Acceleration of energy model input: Visual Geometry

Master 1 Internhip

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CONTEXT & BACKGROUND

- This internship was realized in **CEMOSIS.**
- The context of this internship resides in the partnership between CEMOSIS and **Iloomi.** Working together they aim to democratize energy audits.
- The goal is to create a **digital twin** of a building, so we can optimize its energy consumption or at least understand it's behavior.
- We have to create this digital twin as fast and as accurate as possible

OUR OBJECTIVES

- The goal in the internship was to be a part of this larger project, and work in the generation of the **Visual Geometry.** In other words, the 3D Model of the building.

- The 3D Model must come in a very specific kind of file: the **IFC** format. Furthermore, we shall, carefully, decide what is the best method to come with this generation. Lastly, the IFC file needs to be convertible to a Modelica model.

- It's important that everything is almost automatic. Ideally, Iloomi has worked on a questionnaire and the model should be generated only with the imputed information.

SUMMARY

- I) What is the IFC standard?
  - A)Definition of BIM, IFC, BIM2Modelica
  - B) How can we generate IFC?s
- II) A python script to generate IFC
  - A) Retrieving information
  - B) IfcGenerator
- III) Results
  - A) Iloomi's house example
  - B) Automatic building

BIM & BIM Software

In the civil engineering world, they call **BIM** to the files involved in the generation and management of digital representations of buildings.

We have a variety of BIM software:

BIM Software and their proprietary file types

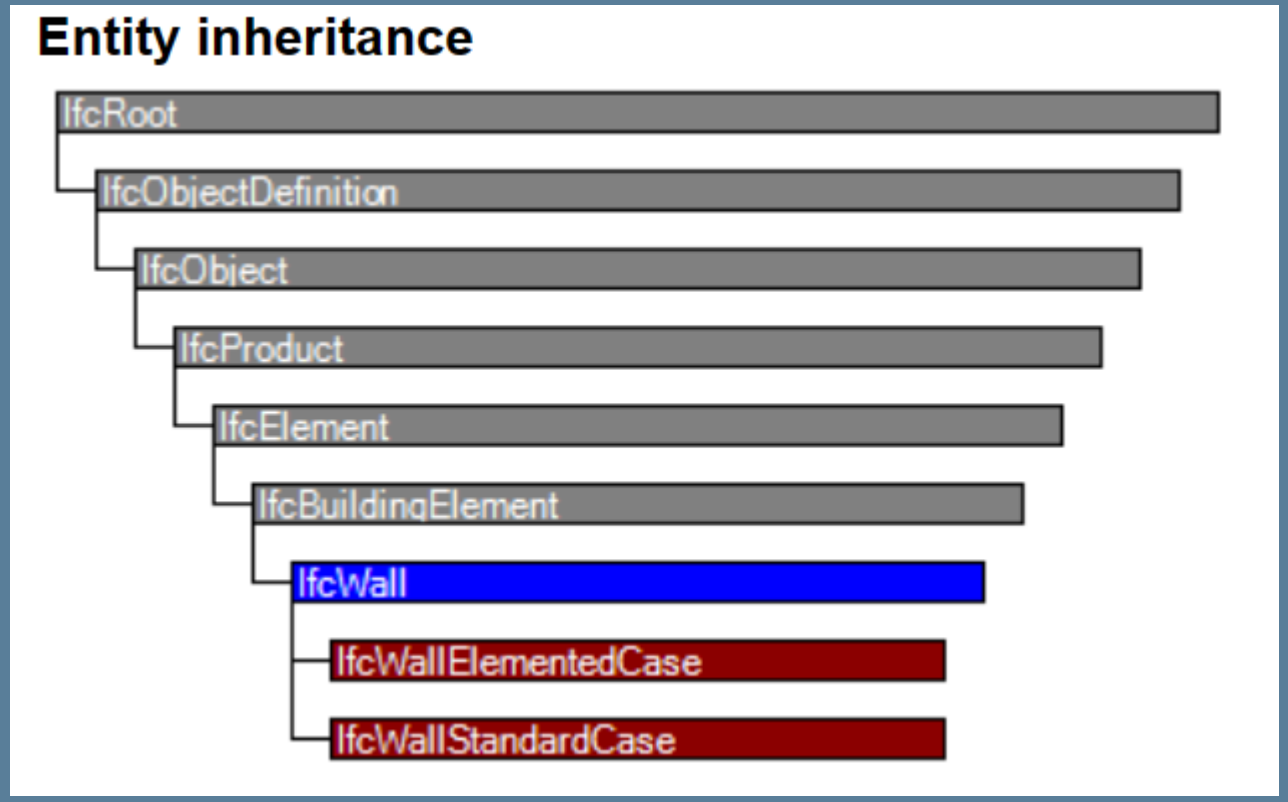
INDUSTRY FOUNDATION CLASS

- Created in 1995, the IFC file allows an interoperability between users and programs
- **Format:** XML,JSON, STEP
- **Versions:** Ifc2x3 or Ifc4

```
ISO-10303-21;
HEADER;
FILE_DESCRIPTION(('ViewDefinition [CoordinationView]'),'2;1');
FILE_NAME('','2023-07-06T16:34:24',(),(),'IfcOpenShell v0.7.0-476ab506d','IfcOpenShell v0.7.0-476ab506d','')
FILE_SCHEMA(('IFC4'));
ENDSEC;
DATA;
#1=IFCPROJECT('17TAgr3CPA1fnvpDhMdfTu',$,'My Project',$,$,$,$,(#10),#5);
#2=IFCSIUNIT(*,.LENGTHUNIT.,.MILLI.,.METRE.);
#3=IFCSIUNIT(*,.AREAUNIT.,$,.SQUARE_METRE.);
#4=IFCSIUNIT(*,.VOLUMEUNIT.,$,.CUBIC_METRE.);
#5=IFCUNITASSIGNMENT((#4,#2,#3));
#6=IFCCARTESIANPOINT((0.,0.,0.));
#7=IFCDIRECTION((0.,0.,1.));
#8=IFCDIRECTION((1.,0.,0.));
#9=IFCAXIS2PLACEMENT3D(#6,#7,#8);
#10=IFCGEOMETRICREPRESENTATIONCONTEXT($,'Model',3,1.E-05,#9,$);
#11=IFCGEOMETRICREPRESENTATIONSUBCONTEXT('Body','Model',*,*,*,*,#10,$,.MODEL_VIEW.,$);
#12=IFCSITE('2HKa9JNCj5Qv9eaWCsE9js',$,'My Site',$,$,$,$,$,$,$,$,$,$);
#13=IFCBUILDING('0Wn7nlE_X4Igl5qO64Tcq7',$,'Building A',$,$,$,$,$,$,$,$,$);
#14=IFCBUILDINGSTOREY('0NWG9x4fTEwBQnrLyEOPfS',$,'Ground Floor',$,$,$,$,$,$,$);
#15=IFCRELAGGREGATES('2rJ5WzZPr6Wweau4zJ_$L1',$,$,$,#1,(#12));
#16=IFCRELAGGREGATES('3UImr6opDES9RQPDWtTL9_',$,$,$,#12,(#13));
```

