Deep Learning Based Oil Spill Detection Using Sentinel-1 SAR Data

I. Introduction

The Eastern Mediterranean Sea is known as an oil pollution hotspot because of the high level of marine traffic and the growth of oil and gas related industrial activity. With the advantage of wide coverage and all-weather observations, Spaceborne Synthetic Aperture Radar (SAR) has played an important role on efficient oil spill detection, but discriminating whether the dark formations in the SAR imagery are from actual oil spills or "look-alikes" remains a challenge. The general procedures involve dark spot segmentation, feature extraction and classification. However, segmenting the dark spots from their background at the same time discards the information of how oil spills look different from their surroundings, which is especially important in the case of oil spills inside algal blooms. This study applied the deep learning based You Only Look Once version 4 (YOLOv4) object detection algorithm [1] for learning not only the features from oil spills but also from the background and aims to evaluate the possibility of applying it to operational oil spill detection.

II. Methodology

The study area is located in the Eastern Mediterranean Sea, between latitudes 30–36°E and longitudes 31–34.7°N. Sentinel-1 SAR Level-1 Ground Range Detected (GRD) products were acquired and pre-processed with the standard corrections. The oil spills inside the pre-processed images were labelled as oil spill objects by two trained individuals to avoid the bias, which were then used to train and fine tune the YOLOv4 object detector and to evaluate the model performance. Different from most of the deep learning based object detection methods which only look at the parts of images with a higher chance of containing an object, YOLO [2] sees the entire image and uses its contextual information about classes along with their appearance. This study applied one-class (i.e. oil spill) object detection, the look-alikes inside the image were regarded as background information. In this preliminary stage, the pre-processed results from 2015 to 2016 with 1999 scenes in total were used for model training, with the training and validation data sets in the proportion of 7:2. Images acquired in 2017 were used to demonstrate the performance of the preliminary test in the following section.

III. Preliminary Results

The average precision of the trained model which calculated from the validation set is 67.9%. Figure 1 shows some examples of the preliminary detection results. The yellow bounding boxes are the oil spill objects detected by the trained model and the confidence score and the red bounding boxes represent the ground truth oil spills which were not detected. Figure 1 (a–d) show some well detected oil spills which are small, inside active transponder interference or near look-alikes. Figure 1 (e–f) show the examples of large oil spills which were not detected. There are many small and regular oil spills in the Eastern Mediterranean Sea, only 7% of the oil spill objects in our training and validation sets have a bounding box with area greater than 40 km^2, thus the performance for detecting large oil spills is not as good that for small ones.

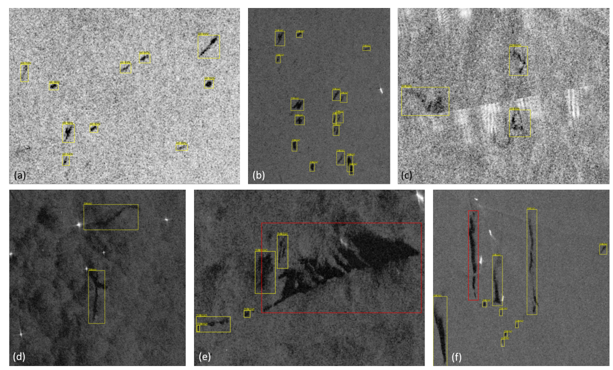

Fig. 1. Some examples of the preliminary detection results. The yellow bounding boxes show the prediction and the confidence score. The red bounding boxes are the oil spills which were not detected by YOLOv4.

IV. Conclusion

This study has applied a preliminary test for oil spill detection with satellite SAR imagery based on the YOLOv4 object detection algorithm. The performance for detecting oil spills seemed to work better when they were small, even inside disturbing signals or near look-alikes, than large oil spills as some of them were not detected. It is suggested that increasing the amount of large oil spill objects in training and balancing the ratio of oil spill objects with different sizes might help improve the overall performance. With the experience from this preliminary test, an improved object detection model and its extensive performance evaluation are foreseen in the near future.

References

[1] A. Bochkovskiy, C.-Y. Wang and H.-Y. M. Liao, "YOLOv4: Optimal Speed and Accuracy of Object Detection," arXiv preprint arXiv:2004.10934, 2020.

[2] J. Redmon, S. Divvala, R. Girshick, and A. Farhadi, "You only look once: Unified, real-time object detection," Proceedings of the IEEE Computer Society Conference on Computer Vision and Pattern Recognition, pp. 779–788, 2016.