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Acquisition and processing of point clouds to support building damage assessment

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Why building damage assessment?

- We spend nearly 90% of our time inside buildings.
- Buildings → excessive loading, natural hazards, man-made hazards.
- Two aspects of building damage:
  - Before it happens: structural health monitoring

  → Maintenance, evacuation guidance.
  - After it happens: detection and assessment of damage

  → Planning for the recovery phase;

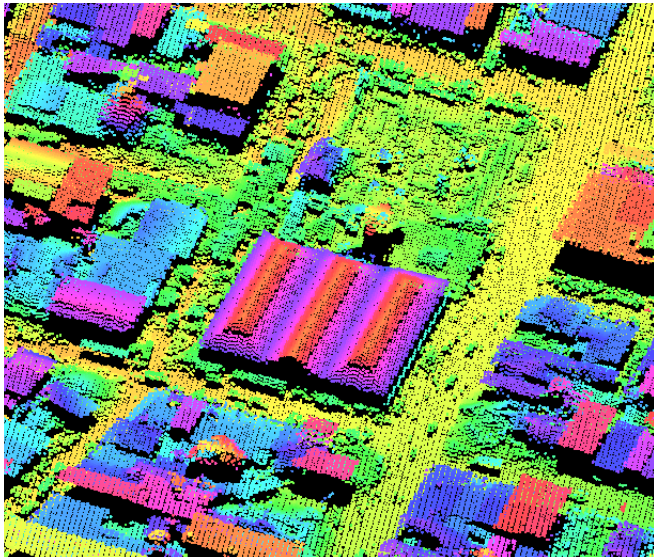
  → Rebuilding damaged buildings;

  → Repairing infrastructure.

Why point clouds?

- Most buildings have simple geometric shapes (polyhedron);
- Point cloud is an accurate representation of 3D geometry;
- Automated processing = Fast, inexpensive, less labor intensive.

Aerial image: convenient for human interpretation



Point cloud: suitable for automated information extraction (e.g. classification, geometric modeling, etc.).

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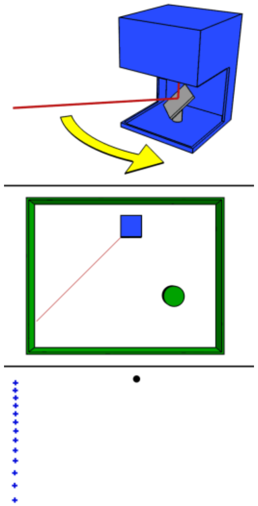
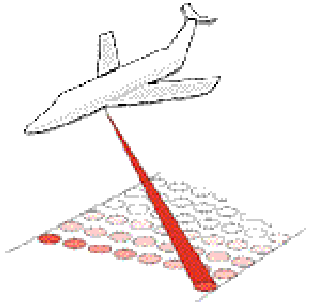
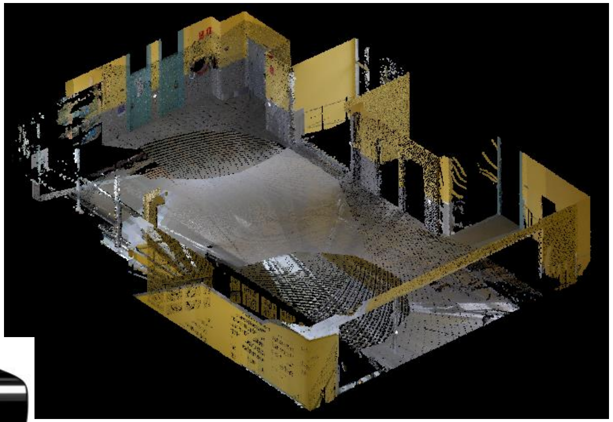
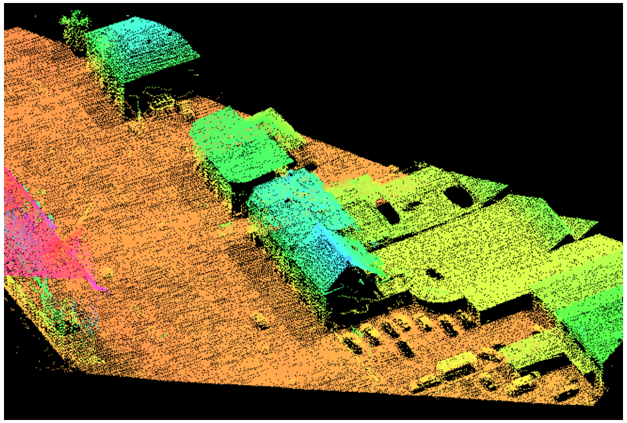
Acquisition of point clouds

