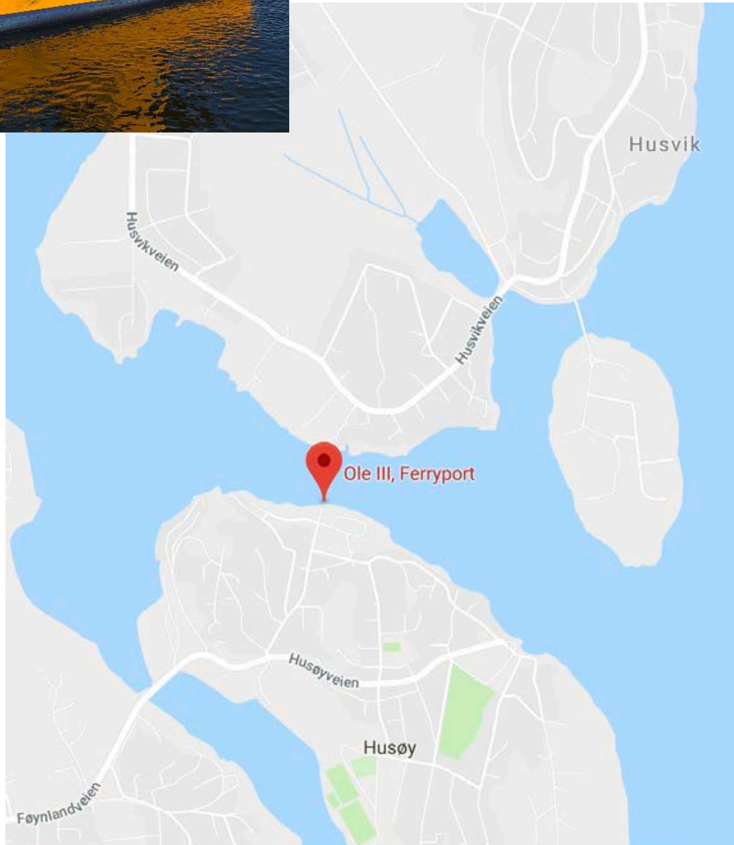
Motivation of Research

- **Tønsberg Municipality**
  - Replacing Ole III with Autonomous Vessel
- **Research Project**
  - Small Autonomous Ferry
  - MARKOM 2020
  - University of South-Eastern Norway (USN)
  - Norwegian University of Science and Technology (NTNU) Ålesund
  - Risk analysis focusing on assessment of leisure vessels operators behavior in accordance with COLREG standard
- **Data Collected**
  - Observational Reports
  - Video Recording
  - Global Positioning System (GPS) location, heading, throttle, and rudder position



Data Collection

- Two Sets of Video Data
  - Optical Camera
  - Thermal Camera

- Observation Data
  - Time and Date
  - Passengers Data
  - Violations of COLREG by passing traffic
  - Captain Decision in case of COLREG violation
  - Crossing Traffic Data in case of Intervening Navigation

Dato	Klokkeslett	Observatør	Skipper

Retning	TRAFIKK VED START		
Husøy-Husvik ☐ Husvik - Husøy ☐		Styrbord	Babord
Totalt Antall passasjerer	Antall fartøyer med kryssende kurs		
Antall Barn (<16 år):	Av dette:		
	Seilbåter under seil		
Antall som trenger assistanse:	Seilbåter på motor		
	Kajakker/robåter		
Sykler:	Motoriserte fartøy		
	Nyttefartøy		

Eventuelle andre objekter i farvannet

SEILAS

Avvik fra sjøveisreglene

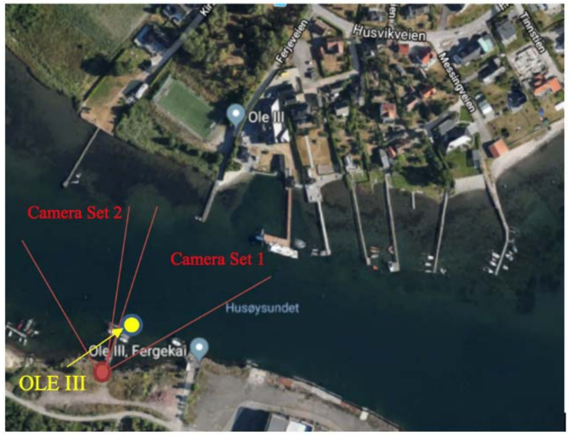
Regel	Beskrivelse av hendelse	Beskrivelse av skippers på Ole 3 handling	Annet

Skipper på Ole 3 handlet for å unngå hendelser

Regel	Beskrivelse av hendelse	Hva gjorde skipper på Ole3	Annet

Skjedde det noen uhell på denne krysningen? Hvis Ja, så beskriv.

Sjøfartsregler		Eksempler på situasjoner:
15	Krysningssituasjoner	Ole 3 måtte ga fra seg sin forkjørsrett.
16	Handling av give-way vessel	Kryssende fartøy avvek fra sjøveisreglene
17	Handling av stand-on vessel	Kryssende fartøy gjorde «feil» i sin unnamanøver



Research Objectives

- Evaluate the potential of computer vision algorithms, in particular, YOLO for autonomous vessel applications such as collision avoidance.

Research Questions:

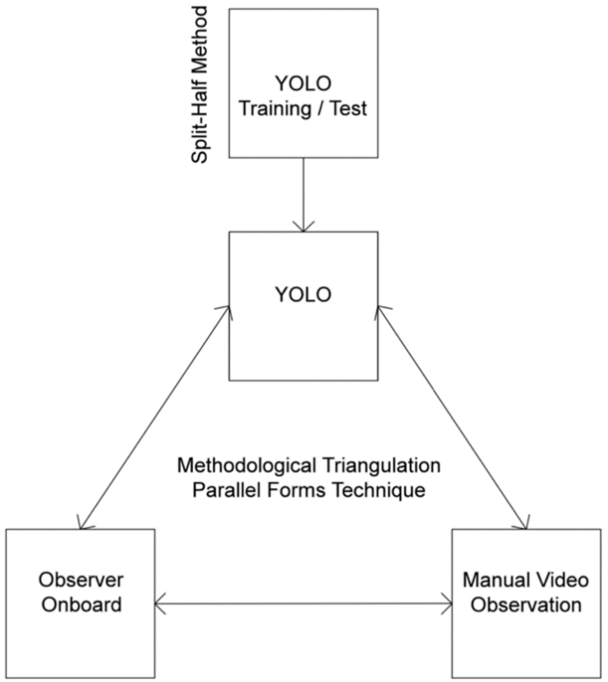
- Does the developed computer algorithm (YOLO) comply with the observation reports gathered by the crew during watchkeeping?
- To what extent is the machine learning algorithm (YOLO) accurate for application in autonomous vessels operations?

