Lightweight Attention-Enhanced U-Net for Vehicle Detection in Parking Lots Using Aerial Imagery

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Abstract

Parking lot management is an important issue in urban planning and traffic management. Accurately understanding the usage of parking lots can not only improve the utilization efficiency of parking resources, but also enhance traffic flow and reduce urban congestion. This study proposes a modified U-Net network with a lightweight structure and an attention mechanism for vehicle detection in parking lots based on aerial images.

First, the lightweight structure of MobileNetV3 was used as the backbone of the U-Net encoder for feature extraction, making the proposed model suitable for real-time processing on resource-limited edge devices. Next, the proposed U-Net model further improved the accuracy of parking area detection in complex backgrounds through a channel and spatial attention mechanism (CSAM). Finally, the study introduced a weighted map mechanism, which makes the model more sensitive to edges and smaller objects by emphasizing vehicle edges in the loss function. The weighted map effectively improves the accuracy of vehicle detection, even in the presence of complex backgrounds or unclear object boundaries.

Experimental results showed that the proposed model can detect parking lot vehicles with an accuracy of more than 87%, which is about 20% higher than the original U-Net. In addition, the proposed model achieved an enhanced IoU (eIoU) of 77% for parking lot areas, approximately 3% higher than the original U-Net. These results demonstrate that the proposed U-Net model achieves good accuracy in multi-scale object detection. In addition to effectively detecting small vehicles, the model can also detect large parking areas with high accuracy.