

Extending IFC with point cloud data

eg-ice 2015

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TU / e

Technische Universiteit
Eindhoven
University of Technology

Where innovation starts



Aims

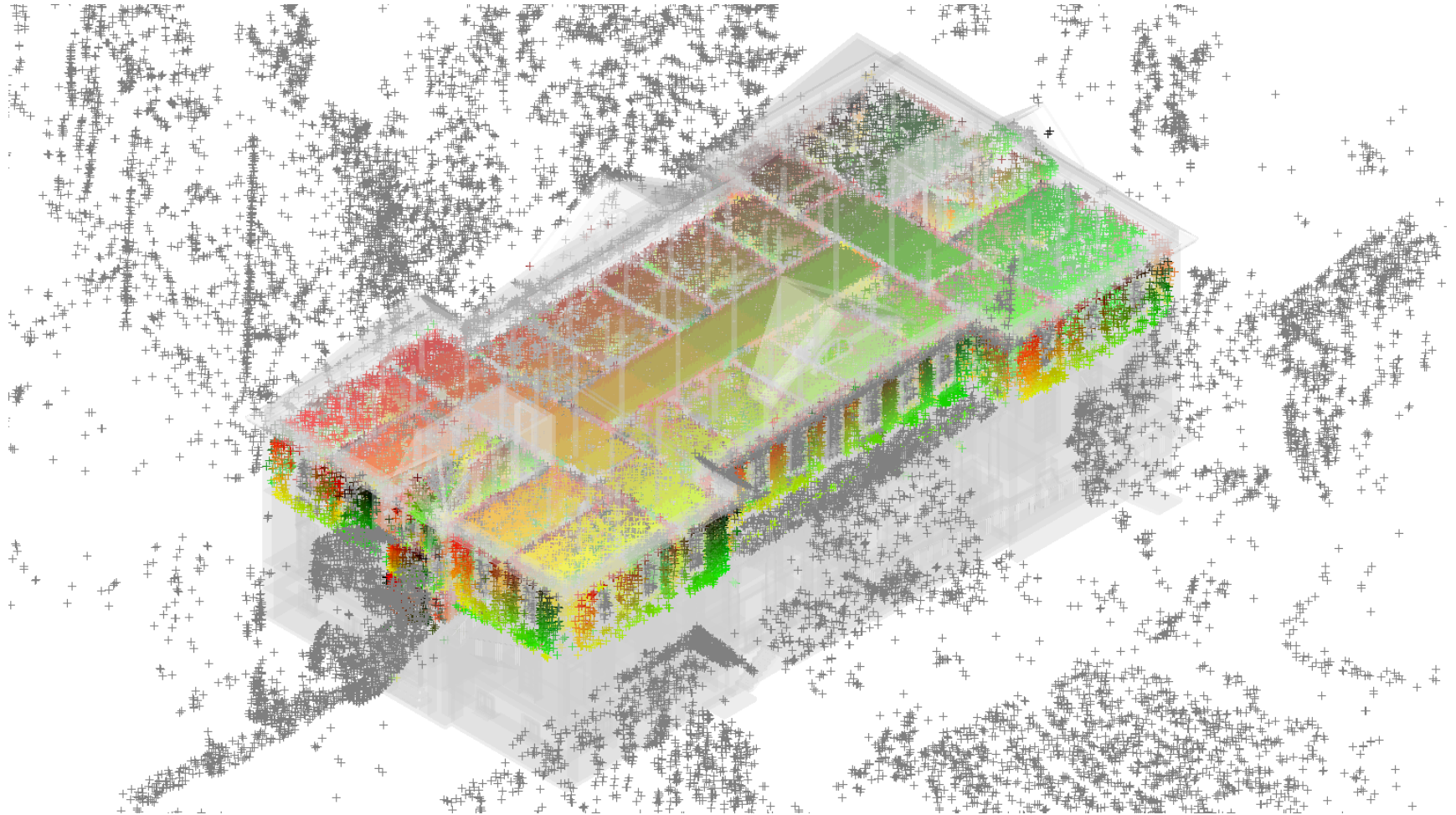
Unite both data carriers

In a **harmonized storage format**

By **extending the IFC schema**

Introduce a **binary serialization format for IFC**

Aims



IFC and point clouds anno 2014

#1=IFCCARTESIANPOINTLIST3D((121.76123809814453,-78.45201110839844,-13.620319366455078),
(121.80341339111328,-78.57342529296875,-12.835342407226562), (121.7803726196289,-78.34296417236328,-
13.846855163574219), (121.78942108154297,-78.3430404663086,-13.734870910644531), (121.78864288330078,-
78.33686065673828,-13.621849060058594), (121.79190826416016,-78.33324432373047,-13.50927734375),
(121.80005645751953,-78.33274841308594,-13.397228240966797), (121.82268524169922,-78.3357925415039,-
13.173797607421875), (122.14295196533203,-78.85536193847656,1.7720565795898438), (122.14188385009766,-
78.8489990234375,1.8842010498046875), (122.1812515258789,-78.74574279785156,1.8790130615234375),
(2.644031524658203,-14.406140327453613,1.1417999267578125), (2.628744125366211,-
14.345318794250488,1.1577377319335938), (3.482269287109375,-17.248559951782227,-1.4286651611328125),
(3.32574462890625,-17.086864471435547,-1.4688568115234375), (3.4234485626220703,-15.845314025878906,-
1.2468643188476562), (3.449533462524414,-15.883966445922852,-1.211181640625), (3.5097713470458984,-
15.58512020111084,-1.1186370849609375), (4.405935287475586,-14.289386749267578,-1.1261444091796875),
(4.405914306640625,-14.280056953430176,-1.0434646606445312), (4.378328323364258,-14.243566513061523,-
1.0649948120117188), (5.349382400512695,-14.975531578063965,-0.90240478515625), (5.226930618286133,-
14.915581703186035,-0.9336929321289062), (2.618467330932617,-10.692724227905273,-1.2475967407226562),
(2.5753402709960938,-10.5256929397583,-1.2720489501953125), (2.642486572265625,-10.534729957580566,-
1.2680206298828125), (2.5160579681396484,-10.395642280578613,-1.3473358154296875), (2.638456344604492,-
10.48128890991211,-1.3255081176757812), (2.763673782348633,-10.58719539642334,-1.269317626953125),
(2.4005050659179688,-10.004755973815918,-1.3596649169921875), (2.8383045196533203,-10.220603942871094,-
1.3677139282226562), (2.854219436645508,-10.277368545532227,-1.3037109375), (2.8745193481445312,-
10.280534744262695,-1.2966690063476562), (2.851787567138672,-10.229779243469238,-1.3521499633789062),
(2.974489212036133,-10.0681791305542,-1.234466552734375), (1.8945045471191406,-10.313359260559082

IFC and point clouds anno 2014

Points for improvement:

No per-point attributes, such as colors, etc.

No level of detail

No explicit means for decomposition

No metadata, such as scanner model, etc.

No way to extract localized subsets

Slow to parse and leading to exorbitant data sizes

Proposed structure

A **schema extension**

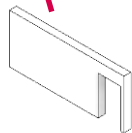
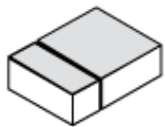
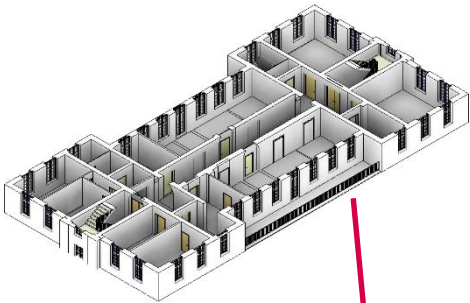
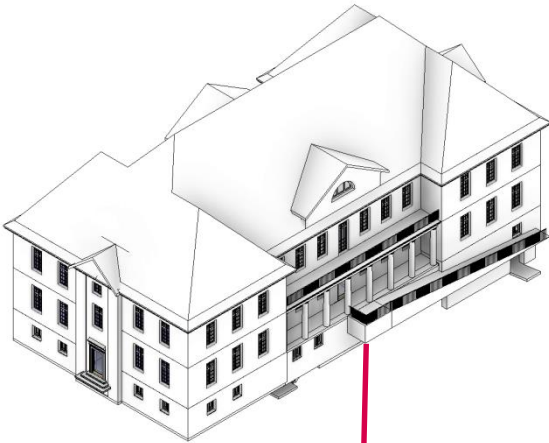
with **point cloud compression techniques**

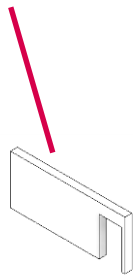
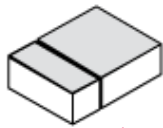
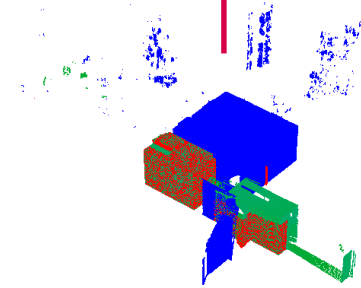
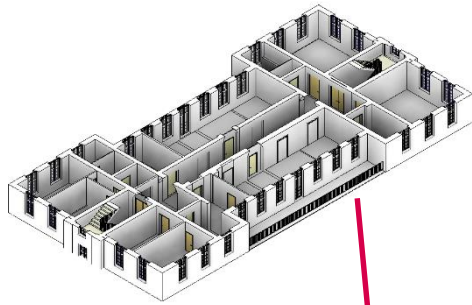
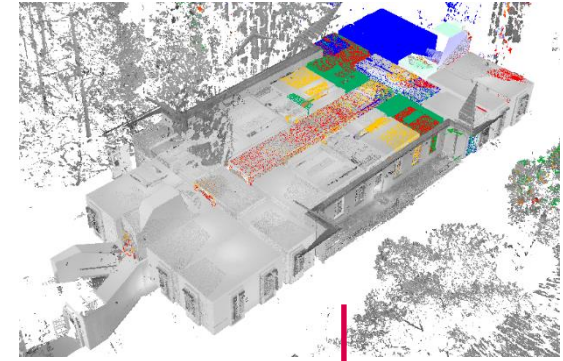
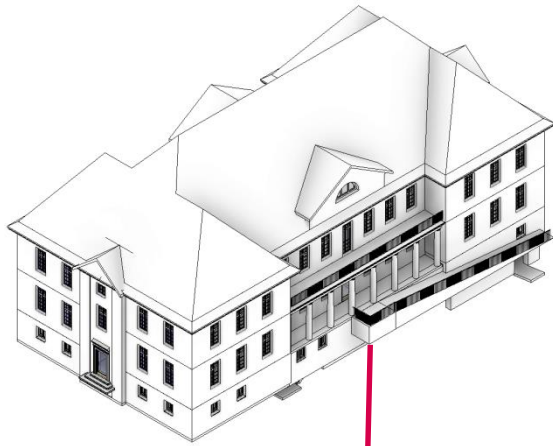
that deepens the **semantic relation** between points and building elements.

