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FACULTY OF CIVIL ENGINEERING

VERIFICATION OF BUILDING STRUCTURES USING BIM AND LASER SCANNING

JÁN ERDÉLYI

Building Information Modeling

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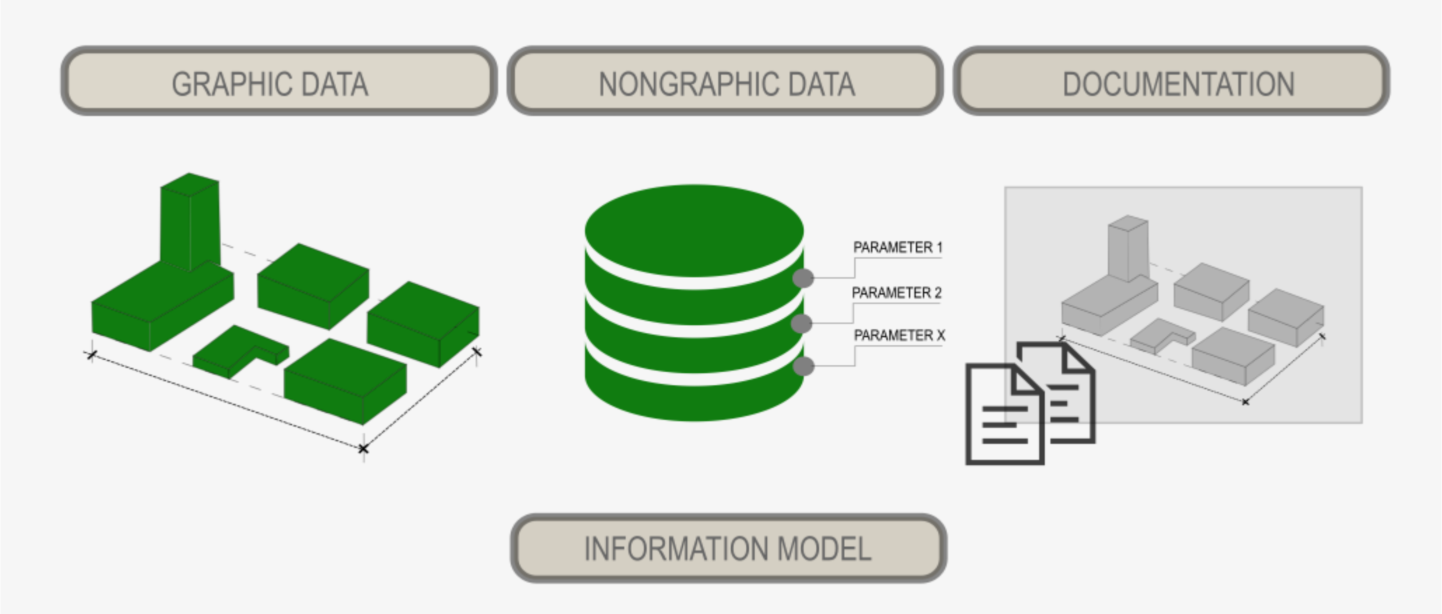
- Information model – BIM model
  - Graphic data
  - Nongraphic data
  - Documentation
- Level of Information Needed – LOIN
  - ISO 19650... Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) — Information management using building information modelling — Part 1-6



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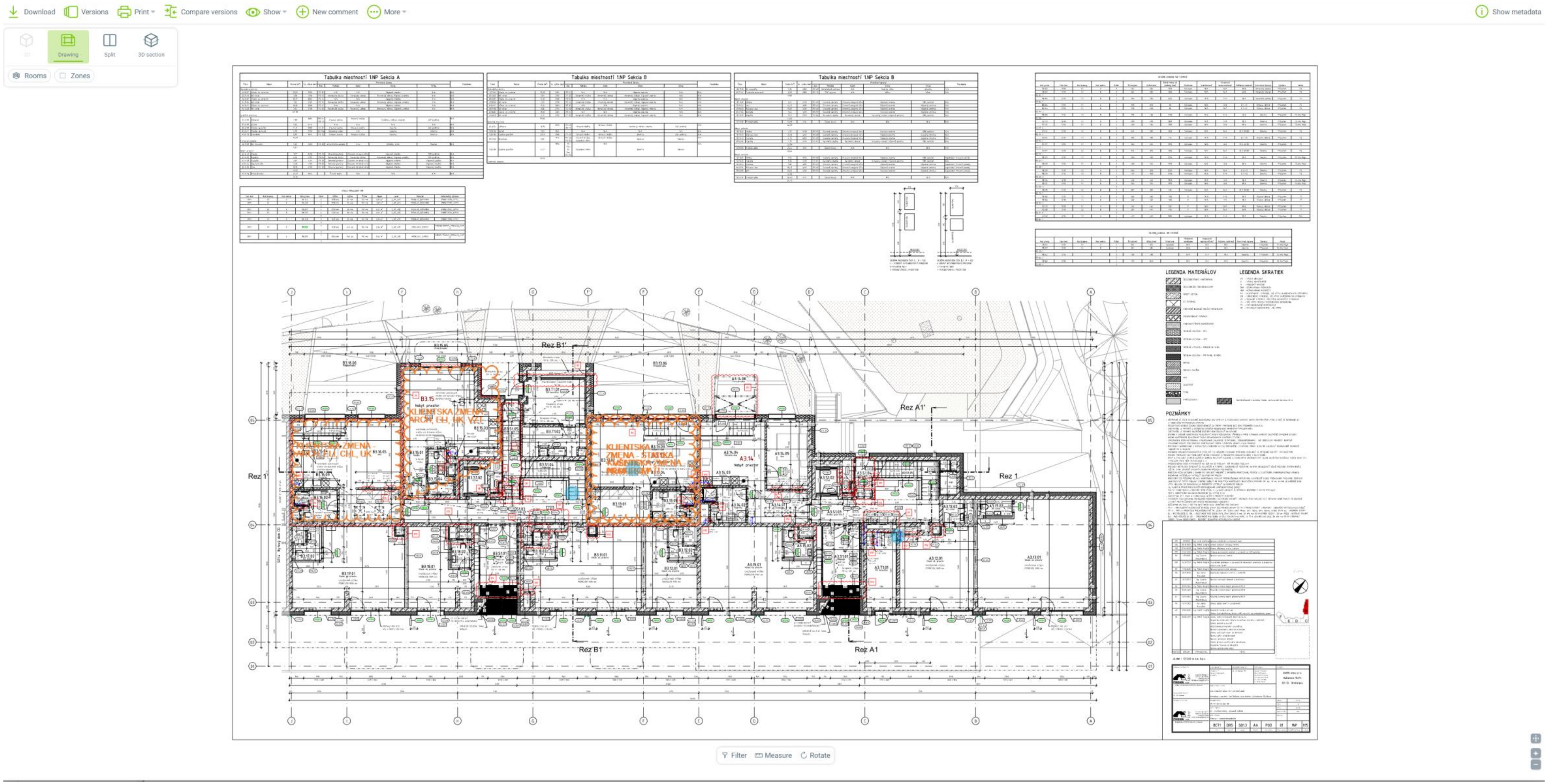

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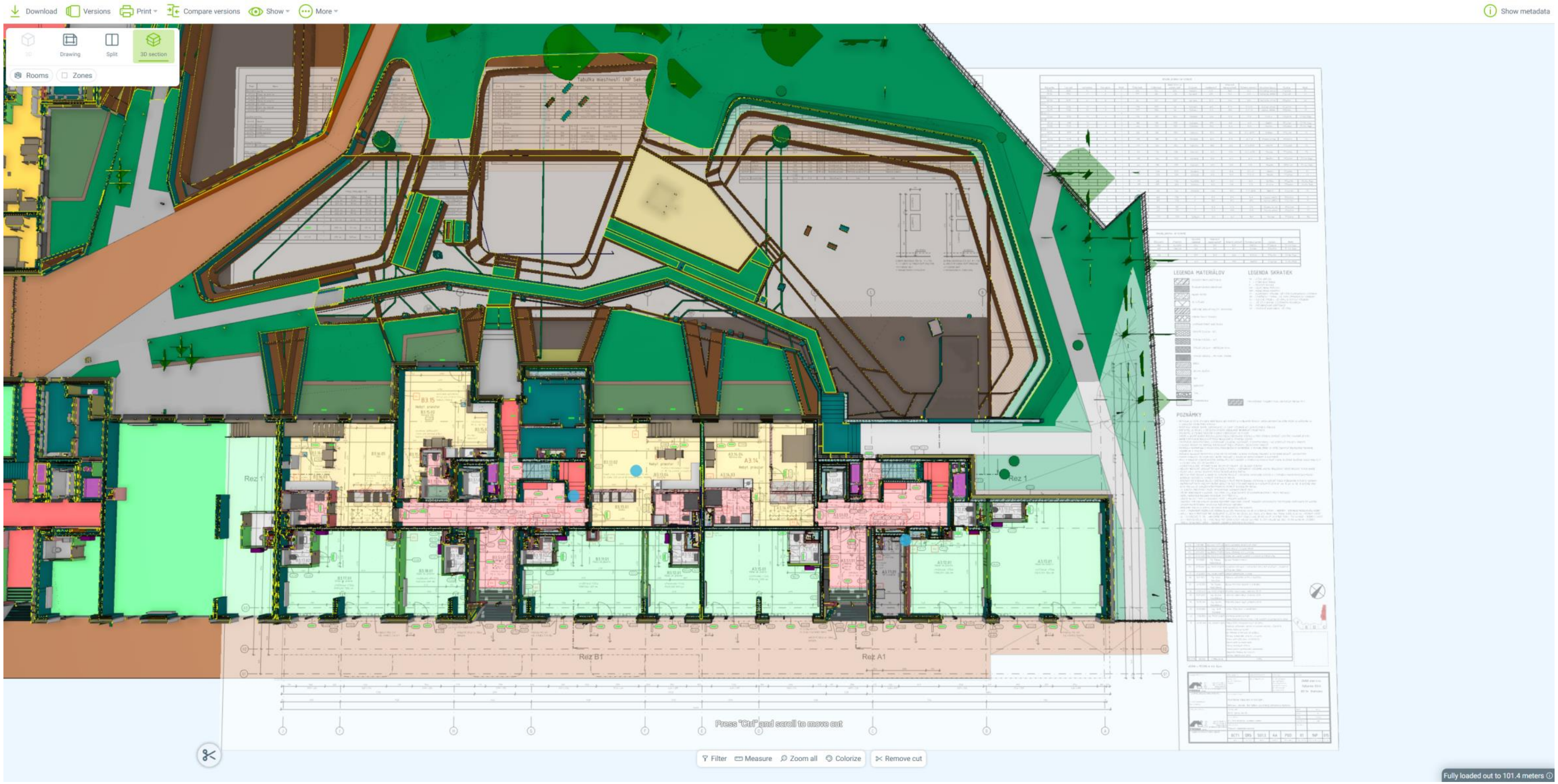

