FIG WORKING WEEK 2019

22–26 April, Hanoi, Vietnam

"Geospatial Information for a Smarter Life and Environmental Resilience"

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Using BIM-Elements as Features for the Transformation of Local Point Clouds with Structure from Motion

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Introduction & Motivation

- Construction progress monitoring as important tool in construction supervision
- Trend: Examination of point clouds for determining the acutal state of the building
- Usage of laser scanners or cameras mounted on crane for large-scale documentation
- Our idea: development of a low-cost application for the usage of local point clouds together with building models

Introduction & Motivation

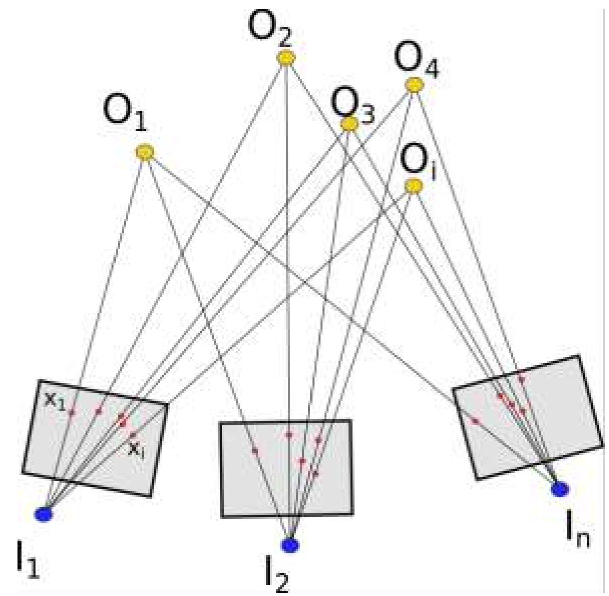
- Photogrammetry / SfM for data acquisition
  - Cost advantage compared to laser scanning
  - Targeted applications users are more familiar to the applied technology
- Use cases:
  - small-scale progress monitoring
  - Document as-build state of the building
  - Measurement of added installations
  - Damage documentation

Structure from Motion

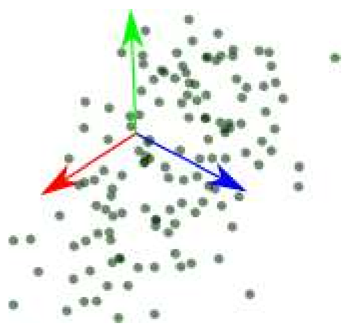
- Image-based 3D reconstruction of an object

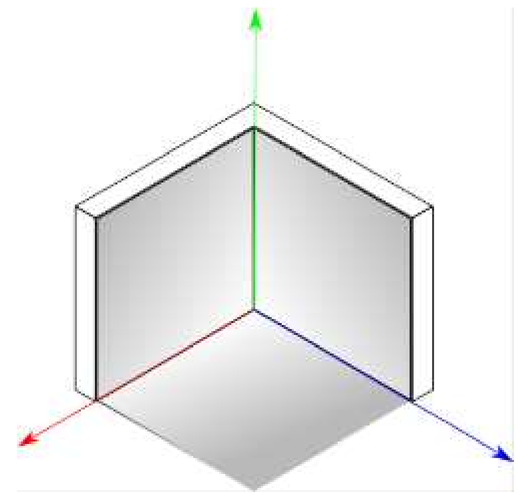
- Estimation of
  - Camera views I_i
  - Camera parameters C_i
  - Object coordinates O_j