Header of an IFC file. STEP format

AN EXAMPLE: IFCWALL



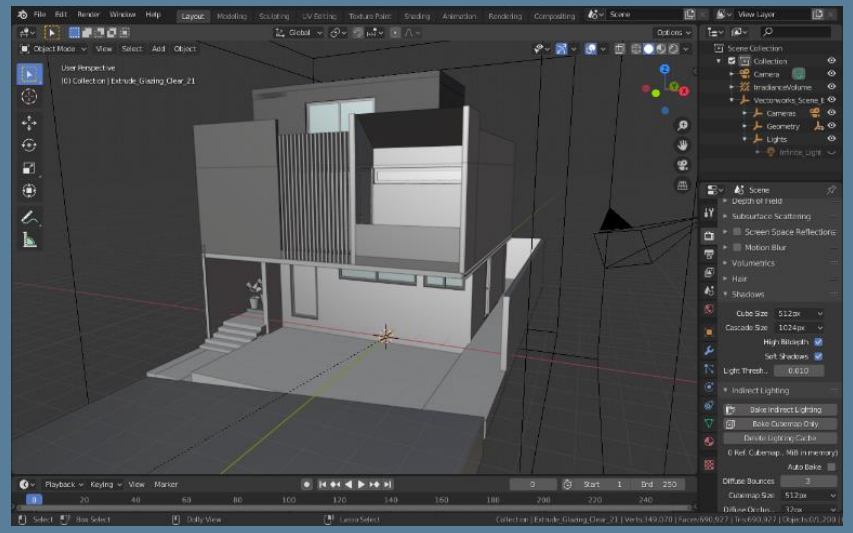
Inheritance of IfcWall

IfcWall	
GlobalId	[1:1]
OwnerHistory	[0:1]
Name	[0:1]
Description	[0:1]
HasAssignments	S[0:?]
Nests	S[0:1]
IsNestedBy	S[0:?]
HasContext	S[0:1]
IsDecomposedBy	S[0:?]
Decomposes	S[0:1]
HasAssociations	S[0:?]
ObjectType	[0:1]
IsDeclaredBy	S[0:1]
Declares	S[0:?]
IsTypedBy	S[0:1]
IsDefinedBy	S[0:?]
ObjectPlacement	[0:1]
Representation	[0:1]
ReferencedBy	S[0:?]
Tag	[0:1]
FillsVoids	S[0:1]
ConnectedTo	S[0:?]
IsInterferedByElements	S[0:?]
InterferesElements	S[0:?]
HasProjections	S[0:?]
ReferencedInStructures	S[0:?]
HasOpenings	S[0:?]
IsConnectionRealization	S[0:?]
ProvidesBoundaries	S[0:?]
ConnectedFrom	S[0:?]
ContainedInStructure	S[0:1]
HasCoverings	S[0:?]
PredefinedType	[0:1]

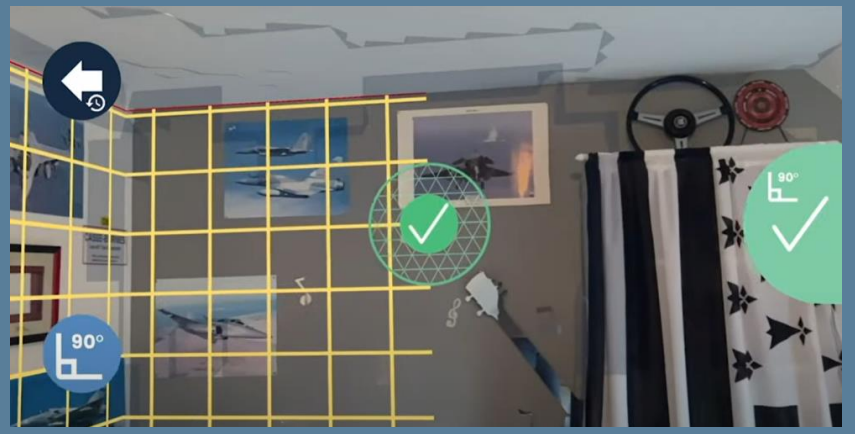
Attributes of IfcWall

How can we generate an IFC?

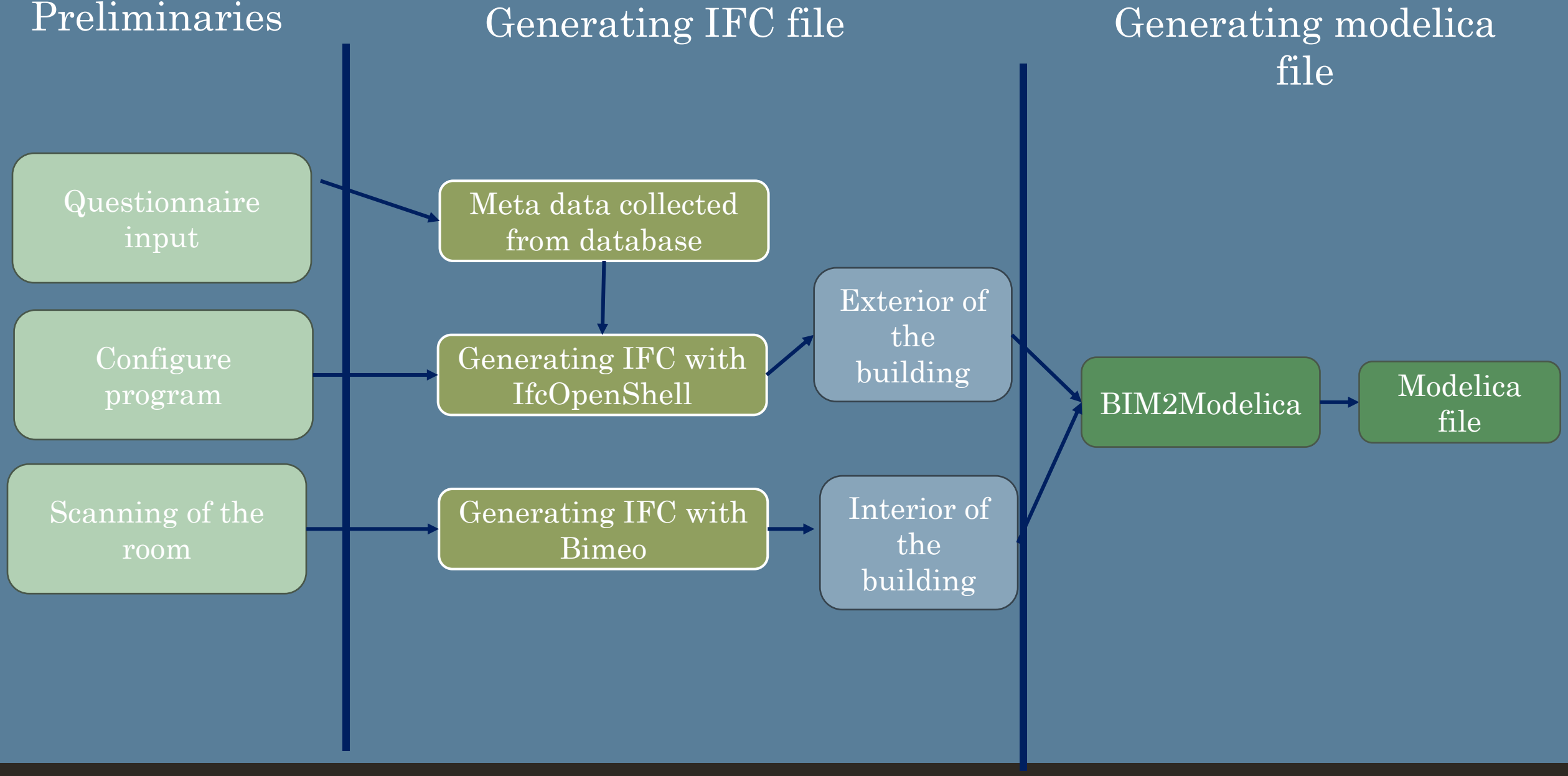
- From **scratch:** Using Blender or Revit
- **Scanning**: Using an application with Lidar technology. (Bimeo)
- **With programming:** Using libraries in Python or C++. (IfcOpenShell, Ifc++)