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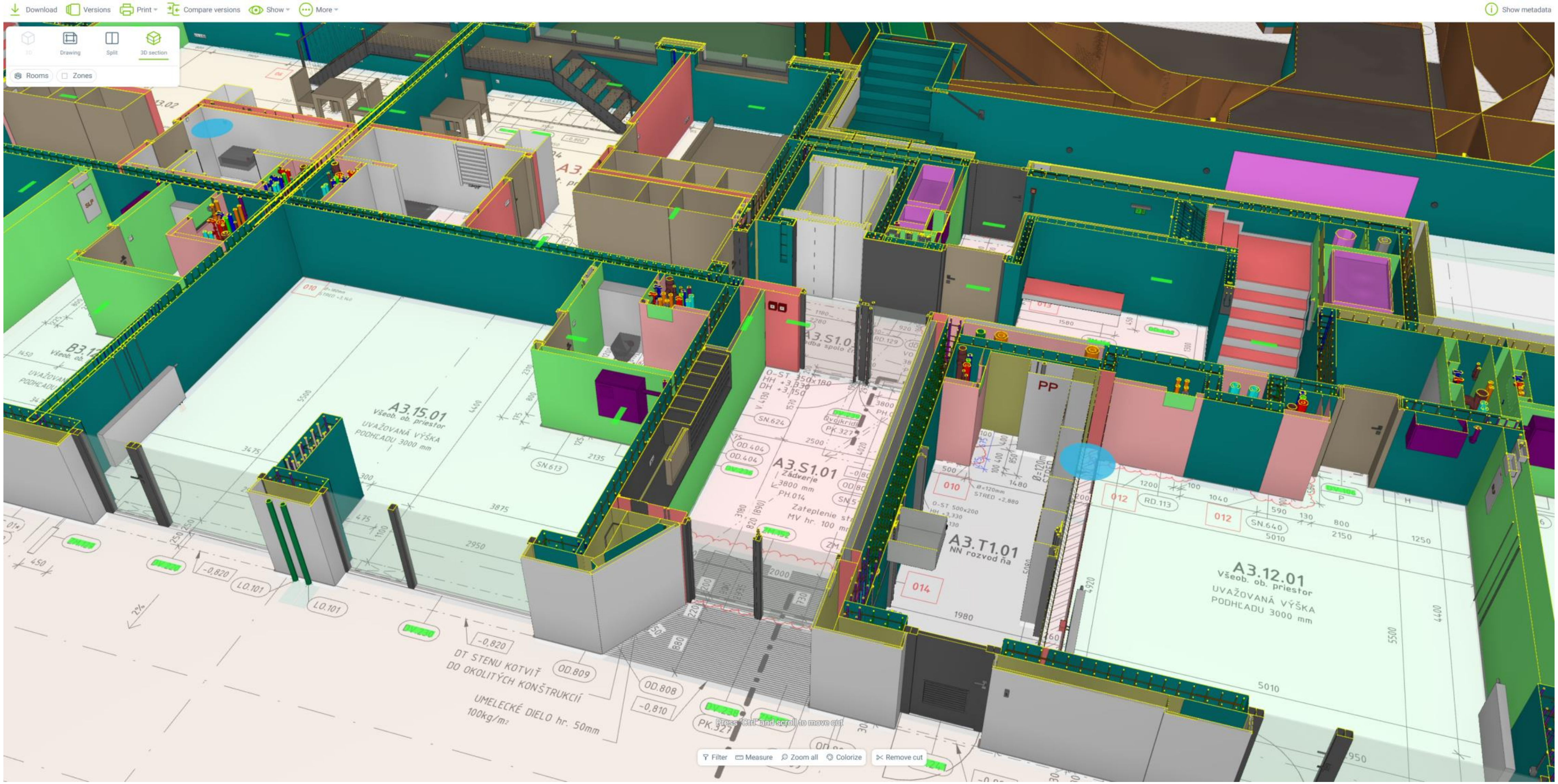

As-built verification

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- 360° images

https://matterport.com/discover/space/greenvale-elementary-main-level

As-built verification

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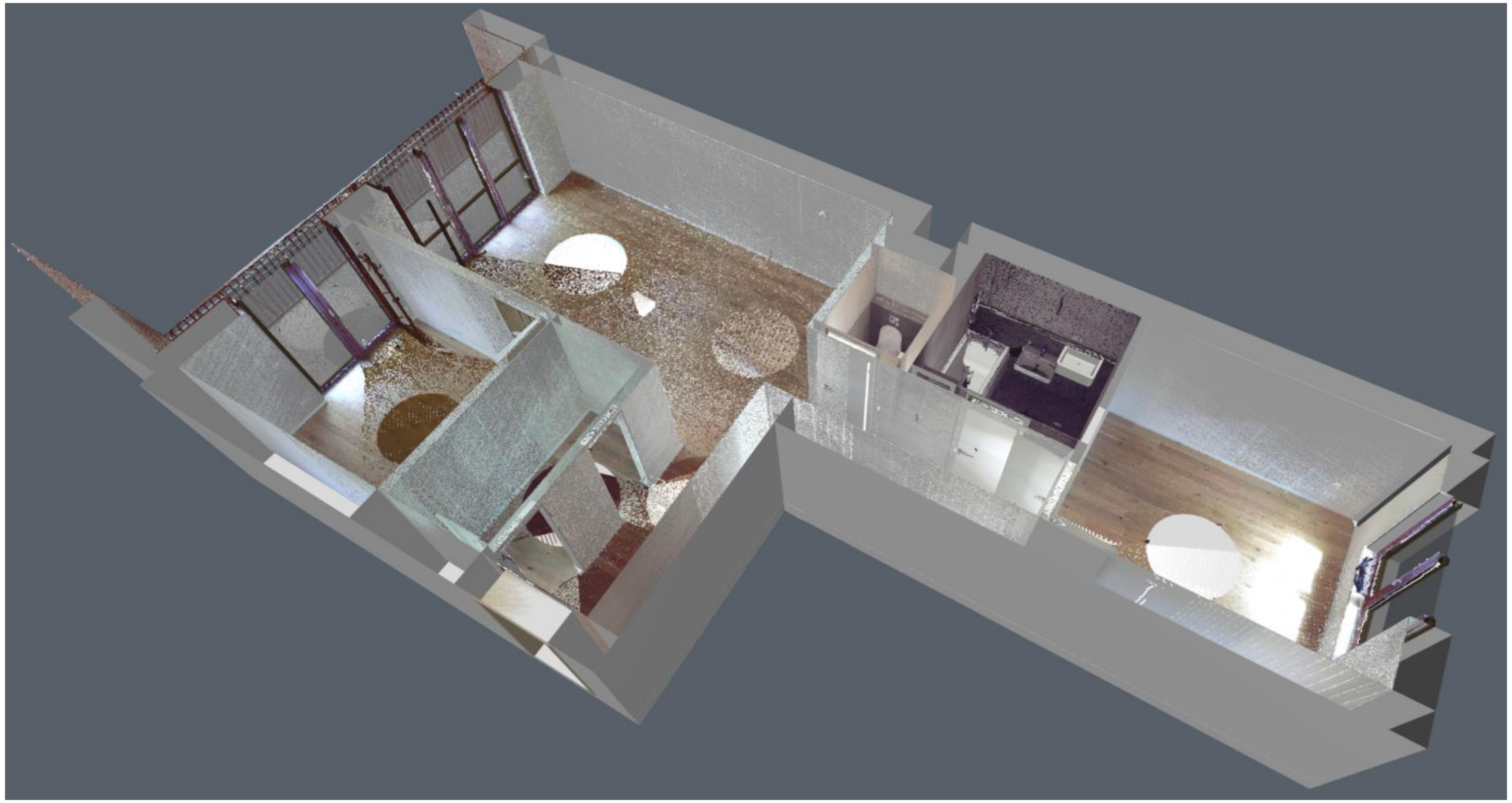
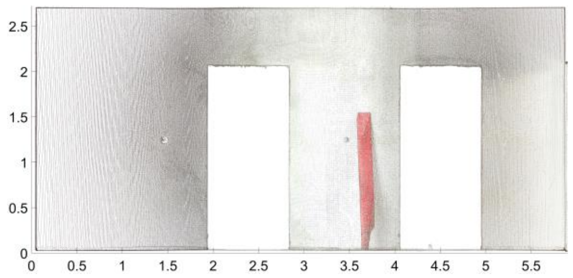
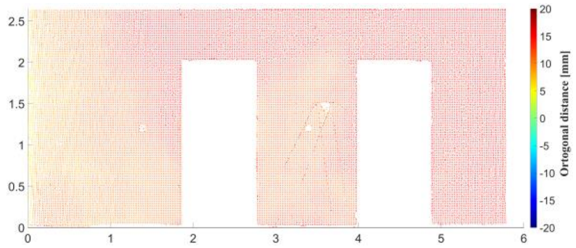
- Scan-vs-BIM
  - Manual modelling
  - Automated (semi-automated) modelling
    - point-to-point, point-to-plane, feature based comparison