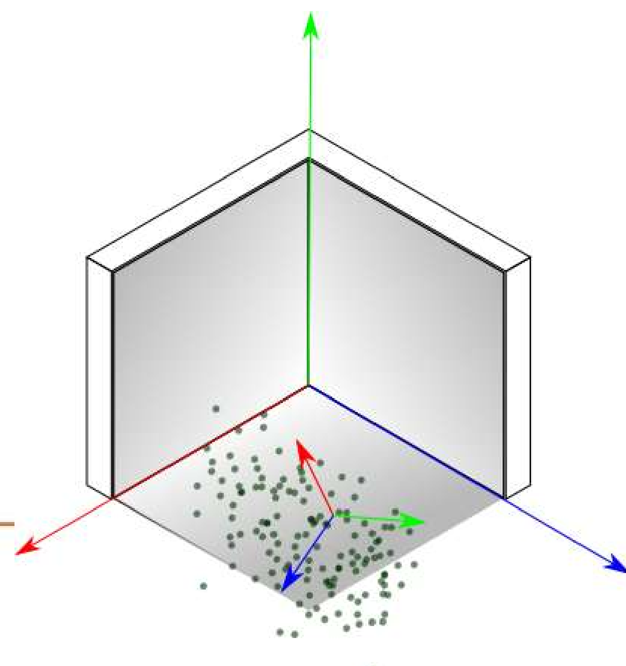
  based on over multiple images tracked feature points x_j



Combining Point Cloud and Building Model

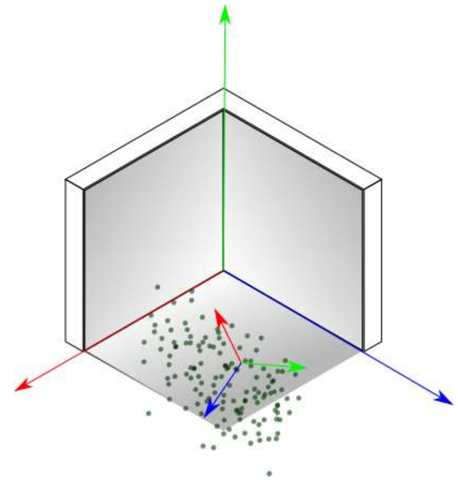






Aligning Point Cloud and Building Model

- The photogrammetric acquired point cloud is not in the building coordinate system
- Classical 7-parameter transformation necessary
  (Rotation, translation and scale are unknown)
- Typically ground control points (GCPs) are used for the estimation of the transformation parameters
- Our Idea: Use line and plane matches to calculate the parameters



(Pseudo-)Observation Equations

- Estimation of parameters using the relationship between normal vector of the plane and the direction vectors of the line

- The rotated direction vector of a line located on a wall must be perpendicular to the corresponding normal vector of the wall

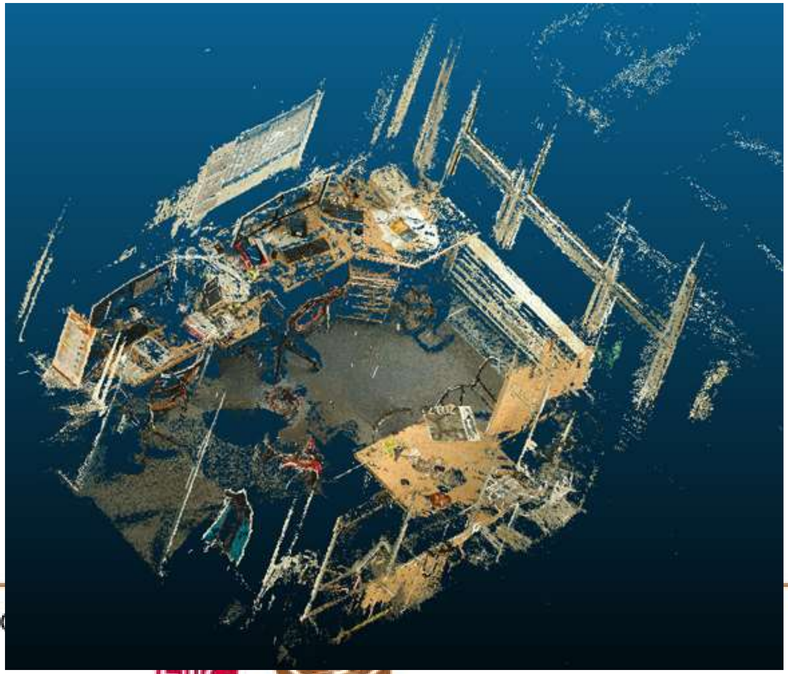
$$l + v = < R * \overrightarrow{u}, \vec{n} > = 0 + v$$

