Difference of Normals as a Scale-based Operator in 3D Point Clouds

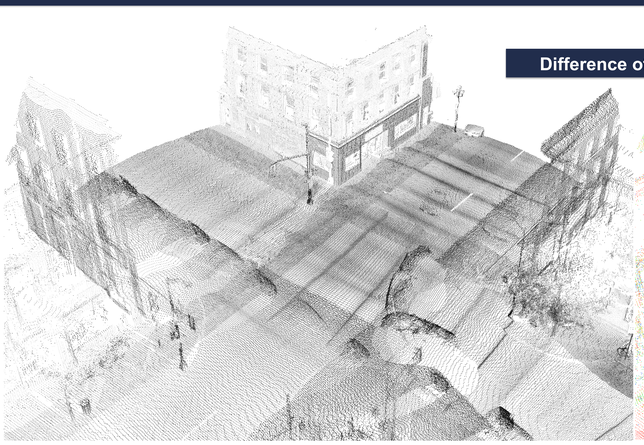
Yani Ioannou[1], Babak Taati[1], Robin Harrap[2] and Michael Greenspan[3]

[1] Toronto Rehab/University of Toronto [2] Geological Sciences, Queen's University [3] School of Computing, Queen's University

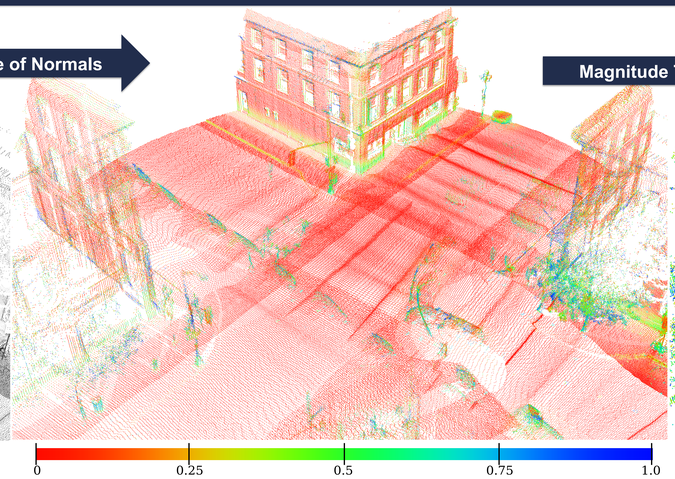
Implemented in PCL 1.7

Scan the QR code to go to the PCL tutorial or visit:

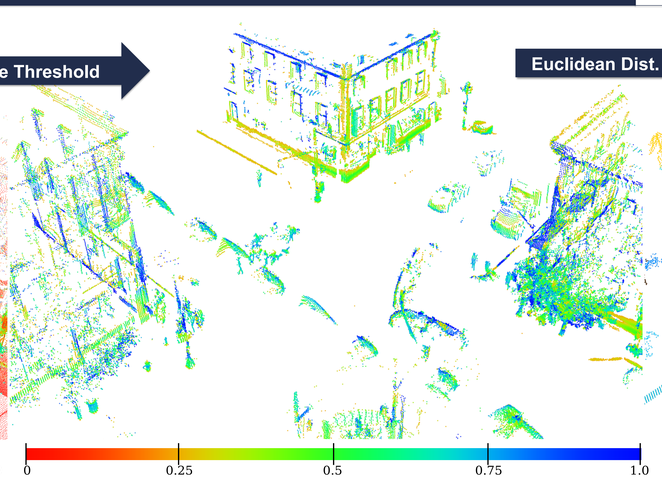
http://goo.gl/dtTn2



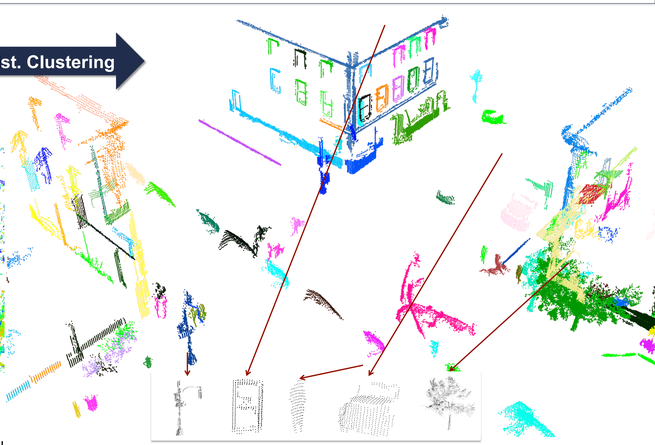
Original Point Cloud (620,820 points)



Difference of Normal Vector Field Magnitudes for r_s = 0.2m and r_l = 2.0m.



Points with Difference of Normal Vector Field Magnitudes ≥ 0.25



Euclidean Distance Clusters Found with Distance Threshold 0.2m.

Introduction

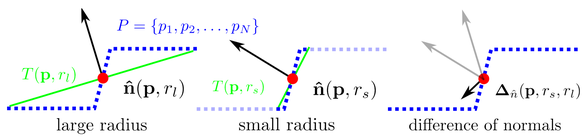
- Difference of Normals (DoN) is a scale-based *surface processing* operator for unorganized point clouds.
- Conceptually similar to the Difference of Gaussians in 2D image processing, but operating on the implicit surface of a point cloud.