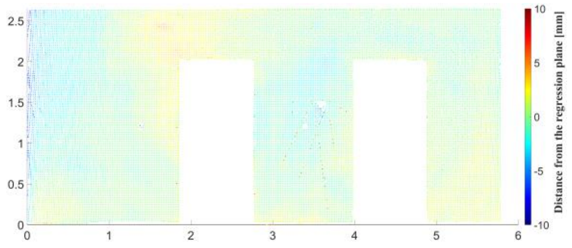


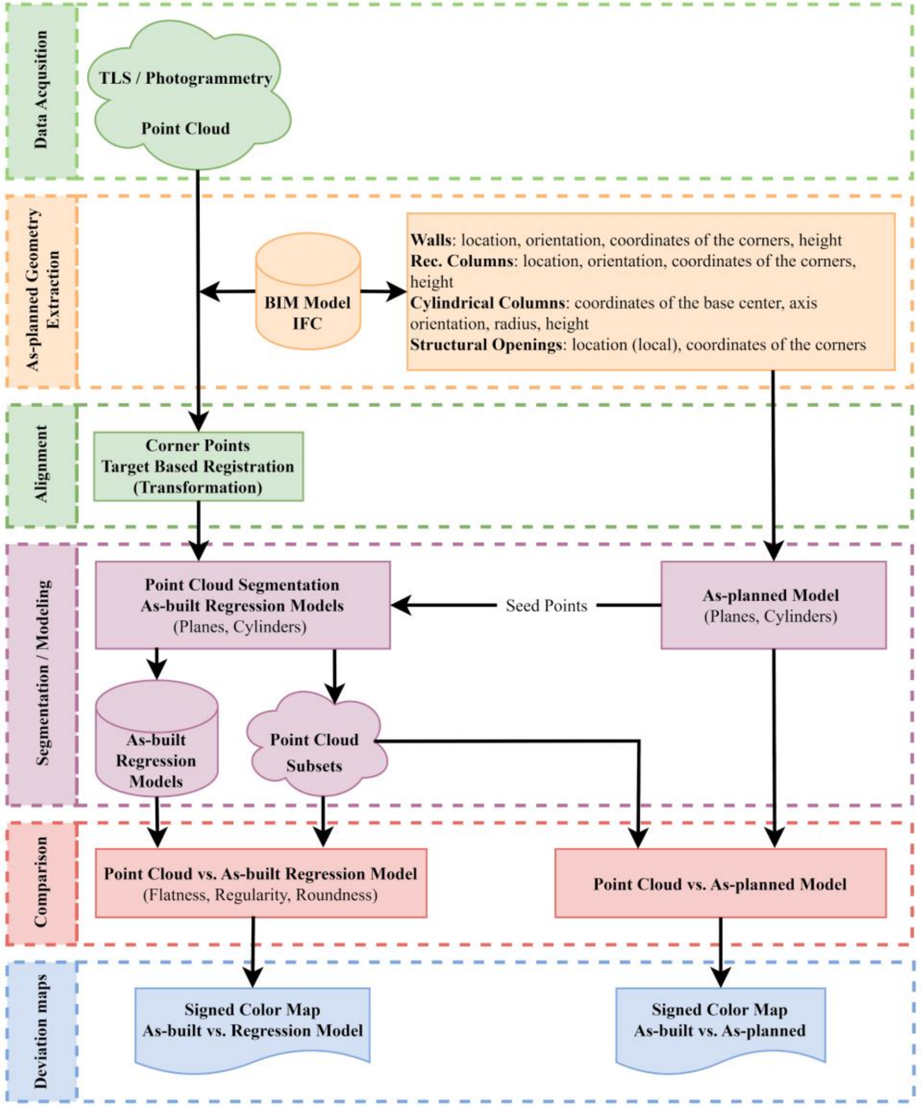
As-built verification – our approach

- To verify parts of rough structure (walls, columns, structural openings)
- Enables verification of relative geometry (flatness, regularity or roundness)
- Detailed point cloud segmentation (filtration of points not lying on the surface – e.g., sockets, skirting boards, paintings, etc.)
- Statistical characteristics are calculated
- To suppress the dependency on file formats IFC is used
- As-planned geometry (extracted from IFC) vs. as-built geometry (expressed by TLS data)









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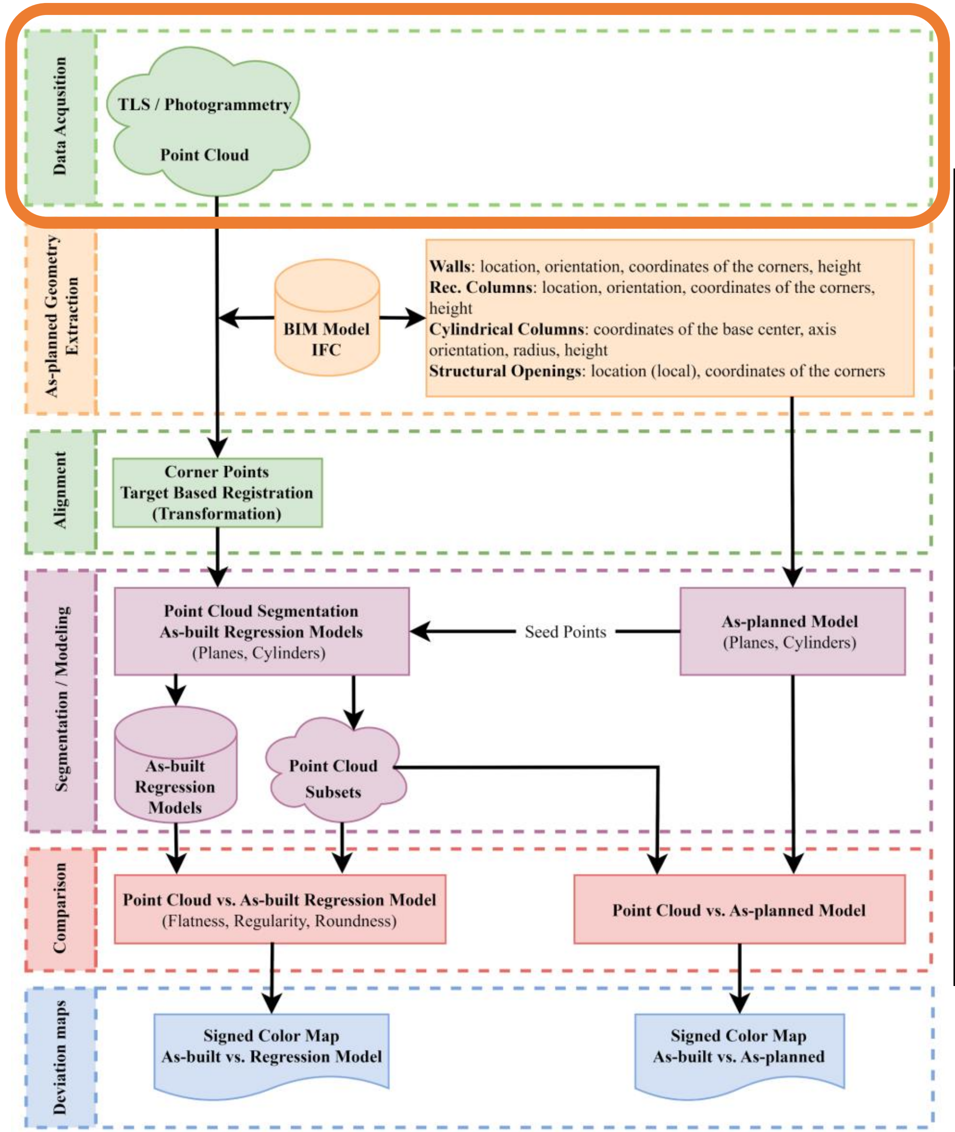
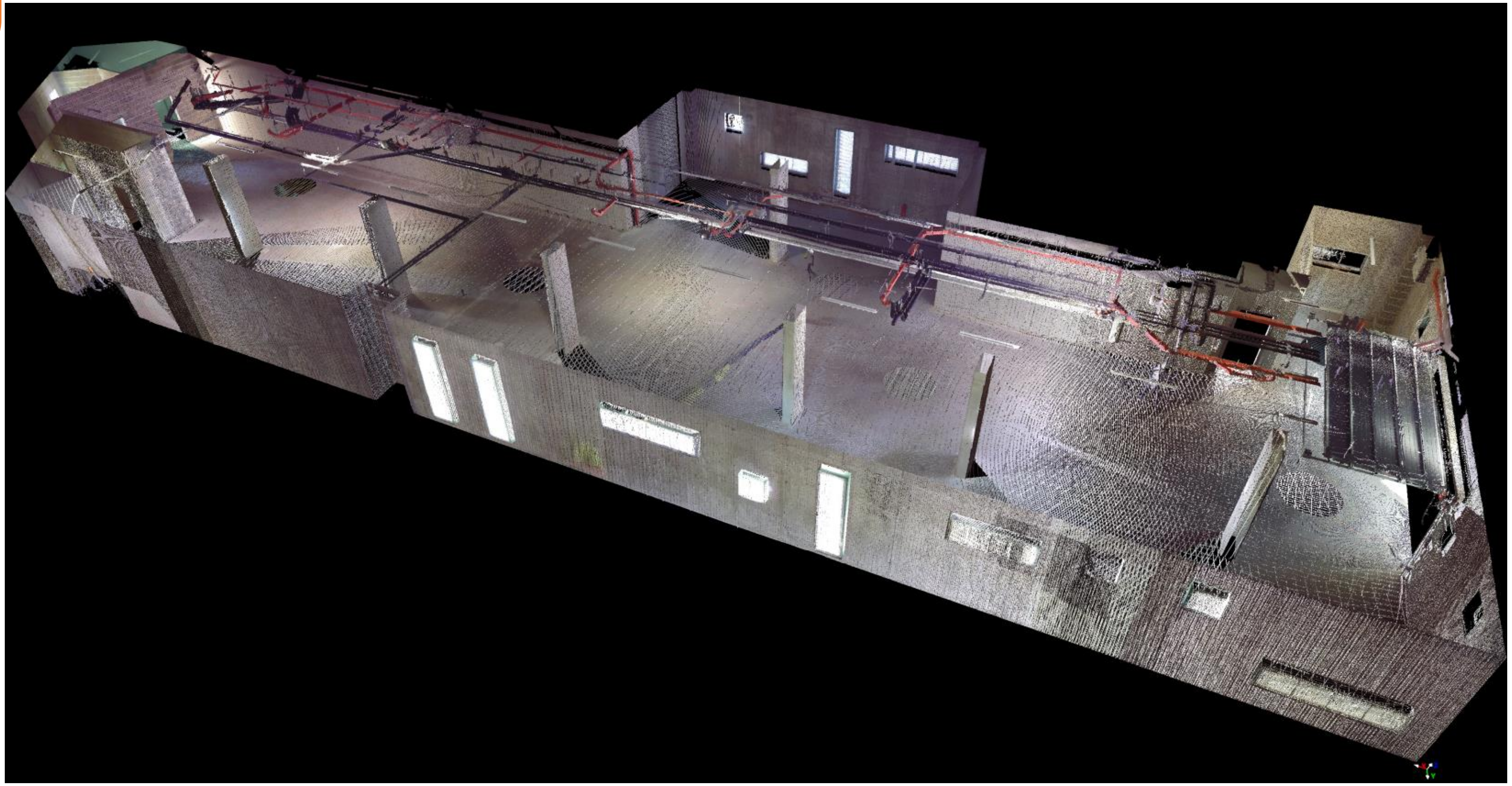
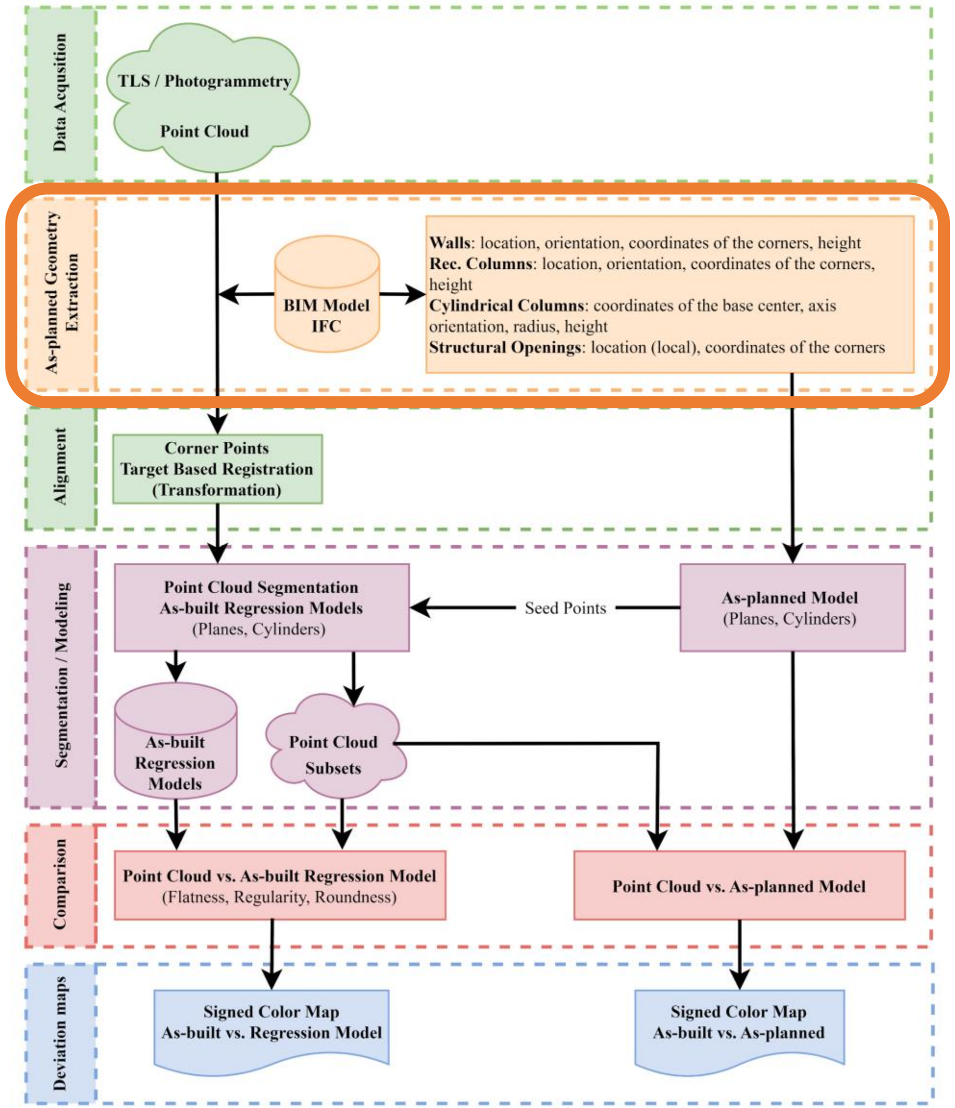
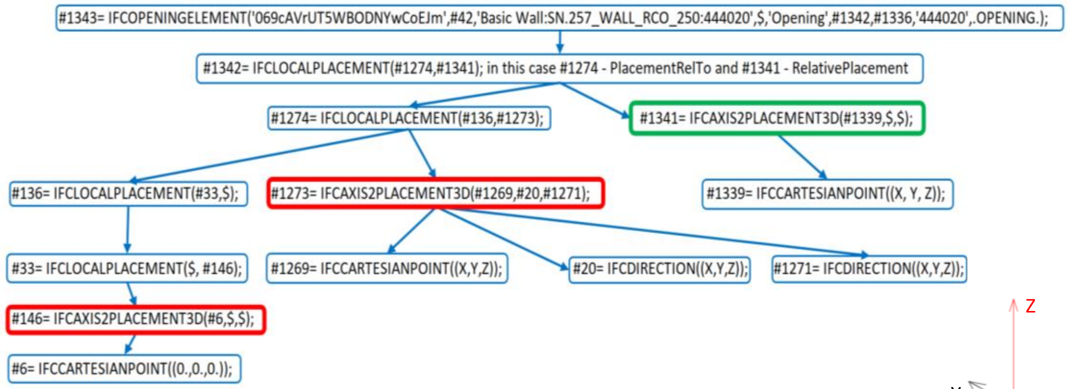