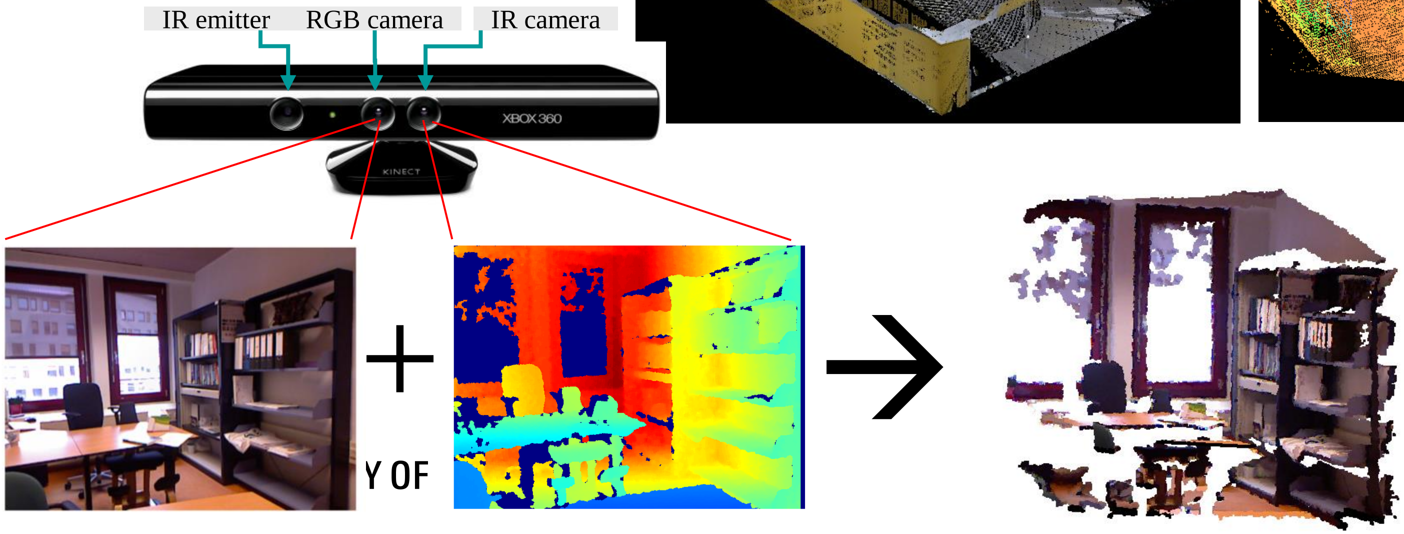


Wikipedia



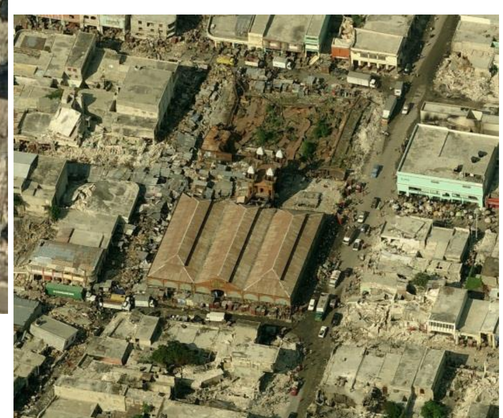






Classification of damaged roofs in aerial point clouds

Port-au-Prince after the earthquake of Jan. 2010.



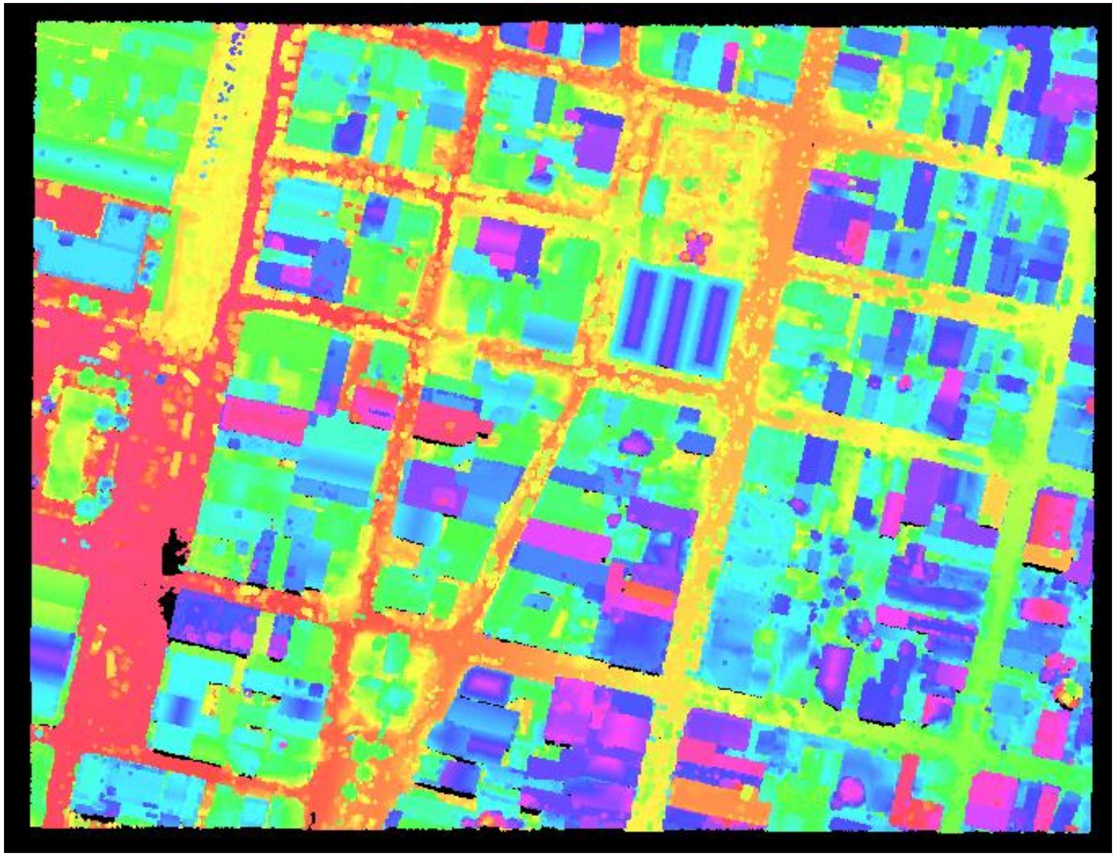
Classification of damaged roofs in aerial point clouds

- Assumptions:

  → Intact building roofs comprise a few large planar segments;

  → Damaged roofs appear as many small segments.

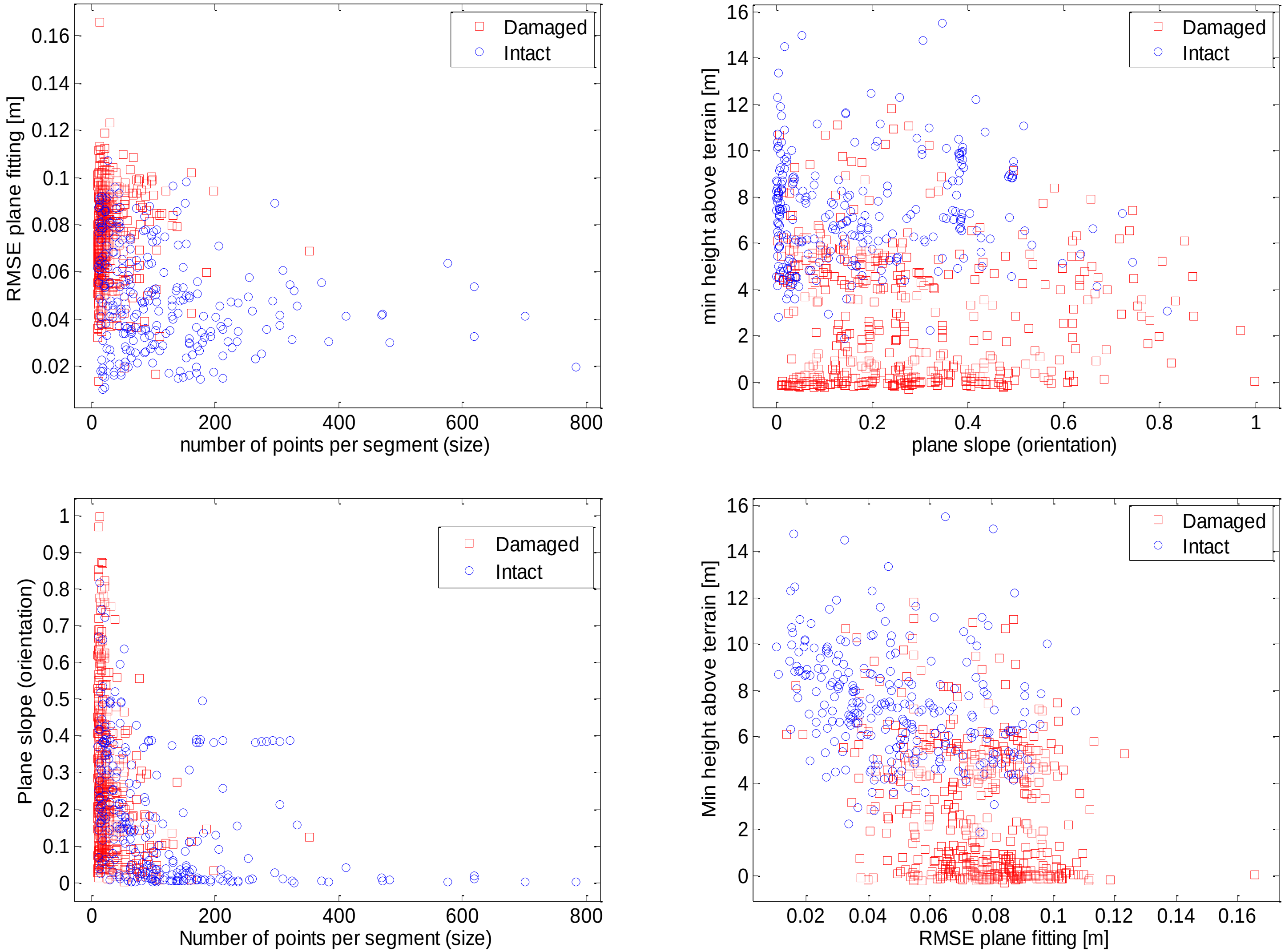
Post-event airborne laser data (3 pnts/m2).



