CAPSTONE PROJECT

Oil Spill Detection from Satellite Imagery

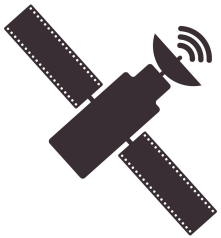
WARINTORN NAWONG

AGENDA

- Problem Statement
- Introduction of Oil Spill
- Introduction of Satellites Imagery
- Model Development Journey
- Conclusion

PROBLEM STATEMENT

To develop OIL Spill Detection from ***Satellite Images*** in order to build spilling detection system.



OIL SPILL MONITORING SYSTEM

REACTIVE DETECTION

To identify oil spilled properties i.e. Location, Size of Spilled Boundary etc. to launch the oil spill response plan according to **IMO/UNEP** Standard and Guidelines.

PROACTIVE DETECTION

To establish the **schedule-based ocean monitoring** to ensure the compliance of oil spill prevention of related operator.

THE CONSEQUENCE OF OIL SPILLS

Environmental Impacts

Oil spill events caused damage to **wildlife, marine ecosystems**, and **coastal environments**.

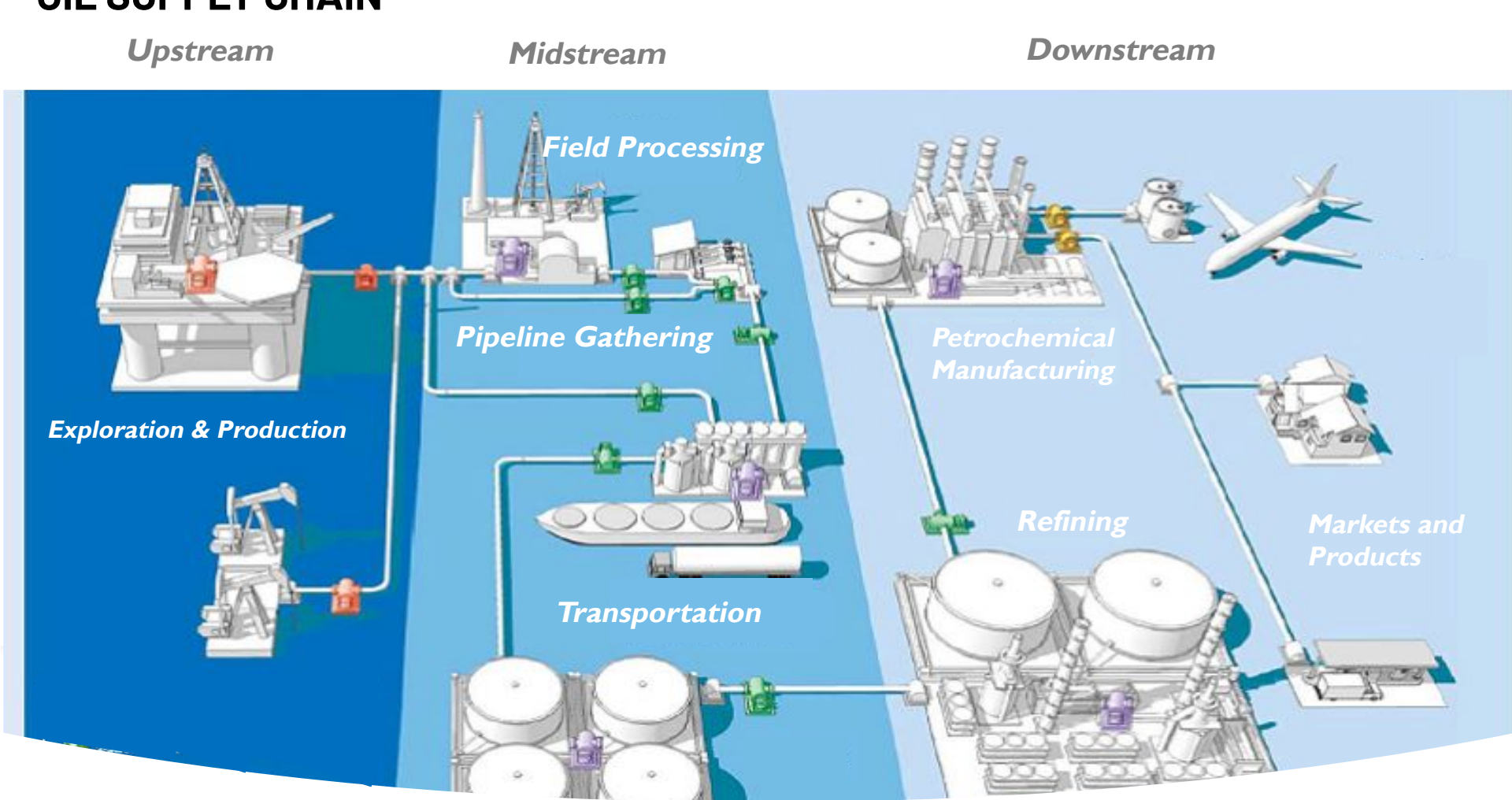
Economical Impacts

Oil spills can lead to severe disruption of the **tourist industry**.

