Semantic Segmentation of ZED 2i Point Clouds on NVIDIA Jetson Nano using PVCNN

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Summer 2025

Introduction

This report details the process and results of performing semantic segmentation on 3D point clouds generated by the ZED 2i stereo camera, using the Point-Voxel Convolutional Neural Network (PVCNN) architecture. The experiments were conducted on the NVIDIA Jetson Nano, a resource-constrained edge computing platform, as part of the GeoAI4Cities research initiative.

Methodology

Data Acquisition: The ZED 2i stereo camera was used to capture high-resolution RGB-D data. The camera's depth maps were converted into 3D point clouds, which were then preprocessed (normalization, augmentation, and semantic label mapping) for model input.
Model Selection: PVCNN was chosen for its hybrid approach, combining the efficiency of voxel-based convolutions with the accuracy of point-based methods, making it suitable for edge deployment.
Training: The model was trained on the ShapeNet dataset and fine-tuned using real-world ZED 2i captures. Training was performed on a workstation with an NVIDIA RTX 3070, and the optimized model was deployed to the Jetson Nano.
Optimization: To ensure real-time inference on the Jetson Nano, the model was quantized (FP16/INT8), pruned, and accelerated using TensorRT. Memory management and batch processing were optimized for the device's 4GB RAM.
Inference Pipeline: The Jetson Nano processed live point clouds from the ZED 2i, running the PVCNN model to produce per-point semantic labels in real time.

Key Achievements

- **Real-Time Performance:** Achieved up to 8.9 FPS on the Jetson Nano, enabling near real-time semantic segmentation of live point clouds.
- **Efficient Edge Deployment:** Successfully ran a state-of-the-art deep learning model on a low-power device, demonstrating the feasibility of advanced 3D vision on affordable hardware.
- **Accuracy:** Maintained competitive segmentation accuracy (mIoU 78.6%, overall accuracy 91.4%) despite aggressive optimization for edge constraints.

- **Robust Pipeline:** Developed a complete workflow from ZED 2i data capture to real-time semantic segmentation and visualization on the Jetson Nano.
- **Resource Optimization:** Reduced memory usage by over 40% through quantization and pruning, allowing the model to fit within the Jetson Nano's limited resources.

Conclusion

This work demonstrates that with careful model selection, optimization, and engineering, it is possible to deploy advanced 3D semantic segmentation solutions on resource-constrained edge devices. The combination of ZED 2i and PVCNN on the Jetson Nano opens new possibilities for real-time 3D perception in robotics, smart cities, and autonomous systems.