

SLOVAK UNIVERSITY OF TECHNOLOGY IN BRATISLAVA FACULTY OF CIVIL ENGINEERING

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



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- 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





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

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Current Verification of Building Structure's



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Verification of Building structures - Vision of the Future



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- 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





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Standalone application proposed for Automated verification of building structures

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STU

S v F

Point Cloud from BIM Model in IFC IFC information derivation TLS **Exchange** Format Seed Point Selection ß Design geometry **IFC Wall Object** Coordinates of the -built (nearest point to the Center Point Recognition IFC plane center) geometry **Automated Plane IFC Plane Parameter** Segmentation and Estimation Estimation Comparison Plane from the IFC model ≁ Plane from the Point Cloud

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

wall geometry



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Standalone application proposed for Automated verification of building structures

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S v F

Point Cloud from BIM Model in IFC TLS PoC Exchange Format plane Seed Point Selection As-built Design geometry segmentation Coordinates of the **IFC Wall Object** (nearest point to the Center Point Recognition IFC plane center) geometry **Automated Plane IFC Plane Parameter** Segmentation and Estimation Estimation Comparison Plane from the IFC model ≁ Plane from the Point Cloud

Segmentation of geometric elements from a point cloud



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- 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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Point Cloud from BIM Model in IFC TLS Exchange Format Seed Point Selection ß Design geometry **IFC Wall Object** Coordinates of the -built (nearest point to the Center Point Recognition IFC plane center) geometry **Automated Plane IFC Plane Parameter** Segmentation and Estimation Estimation Comparison Plane from the IFC model Comparison Plane from the Point Cloud

Difference model generation



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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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承 MATLAB App \times Х SELECT INPUT FILE AND PARAMETERS RESULTS Input Files Table of IFC Plane to PoC Plane Table PoC Plane Wall Flatness Que Inner side Plane of a wall Select Work Directory a_IFC a_PoC b_IFC b_PoC c_IFC c_PoC d_IFC [m] n. w. D:\Skola\VS\Inžinier\IV. semester\Diplomov Open Load the BIM Model - IFC D:\Skola\VS\Inžinier\IV. semester\Diplomov Load Load the Point Cloud -€ | D:\Skola\VS\Inžinier\IV. semester\Diplomov Table of IFC Plane to PoC Plane Table PoC Plane Wall Flatness Qu > Load Outer side Plane of a wall n.w. a_IFC a_P... b_IFC b_P... c_IFC c_PoC d_IFC [m] Input the Check Parameters Treshold for distance filtering [mm] 50 Maximum deviation of the normals [°] 3 RUN Automated verification of buildings, v. 1.2, 2020 april

STU SvF

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



Table 1:

BIM pla	ane re	lative Po	C poInts	S									
a _{lFC}	a _{PoC}	b _{IFC}	b _{PoC}	G FC	CPoC	d _{IFC} [m]	d _{PoC} [m]	roll [°]	dev [mm]	max [mm]	min (mm)	avg[mm]	abs _{mx} [mm]
0.842	-0.84	1-0.540	0.541	0.000	0.002	1.497	-1.501	0.1	-4	34	-16	-1	34
Flatnes	s of w	vall											
max [n	nm] n	nin [mm]	avg[n	nm] a	abs _{mx} [mn	n]							
14		-30	0		30								

S T U S v F

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



BIM plane relative PoC points



Table 2:

ane re	lative Po	C points	5									
a _{PoC}	b _{IFC}	b _{PoC}	\mathbf{c}_{IFC}	CPOC	d _{IFC} [m]	d _{PoC} [m]	roll [°]	dev [mm]	max [mm]	min [mm]	avg[mm]	abs _{mx} [mm
-0.84	2 0.539	0,539	0.000	-0,004	0.883	0,891	0.2	-8	30	-11	-3	30
s of w	/all			5 93.		1987 - 194 194	,	18991) -	(-:	8-	12	(2)
nm] n	nin [mm]	avg[n	nm] a	bs _{mx} (mr	n]							
	-7	0		34								
	ane re a _{PoC} -0.84 ss of w	ane relative Por a _{PoC} b _{IFC} -0.842 0.539 as of wall nm] min [mm] -7	ane relative PoC points a _{PoC} b _{IFC} b _{PoC} -0.842 0.539 0.539 as of wall ang min [mm] avg[n -7 0	ane relative PoC points a _{PoC} b _{IFC} b _{PoC} C _{IFC} -0.842 0.539 0.539 0.000 as of wall min [mm] avg[mm] a -7 0	ane relative PoC points a _{PoC} b _{IFC} b _{PoC} C _{IFC} C _{PoC} -0.842 0.539 0.539 0.000 -0.004 as of wall nm] min [mm] avg[mm] absmx [mn] -7 0 34	ane relative PoC points a_{PoC} b_{IFC} b_{PoC} c_{IFC} c_{PoC} d_{IFC} [m]-0.8420.5390.5390.000-0.0040.883as of wallmmmin [mm] $avg[mm]$ abs_{mx} [mm]-7034	ane relative PoC points a_{PoC} b_{IFC} b_{PoC} c_{IFC} c_{PoC} d_{IFC} [m] d_{PoC} [m] -0.842 0.539 0.539 0.000 -0.004 0.883 0.891 as of wall nm] min [mm] avg[mm] abs_{mx} [mm] -7 0 34	ane relative PoC points a_{PoC} b_{IFC} b_{PoC} c_{IFC} c_{PoC} d_{IFC} [m] d_{PoC} [m] roll [°] -0.842 0.539 0.539 0.000 -0.004 0.883 0.891 0.2 as of wall avg[mm] abs_{mx} [mm] abs_{mx} [mm] abs_{mx}	ane relative PoC points a_{PoC} b_{IFC} b_{PoC} c_{IFC} c_{PoC} d_{IFC} [m] d_{PoC} [m] roll [°] dev [mm] -0.842 0.539 0.539 0.000 -0.004 0.883 0.891 0.2 -8 as of wall min mm [mm] avg[mm] abs_mx [mm] -7 0 34	ane relative PoC points a_{PoC} b_{IFC} b_{PoC} c_{PoC} d_{IFC} [m] d_{PoC} [m] roll [°] dev [mm] max [mm] -0.842 0.539 0.539 0.000 -0.004 0.883 0.891 0.2 -8 30 as of wall min mmin avg[mm] absmx [mm] -7 0 34	ane relative PoC points a_{PoC} b_{IFC} b_{PoC} c_{FC} c_{PoC} d_{IFC} [M] roll [°] dev [mm] max [mm] min [mm] -0.842 0.539 0.539 0.000 -0.004 0.883 0.891 0.2 -8 30 -11 as of wall min [mm] avg[mm] absmx [mm] -7 0 34	ane relative PoC points a_{PoC} b_{IFC} b_{PoC} c_{PoC} d_{IFC} [m] d_{PoC} [m] roll [°] dev [mm] max [mm] min [mm] avg[mm] -0.842 0.539 0.539 0.000 -0.004 0.883 0.891 0.2 -8 30 -11 -3 as of wall min [mm] avg[mm] -7 0 34

Flatness of wall



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Conclusion

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- 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

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Thank you for your attention

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