Manhattan-world Urban Reconstruction from Point Clouds

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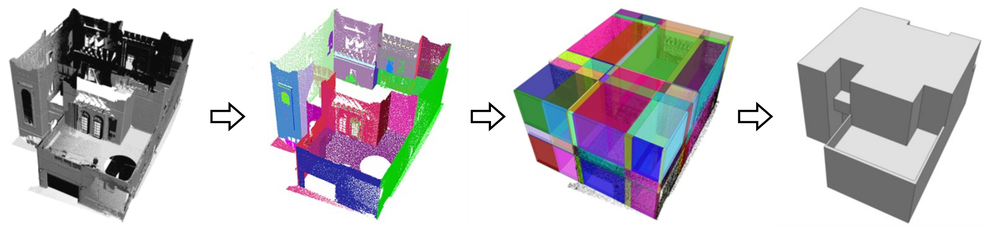
ECCV'16 EUROPEAN CONFERENCE ON COMPUTER VISION

1. Motivation

Given a point cloud of a Manhattan-world building, we want to approximate its geometry using a set of boxes.

Manhattan-world assumption: the major components of a building consist of axis-aligned planes.



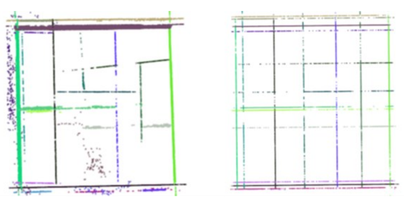
(a) Point cloud (b) Planes (c) Candidate boxes (d) Model

Pipeline

2. Method

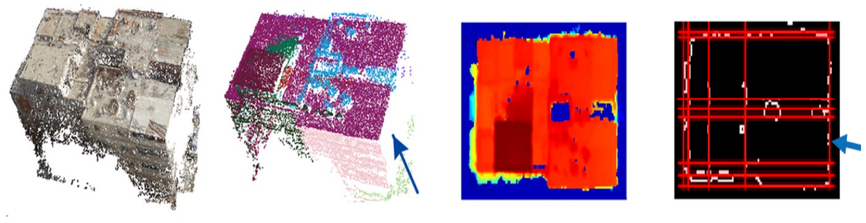
2.1 Candidate box generation

- RANSAC-based plane extraction [Schnabel *et al.* 2007].
- Iterative plane refinement.
- Detecting missing walls and roofs.
- Partitioning the space into a non-uniform grid.



(a) Initial (b) Refined

Plane refinement



(a) Point cloud (b) Planes (c) Height map (d) Walls

Detecting missing planes

2.2 Energy terms

- **Data fitting** measures how well a candidate box is supported by the point cloud.

$$S(b_i) = \sum_f^6 \sum_j^M \mathbf{n}_f \cdot \mathbf{n}_j \cdot dist(p_j)$$

$$dist(p_j) = \begin{cases} 1/(t + d_j), & d_j < d_t \\ 0, & \text{otherwise} \end{cases}$$

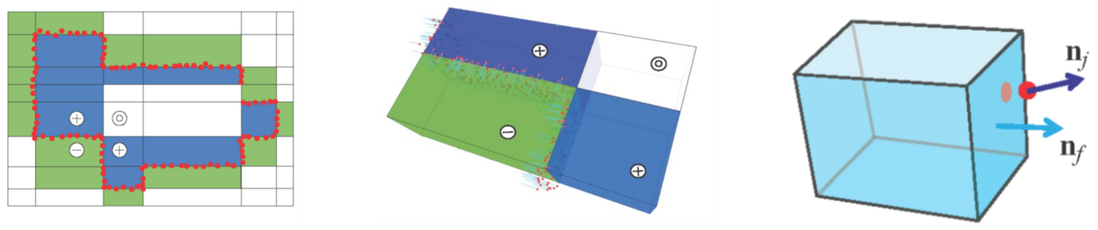
Three types of candidate boxes:

- *Positive boxes: positive scores,* inside the building (blue).
- *Negative boxes*: negative scores, outside the building (green).
- *Blank boxes:* scores close to zero (white).

- **Compactness** discourages holes and protrusions, defined on adjacent boxes:

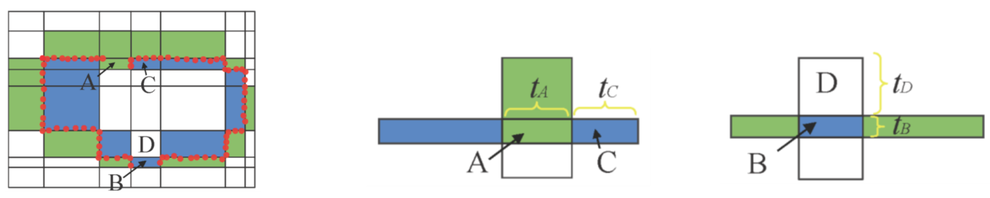
$$C_{i,j} = \frac{1}{min(t_i, t_j)}$$

t_i and t_j are the thickness values of two adjacent boxes b_i and b_j.



(a) Three types of boxes (b) A zoom-in (c) A supporting point

Candidate boxes and supporting points



(a) Candidate boxes (b) A hole (c) A protrusion

A 2D illustration of holes and protrusions

2.3 Optimization

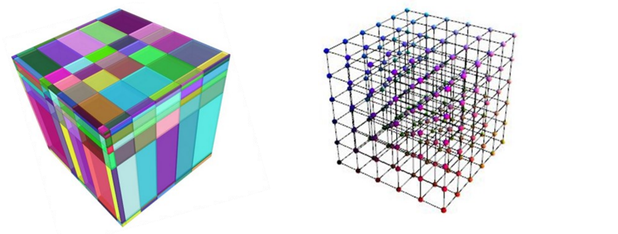
- **A Markov Random Field formulation**. The nodes of the graph represent all candidate boxes and edges connect adjacent boxes.

