LIDAR DATA ANALYSIS: OBJECT DETECTION VERIFICATION; GRAPH CUTS BASED INTERACTIVE SEGMENTATION

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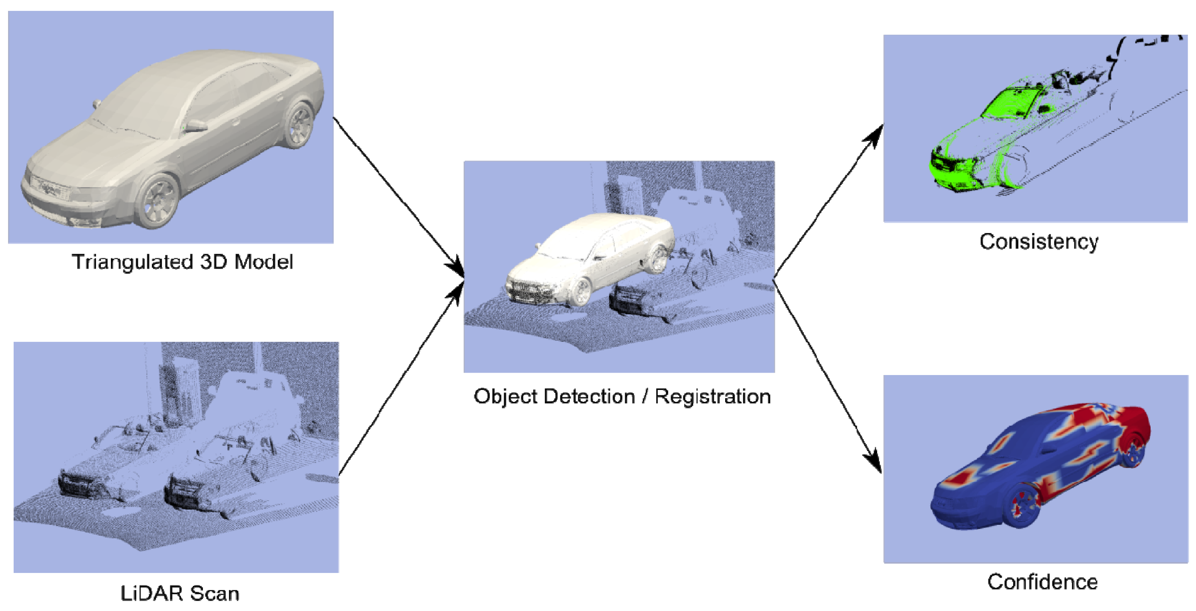
Object Detection Verification

Abstract

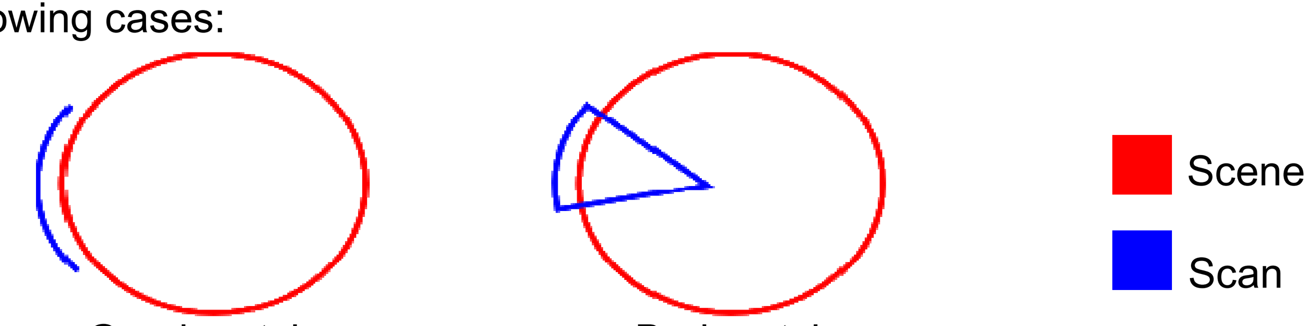
Our work involves analyzing and interpreting data produced by 3D range (LiDAR) scanners. First, we have introduced a dual metric, Consistency and Confidence, for verifying in a physically meaningful way whether a 3D model occupies a hypothesized location in a set of LiDAR scans. Our current work involves interactively segmenting objects in LiDAR data using graph theoretic techniques. Our goal is to allow users to select an entire object in a scan using two mouse clicks.