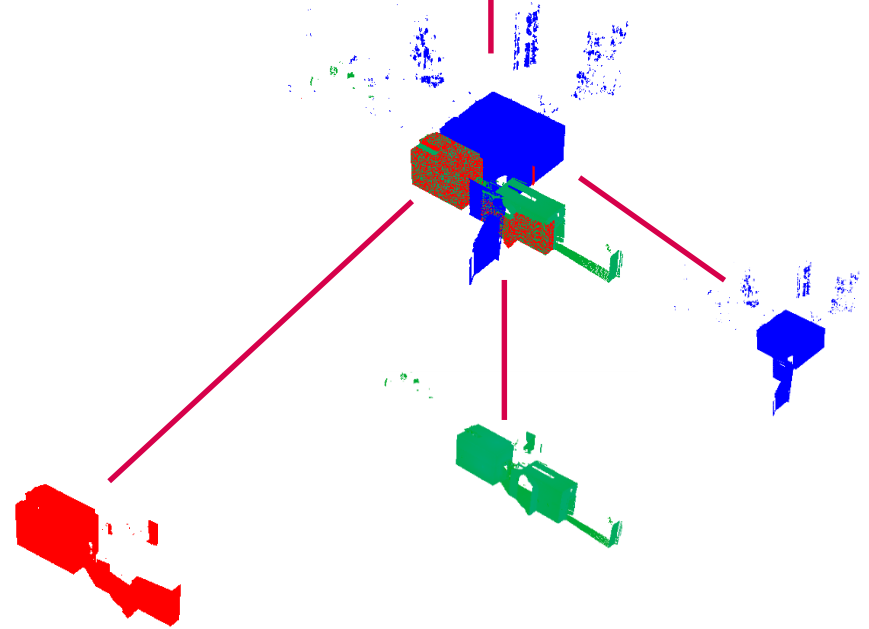
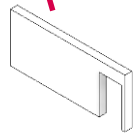
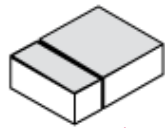
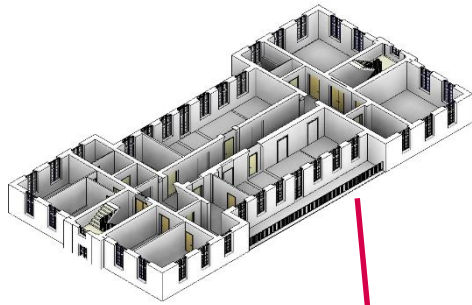
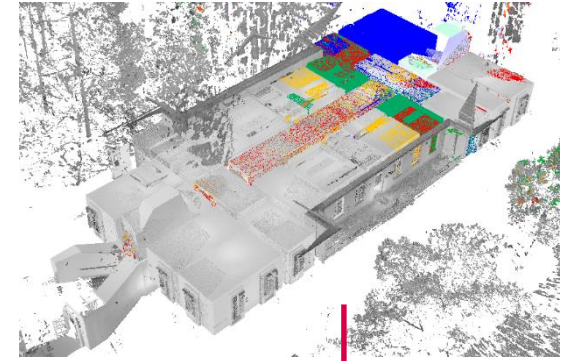
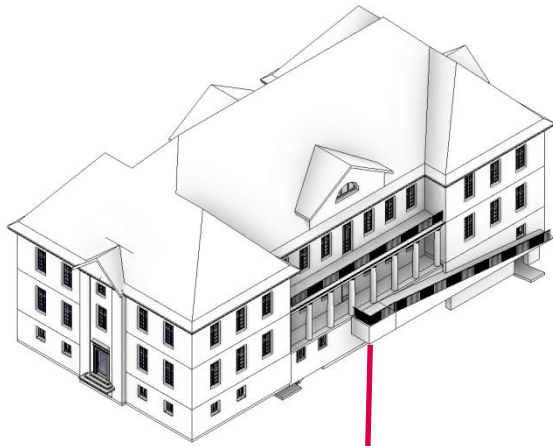
Proposed structure

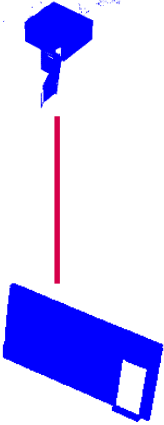
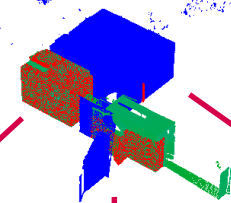
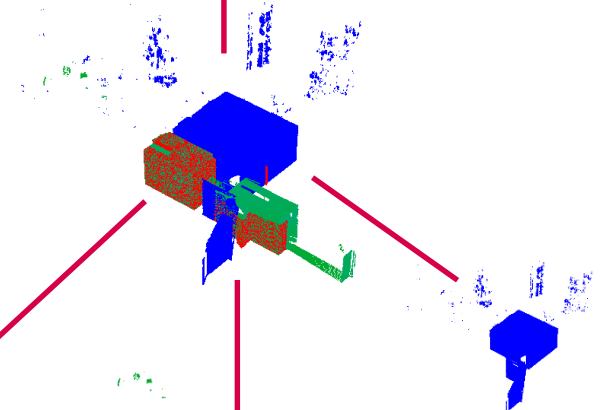
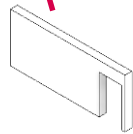
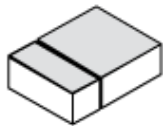
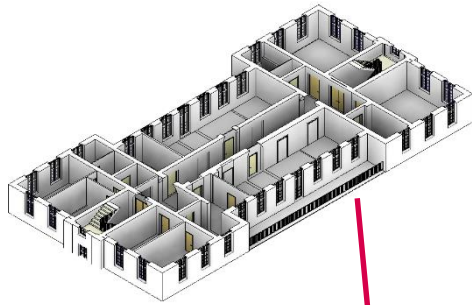
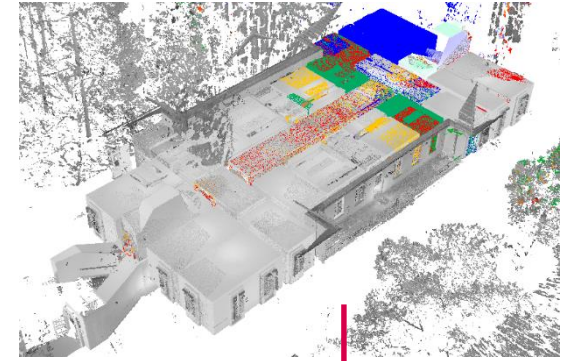
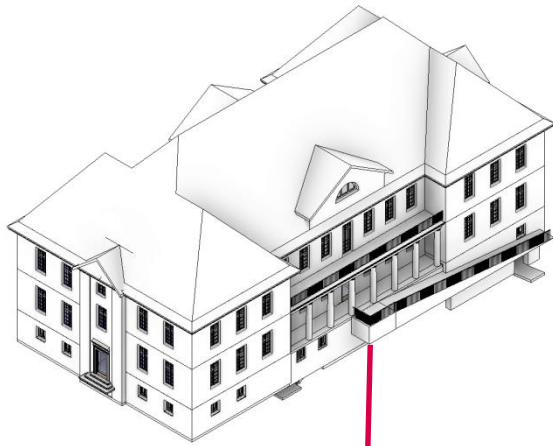
Three layers of compression:

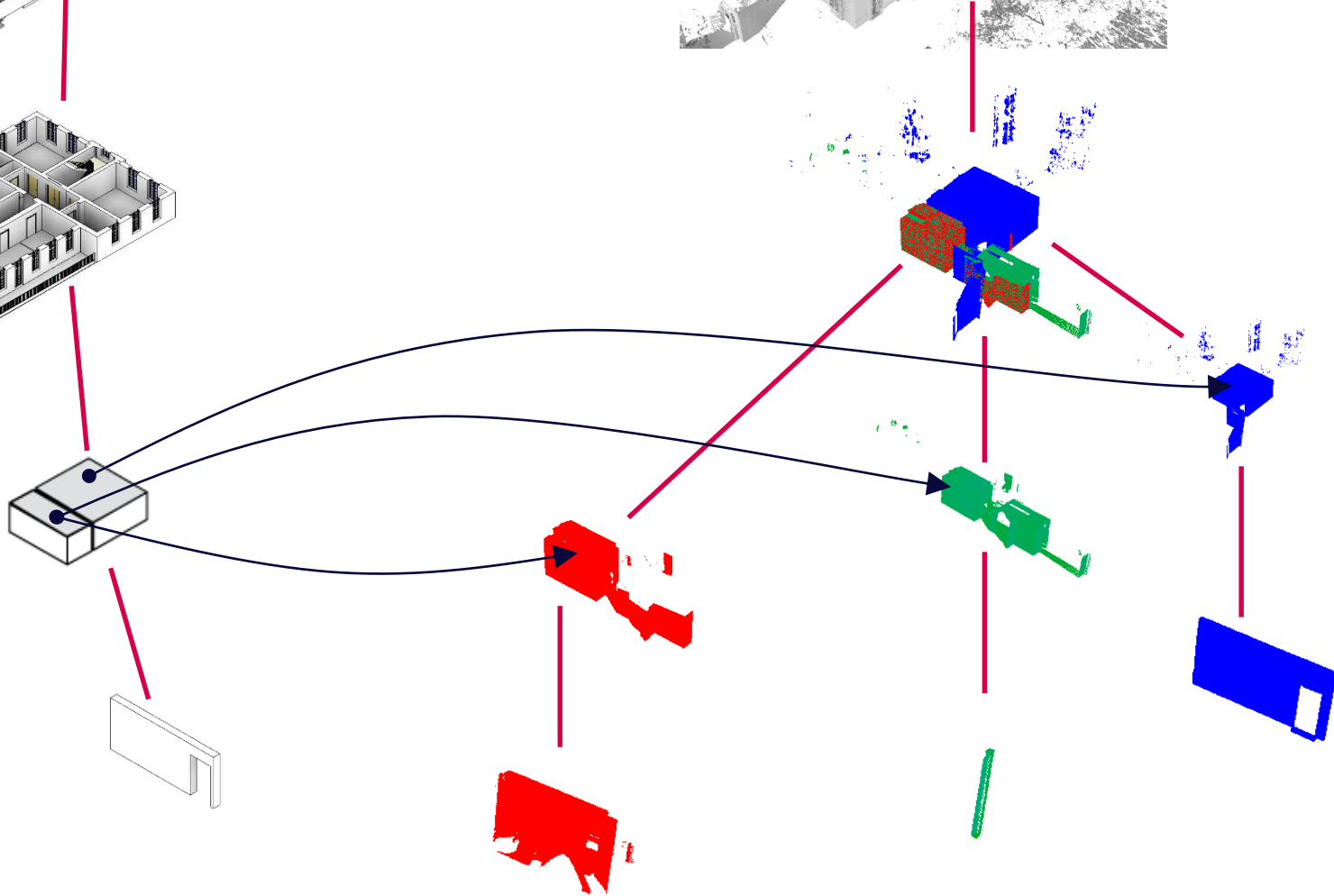
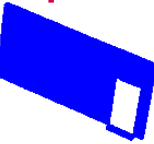
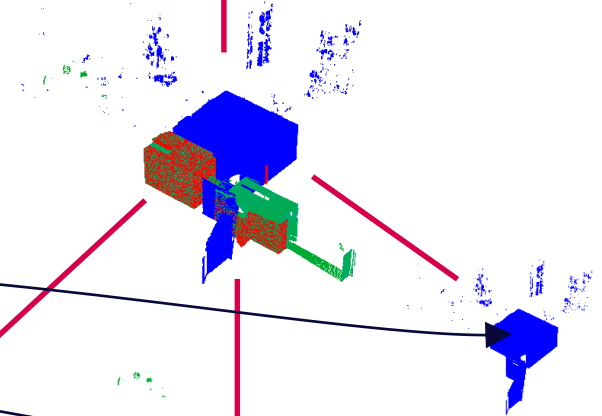
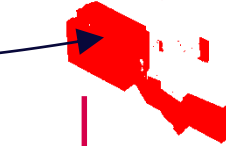
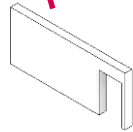
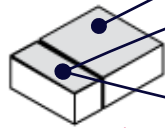
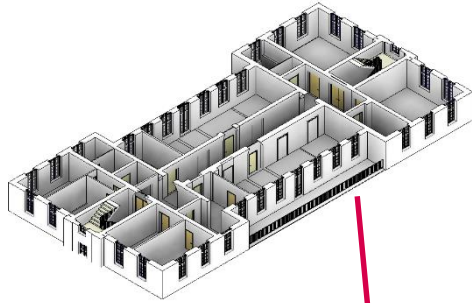
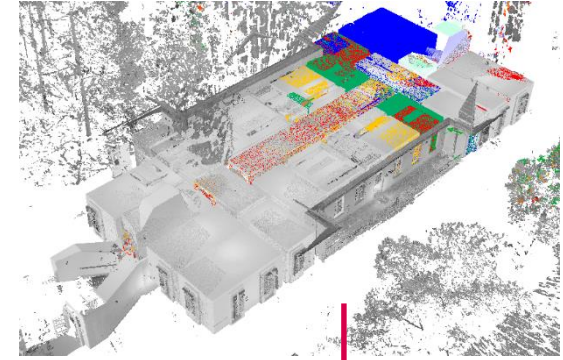
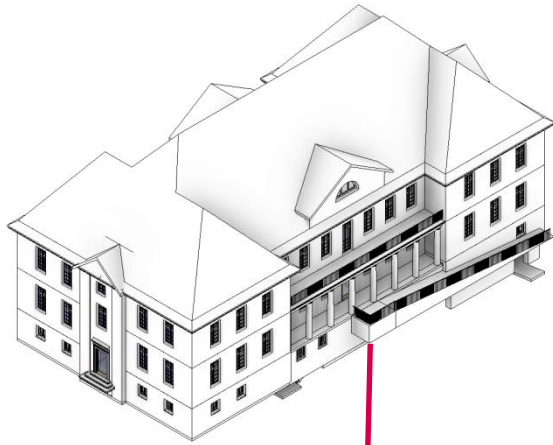
- Project points into **bounded parametric space**
- Reduce the dimensionality of points by **grid discretization**
- **Transparent compression** on a file format level (HDF5)