Blender GUI

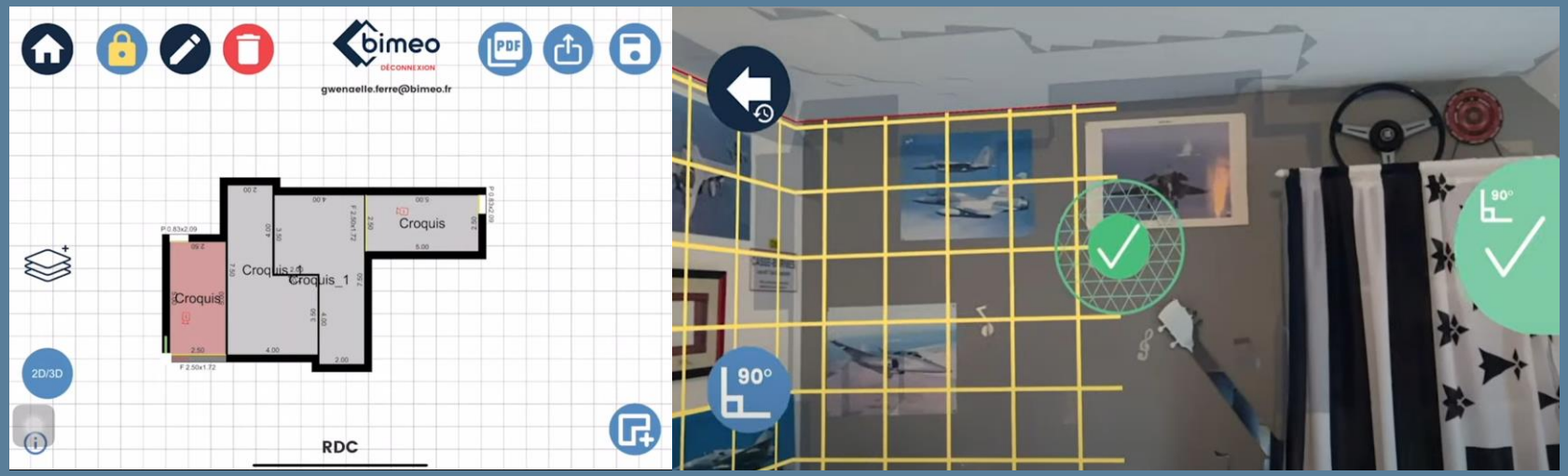


Bimeo GUI

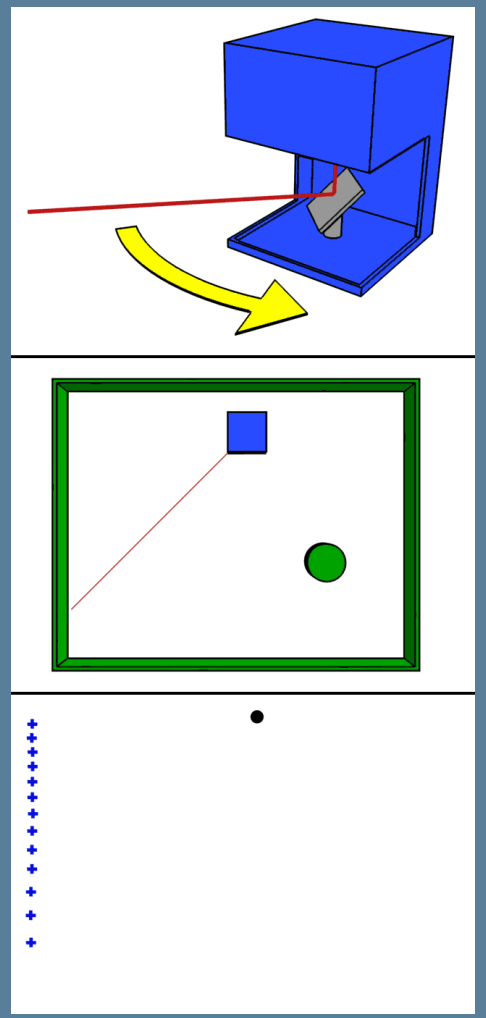

Preliminaries
Generating IFC file
Generating modelica file
Questionnaire input
Configure program
Scanning of the room
Meta data collected from database
Generating IFC with IfcOpenShell
Generating IFC with Bimeo
Exterior of the building
Interior of the building
BIM2Modelica
Modelica file

Generating an IFC with BIMEO

- **Bimeo** uses LiDAR technology to scan the room
- It produces Ifc2x3 or Ifc4
- We can edit it afterwards on the app

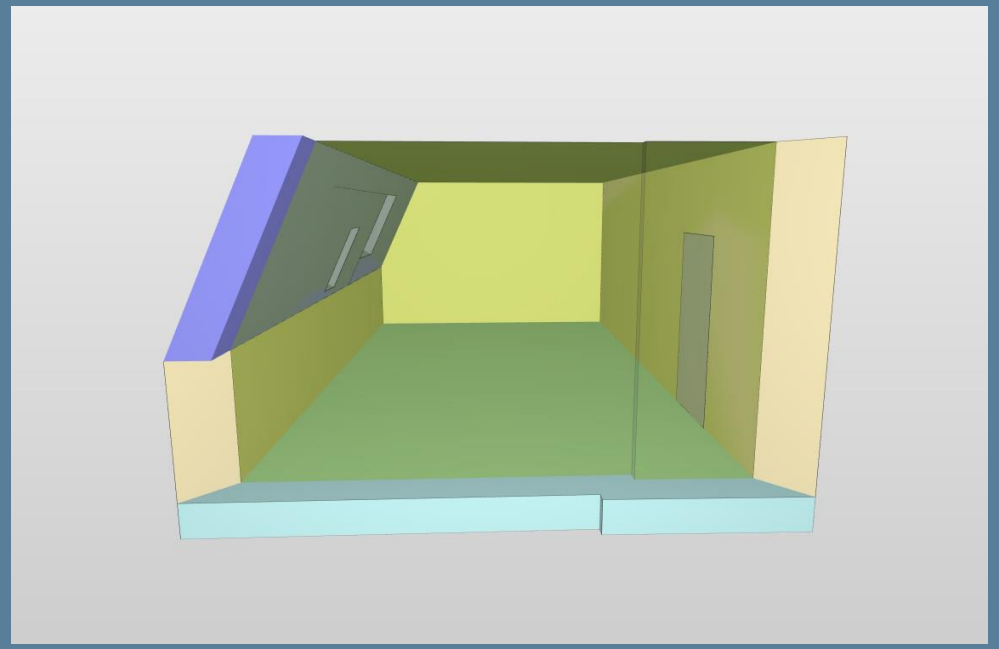


Bimeo GUI

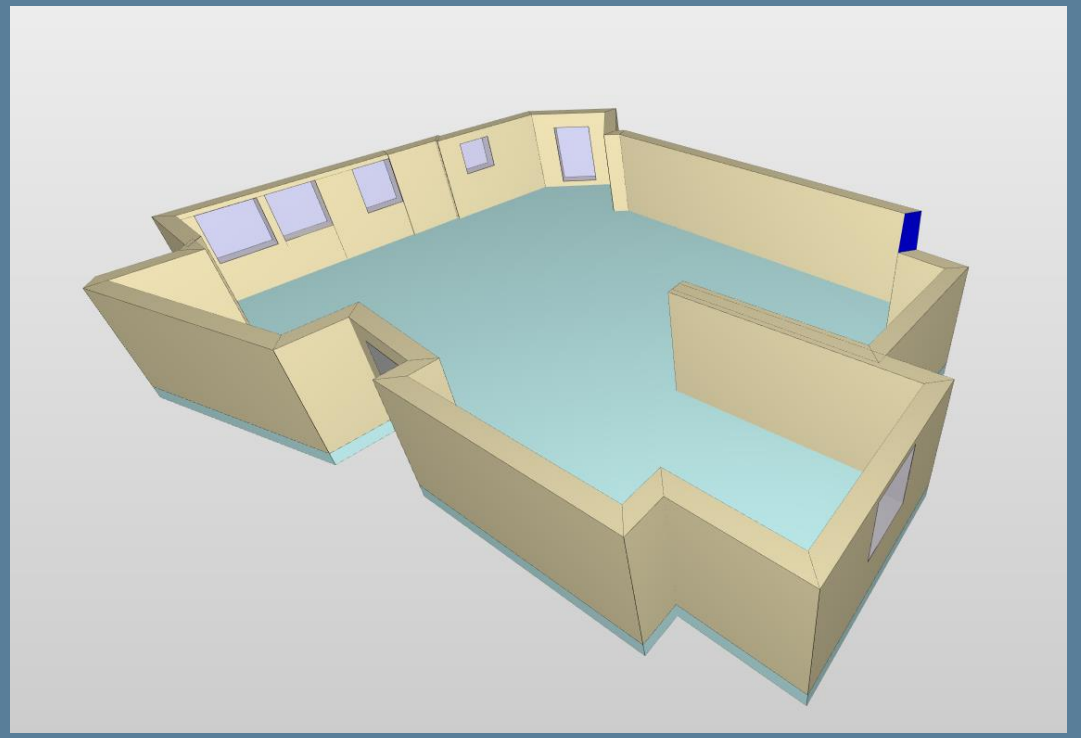


Lidar example

Scanned rooms with Bimeo in St.Georges



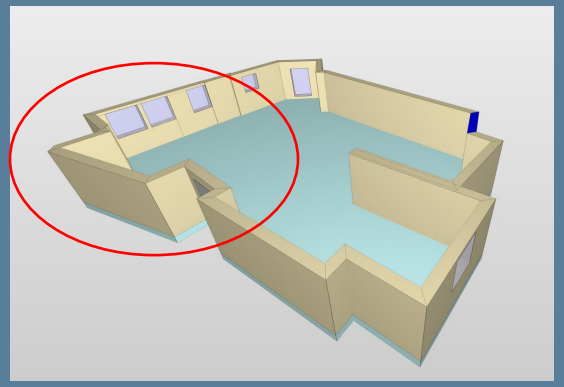
Office scanned. Visualization in Solibri



