Unsupervised Learning for Subterranean Junction Recognition Based on 2D Point Cloud

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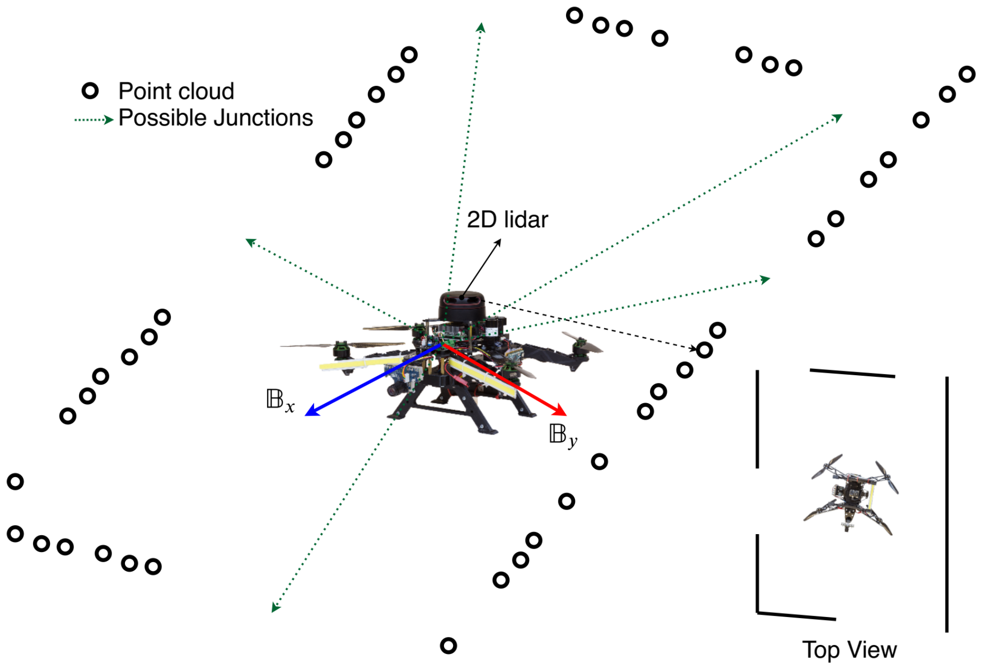
Problem Statement

- Integration of the MAVs in inspection and production areas
- MAV equipped with sensor suites to autonomously navigate along the tunnel and collect information
- These platforms can be considered as consumables that can be instantly replaced



Contributions

- Develop a new framework for recognizing subterranean junctions using spectral clustering
- The proposed method allows us to uncover intrinsic structures from the 2D point cloud extracted from a lidar.
- A comprehensive evaluation of the proposed method in simulation environments with complex geometry and data-sets

Junction Detection

- $X \in R^{n \times 2}$ be a data matrix comprising of n data points
- Construct a similarity graph $G = (V, E, W)$
- The matrix $W \in R^{n \times \mathrm{n}}$ is the adjacency matrix
- Use the RBF as a measure of similarity

Junction Detection

- For some user-defined $\sigma > 0$, we compute the pairwise similarity between x_i and x_j

$$W(i,j) = \exp(-\sigma \|x_i - x_j\|_2^2), \ \forall i,j \in \{1,\ldots,n\}$$

- The next task is to compute a spectral embedding of the original data points $x_1, \ldots, x_n$