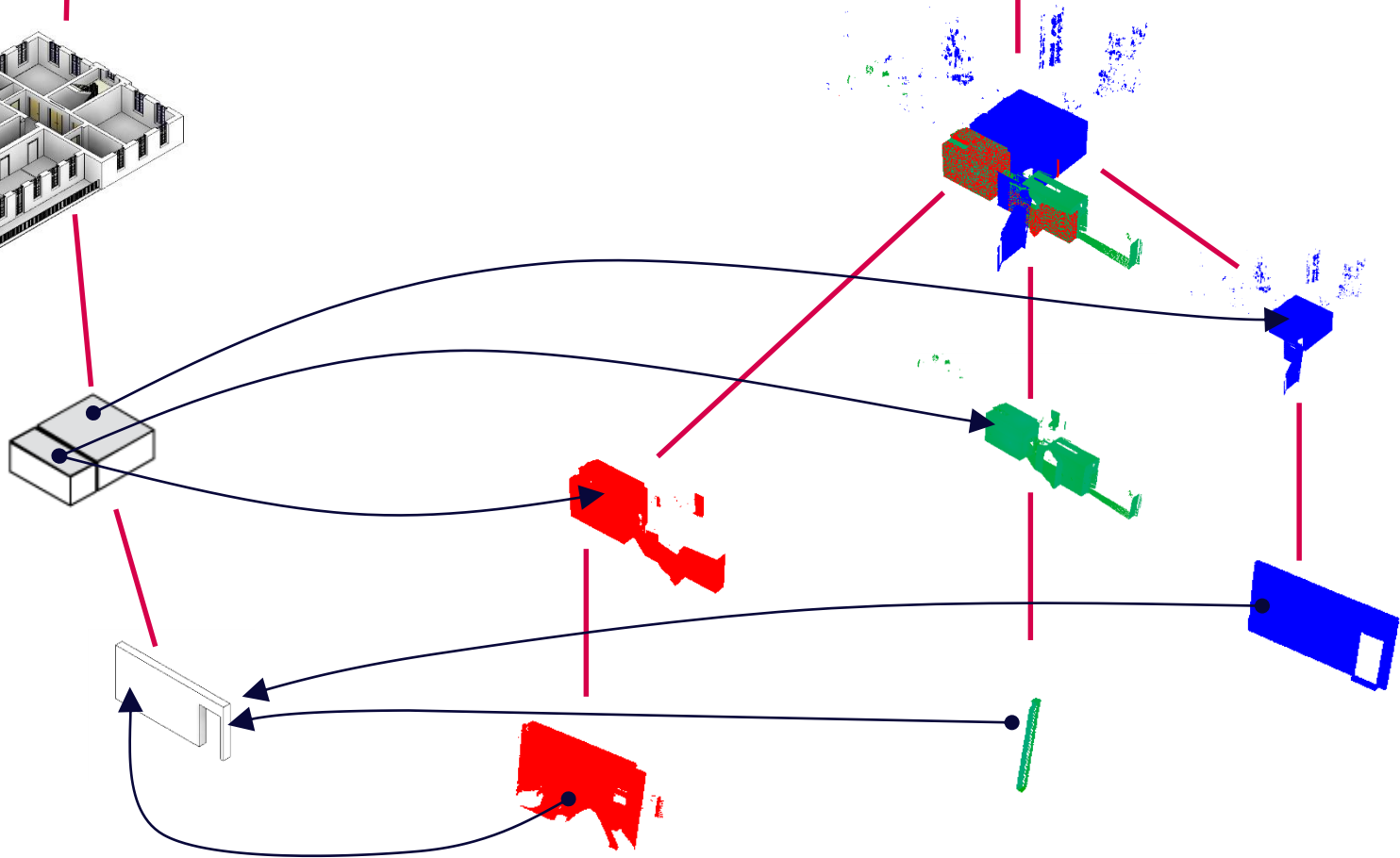
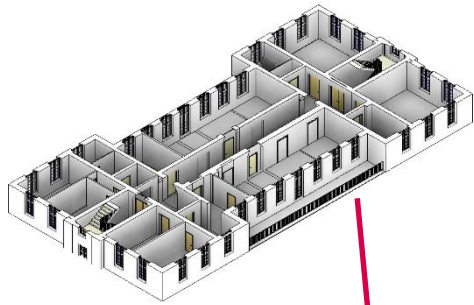
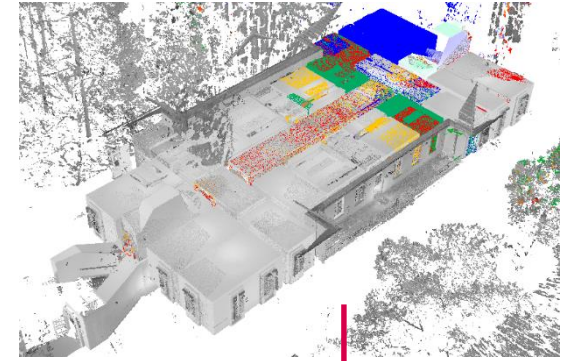
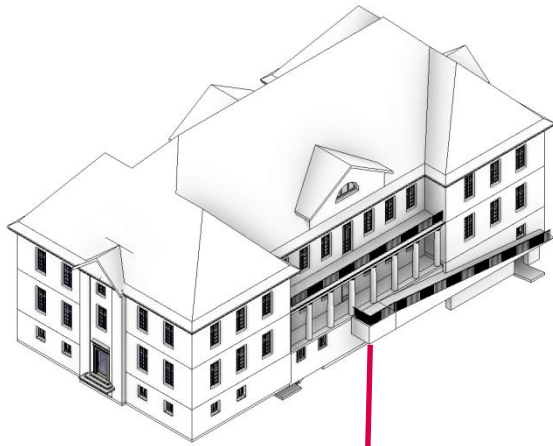






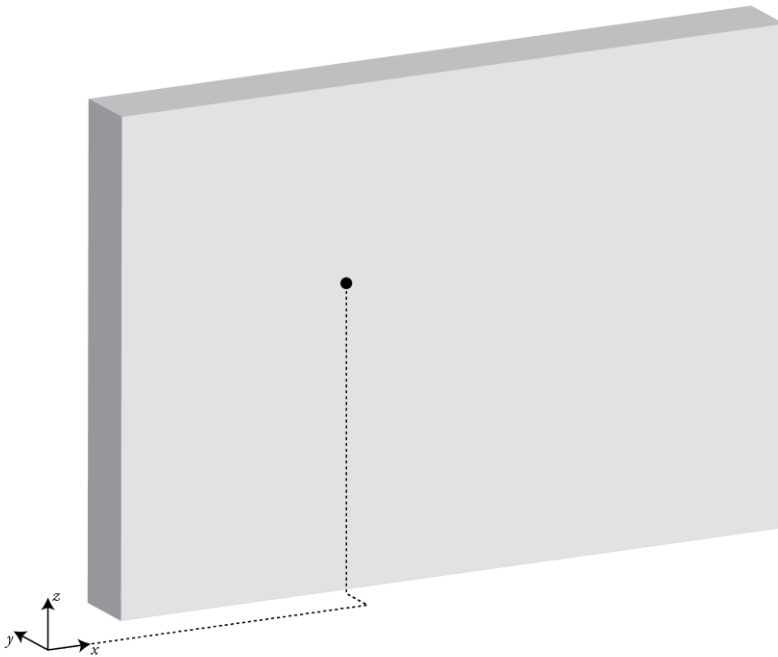






Proposed structure

Cartesian coordinates offer:

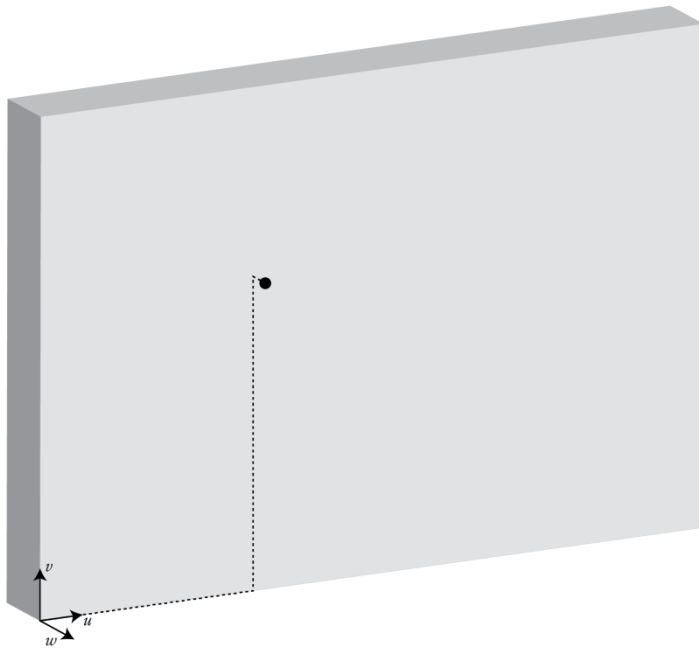


An **easy and intuitive** way to store point cloud data.