Human Impacts

Oil spills impact on human health, including **respiratory,** and **immune system** damage.

OIL SUPPLY CHAIN



CAUSE OF OIL SPILL

Oil Tanker/Transport Vessels

Oil Rig/Platform

Pipeline

Storage tanks

≈ 50.0 %

of all oil spills are directly or indirectly caused by **human error.**

≈ 40.0 %

of oil spills are attributed to **equipment failure or malfunction**.

≈ 21.0 %

of oil releases are from **Operational discharges** from vessels.

SOURCE :World Scientific Series in Current Energy Issues, Michel, Jacqueline; Fingas, Merv, Journal of Hazardous Materials, Burgherr, Peter.

OIL SPILL CHARACTERISTICS

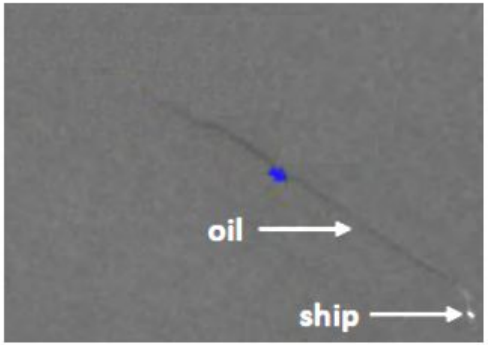
Operational Discharges

- Tank-washing Procedure
- Platform-sourced pollution

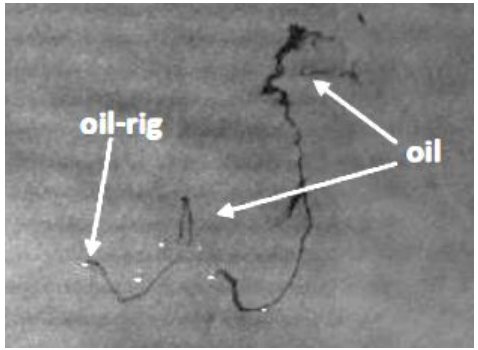
Accidental Discharges

- Ship Accident
- Platform Accident

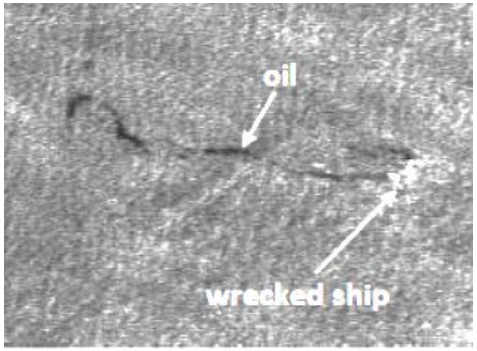
Straight Linear



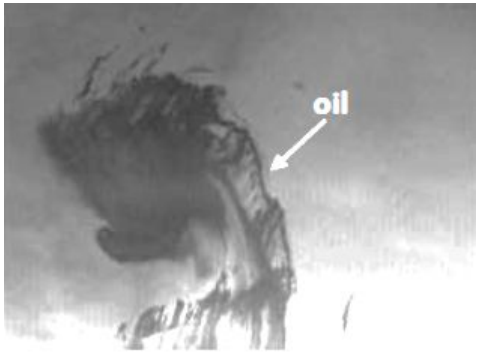
Curvilinear



Discontinuous Patches



Rounded Shape



SOURCE : SAR Marine Applications – DR. Domenico Velotto, European Space Agency

OIL SPILL CHARACTERISTICS

LINE SHAPE

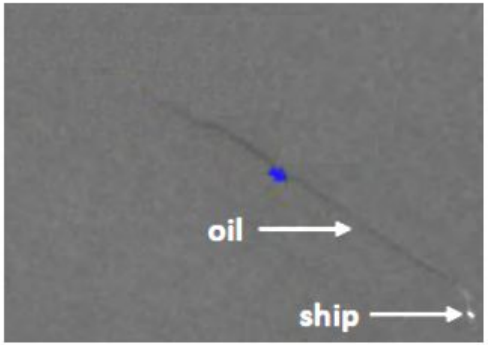
