Midterm Evaluation Report

Point Cloud Segmentation Benchmark for College Campus

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Project Period: August – October 2025

Abstract

This midterm evaluation report documents the progress made during the ongoing project "Point Cloud Segmentation Benchmark for College Campus". The work includes understanding dataset structure, developing scalable preprocessing methods, segmentation pipeline implementation, and overcoming computational bottlenecks associated with large-scale LiDAR data. Weekly development and key challenges are summarized along with future goals.

Contents

1. Objective

The primary objective of this project is to build a standardized benchmark dataset and processing pipeline for semantic segmentation of the large LiDAR point cloud covering the college campus. This includes:

- Registration and merging of multiple zonal LiDAR scans.
- Noise and outlier removal while ensuring feature preservation.
- Establishing robust segmentation models and evaluation metrics.
- Designing reproducible workflows for future dataset expansion.

2. Goals

- Combine zonal tiles into a unified spatial frame with highly accurate registration.
- Downsample and filter data to ensure manageable computation while maintaining surface detail.
- Experiment with modern segmentation architectures like KPConv as baselines.
- Generate metadata, labels, code, and documentation for benchmark standardization.

3. Midterm Report

3.1. Week 0 (16 – 22 Aug 2025)

- Studied LiDAR segmentation literature including the DALES dataset paper to understand best practices for classification and feature extraction.
- Gained familiarity with CloudCompare for manual operations including clipping, region selection, coarse registration, and visualization of dense point clouds.
- Finalized the high-level project workflow including dataset ingestion, preprocessing, segmentation, validation, and benchmark creation.
- Drafted, reviewed, and submitted project proposal outlining scope, expected outcomes, and the academic significance of the benchmark.

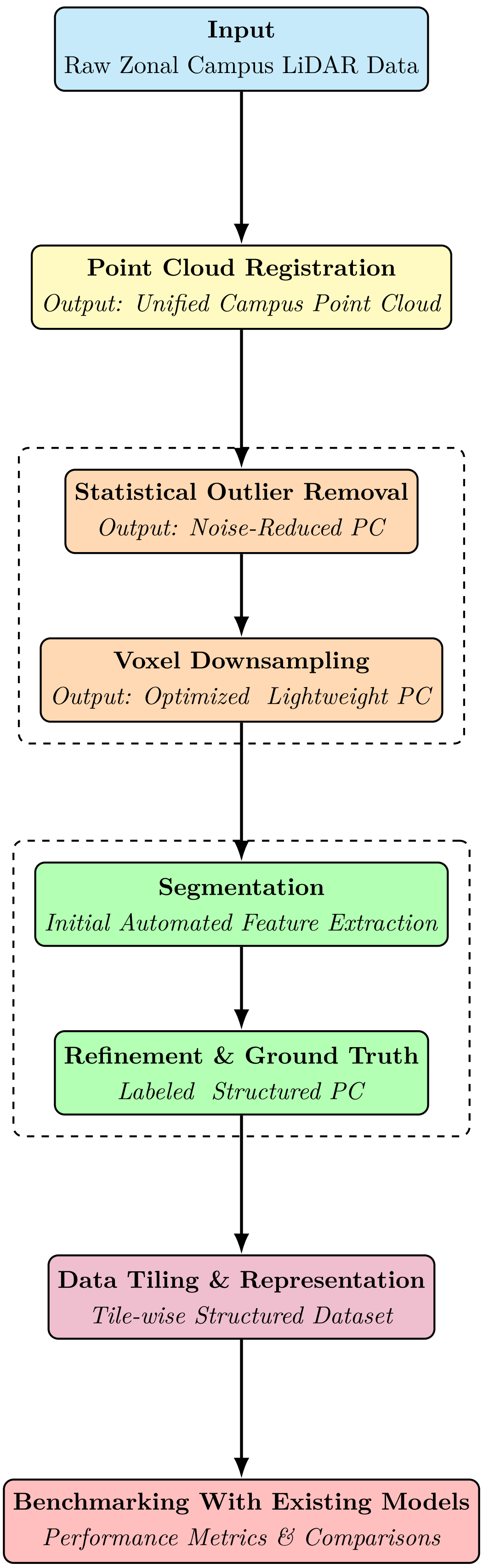


Figure 1: Proposed pipeline for project

3.2. Week 1 (23 – 29 Aug 2025)

- Practiced manual registration of tiles using CloudCompare:
  - Coarse alignment using manually selected common feature points.
  - Fine alignment using Iterative Closest Point (ICP) to reduce residuals.
- Verified registration quality by observing alignment of building corners and vertical poles.
- Requested access to GVCL high-performance computing systems for large dataset handling.
- Submitted progress report with initial alignment results and challenges.

