# A Comparison of Ground-Point Separation Methods Applied to Terrestrial Laser Scanner Mapped LiDAR Point Clouds

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## Introduction

- Varying scan angles, scanner orientation, and point density between terrestrial laser scanners (TLS) and airborne laser scanners (ALS) cause differences in their derived LiDAR point clouds (Shan and Toth, 2008).
- Ground-point separation is the process of removing off-terrain objects (OTO) from LiDAR point clouds. Most ground-point separation methods have been developed for use with ALS LiDAR point clouds.
- This study compares the performance of three common ground-point separation methods applied to TLS LiDAR data sets.

## Study Sites

- LiDAR point clouds were collected using a Leica ScanStation C10 TLS at four study sites across the University of Guelph Campus (Fig. 1):
  1. Christie Lane Site (929.2 $m^2$; 62,541,838 points)
  2. Hutt Basement Site (174.7 $m^2$; 32,505,723 points)
  3. Science Complex Site (3,818.6 $m^2$; 11,810,574 points)
  4. Johnson Green Site (54,890.6 $m^2$; 13,143,868 points)

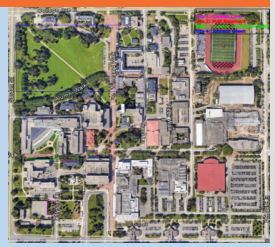

*Fig. 1. Univ. of Guelph campus map with study sites marked.*

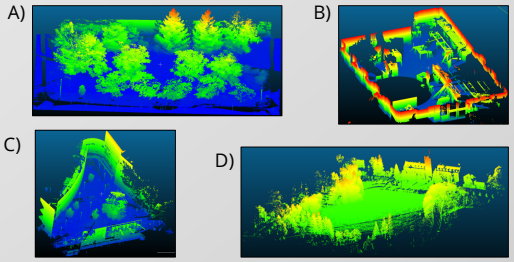


*Fig. 2. LiDAR point clouds of study sites, including A) Christie Lane, B) Hutt Basement, C) Science Complex, and D) Johnson Green.*

## Ground-Point Separation Methods

- Three methods for OTO removal were tested:
  1. Lindsay (2016) Slope Based Filter
  2. Lindsay (2016) Segmentation Based Filter
  3. Isenburg (2015) Modified TIN Densification Based Filter
- Comparisons were made between filters to a reference data set classified using a semi-manual technique and assessed using a Kappa Index of Agreement (KIA).

## Results

*Table 1. Accuracy performance of ground-point separation methods at Site 1.*

| | TIN Densification | Segmentation | Slope |
|---|---|---|---|
| **Kappa** | 0.649 | 0.835 | 0.680 |
| **Overall Accuracy** | 85.6% | 92.5% | 84.7% |

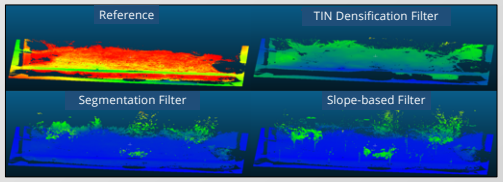


*Fig 3. Site 1 (Christie Lane) OTO filtering methods results.*

*Table 2. Accuracy performance of ground-point separation methods at Site 2.*

| | TIN Densification | Segmentation | Slope |
|---|---|---|---|
| **Kappa** | 0.911 | 0.826 | 0.336 |
| **Overall Accuracy** | 98.3% | 96.5% | 81.8% |

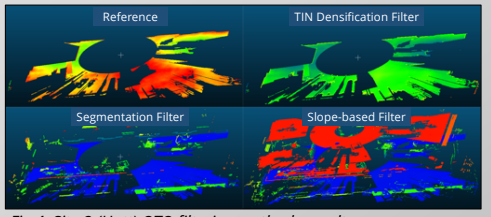


*Fig 4. Site 2 (Hutt) OTO filtering methods results.*

*Table 3. Accuracy performance of ground-point separation methods at Site 3.*

| | TIN Densification | Segmentation | Slope |
|---|---|---|---|
| **Kappa** | 0.830 | 0.974 | 0.906 |
| **Overall Accuracy** | 91.85% | 98.72% | 95.34% |

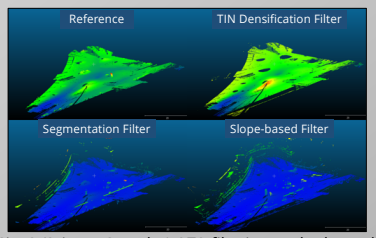


*Fig 5. Site 3 (Science Complex) OTO filtering methods results.*

*Table 4. Accuracy performance of ground-point separation methods at Site 4.*

| | TIN Densification | Segmentation | Slope |
|---|---|---|---|
| **Kappa** | 0.899 | 0.982 | 0.955 |
| **Overall Accuracy** | 95.12% | 99.17% | 97.91% |

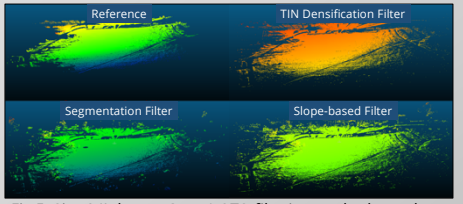


*Fig 5. Site 4 (Johnson Green) OTO filtering methods results.*

*Table 5. Filter computation times in seconds.*

| Site | TIN Densification | Segmentation | Slope |
|---|---|---|---|
| 1 (Christie Lane) | 508.6 | 8993.2 | 1103.3 |
| 2 (Hutt) | 39.9 | 2729.3 | 470.1 |
| 3 (Science Complex) | 47.7 | 1517.6 | 223.5 |
| 4 (Johnson Green) | 60.2 | 1441.9 | 233.8 |
| **Average** | 254.1 | 3670.5 | 507.7 |

- The TIN Densification filter tended to over-smooth variable terrain surfaces on all four sites.
- The slope filter did not handle off terrain flat surfaces, such as the ceiling in Site 2 and building walls within Site 3, well.
- The segmentation filter had the longest computation time, however typically yielded the best results.

## Conclusions

- Many current filtering methods were developed using a constant search window for neighborhood selection rather than a variable search window.
- The highly variable point densities typical of TLS LiDAR are not handled well by constant search windows, resulting in ranges of points per neighborhood from hundreds of thousands near the scanner, to mere hundreds in the corners of the study area.
- Variable search window sizes were instead used, however this resulted in many neighborhoods being very small in size.

## References

- Isenburg, M. (2015, January 25). LasGround_New. Retrieved December 07, 2016 form http://www.cs.unc.edu/~isenburg/lastools/download/ lasground_new_README.txt
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