Automatic detection of disaster-causing organisms near the waters of nuclear power plant based on LiveScope scanning sonar images

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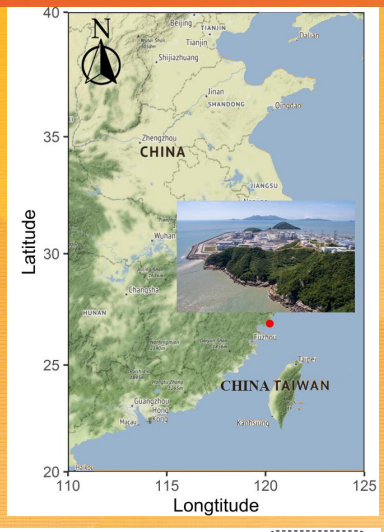
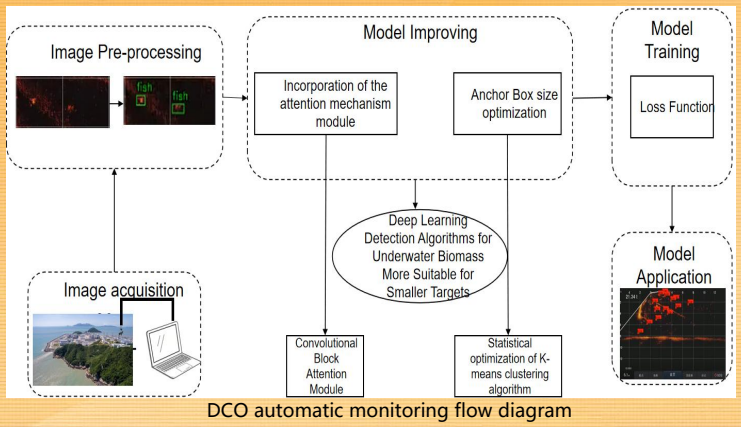
Background



- Nuclear power is a clean, efficient, and low-carbon energy source, and most nuclear power plants are located in coastal areas using seawater for cooling.
- The outbreak of **disaster-causing organisms (DCOs)** such as jellyfish, algae, and shrimp can **block intake screens**, reduce cooling efficiency, or even lead to unit shutdowns.
- Traditional underwater camera monitoring is limited by turbidity and low-light conditions.
- **LiveScope scanning sonar** enables real-time biological observation in turbid waters.
- This study develops an **automated detection model** to identify and track DCOs around nuclear power intakes using sonar imagery.

Methods and Technical Framework

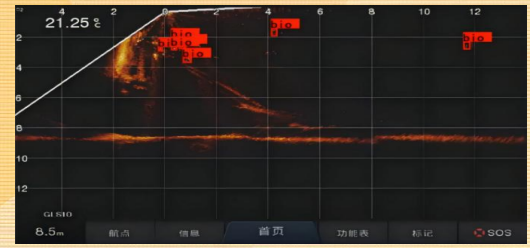
- A total of **22,017 LiveScope sonar videos** (June 2022 – October 2023) were collected from **Dayushan waters** and the **Ningde Nuclear Power Plant intake** to construct a labeled DCO dataset for training and validation.
- An improved **Bio-YOLOv7** model with **CBAM attention** and **optimized anchor boxes** was trained via data augmentation and transfer learning, improving detection accuracy and robustness in noisy sonar imagery.



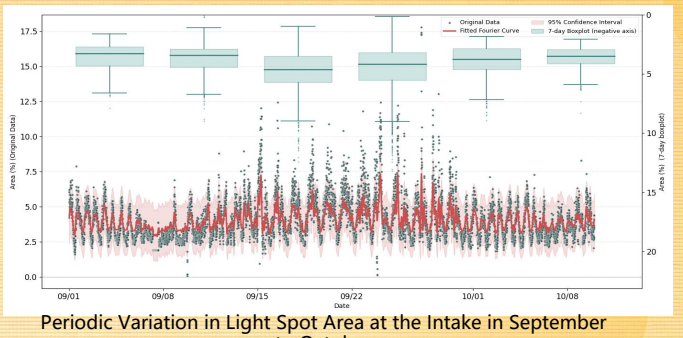
DCO automatic monitoring flow diagram

Results and Model Performance

- Detection Accuracy: The Bio-YOLOv7 model achieved 85.3% precision, **83.3% recall, 81.5% AP, F1 = 0.84, and 63.8 FPS**, meeting real-time monitoring requirements.
- Multi-Scenario Performance: Accurate and robust detection was maintained across **blank, sparse, dense, and outbreak** underwater scenes with minimal false targets.
- Temporal Variation: Light-spot area analysis revealed a **12.3 h semi-diurnal cycle**, consistent with tidal rhythm and indicating DCO outbreak dynamics.



Real-time detection of DCO light-spot area



Periodic Variation in Light Spot Area at the Intake in September to October

Conclusion and Outlook

- Summary: The proposed Bio-YOLOv7 model enables real-time, high-accuracy detection of DCOs in sonar images, supporting automatic monitoring near nuclear power intakes.
- Application: The system effectively provides early warning of biological clogging, improving operation safety and maintenance efficiency of coastal nuclear facilities.
- Future Work: Future efforts will focus on larger sonar datasets, cross-environment generalization, lightweight embedded deployment, and integration of non-tidal drivers for outbreak prediction.