Intended for **geographic features** or **unassociated points** unrelated to building element.

Proposed structure

Parametrization

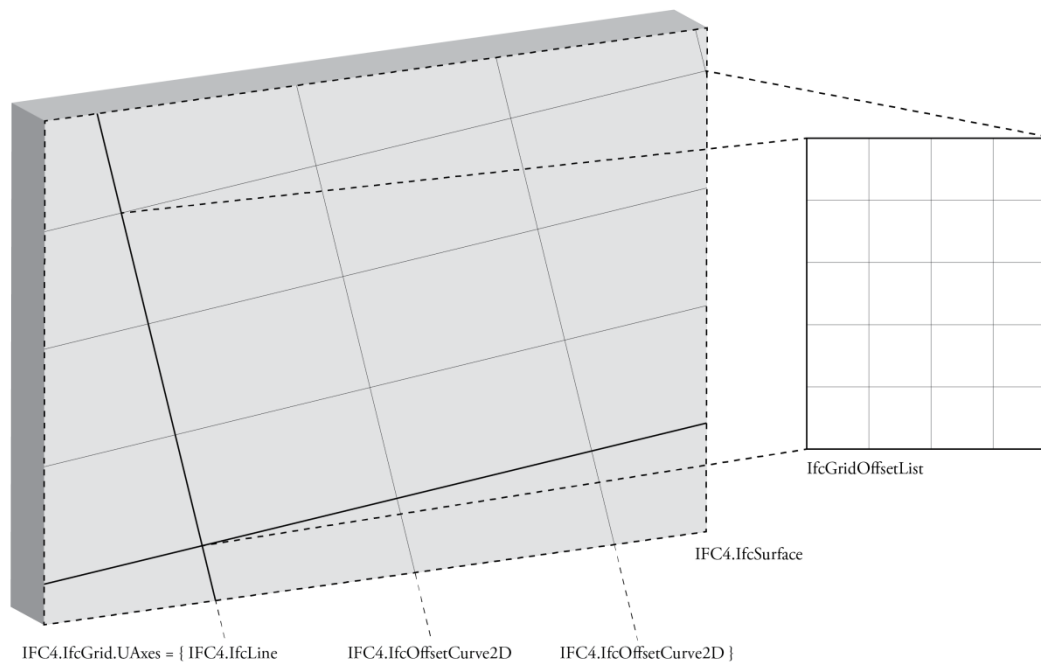


Associated points described in the **parametric** space of building surfaces.

Three components $\{u,v,w\}$ required, but the range of values is **bounded** and can be **more efficiently encoded**.

Proposed structure

Height fields



{u,v} components defined as the intersection of **grid** axes.

Per point only **one component** needs to be stored.

Proposed structure

Floating point discretization

(0.8482145585275755,0.4089384818729891,0.8027061702482456,0.11449717768247669)

Proposed structure

Floating point discretization

(0.8482145585275755, 0.4089384818729891, 0.8027061702482456, 0.11449717768247669)

≈	≈	≈	≈
(55587,	26799,	52605,	7503)
-----	-----	-----	-----
65535	65535	65535	65535

Proposed structure

Floating point discretization

(0.8482145585275755, 0.4089384818729891, 0.8027061702482456, 0.11449717768247669)

≈	≈	≈	≈
(55587,	26799,	52605,	7503)
-----	-----	-----	-----
65535	65535	65535	65535

((55587, 26799, 52605, 7503), 65535)

Proposed structure

Floating point discretization

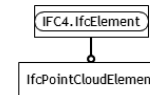
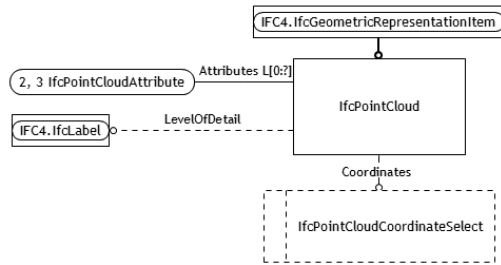
$(0.8482145585275755, 0.4089384818729891, 0.8027061702482456, 0.11449717768247669)$

\approx \approx \approx \approx

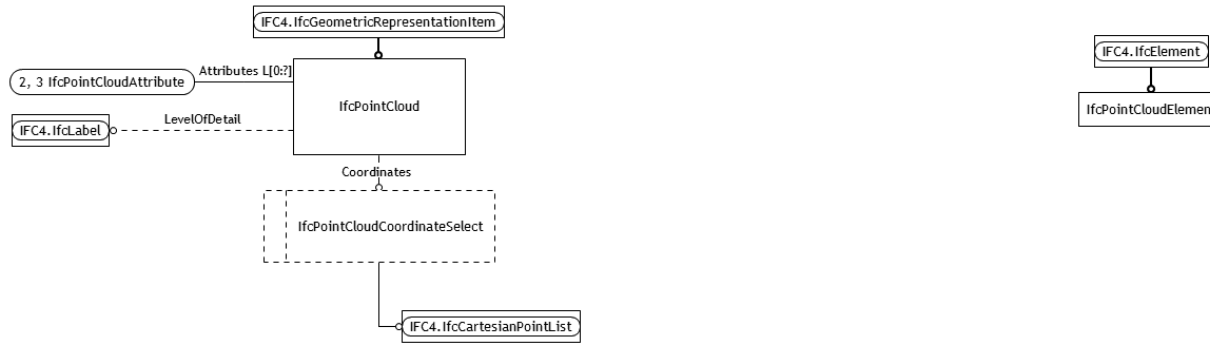
(55587,	26799,	52605,	7503)
-----	-----	-----	-----
65535	65535	65535	65535

