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Marine target detection based on Marine-Faster R-CNN for navigation radar plane position indicator images

Key words: Marine target detection; Navigation radar; Plane position indicator (PPI) images; Convolutional neural network (CNN); Faster R-CNN (region convolutional neural network) method

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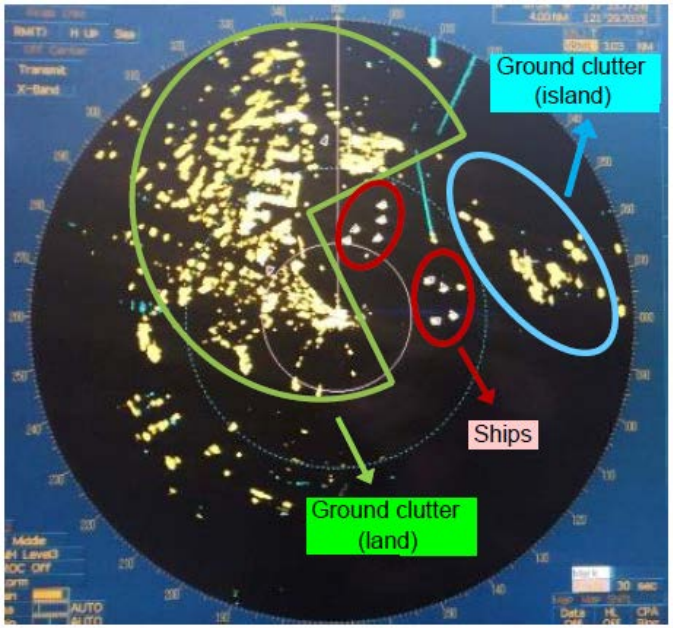
Motivation

1. Marine target detection is an important research branch in the field of target detection. It is of great significance for maritime transportation, marine environment monitoring, and small target search and rescue at sea.

2. The detection of target is influenced by target mobility, clutter, and noise disturbance, which is difficult in the actual detection under a complicated background. Existing methods have low generalization capability and limited performance in complex environments.