Workflow



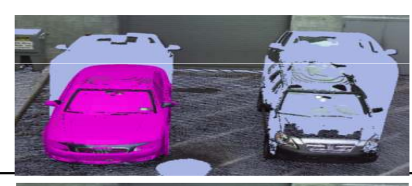
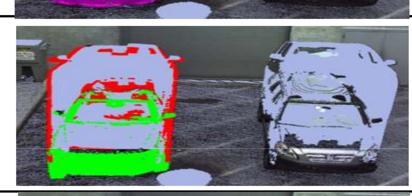
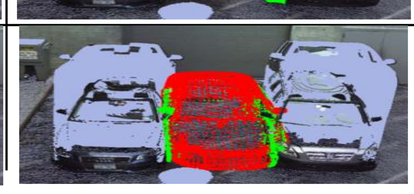
Partial Matches

- Allowing for partial matches forces one to use a cost function which has a similar score in the following cases:



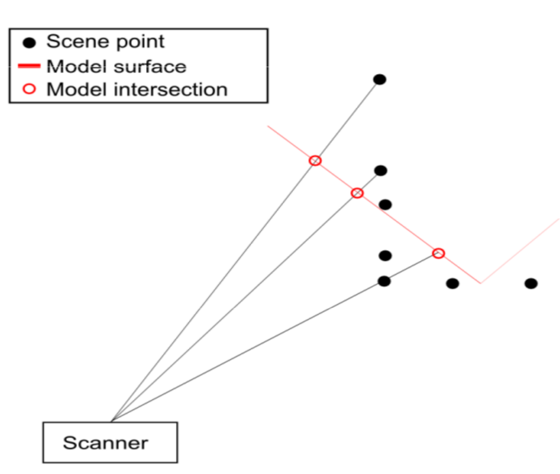
Incorrect Matches

- Traditionally difficult to distinguish; very obvious with our dual metric

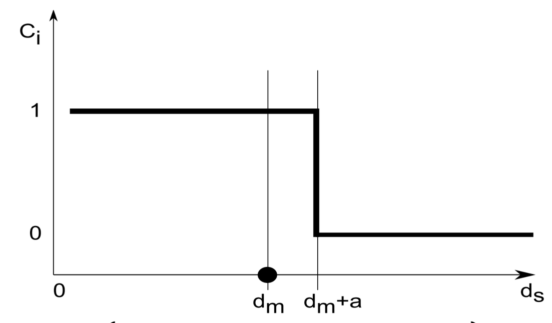
		Correct	Incorrect	
ICP Mean Distance	0.057			0.094
Consistency	0.589			0.077
Confidence	0.579			0.252

The Consistency Measure

"If the model was present, could we have seen this point?"



Assign a binary value of 1 (consistent) or 0 (inconsistent) to each scan point



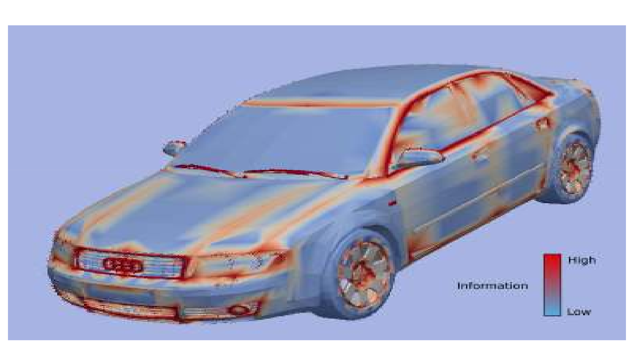
$$C_i = \begin{cases} 1 & (d_m + a) - d_s \geq 0 \\ 0 & (d_m + a) - d_s < 0 \end{cases}$$

Consistency = $\frac{1}{N_c}\sum_{i=1}^{N_c} C_i$

Multiple Scan Consistency = $\frac{\sum_{k=1}^{K}\sum_{i=1}^{N_c^k} C_i^k}{\sum_{k=1}^{K} N_c^k}$

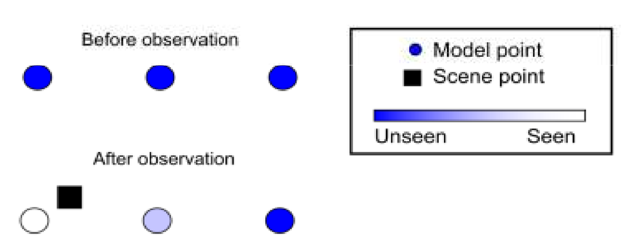
The Confidence Measure

- "How much of the model have we observed?"
- If scan is consistent, we can only declare the model *could be* at the hypothesized location, not that it *is* at that location
- Indicates the reliability of the hypothesis



