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FACULTY OF CIVIL ENGINEERING

AUTOMATED VERIFICATION OF BUILDING STRUCTURE’S GEOMETRY USING BIM AND TLS DATA

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Contents

- characteristics of BIM and IFC
- current Verification of Building Structure’s
- standalone application proposed for Automated verification of building structures
- verification of the application on a case study

Characteristics of BIM and IFC

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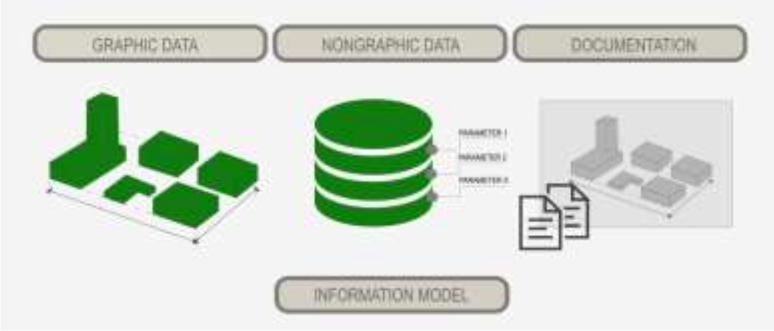
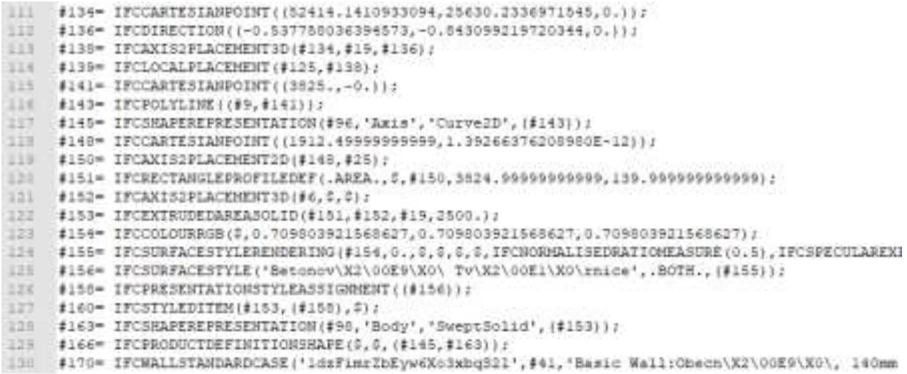
- the result of BIM (Building Information Modelling) is BIM model
- exchange formats for BIM = CAD format, CIS/2, BACnet, CityGML and IFC



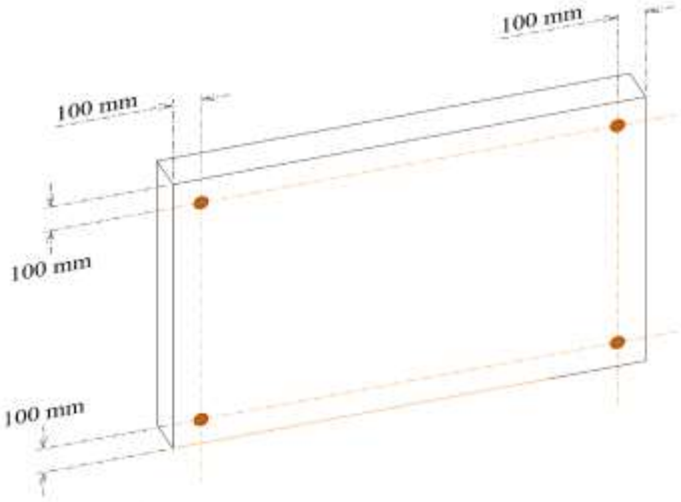
(Erdélyi, et al., 2017)

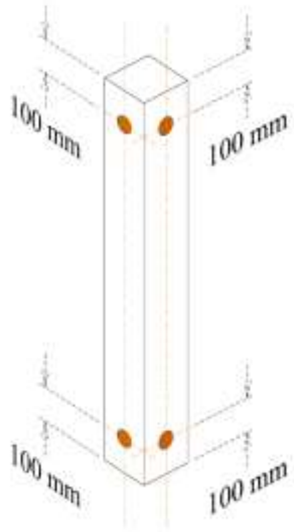
- EN ISO 16739:2016 Industry Foundation Classes (IFC) for data sharing in the construction and management industries
- BuildingSMART – the industry-led international organization



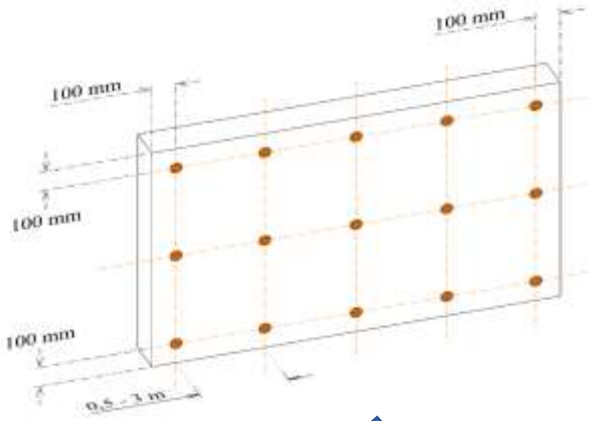
Current Verification of Building Structure’s

- Verification of Building Structure’s according to the older technical standard is currently being performed
- geodetic measurements (use of UMS)
- drawback = measured only at reference (observed) points





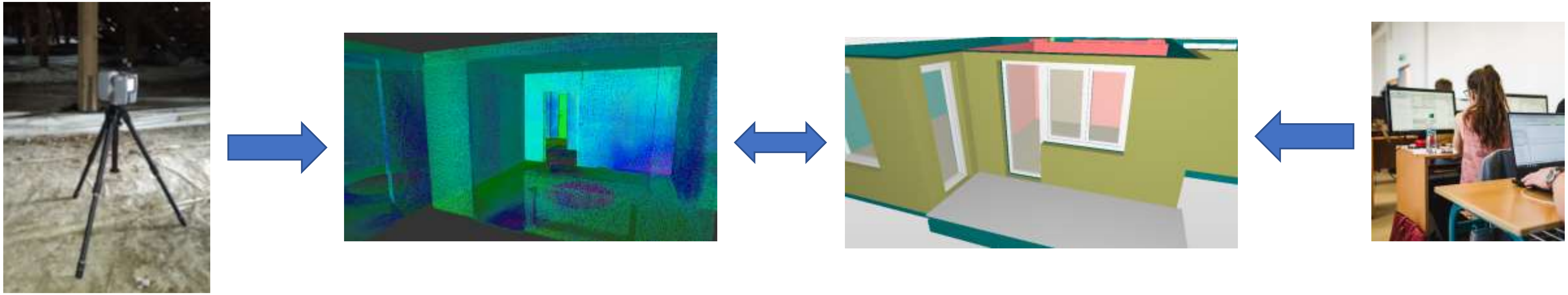
position control



control of flatness

Verification of Building structures - Vision of the Future

- use of point clouds (TLS, photogrammetry) and BIM models
- monitoring at each point of the building structure
- the aim is to introduce the standalone application proposed for Automated verification of building structures, the input data for the application are a BIM model and a point cloud of an existing building.
- quick evaluation using standalone application proposed for Automated verification of building structures