Operational Discharges

- Tank-washing Procedure
- Platform-sourced pollution

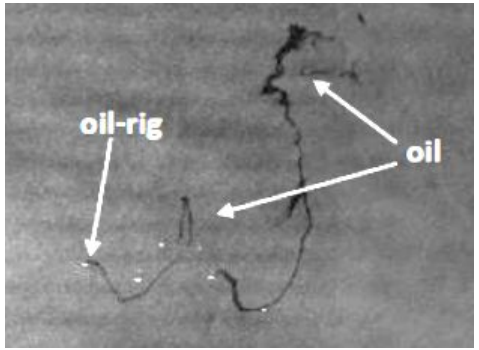
Accidental Discharges

- Ship Accident
- Platform Accident

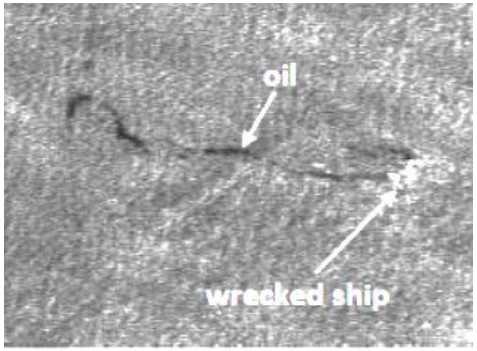
Straight Linear



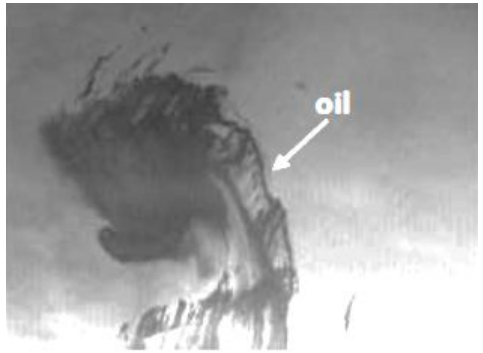
Curvilinear



Discontinuous Patches



Rounded Shape



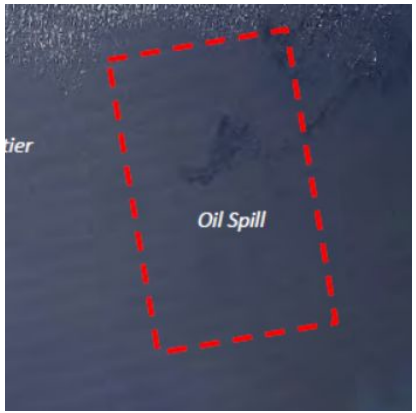
NON-LINE SHAPE

SOURCE : SAR Marine Applications – DR. Domenico Velotto, European Space Agency

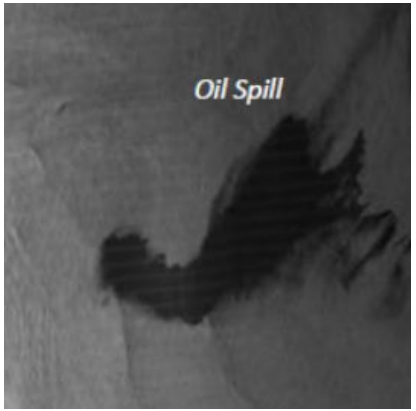
SATELLITES IMAGE TYPES OF OCEAN MONITORING

- OPTICAL
  - VISIBLE
  - INFRARED
  - ULTRAVIOLET
  - LFS
- MICROWAVE
  - MWR
  - SAR

Example of **Optical Image** acquired by the NASA Satellite



Example of **Synthetic Aperture Radar (SAR) Image** acquired by the Terra SAR-X.



SOURCE : SAR Marine Applications – DR. Domenico Velotto, European Space Agency

SATELLITES IMAGE TYPES OF OCEAN MONITORING

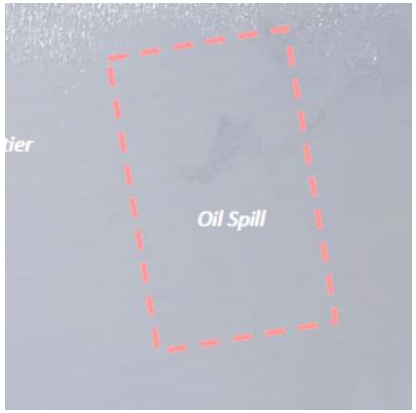
OPTICAL

VISIBLE | INFRARED | ULTRAVIOLET | LFS

MICROWAVE

MWR | **SAR**

Example of **Optical Image** acquired by the NASA Satellite



Example of **Synthetic Aperture Radar (SAR) Image** acquired by the Terra SAR-X.