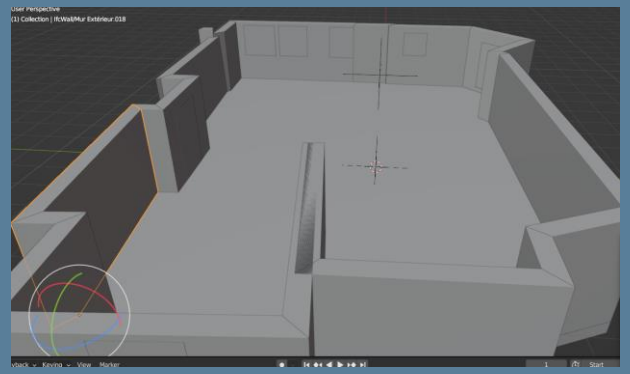
Cafeteria scanned. Visualization in Solibri

Encountered issues with the app

Problems with wall alignment

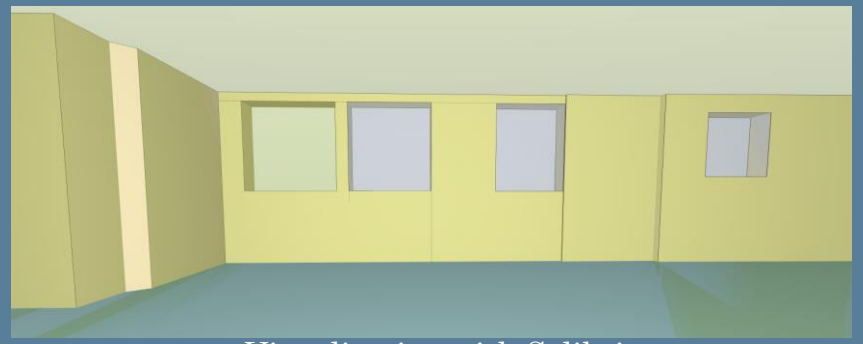


Cafeteria visualization with Solibri



Cafeteria correction with BlenderBIM

Problems with window distance



Visualization with Solibri

On top of the misalignment of the walls:

If a window or other opening is forgotten, there is no way to add it.

Sometimes the conversion to a modelica file is not possible

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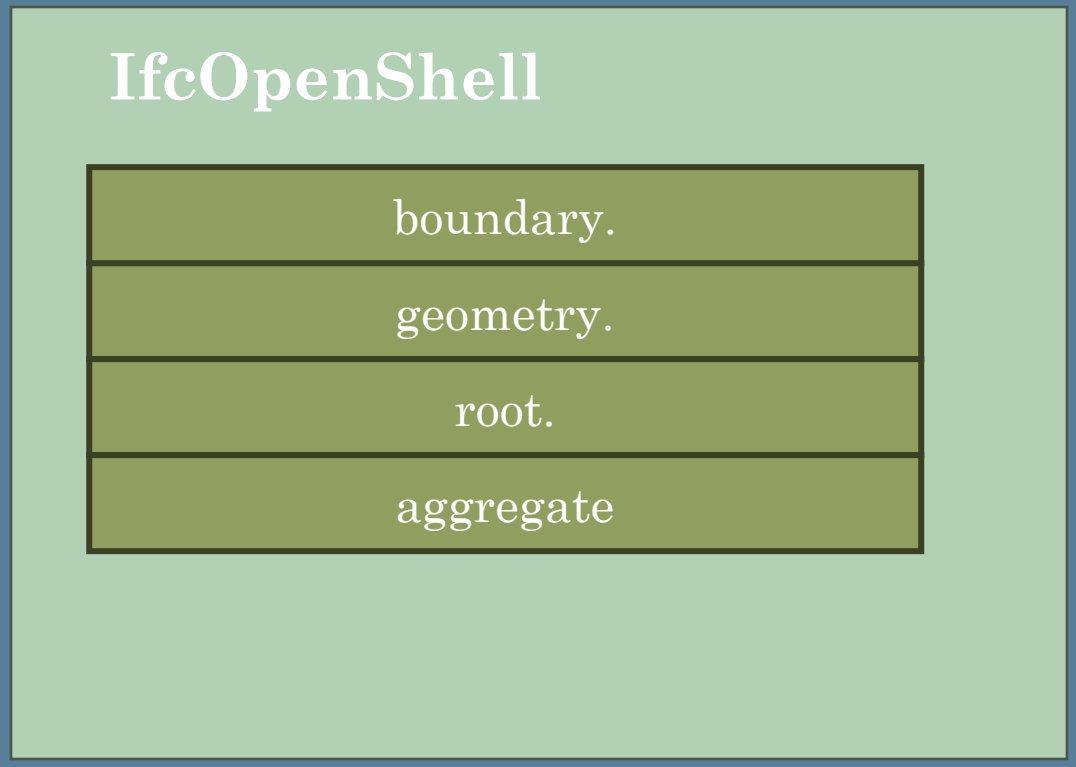
Our python program

Tools:

- We used Python 3.8 and IfcOpenShell 0.7.0 for the code
- GitHub for control and management through the project
- Visualization in Solibri

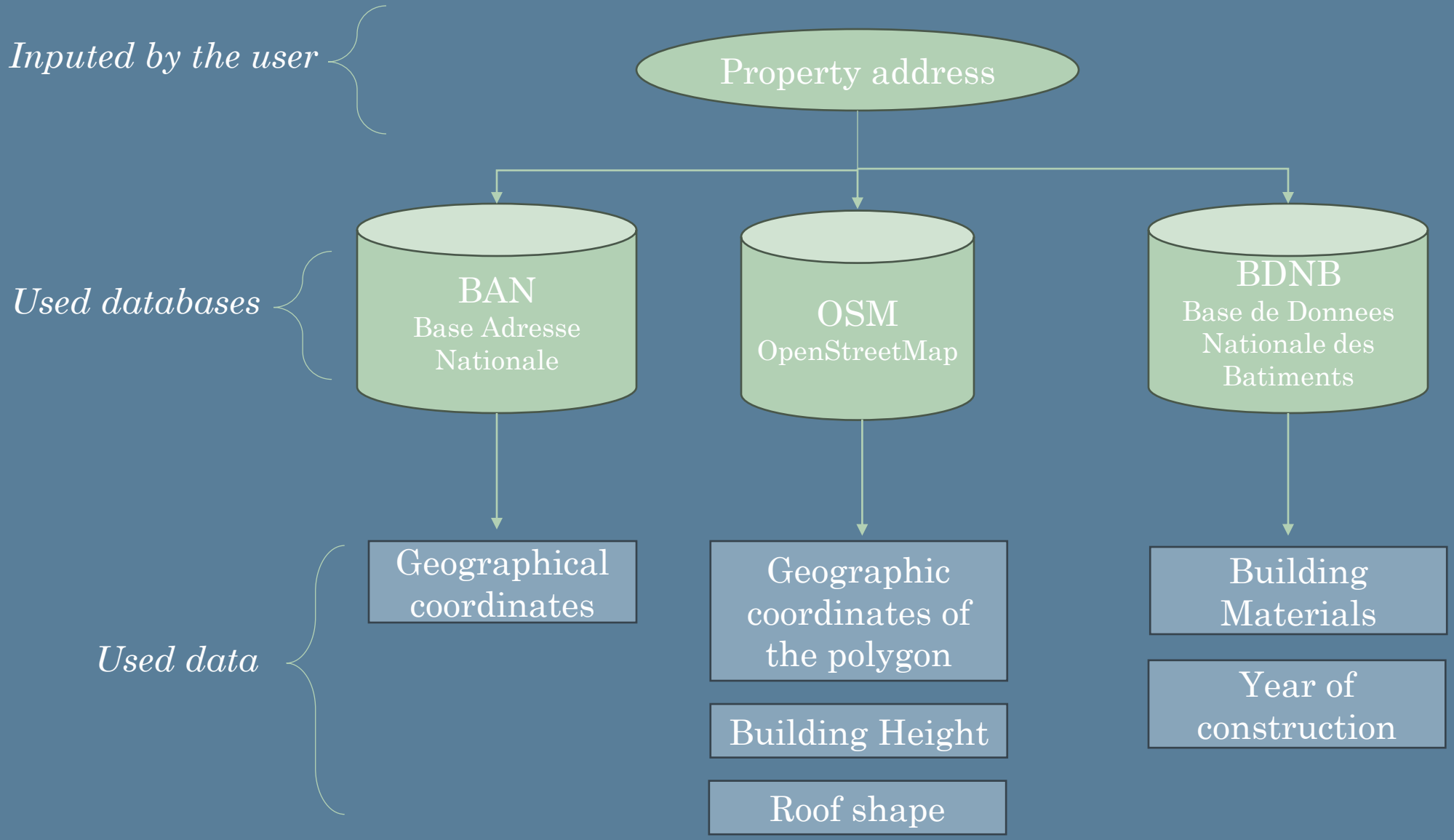
Output:

- An Ifc 2x3 file

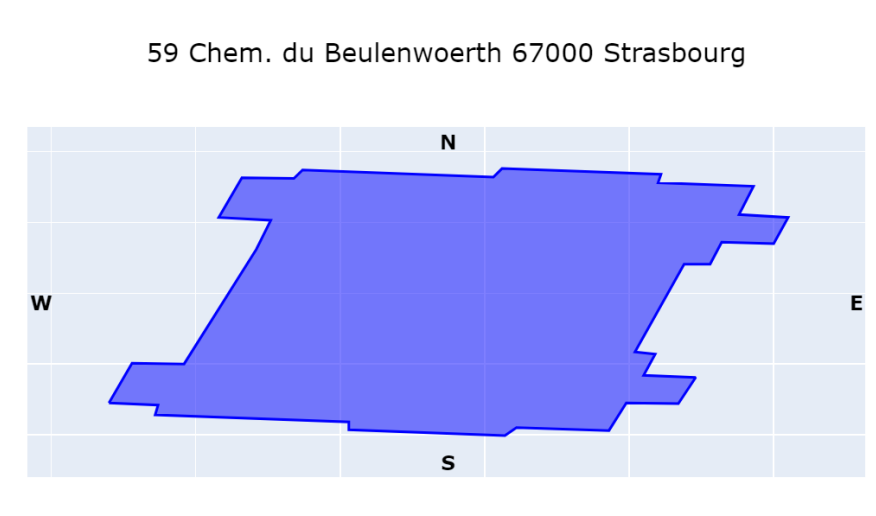


IfcOpenShell used modules

Retrieving building information:



Building the Model



Graphic visualization of the polygon with matplotlib

Our script will use the retrieved information to build a proper Ifc.

Of course, the ifc can only be as accurate as the database information.

Wall material	Floor material	Roof material
Hollow brick	Concrete slab	Joist wood

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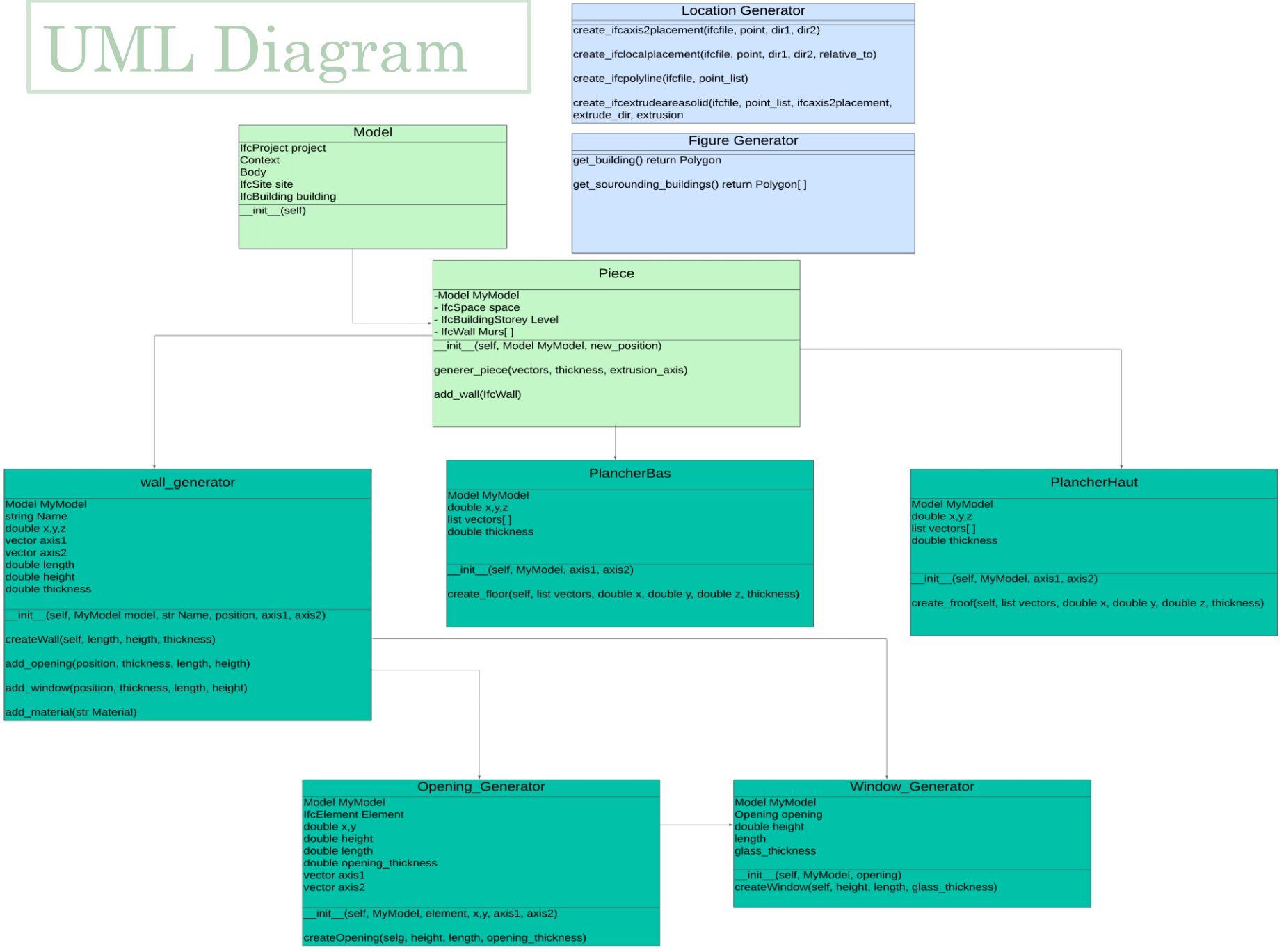
UML Diagram