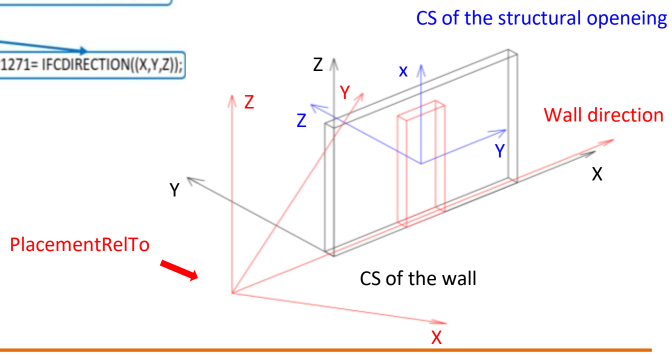


As-built verification – our approach



- As-planned geometry extraction
  - IFC (Industry Foundation Classes - ISO 16739-1:2018...) neutral exchange format for BIM models with open specification STEP Physical File (ASCII)
  - Walls – location, orientation, coordinates of the comers, height
  - Rec. columns – location, orientation, coordinates of the comers, height
  - Cylindrical columns – coordinates of the base center, axis orientation, radius, height
  - Structural openings – location (local), coordinates of the corner





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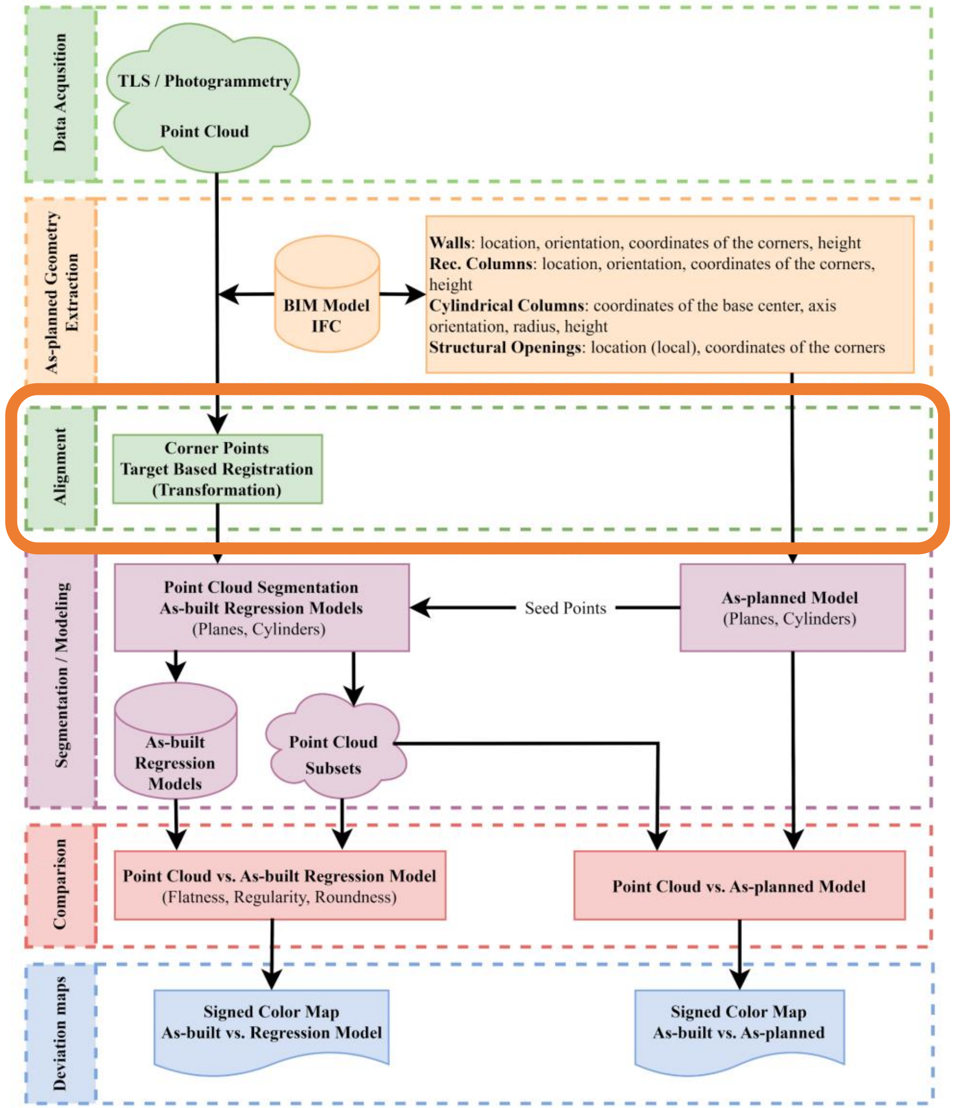
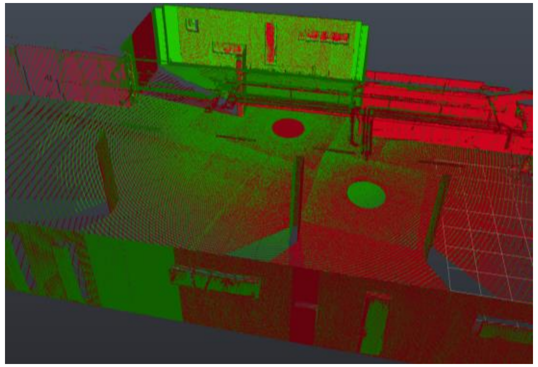
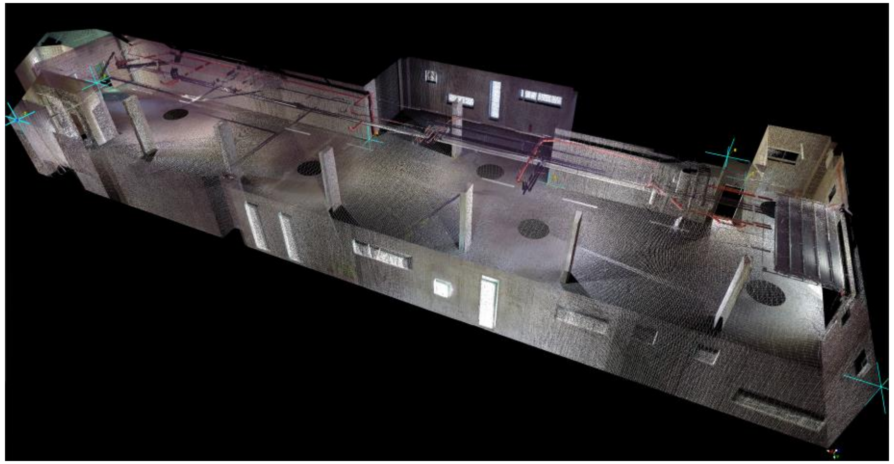


- Alignment
  - Point cloud aligned with the BIM model
  - Target-based registration
    - Characteristic points – wall corners or artificial targets
  - The registration error directly affects the results of scan-vs-BIM but not the quality of relative geometry inspection