Motivation

- Availability of large (millions of points), composite unorganized (non-regularly sampled) LIDAR data of urban street neighborhoods.
- Common use of such data is to create Geographic Information System (GIS) models.
- *Street furniture* in particular is of interest, such as fire hydrants, traffic lights, etc.
- Other objects of interest to GIS models include buildings (inc. building facades), curbs, roads, trees.
- Current models are laboriously created manually! Is automatic modeling of this data possible?
- Key problem is segmentation of the data!

Method

- Compare surface descriptors at different scales to identify at which scale each point has influence.
- Surface normals are the simplest surface descriptors, calculated given a point and a support radius.



- Normals for a point estimated with different support radii reflect different scales, as illustrated above.
- The difference between normal vectors at different support radii gives a measure of how much change there is between the scales of the two radii.
- We define the Difference of Normals (DoN) operator:

$$\Delta_{\hat{\mathbf{n}}}(\mathbf{p}, r_s, r_l) = \frac{\hat{\mathbf{n}}(\mathbf{p}, r_s) - \hat{\mathbf{n}}(\mathbf{p}, r_l)}{2}$$

where $\mathbf{p}$ is the point, r_s is the small support radius, and r_l is the large support radius. Is normalized difference of units vectors, thus magnitude always in range [0, 1].

- The resulting vector field may be thresholded by magnitude to find points that have the strong response at a given scale, or can be used to find oriented edges.

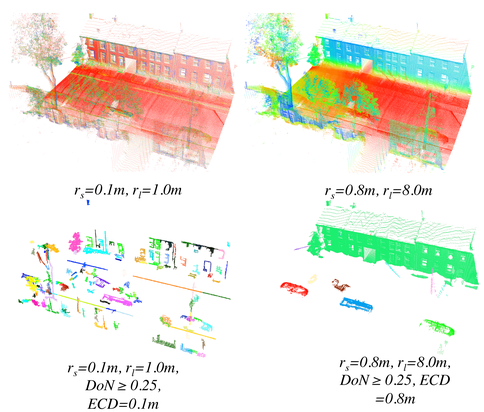
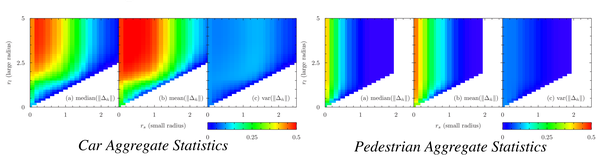


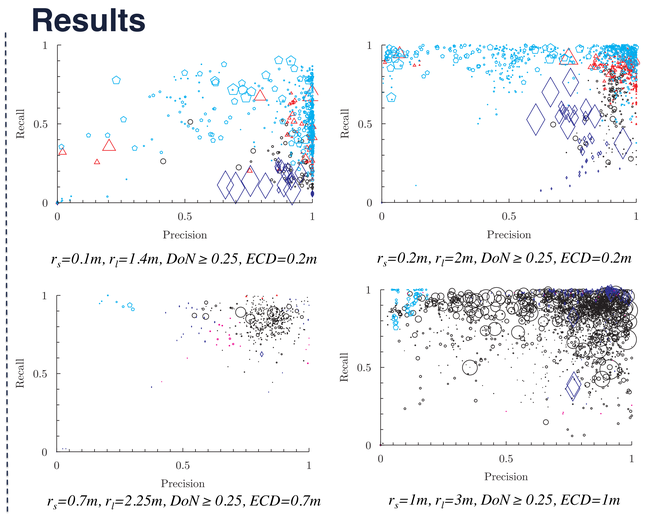
Illustration of DoN Thresholding/Clustering with Different Scales

- The two parameters r_l ,r_s provide scale-based parameters to the filter.
- Parameter selection is done by choosing parameters maximizing the inter-class distance in classification and minimizing variance.



Parameter Selection by Per-Class Aggregate Statistics

Results



Results of DoN Clustering v.s. Ground Truth on KITTI Data Set

- Found good recall/precision on large pubilc dataset of outdoor Velodyne LIDAR data (KITTI[2] data set) as compared with ground truth segmentations.
- Objects of different scales are segmented best with parameters matching their scale, as expected.
- Quantitatively shown to be consistent across point clouds scanned from the same underlying surface with different scanners and sampling[1].

References

1. *Shape Matching of Repeatable Interest Segments in 3D Point Clouds*, PCP, 2012, J. Lam, et. al.
2. *Are we ready for Autonomous Driving? The KITTI Vision Benchmark Suite,* CVPR 2012, A. Geiger et. al.
3. *Difference of Normals as a Multi-Scale Operator in Unorganized Point Clouds*, Y. Ioannou et. al.

Poster Available Online

Scan the QR code or visit

http://goo.gl/cuI6V

Acknowledgements

We would like to thank Geodigital Inc. (formerly Terrapoint Inc.) for their cooperation and the opportunity to work with TITAN data. I also acknowledge the financial support of the Geoide Network Center of Excellence of NSERC, and the Ontario Centres of Excellence.