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

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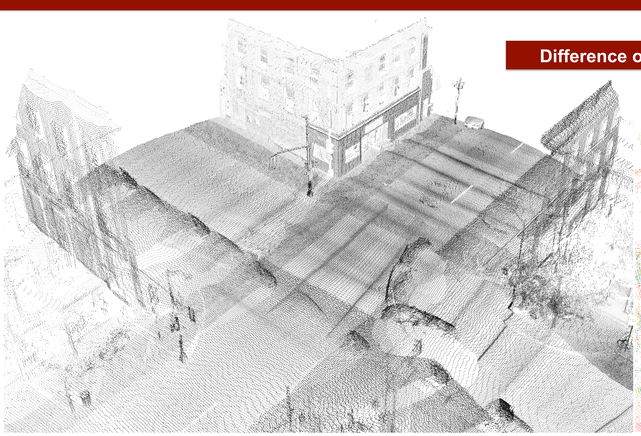
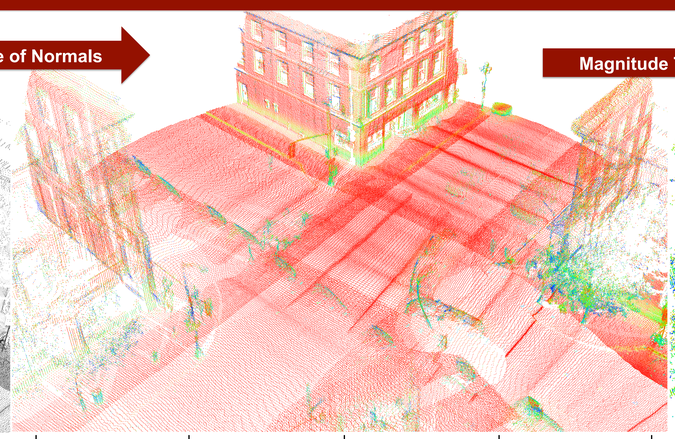
pcl Library & Example Code

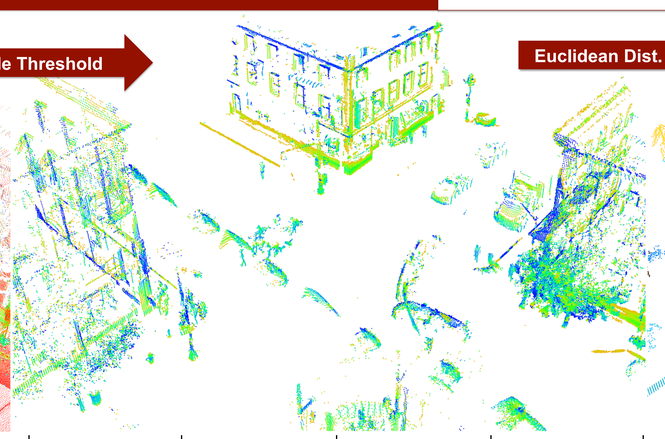
A PCL implementation of the DoN operator is available along with examples at http://yanii.github.com/DoNPCL - scan the QR code with your smartphone to go there now!



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

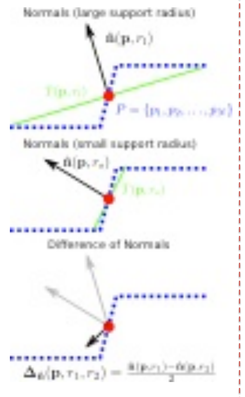
- Difference of Normals (DoN) is a scale-based *surface processing* operator for unorganized point clouds.
- Conceptually similar to the Difference of Gaussians in 2D image processing, but operating on the implicit surface of a point cloud.

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 and may be calculated easily given a point and a support radius.
- Normals for a point estimated with different support radii reflect different scales.
- 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.

- Result is normalized difference of units vectors, thus DoN magnitude always in range [0, 1.0].
- The resulting vector field may be thresholded by magnitude to find points that have the strong response at a given scale.
- The two parameters r_l ,r_s provide parameters to the scale and bandwidth of the filter, similar to the two standard deviations σ_1,σ_2 of the Difference of Gaussian.
- Empirically it was found that that the best results were found with radii with a ratio of one octave, i.e. $r_l = 10 \times r_s$.

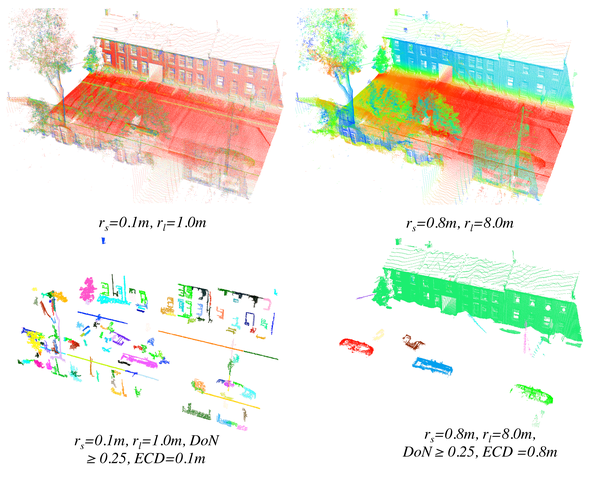


Illustration of DoN Thresholding/Clustering with Different Scales

Results

- Together with a clustering algorithm, empirically found to provide a good scale-based segmentation of unorganized point clouds with highly variable sparsity and sampling.
- Quantitatively shown to be a consistent saliency operator across point clouds scanned from the same underlying surface with different scanners and sampling[1].

Future Work

- Thorough quantitative evaluation of clustering/ segmentation results, however without ground truth this is a significant hurdle - suggestions welcome!
- Automatically determine parameters to isolate a known object.
- Use connected components to find clusters instead of far simpler Euclidean distance clustering.
- Perform object recognition on resulting clusters.

References

1. Shape Matching of Repeatable Interest Segments in 3D Point Clouds, Int. Workshop on Point Cloud Processing, 2012, Joseph Lam, et. al.
For more references see: *Automatic Urban Modelling using Mobile Urban LIDAR Data, M.Sc. Thesis, Queen's University, Yani Ioannou.*
http://qspace.library.queensu.ca/handle/1974/5443 - use QR code at right.

Acknowledgements

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