Legend

Useful functions

Connection to databases, generation of placements and extrusions

Representation of the model

Inherent classes to the building, supposed to be used once

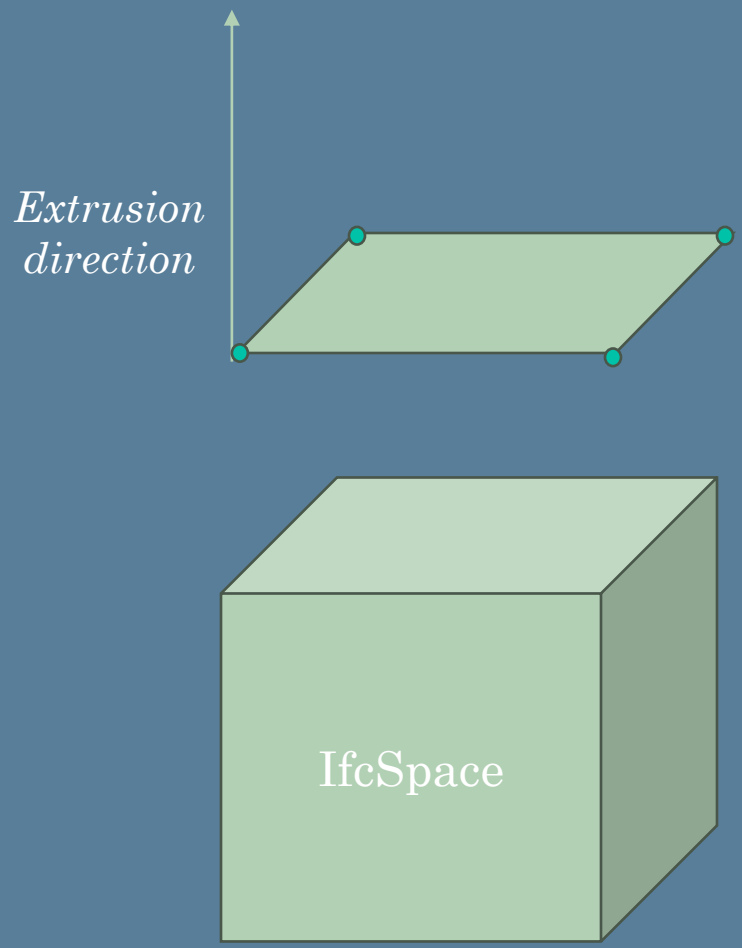
Element generator

Creation of common elements and its geometric representation

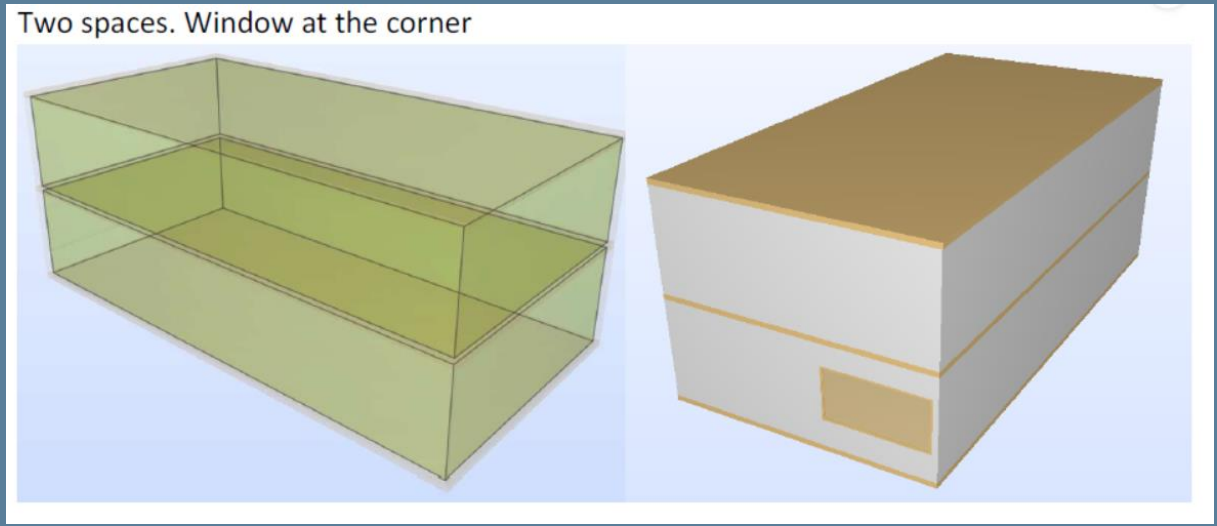
Example of class:

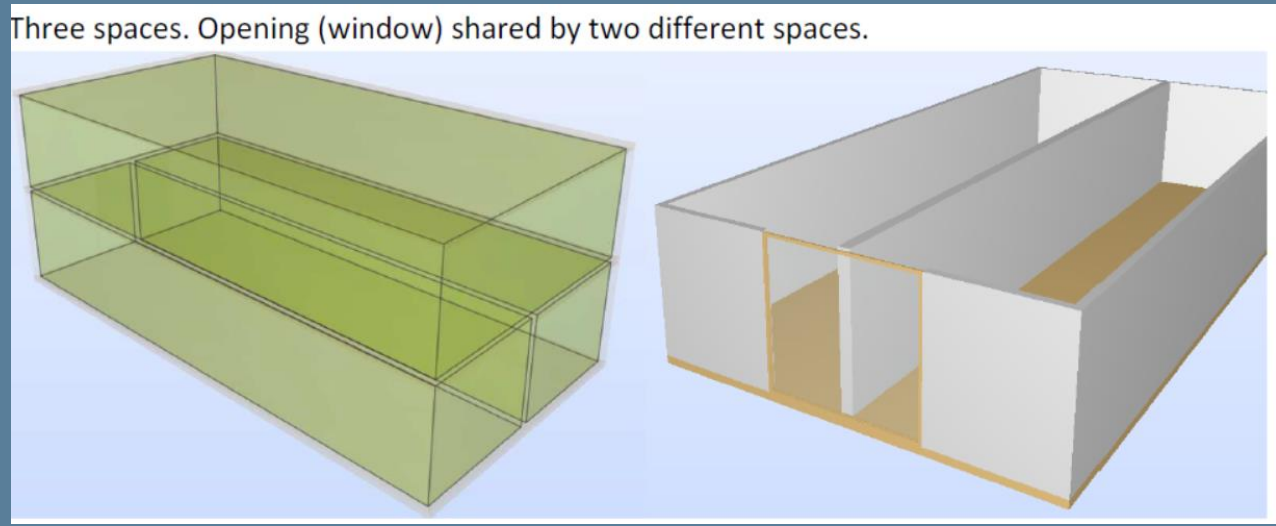
IfcSpace it´s one of the most important classes and it's crucial to the model generation

Piece
Model MyModel IfcSpace IfcBuildingStorey level IfcWalls mywall[ ]
__init__(self,Model MyModel, position) createRoom(vectors, thickness, extrusion_axis)



VISUALIZATION OF IFCSPACE





Examples of Ifc's furnished by BIM2Modelica.
Visualization in Solibri

Example of code:

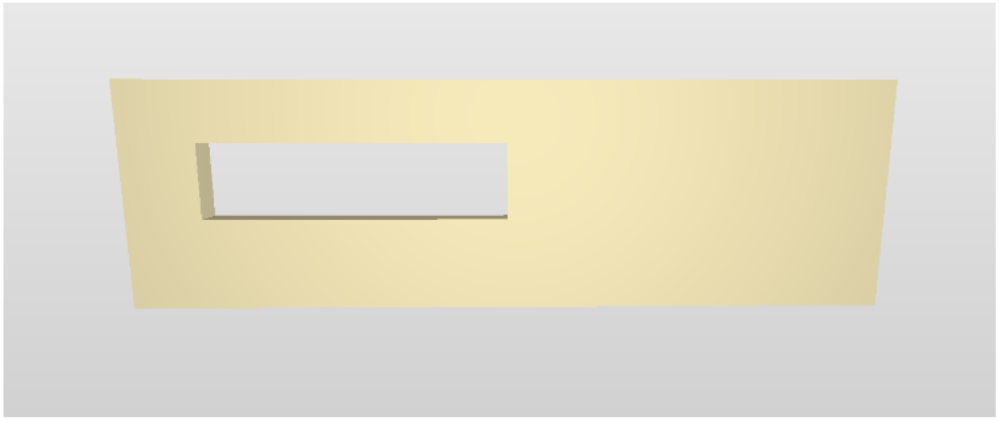
Now with extreme ease in python we can generate several elements: Walls, opening, Windows, floors and roofs.

```
MyModel = Model()

wall1 = wall(MyModel, "wall1", position = (1000.,1000.), axis1 =(0.,0.,1.), axis2= (1.,0.,0.))
wall1.createWall(10., 3., 0.3)

opening1 = opening(MyModel, wall1.theWall, (500., 500.), (0.,0.,1.), (1.,0.,0.))
opening1.createOpening(height=1., lenght=3., wall_thickness=0.3)

MyModel.ifcfile.write("MyModel.ifc")
```