SOURCE : SAR Marine Applications – DR. Domenico Velotto, European Space Agency

THE STRENGTH OF SAR IMAGES

“ Synthetic Aperture Radar (SAR)“

All WEATHER CONDITION

SAR sensors are self-illuminating and can **penetrate clouds, fog, smog, darkness** and **smoke.**

24 HR OPERATION

SAR satellites can capture images from precisely the **same imaging geometry** every 24 hours.

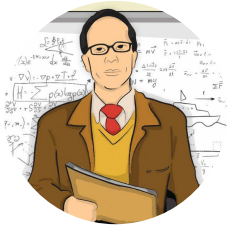
HIGH SPATIAL RESOLUTION AND COVERAGE

SAR can provide a **wide range** of spatial resolution and coverage.

DATASET

DATASOURCE

The trained data source **(SARImgV3)** is stored in Roboflow websites.



DATA PROVIDER

The data is provided by Mr. Matteo Attimonelli. (Student of Oil Spill Detection Professor)

TYPE OF DATA

The Oil spill Satellite Data is the **Synthetic Aperture Radar (SAR)** type.

1,400

No. of TRAIN SET

200

No. of VAL SET

100

No. of TEST SET

416 x 416

Dimensions (pixels)

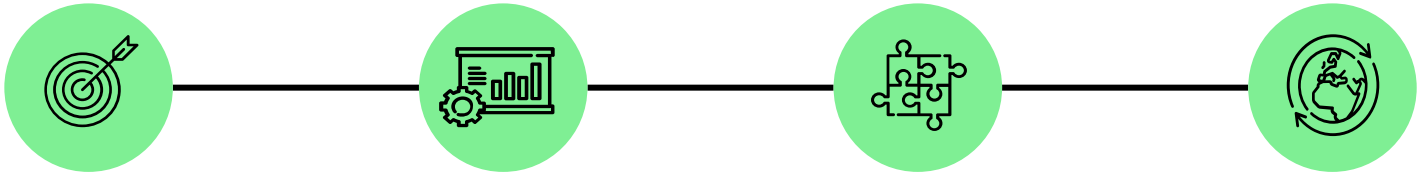
MODEL DEVELOPMENT JOURNEY

MODEL PRIMARY SELECTION

To select the most appropriate model.

OIL SPILL SHAPE AUGMENTATION

To do shape-based image augmentation.



EPOCHS OPTIMIZATION

To find the most optimized epochs per performance.

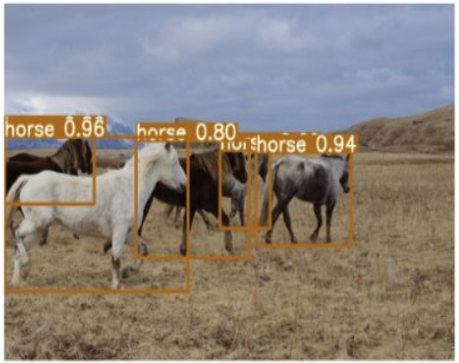
OIL SPILL DIRECTION EQUALIZATION

To do direction-based image augmentation.

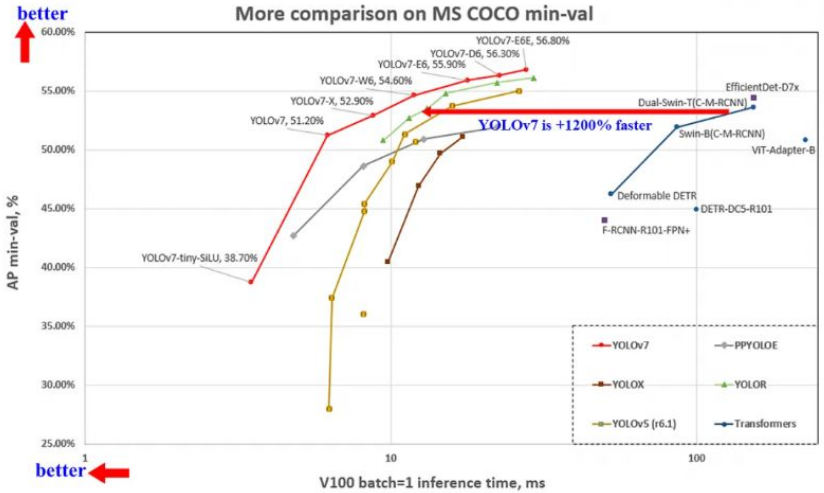
MODEL PRIMARY SELECTION

YOLO (YOU ONLY LOOK ONCE) **Version 7**.