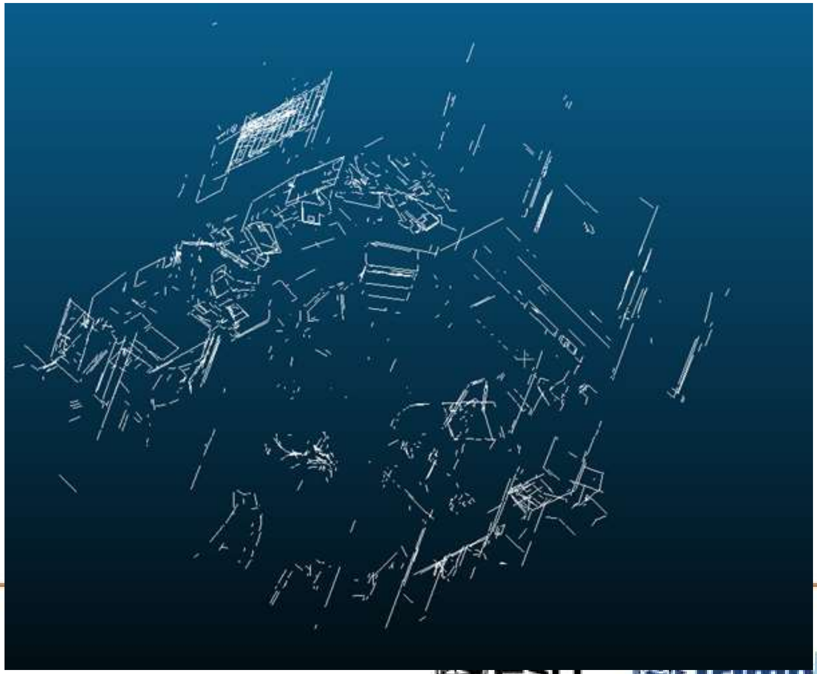
- The start and end points of the rotated, translated and scaled lines must be lying in the corresponding plane:

$$l + v = m \; * < \left(R * \vec{s} + \vec{t}\right), \vec{n} > -d = 0 + v$$

Tool Line3D++

- Extraction of 3D lines from the relative oriented images
- Hofer, M., Maurer, M., & Bischof, H. (2017). Efficient 3D scene abstraction using line segments. *Computer vision and image understanding*, *(CVIU), 2016.*
- Line segments defined by 3D coordinates of start and end points





Tool Line3D++

- At first line 2D line segments are extracted from the single images
- Matching of equal lines and calculation of the 3D coordinates of the start and end points

Where to get the Planes from?

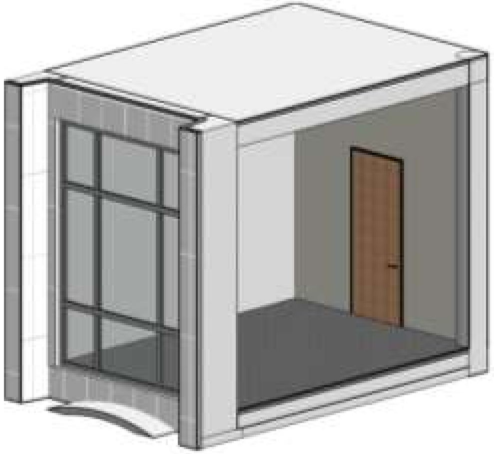
- The proposed method requires a BIM-Model

