Thermal analysis of IFC building models using voxelized geometries

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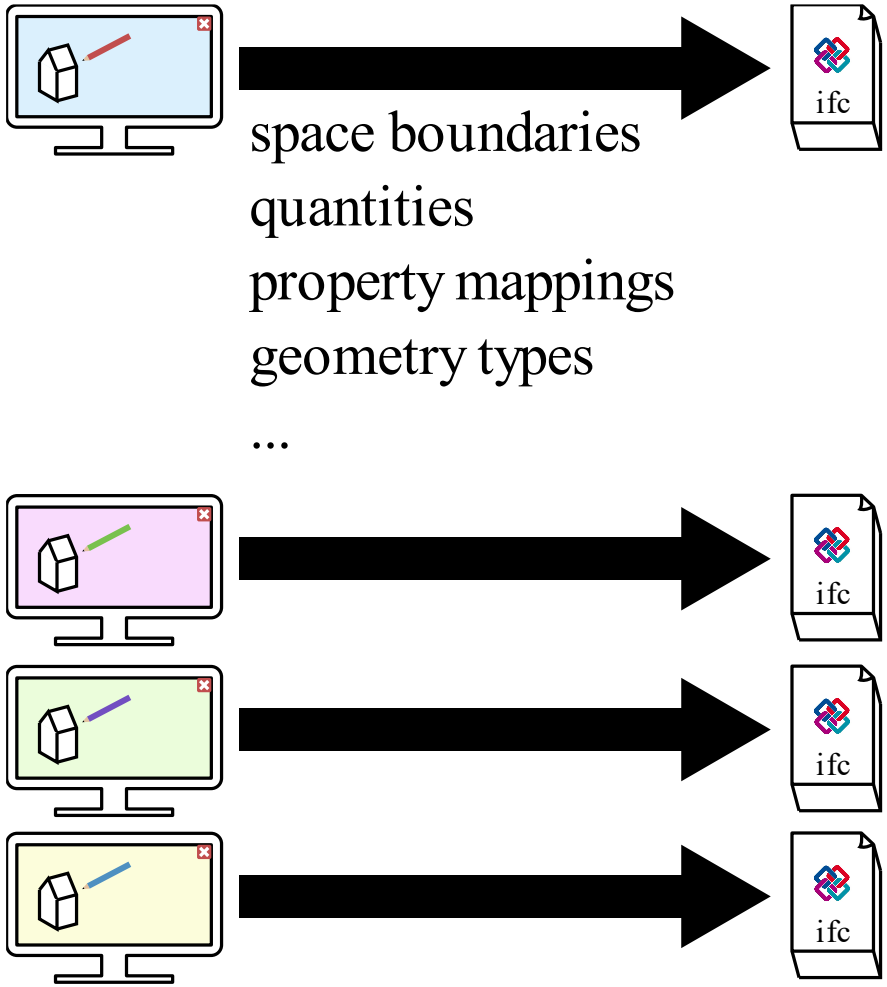
Rationale. Current IFC export architecture

slow release cycles
diffuse focus
repeated effort
no alternatives



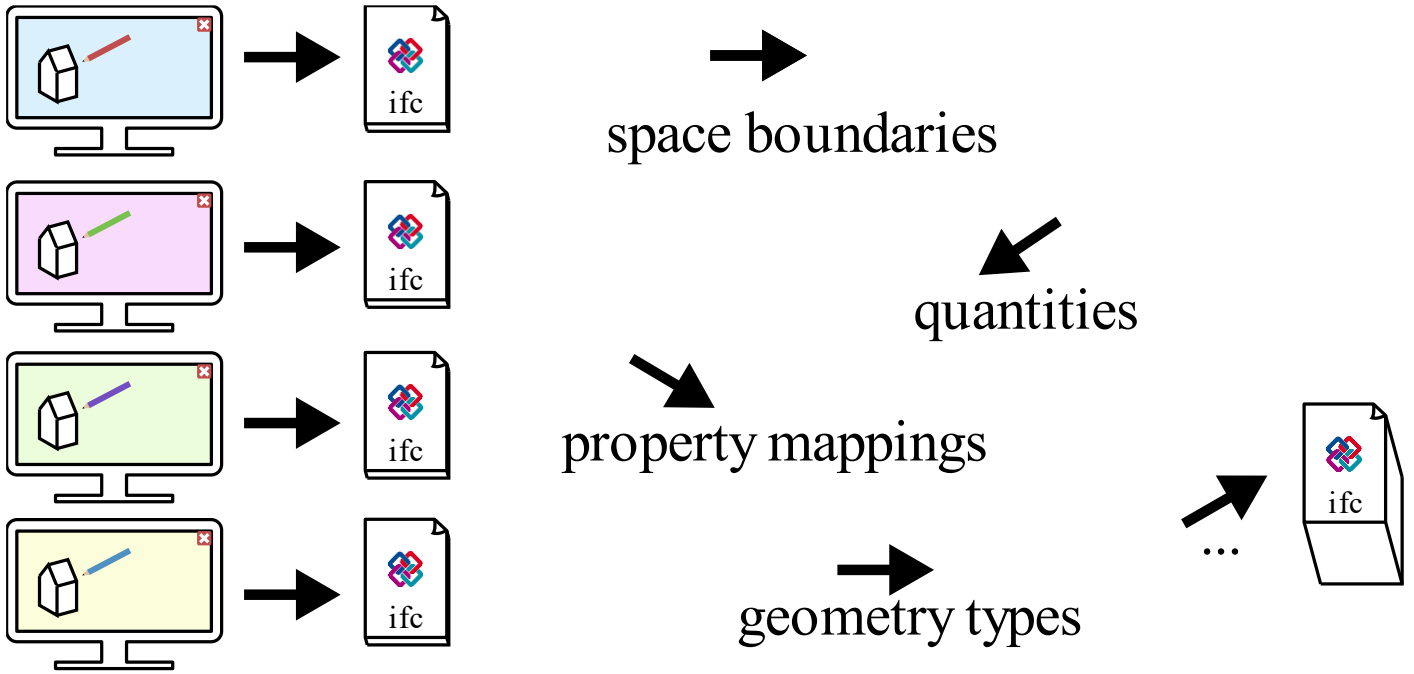
Rationale. Envisioned IFC export architecture

