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북한 강선 핵시설 인근 선박 이동량 모니터링
: Sentinel-1 영상의 객체 탐지와 오픈 소스 GIS를 연계하여

Monitoring Vessel Movements Near North Korea's Kangson Nuclear Facility
: Object Detection of Sentinel-1 Imagery Using Yolov5 and Integration

FOSS4G
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Contents

0. About Presenter

- As a junior geospatial researcher, I aim to contribute to and eventually lead technological innovation by leveraging OSINT (Open Source Intelligence) and open-source projects to address complex geospatial challenges.

Education

Integrated PhD in Civil & Environmental Engineering, Seoul National University (2024~)

BS in Human Environment Design, Yonsei University (2016 ~ 2021)

Professional

Industry Consultant, Dassault Systèmes, Seoul (2022 ~ 2024)

Interest

Estimation of Geospatial Information in Restricted Access Zones, Geospatial AI, Open-source GIS Development

- This study presents an approach utilizing Open Source Intelligence (OSINT) to effectively monitor vessel activity near North Korea's Kangson nuclear facility, which has recently been identified by U.S. and South Korean intelligence agencies as a key site for nuclear material production
- ...Current research largely relies on non-public satellite data, limiting accessibility and transparency. This study utilizes OSINT open data to enhance transparency, playing a key role in monitoring North Korea's non-proliferation.

Technical Note

OSINT-Based Vessel Traffic Analysis Near North Korean Kangson Nuclear Sites using Sentinel-1 imagery and Yolov5

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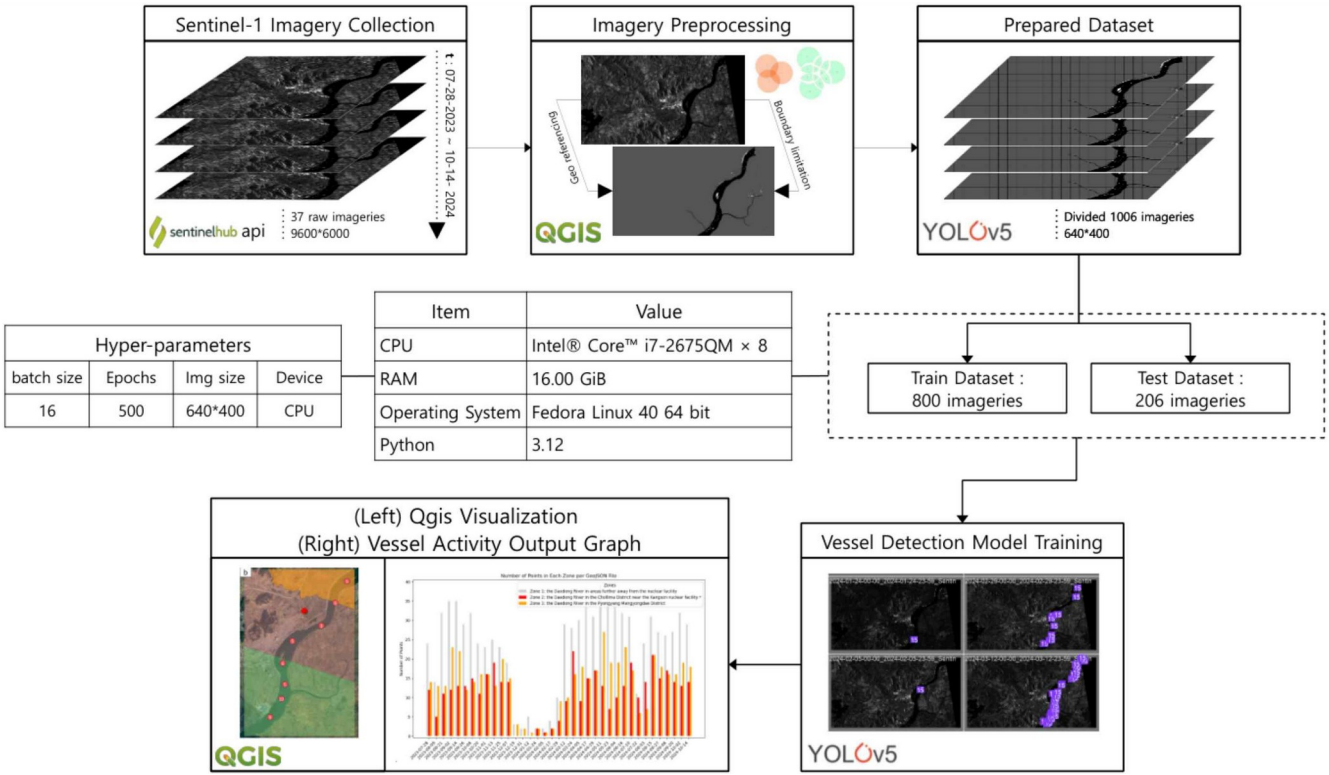
- Open-Source Intelligence (OSINT) refers to publicly available information, including satellite images, photos, news articles, and government documents, which can be used for verification without revealing classified sources. It is increasingly affordable and accessible, allowing universities and NGOs to contribute to arms control analysis.
- ...First, it helps build trust before an agreement is reached by providing transparent assessments and enabling dialogue among countries involved in negotiations, such as the United States, China, Japan, Russia, and South Korea.
- Second, OSINT plays a vital role in verifying and monitoring agreements once they are made. It can complement traditional closed-source verification methods by integrating OSINT data into the agreement, making it easier to verify troop movements, equipment deployments, and nuclear disarmament measures.

