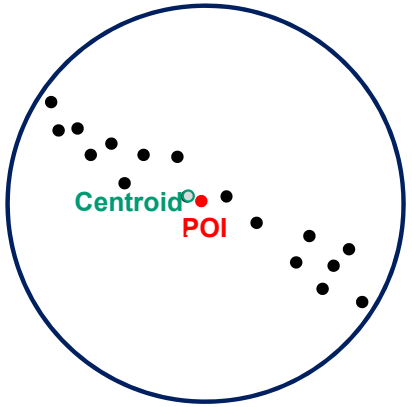
PCA-Based Seed Region Classification

- **Classification using Eigen value analysis of the dispersion of 3D neighboring points relative to their centroid:**
- **Define a spherical neighborhood for the point of interest – the neighborhood includes *n* points (number of points needed for reliable seed region classification)**
- **Calculate the dispersion matrix of the points in the spherical neighborhood relative to the centroid point**

$$C_{3\times 3} = \frac{1}{n+1}\sum_{i=1}^{n+1}(\vec{r}_i - \vec{r}_{centroid})(\vec{r}_i - \vec{r}_{centroid})^T$$

$$\vec{r}_i = \begin{bmatrix} X_i & Y_i & Z_i \end{bmatrix}^T$$

$$\vec{r}_{centroid} = \frac{1}{n+1}\sum_{i=1}^{n+1}\vec{r}_i$$



- **Eigen value decomposition of the dispersion matrix**

$$C = W\Lambda W^T = \begin{bmatrix} \vec{e}_1 & \vec{e}_2 & \vec{e}_3 \end{bmatrix} \begin{bmatrix} \lambda_1 & 0 & 0 \\ 0 & \lambda_2 & 0 \\ 0 & 0 & \lambda_3 \end{bmatrix} \begin{bmatrix} \vec{e}_1^T \\ \vec{e}_2^T \\ \vec{e}_3^T \end{bmatrix}$$

- **If $\lambda_3\ (\approx 0) \ll \lambda_1, \lambda_2$ the point of interest (POI) is considered to belong to a planar surface.**

PCA-Based Seed Region Classification: 1st Option

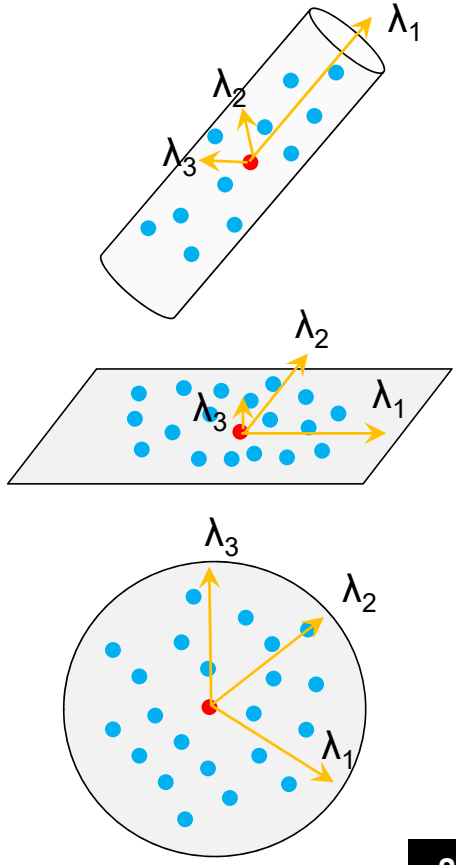
- **Threshold-based PCA**
  - Normalize the ordered eigenvalues

$$\lambda_{1n} \geq \lambda_{2n} \geq \lambda_{3n} > 0 \; - where \; \lambda_{in} = \frac{\lambda_i}{\lambda_1 + \lambda_2 + \lambda_3}$$

Linear/cylindrical: $\lambda_{1n} > Threashold_1$

Planar : $\lambda_{3n} < Threashold_2$ $\quad \frac{\lambda_{2n}}{\lambda_{1n}} > Threashold_3$

Note: the thresholds are based on a trial and error process

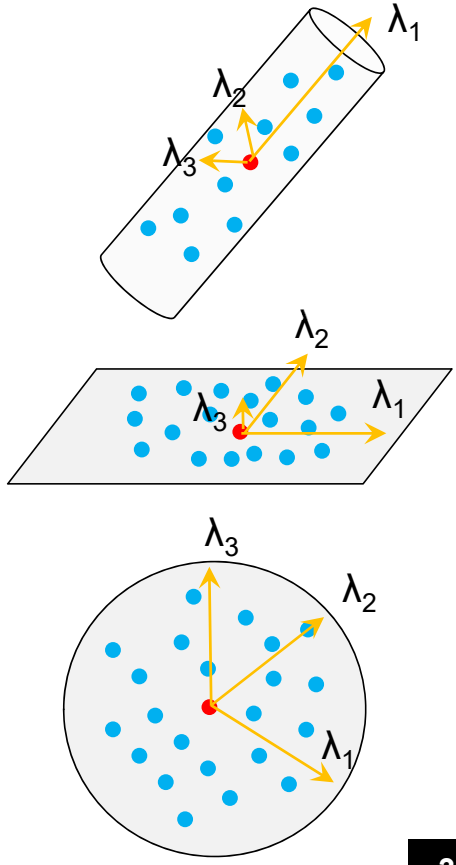


PCA-Based Seed Region Classification: 2nd Option

- **Use PCA → decide whether the point belongs to a planar, linear/cylindrical, or rough neighborhood**
  - Derive eigenvalues (λ_1, λ_2, and λ_3), where $\lambda_1 \geq \lambda_2 \geq \lambda_3 > 0$

- **Dimensionality-based PCA (Demantke et al., 2011)**
  - a_{1D} (linear/cylindrical), a_{2D} (planar), and a_{3D} (rough)
    - ➔ The largest value indicates the type of the neighborhood

$$a_{1D} = \frac{\sqrt{\lambda_1} - \sqrt{\lambda_2}}{\sqrt{\lambda_1}} \qquad a_{2D} = \frac{\sqrt{\lambda_2} - \sqrt{\lambda_3}}{\sqrt{\lambda_1}} \qquad a_{3D} = \frac{\sqrt{\lambda_3}}{\sqrt{\lambda_1}}$$



J. Demantké, C. Mallet, N. David, and B. Vallet, "Dimensionality based scale selection in 3D lidar point clouds," Int. Arch. Photogramm. Remote Sens. Spat. Inf. Sci., vol. 38, no. Part 5, p. W12, 2011.