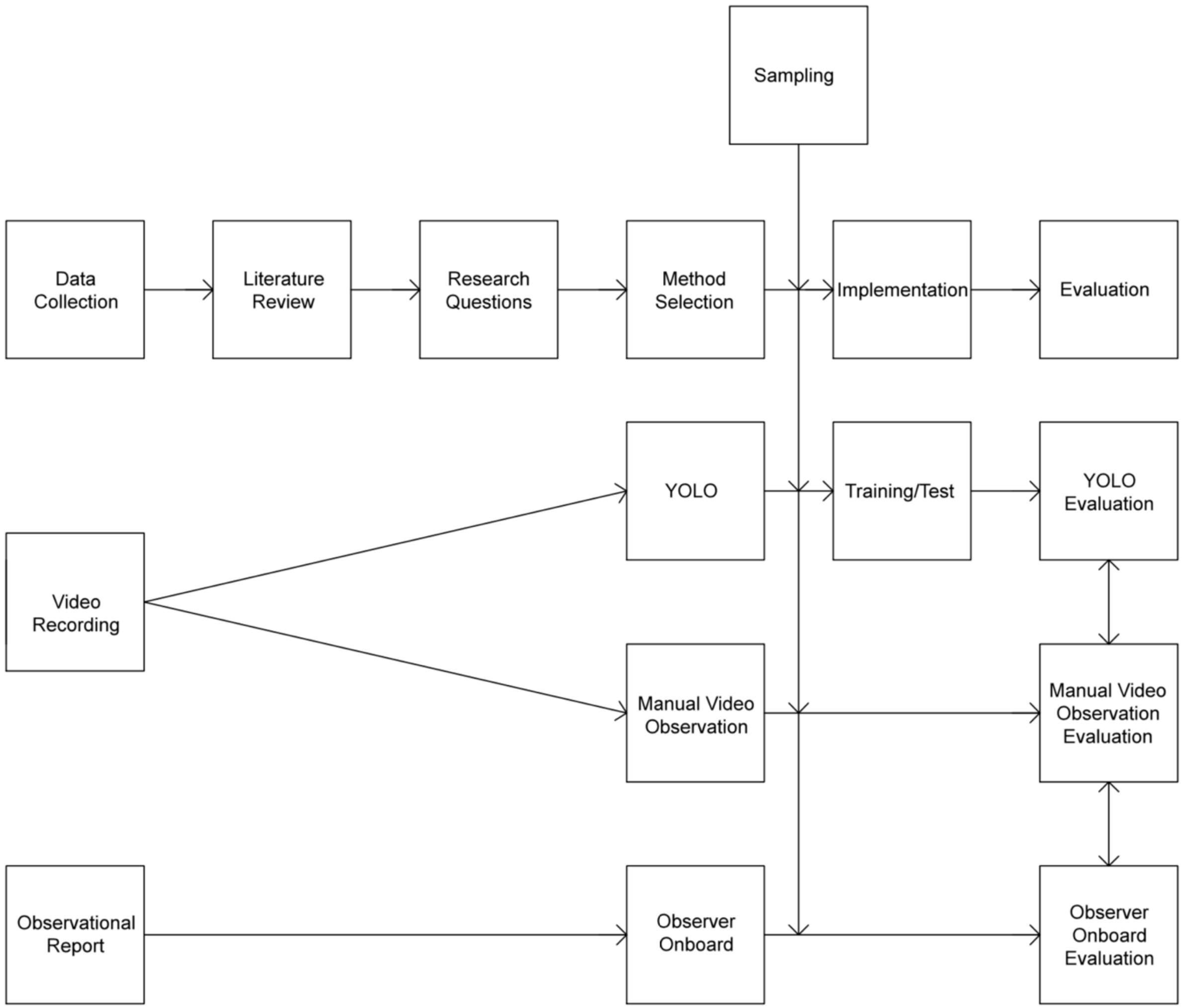
Literature

- Autonomous Vessels
  - Recent Developments in Autonomous Area (Industry and Research)
    - Maritime Unmanned Navigation through Intelligent in Networks (MUNIN) (MUNIN, 2016)
    - Advanced Autonomous Waterborne Applications Initiatives (AAWA) (Rolls-Royce, 2016)
    - DNV-GL Revolt (DNV GL, 2019)
    - YARA-Birkeland (Kongsberg Maritime, 2019)
  - Safety and Risk Models Thieme, Utne, and Haugen (2018), Wróbel, Montewka, and Kujala (2018)
  - Lack of Empirical Data

- Machine Learning and Computer Vision
  - Computer Vision Algorithms (Goodfellow, 2017), (Finlay, 2017)
  - Limited research for Maritime Application Kim, Hong, Choi, and Kim (2018), Rodin et al. (2018), Yang-Lang et al. (2019)

Research Design





Population and Sample

- Population

Data Type	Duration	Start Date	End Date	Total Data Points
Observational Reports	2 Months	04 June 2018	04 August 2018	4803 Reports
Video Recordings	Two Months and 21 Days	06 June 2018	27 August 2018	82 Days

- Purposive Sampling
  - Criteria “Violating of COLREG by passing traffic distinguished by the observer onboard Ole III”

Data Type	Percentage	Number of Data Points (Crossings)
Training	60%	101
Test	20%	33
Evaluation	20%	34
Total	100%	168

- Training and Test Input Preparation
  - 845 Images Captured on Training and Test Dataset
  - 442 Selected for Training and Test

- Class Definitions

Class Number	Class Name	Description
0	Ole	Ole III
1	Motorboat	All the vessels with engines for propulsion including jet-skies
2	Sailboat	Sailboats sailing or using engines
3	Rowboat	Vessels with human energy as propulsion
4	Other	Utility, construction, and passenger vessels