https://carnegieendowment.org/posts/2021/07/new-approaches-to-verifying-and-monitoring-north-koreas-nuclear-arsenal?lang=en

- Workflow for monitoring vessel activity near North Korea's Kangson nuclear facility using Sentinel-1 SAR imagery. Sentinel-1A SAR imagery was collected using the SentinelHub from July 28, 2023, to October 14, 2024.



- ...These images include VV-polarized interferometric wide-swath data, which are particularly effective for vessel monitoring due to their superior reflection characteristics over water surfaces, allowing clearer detection.

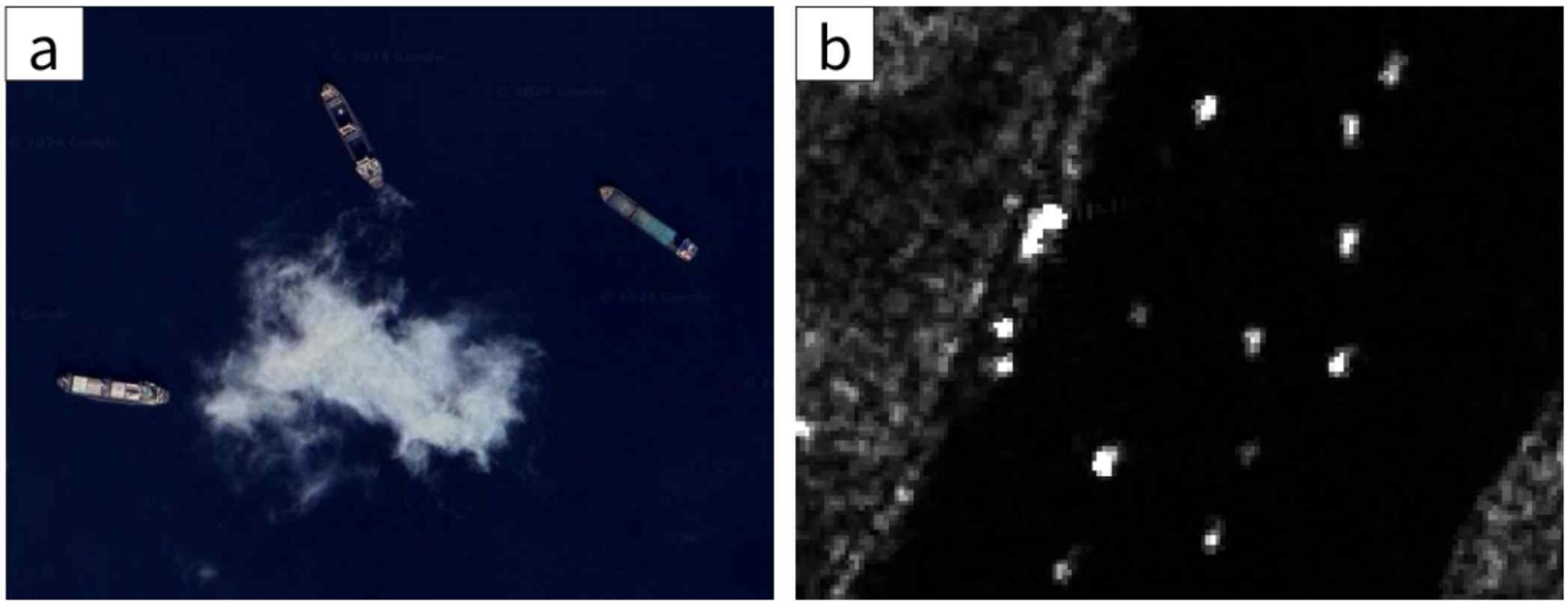