- Possibly relevant features:
  → segment size;
  → planarity;
  → orientation;
  → height above terrain;
  → … ?

- Simple scenario:
  → only buildings (existing map)
  → two classes.

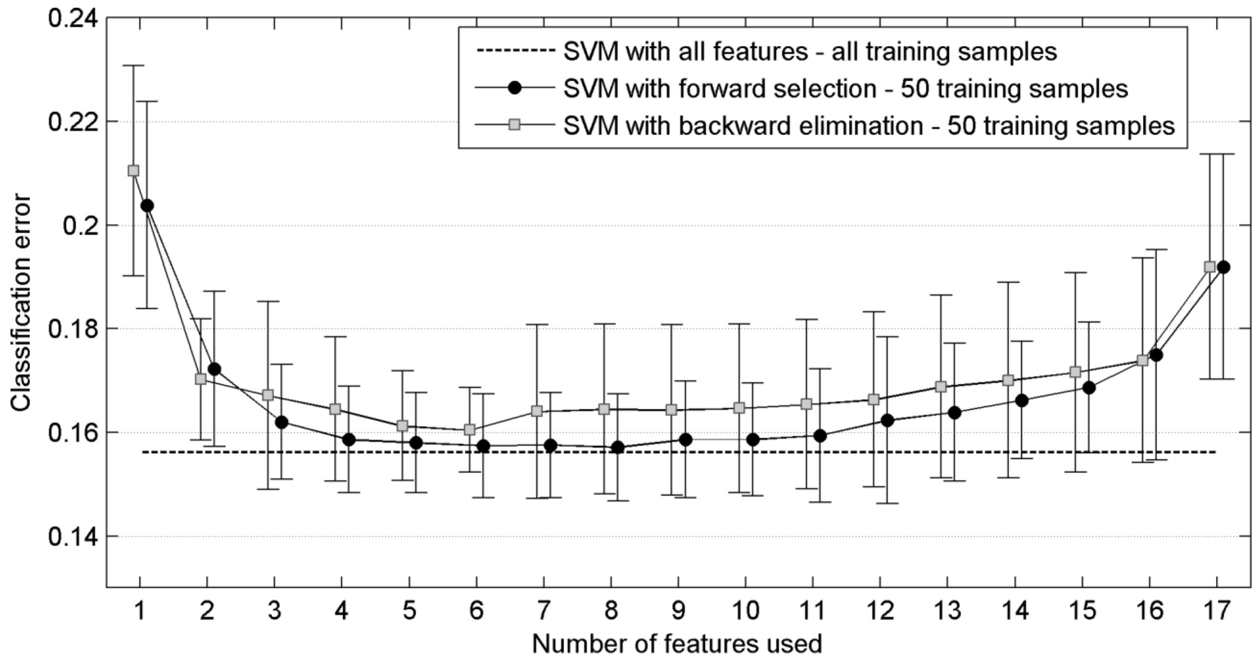
What are features of damaged/intact roof segments?



Lesson learned: geometric properties of segments are <u>not so distinctive</u> features as one might think!

Feature selection

- Using Support Vector Classifier (SVM)