fast release cycles

focus

reduced effort

choice

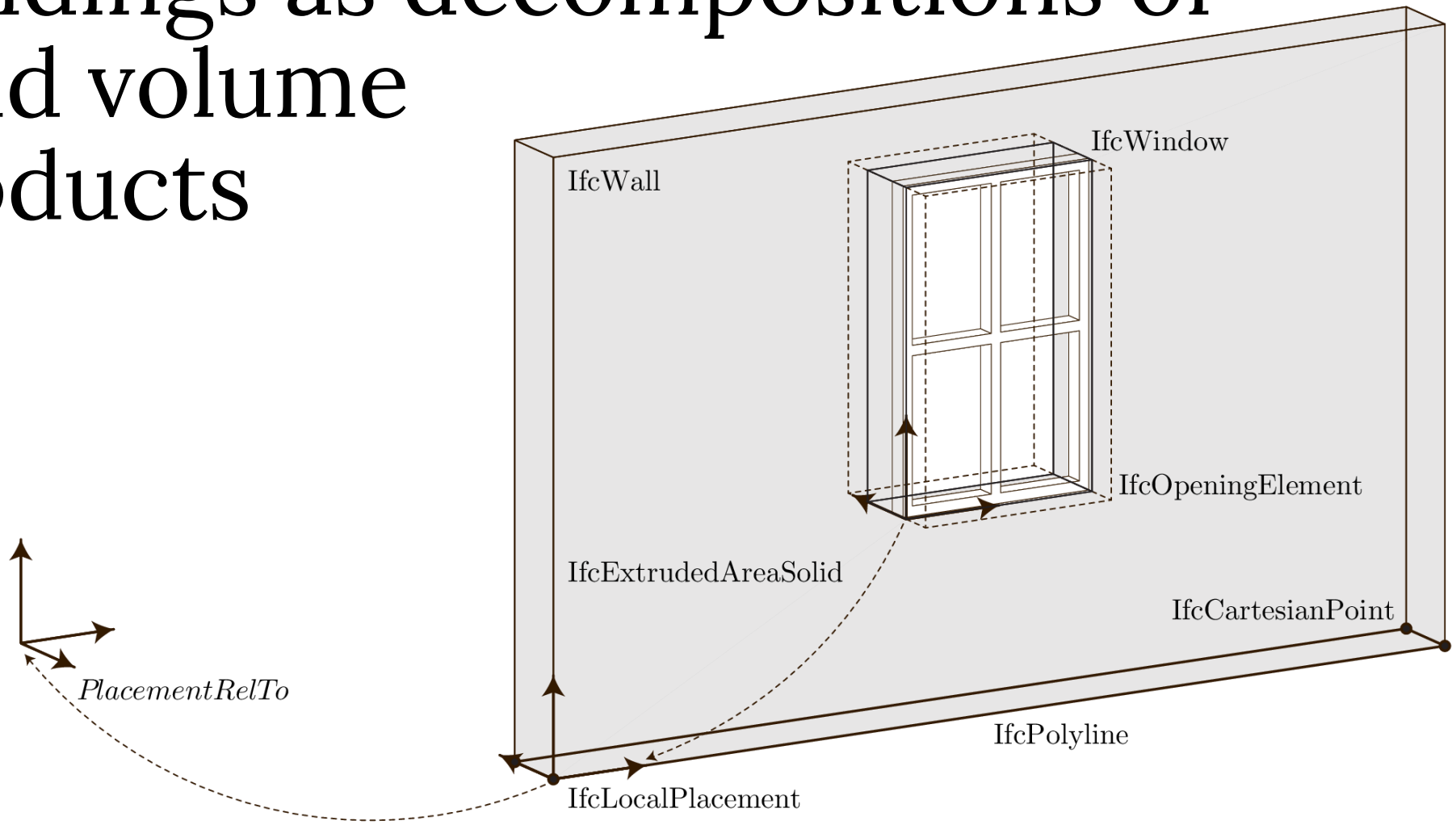


Unix philosophy

> *Write programs that do one thing and do it well.*
>
> *Write programs to work together.*
>
> *Write programs to handle text streams, because that is a universal interface.*

Douglas McIlroy, Peter H. Salus

Buildings as decompositions of solid volume products



source: **(Pauwels, Krijnen, Terkaj & Beetz 2016)**

Thin-walled thermal interfaces

OpenStudio 1.9.0 Basic Workflow Guide (March 2015)

openstudio.net

SketchUp — Building Envelope

Notes

After using native SketchUp tools to draw a space outline, you use the Spaces From Diagram tool to project the diagram into a multistory building. Although the geometry is automatically generated from the diagram, you can edit it using standing SketchUp Tools.

You can take a similar approach for fenestration. Again draw loose geometry with native SketchUp tools, but this time use the Project Loose Geometry tool to apply the fenestration to the appropriate spaces. Optionally use the user scripts to create windows based on window to wall ratio or project overhangs based on a projection factor.

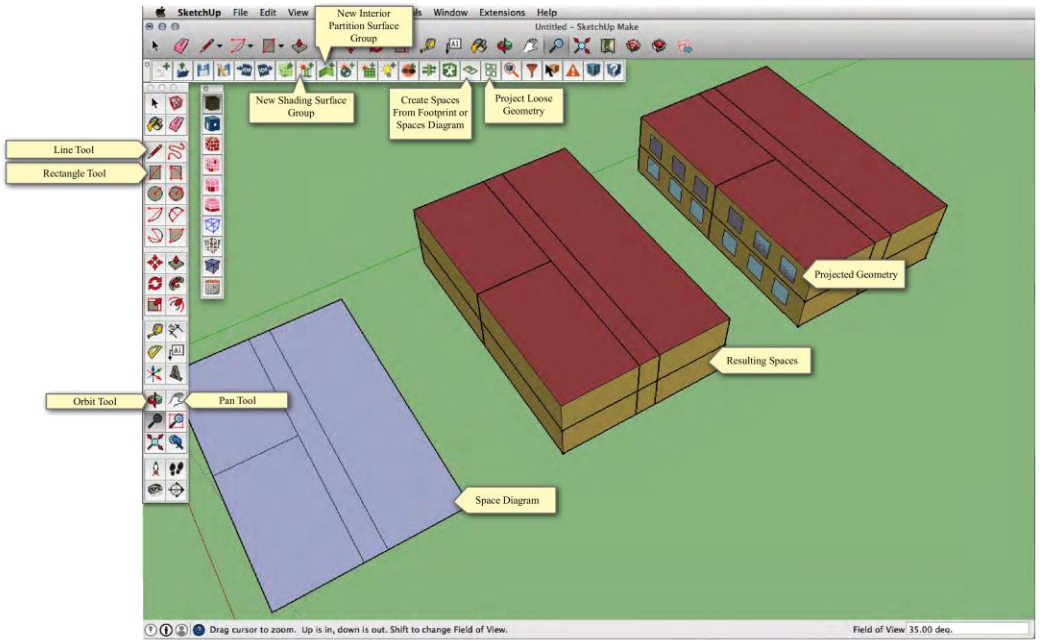
You can create additional model geometry using the Shading Surface Tool and the Interior Partition Surface Tool. Spaces can also be imported from gbXML.

Key SketchUp Plug-in Tools

Choose Template

Building Envelope

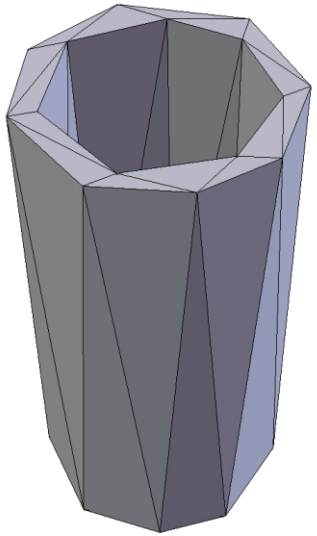
Surface & Space Attributes

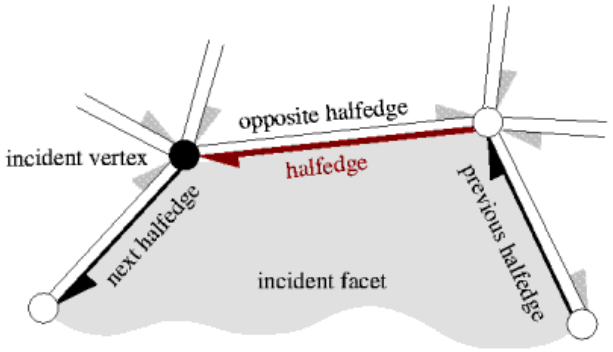


OpenStudio is developed in collaboration by NREL, ANL, LBNL, ORNL, and PNNL.
NREL is a National Laboratory of the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, operated by the Alliance for Sustainable Energy, LLC.