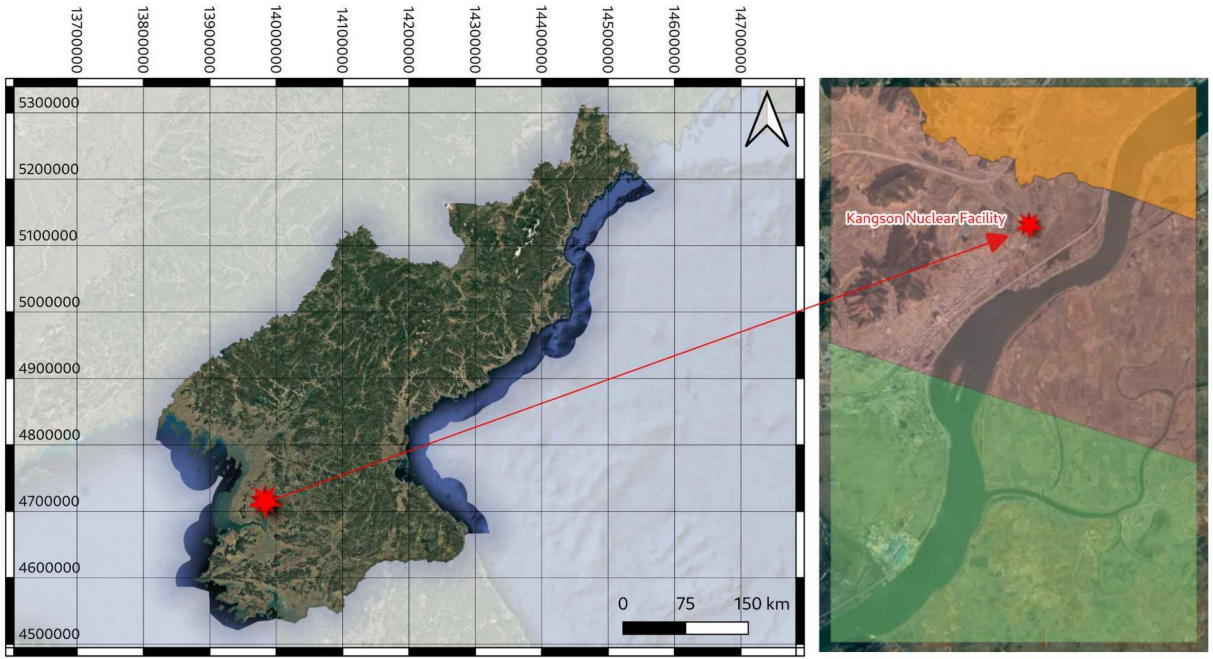


Figure 3. (a) Landsat 8 satellite image with clouds (b) Sentinel-1 SAR image.

- Research areas were defined near the Kangson complex located in the Chollima District of Nampo
  1) Daedong River in the Pyongyang Mangyongdae District (**orange area**)
  2) Daedong River near the Kangson nuclear facility (**red area**)
  3) Daedong River in areas further away from the nuclear facility (**green area**)



...The corner coordinates of the research area are as follows, based on CRS3857. These coordinates are defined in UTM Zone-53, with WGS-84 used as the reference ellipsoid.