Point cloud

BIM model

Standalone application proposed for Automated verification of building structures

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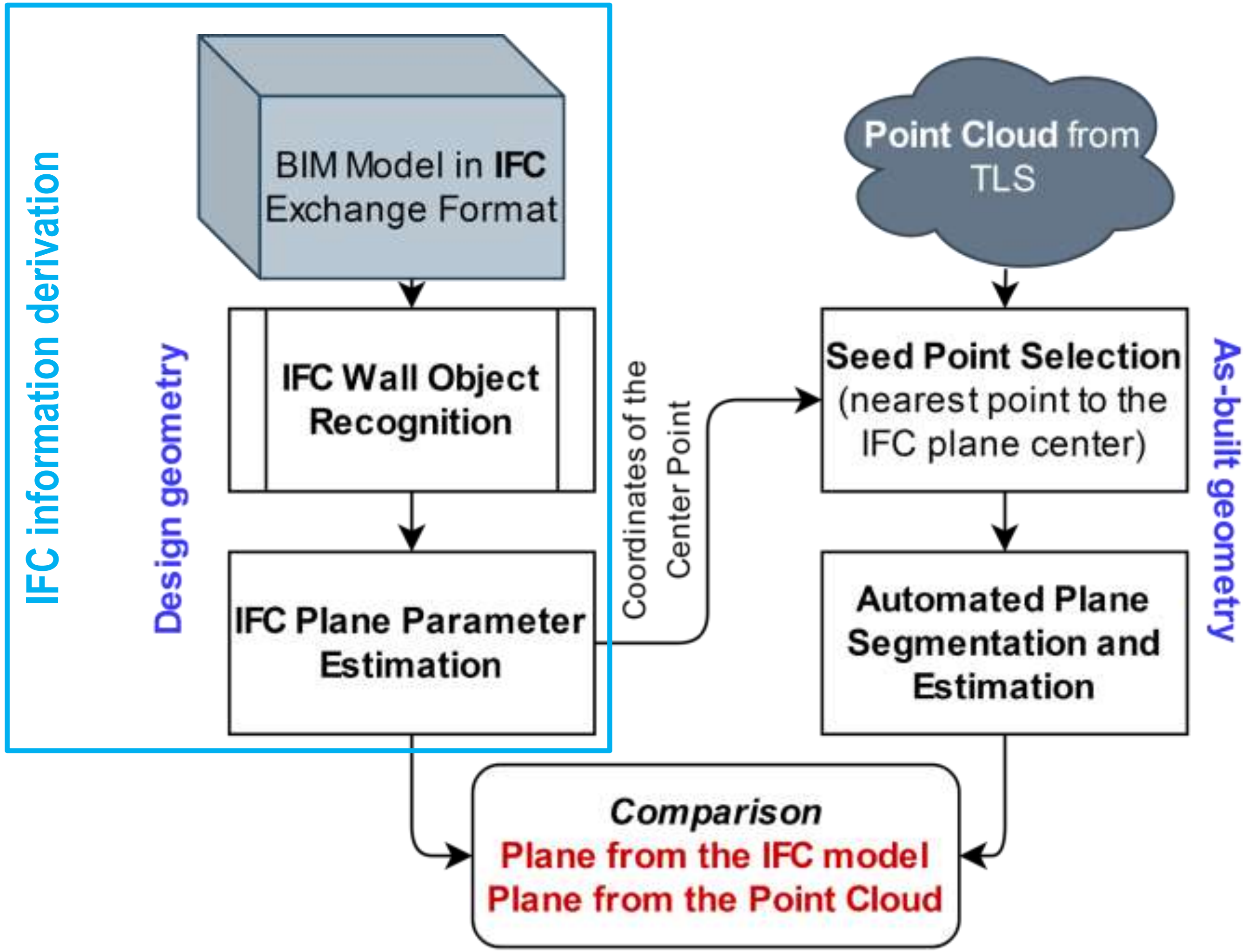

Identification of the geometric parameters from the IFC file and reconstruction of the wall geometry

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Origin (reference point)

```
#326= IFCCARTESIANPOINT((51995.1110077108,20583.7768044136,0.));
#328= IFCDIRECTION((-0.533954923697831,-0.845512944583844,0.));
#330= IFCAXIS2PLACEMENT3D(#326,#20,#328);
#331= IFCLOCALPLACEMENT(#143,#330);
#332= IFCCARTESIANPOINT((3968.71044757762,0.));
#334= IFCPOLYLINE((#10,#332));
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#338= IFCCARTESIANPOINT((1984.35522378881,-7.81597009336110E-13));
#340= IFCAXIS2PLACEMENT2D(#338,#26);
#341= IFCRECTANGLEPROFILEDEF(.AREA.,$,#340,3968.71044757762,199.999999999996);
#342= IFCAXIS2PLACEMENT3D(#6,$,$);
#343= IFCEXTRUDEDAREASOLID(#341,#342,#20,2500.);
#344= IFCSTYLEDITEM(#343,(#185),$);
#347= IFCSHAPEREPRESENTATION(#105,'Body','SweptSolid',(#343));
#349= IFCPRODUCTDEFINITIONSHAPE($,$,(#336,#347));
#353= IFCWALL('1NxUDlTOr0Ke26yoDk8vH2',#42,'Basic Wall:Generic - 200mm:202135'
```
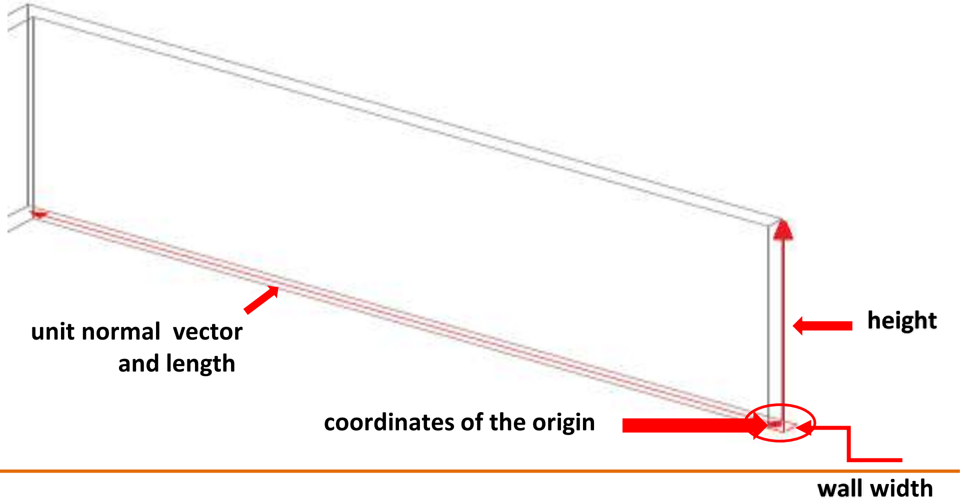
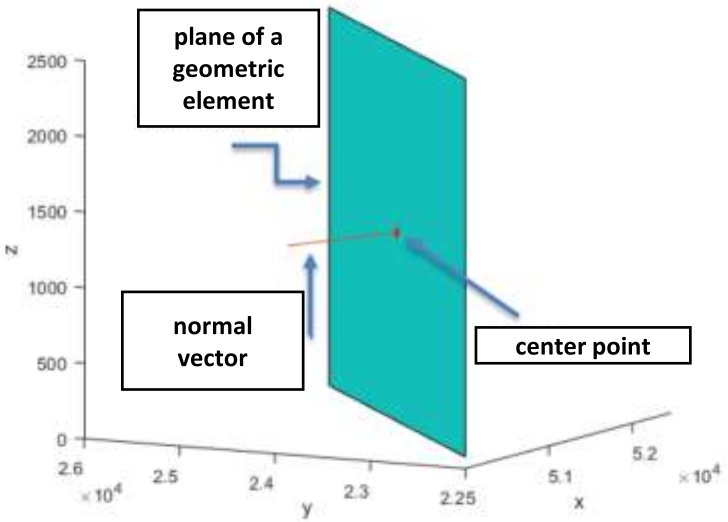