Junction Detection

- Form the normalized Laplacian matrix $L \in R^{n \times n}$

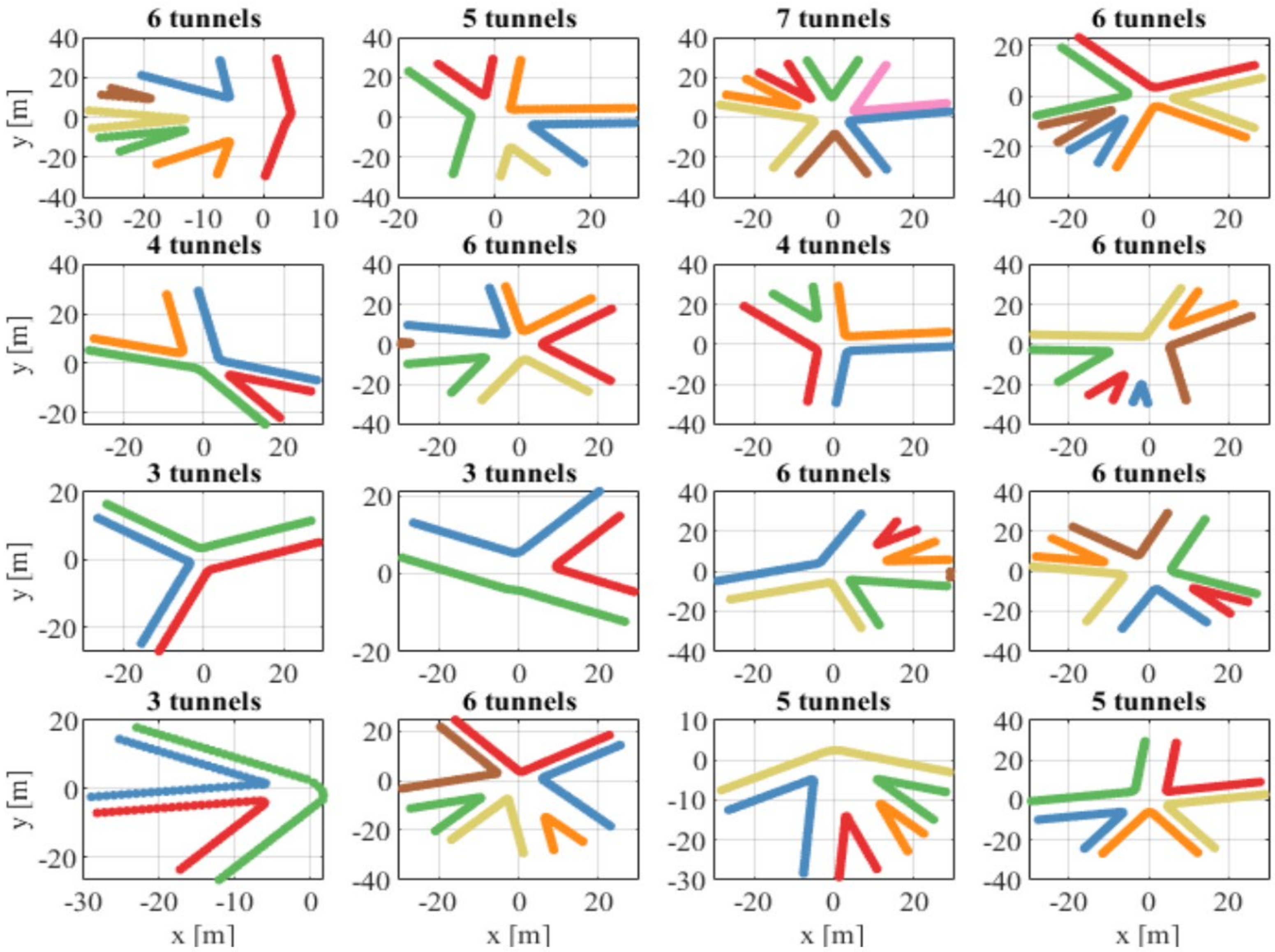
$$L = I - D^{-1/2} W D^{-1/2}$$

- The eigenvalue decomposition of L provides valuable insights about the structure of the similarity graph
- The number of connected components in the graph G is equal to the multiplicity of the 0 eigenvalue.

- k be the estimated number of connected components
- we compute the eigenvectors associated with the k smallest eigenvalues of L
- we form a new matrix $U \in R^{n \times k}$ by concatenating these k eigenvectors column-wise
- The last step is to perform the *K-means* clustering algorithm on the non-linearly transformed data points $u_1, \ldots, u_n$

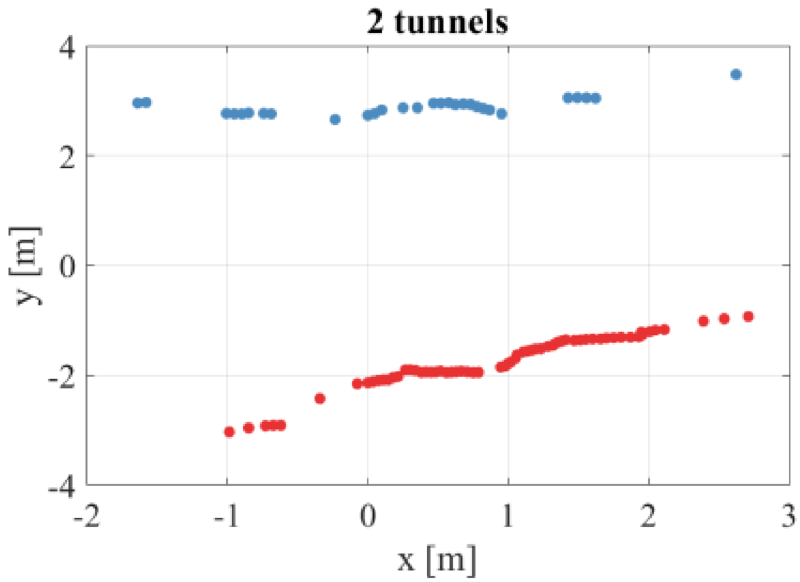
$$\min_{\mathcal{C}} f(\mathcal{C}, U) = \sum_{i=1}^{n} \min_{c \in \mathcal{C}} \|u_i - c\|_2^2$$