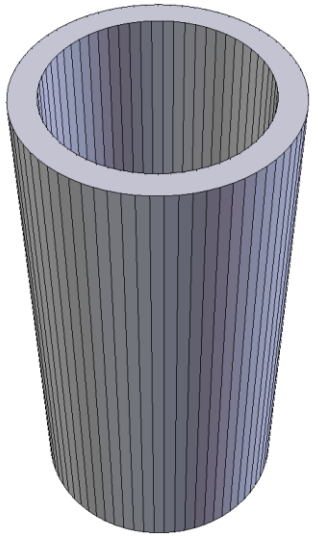
http://nrel.github.io

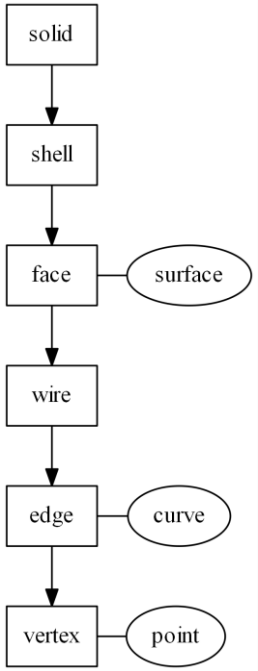
Geometry

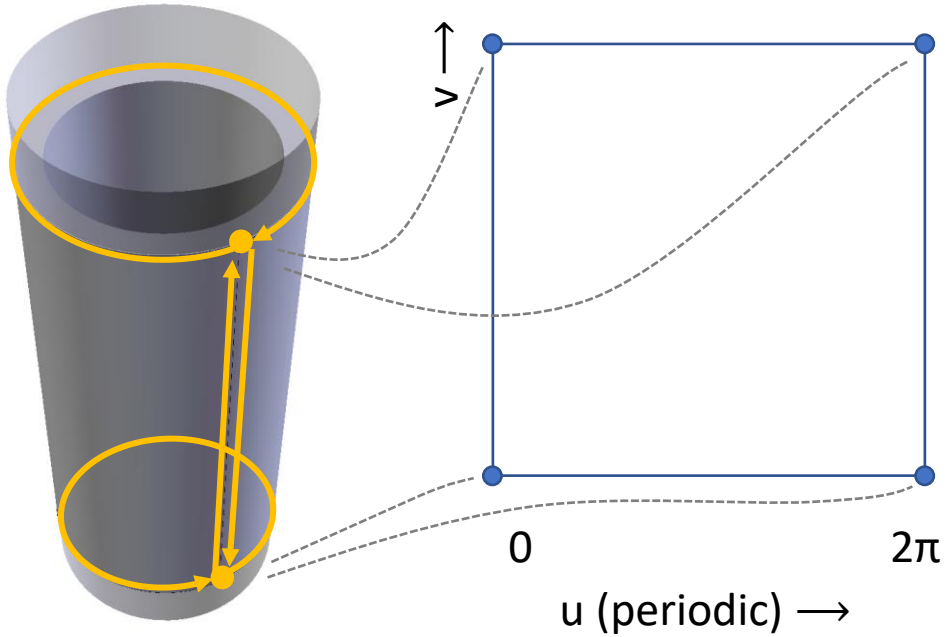


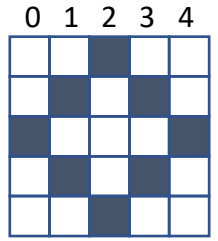


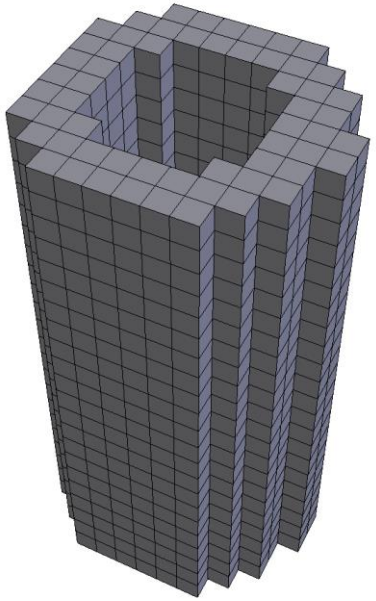
https://doc.cgal.org





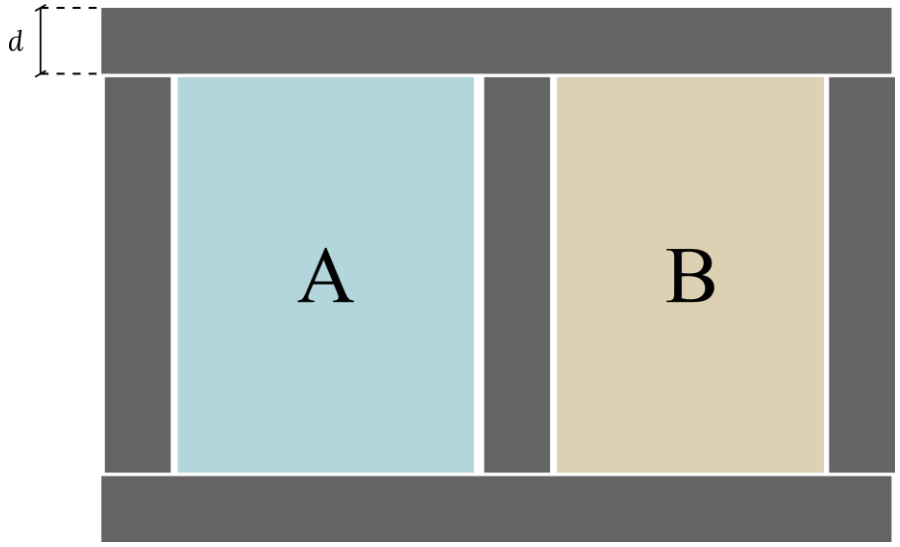




