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AGRICULTURE-VISION

CherryPicker: Semantic Skeletonization and Topological Reconstruction of Cherry Trees

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Introduction

CherryPicker is an automatic pipeline for accurate trait extraction from 3D point clouds of trees. It reconstructs photometric point clouds, performs semantic segmentation, and extracts the tree's topological structure. It overcomes scale ambiguity, applies semantic skeletonization, and removes artifacts, resulting in high-quality topology reconstructions of cherry trees.

Contributions:

- Automatic reconstruction pipeline for extracting the topology of cherry trees
- Semantic Laplacian-based contraction algoritm
- ArUco-marker-based scale factor estimation for metric point clouds

Cherry Picker

Reconstructor: Images were captured from multiple angles and heights, resulting in around 250 images per tree. COLMAP was used to extract camera poses and a dense point cloud

Point Cloud Restorer: The restoration step of the pipeline focuses on transforming the point cloud to a defined orientation, extracting the region of interest (ROI), and performing denoising. Alignment involves orienting the ground plane of the point cloud with the local coordinate system's xy-plane, while the ROI extraction removes the background and isolates the tree using camera positions and a bounding box. Denoising tackles errors caused by noisy depth values and sky image projections using statistical filtering and a U-Net neural network for sky silhouette removal.

Enabling navigation inside a cherry tree by using topology

Snap a photo to get your hands on the **full paper** and **poster**

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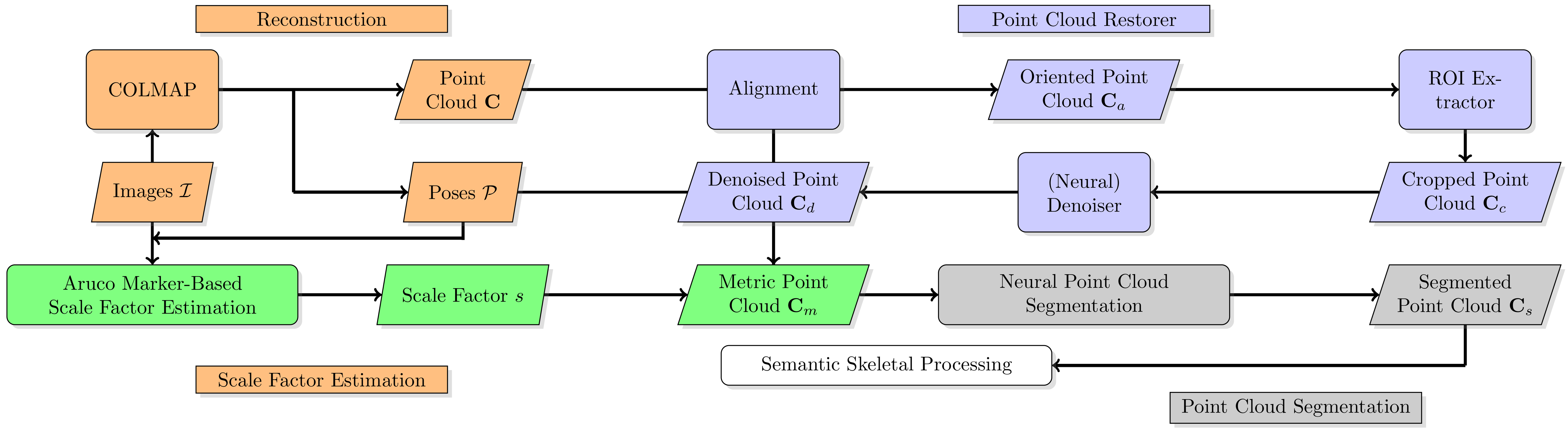
Scale Factor Estimator: The proposed method utilizes a single ArUco marker with a known size placed in the scene to determine the scale factor, overcoming the scale ambiguity in MVS. By minimizing the sum of squared distances between intersecting lines, the 3D corners of the ArUco marker are obtained, allowing the computation of the scale factor and achieving accurate results such as trunk diameter estimation.

Point Cloud Segmentor: The point cloud is segmented using a Deep Graph Convolutional Neural Network (DGCNN) to assign semantic labels to each point, resulting in a high-quality segmented point cloud that can be further processed to extract the skeleton and create a simplified graph representation.