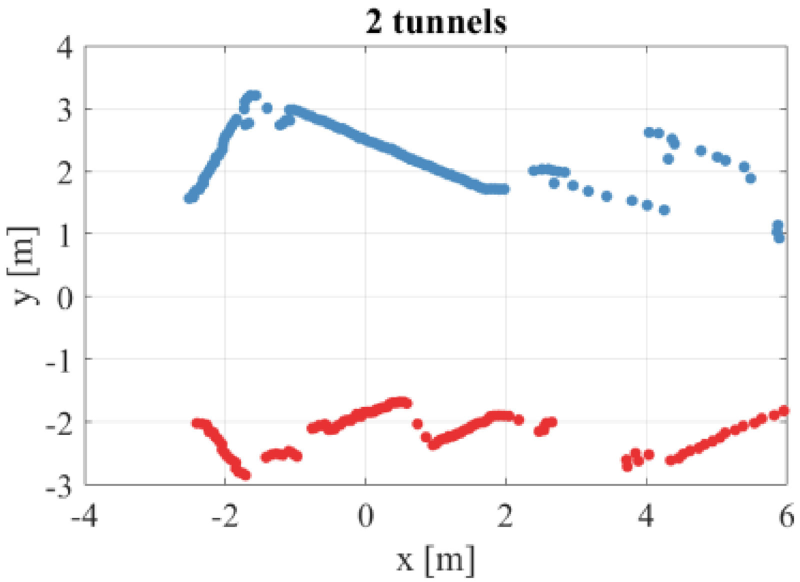
Simulation Evaluations

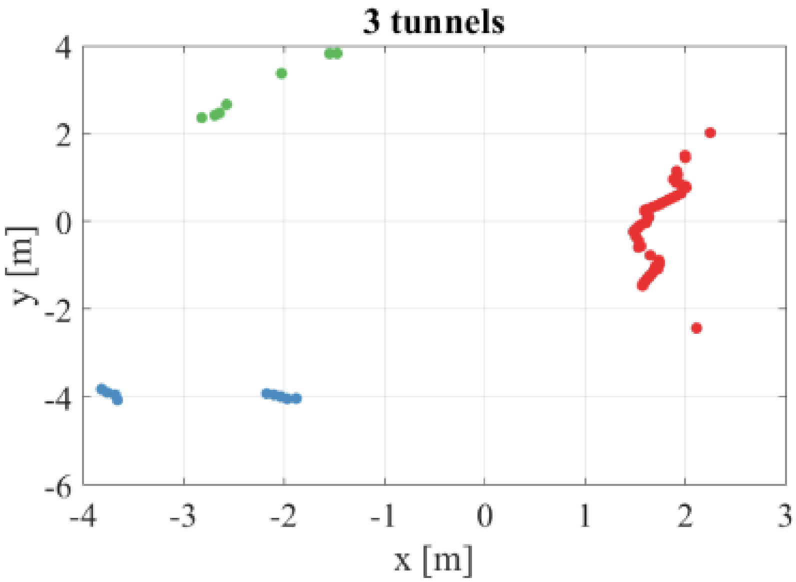


Experimental Data-sets Evaluations

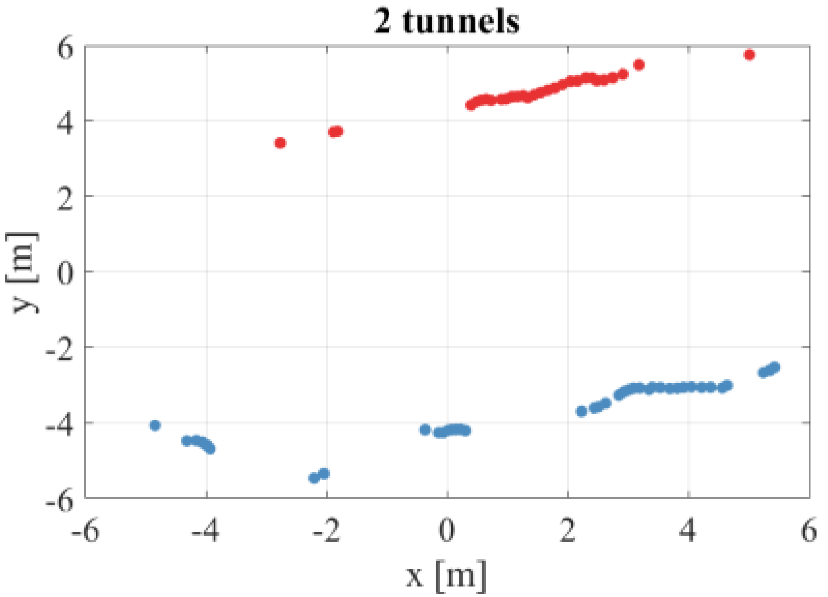