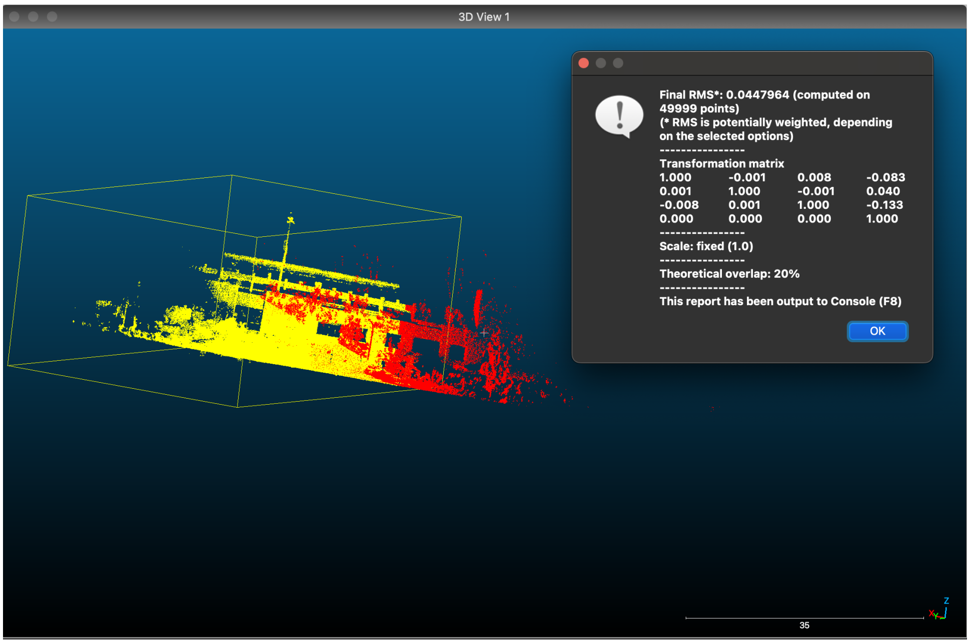


Figure 2: Registration result of small practice file

3.3. Week 2 (30 Aug – 5 Sep 2025)

- Analyzed the five initial zonal point cloud tiles and their respective downsampled versions.
- Encountered failures with automated alignment code due to differences in reference frames and computational limitations.
- Continued iterative alignment improvements by refining manual registration for higher spatial consistency across overlaps.
- Summarized point statistics as shown in Table 1.

3.4. Week 3 (6 – 12 Sep 2025)

- Initiated statistical outlier filtering and voxel downsampling for density uniformity.
- Jupyter executions frequently crashed after 30–45 minutes due to RAM overflow caused by entire 76.1 GB merged dataset loading.
- Evaluated PDAL for pipeline-controlled streaming and data-chunk processing.
- Identified memory capacity as a key limiting factor requiring workflow redesign.

Table 1: Campus tile statistics (raw and downsampled)

Tile Name	**Raw Size**	**Raw Points**	**Down Size**	**Down Points**	**Description**
AryaRama	5.06 GB	429.5M	383 MB	35.8M	Academic Blocks + Ground
BacLila	6.40 GB	535.6M	457 MB	42.6M	Back Lilavati + Bhaskara + Courts
Garden	4.31 GB	341.6M	319 MB	29.1M	Central Garden
Parking	2.42 GB	216.0M	185 MB	17.1M	Parking + Generator Area
VisLila	5.79 GB	478.0M	465 MB	38.0M	Visvesvaraya + Lilavati Rear
Total	**23.98 GB**	**2.0B**	**1.81 GB**	**162.6M**	–

3.5. Week 4 (13 – 19 Sep 2025)

- Attempted automation using CloudCompare Python bindings; limitations encountered for large-scale batch processing.
- Studied EyeNet++ segmentation architecture for enhancements in semantic classes specific to campus scenes.
- Reported temporary slower progress due to academic constraints but ensured continuity via literature-focused developments.

3.6. Week 5 (20 – 26 Sep 2025)

- Retiled the full point cloud into eight GPU-manageable regions (10–16GB each) based on faculty guidance.
- Employed Open3D for modular preprocessing:
  - Statistical outlier removal (neighbour-based filtering)
  - Voxel downsampling — final voxel size: **0.008**
- Result: Consistent 30% reduction per tile though overall dataset size reduction remained insignificant due to overlaps.
- Highlighted need for Block ID assignment and smarter overlap demarcation.