- Selection of the particular room

- Extraction of plane parameters from the model in the building coordinate system

- Planes are later processed using the coordinate form requiring the following plane parameters:

$$ax + by + cz = d$$



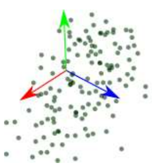
Workflow for the Transformation of the Point Cloud

Images → SfM

SfM → Point Cloud

SfM → Relative oriented Images

Relative oriented Images → 3D Lines



BIM Model → Selected Room → Plane Parameters

3D Lines + Plane Parameters → Matching lines planes

Matching lines planes → Estimation of transformation parameters

Estimation of transformation parameters → Point Cloud

Critical Step: Finding Line Plane Matches

- The estimaton algorithm requires a correct match between lines and planes
- Minimal configuration consists of 4 non complanar line plane pairs
- Huge amount of possibilities
  E.g. 19 Lines and 6 Planes → 609.359.740.010.496 combinations
- „Brute Force“ not suitable, other filtering methods necessary

Line-Plane-Matching

Lines

filter using the triple product of a three line combination

Plane Parameter

filter using the triple product of a three line combination

Random assignment of a line combination to a plane combination (cf. RANSAC-Algorithm)

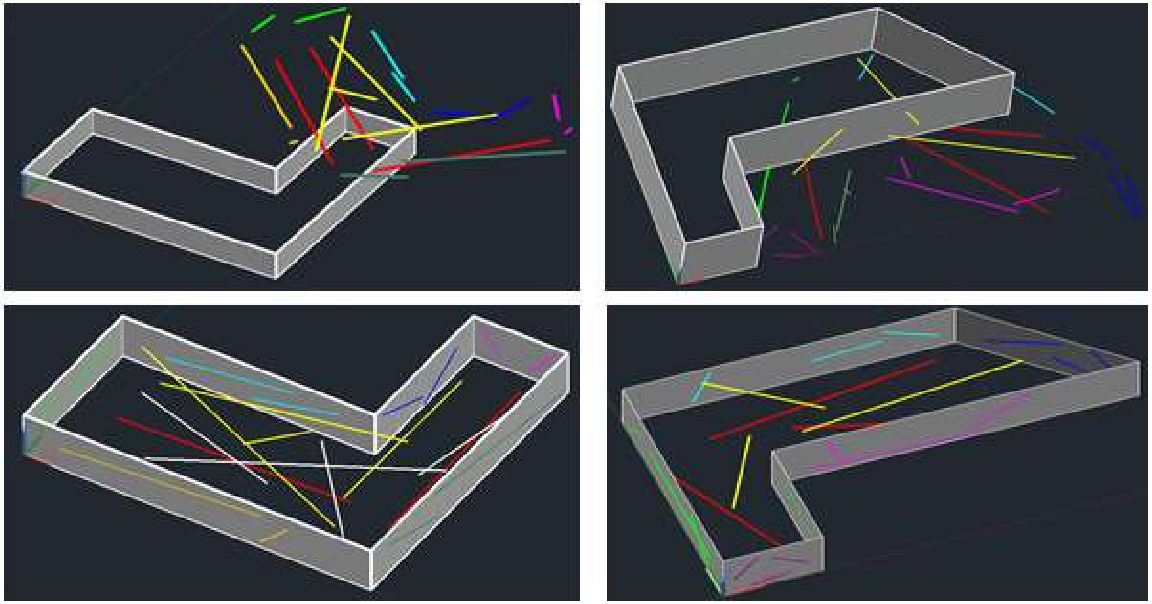
Selection of a fourth non-complanar line-plane-combination

Adjustment calculation for the estimation of the transformation parameters using the minimal configuration

Validation of the transformation parameters using the complete line plane data set

Validation of the presented Approach

- Usage of synthetic test data



Further Steps

- Generate a realistic test bed
- Validate the transformation process using the test bed
- Investigate the accuracy of the transformation