$((55587, 26799, 52605, 7503), 65536)$

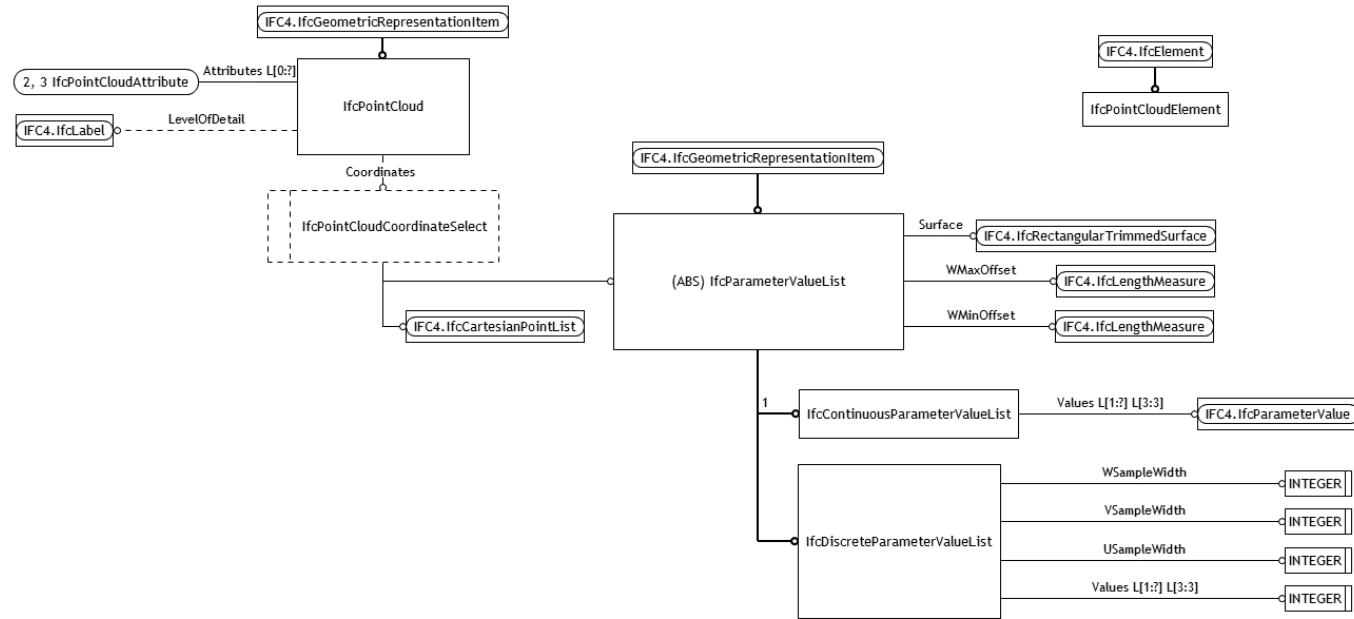
Proposed structure



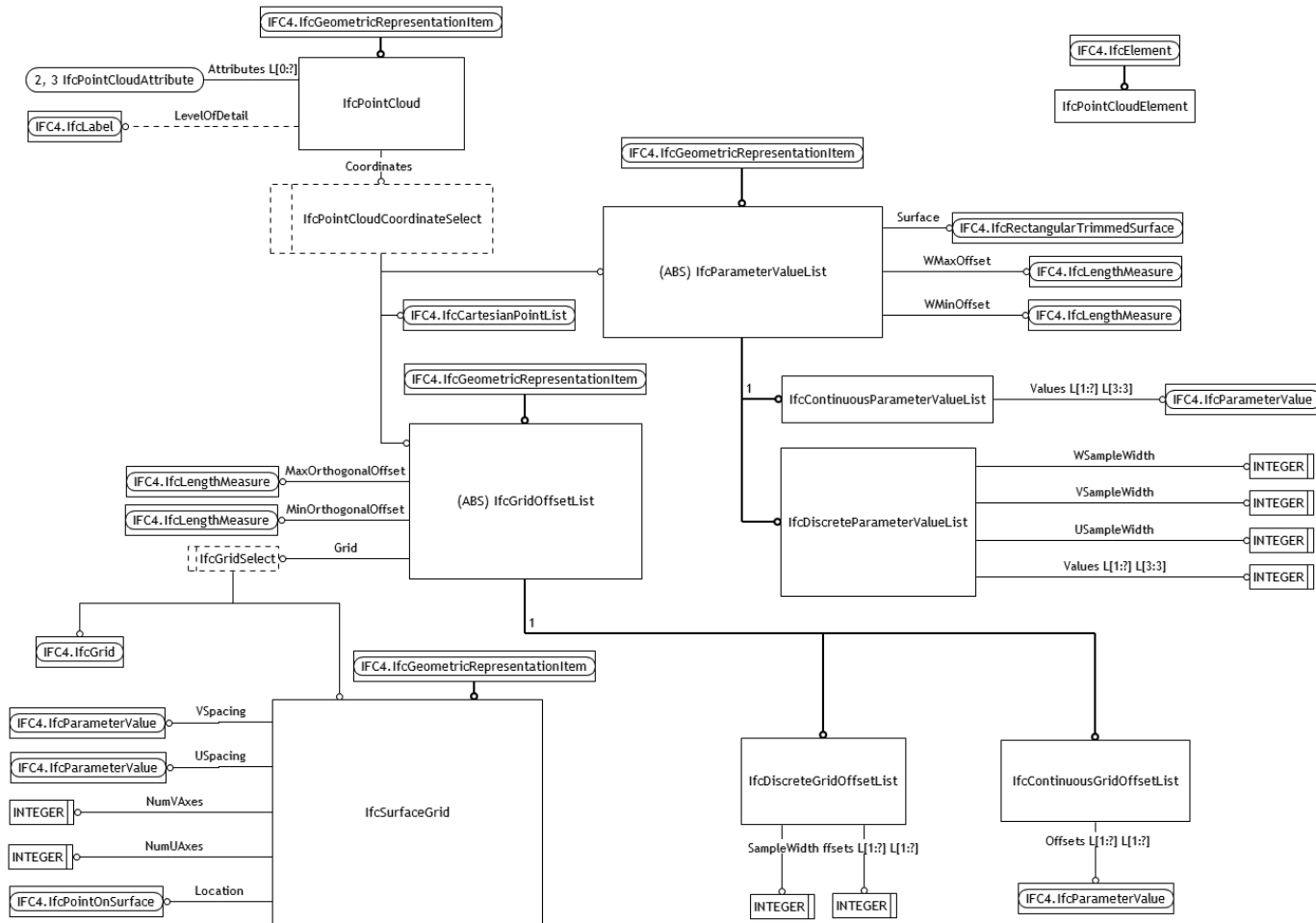
Proposed structure



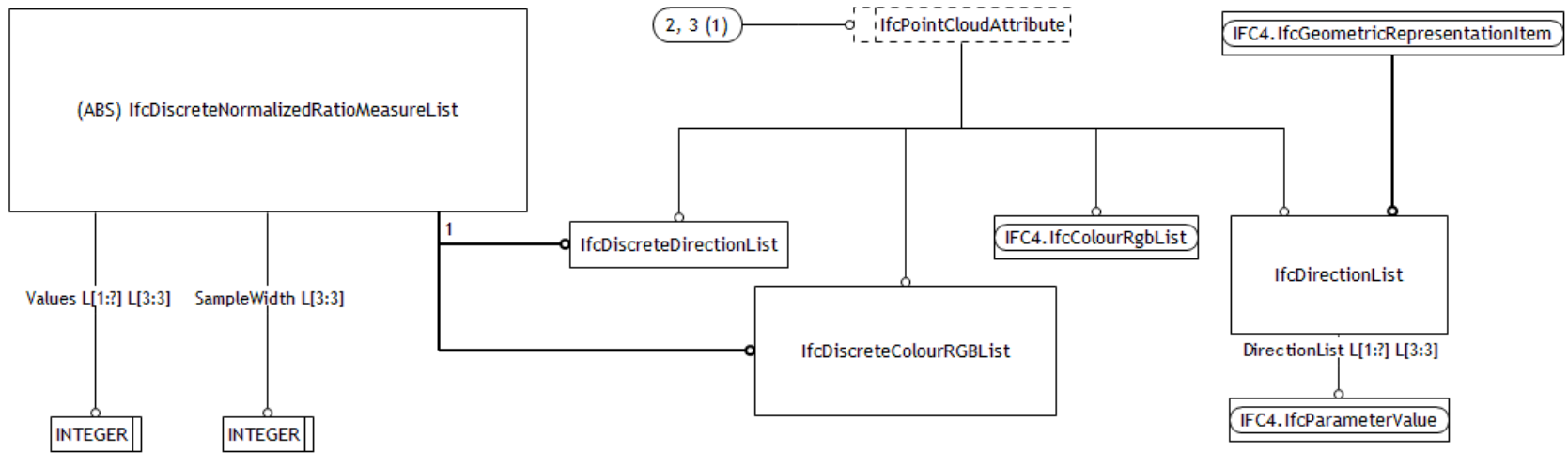
Proposed structure



Proposed structure



Proposed structure



Serialization in HDF5

HDF5 is a:

hierarchical, binary data format

for **heterogeneous** data

stored according to **self-documenting** data types
with **b-tree indexes** and **transparent compression**.

It is an **open standard** and an

EXPRESS-HDF5 mapping is standardized as **ISO 10303-26**.

Serialization in HDF5

Recent Files: J:\src\ifcpc\Plan3D_Haus30_PREVIEW_NEW_plus_pc.ifc.hdf

Plan3D_Haus30_PREVIEW_NEW_plus_pc.ifc.hdf

- Haus30_population
 - IfcAnnotation_objects
 - IfcApplication_objects
 - IfcArbitraryClosedProfileDef_objects
 - IfcArbitraryOpenProfileDef_objects
 - IfcArbitraryProfileDefWithVoids_objects
 - IfcAxis2Placement2D_objects
 - IfcAxis2Placement3D_objects
 - IfcBooleanClippingResult_objects
 - IfcBuildingElementProxy_objects
 - IfcBuildingStorey_objects
 - IfcBuildingStorey_instances
 - IfcBuilding_objects
 - IfcCartesianPointList3D_objects
 - Aggr_CoordList_640482
 - Aggr_CoordList_642342
 - IfcCartesianPointList3D_instances
 - IfcCartesianPoint_objects
 - IfcCartesianTransformationOperator3D_objects
 - IfcCircleProfileDef_objects
 - IfcCircle_objects
 - IfcClassification_objects
 - IfcClosedShell_objects
 - IfcColourRgb_objects
 - IfcColumnType_objects
 - IfcColumn_objects
 - IfcCompositeCurveSegment_objects
 - IfcCompositeCurve_objects
 - IfcConnectionSurfaceGeometry_objects
 - IfcConversionBasedUnit_objects
 - IfcCurveBoundedPlane_objects
 - IfcCurveStyleFontPattern_objects
 - IfcCurveStyleFont_objects
 - IfcCurveStyle_objects
 - IfcDerivedUnitElement_objects
 - IfcDerivedUnit_objects
 - IfcDimensionalExponents_objects
 - IfcDirection_objects

Table: Aggr_CoordList_640482 at /Haus30_population/ifcCartesianPointList3D_obj

	0	1	2
0	-1.62...	14.30...	7.215...
1	-1.68...	14.35...	7.200...
2	-1.58...	14.36...	7.193...
3	-1.51...	14.33...	7.212...
4	-1.44...	14.31...	7.214...
5	-1.57...	14.47...	3.875...
6	-1.51...	14.40...	7.169...
7	-1.34...	14.29...	7.213...
8	-1.47...	14.47...	3.879...
9	-1.36...	14.34...	7.205...
10	-1.61...	14.51...	7.104...
11	-1.65...	14.56...	7.079...
12	-1.61...	14.53...	7.096...
13	-1.30...	14.32...	7.211...

Table: IfcBuildingStorey_instances at /Haus30_population/ifcBuildingStorey_objects/ [Plan3D_Haus30_PREVIEW_NEW...]

set_u...	Entity...	GlobalId	Owne...	Owne...	Name	Desc...	Obj...	Obj...	Obj...
0	935	115	1c3TSFyqj1\$htdMPxSukBs	63	0	Ebene -1		51	1
1	935	121	1c3TSFyqj1\$htdMPxSvmhC	63	0	Eingang		51	2
2	935	127	1c3TSFyqj1\$htdMPxSuk4R	63	0	Ebene 0		51	3
3	935	133	1c3TSFyqj1\$htdMPxSuk9R	63	0	Ebene 1		51	4
4	935	139	1c3TSFyqj1\$htdMPxSuk5R	63	0	Ebene 0		51	5

Aggr_CoordList_640482 (4623476, 2)
 64-bit floating-point, 187552 x 3
 Number of attributes = 0

Log Info | Metadata

Serialization in HDF5

The screenshot displays the HDFView 3.13.1 interface. The left pane shows a hierarchical tree of objects under the file 'Plan3D_Haus30_PREVIEW_NEW_plus_pc.ifc.hdf'. The right pane shows a table of data for the selected object 'IfcBuildingStorey_instances at /Haus30_population'. A magnifying glass highlights a portion of this table.

Table: IfcBuildingStorey_instances at /Haus30_population

	set_u...	Entity...	GlobalId
0	935	115	1c3Tsfyqj1\$htdMPxSukBs
1	935	121	1c3Tsfyqj1\$htdMPxSvmhC
2	935	127	1c3Tsfyqj1\$htdMPxSuk4R
3	935	133	1c3Tsfyqj1\$htdMPxSuk9R
4	935	139	1c3Tsfyqj1\$htdMPxSuk9R

Additional table data visible in the background:

0.0	16013553691506	14.31...	1	2	
	-1.38014954840123	14.50...	7.10	7.215...	
29	-1.11986037054718	14.29...	7.212...		
30	-1.49387919616222	14.60...	7.054...		
31	-1.20835817205191	14.37	7.183		

Serialization in HDF5

HDF5View 3.33

File Window Tools Help

Recent Files J:\src\ifcpc\Plan3D_Haus30_PREVIEW_NEW_plus_pc.ifc.hdf

Plan3D_Haus30_PREVIEW_NEW_plus_pc.ifc.hdf

Haus30_population

- IfcAnnotation_objects
- IfcApplication_objects
- IfcArbitraryProfileDef_objects
- IfcArbitraryProfileWithBounds_objects
- IfcBuildingElementProxy_objects
- IfcBuildingStorey_objects
- IfcBuildingStorey_instance_objects
- IfcBuilding_objects
- IfcCartesianPointList3D_objects
- Aggr_CoordList_640482**
- Aggr_CoordList_642342**
- IfcCartesianPointList3D_instance_objects
- IfcCartesianPoint_objects
- IfcCartesianTransformationOperator3D_objects
- IfcCircleProfileDef_objects
- IfcCircle_objects
- IfcClassification_objects
- IfcColor_objects
- IfcCompoundPlaneProfileDef_objects
- IfcConnection_objects
- IfcConversionBasedProfileDef_objects
- IfcCurveBoundedPlane_objects
- IfcCurveStyleFontPattern_objects
- IfcCurveStyleFont_objects
- IfcCurveStyle_objects
- IfcDerivedUnitElement_objects
- IfcDerivedUnit_objects
- IfcDimensionalExponents_objects
- IfcDirection_objects

IfcCartesianPointList3D_instances at /Haus30_population/IfcCartesianPointList3D_instances

	0	1	2
16	-1.39010970630123	14.57...	7.069...
19	-1.64800431001544	14.62...	7.041...
20	-1.34185869274497	14.46...	3.887...
21	-1.59475541096985	14.61...	7.051...
22	-1.21008224394679	14.32...	7.211...
23	-1.64368387691438	14.66...	7.017...
24	-1.26442228970349	14.38...	7.178...
25	-1.69073089292526	14.76...	4.594...
26	-1.28278520133436	14.40...	7.167...
27	-1.16013553691506	14.31...	7.211...
28	-1.38014954840123	14.50...	7.107...
29	-1.11986037054718	14.29...	7.212...
30	-1.49387919616222	14.60...	7.054...
31	-1.20835817205191	14.37...	7.183...