- (Y = 4,703,000 m, X = 1,397,700 m)
- (Y = 4,719,000 m, X = 1,398,800 m)
- (Y = 4,710,000 m, X = 1,398,800 m)
- (Y = 4,703,000 m, X = 1,397,700 m)

Albright, D.; Burkhard, S. Revisiting Kangsong: A suspect uranium enrichment plant. Institute for Science and International Security, 2 October 2018.

- 37 Sentinel-1 SAR images (9600 × 6000 pixels) covering the research areas mentioned in Section 2.1 were segmented for use in artificial intelligence training and analysis.

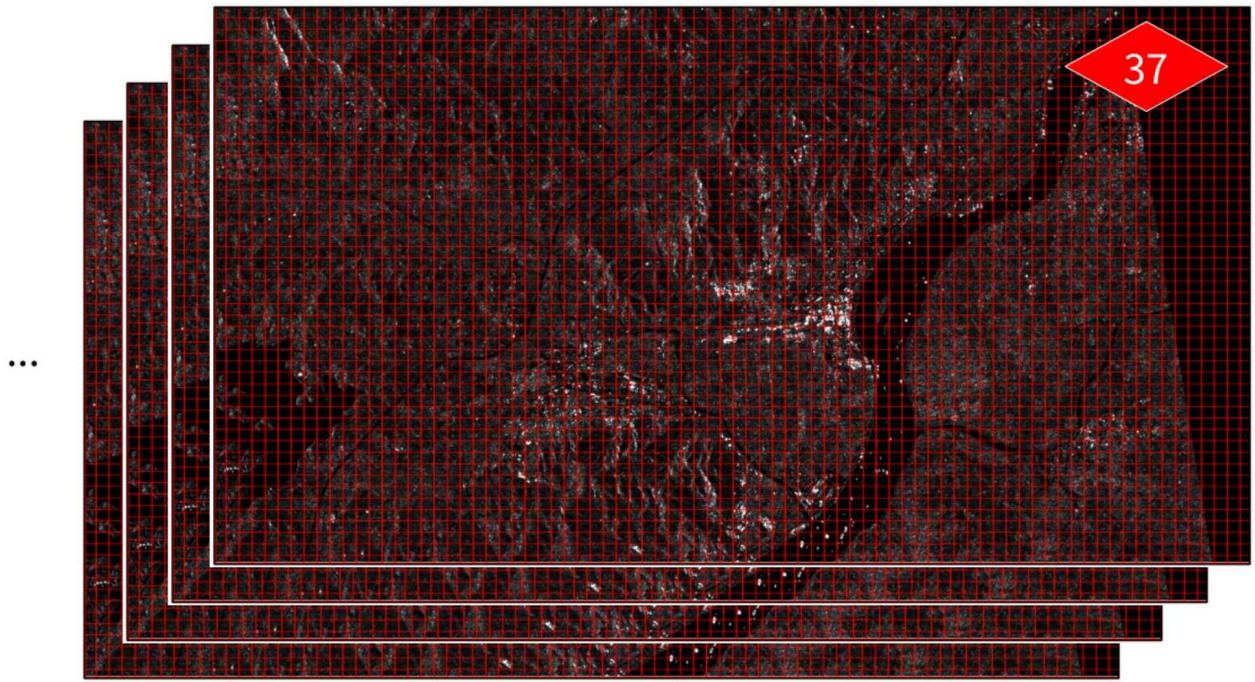
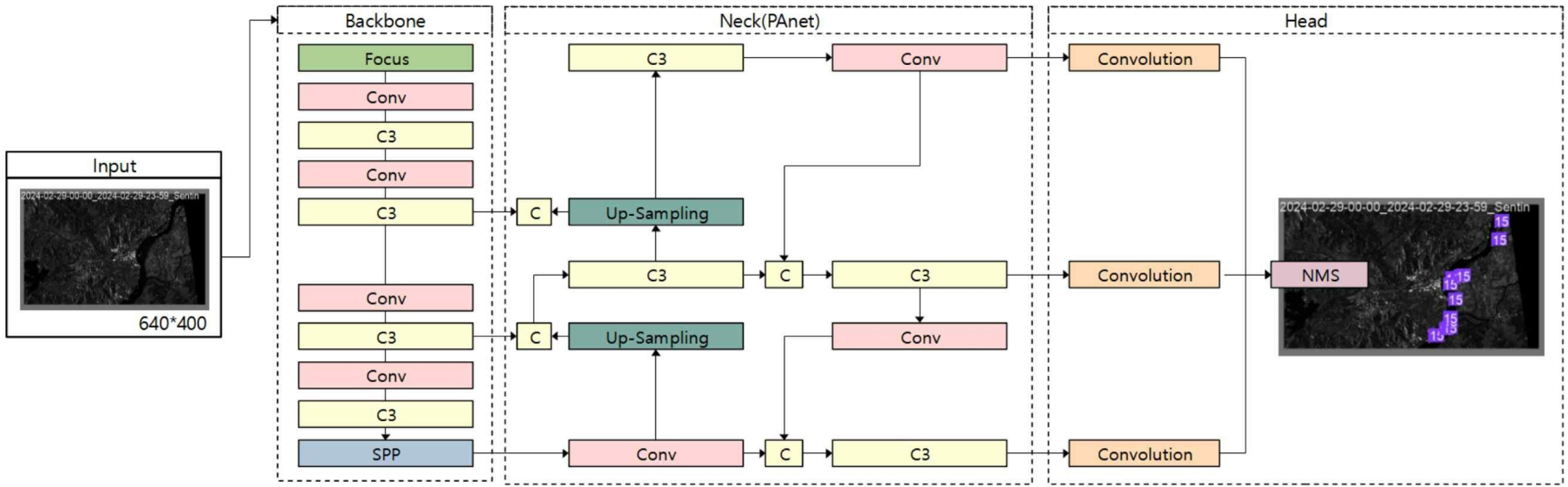
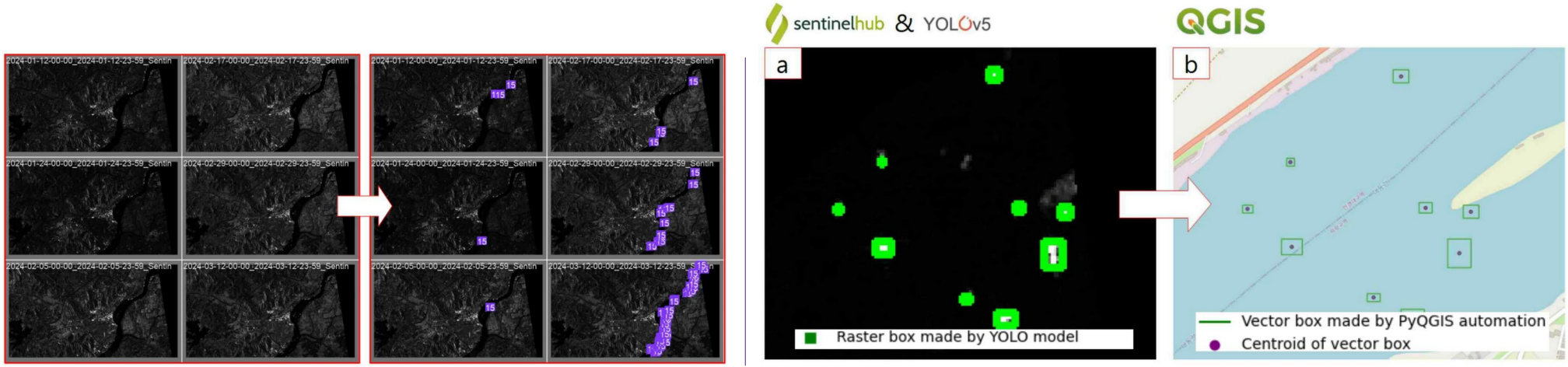


