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SUPER-RESOLUTION-BASED SMALL OBJECT DETECTION FOR REAL-TIME SURVEILLANCE AND MONITORING: AN ONBOARD SATELLITE FPGA IMPLEMENTATION

Abstract

Accurate target detection and rapid information extraction through optical remote sensing imagery is crucial for a wide range of military and civilian operations, including search and rescue missions, maritime surveillance, airport surveillance, vehicle monitoring, and military reconnaissance. Reliable and timely data is essential to enable early warnings or real-time oversight of potentially hazardous events, thereby supporting decision-makers in their mitigation efforts. However, the small size of the targets and the spatial resolution of the imagery can result in minimal pixelated representations of the objects of interest, leading to inadequate feature extraction, unsatisfactory detection performance, and instances of missed or erroneous detections. Moreover, conventional remote sensing methodologies are based on ground-based image processing, which results in delays between data acquisition and the generation of actionable insights. To address these challenges, we first introduce an enhanced convolutional neural network-based algorithm, specifically tailored for detecting small-scale objects, like cars, vessels, or planes, within remote sensing imagery. This augmented object detection framework incorporates a super-resolution backbone, facilitating the extraction of fine details and features of small targets of interest to improve the detection accuracy. Then, we propose a Field Programmable Gate Array (FPGA)-based implementation for the onboard processing. FPGA devices contain a matrix of configurable logic blocks that can be customized, even in-flight, to perform specific computing tasks, such as accelerating the principal operations characteristic of an artificial neural network with high throughput and low power consumption. We conduct a quantitative analysis to assess the performance of the detector, deployed on Microchip's PolarFire FPGA, demonstrating its effectiveness for real-time surveillance and monitoring directly via satellite. The results validate the robustness of our approach, yielding accurate and prompt information that exceed existing benchmarks, particularly in detecting small-scale objects.