A certain amount of information, I_i, is associated with every model point, related to how locally distinctive the point is

- Each scan point collects information from the scene



$$O_i \leftarrow \min\left(I_i, O_i + I_i e^{\frac{-d_{ij}^2}{2\sigma^2}}\right)$$

$$\text{Confidence} = \sum_{i=1}^{N_m} O_i$$

- The computation of the confidence over **K** multiple scans is computed as if all scene points came from a single scan

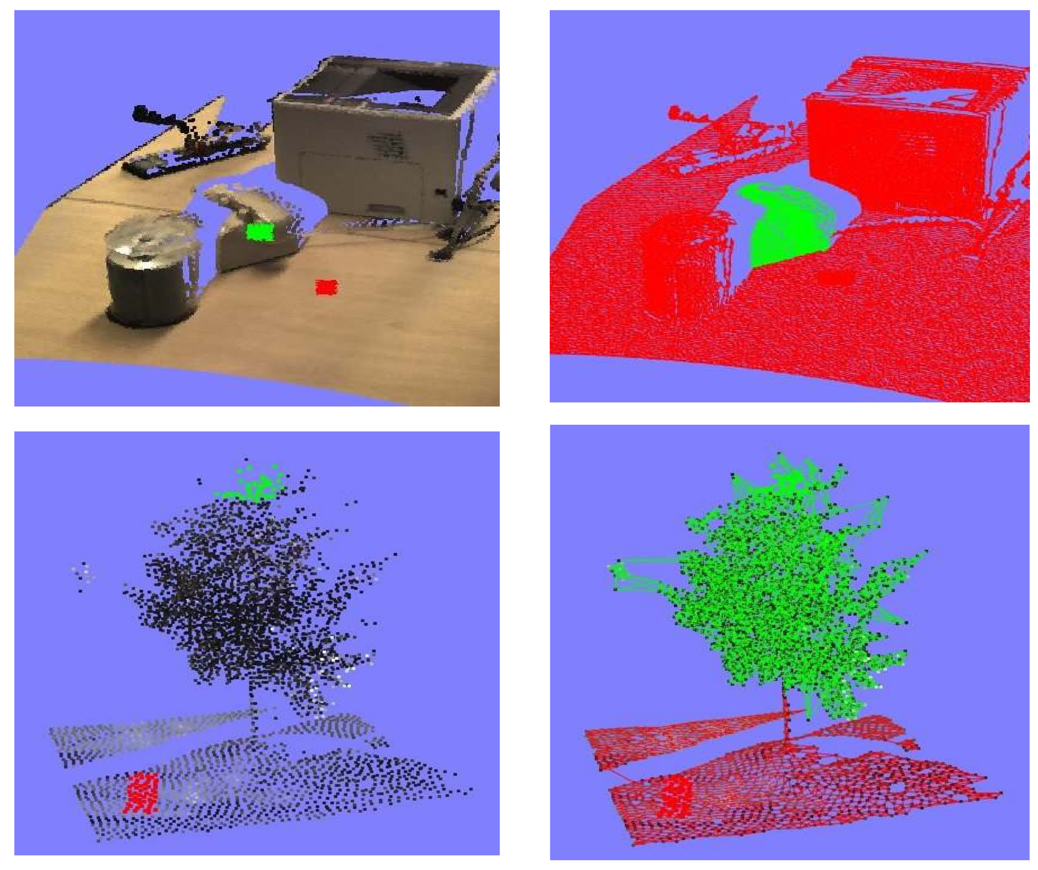
Graph Cuts Based Interactive Segmentation

Building the Graph

- We use a Riemannian graph on the scan points
- Building the Riemannian graph on large scans is very slow (depends on the EMST which depends on the Delaunay tetrahedralization)
- We are experimenting with simpler graphs (connected KNN graphs, etc)

Weighting the Graph

- We incorporate all of the information we have about the points into the edge weight function
- Normal distance (D_N) – the angle between the normals of adjacent points
- Color distance (D_C) – the Euclidean distance in RGB space between the color of adjacent points
- Euclidean distance (D_E) – the distance between the coordinates of adjacent points
- Many objects can be segmented using only one of these distances:



Optimizing the Weight Function

- We want to weight these three distances appropriately according to what kind of object we are segmenting