Aggr_CoordList_640482 at /Haus30_population/IfcCartesianPointList3D_objects

	0	1	2
0	-1.62...	14.30...	7.215...
1	-1.68...	14.35...	7.200...
2	-1.58...	14.36...	7.193...
3	-1.51...	14.33...	7.212...
4	-1.44...	14.31...	7.214...
5	-1.57...	14.47...	3.875...
6	-1.51...	14.40...	7.169...
7	-1.34...	14.29...	7.213...
8	-1.47...	14.47...	3.879...
9	-1.36...	14.34...	7.205...
10	-1.61...	14.51...	7.104...
11	-1.65...	14.56...	7.079...
12	-1.61...	14.53...	7.096...
13	-1.30...	14.32...	7.214...

IfcBuildingStorey_instances at /Haus30_population/IfcBuildingStorey_instances

	set_u...	Entity...	GlobalId	Owne...	Owne...	Name	Desc...	Objec...	Objec...	Obj
0	935	115	1c3TSTFyqj1\$htdMPxSUKBs	63	0	Ebene -1			51	1
1	935	121	1c3TSTFyqj1\$htdMPxSVmhC	63	0	Eingang			51	2
2	935	127	1c3TSTFyqj1\$htdMPxSUK4R	63	0	Ebene 0			51	3
3	935	133	1c3TSTFyqj1\$htdMPxSUK9R	63	0	Ebene 1			51	4
4	935	139	1c3TSTFyqj1\$htdMPxSUK4R	63	0	Ebene 0			51	5

Aggr_CoordList_640482 (4623476, 2)
64-bit floating-point, 187552 x 3
Number of attributes = 0

Log Info Metadata

Implementation

A **prototypical implementation** is provided using only **open source components**, such as:

IfcOpenShell,

h5py,

Point Cloud Library (PCL),

e57lib,

NumPy,

Scipy and

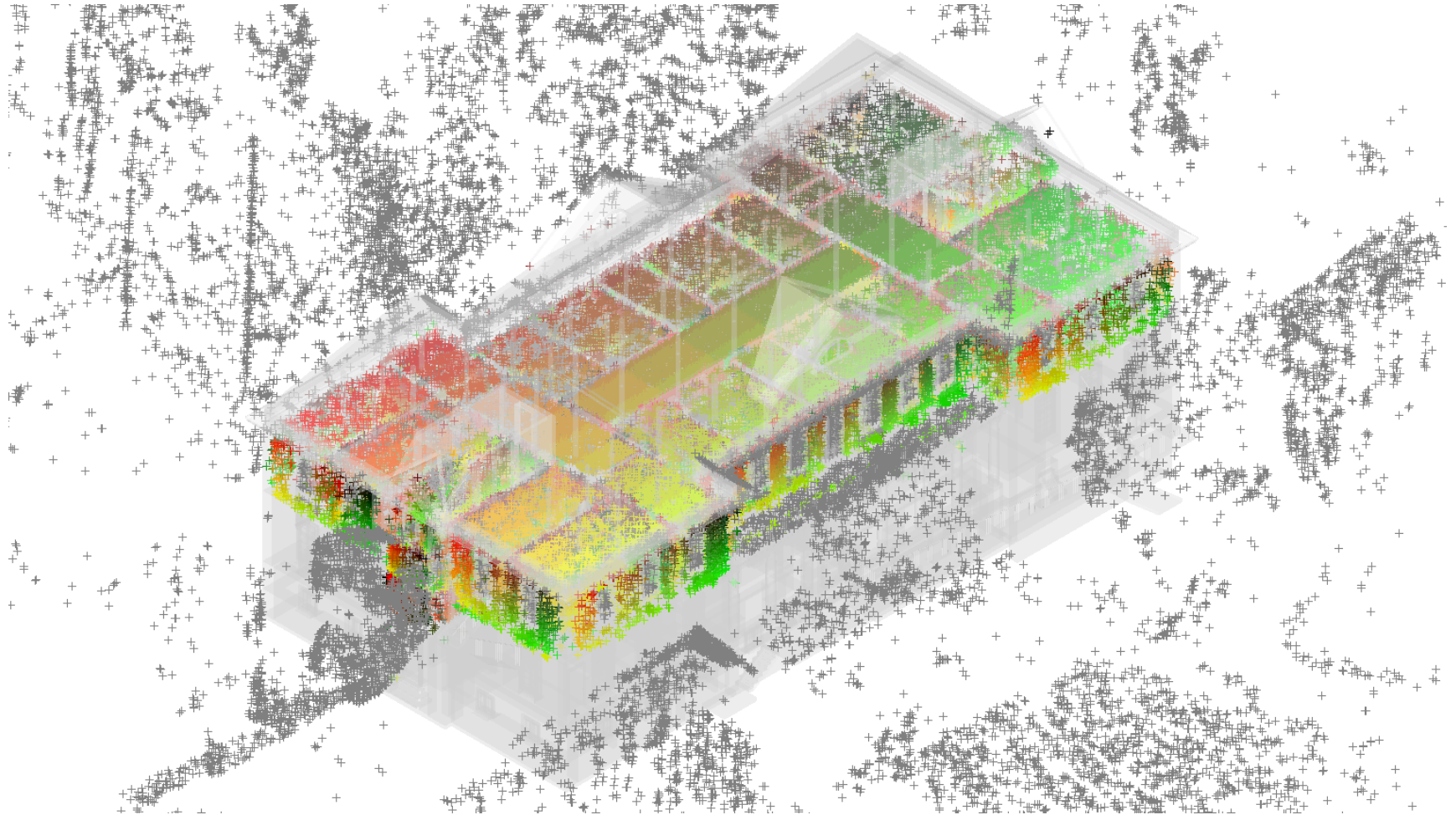
OpenCascade

Results

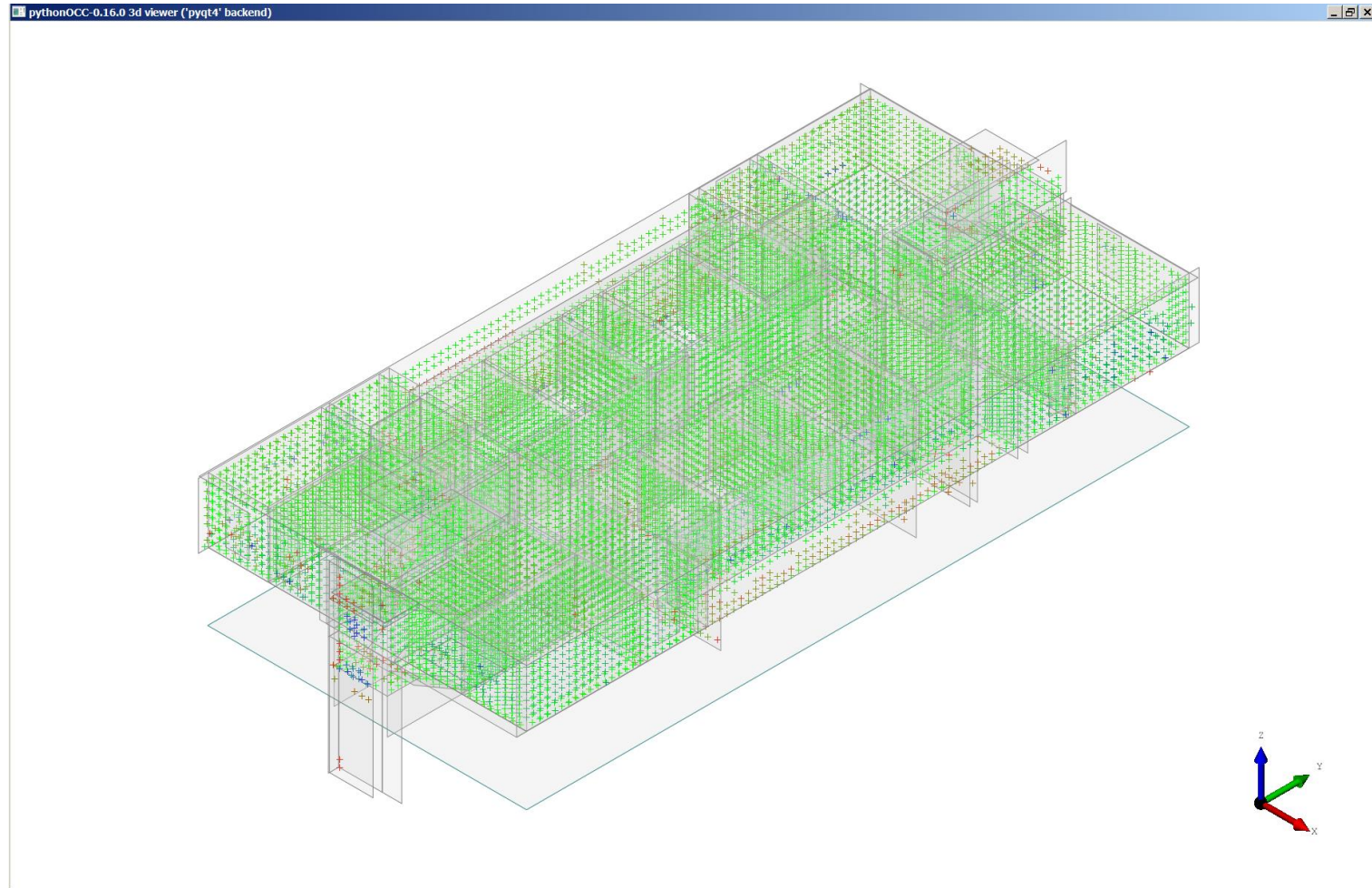
The dataset for this experiment consists of a professionally modelled **IFC file** and subsampled point cloud scan of roughly **15 million points**.