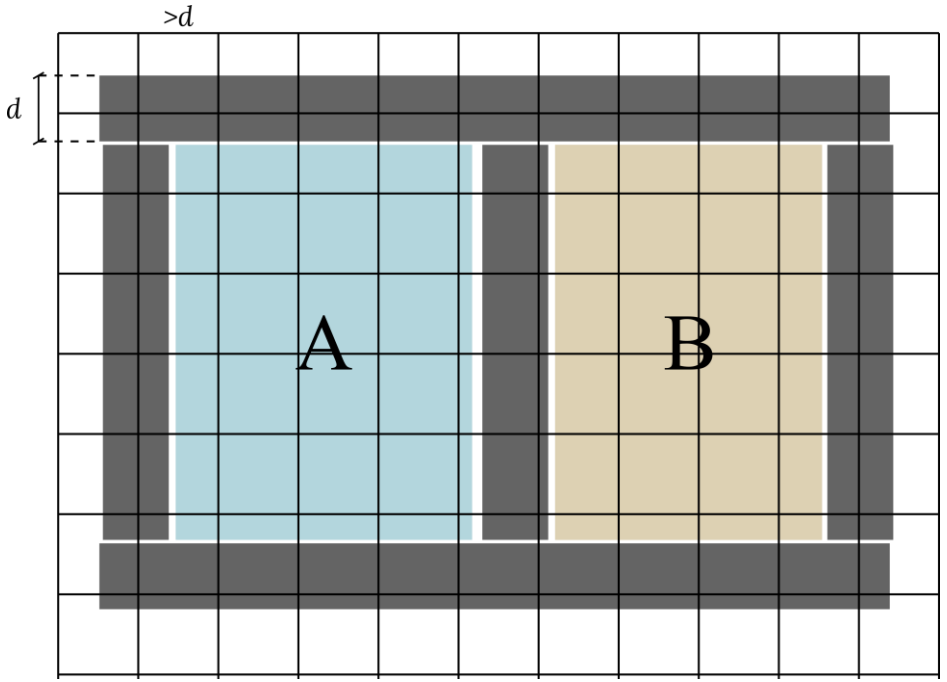


Process outline

BIM input

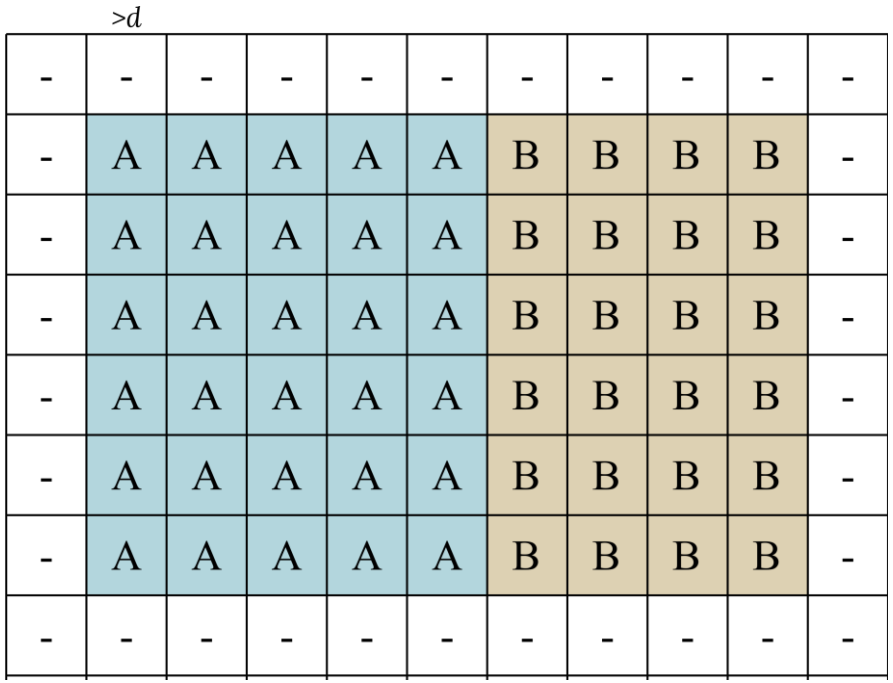


Grid overlay

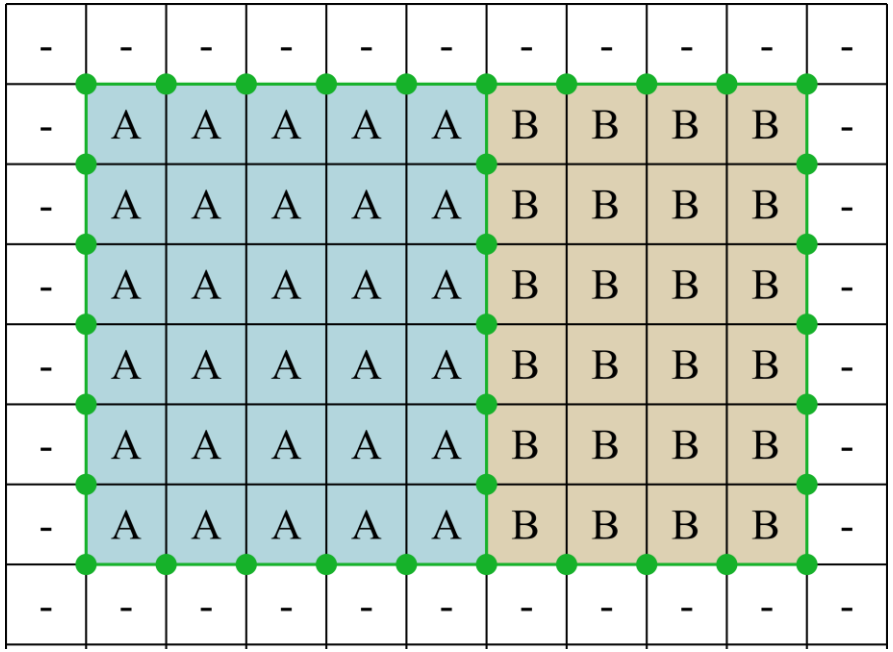


Process outline

Space voxelization



Discontinuities mesh

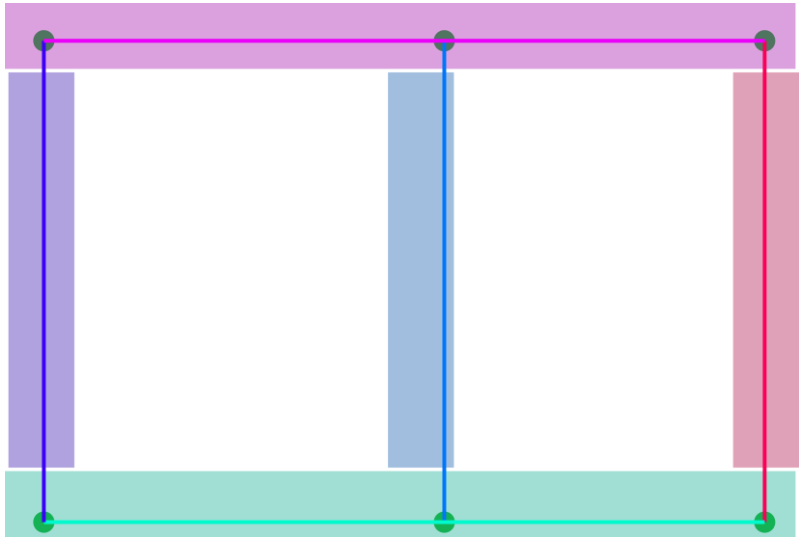


Process outline

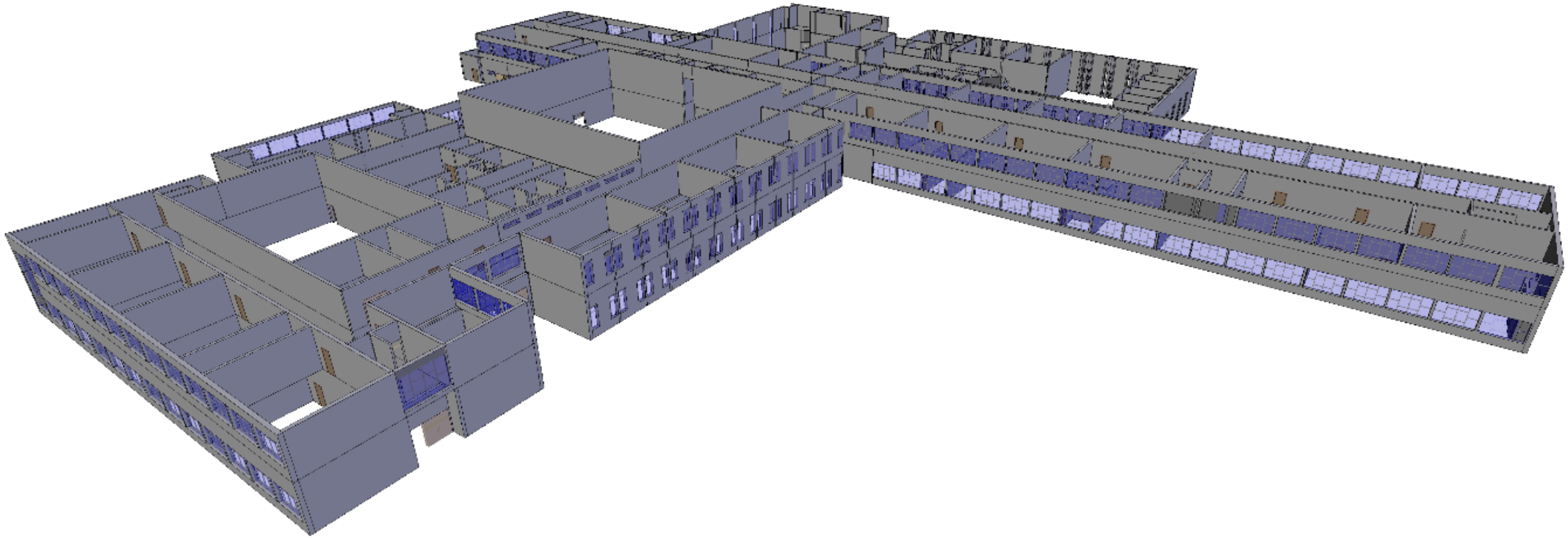
