Automated Scan-to-BIM pipeline for construction-site robotics

Advanced Robotics, Computer Vision & Building Information Modelling

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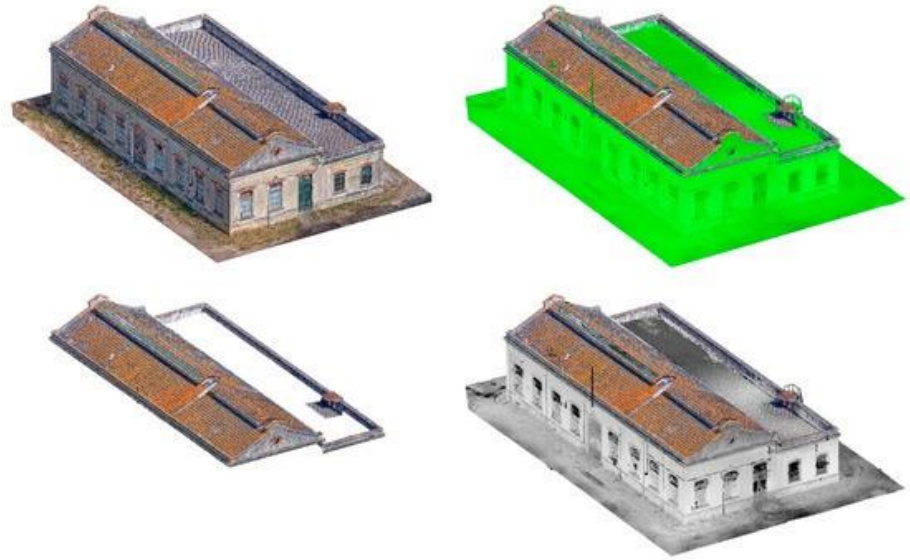

Point cloud data which can be selected by segments.
Rocha, G.; Mateus, L.; Fernández, J.; Ferreira, V. A Scan-to-BIM Methodology Applied to Heritage Buildings. *Heritage* **2020**, *3*, 47-67. https://doi.org/10.3390/heritage3010004

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TYPE
Master's thesis

LANGUAGE
English

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REQUIREMENTS
Programming: Python, C++, ROS 2
ML/DL: PyTorch/TensorFlow, Lightning, CUDA
Geometry Processing: Open3D, CGAL fundamentals
Simulation: NVIDIA Isaac Sim / Omniverse
BIM: IFC schema, IfcOpenShell

Background

Accurate, up-to-date Building Information Models (BIM) are essential for planning, progress monitoring and safety management on modern construction sites. However, generating or updating BIM data from on-site reality capture remains a labor-intensive process that can take days or weeks. Recent advances in mobile robotics, LiDAR/photogrammetry sensors and deep-learning-based point-cloud understanding enable a new **Scan-to-BIM** (S2B) workflow in which robots autonomously acquire 3D data and convert it into semantically rich BIM objects within hours. A robust, open-source pipeline tightly integrated with ROS 2 would accelerate digital-twin adoption and unlock on-site automation scenarios such as progress-aware task planning and clash avoidance.

Description

This Master's thesis investigates and implements a modular Scan-to-BIM pipeline that:

- **Autonomously captures** high-resolution point clouds of interior and exterior construction areas using a mobile robot platform.
- **Pre-processes** and registers multiple scans into one global frame (SLAM, loop-closure).
- **Segments and classifies** structural (slabs, beams, columns, walls) and MEP (pipes, ducts, cables) elements with state-of-the-art deep-learning techniques.
- **Parametrically fits** geometric primitives and boundary-representation (B-Rep) solids to segmented clusters.
- **Exports** the resulting model to **IFC** (Industry Foundation Classes) for ingestion by BIM authoring tools (Revit, Archicad).
- **Validates** the pipeline both in simulation (NVIDIA Isaac Sim, using synthetic ground-truth IFC).

Tasks

- **Literature & Technology Survey** – Scan-to-BIM algorithms, point-cloud DL, ROS 2 mapping stacks (AEDE by CMU, LIO-SAM, etc.).
- **Data Acquisition Framework** – Design ROS 2 launch files for robot navigation & scanning; implement adaptive coverage planning.
- **Pre-processing Module** – Outlier removal, global registration, clustering; leverage Open3D + CUDA acceleration.
- **Semantic Segmentation & Classification** – Train/finetune DL model on combined public (ScanNet, S3DIS) and simulated datasets; metrics: mIoU, per-class F1.
- **Geometry Reconstruction** – RANSAC primitive fitting, surface reconstruction, CSG boolean operations; generate parametric IfcBuildingElement proxies.
- **IFC Export & Integration** – Use IfcOpenShell/Python-OCC; provide ROS service for incremental BIM updates;
- **Evaluation** – Benchmark the pipeline in NVIDIA Isaac Sim against known ground-truth BIM.
- **Documentation & Dissemination** – Full thesis, repository, video demo.

Deliverables

1. **Modular Scan-to-BIM pipeline** (ROS 2 packages + Python libraries).
2. **Evaluation report** containing quantitative results and user-study analysis.
3. **Master's thesis document** with detailed methodology and discussion.
4. **Presentation & demo video** for defense and dissemination.

Further Readings

- Abreu, Nuno, et al. "Procedural point cloud modelling in scan-to-BIM and scan-vs-BIM applications: A review." *ISPRS International Journal of Geo-Information* 12.7 (2023): 260.
- Rocha, G.; Mateus, L.; Fernández, J.; Ferreira, V. A Scan-to-BIM Methodology Applied to Heritage Buildings. Heritage 2020, 3, 47-67. https://doi.org/10.3390/heritage3010004