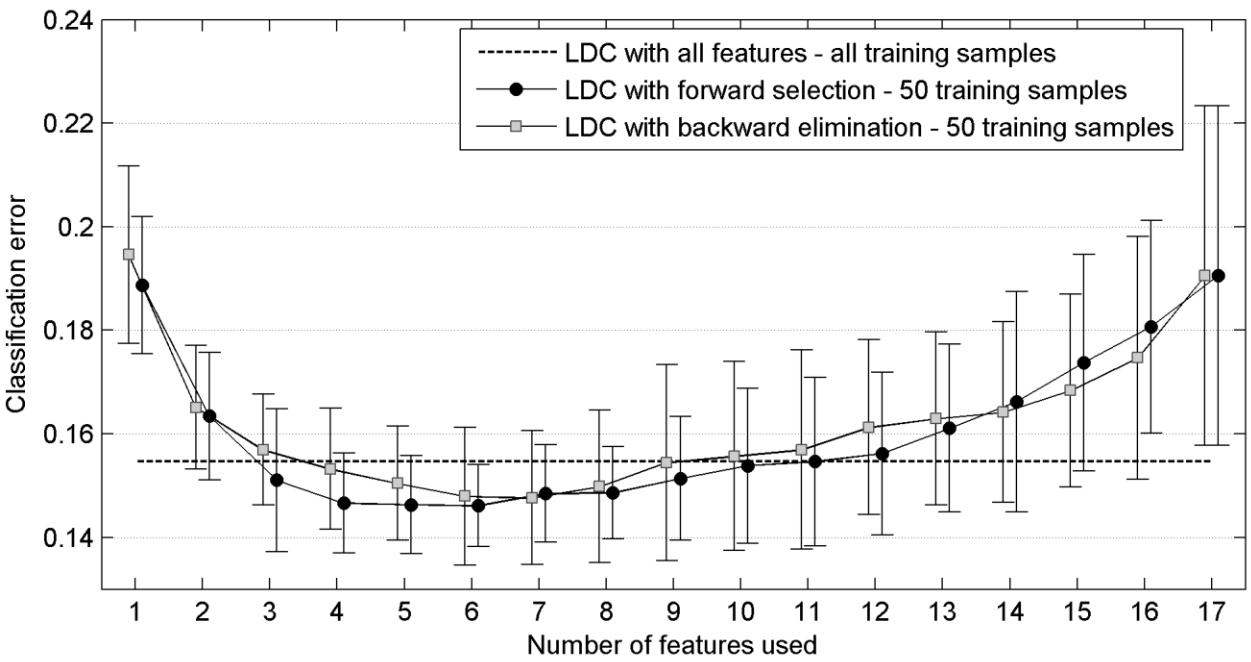


FEATURES EXTRACTED FOR EACH PLANAR SEGMENT

feat. id	Description
1	number of points per segment (nP)
2	root mean square of plane fitting residuals (rmsRes)
3	ratio of plane fitting outliers (rOut)
4	plane slope (s)
5	z component of plane normal (n_z)
6	mean reflectance per segment (meanRfl)
7	standard deviation of reflectance per segment (stdRfl)
8	minimum height above DTM (minH)
9	maximum height above DTM (maxH)
10	mean height above DTM (meanH)
11	ratio of points in a segment that have an unsegmented point in a neighbourhood of 1 m (rUnseg)
12	mean point density in the bounding box of the segment (meanDns)
13	mean planarity per segment (meanPλ)
14	mean sphericity per segment (meanSλ)
15	mean linearity per segment (meanLλ)
16	mean point spacing per segment (Aps)
17	standard deviation of average point spacing (stdAps)

Feature selection

- Using Linear Discriminant Classifier (LDC)



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Visual analysis

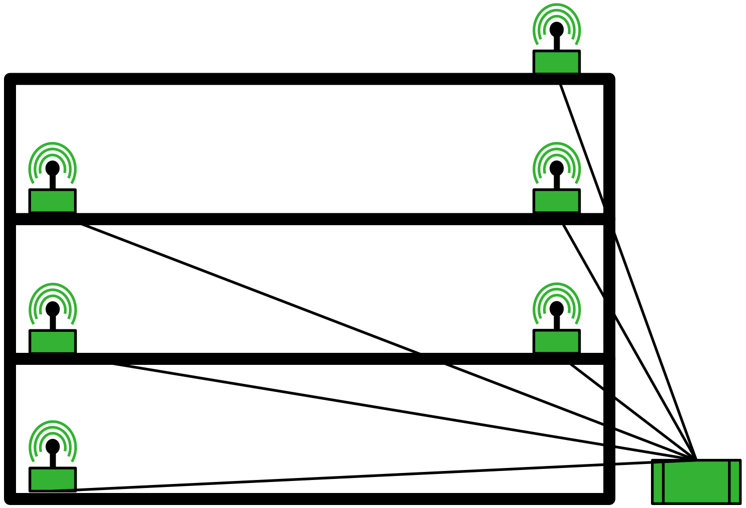
Visual analysis

Challenges …

- Classification to intact and rubble is not so useful in practice
  - More damage classes → damage grades
  - More damage classes = more difficult patterns
- Intact roof ≠ intact building
  - Damaged walls → oblique images → data fusion approach
- The question still remains: what are relevant features of damaged buildings (of different grades), which can be extracted from point clouds and/or images?
- Validation/verification?
- …

Structural health monitoring

- Low-cost wireless sensor networks collect data of structural integrity of buildings;
- These data are linked to (just) locations inside the building;
- Semantically rich indoor models → intelligent sensor networks
- Example: critical deformation, evacuation.
  - → where are the exits?
  - → what is the optimum route?
  - → …



Smart cities: sensor networks coupled with 3D models

3D city model

Image from ESRI City Engine

Indoor model

1st floor

2nd floor

Model from Google 3D warehouse

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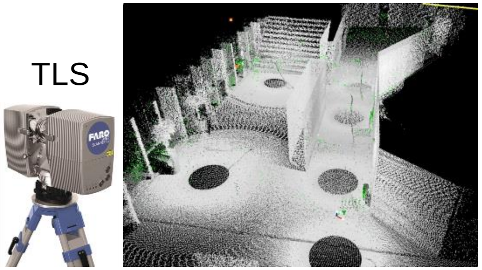
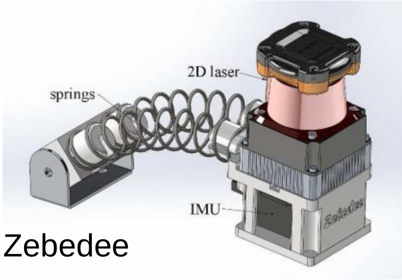
Why aren’t there indoor maps/models in Google Maps?

- 3D Models created from 2D floor plans and evacuation maps do not necessarily show the current situation of the building;
- Up-to-date 3D models from point clouds or images
- Data acquisition challenge
  - Image-based → low light
  - Mobile mapping, e.g. mobile laser → no GPS signals (deformed data)
  - Static laser scanning → time- and labor intensive;
  - SLAM techniques → not yet a mature technology
- Modeling challenge
  - Manual method → slow and costly
  - Automated methods → variety of indoor architectures