Original Image



Detected Image



YOLOv7 Architecture

- Extended Efficient Layer Aggregation Network (E-ELAN).
- Model Scaling for Concatenation based Models.

" YOLOv7 is the **fastest** and **most accurate** real-time object detection model for computer vision tasks. (2022) "

SOURCE : https://blog.roboflow.com/yolov7-breakdown/

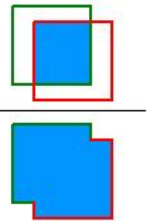
EPOCH OPTIMIZATION

mAP : Mean Average Precision

$$mAP = \frac{1}{|classes|} \sum_{c \in classes} \frac{|TP_c|}{|FP_c| + |TP_c|}$$

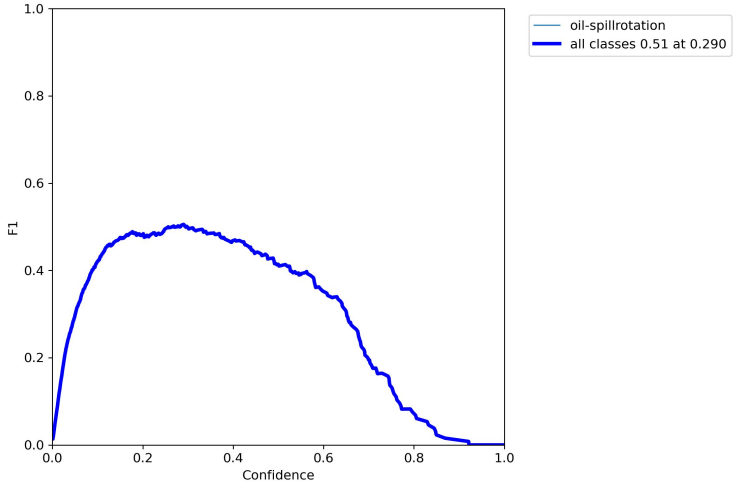
IoU : Intersect Over Union

$$IOU = \frac{\text{area of overlap}}{\text{area of union}} =$$



Metrics	200 EPOCHS	300 EPOCHS
Precision	0.598	**0.675**
Recall	**0.438**	0.352
mAP @ IoU > 0.5	**0.432**	0.367

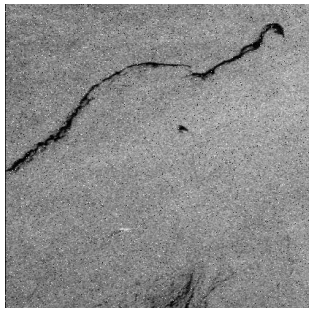
BASELINE RESULTS



Metrics	200 EPOCHS
Precision	0.598
Recall	0.438
mAP @ IoU > 0.5	0.432

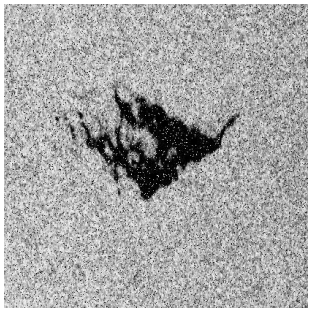
ERROR ANALYSIS

01 Imbalanced Shape Prediction



Line Shape Oil Spill

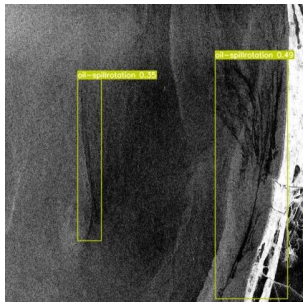
> 70 ~ 80 % of Training Set.



Non-line Shape Oil Spill

< 20 ~ 30 % of Training Set.

02 Spill Direction Bias Prediction

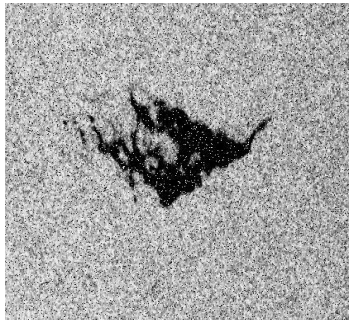


Vertical-like Direction

Horizontal-like Direction

IMAGE AUGMENTATION STRATEGY

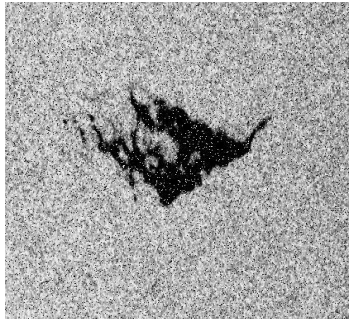
Add 300 pics.



