Fast and Robust Edge Extraction in Unorganized Point Clouds

In this project, a method to detect sharp edge features by analysing the eigenvalues of the covariance matrix that are defined by each point's k-nearest neighbors.

1. For each point of the cloud, a least squares local plane is fitted to its k nearest neighbors. The normal of each point is the eigenvector corresponding to the smallest eigenvalue of the covariance matrix.

2. A method is proposed to extract sharp edges without clustering. Since estimating normals by PCA is based on the eigenvalues of the covariance matrix, we extract edge features merely with the variation of the eigenvalues for each point

3. Covariance is a measure of how much each of the dimensions varies from the mean with respect to each other. For a 3 dimensional data set (X, Y, Z), the 3×3 Covariance matrix C for a sample point p(x,y,z) is given by:

$$C = \begin{bmatrix} Cov(x,x) & Cov(x,y) & Cov(x,z) \\ Cov(y,x) & Cov(y,y) & Cov(y,z) \\ Cov(z,x) & Cov(z,y) & Cov(z,z) \end{bmatrix}$$

4. Then the concept of surface variation σk(p) is used.
   The surface variation, σk(p), for each sample point with k neighbors allows us to distinguish whether the point belongs to a flat plane or to a salient point (edge) in the point cloud. Since the smallest eigenvalue of covariance matrix for the flat surfaces is zero then the value of the surface variation for the flat surfaces would be zero.

Proposed Future Work Methodology:

1. Use existing algorithms to detect edge points.
2. Use Hough Transform to identify planar surfaces. (Ref : link)
3. Isolate edges and planes into individual objects.
4. Compute pose (orientation) for each segmented object using the PnP (Perspective-n-Point) problem using matched correspondences. (Ref : Perspective-n-Point (PnP) pose computation)

WorkFlow:

1. Preprocess PCD → detect edges.
2. Detect planes (Hough) → cluster edges.
3. Isolate objects → estimate pose.
4. Visualize results.

Base Paper : link Paper which used base paper as ref : link