TMMS

TLS



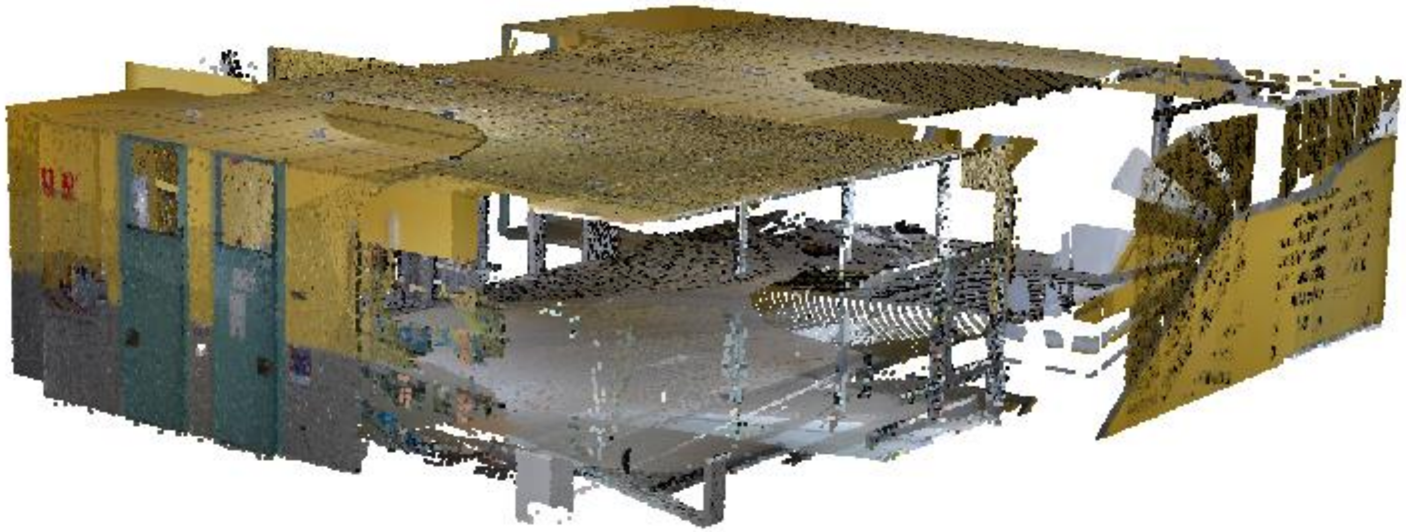


Zebedee

Example: semi-automated modeling from a point cloud

- Oriented point cloud

Work of Lucia Diaz Vilarino



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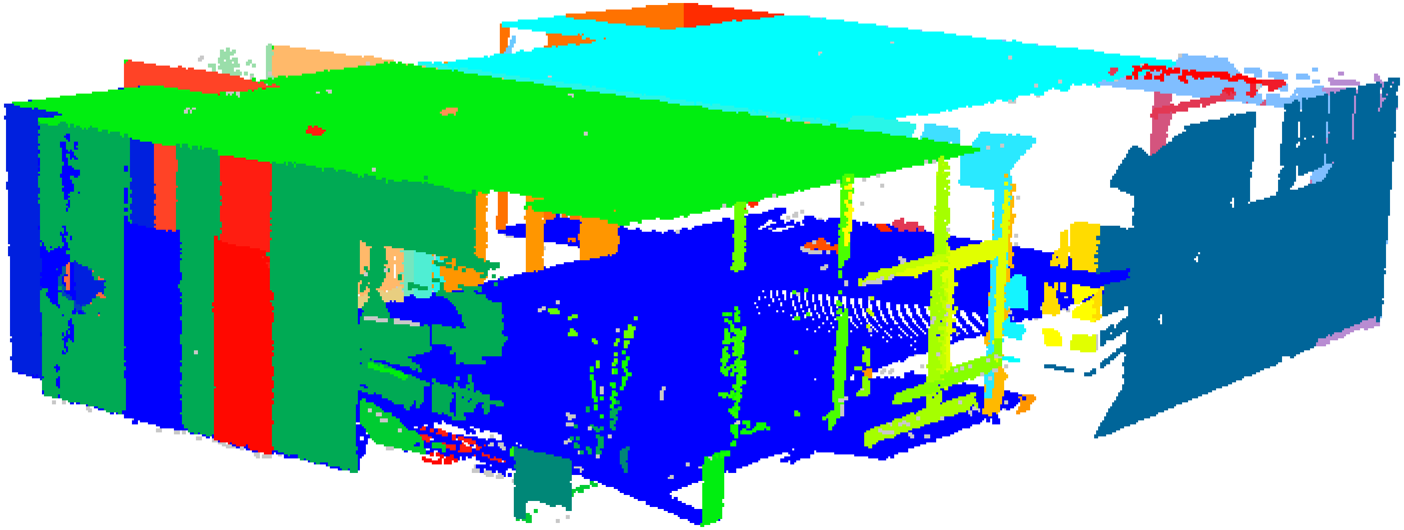
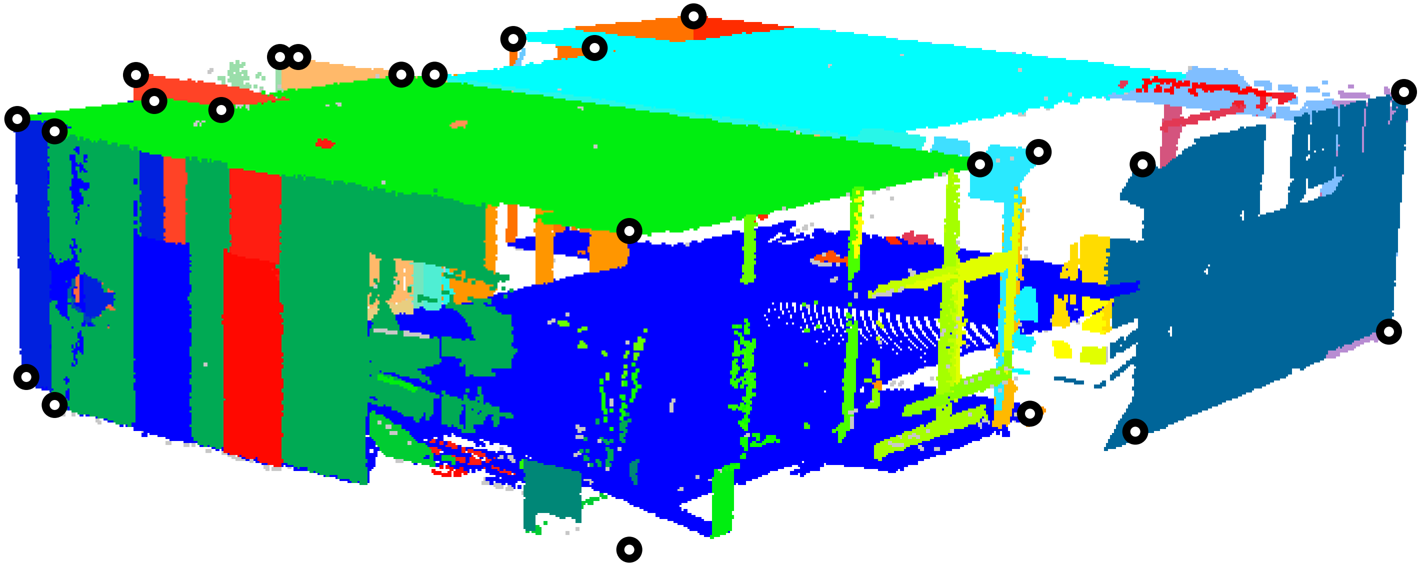
Example: semi-automated modeling from a point cloud

