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"Geospatial Information for a Smarter Life and Environmental Resilience"
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 an important tool in construction supervision

• Trend: Examination of point clouds for determining the actual 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

\[ l + v = < R \cdot \vec{u}, \vec{n} > = 0 + v \]

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

\[ l + v = m \cdot < (R \cdot \vec{s} + \vec{t}), \vec{n} > - d = 0 + v \]
Tool Line3D++

- Extraction of 3D lines from the relative oriented images
- 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

1. Images → SfM → Point Cloud
2. Relative oriented Images → 3D Lines
3. Matching lines planes
4. Estimation of transformation parameters
5. BIM Model → Selected Room → Plane Parameters
Critical Step: Finding Line Plane Matches

- The estimation 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 $\rightarrow$ 609,359,740,010,496 combinations.
- „Brute Force“ not suitable, other filtering methods necessary.
Line-Plane-Matching

1. Random assignment of a line combination to a plane combination (cf. RANSAC-Algorithm)
2. Selection of a fourth non-complanar line-plane-combination
3. Adjustment calculation for the estimation of the transformation parameters using the minimal configuration
4. 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