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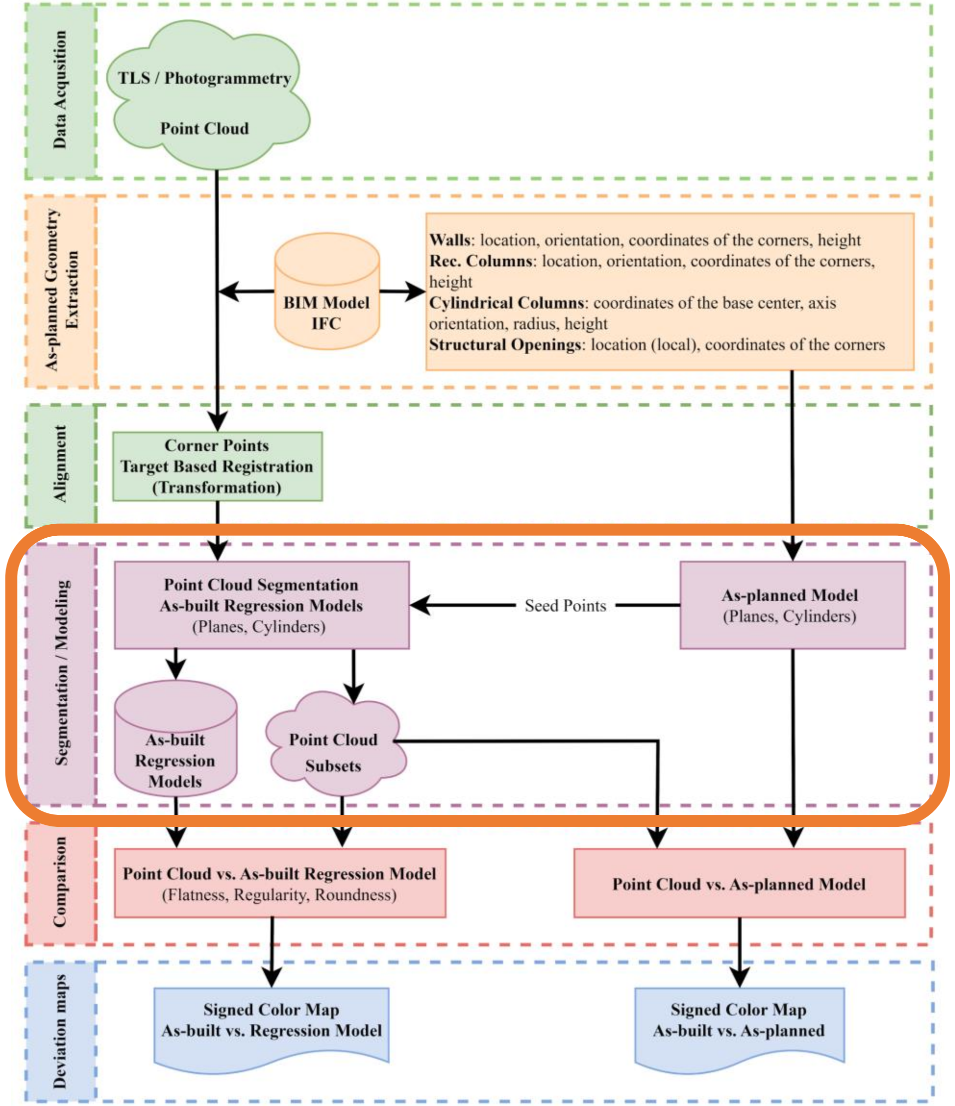

- Segmentation / Modelling
  - Preprocessing
    - Estimation of normal vectors (if the n vectors are not part of the data) *k*-NN
    - Local normal variation (from the normal vectors of *k*-NN)
    - Seed point candidates
  - Model-driven segmentation
    - Region-growing method
    - Model-based method

As-built verification – our approach

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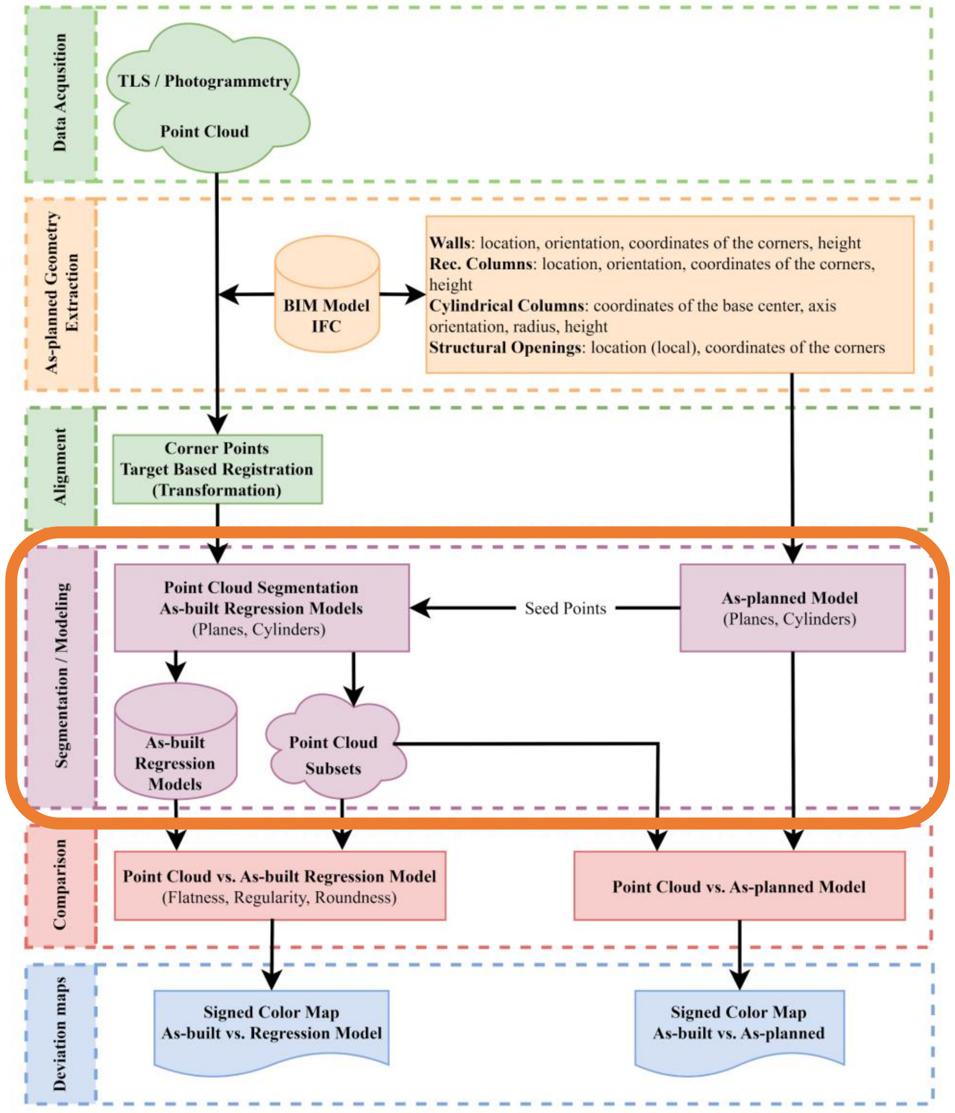
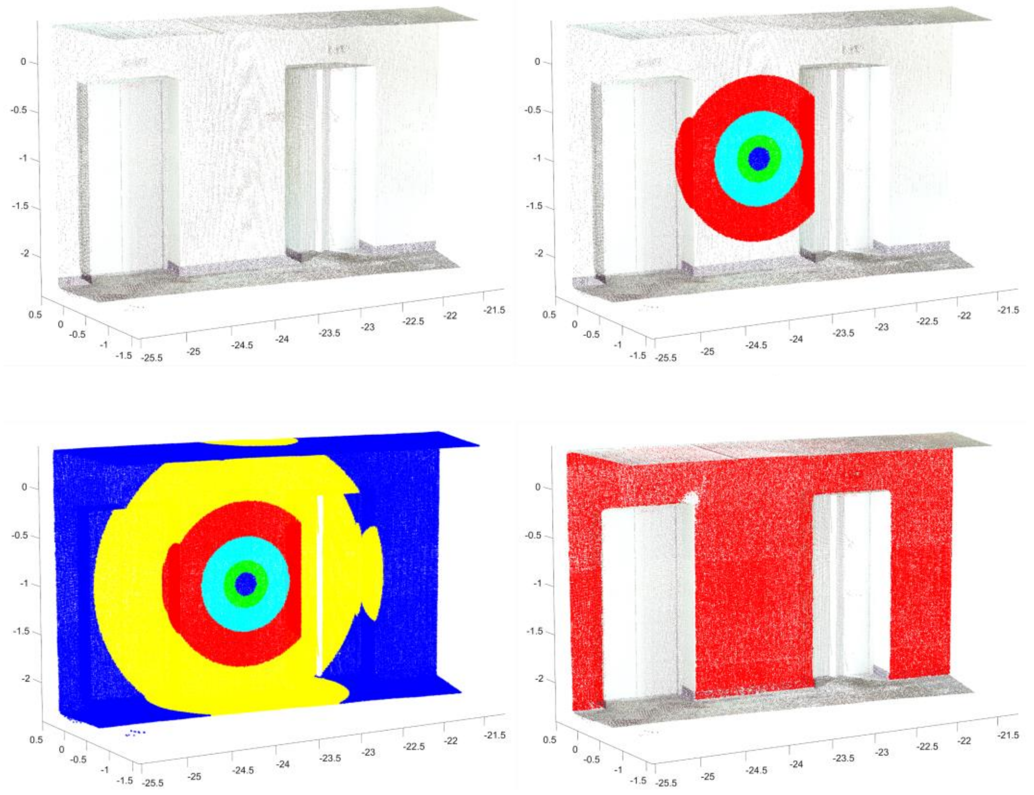


- Segmentation / Modelling
  - Model-driven segmentation
    - Walls - Region-growing method (mod. RANSAC), the seed point is the closest SPC to the center of gravity of IFC element
    - 1st crit.: distance threshold, 2nd crit.: normal vector orientation