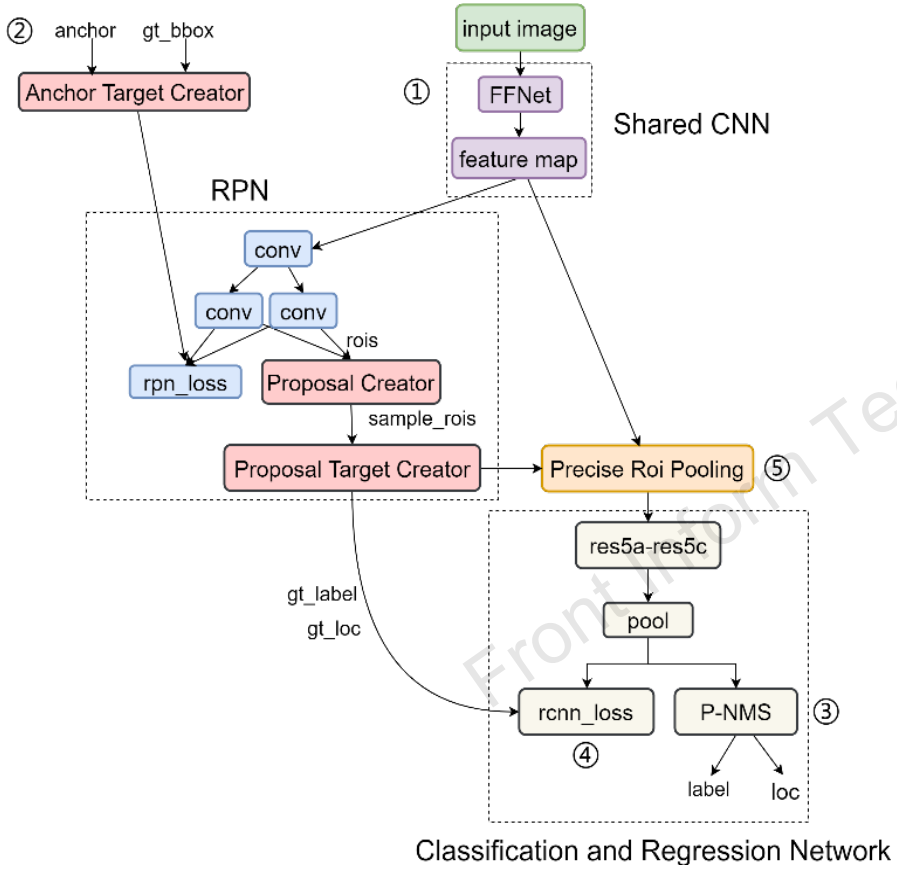
Main idea

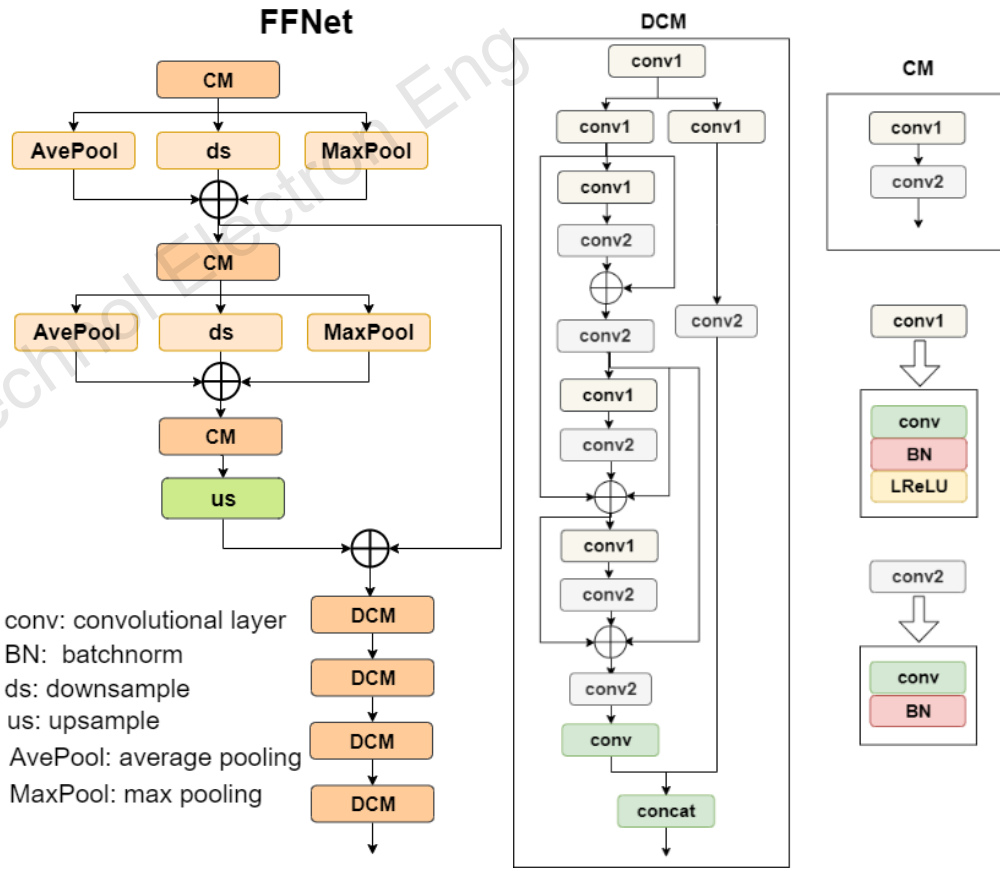
1. We propose a CNN-based method, named Marine Faster R-CNN, for marine target image detection of low and medium resolution radars. The method includes the feature fusion network (FFNet) for improving the feature extraction ability and reducing the false alarm rate, small-scale anchors for improving the ability to detect small targets, and the power non-maximum suppression (P-NMS) method for improving the ability to detect multiple targets. In particular, FFNet achieves target enhancement and sea clutter suppression through feature fusion when extracting image features.

Main idea

2. Construct relatively complete marine target radar image datasets to test the performance of the new method under different observation conditions.

Method





The structure of Marine-Faster R-CNN

The structure of FFNet

Method

1. A marine target detection method called Marine-Faster R-CNN is proposed to extract and identify targets in radar PPI images.
2. The Faster R-CNN algorithm is optimized in five respects: a new backbone network, anchor point scale, data balance, scale normalization, and dense target detection.