Example of code and it´s result. Visualization in Solibri

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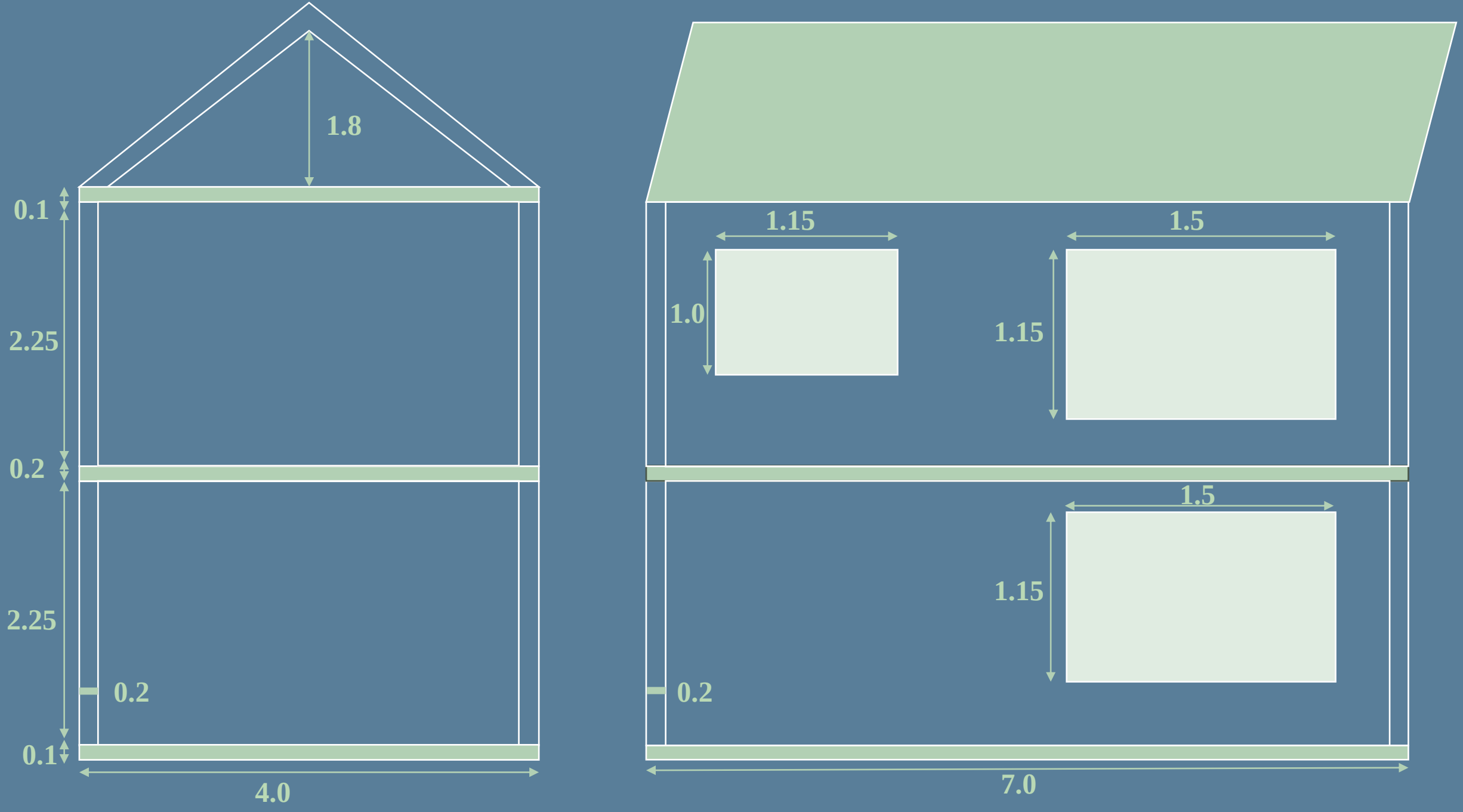
ILOOMI'S HOUSE EXAMPLE

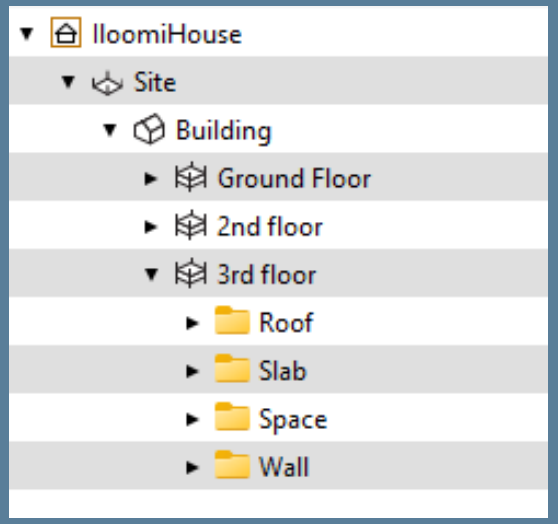
We will use the database information to retrieve the measurements of the house .

Then we will use the functions we developed to generate the 3D Model.

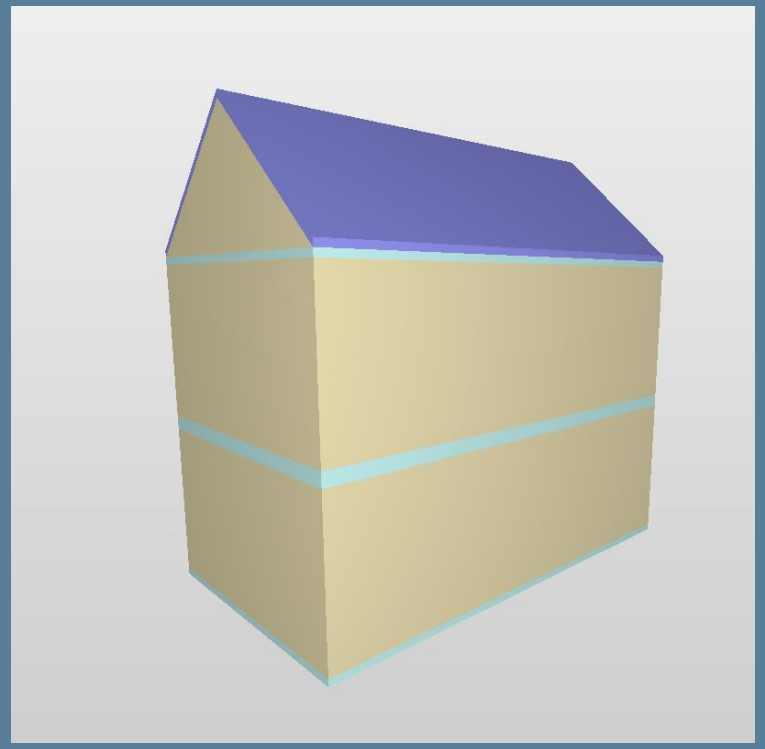
Test case by Iloomi. Photo taken on GoogleMaps


1.8
0.1
2.25
0.2
2.25
0.2
0.1
4.0
1.15
1.0
1.5
1.15
1.5
1.15
0.2
7.0

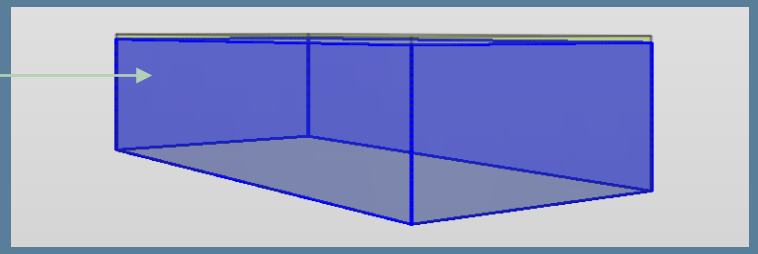
Visual results:



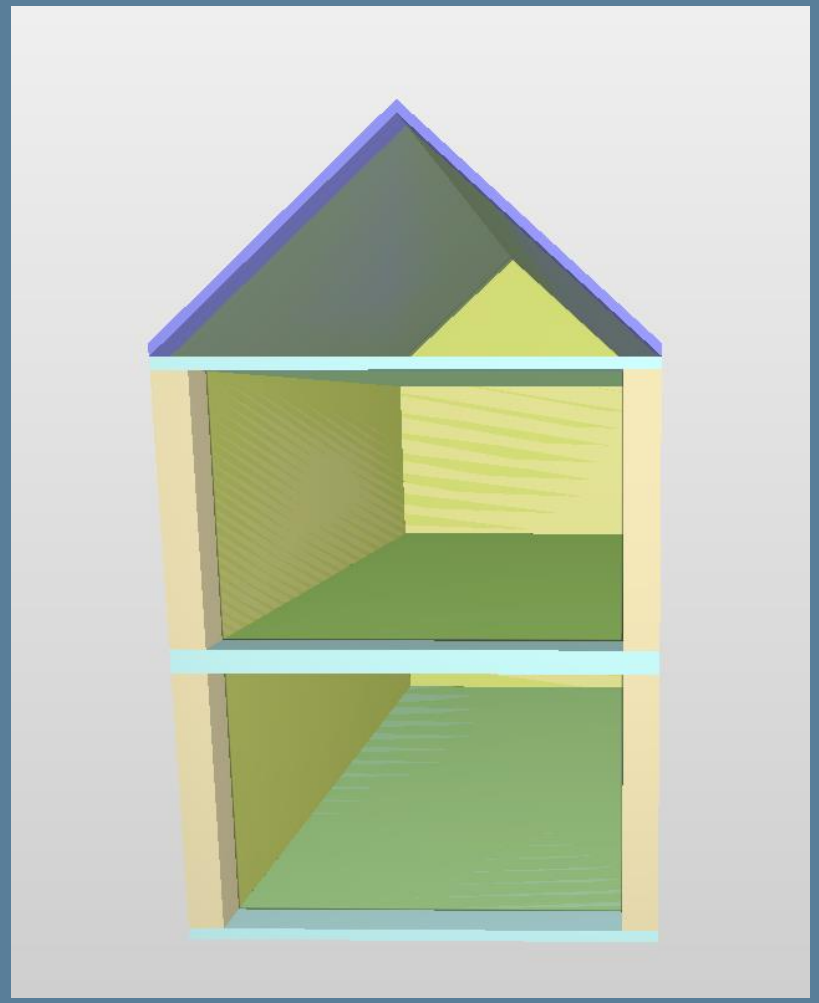
Iloomi house. Visualization in Solibri



Boundaries



IfcSpace. Visualization in Solibri

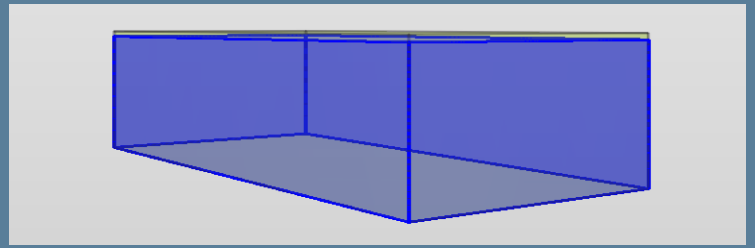


Modelica results

The Modelica file with the thermal zone is incomplete.

Problems arrive when we add the boundaries. If we do not put them, the model is generated only with the thermal zone, but not wall, slab or roof will appear.

We still working on the bug, and solution will come soon



Visualization of IfcSpace on Solibri

Component	Type	Area
Slab	Concrete Block 200	200.00 m2
Space Boundary	Undefined	200.00 m2
Wall	Concrete Block 200	228.00 m2

Boundaries of IfcSpace in Solibri

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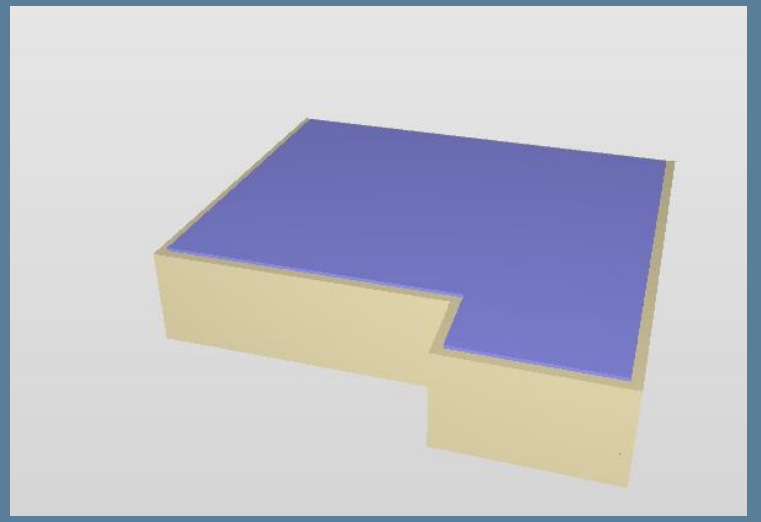
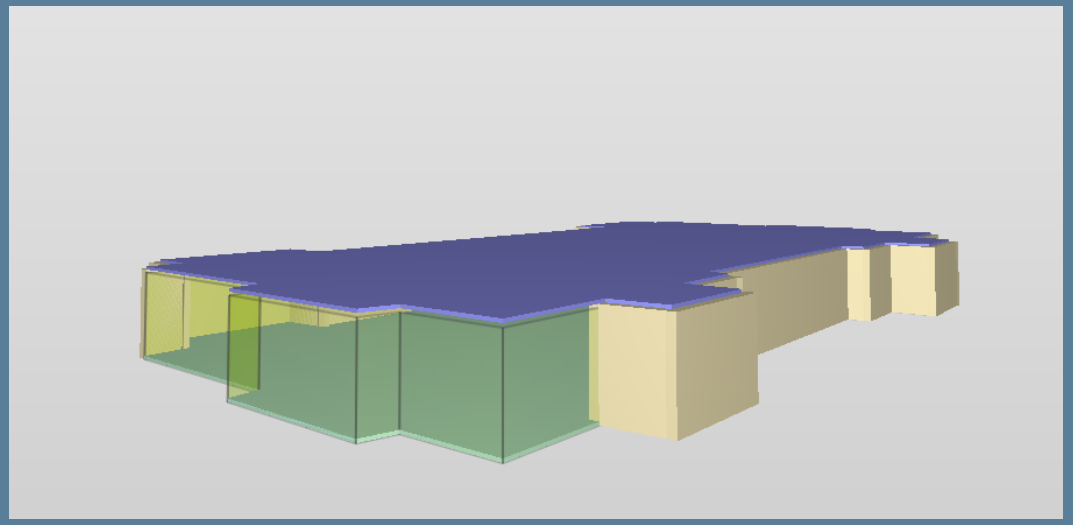
Automation

We generated several addresses automatically.

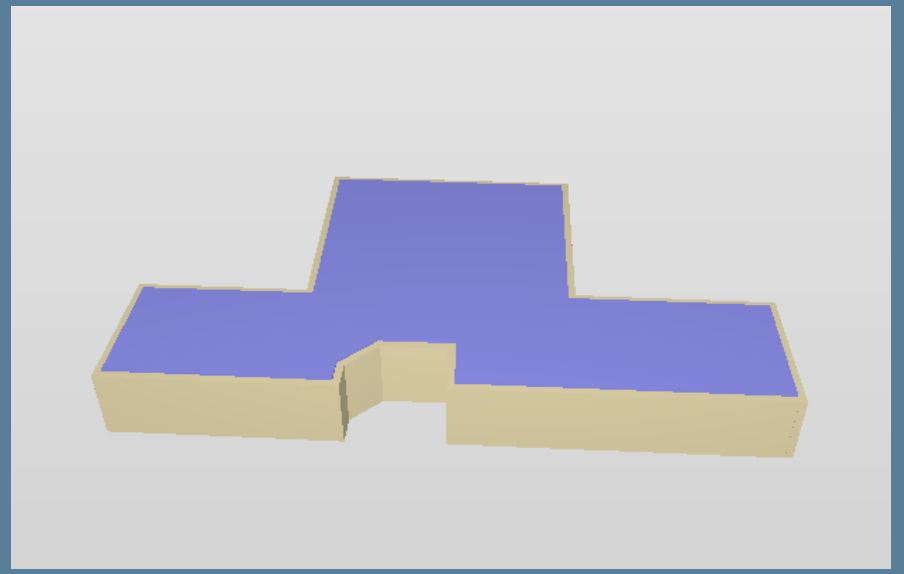
Elements are generated properly



42 avenue de la République, 44000 Nantes



59 chemin du Beulenwoerth



6 Rue Fizeau 75015 Paris

Conclusion & Perspective

- Generation of an Ifc file with all it's components
- Add a layer of abstraction on top of IfcOpenShell. And creating a set of functions to generate faster Ifc with code
- Automation of the process
- Go from an Ifc file to a modelica file. Compare the results of the iloomi report to our model

In the following days we will try to generate a proper modelica file with its components.

And find a way to join the bimeo files with the ifc generated with code.

Personal experience

Learning:

- I feel I got a better grasp on how GitHub works.
- The basics of Pytest
- A good understanding of the ifc structure, and the IfcOpenShell library

Difficulties

- The lack on documentation on the IfcOpenShell geometry model and entity creation.