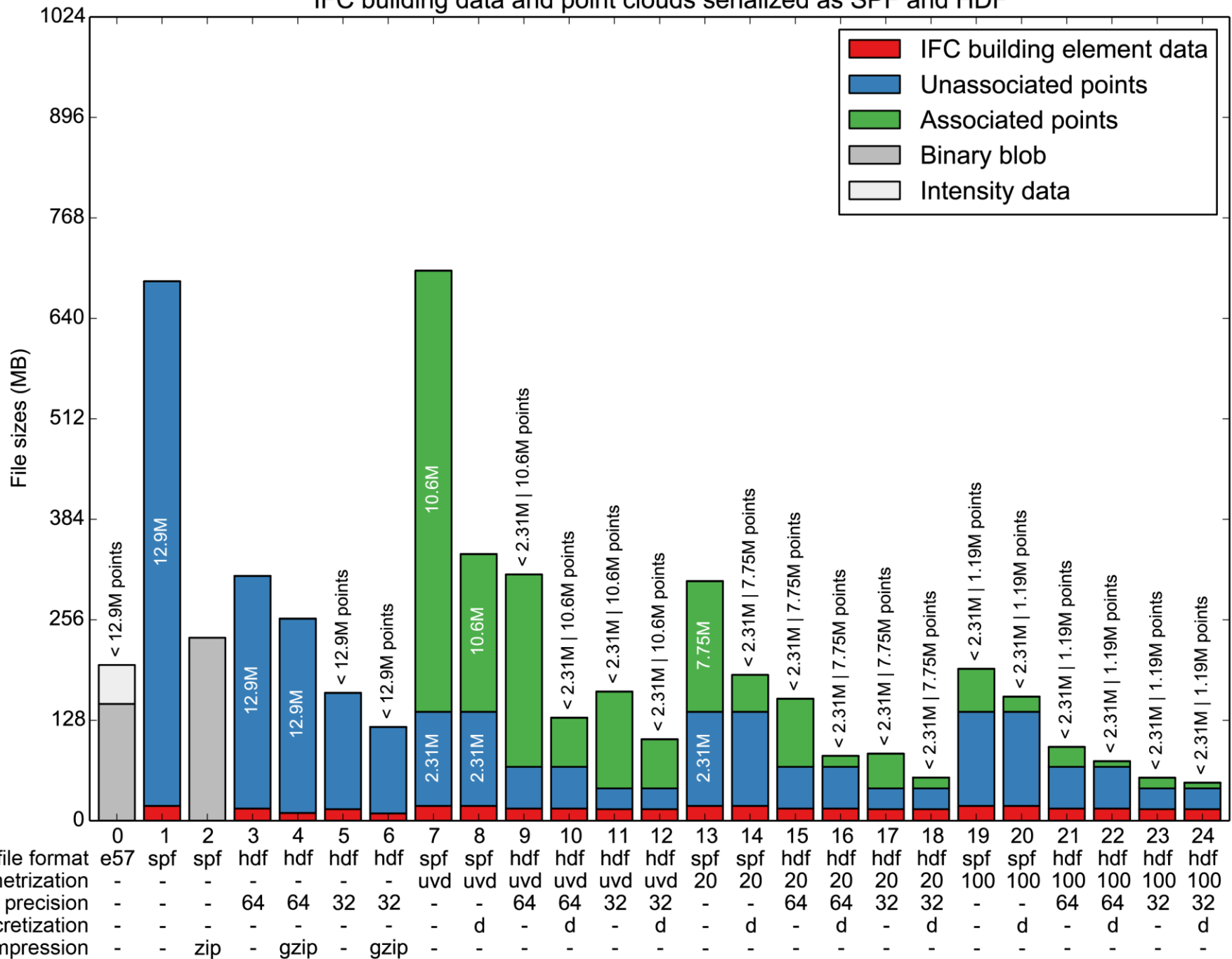
Results



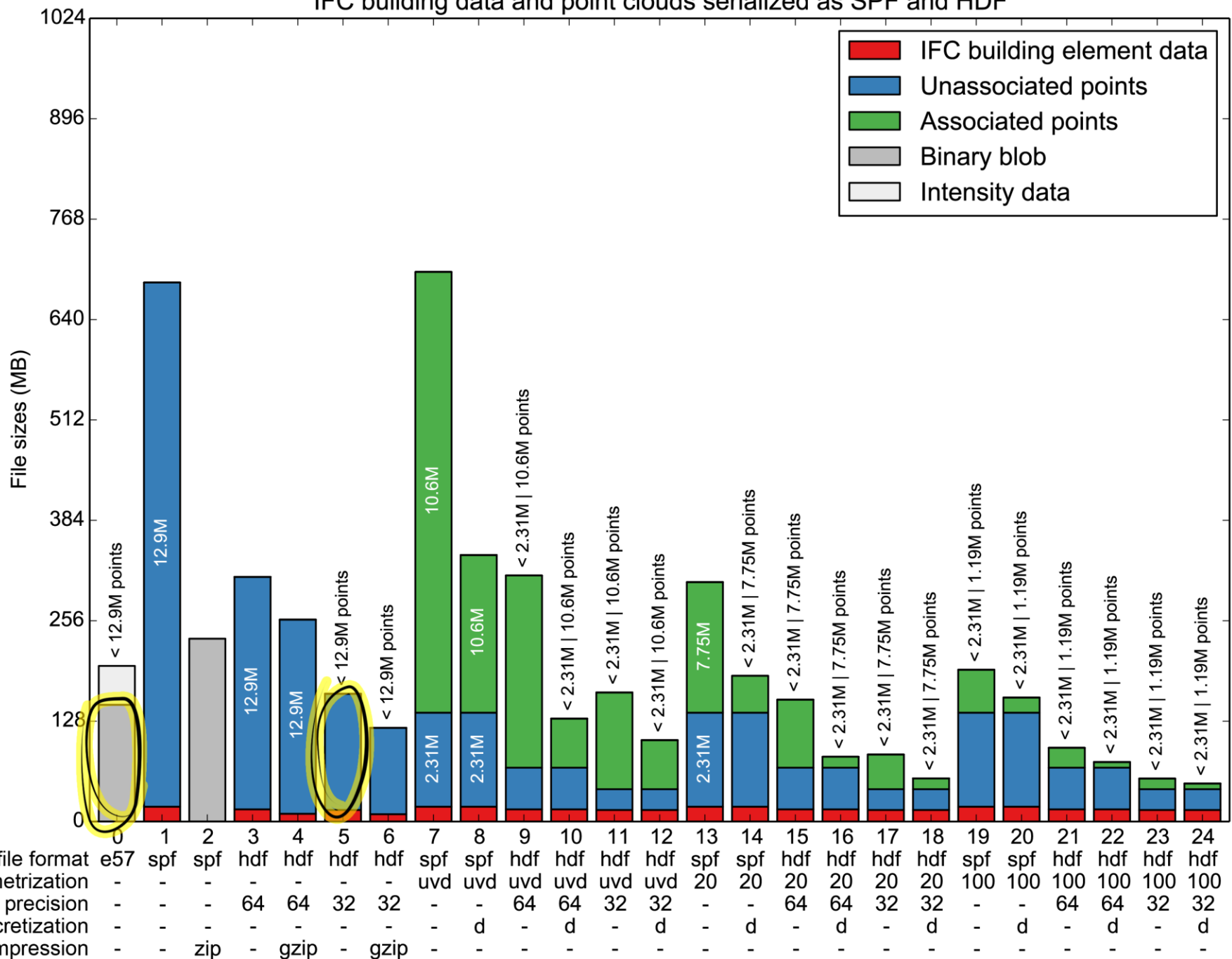
Results



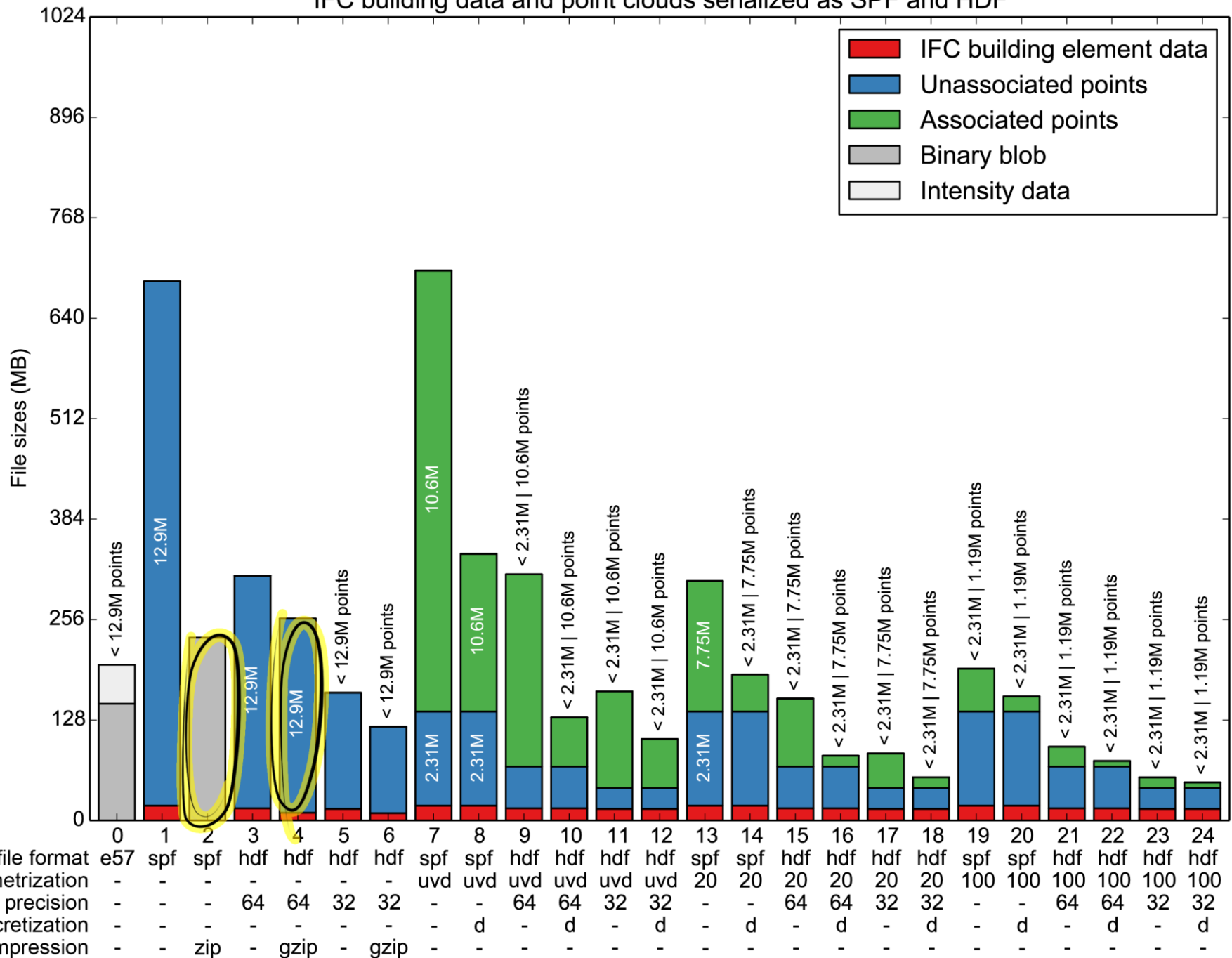
IFC building data and point clouds serialized as SPF and HDF