unit normal vector

length

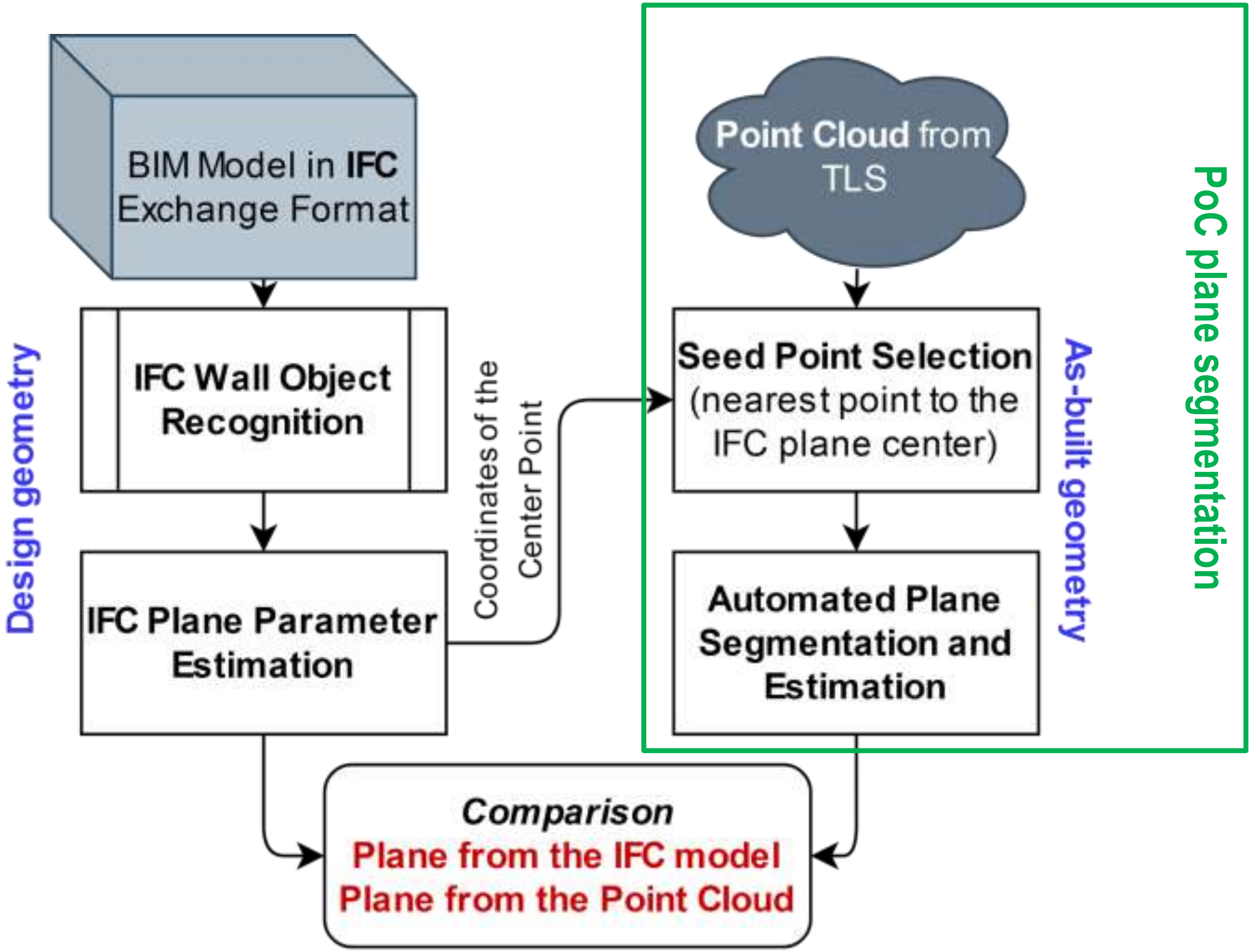
height

wall width



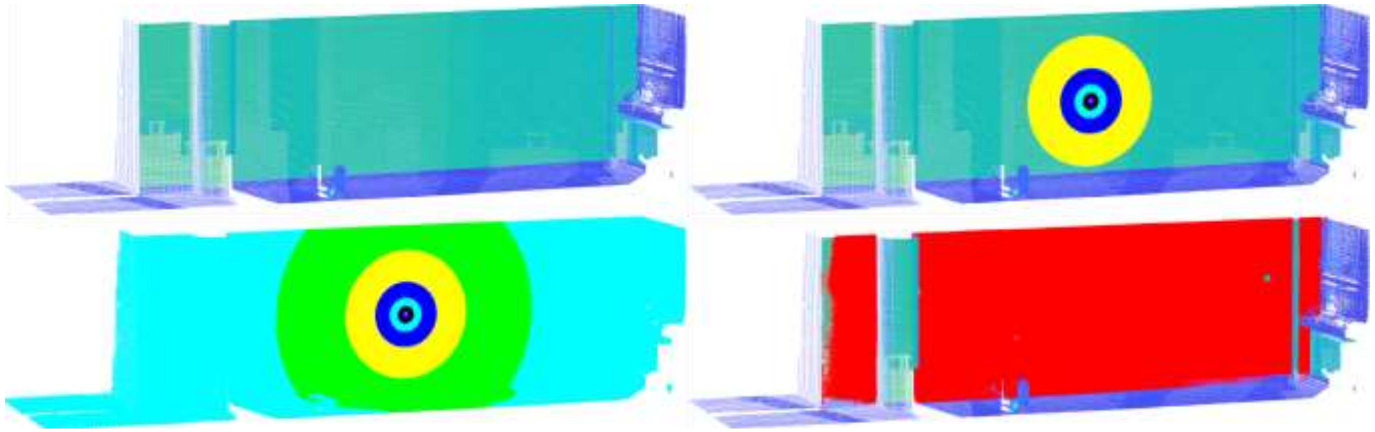


Standalone application proposed for Automated verification of building structures



Segmentation of geometric elements from a point cloud

- based on the modified RANSAC algorithm and the region-based segmentation method
- threshold value selection for distance filtering
- selection 100 nearest points from the center point → approximation of selected points by a plane, estimated by orthogonal regression analysis → the estimated plane model is tested against the selected neighbors, while the points lying in this plane are identified → plane re-estimation is repeated until the plane size stops increasing

