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RSO-SAM: A ZERO-SHOT SEGMENTATION FRAMEWORK FOR RESIDENT SPACE OBJECTS USING THE SEGMENT ANYTHING MODEL

Abstract

Zero-shot segmentation is crucial for autonomous perception of Resident Space Objects (RSOs), given the limited availability of annotated space datasets. Current methods encounter significant challenges due to severe shadows, depth ambiguities from dynamic Earth backgrounds, and inconsistent mask quality. In this paper, we propose RSO-SAM, a zero-shot segmentation framework based on the Segment Anything Model (SAM), enhanced by three specialized feature modules: (1) Shadow Removal Module: Detects shadows through brightness gradients and performs adaptive illumination normalization within sequential image frames, restoring spacecraft structural details obscured by shadows. (2) Depth-Guided Feature Enhancement Module: Explicitly guides segmentation boundaries using precise depth-edge cues predicted by monocular depth estimation, effectively refining segmentation against dynamic Earth backgrounds. (3) Mask Quality Scoring Module: Jointly predicts mask IoU and explicitly identifies segmentation anomalies (holes, outliers, and irregular regions), recalibrating mask confidence to enhance segmentation reliability. Additionally, to preserve SAM's zero-shot generalization capability, we freeze the pre-trained SAM backbone and selectively fine-tune only a lightweight feature fusion module. This fine-tuning integrates local structural information from early-layer features with global semantic context from deeper layers, accurately adapting SAM to the specific structural and illumination characteristics in our large-scale spatial-domain dataset (228K images, 851K masks). Comprehensive experiments verify that RSO-SAM effectively enhances segmentation precision and robustness for autonomous on-orbit perception tasks involving Resident Space Objects.