- Segmented point cloud



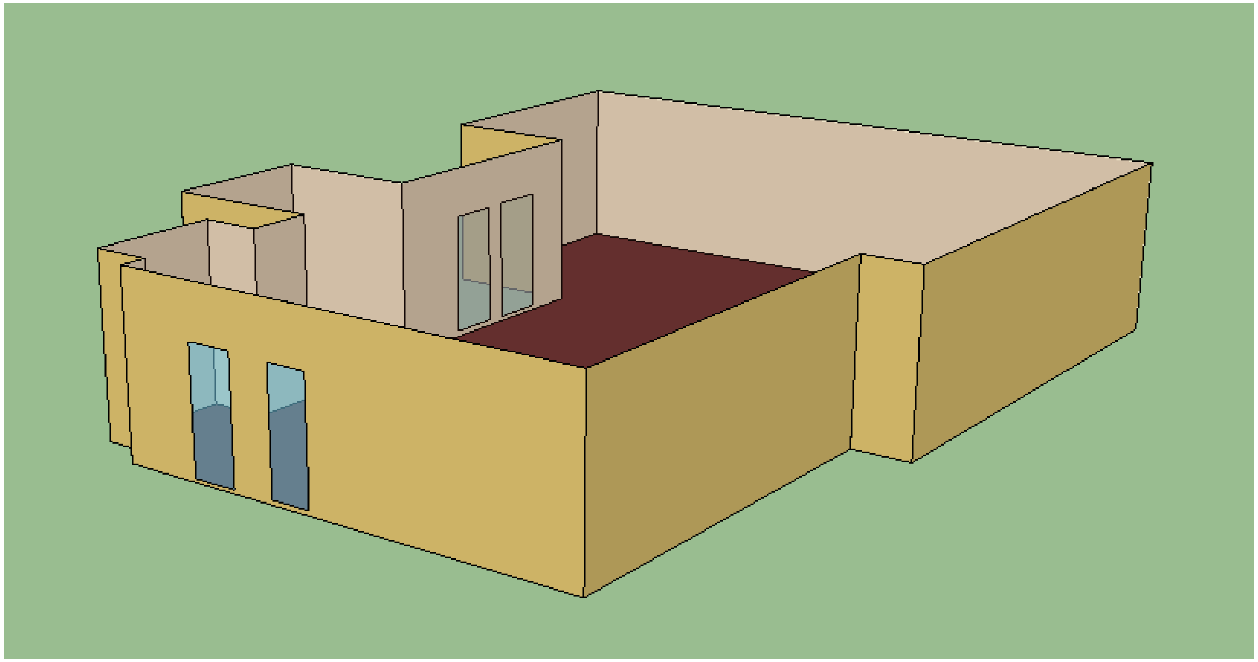
Example: semi-automated modeling from a point cloud

- Intersecting adjacent planes → vertices



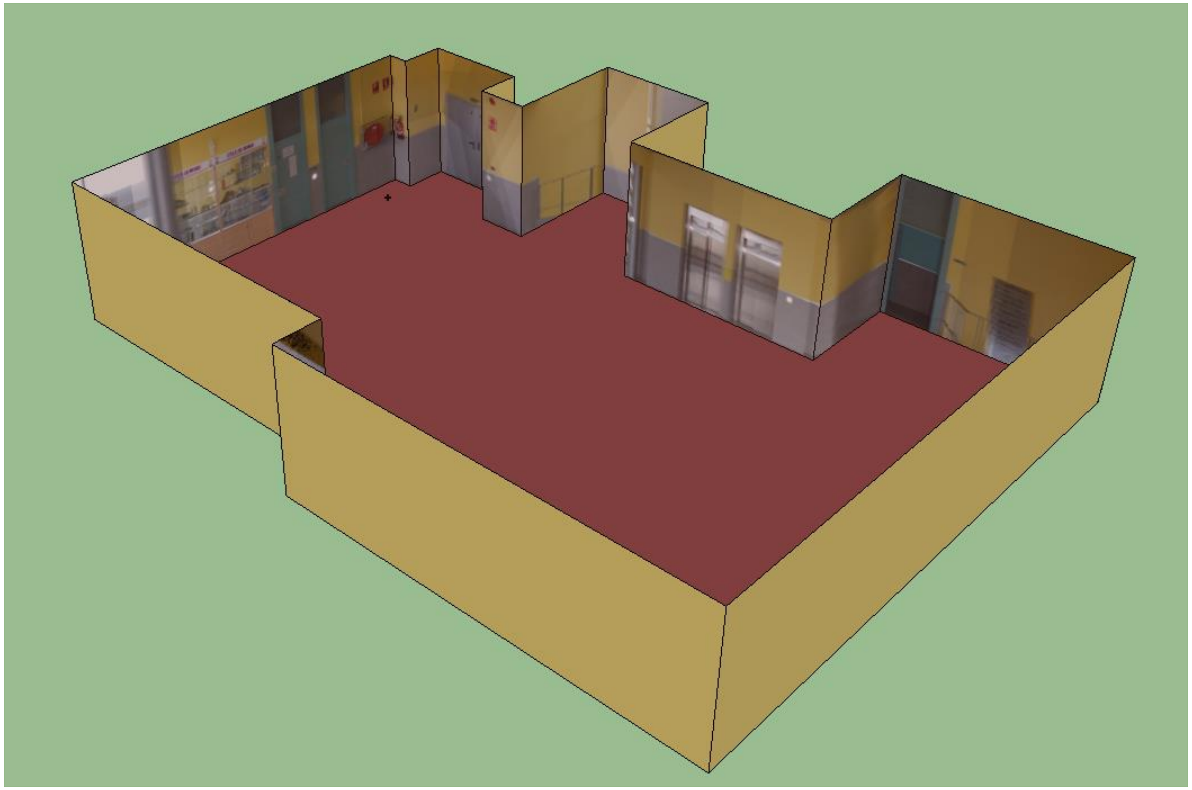
Example: semi-automated modeling from a point cloud

- Model with faces and vertices



Example: semi-automated modeling from a point cloud

- Model with added texture



Discussion

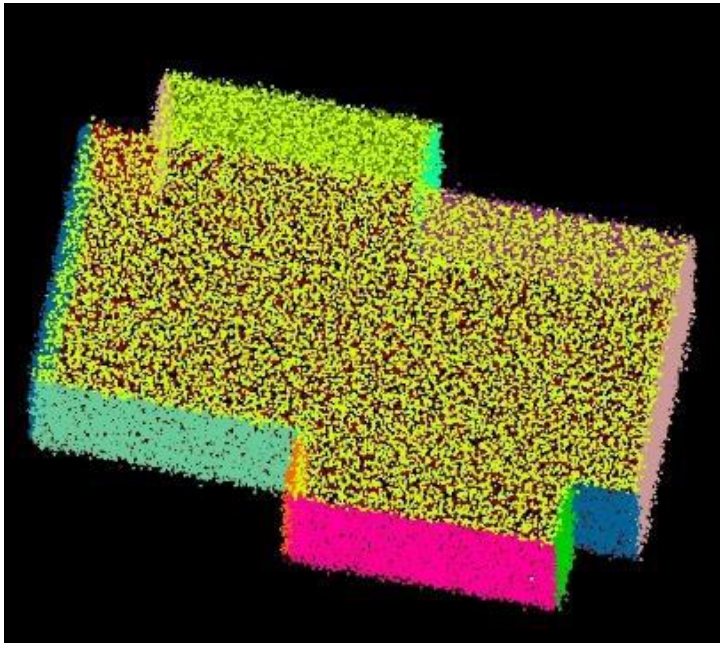
- Data → information, Q: what information?
- What are the challenges from your perspective?
- What are application requirements (e.g. for SHM)?
- …