Simplified mesh

-	-	-	-	-	-	-	-	-	-	-
-	A	A	A	A	A	B	B	B	B	-
-	A	A	A	A	A	B	B	B	B	-
-	A	A	A	A	A	B	B	B	B	-
-	A	A	A	A	A	B	B	B	B	-
-	A	A	A	A	A	B	B	B	B	-
-	A	A	A	A	A	B	B	B	B	-
-	-	-	-	-	-	-	-	-	-	-

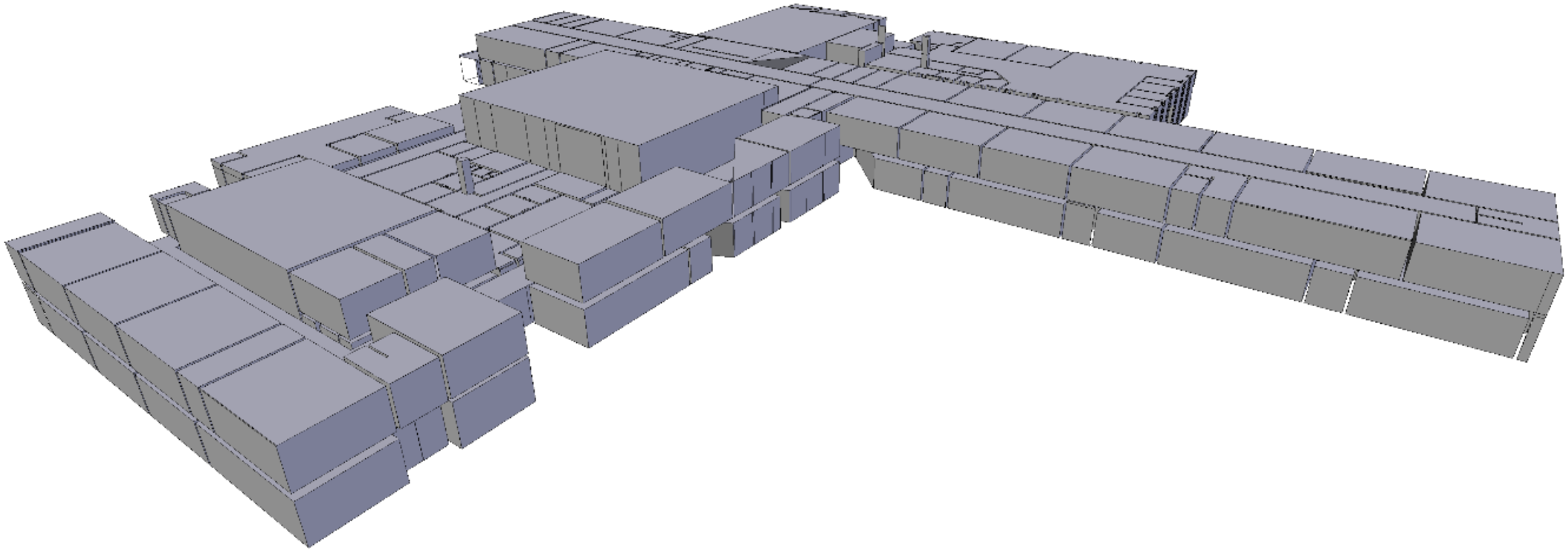
Associated semantics and projected sub-surfaces (windows, walls)