Figure 4. Dataset creation by segmenting large Sentinel-1 SAR images

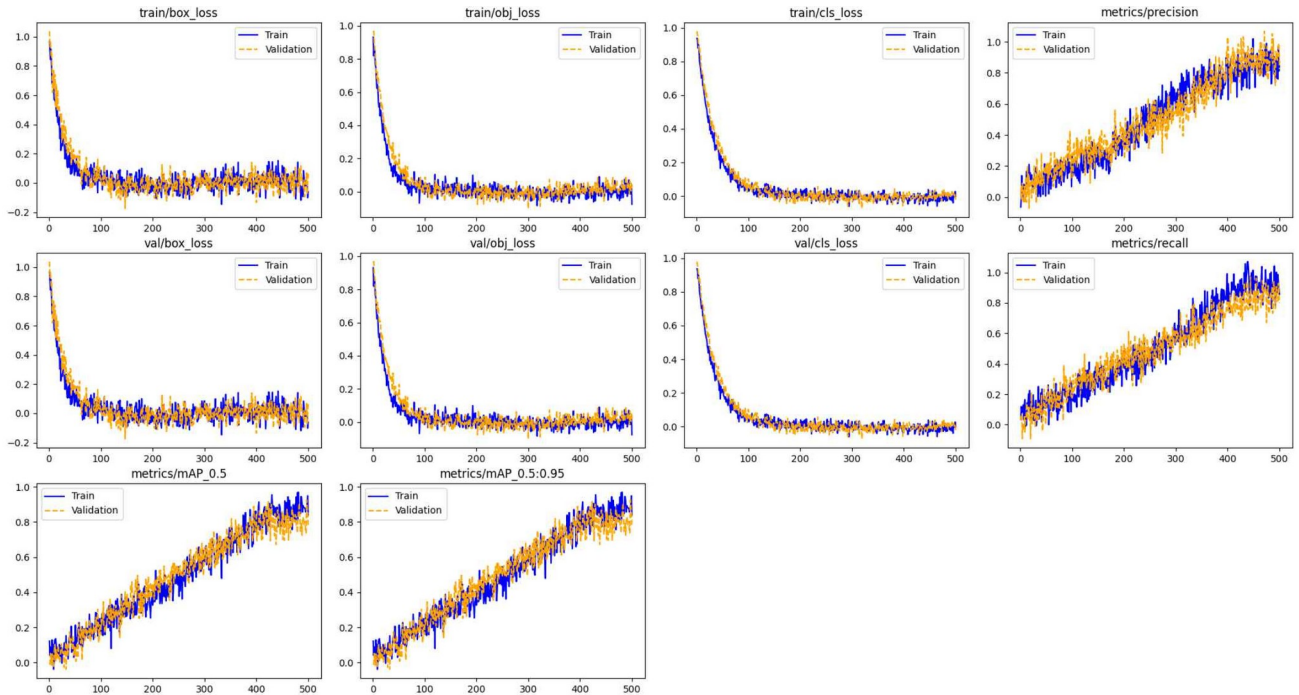
- The YOLOv5 architecture used in this study processes 640×400 SAR images to detect vessels as white dots, utilizing Backbone, Neck (PANet), and Head modules to extract features, combine multi-scale information, and output optimized detections with green boxes via NMS.



- The converted vector data were mapped and clustered based on three classifications of the study area, and to enhance the usability and clarity of the results, the QGIS platform was used to transform the clustered data into visual and interactive map formats.
  - (Left) Validation process of the Yolov5 model on vessel detection near Daedong River.
  - (Right) Process of converting YOLOv5 bounding boxes into vector lines and POIs for vessel classification in Qgis



- The model showed significant improvements in performance metrics after completing 100 epochs. Specifically, it achieved a Precision of 0.85, a Recall of 0.88, and a Mean Average Precision (mAP) of 0.85 at an IoU threshold of 0.5. The mAP across the IoU threshold range (mAP_0.5:0.95) was 0.85.



- The results of this analysis play a significant role in enhancing our understanding of the frequency and patterns of vessel activity, particularly around North Korea's nuclear facilities.