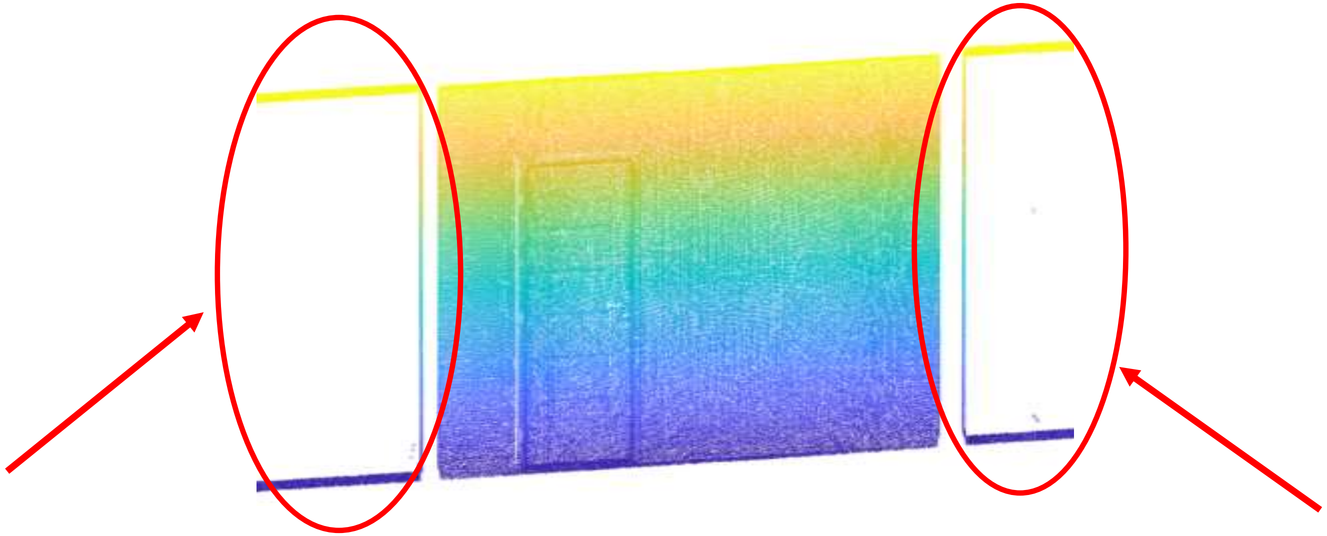


(Honti, 2021)

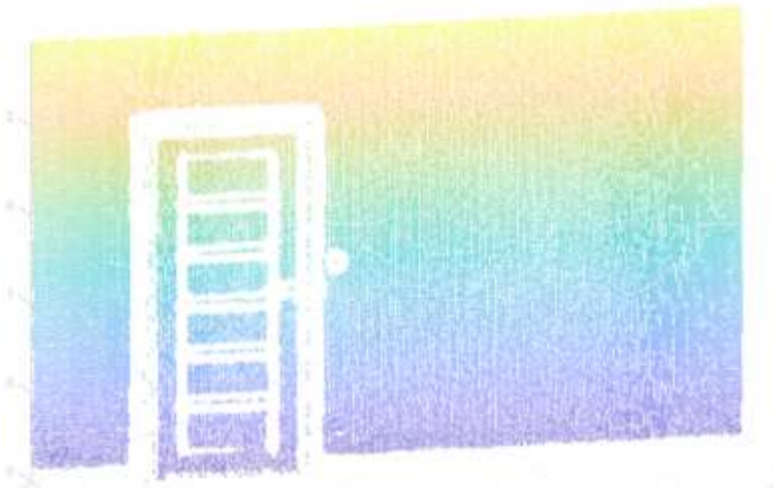
Filtration based on the local normals

- since, after the segmentation process, some points that do not belong to the estimated plane also meet the threshold value, it was necessary to add a normal vector-based filter to eliminate these points
- filtration based on local normal vectors
- use of the 50 nearest neighbors – dependence on the density of point cloud
- selected condition for maximum deviation of normal vectors

Before the filtration based on local normals

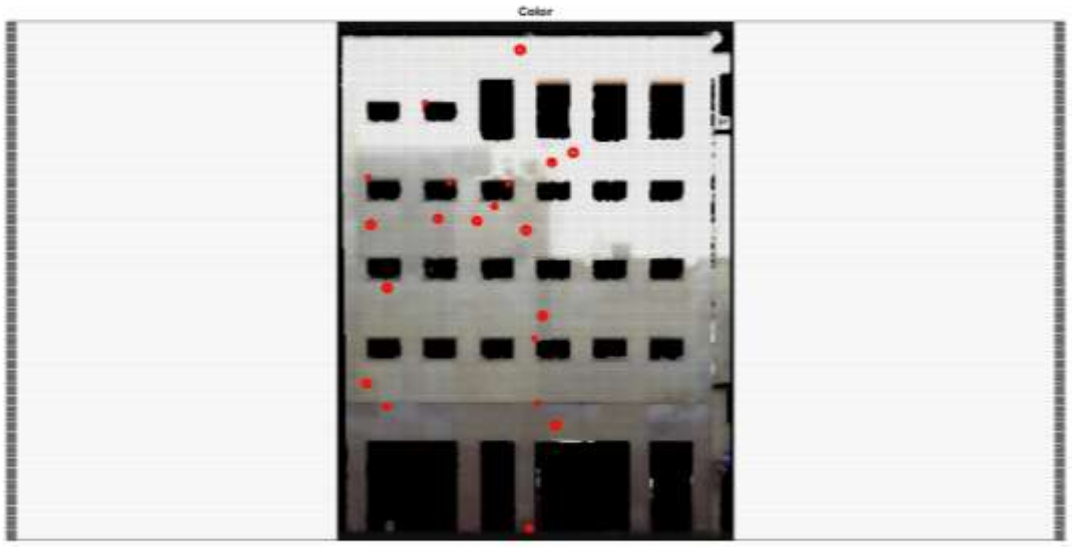


After the filtration based on the local normals



Filtration using curve segmentation

- in some cases, even the normal based filtration do not eliminate all the outliers – e. g. points of the doors, switches, windows, etc.
- in cooperation with the Department of Mathematics and Descriptive Geometry (FCE, STU BA) a curve segmentation methodology has been developed to eliminate the remaining outliers
- the intensity of the point cloud, the distance of the points from the fitted plane and the color values (R, G, B) of the points are used for outlier removal



- the generated curve eliminates the outliers for the estimated plane. The outliers are the points, where the change of these indicators (R, G, B, intensity, distance) is greater than a specified threshold.