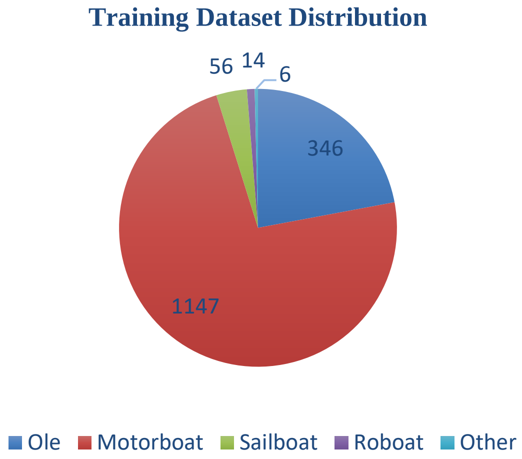
Training Inputs

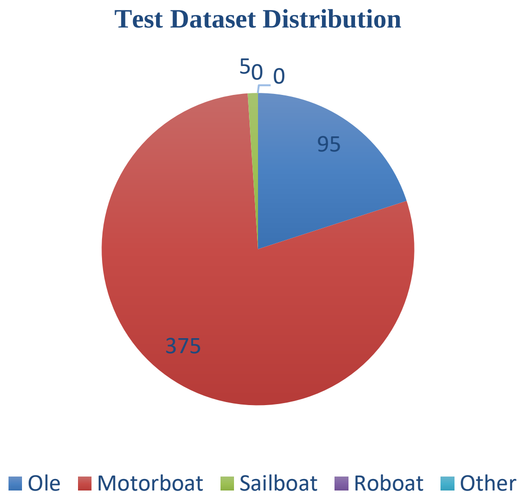
- Input Preparation


```
0 0.348828 0.372917 0.053906 0.048611
1 0.695703 0.381944 0.066406 0.041667
1 0.767969 0.470139 0.103125 0.087500
1 0.706641 0.451389 0.121094 0.080556
1 0.560938 0.413194 0.042188 0.026389
2 0.489844 0.344444 0.059375 0.150000
3 0.592188 0.445139 0.060938 0.029167
4 0.807813 0.397222 0.132812 0.108333
```

- Object Distribution in Training and Test Inputs

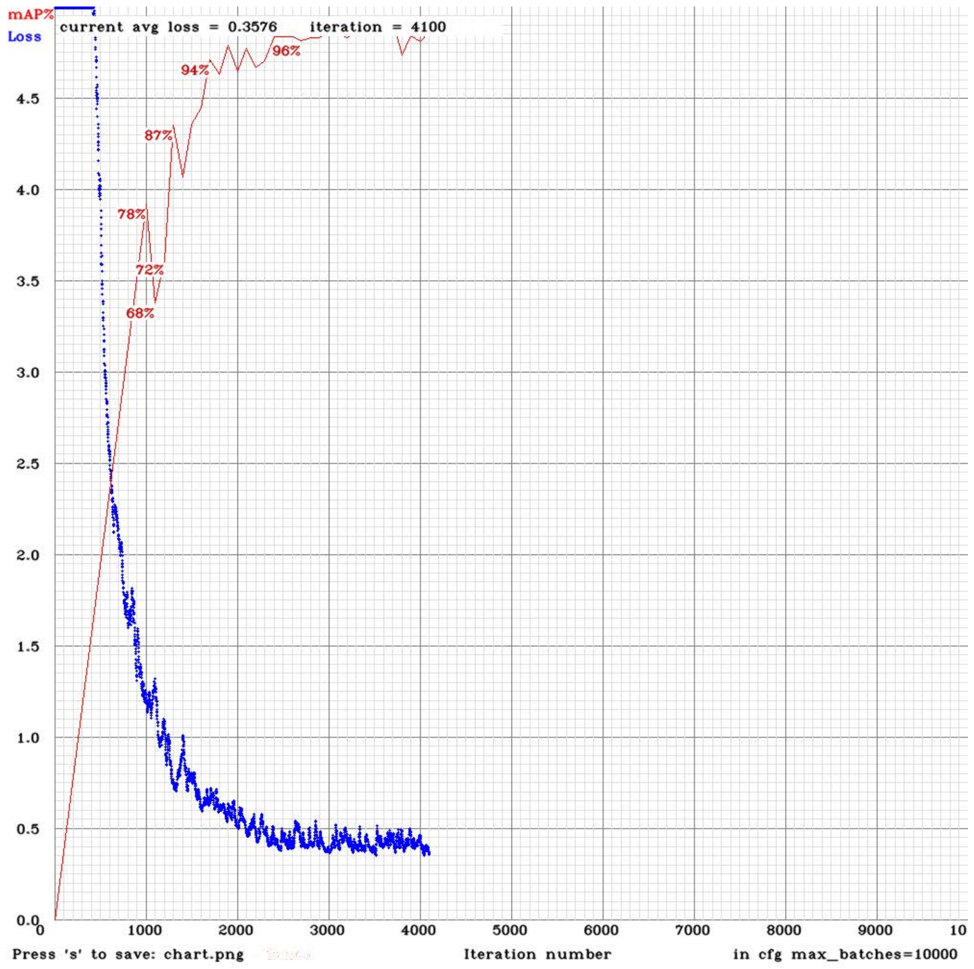
Description	Number of Images	Class Content (Number of Objects)					
		Ole	Motorboat	Sailboat	Rowboat	Other	Total
Training Dataset	347	346	1147	56	14	6	1569
Test Dataset	95	95	375	5	0	0	475