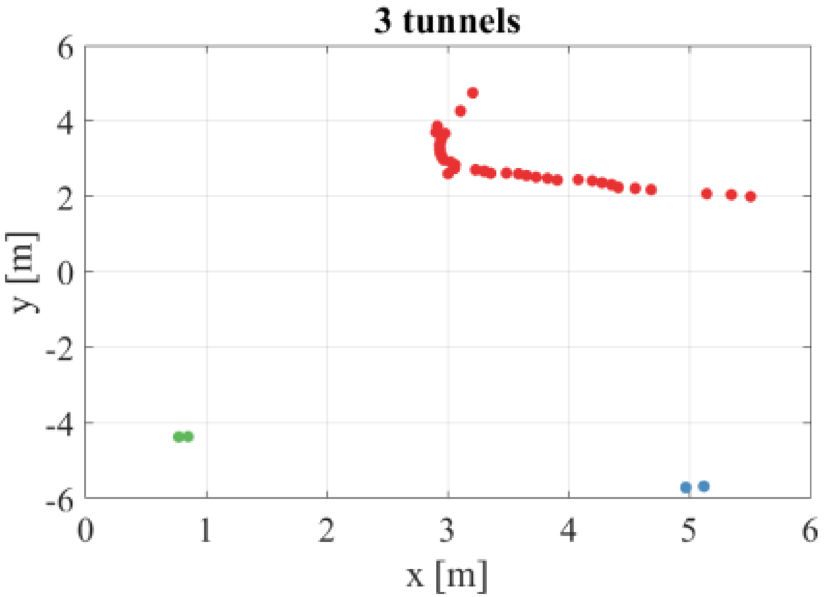


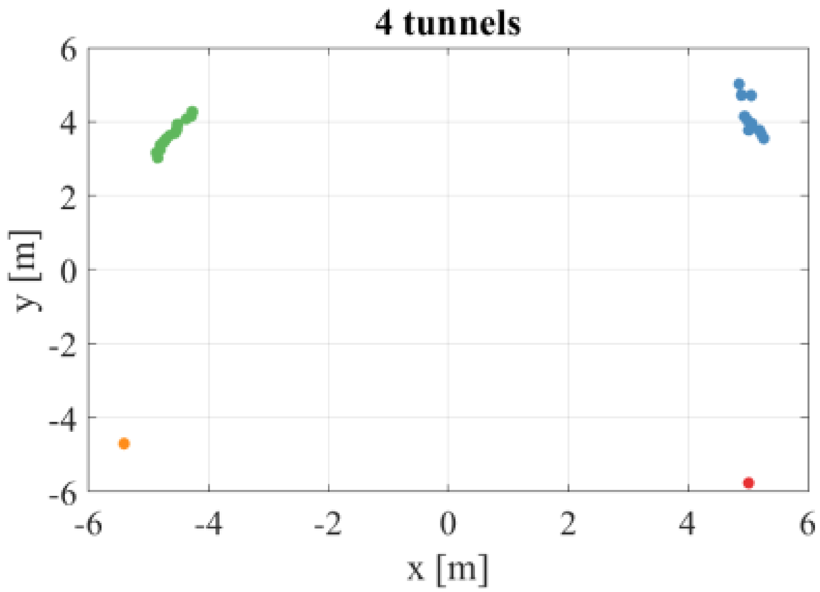




Experimental Data-sets Evaluations







Thank you!

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