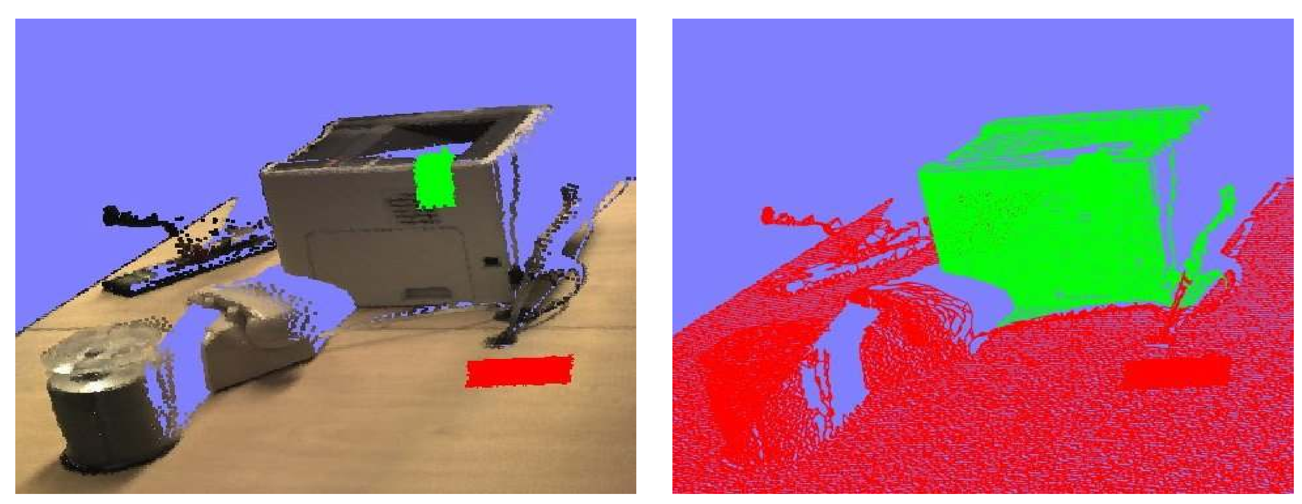
$$W = W_N D_N + W_C D_C + W_E D_E$$

- Automatic
  - No need for a training database
  - No user parameter estimates required
- Gradient descent optimization on the cut weight

Current/Future Work

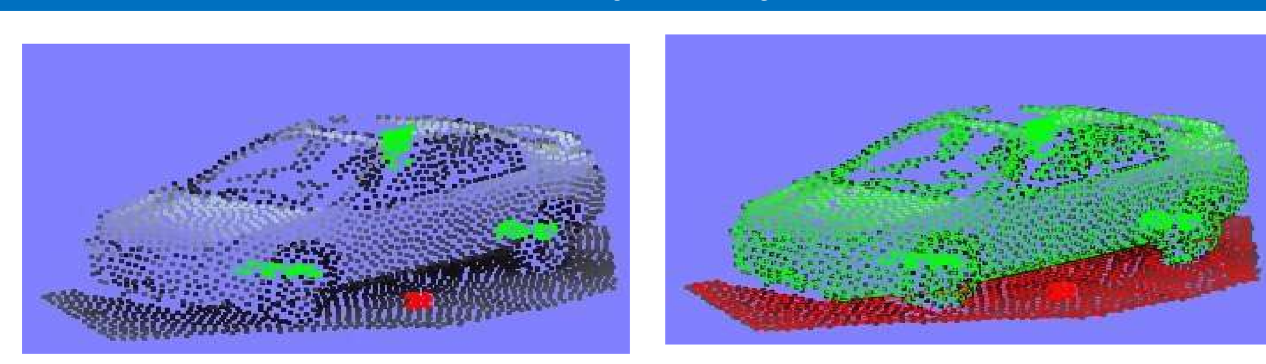
Compactness

- We are looking for a definition of "compactness" of a segmentation
- Many researchers have added "boundary smoothness" terms to the graph cut optimization function in images
- This is not directly applicable, but we hope to address cases like this:



- The segmentation should group the wires with the background
- The segmentation with the wires in the foreground leads to a much less "constrained" object
- By defining and analyzing the "shape" of the 3D cut, we hope to correct these cases.

Complex Objects



- Some difficult object require more than one foreground or background stroke
- The goal is to select any object with a single stroke, just as humans recognize the collection of points as a single object

Contact

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