- **Energy function:** $E(\mathbf{X}) = \sum_{b_i} D(b_i) + \lambda \cdot \sum_{\{b_i, b_j\} \in \mathbb{E}} V(b_i, b_j)$

where $D(b_i) = \begin{cases} -S(b_i), & \text{for positive boxes} \\ S(b_i), & \text{otherwise} \end{cases}$ and $V(b_i, b_j) = \begin{cases} C_{i,j}, & \text{if } min(t_i, t_j) \leq 1 \\ 1, & \text{otherwise} \end{cases}$

. *Data term* $D(b_i)$ encourages to choose boxes having higher data fitting scores.

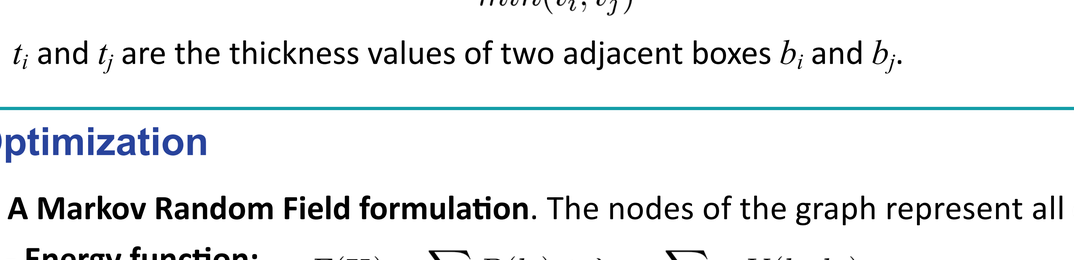
. *Smoothness term* $V(b_i, b_j)$ discourages holes and protrusions.



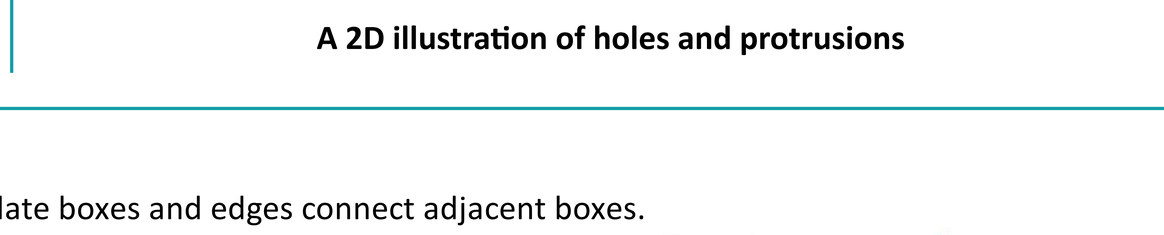
(a) Candidate boxes (b) The graph

Graph construction

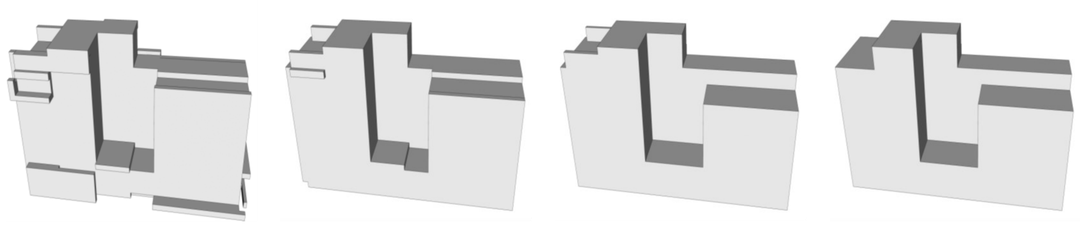
3. Results



Reconstruction from airborne LiDAR data

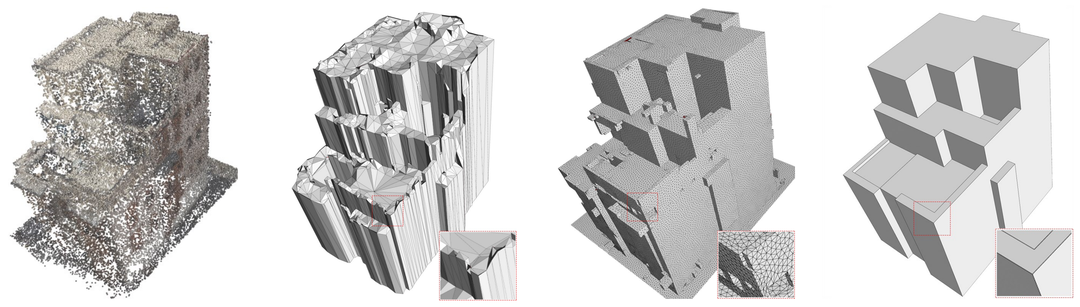


Reconstruction from MVS point clouds



λ= 0 λ= 10 λ= 30 λ= 50

The effect of parameter λ



Comparisons. From left to right: MVS points, 2.5D DC [Zhou *et al*. ECCV'10], L1-based polycube [Huang, *et al*. TOG'14], and our result.