01

NON-LINE SHAPE AUGMENTATION FOR 300 PICs.

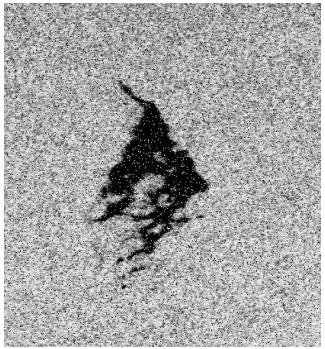
Add 900 pics.



02

NON-LINE SHAPE AUGMENTATION FOR 900 PICs.

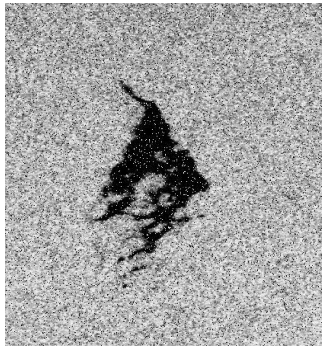
Add 300 pics.



03

Version 01 with 90 deg Rotation AUGMENTATION.

Add New augmentation



04

Version 03 with New Augmentation Properties.

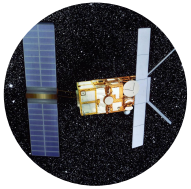
MODEL COMPARISON

Metrics (Test Set)	300 Non-line augmentation	900 Non-line augmentation	300 Non-line augmentation with 90-rotation.	300 Non-line with additional augmentation.
Precision	0.675	0.659	0.599	0.599
Recall	0.352	0.429	**0.457**	0.449
Max F1 Score	0.51 @ 0.413 conf	0.52 @ 0.29 conf	**0.52 @ 0.29 conf**	0.51 @ conf
mAP @ IoU > 0.5	0.367	0.429	**0.453**	0.439

ERROR ANALYSIS ON REAL CASE

SENTINEL-1/2

EUROPEAN SPACE AGENCY



ERS-1/2

EUROPEAN SPACE AGENCY

ENVISAT

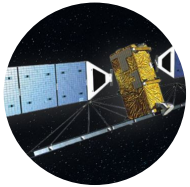
EUROPEAN SPACE AGENCY

ALOS-2

JAXA

Terra SAR-X

German Aerospace Center



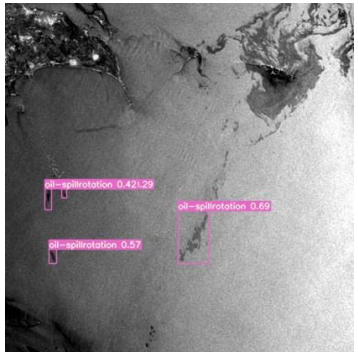
RADARSAT-1/2

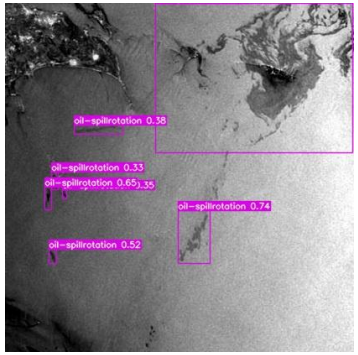
Canadian Space Agency

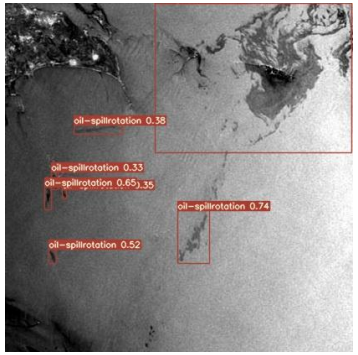
15 Major Oil Spill Events around the world

POST-AUGMENTATION RESULTS

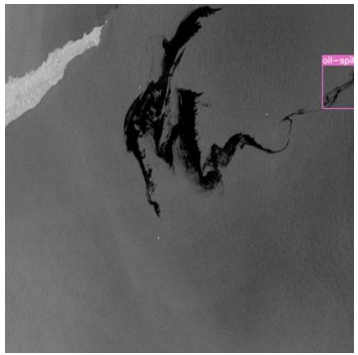
Oil Spill Case from Caspian Sea, Azerbaijan