Standalone application proposed for Automated verification of building structures

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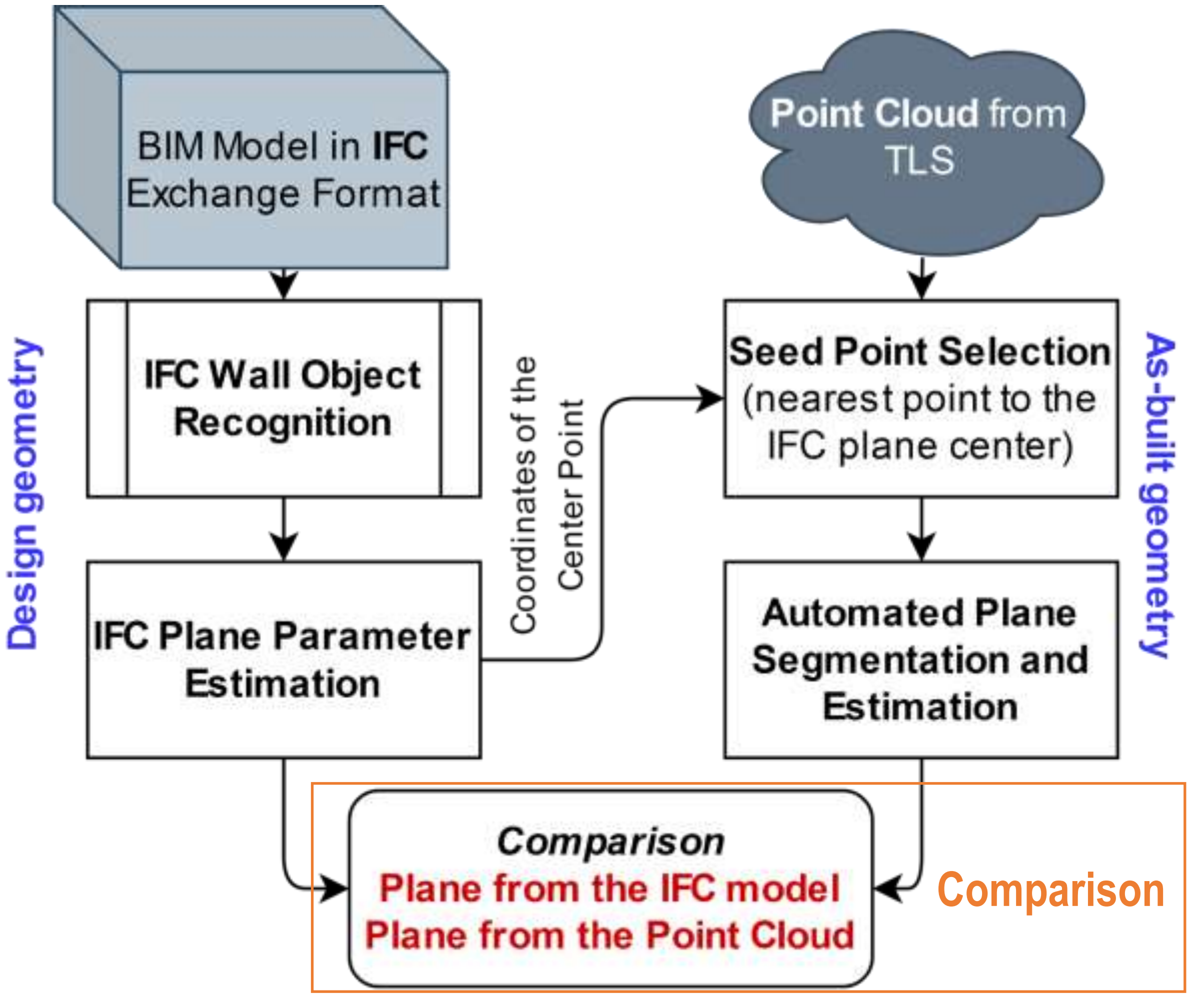
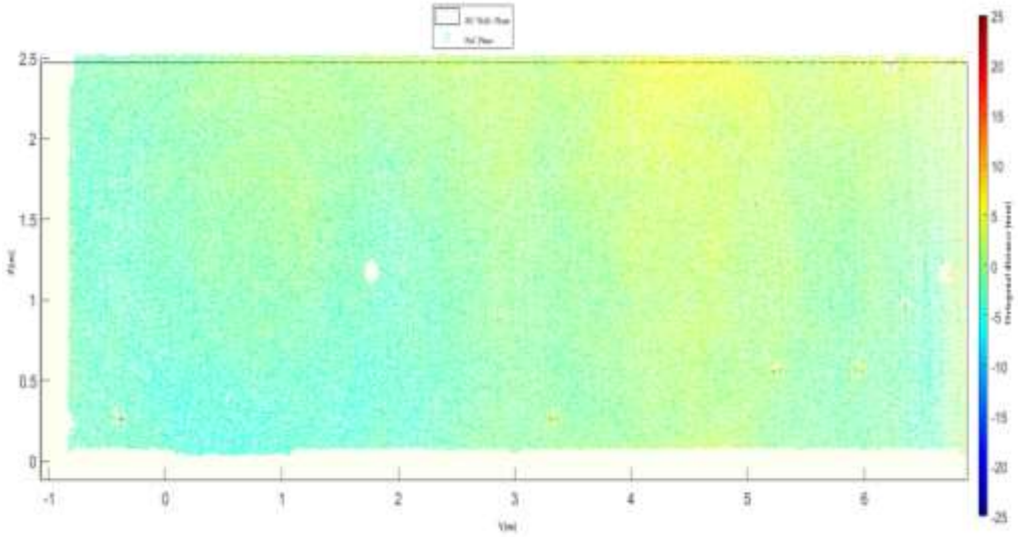
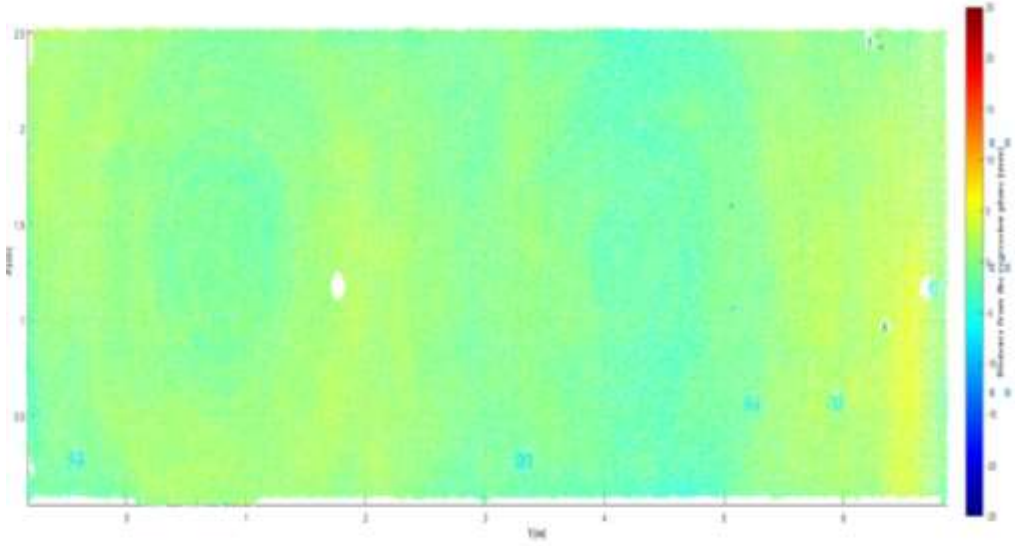