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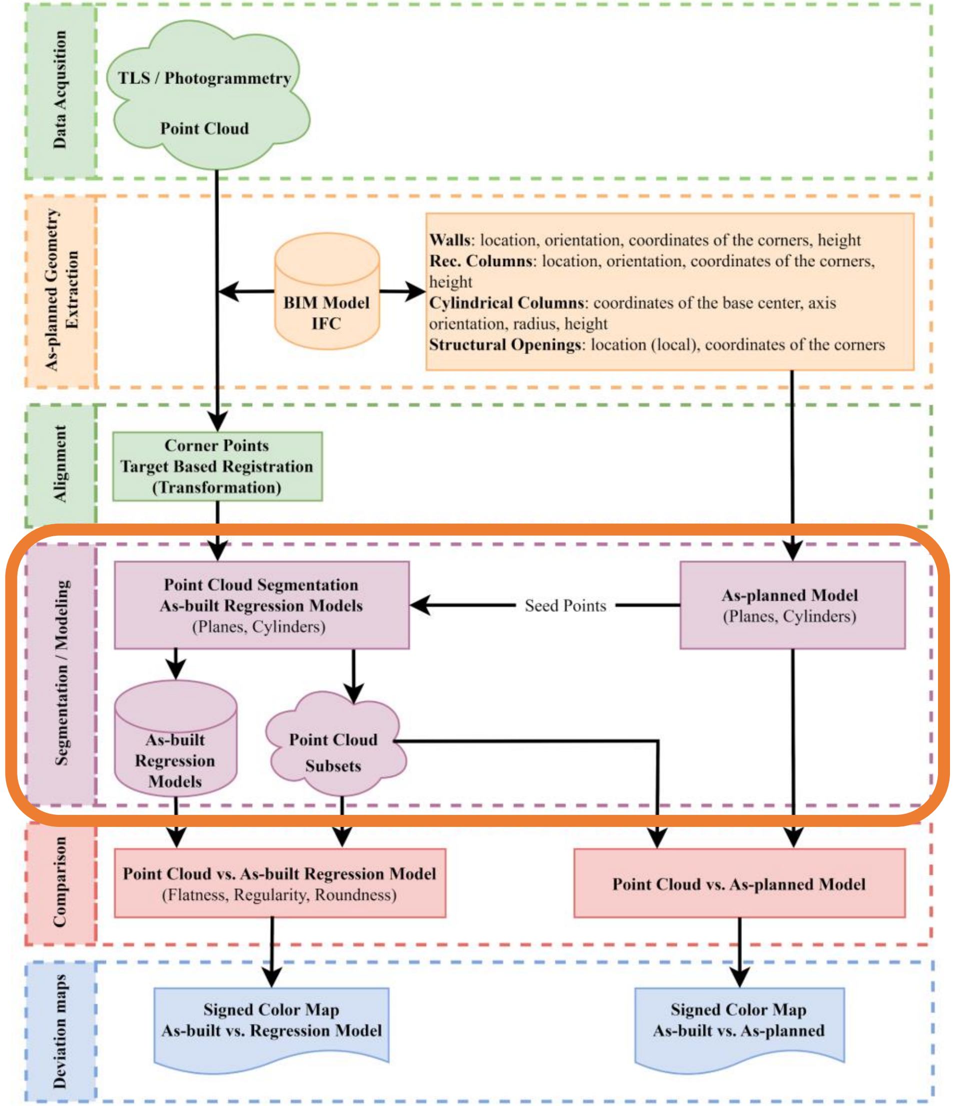
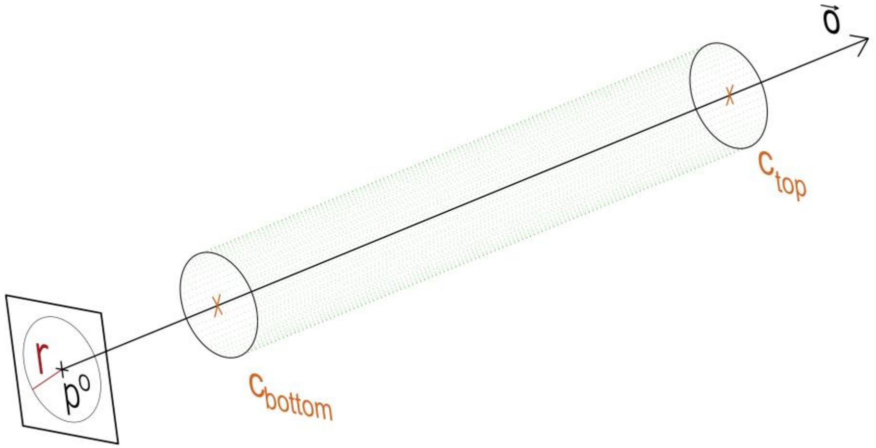


- Segmentation / Modelling
  - Model-driven segmentation
    - Cylindrical columns Model-based method (Hough transform), the seed point is the closest SPC to the center of gravity of IFC element
      - axis orientation
      - projection onto a plane
      - circle modeling (coord. of center and radius)
      - endcaps
    - Iterative estimation – 1st crit.: distance threshold, 2nd crit.: normal vector orientation



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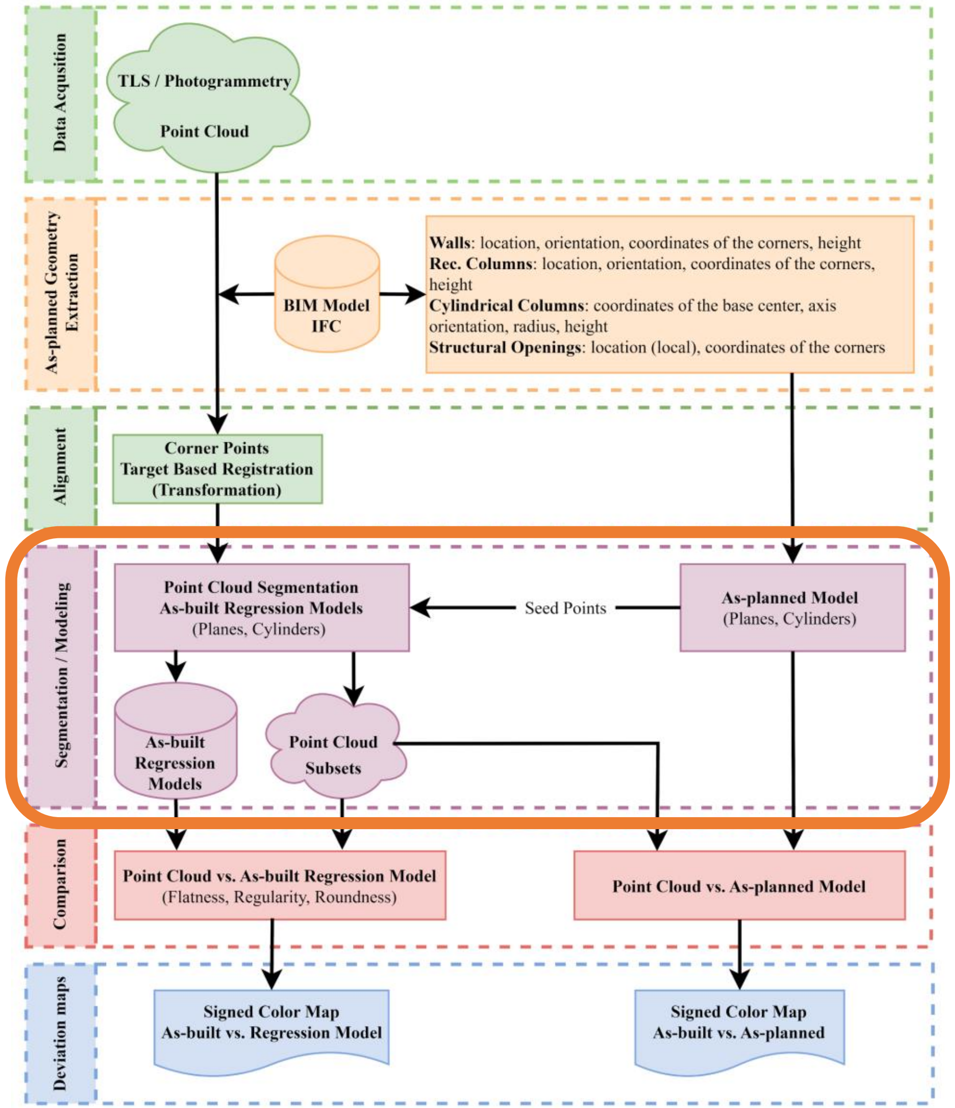
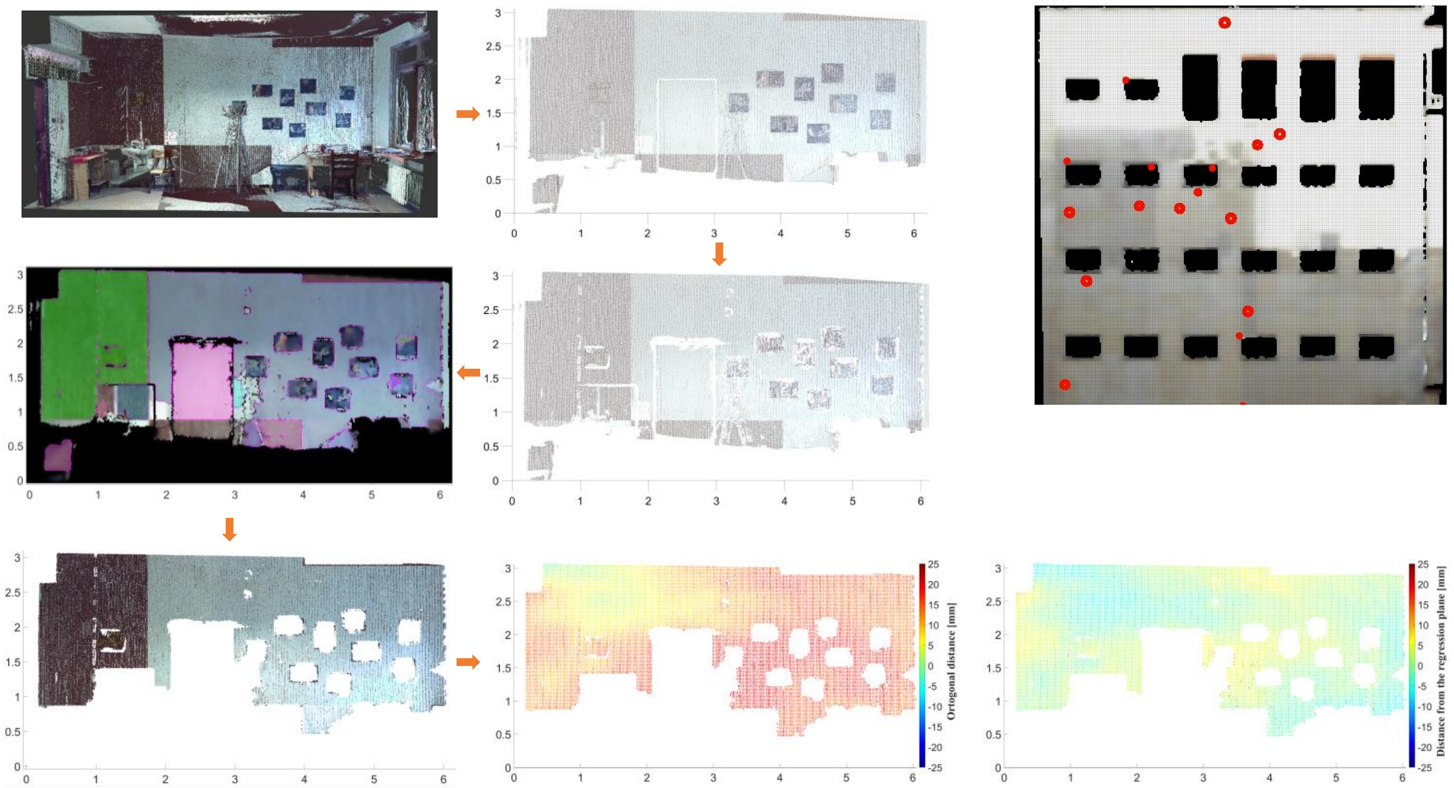