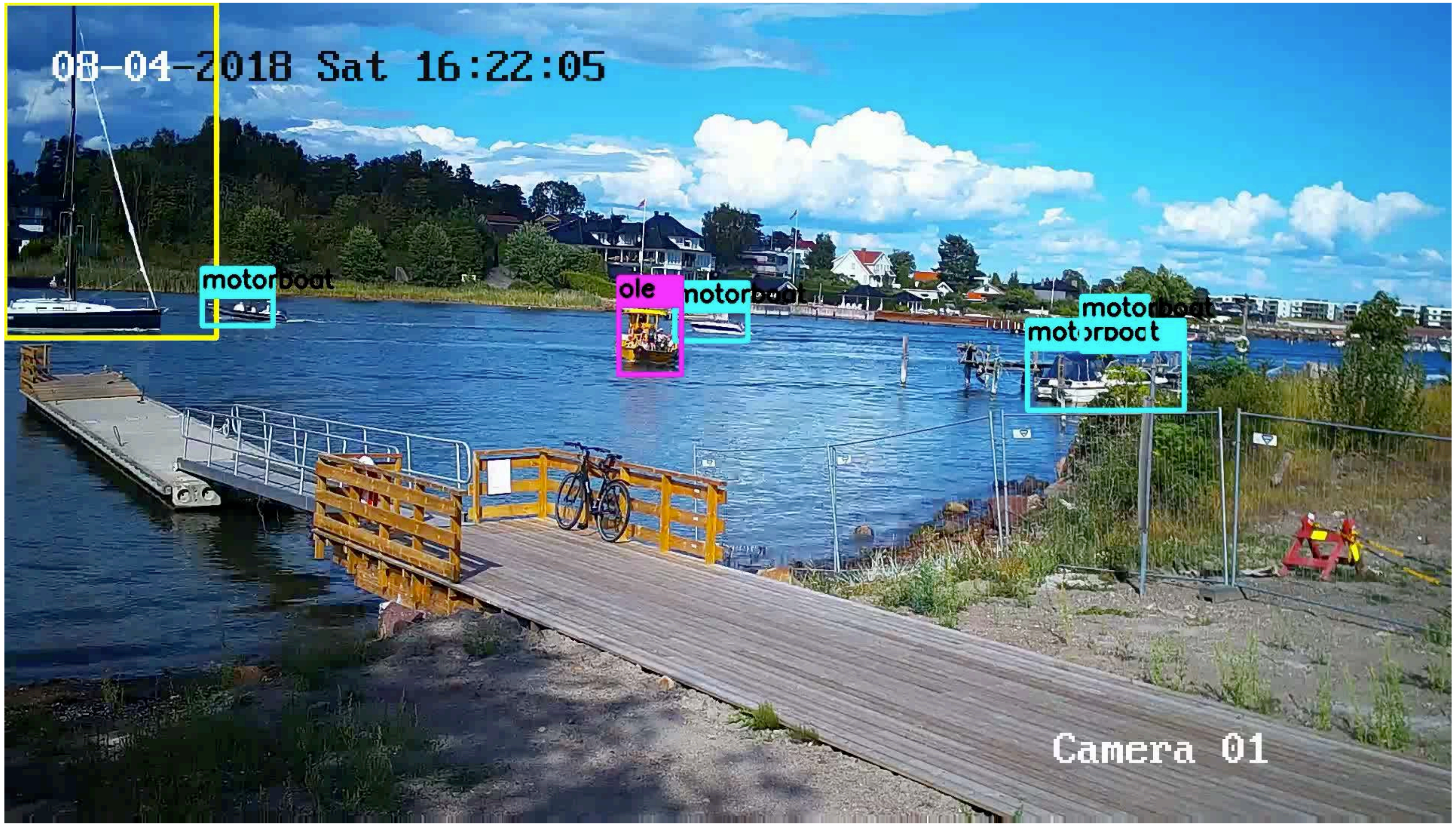


Results – Training of YOLO

- Elbow Point at Epoch 2000
- Training Accuracy 94%
- Detection Criteria for YOLO
- Misdetection and Misclassification Errors



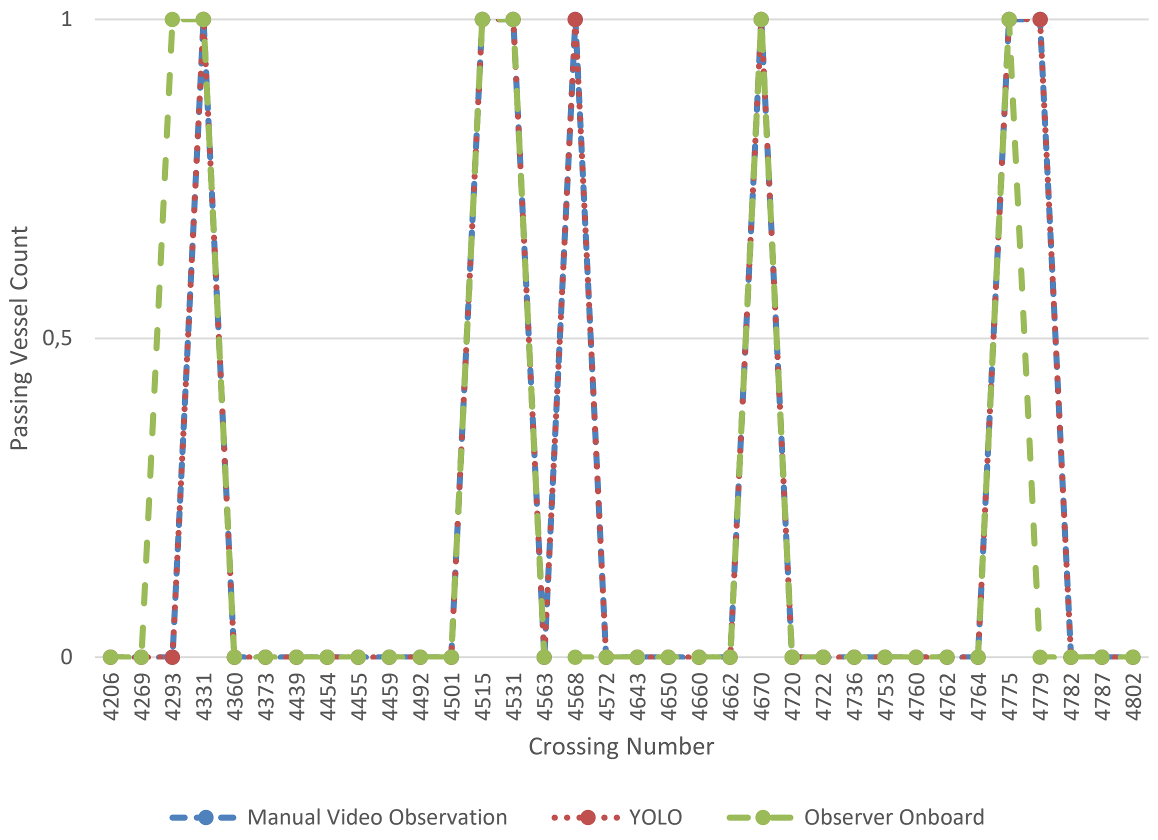
Results – Sample Video of YOLO v3 Detections - 4775