Difference model generation

- **Orthogonal deviations between the IFC plane and the point cloud plane**
  - calculation of the rotation and distance of the BIM model plane with respect to the estimated regression plane PoC
  - maximum, minimum and average deviations of PoC points from the BIM model
- **Flatness of walls**
  - maximum, minimum and average deviations of PoC points from estimated regression plane PoC





The standalone application proposed for Automated verification of building

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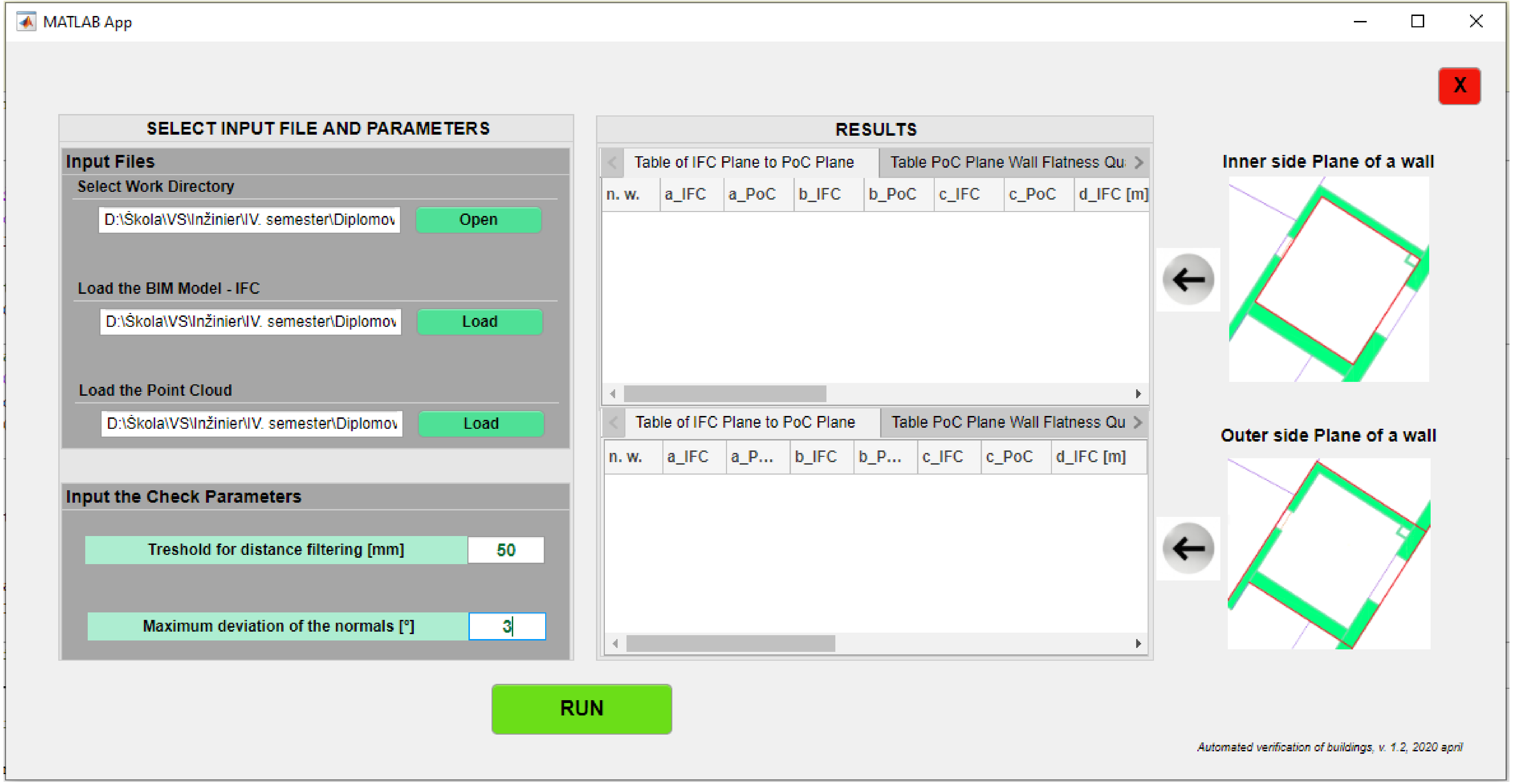
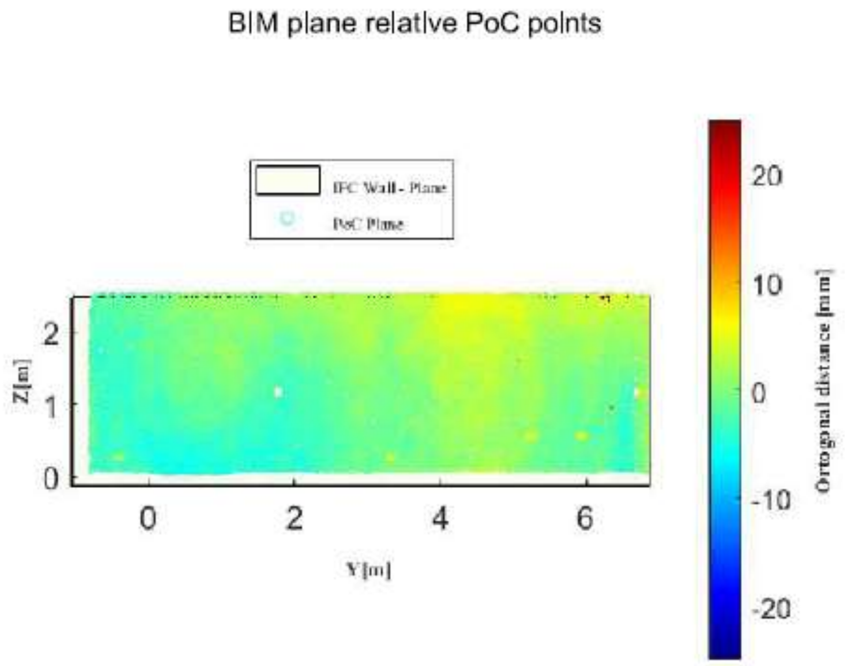


Wall n. 3, plane 1 (scanned from the living room):