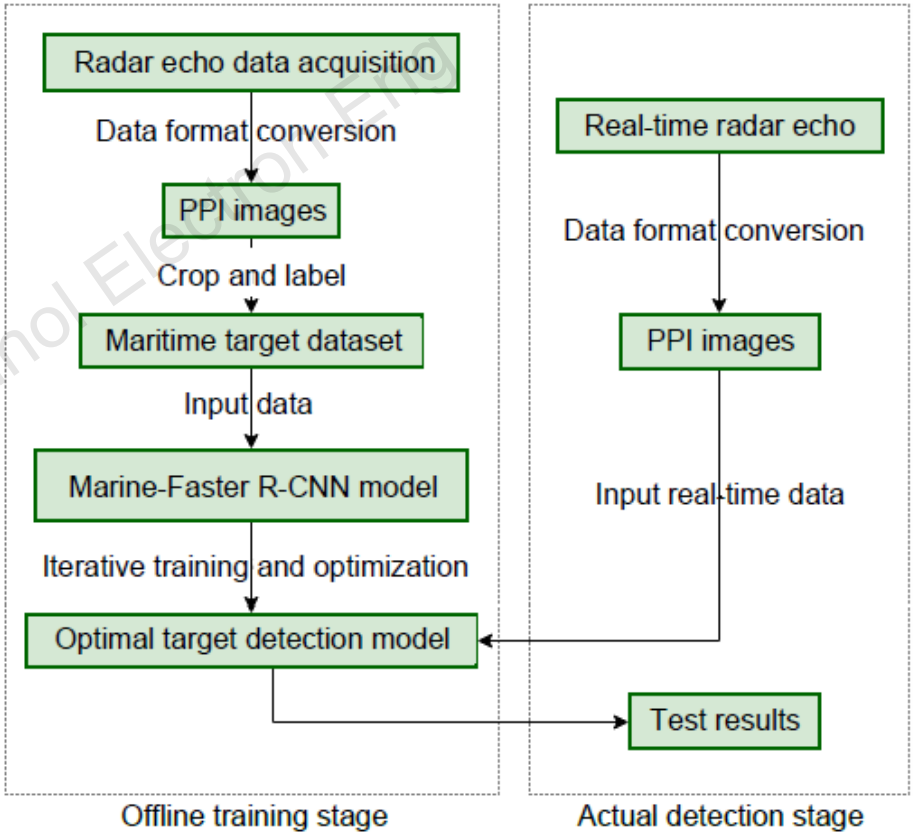
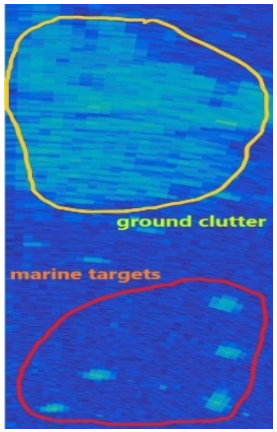


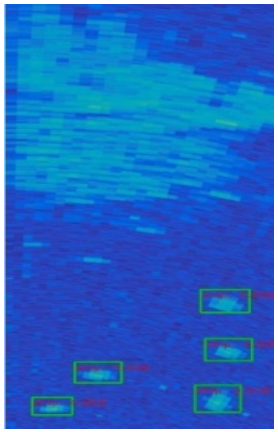
Fig. 3 Flowchart of the marine target detection algorithm

Major results

1. The test results of different optimizations

Method	Recall	Frame rate (frame/s)
Faster R-CNN (FFNet)	91.34%	3.95
Faster R-CNN (FFNet)+P-NMS	91.90%	3.94
Faster R-CNN (FFNet)+precise ROI pooling	91.85%	3.94
Faster R-CNN (FFNet)+focal loss	91.96%	4.02
Faster R-CNN (FFNet)+small anchors	92.01%	3.99
Marine-Faster R-CNN (all)	93.65%	3.97



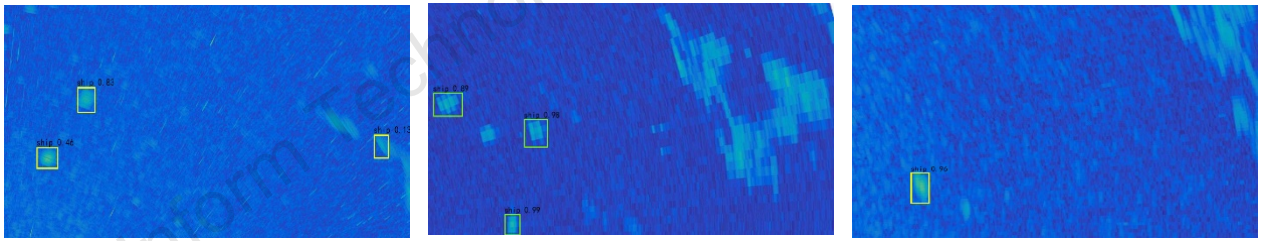


Major results (Cont'd)