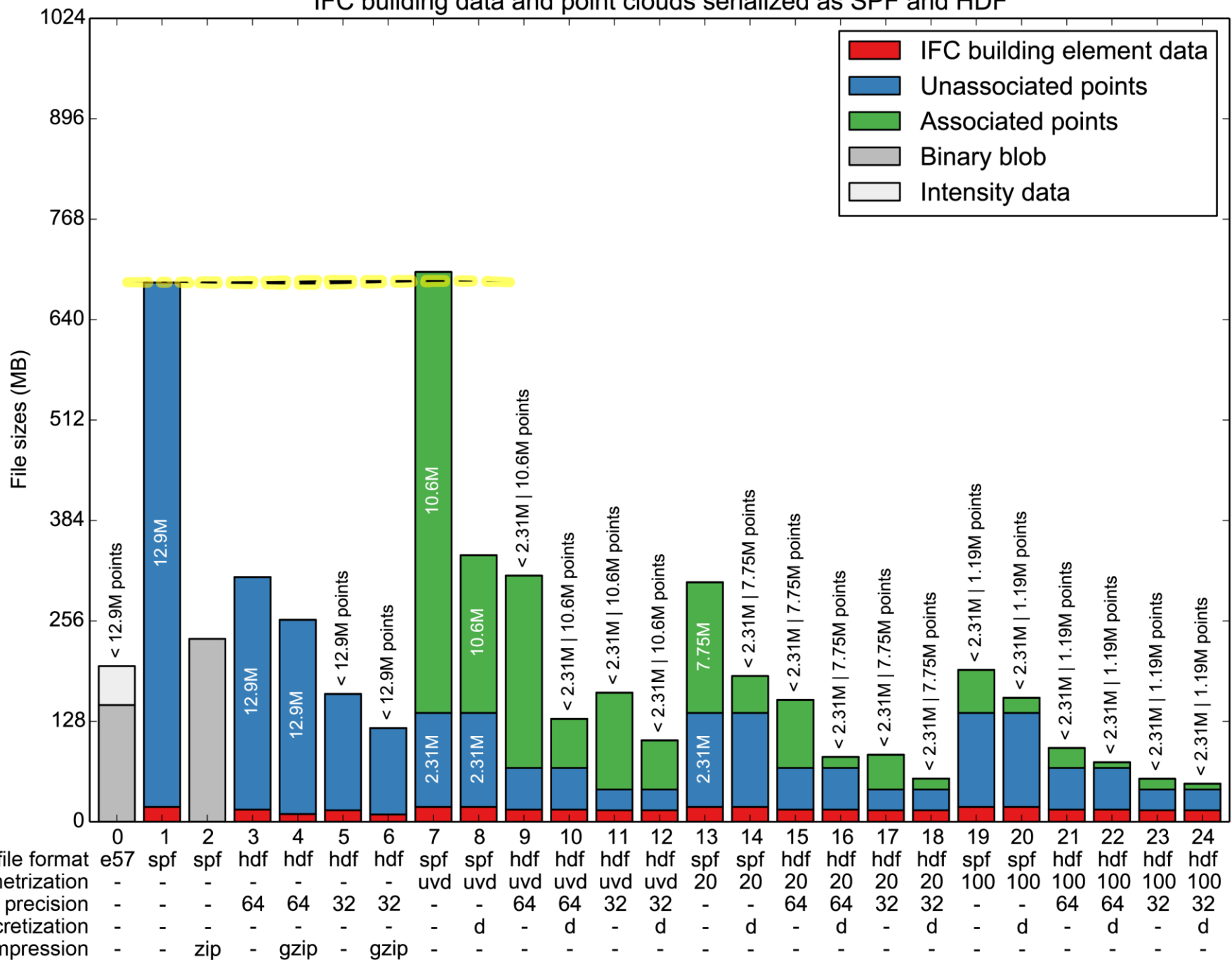
IFC building data and point clouds serialized as SPF and HDF



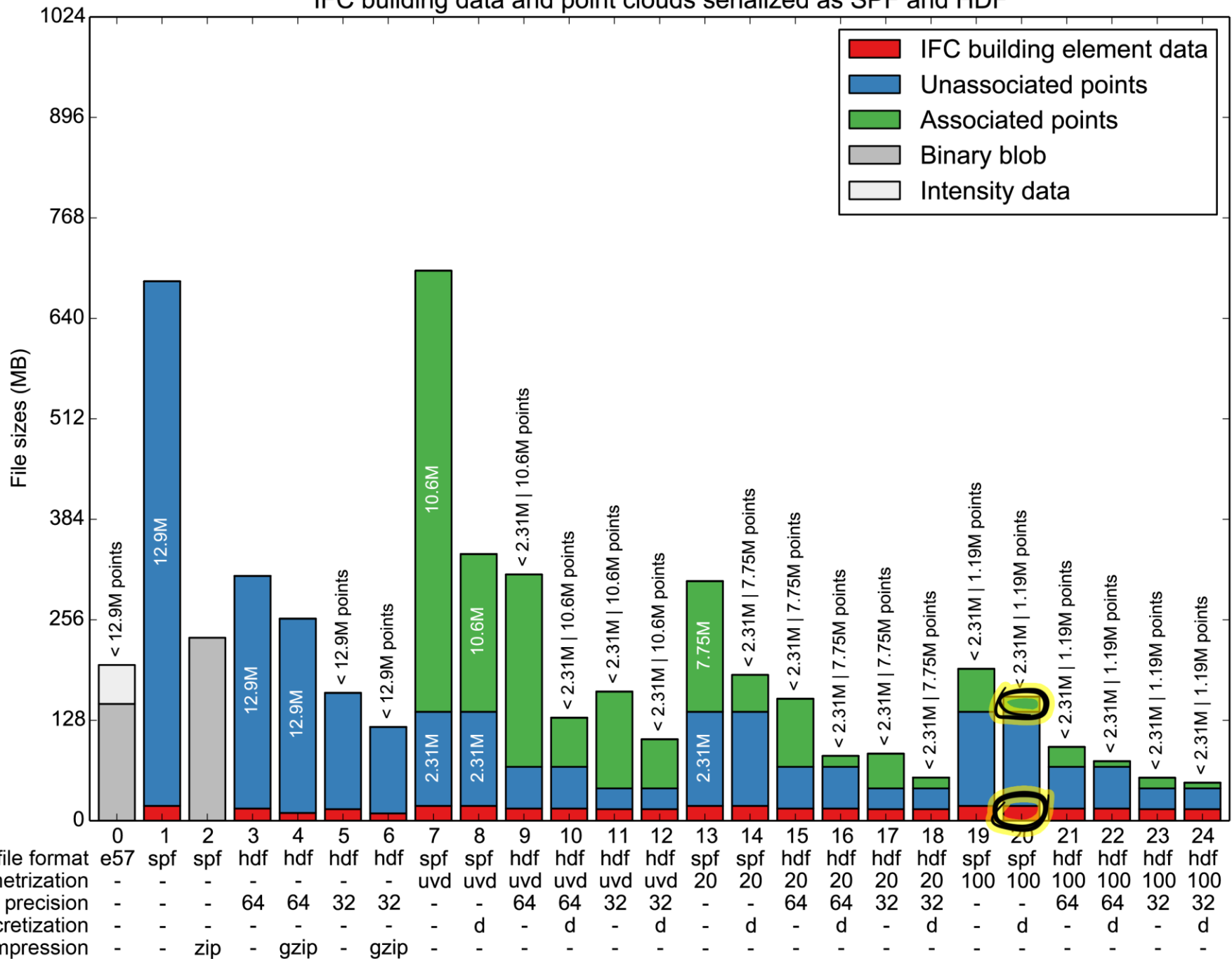
IFC building data and point clouds serialized as SPF and HDF



IFC building data and point clouds serialized as SPF and HDF



IFC building data and point clouds serialized as SPF and HDF



IFC and point clouds anno 2014

Points for improvement:

No per-point attributes, such as colors, etc.

No level of detail

No explicit means for decomposition

No metadata, such as scanner model, etc.

No way to extract localized subsets

Slow to parse and leading to exorbitant data sizes

IFC and point clouds anno 2015

Points of improvement:

~~No per-point attributes, such as colors, etc.~~

~~No level of detail~~

~~No explicit means for decomposition~~

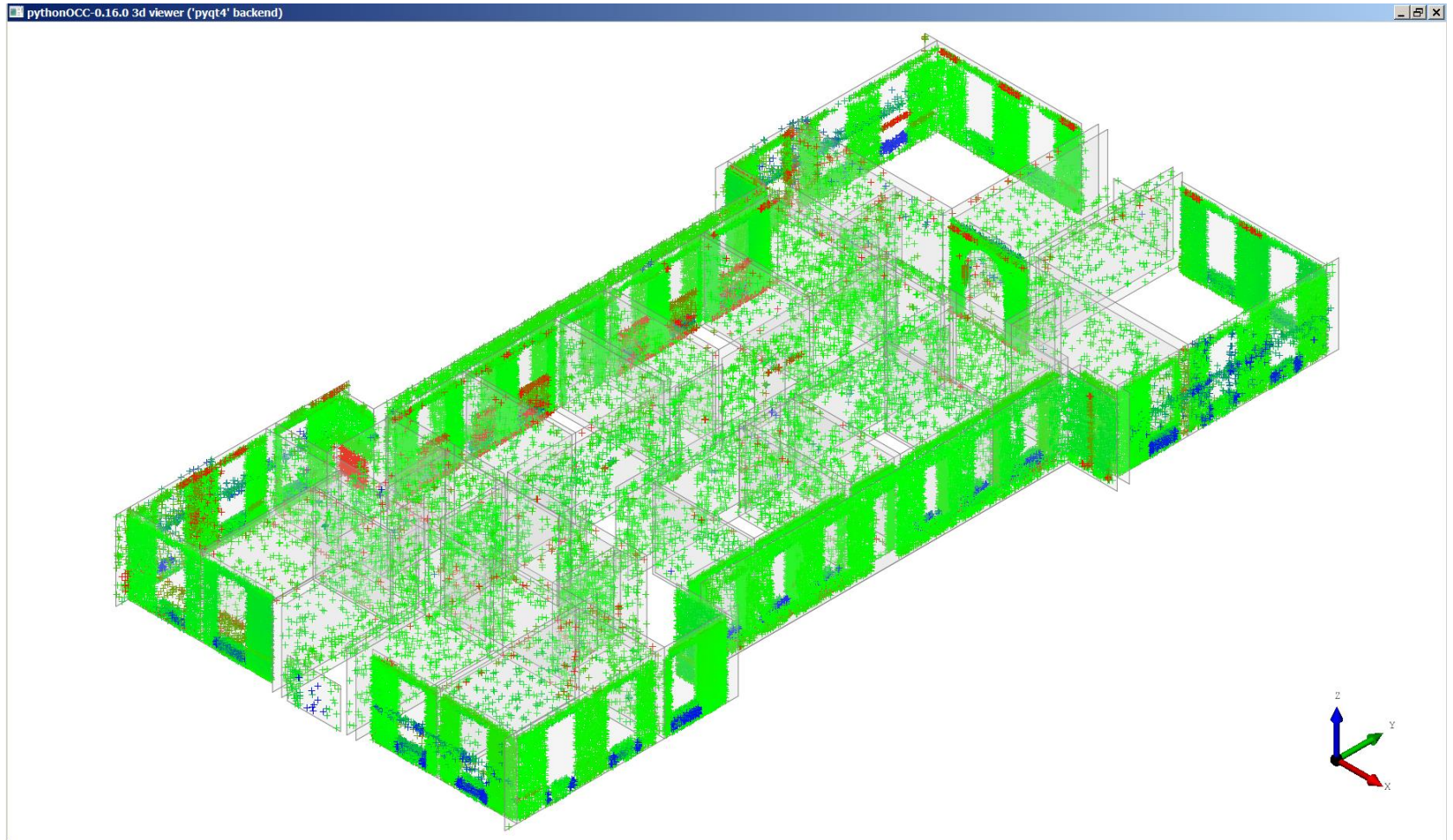
~~No metadata, such as scanner model, etc.~~

~~No way to extract localized subsets~~

~~Slow to parse and leading to exorbitant data sizes~~

Efficient to parse and file sizes under industry standard point cloud formats.

IFC and point clouds anno 2015



IFC and point clouds anno 2015

<https://github.com/DesignSystemsEindhoven/IFCPointCloud>

Extending IFC with point cloud data

eg-ice 2015

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Where innovation starts