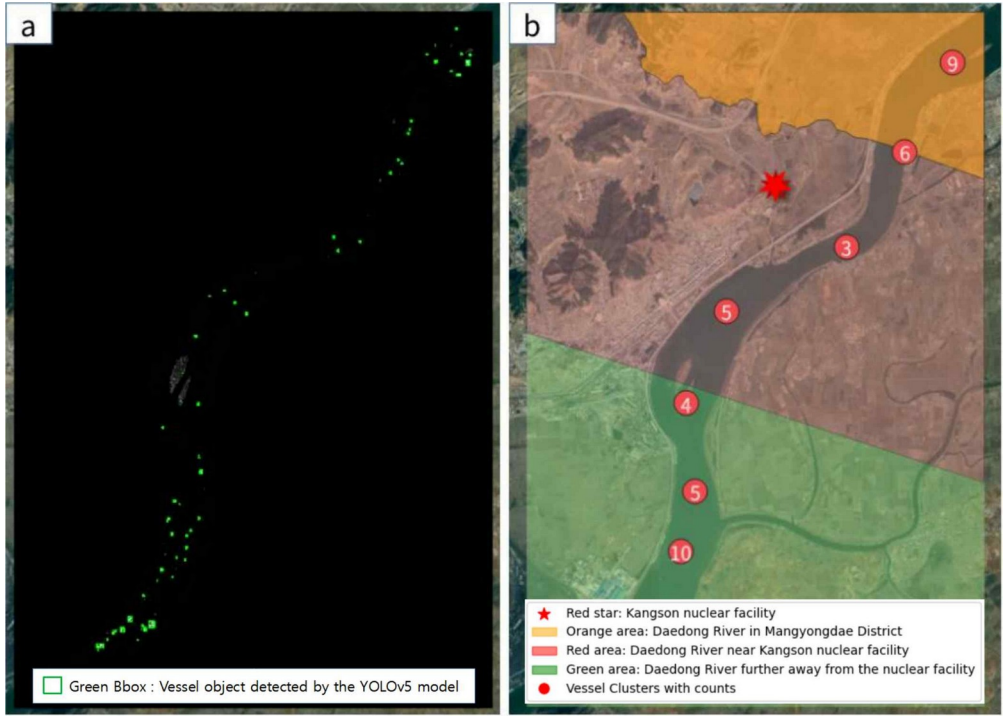
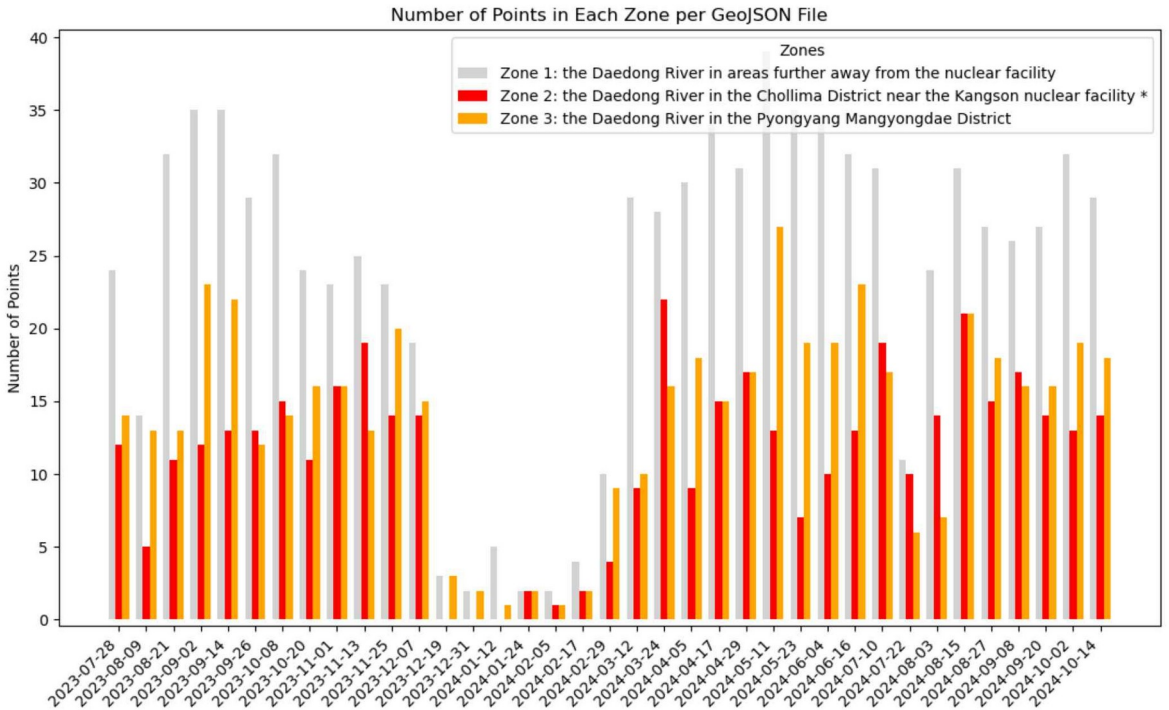