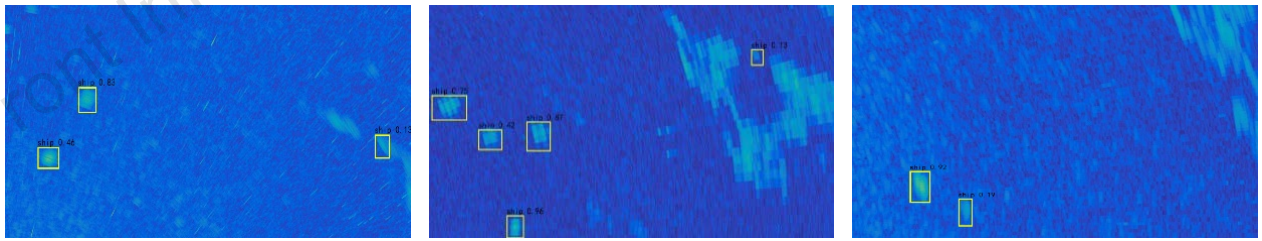
2. Comparison of test results

Method	Recall	Precision	False alarm	Frame rate (frame/s)
Faster R-CNN (VGG16)	88.77%	97.34%	2.66%	6.32
Faster R-CNN (Resnet101)	92.59%	97.46%	2.54%	2.37
Marine-Faster R-CNN	93.65%	99.02%	0.98%	3.97

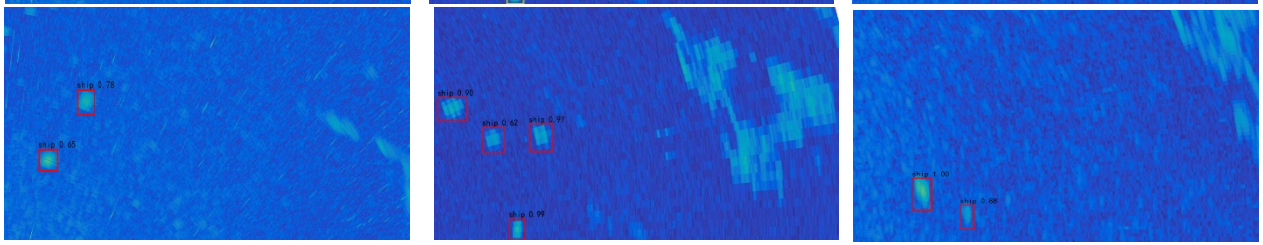
Faster R-CNN (VGG16)



Faster R-CNN (Resnet101)



Marine-Faster R-CNN



Conclusions

1. Experiments with measured data proved that Marine-Faster R-CNN has higher detection accuracy and better generalization ability than the classic Faster R-CNN and CFAR, and can achieve better marine target detection.
2. The proposed optimization methods may have good improvements on the optimization of Faster R-CNN.
3. The method can be applied to the detection of marine targets for navigation radar. Its performance was tested with datasets from different observation conditions (sea states, radar parameters, and targets).

Our related papers

Xiaolong Chen was born in Yantai, Shandong, China, in 1985. He received the BS and MS degrees in signal and information processing and the PhD degree in radar signal processing from Naval Aviation University (NAU), Yantai, in 2008, 2010, and 2014, respectively. He is currently an associate professor with the Marine Target Detection Research Group, NAU. He has published more than 110 academic articles, two books, and holds 42 national invention patents. His research interests include radar signal processing, especially for marine target detection. He is a senior member of IEEE and Chinese Institute of Electronics. He has been on the editorial boards of *Journal of Radars* and *Journal of Signal Processing*, and served as an associate editor of *IEEE Access* since 2018.

Xiaoqian Mu was born in Yantai, Shandong, China, in 1995. He received the BS and MS degrees in signal and information processing from Naval Aviation University (NAU), Yantai, in 2018 and 2020, respectively. His research interests include intelligent radar signal processing and moving target detection.

Jian Guan received the PhD degree in electronic engineering from Tsinghua University, Beijing, China in 2000. He is currently a professor of NAU. His research interests include radar target detection and tracking, image processing, and information fusion. He is the author of two books related to radar detection. Prof. Guan is a senior member of the CIE and committee member of Radio Positioning Technology Branch in CIE. He has won the prize of the National Excellent Doctoral Dissertation, "Realistic Outstanding Youth Practical Engineering Award" of CAST, and was selected for National Talents Engineering of Ministry of Personnel of China. He is on the editorial boards of many radar related journals. He has served in the technical committee of many international conferences on radar.

Ningbo Liu was born in Yantai, China, in 1983. He received the PhD degree from the Naval Aeronautical and Astronautical University in 2012. He is now an associate professor of Naval Aviation University, and now works at the postdoctoral research station of the Second Academy of China Aerospace Science and Industry Corporation. His research interests include intelligent signal processing, radar target detection within sea clutter, and radar experiment and detection performance evaluation.

Wei Zhou was born in Hubei, China, in 1980. He received the MS and PhD degrees in information and communication engineering from NAU in 2006 and 2011, respectively. From 2011 to 2016, he has been a lecturer in the Department of Electronic and Information Engineering of NAU. He is now an associated professor in NAU. His current research interests include image processing and information fusion.