- Segmentation / Modelling
  - If necessary...
    - e.g., when criterions based on distance threshold and normal vector orientation are not able to segment the surface inspected
  - Multichannel (RGB, Intensity, local normal) segmentation using evolving curves



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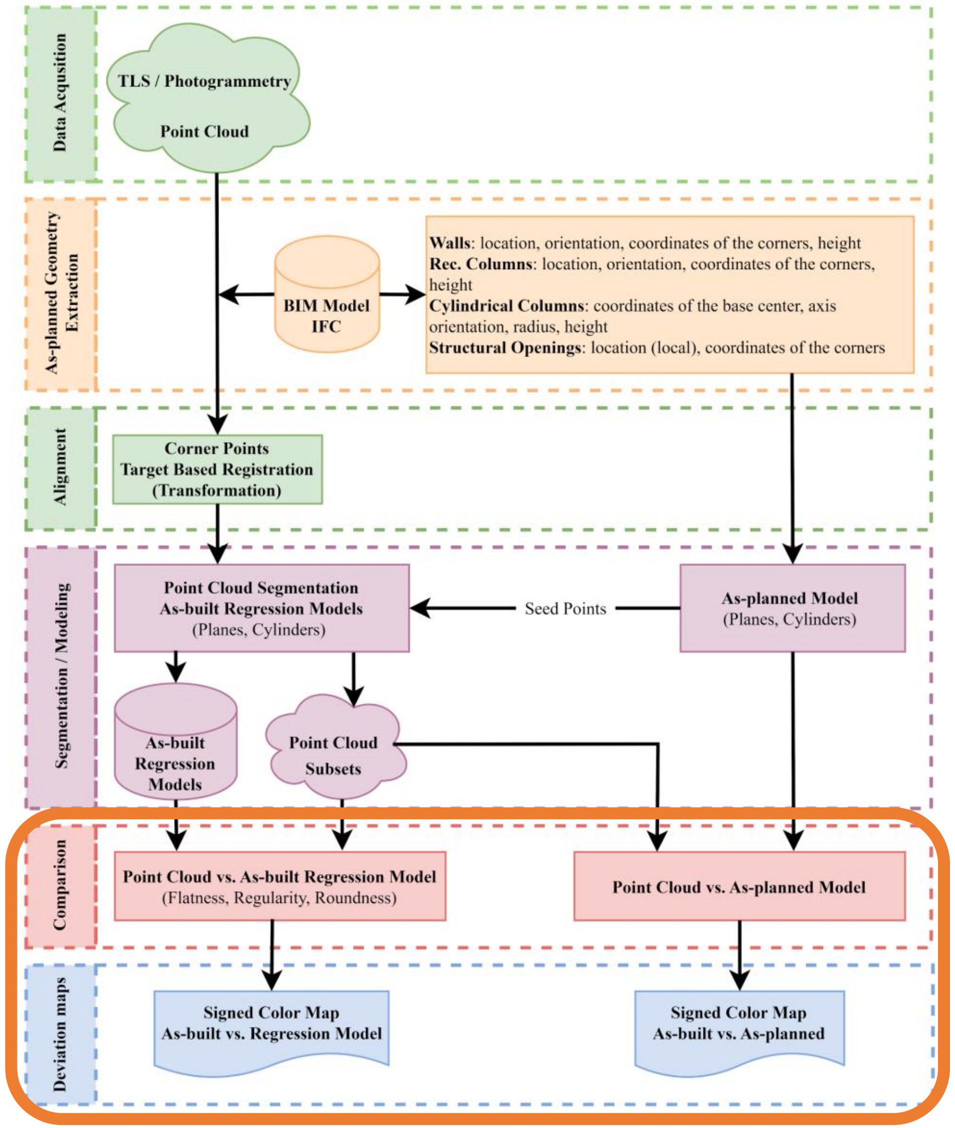
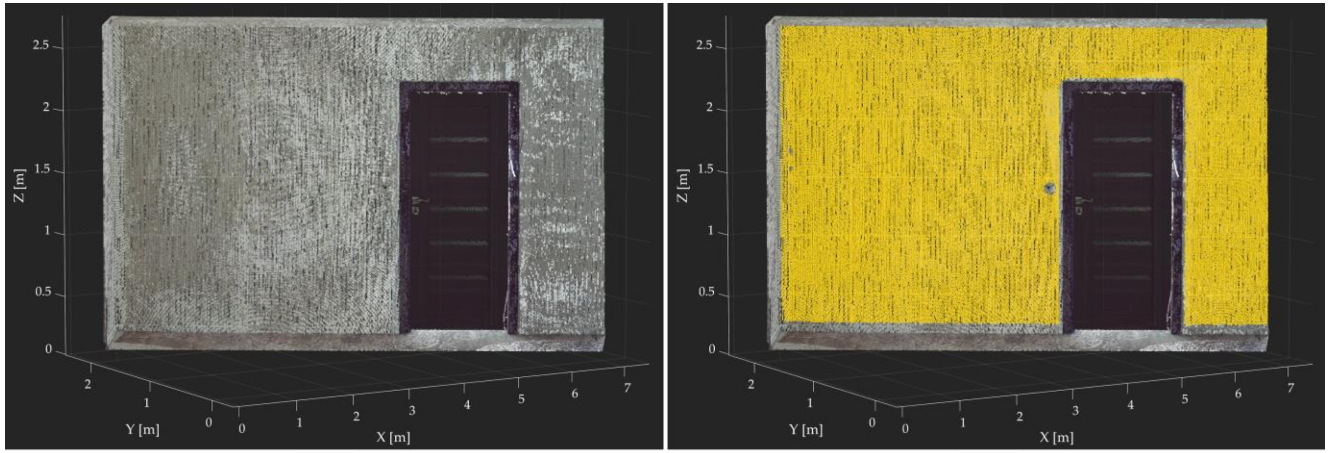
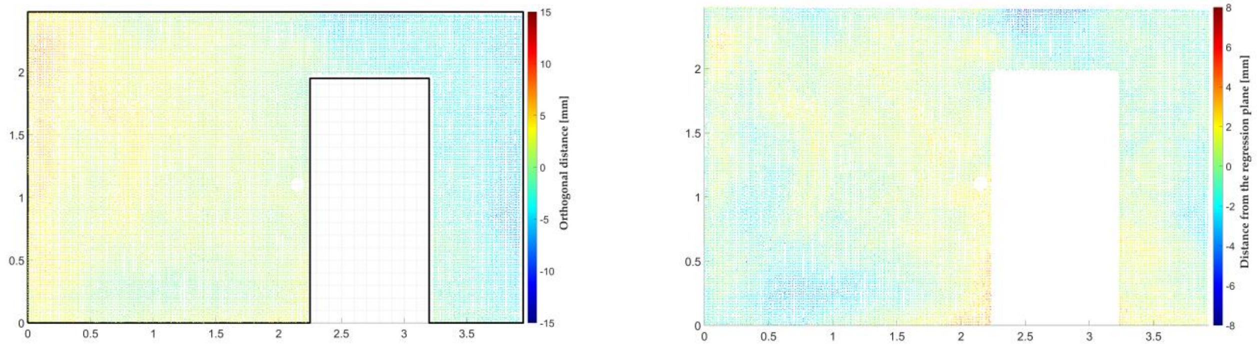


- Comparison
  - Point cloud vs. as-built regression model
  - Point cloud vs. as-planned model (BIM)
  - Tables, deviation maps (signed color maps)





