High-Detail Surface Reconstruction of Individual Building Components for Robotic Manipulation

Robotic Perception Software Development

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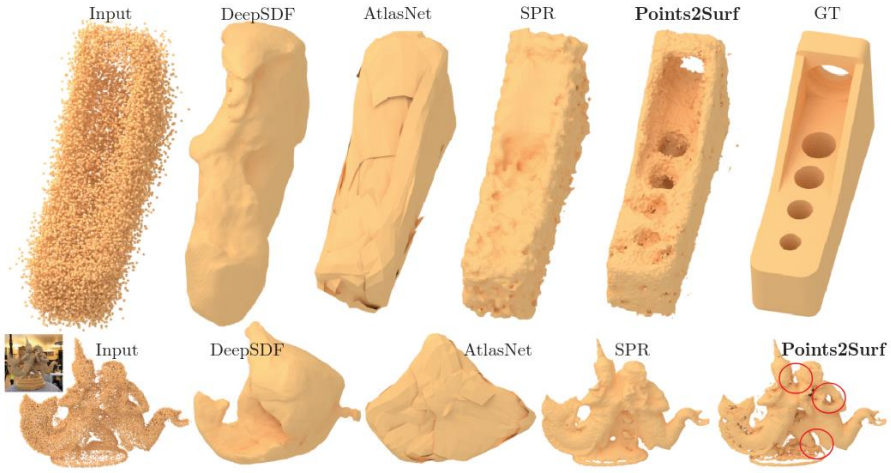

Image taken from: Erler, Philipp, et al. "Points2surf learning implicit surfaces from point clouds." *European Conference on Computer Vision*. Cham: Springer International Publishing, 2020.

Background

Robotic inspection on active construction sites increasingly depends on centimeter-level, high-fidelity surface models of individual structural elements—fresh concrete walls, steel columns, façade frames, etc. Accurate meshes enable tolerance checks, surface-quality assessment, and incremental digital-twin updates without re-meshing an entire site. Although dozens of surface-reconstruction algorithms exist, their performance on noisy, non-uniform, outdoor point clouds remains unclear. A rigorous benchmark plus a lightweight enhancement to a strong baseline can therefore provide immediate value to practitioners and open a clear research contribution.

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TYPE
Bachelor's/Master's thesis

LANGUAGE
English

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REQUIREMENTS
Programming: Python, C++ (optional)
Frameworks: ROS2
Simulation: NVIDIA Isaac Sim, basic 3D simulation concepts
3-D Processing: PCL, Open3D, CGAL, OpenVDB
ML (baseline): PyTorch
Dev Ops: Git, Docker, CI for reproducibility

Description

The thesis adopts an **80 % survey / benchmarking** and **20 % targeted enhancement** strategy:

1. **Benchmark Suite (80 %)** – Build a ROS 2-ready pipeline that ingests robot-collected point clouds of construction-site components (≤ 10 m³) and runs several state-of-the-art algorithms—Screened Poisson, Adaptive Ball-Pivoting, Voxel-Hash TSDF, and a local neural-implicit model (e.g. Points2Surf). Quantify accuracy, completeness, runtime, and memory against from every model.
2. **Focused Improvement (20 %)** – Identify the dominant failure mode revealed by the benchmark (e.g. Poisson's false back-faces or Ball-Pivoting's density sensitivity). Design and implement an **effective modification**—such as confidence-weighted voxel pruning for Poisson or an adaptive-radius scheme for Ball-Pivoting—and show measurable gains on the same dataset for scans taken from the construction site.

The deliverable is a **ROS 2 package** containing the dataset, launch files, evaluation scripts, and the improved algorithm variant, ready for direct use in construction-robotics projects.

Tasks

Phase	Key Activities
1. Literature & Data Plan	• Review object-scale reconstruction literature. • Define evaluation metrics (Chamfer, normal error, completeness). • Plan data collection.
2. Data Acquisition & Pre-processing	• Record ≥ 10 diverse components. • Implement ROS 2 node for filtering, registration, normal estimation. • Generate ground-truth meshes.
3. Baseline Integration	• Wrap baseline algorithms in ROS 2 (Poisson, BPA, TSDF, Points2Surf). • Standardize I/O and parameters; run preliminary tests.
4. Benchmark & Failure Analysis	• Execute full benchmark; collect quantitative results. • Visualize systematic failure modes; select target for improvement.
5. Targeted Enhancement	• Design modification (e.g. support-density trimming for Poisson). • Implement, optimize, and integrate into pipeline. • Re-benchmark to quantify improvement.
6. Documentation & Release	• Package code, dataset, and evaluation scripts. • Write thesis.

Further Readings

- Kazhdan, Michael, and Hugues Hoppe. "Screened poisson surface reconstruction." *ACM Transactions on Graphics (ToG)* 32.3 (2013): 1-13.
- Erler, Philipp, et al. "Points2surf learning implicit surfaces from point clouds." *European Conference on Computer Vision*. Cham: Springer International Publishing, 2020.
- Huang, Zhangjin, et al. "Surface reconstruction from point clouds: A survey and a benchmark." *IEEE transactions on pattern analysis and machine intelligence* (2024).
- Hildebrand, J., et al. "Simulating LiDAR to create training data for machine learning on 3D point clouds." *ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences* 10 (2022): 105-112.