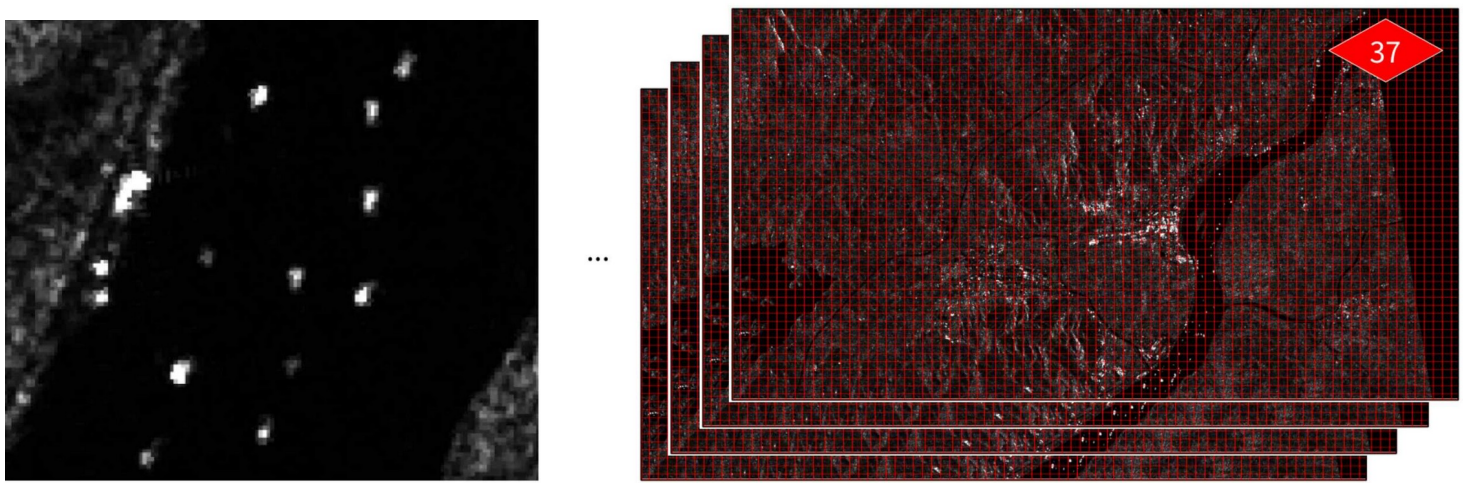
Figure 9. (a) Vessel detection results of the Yolov5 model (b) Visualization results in QGIS

- Based on the provided data, the analysis of monthly trends in vessel activity in the three designated zones near the Daedong River reveals several noteworthy patterns.
- Specific analyses of seasonal influences and regional anomalies are detailed below.



Low resolution limits detection accuracy

- In this study, vessel detection achieved a Precision of 0.85, Recall of 0.88, and mAP of 0.85, demonstrating strong performance by the Yolov5 model.
- However, limitations were identified. SAR imagery often detects overlapping or clustered vessels as a single entity, reducing accuracy, particularly in densely populated areas.
- Additionally, the low resolution of OSINT SAR imagery limits the ability to distinguish vessel shapes and identify their types or sizes. Addressing these challenges requires higher-resolution SAR data or supplementary data sources.



Low resolution limits detection accuracy

- In conclusion, this study demonstrates the potential of OSINT-based approaches to ensure the transparency and security of nuclear material movements, offering a reliable verification system for future monitoring activities.
- By integrating AI detection models with real-time satellite data, it provides a comprehensive and accessible solution for monitoring nuclear material movements in North Korea, contributing to global efforts in nuclear non-proliferation and responsible management.

https://sudanwarmonitor.com/p/a-conversation-with-chatgpt-about

Thank you.