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A REVIEW OF YOLOV11 BASED ON SAR SHIP DETECTION

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Annotation. Synthetic Aperture Radar (SAR) imaging technology holds significant value in military reconnaissance and maritime monitoring due to its all-weather and all-time imaging capabilities. Ship detection, as a core task of maritime monitoring, plays a crucial role in ensuring maritime safety, combating illegal fishing, protecting the marine environment, and military target reconnaissance. However, SAR images inherently suffer from noise, difficulties in detecting small targets, and interference from complex sea conditions, which pose challenges to the design of ship detection algorithms. In recent years, the YOLO series of algorithms has continuously evolved in SAR ship detection, with the latest version, YOLOv11, significantly improving detection accuracy and efficiency through innovations such as lightweight design, multi-scale feature modeling,

and improved attention mechanisms. This paper analyzes the key technological features of YOLOv11 and its performance advantages in SAR ship detection while exploring its application prospects in complex scenarios and future optimization directions.

Keywords: SAR ship detection, YOLOv11, object detection algorithm.

Introduction. With the growing global demand for ocean resource development, maritime traffic management, and military reconnaissance, ship detection has become increasingly important. SAR, with its active microwave imaging technology, overcomes the limitations of traditional optical sensors affected by weather and lighting conditions, making it an essential tool for maritime monitoring. However, the inherent speckle noise, low resolution, and target occlusion in SAR images under complex sea conditions increase the difficulty of detection. Therefore, leveraging advanced algorithms to improve the accuracy and efficiency of SAR ship detection has become a key research focus. As the latest version of the YOLO series, YOLOv11 achieves breakthroughs in both accuracy and efficiency through a series of technical improvements, demonstrating stronger adaptability in complex scenarios.

Main Content. YOLOv11 excels in object detection tasks, with its technical enhancements primarily reflected in three aspects. First, the C3k2 module adopts a lightweight design to replace the traditional C2f module, reducing the number of parameters while maintaining multi-scale feature fusion capabilities. Second, the Fast Spatial Pyramid Pooling (SPPF) enhances the model's robustness to various target sizes through multi-scale pooling. Lastly, the Parallel Spatial Attention Convolution Block (C2PSA) combines self-attention mechanisms with parallel processing paths to strengthen global feature modeling. These improvements enable YOLOv11 to perform exceptionally well in tasks such as instance segmentation, pose estimation, and oriented object detection, particularly in complex scenarios like ship detection.

YOLOv11 performs excellently in SAR ship detection, mainly due to its multiple technical improvements. First, it can simultaneously capture global features of large targets and detailed information of small targets through a multi-scale feature pyramid and a dynamic anchor point allocation mechanism, effectively addressing the issue of significant size differences in ships 0. Second, in response to the complex sea waves and clutter backgrounds in SAR images, YOLOv11 introduces an improved attention mechanism and context information modeling, significantly enhancing its ability to suppress background noise and reducing both false detection and missed detection rates 0. Additionally, YOLOv11 adopts a lightweight design, with only 2.4M parameters, fast inference speed, and high computational efficiency, meeting real-time requirements **Error! Reference source not found.**. This makes it highly applicable and reliable in practical applications such as maritime safety monitoring. Overall, YOLOv11 provides strong technical support for SAR ship detection with high precision, adaptability, and efficient performance.

Performance Comparison and Experimental Analysis. In the SAR-Ship-Dataset, the performance comparison between YOLOv11 and YOLOv10 is shown in Table .

Table 2.YOLO Model Performance Evaluation Table

Model	P	R	mAP50	mAP50-95
YOLOv10	0.906	0.869	0.947	0.613
YOLOv11	0.927	0.898	0.967	0.613

YOLOv11 improved by 2.32%, 3.34%, and 2.11% in precision, recall, and mAP50, respectively, but showed no improvement in the overall metric mAP50-95. Additionally, the training and validation loss curves of YOLOv11 decline more quickly and smoothly, indicating faster convergence and stronger generalization ability.

Conclusion. YOLOv11 demonstrates outstanding technical advantages in SAR ship detection tasks. Experimental results indicate that it significantly outperforms YOLOv10 in key metrics such as precision, recall, and mAP50, while also achieving faster convergence and stronger adaptability. However, its performance on the comprehensive metric mAP50-95 still requires improvement. Future research should focus on further optimizing the algorithm's adaptability to complex physical environments and enhancing the physical characteristic modeling of SAR images to improve detection robustness and overall performance.

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