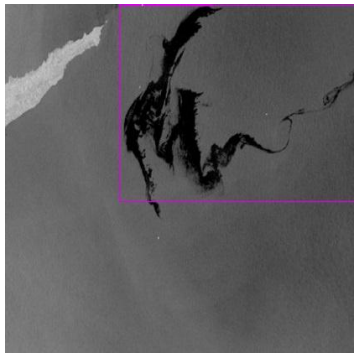




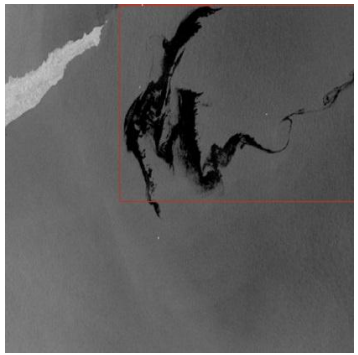
Oil Spill Case from Latakia, Syria to Cyprus



Before non-line shape augmentation



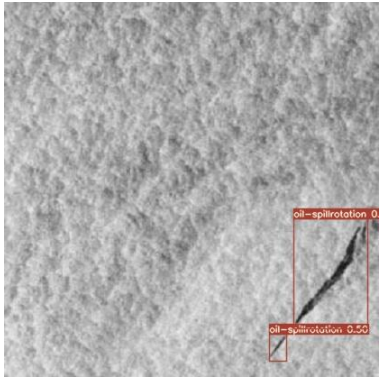
After non-line shape augmentation ver. 1



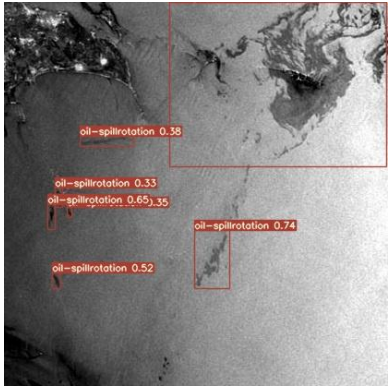
After non-line shape augmentation ver. 3