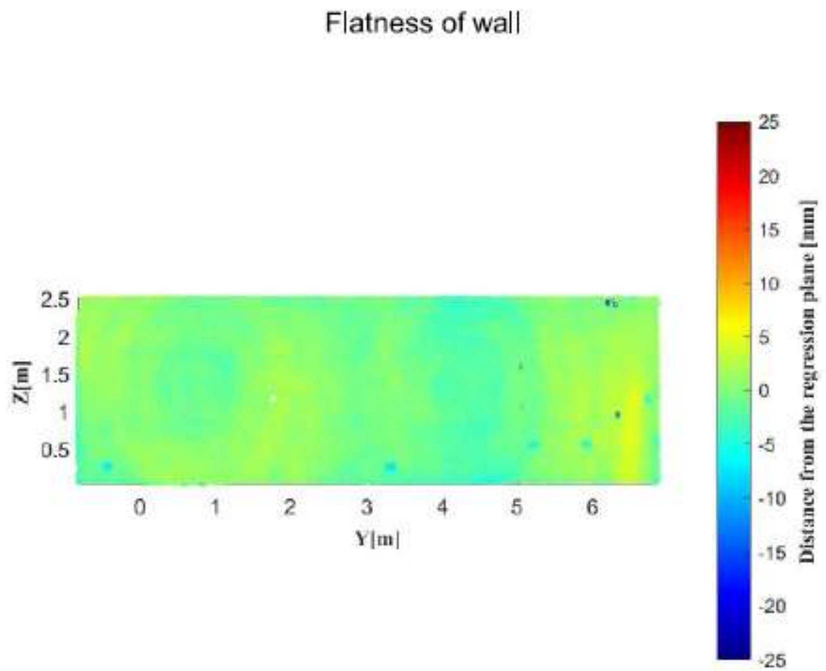
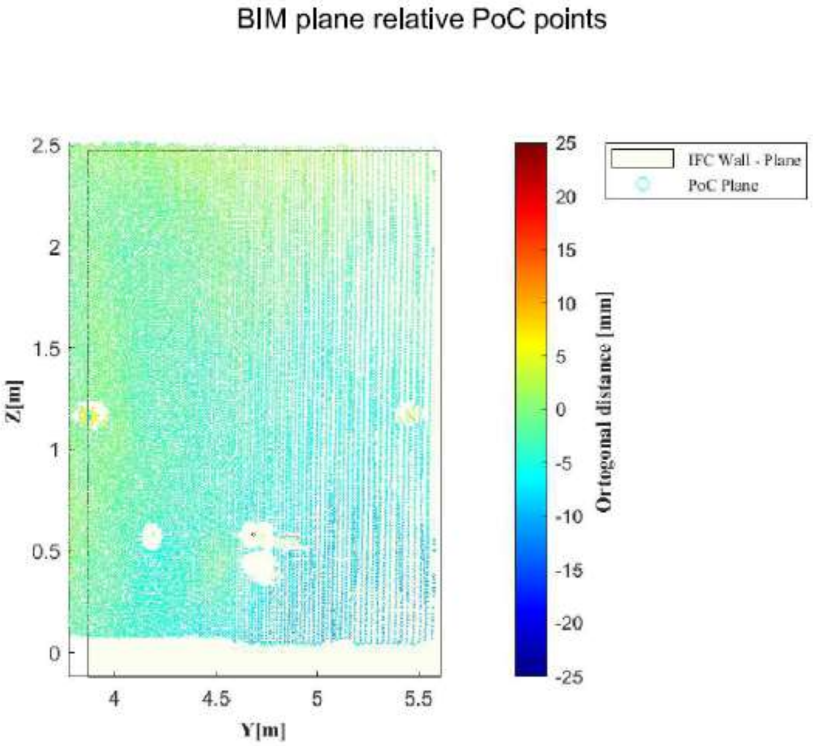


Table 1:

BIM plane relative PoC points													
a_{IFC}	a_{PoC}	b_{IFC}	b_{PoC}	c_{IFC}	c_{PoC}	d_{IFC} [m]	d_{PoC} [m]	roll [°]	dev [mm]	max [mm]	min [mm]	avg[mm]	abs_{mx} [mm]
0.842	-0.841	-0.540	0.541	0.000	0.002	1.497	-1.501	0.1	-4	34	-16	-1	34

Flatness of wall			
max [mm]	min [mm]	avg[mm]	abs_{mx} [mm]
14	-30	0	30

Wall n. 14, Plane 2 (scanned from the kitchen):



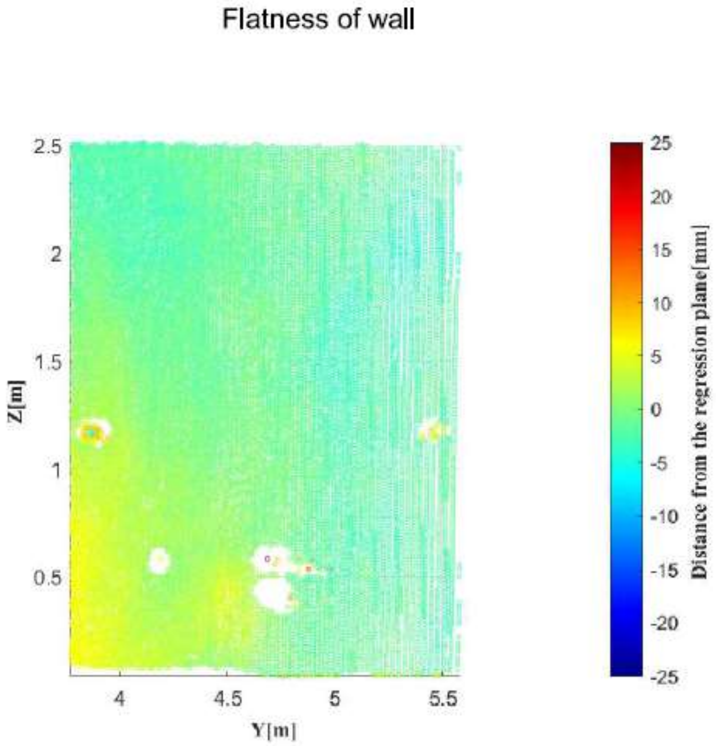
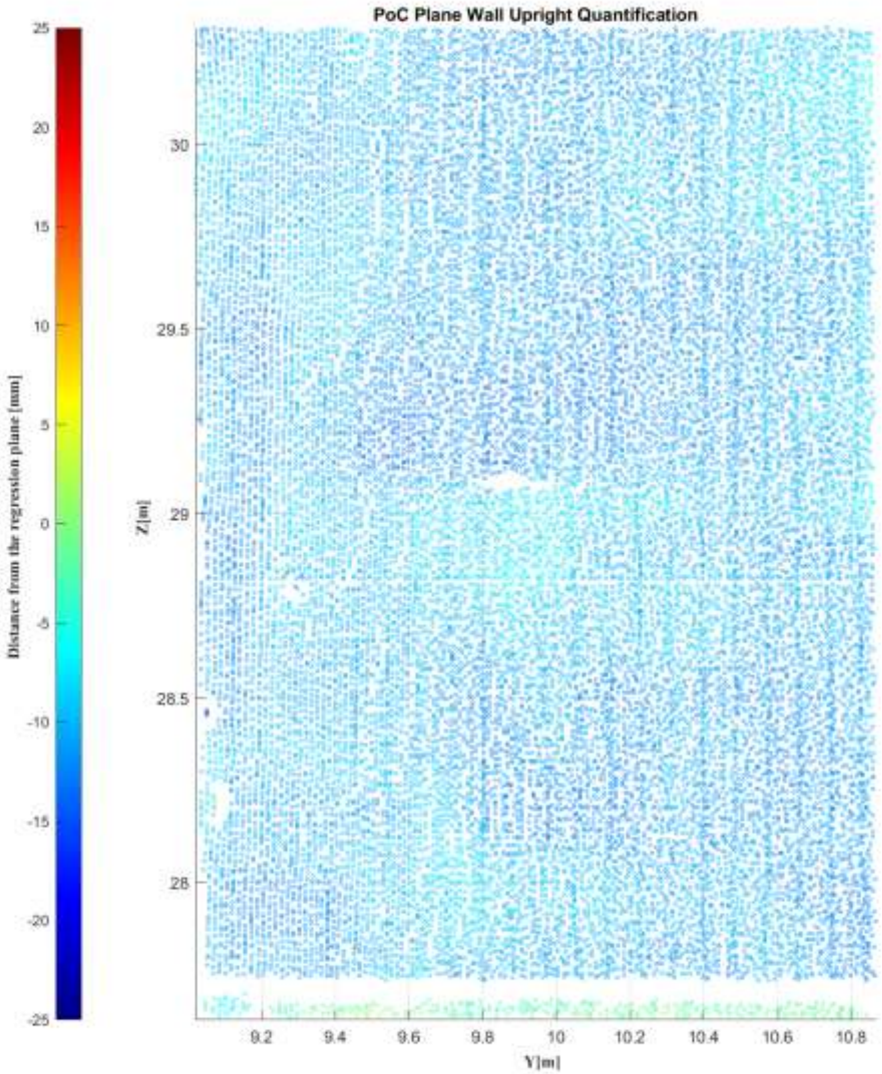