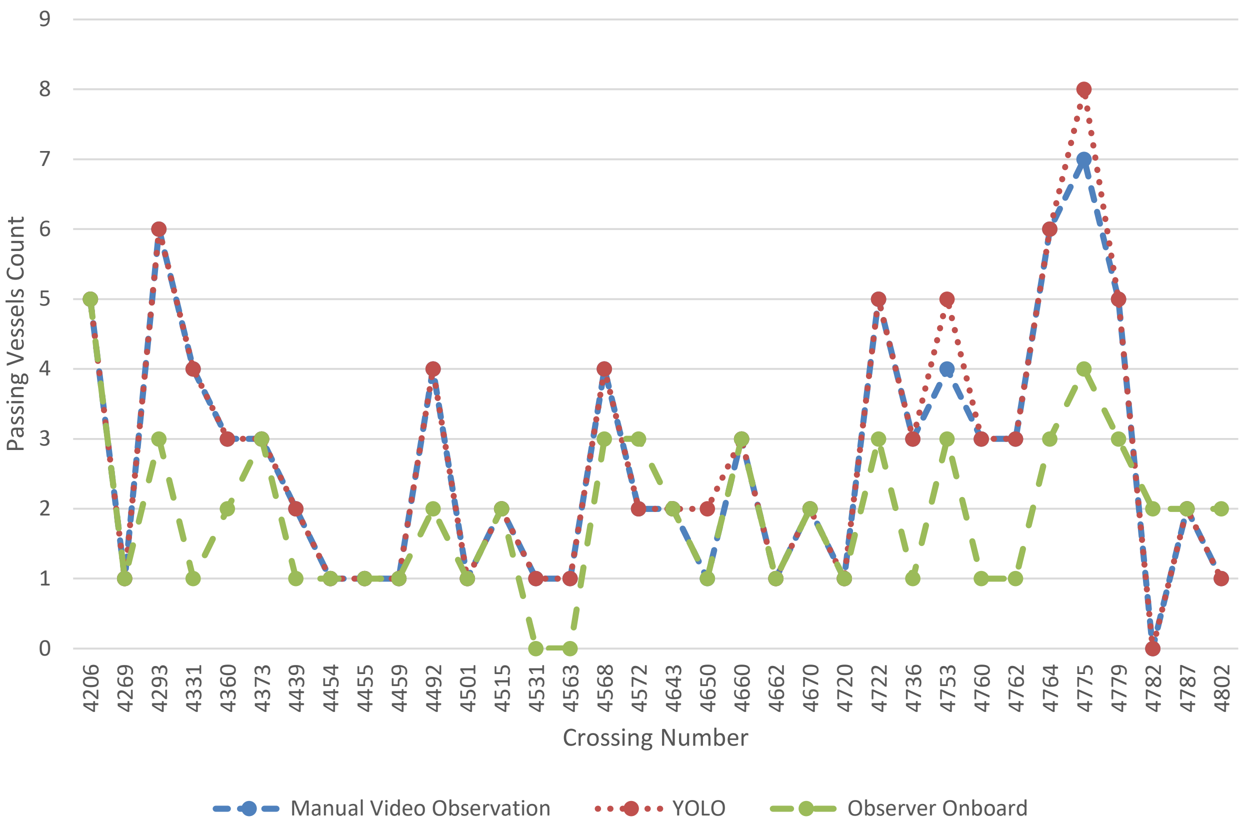
Results – Ole and Sailboat Classes

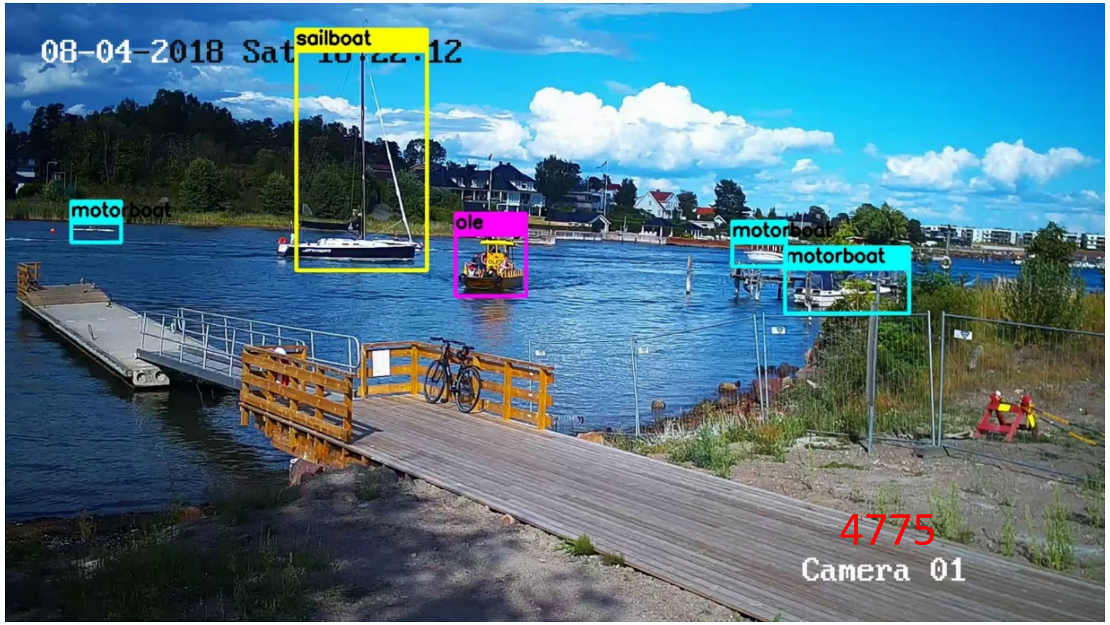
- Ole Class
  - Observer Onboard
    - Not Applicable
  - YOLO
    - 100% Accuracy
  - Manual Video Observation
    - Not Applicable