BEST MODEL PREDICTION

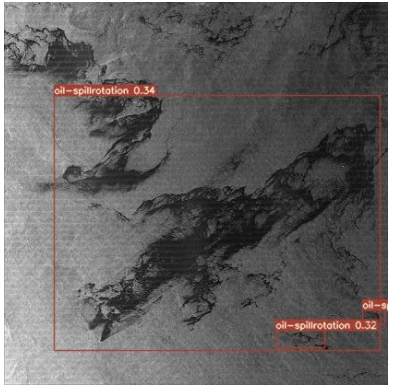
East China Sea, China/Japan



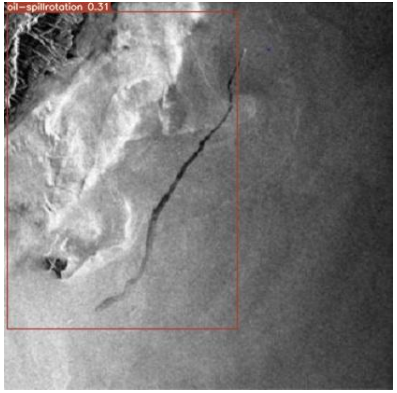
Caspian Sea, Azerbaijan



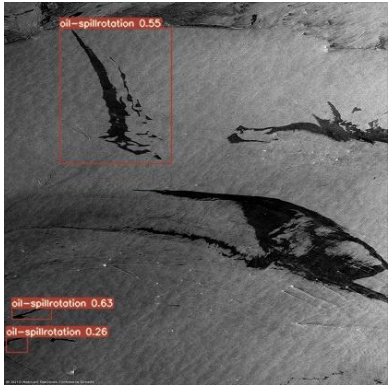
Montara, Australia



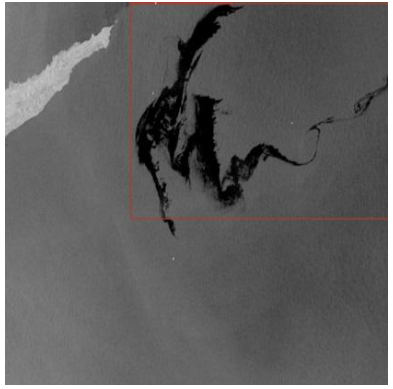
Kuroshio, Taiwan



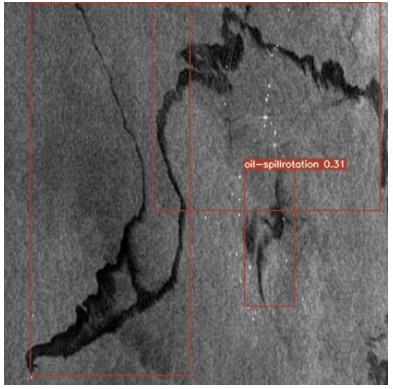
Gulf of Mexico, USA



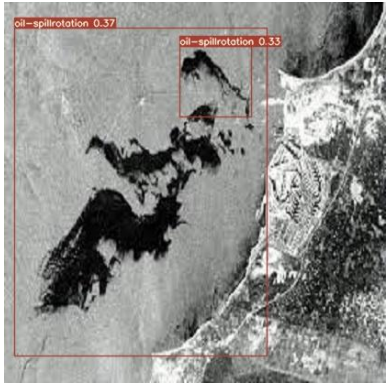
Latakia, Syria to Cyprus



Coast of Galicia, Spain

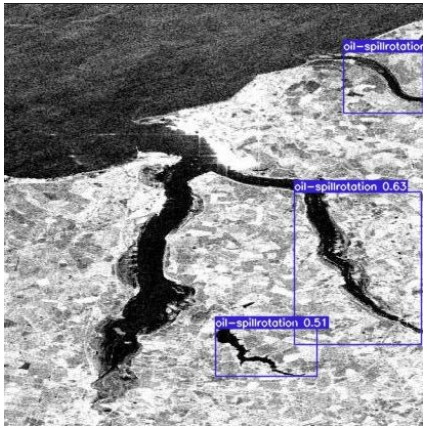


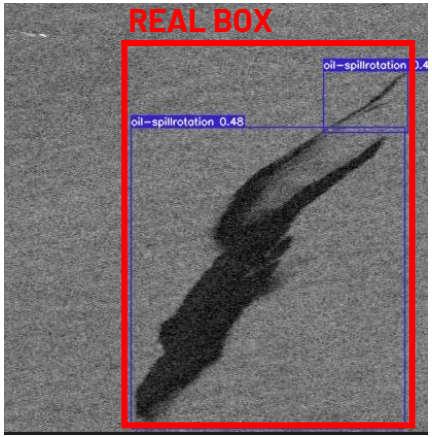
Al Khafji, Kuwait



MODEL CONSTRAINTS

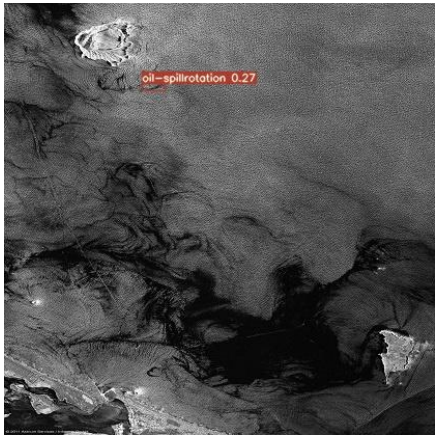
FALSE POSITIVE (FP)





- Model misclassified the label of real objects such the **river or water** resource near the ocean.
- Model framed the over/undersize of the real label which caused the low score in **mAP@IoU > 0.5**.

FALSE NEGATIVE (FN)



- Model could not detect high complexity of oil spill shape.

CONCLUSION

01 Final Model : YOLOV7

02 Augmented Method

- 90 Rotate : Clockwise, Counter-Clockwise and Upside Down.
- Crop : 0 – 37 % of Zoom
- Rotation : -5 to 5
- Brightness : -30 - 0 %
- Blur : Up to 2 Px
- Noise : Up to 10% of pixel

03 Hyperparameter

- **Defaults Hyperparameter** as per developer suggestions such as Lr0 = 0.01, Lrf = 0.1 etc.

04 Model Performance

Metrics (Test Set)	Baseline	Best Model
Precision	0.598	0.599
Recall	0.438	0.457
Max F1 Score	0.51 @ 0.29 conf	0.52 @ 0.29 conf
mAP @ IoU > 0.5	0.432	0.453

05 Model Constraints

- Real water resource misclassification
- Wrong size of box prediction
- Complexity of Shape misclassification

WAY FORWARD

Consult Domain Experts

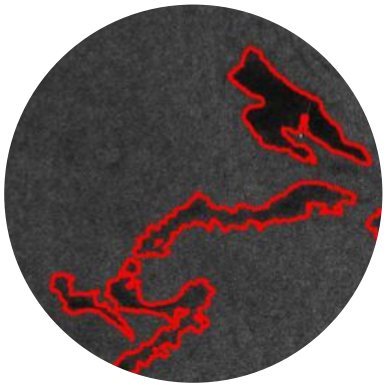
To explore more features of **oil spill and ocean characteristics** with domain experts to boost spill detection.

Satellite Data

To gather a higher size of train data to increase the **model performance** and **reliability**.

Explore more data in Thailand

To seek out Thailand-based satellite data to **domestically utilize** oil spill detection in risk location i.e. Gulf of Thailand.



Alternative Options

To explore more advanced options such as **image segmentation** in order to reduce the limitations of object detection.


THANK YOU
for listening!