Table 2:

BIM plane relative PoC points													
a_{IFC}	a_{PoC}	b_{IFC}	b_{PoC}	c_{IFC}	c_{PoC}	d_{IFC} [m]	d_{PoC} [m]	roll [°]	dev [mm]	max [mm]	min [mm]	avg[mm]	abs_{mx} [mm]
-0.842	-0.842	0.539	0.539	0.000	-0.004	0.883	0.891	0.2	-8	30	-11	-3	30

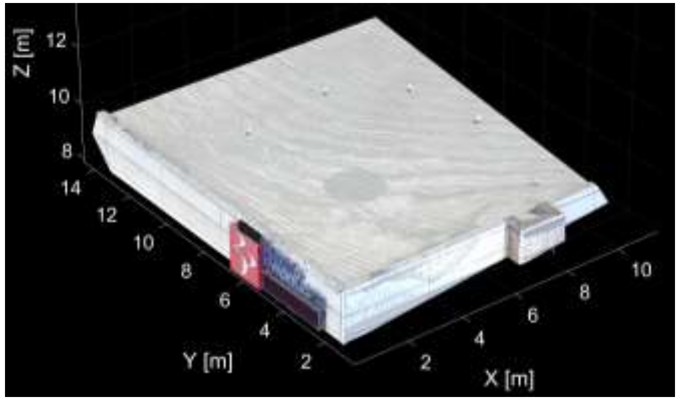
Flatness of wall			
max [mm]	min [mm]	avg[mm]	abs_{mx} [mm]
34	-7	0	34



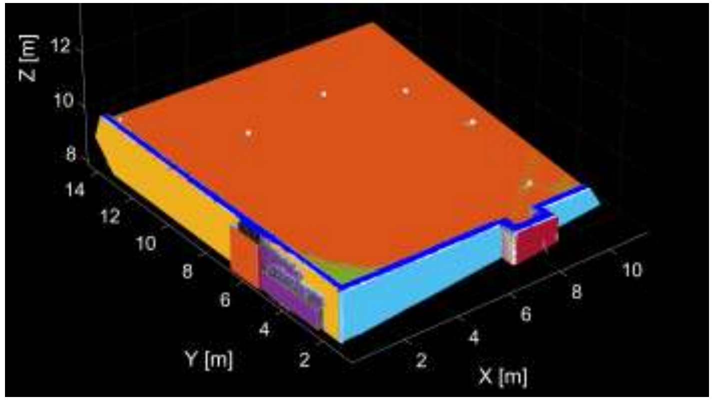
	max [mm]	min [mm]	avg [mm]	abs_max [mm]
1	2.9666	-59.5221	-10.2172	59.5221

Conclusion

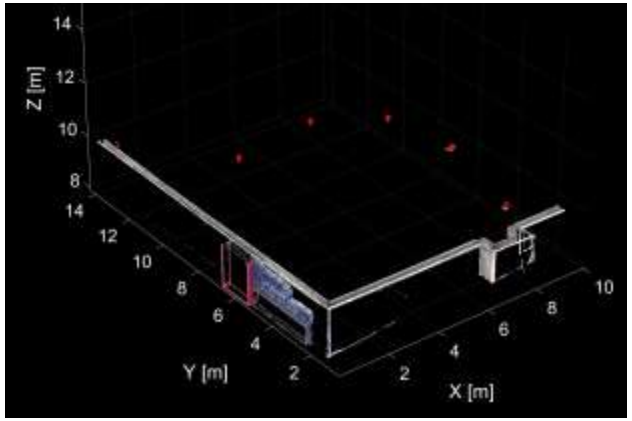
- the aim of this presentation was to introduce the application proposed for automated verification of building structures
- the application is still under development and currently only walls and columns with a rectangular or square base can be verified, in further development columns with a circular base and various other construction elements will also be verified



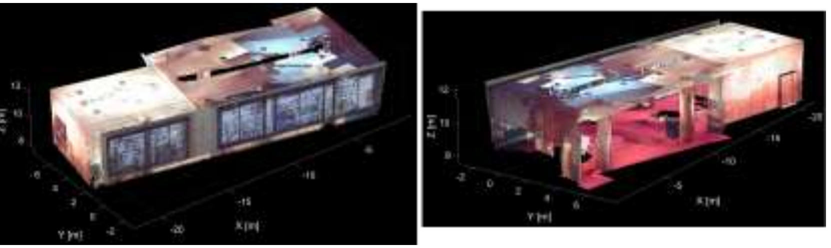
merané mračno bodov



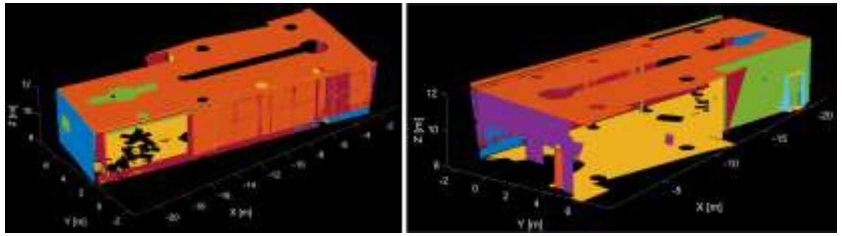
segmentované roviny



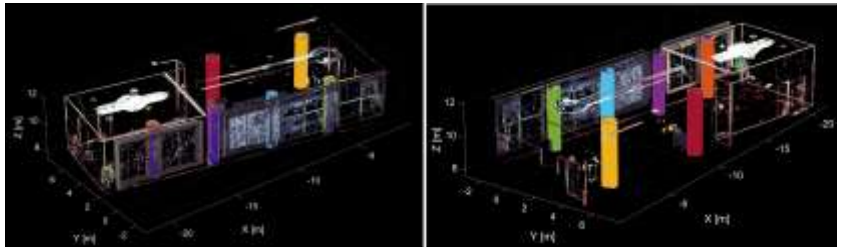
segmentované sféry



merané mračno bodov



segmentované roviny



segmentované valcové plochy

Thank you for your attention

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