Extras

Model-driven modeling from a point cloud

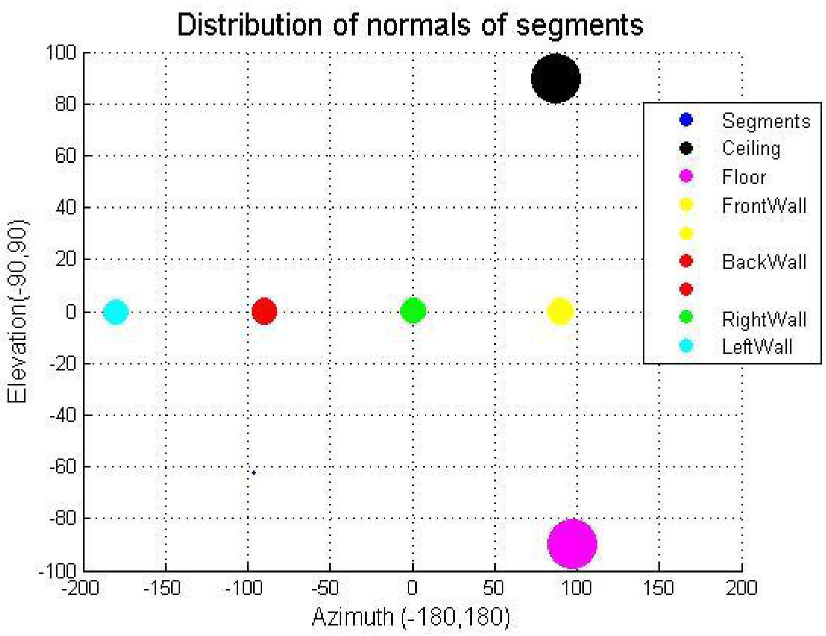
- Simulated point cloud

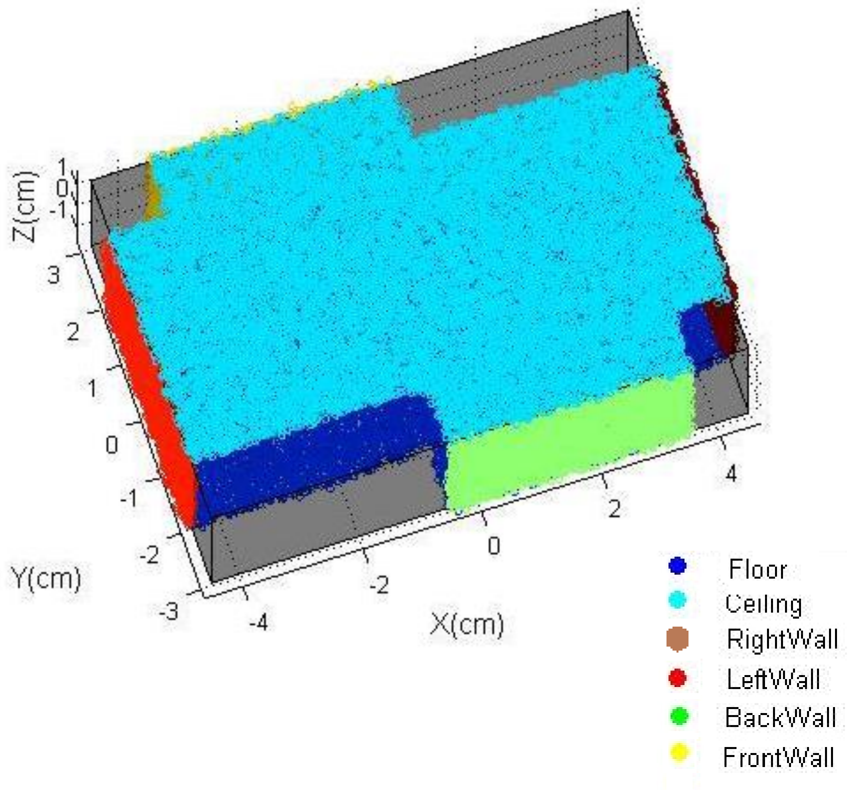
Work of Mina Mehranfar



Model-driven modeling from a point cloud

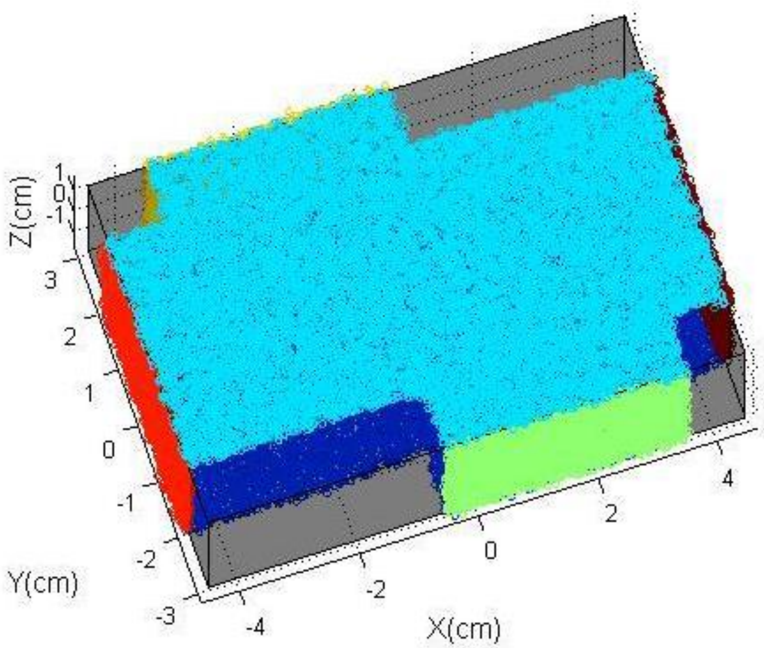
- Segmentation and classification by clustering normals