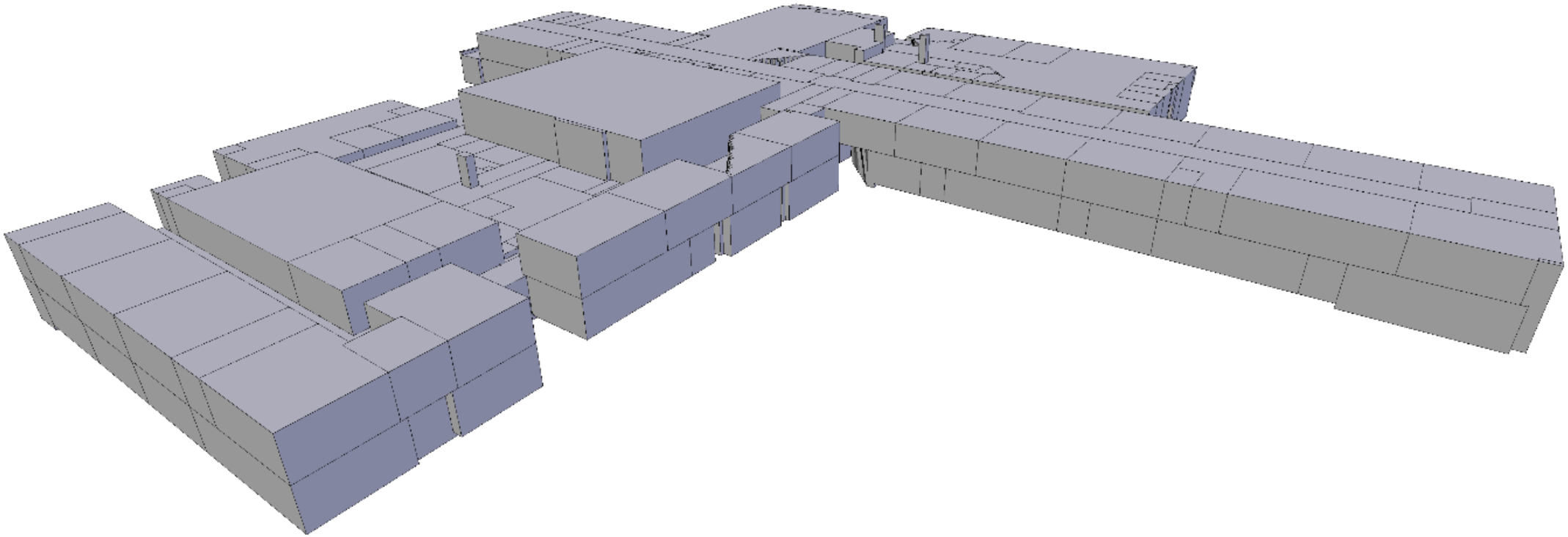
Original IFC wall and infill elements



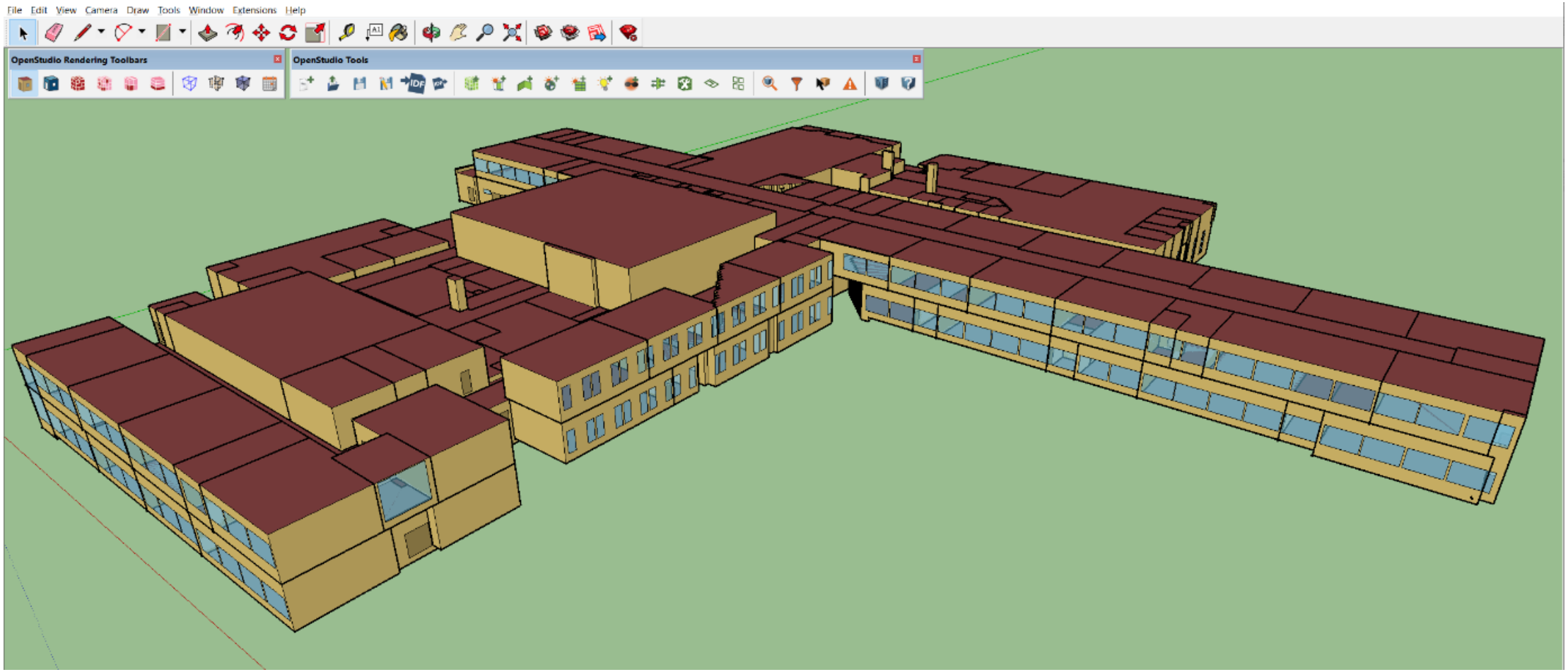
Original IFC space geometries



Voxelized space volumes (now touching)



