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Pinwheel-shaped Convolutional and Dynamic Complete IoU Loss For Infrared Dim Small Target Detection

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Abstract : These recent years have witnessed that convolutional neural network (CNN)-based methods for detecting infrared dim small targets have achieved outstanding performance. However, these methods typically employ standard convolutions, neglecting to fully consider the spatial characteristics of the pixel distribution of infrared dim small targets. Therefore, based on interleaved group convolutions, we propose a Pinwheel-shaped convolution (PConv) to replace the first two layers of standard convolutions in the backbone network. Compared to standard convolutions, PConv better conforms to the pixel spatial distribution of dim small targets and introduces only a minimal increase in parameters while effectively enhancing the extraction of features from dim small targets. Additionally, the latest loss function, combining intersection over union (IoU) loss and distance loss, fails to adequately account for the sensitivity differences in scale and position for targets of different sizes, thereby underutilizing the detection performance of neural networks for weak, small targets. To address this, we introduce dynamic completely IoU (DCIoU) loss, dynamically adjusting the influence coefficients of IoU and distance based on the size of the target bounding box, enhancing the neural network's ability to converge on targets of varying scales, thereby significantly boosting detection accuracy. Finally, we have curated the largest and most challenging dataset of real-shot single-frame infrared dim small target detection to date: SIRST-UAVB. Integrating PConv and DCIoU into the state-of-the-art small target detection algorithm, we conduct tests on both public datasets and SIRST-UAVB, achieving significant performance improvements, thus validating the effectiveness and generalizability of our approach.

Keywords : infrared dim small target detection, deep learning, interleaved group convolutions, feature extraction, loss function, dataset
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