- Sailboat Class

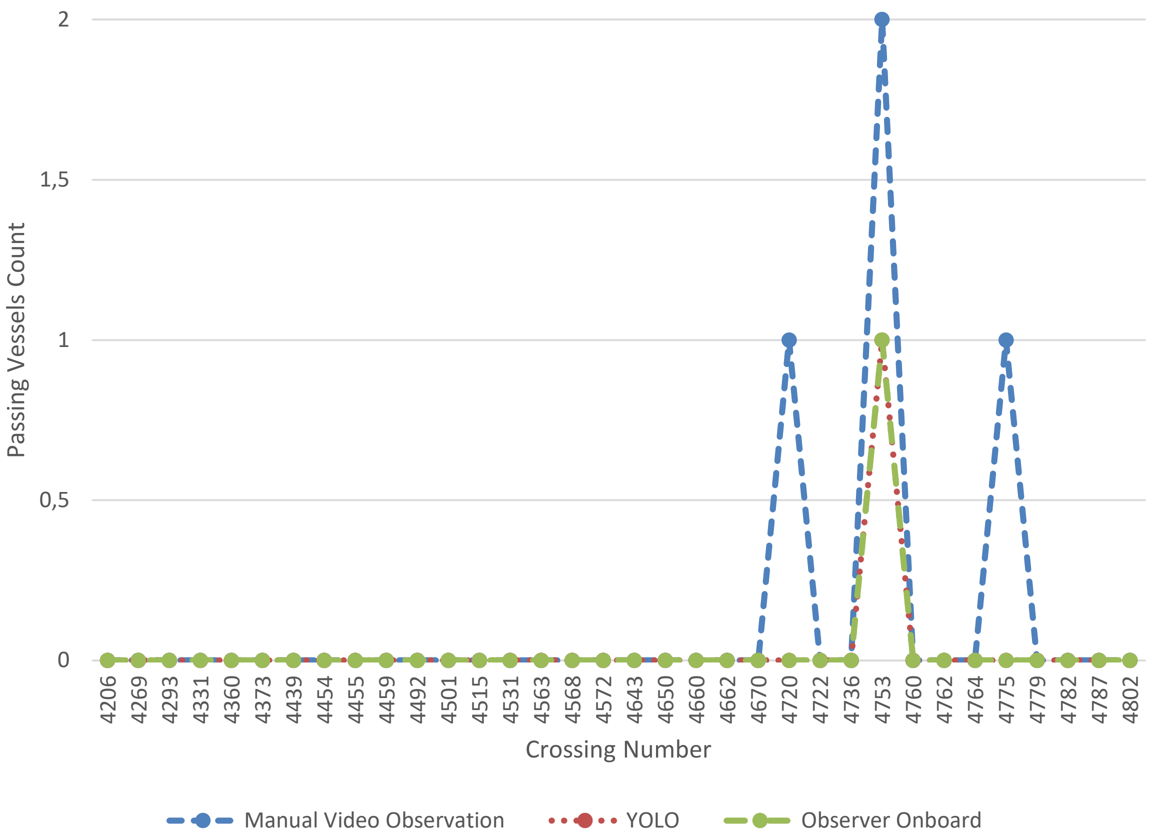


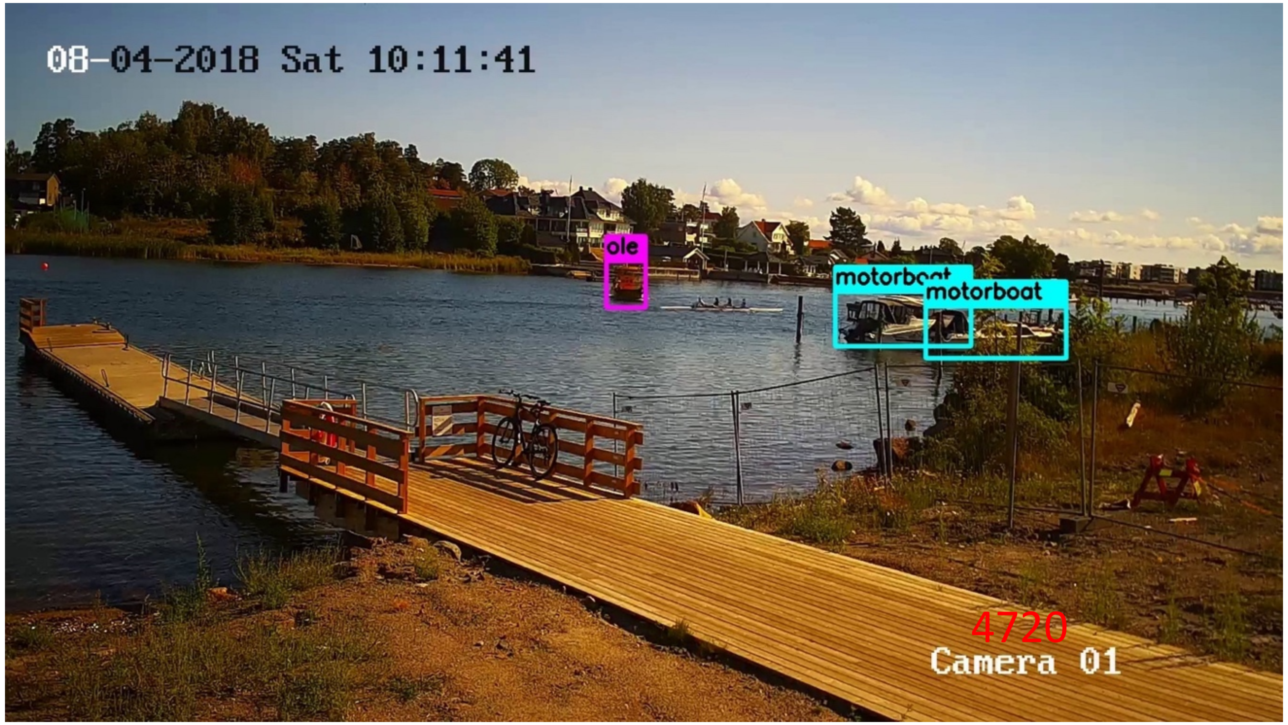
Results – Motorboat Class



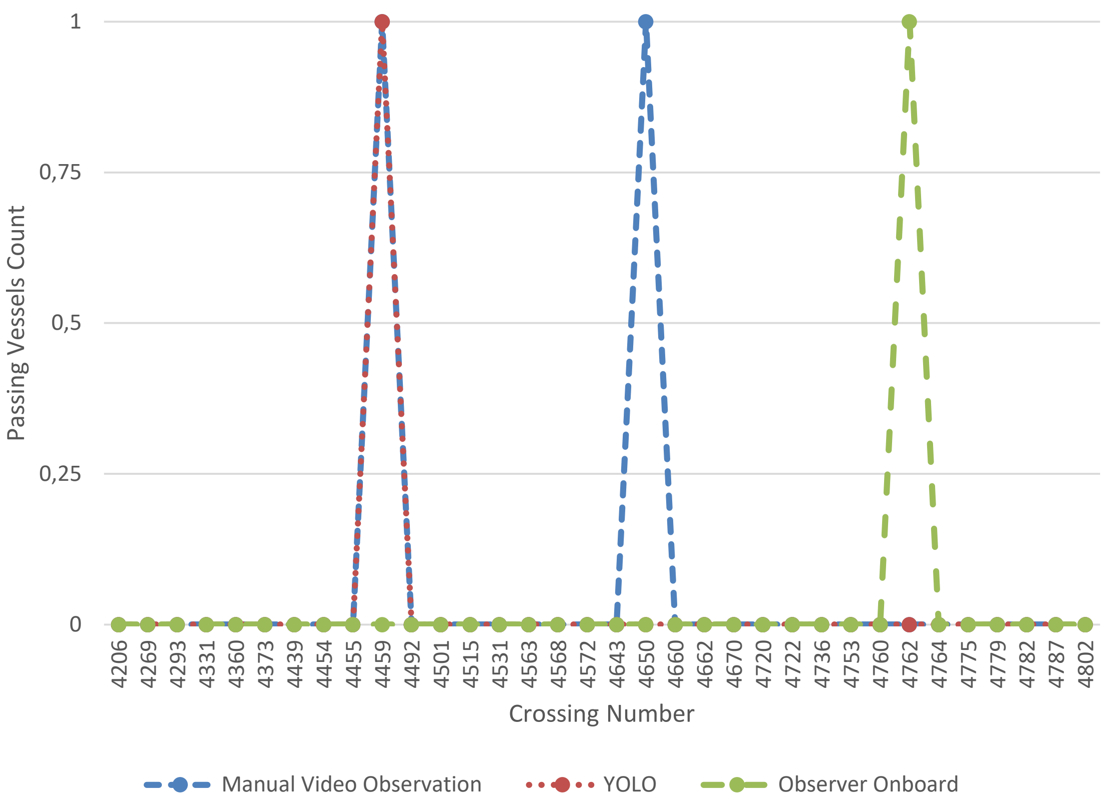


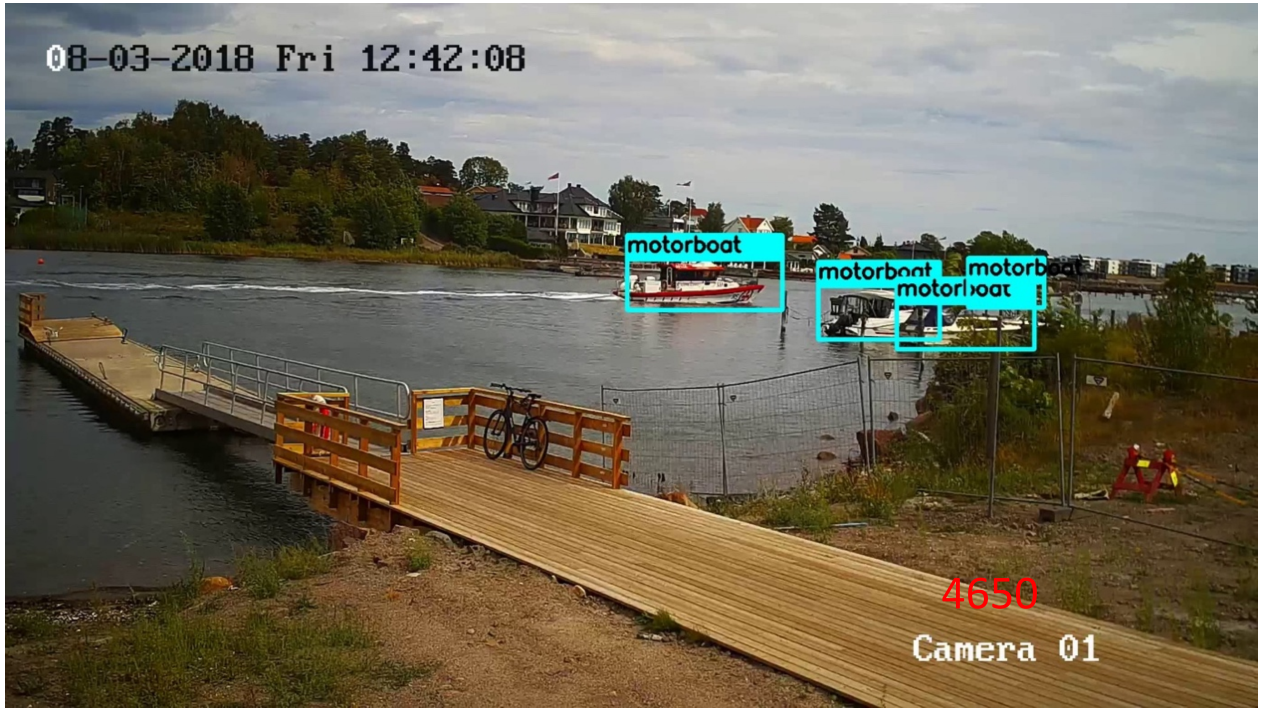
Results – Rowboat Class



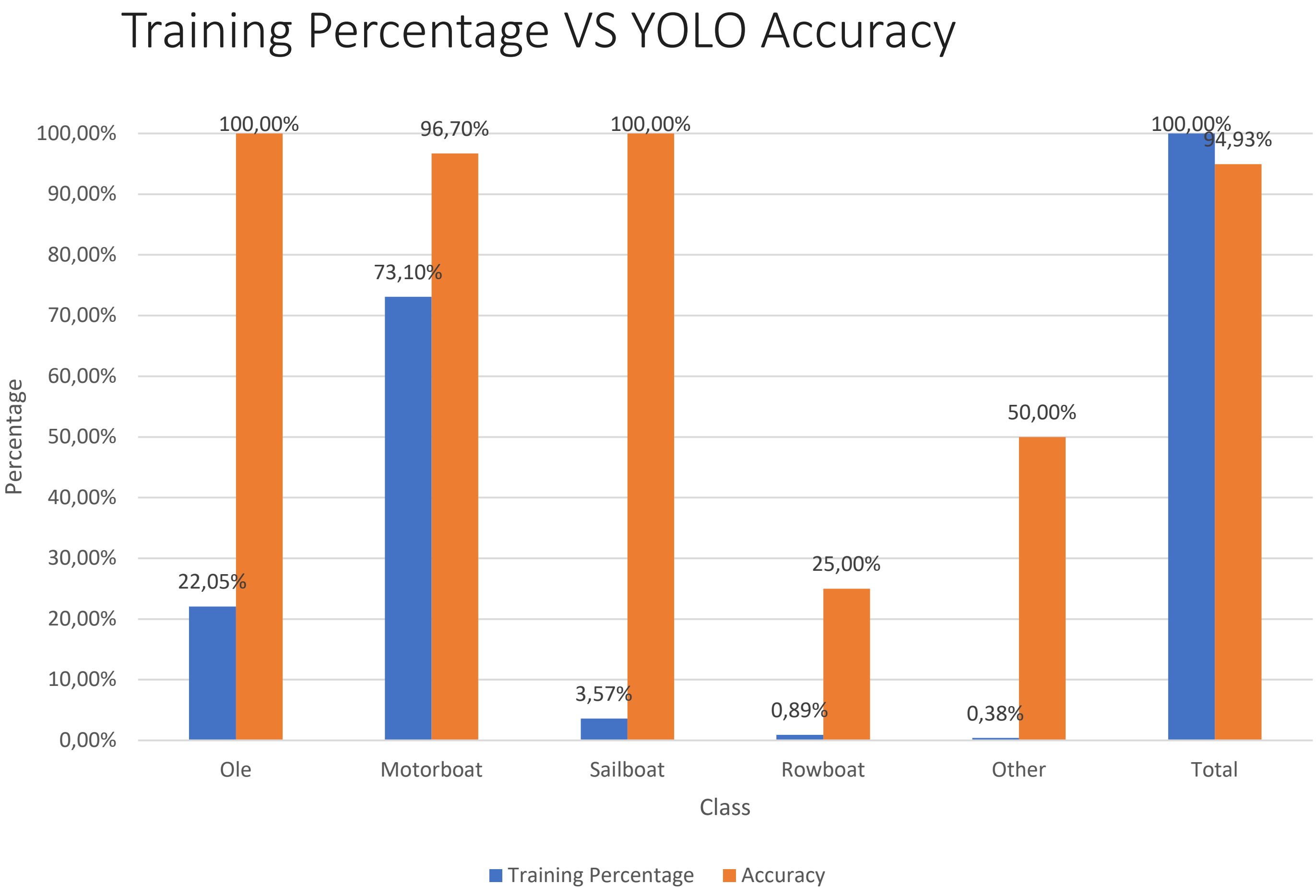


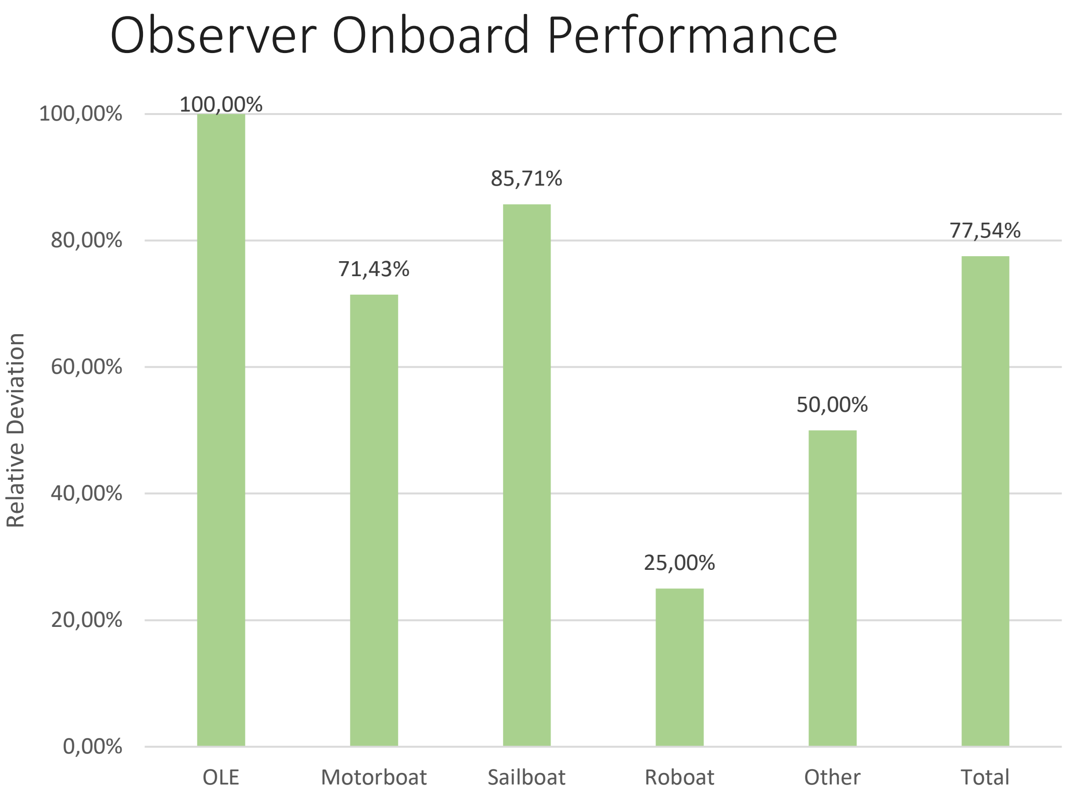
Results – Other Class





Discussions





Discussions

- Validity and Reliability
  - YOLO Accuracy During Training/Test Phase : 94%
  - YOLO Accuracy in Evaluation Phase: 95%
- Benchmarks:
  - PASCAL VOC, COCO Not Applicable
  - Rodin et al. (2018) 92.5%
  - Yang-Lang et al. (2019) 90.0%
- Misclassification and Misdetection Errors
- Traffic Situation
- Application in Autonomous Operations
- Hardware Reliability

Limitations

- Secondary Data
- Generalization
- Observer Onboard Evaluations
  - Primary Objective: COLREG Violation and Captains Decision
  - Secondary Objective: Traffic Reporting in Case of Affecting the Navigation of Ole III
  - Different Detection Criteria with YOLO
  - Different Field of View in Comparison with Camera
- Camera Resolution and Video Speed (FPS)
- Computational Power

Conclusions

- Detection accuracy of YOLO was lower in the classes with lower percentage contribution in the training phase while classes with a higher number of objects in the training phase achieved higher accuracy.
- YOLO achieved 94% and 95% detection accuracies on training/test and evaluation phases.
- The accuracies are within the same range as benchmarks.
- Well-developed computer vision algorithm is a promising alternative for practical applications.
- Inconsistencies are seen between observational reports and video recordings.
- Further research is needed to evaluate the safety aspects of implementing this technology.

Recommendations for Future Research

- Increase the number of training inputs by analyzing more crossings.
- Implement the system on other settings.
- Different camera arrangements.
- Comparison with other computer vision systems in the same settings.
- More systematic observations with improved instructions.

Thank You For Your Attention

Any Questions?