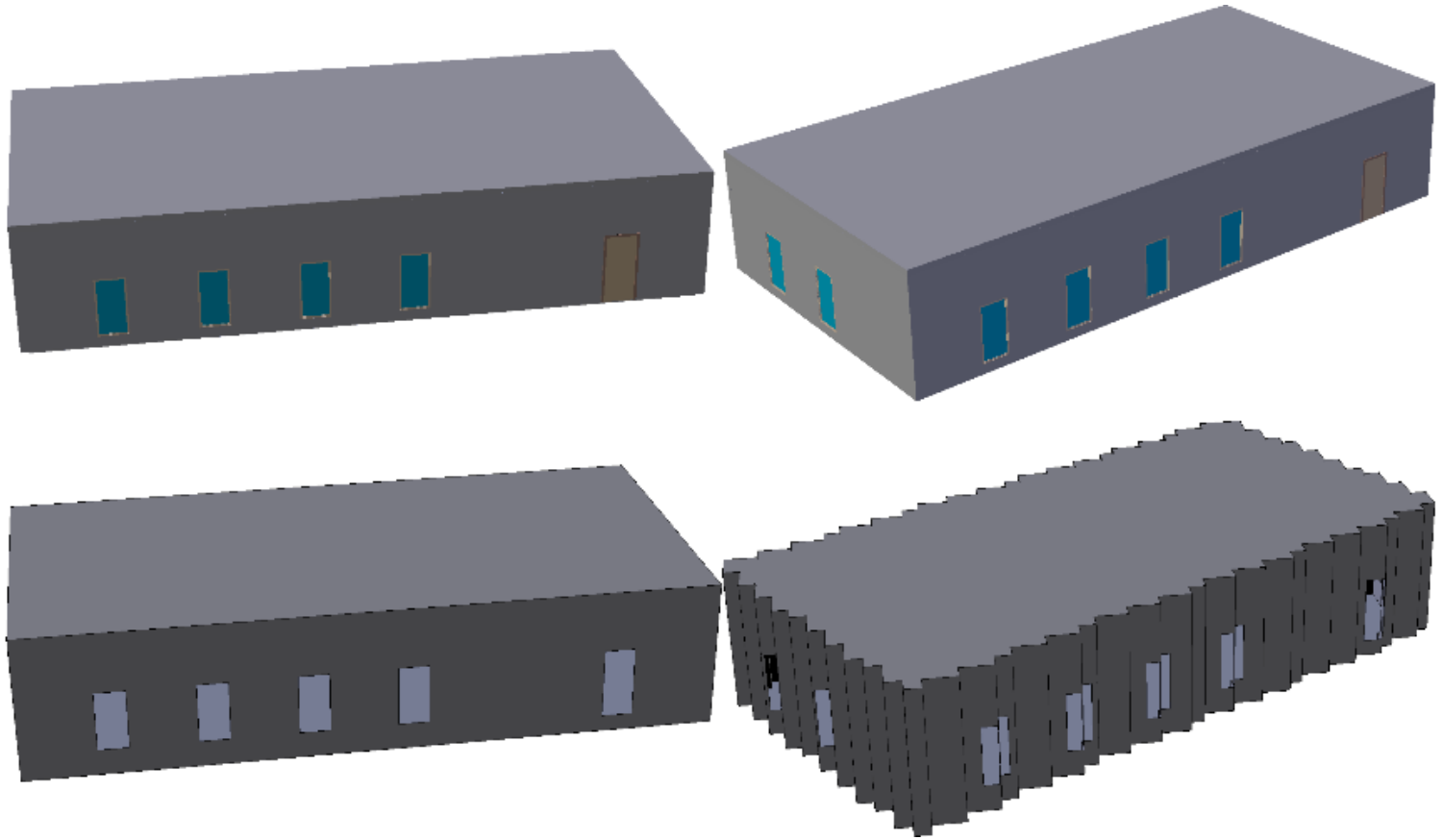
Exported model in Open Studio



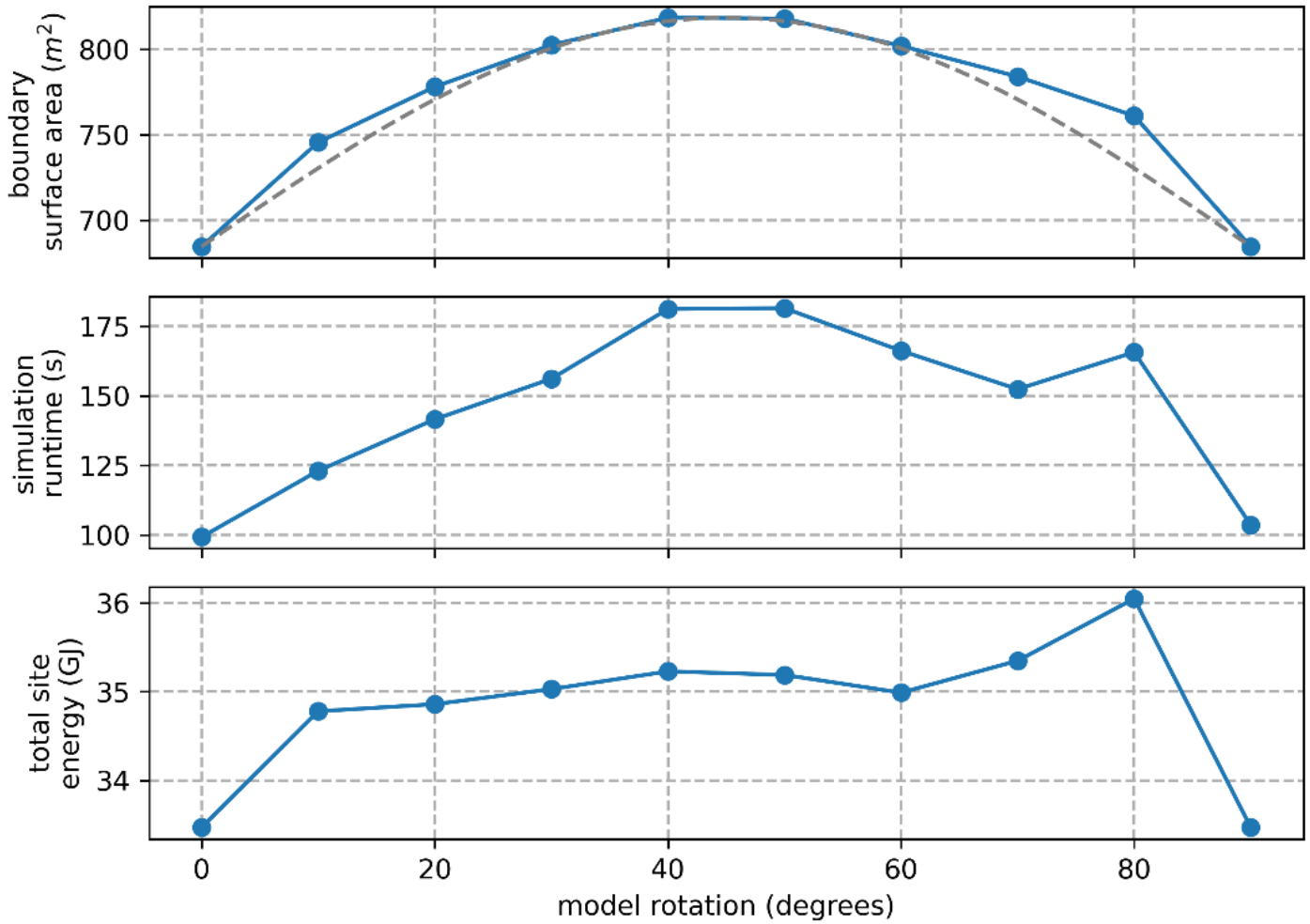
Statistics

Voxel space volume	58071.25 (464570 × 0.5^3)
IfcSpace volume sum	47257.91
One-sided thermal interface sum	36640.25
IfcWall area sum (length x height)	16683.05
IfcSlab area sum (volume / thickness)	20315.27
IfcWall + IfcSlab area sum	36998.32
Number of IfcSpaces	218
Number of unique boundary sides	208