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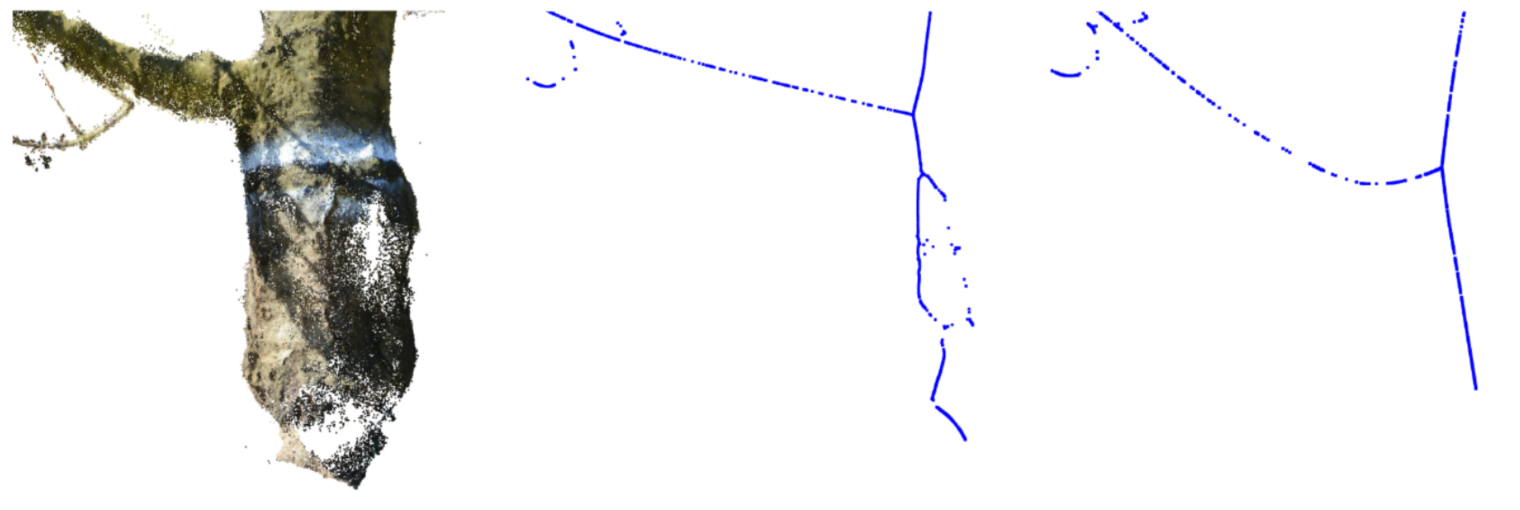
Semantic Laplacian-Based Contraction

We employed Laplacian-based Contraction (LBC) and Semantic Point Cloud Contraction (S-LBC).

$$\begin{bmatrix}\mathbf{S}\circ\mathbf{W}_L\mathbf{L}\\ \mathbf{W}_H\end{bmatrix}\mathbf{C}' = \begin{bmatrix}\mathbf{0}\\ \mathbf{W}_H\mathbf{C}\end{bmatrix}$$

$\mathbf{W}_L$ and $\mathbf{W}_H$ are sparse weighting matrices to regulate contraction and attraction. $\mathbf{L}$ is the cotangent Laplacian matrix. $\mathbf{S}$ is a semantic weighting matrix to weight trunk and branches differently. LBC compresses a 3D point cloud $\mathbf{C}$ while preserving its global geometric characteristics. However, LBC can lead to distortion and incorrect contractions in cases where there is a significant disparity in diameter between trunk and branches, or when there are holes in the point cloud.
To address these issues, S-LBC integrates semantic information of the point cloud segmentation into the contraction process, resulting in a more accurate skeletonization of the tree trunk.



(a) Original PCD (b) LBC (c) S-LBC (Ours)

Conclusion & Future Work

We present a pipeline for automatic extraction of topological structures from PCD's of trees. The extracted skeletons enable navigation within trees, which makes it possible to determine locations of fruits, blossoms, and leafs. This is a crucial step for digital twins in horticulture and precise measuring of trees.