Case study

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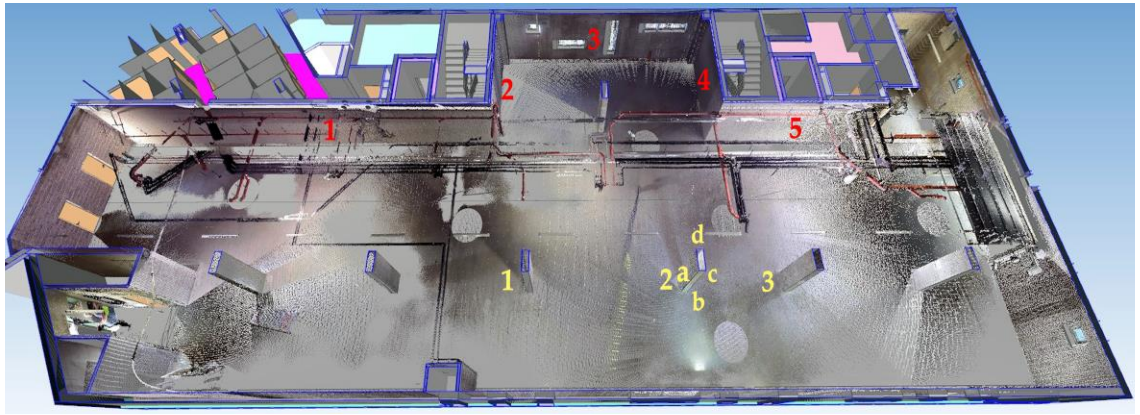
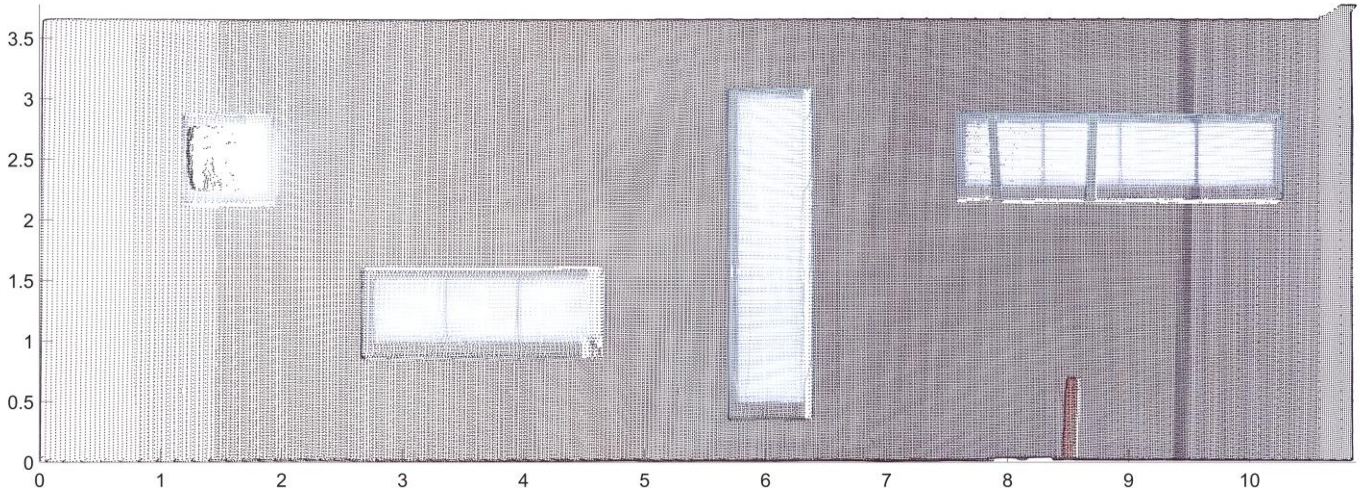
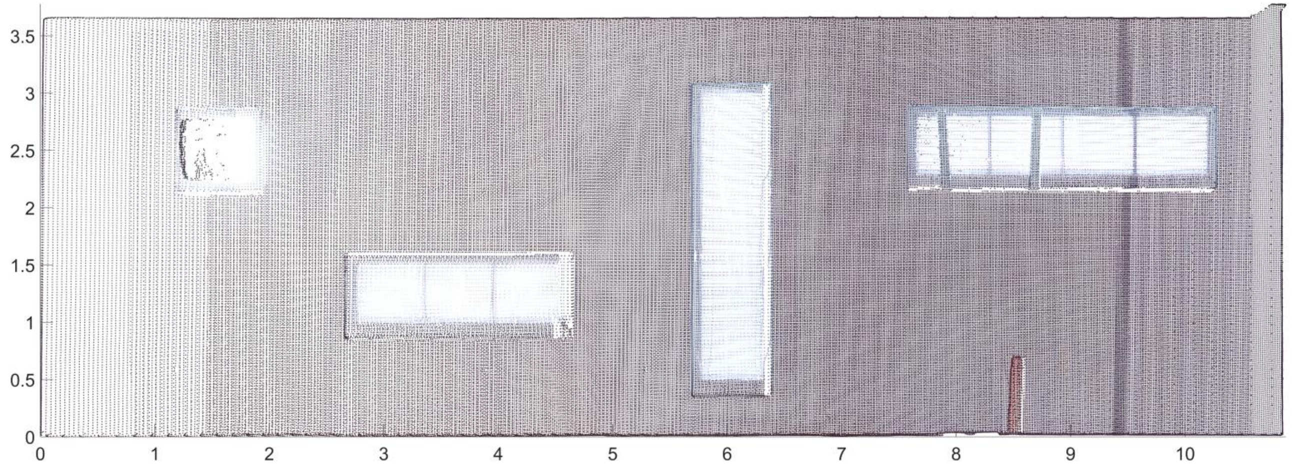
- Part of a polyfunctional building – NUPPU in Bratislava
  - LOG 300 - the building element is graphically represented within the model as a specific system, in which the object has specific quantities, dimensions, shapes, position and orientation
  - Scanned by Trimble TX5, resolution 1/16 (24.5 mm x 24.5 mm / 10 m)
  - TLS data aligned with the BIM model using surface-based registration and target-based registration (registration error was 8 mm)



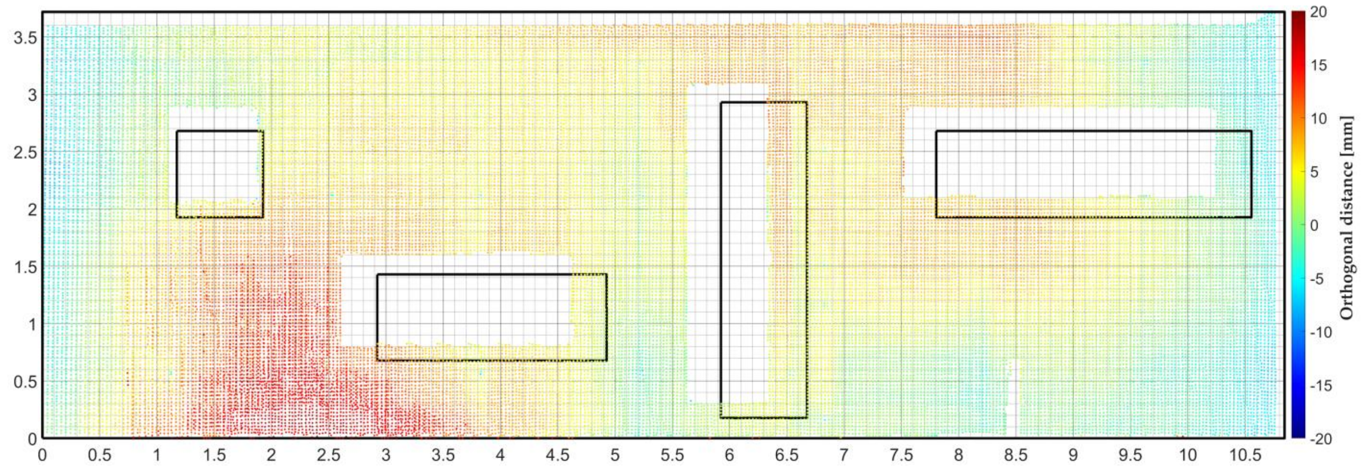


Case study

- Part of a polyfunctional building – NUPPU in Bratislava
  - Segmentation / modeling
    - Distance-based criterion: 20 mm
    - Normal vector-based criterion: 1°
  - Point cloud vs. as-planned model (BIM) comparison



n	*α* [°]	*d* [mm]	*min* [mm]	*max* [mm]	*avg* [mm]	abs_{max} [mm]
1	0.0211	+8	0	+15	+8	15
2	0.0839	-7	-13	−2	-7	13
3	0.0477	+5	-11	+20	+5	20
4	0.0171	+20	+14	+24	+19	24
5	0.0406	+8	+1	+23	+8	23



Case study

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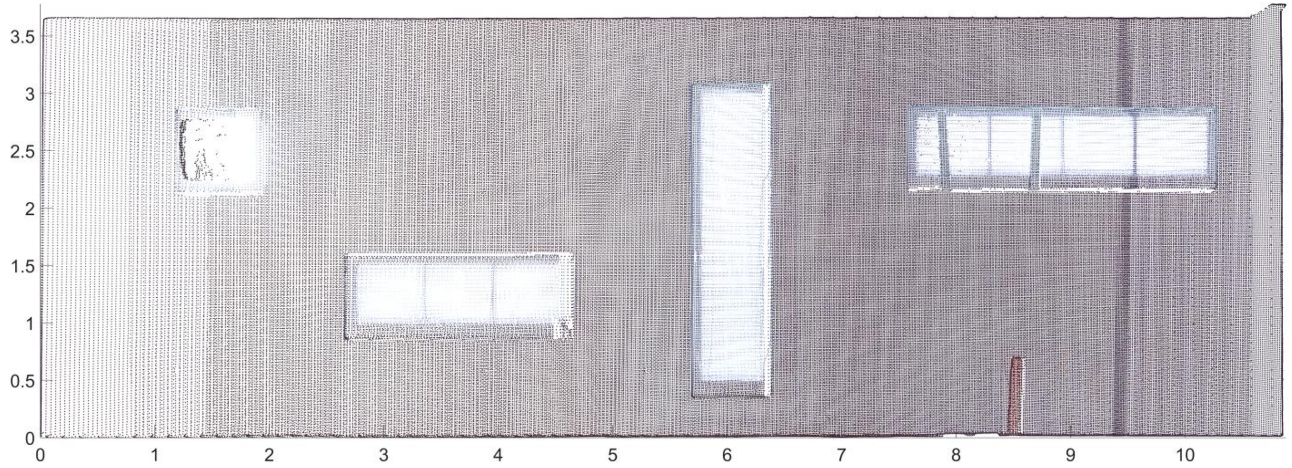
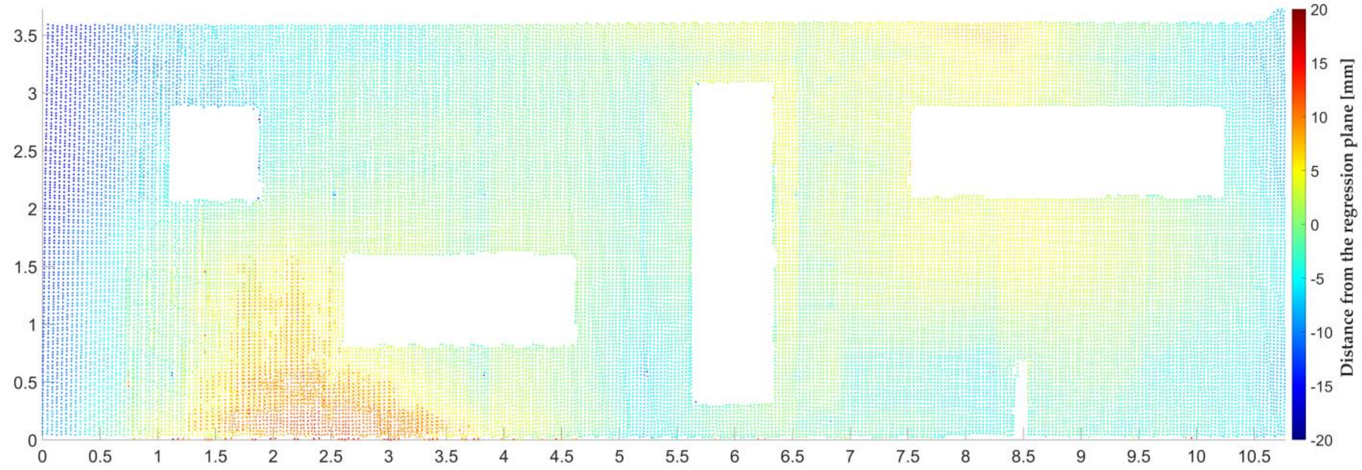
  - Segmentation / modeling
    - Distance-based criterion: 20 mm
    - Normal vector-based criterion: 1°
  - Point cloud vs. as-planned model (BIM) comparison

n	*min [mm]*	*max [mm]*	*abs_{max} [mm]*	*std [mm]*
1	*-7*	*+7*	*7*	*2*
2	*-5*	*+6*	*6*	*2*
3	*-16*	*+16*	*16*	*4*
4	*-5*	*+5*	*5*	*2*
5	*-7*	*+9*	*9*	*3*





Thank you for your attention

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