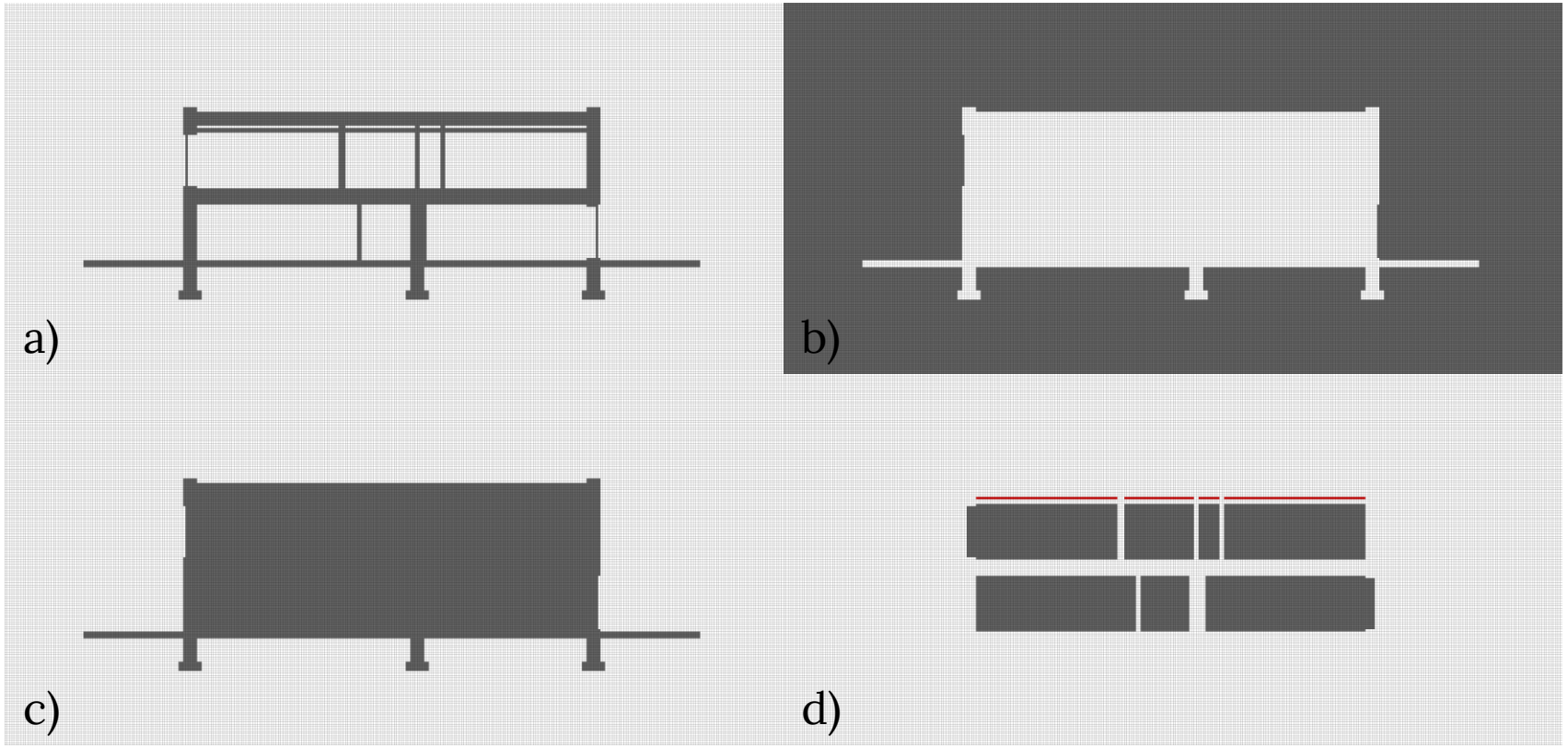
Synthetic model



Effect of surface increase due to staircases



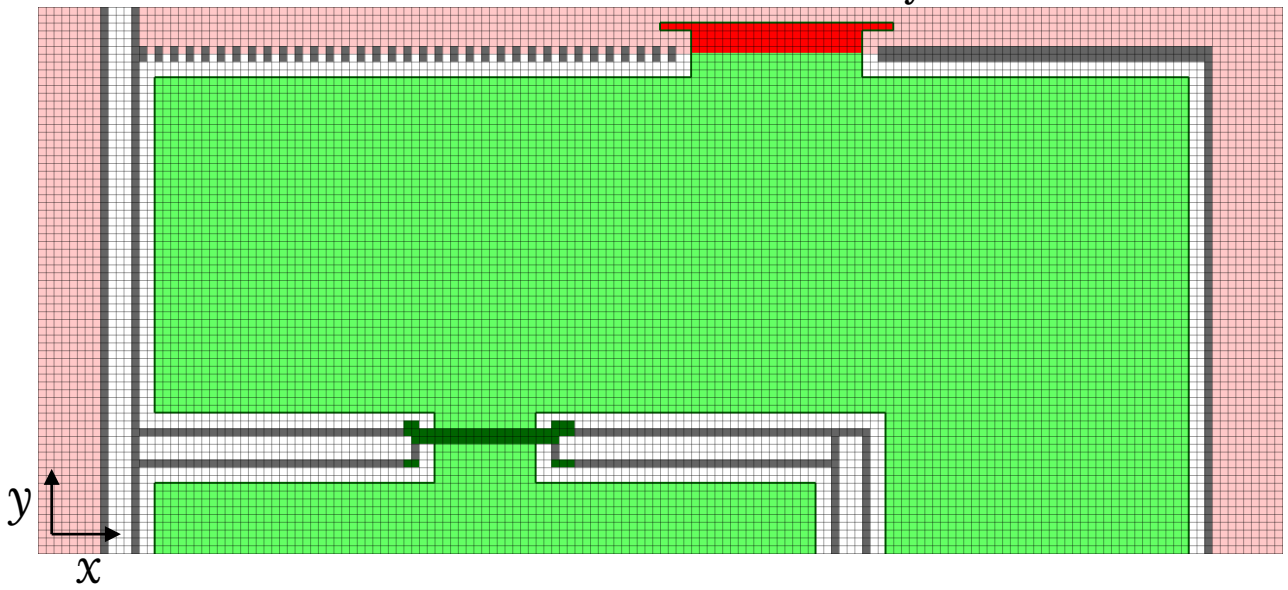
Future work: automated detection of spaces

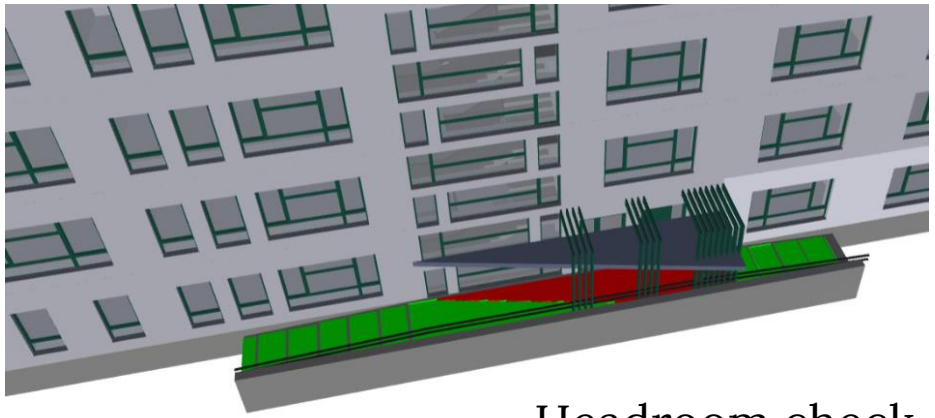


(a) voxelized IFC geometries (b) exterior (c) interior as negation of b (d) spaces obtained as c - a

Side step: other voxel use cases

Safety barriers check

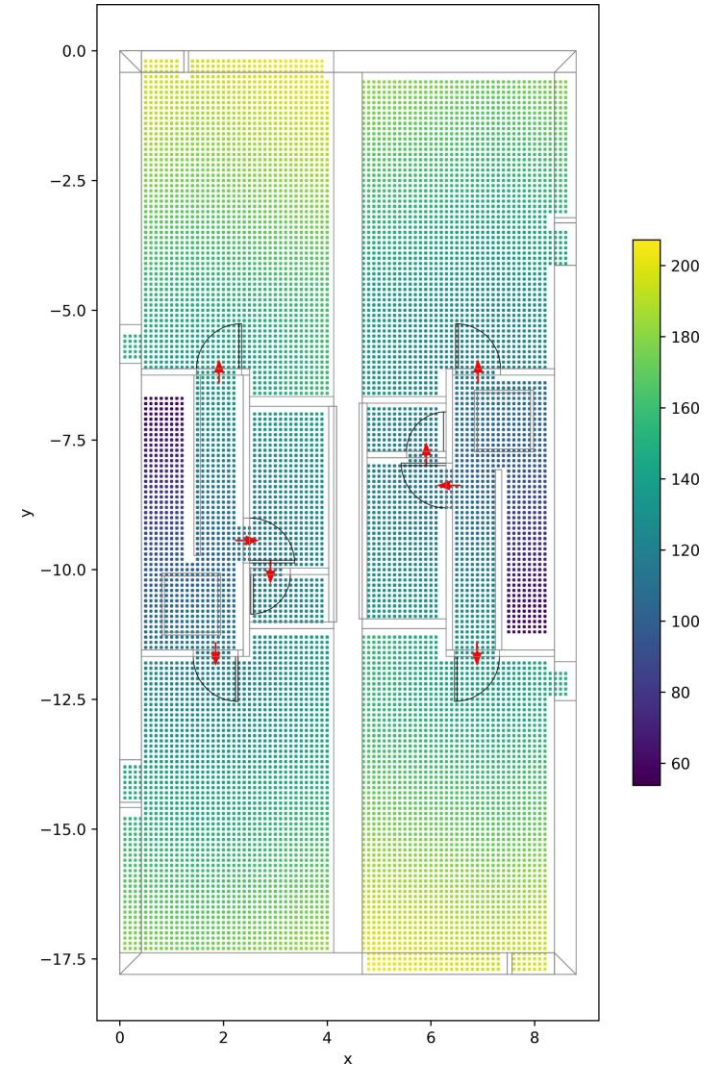




Headroom check

Door direction check

Distance from exterior door



Conclusion

IFC as a driver for innovation in modular tools

A robust, but less accurate, approach for thermal analysis on building models is presented

Voxelization as a “low tech” solution to computational geometry problems in our industry