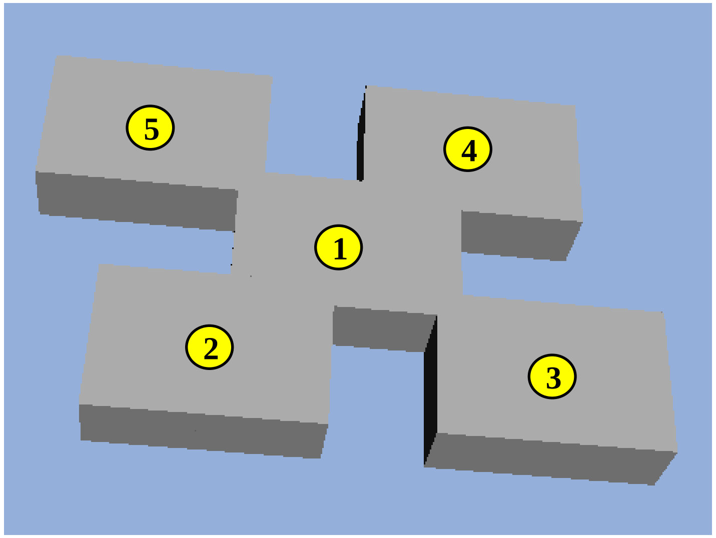




Model-driven modeling from a point cloud

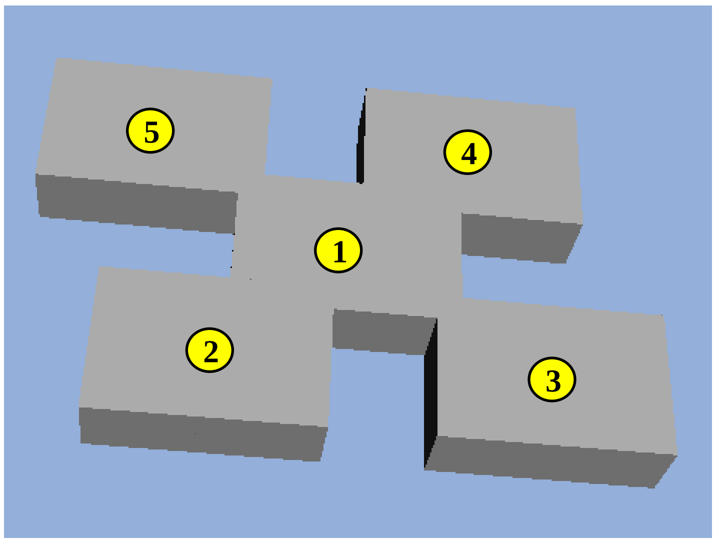
- Fitting cuboids to connected components

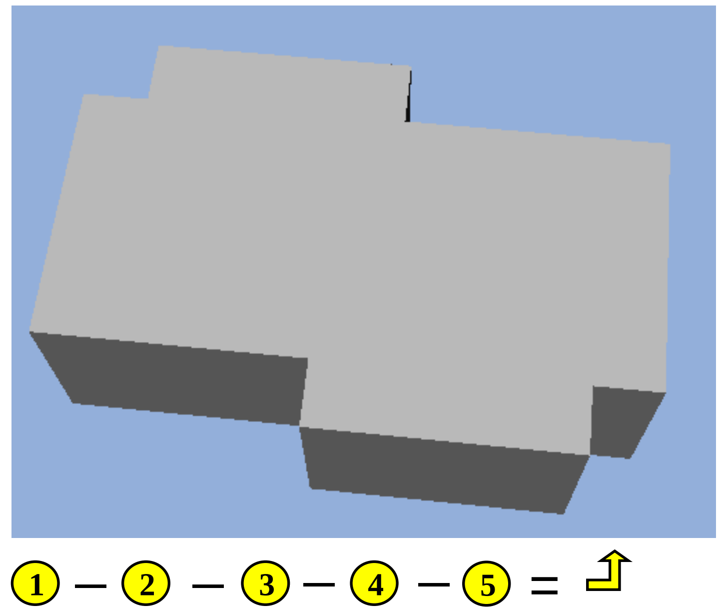




Model-driven modeling from a point cloud

- Subtraction



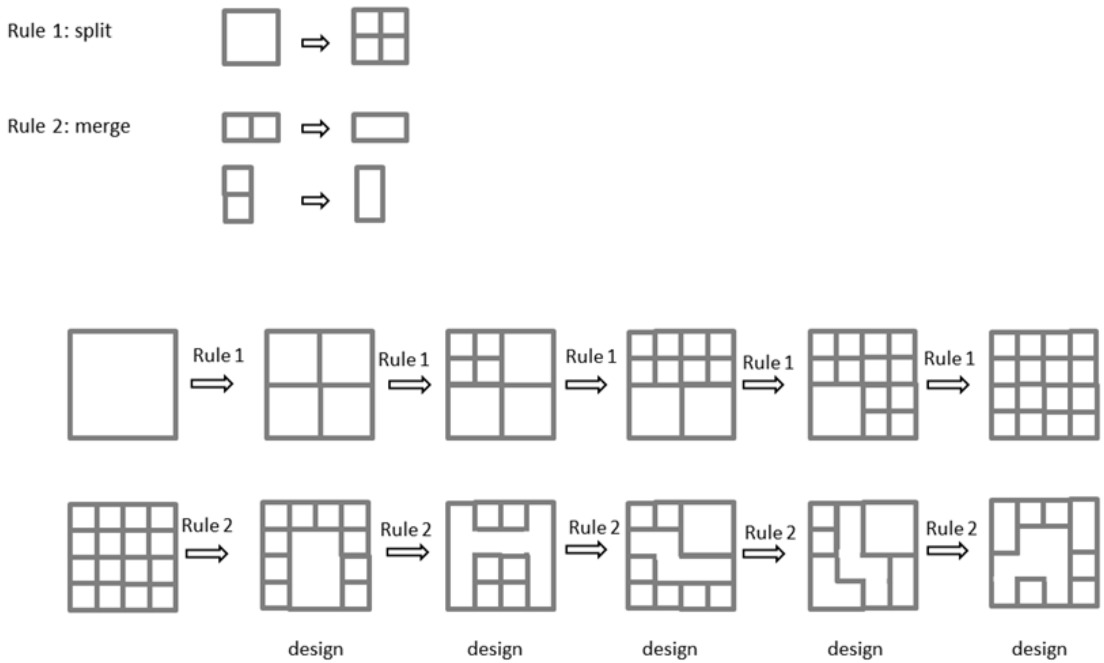


Modeling indoor environments using point clouds

- How to cope with the large variety of interior architectures?
  → Understand interior architecture
  → Translate it to a modeling algorithm

- Interior architecture:
  1. Regularity
  2. Repetition
  3. Creativity

  1+2+3 = shape grammar!



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