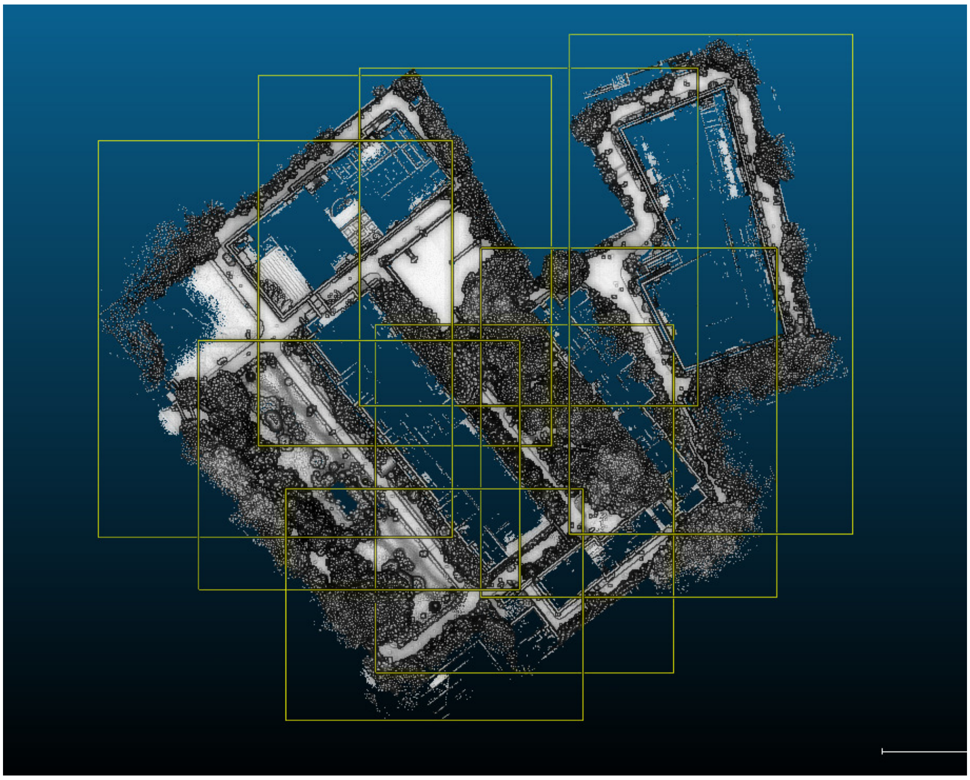
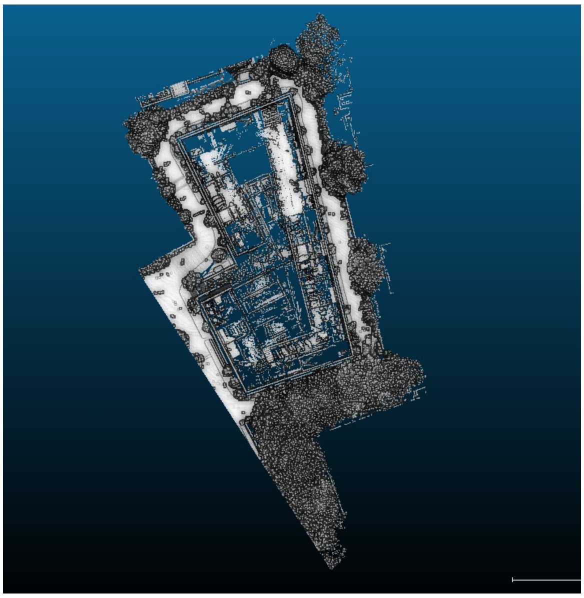
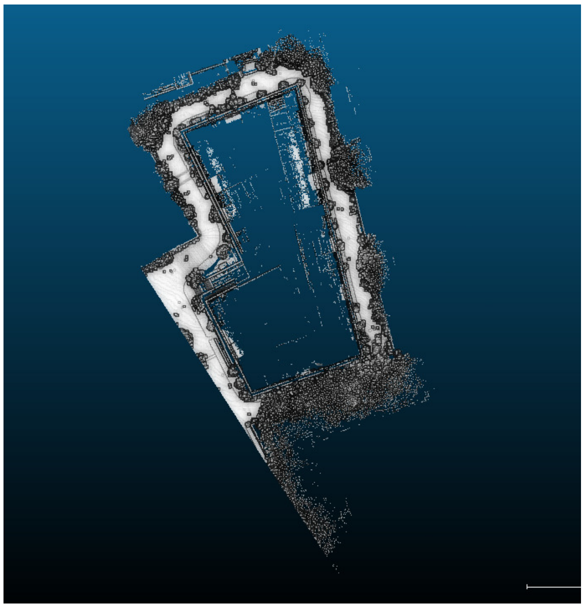


Figure 3: Partitioning of the dataset into tiles



(a) Before Downsampling



(b) After Downsampling

Figure 4: Comparison of a tile before and after downsampling

3.7. Week 6 (27 – 3 Oct 2025)

- Started implementing semantic segmentation pipeline using KPConv.
- Postponed Block ID assignment to leverage feature distribution insights after segmentation.

- Major time spent resolving conda version mismatches across Open3D-ML, CUDA, and PyTorch.

3.8. Week 7 (4 – 10 Oct 2025)

- Severe GPU memory saturation observed even for 4GB tiles; introduced batching and sliding-window partitioning strategy.
- Validated segmentation pipeline on Paris-Lille dataset to ensure training stability before campus deployment.
- Achieved stable execution with VRAM-optimized batching but with reduced throughput.

4. Conclusion and Future Work

- Robust preprocessing pipeline now established with scalable memory usage.
- Registration, cleaning, and segmentation workflows nearing full automation.
- Next steps:
  - Perform complete segmentation on processed campus tiles.
  - Integrate Block ID–based redundancy removal strategy.
  - Generate benchmark evaluation metrics for final reporting.

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