IBPSA Project 1

IBPSA Project 1

Task 2: Building and City Quarter Models
WP 2.2: Building Information Modeling

Christoph van Treeck
Eric Fichter

IBPSA Project 1

Work Package 2.2 – Geometry Processing

Content

- **Space boundary** algorithms for model topology analysis and multi-scale simulation model generation
- **Update exchange** with BPS tools such as Energy Plus

Method

- **Review** of existing approaches, algorithms, codes and model checkers
- Evaluation of **best-in-class algorithms** for model-garbage analysis and processing
- Decision on **development path** and code re-use
- Development of **modular tools** for space boundary and model topology analysis

Result

- Joint journal **publication** / review paper
- **GIT repository** with
  - modular tools
  - test models

Suggestions from the Coordination Meeting, 10 July 2018

Geometry

- Reading and **parsing IFC** and dealing with this information
- **Full access** to geometry and topology
- **Separation** of geology and topology as long as possible
- Creation of **connection graphs** between objects
- **Manipulation** of geometry:
    - Reduction of level of detail and complexity
    - Finding relations between room and spaces based on topology only
- In the end discussing about **space boundaries**

Suggestions from the Coordination Meeting, 10 July 2018

General

- Review of **state of the art** (Annex 60, SBT, …)
- Testing libraries based on **IFC files**
- **Authoring tools** don't matter at this point
- Different **setup test cases**, from easy to complex
- as well, constructing an example with **all building related entities** available in IFC
- **Sharable IFC-examples** stored in Git
- Creation of an open source '**Sharable Environment** Team'

Current Tasks

Today's Agenda

- **Team structure**, active developers, commitment of resources

- Determination of tools and software **development environment** for model parsing, visualization and analysis

- **Consensus** on overall process of geometry reading and processing, BRep transformation, decomposition and space boundary generation

Current Tasks

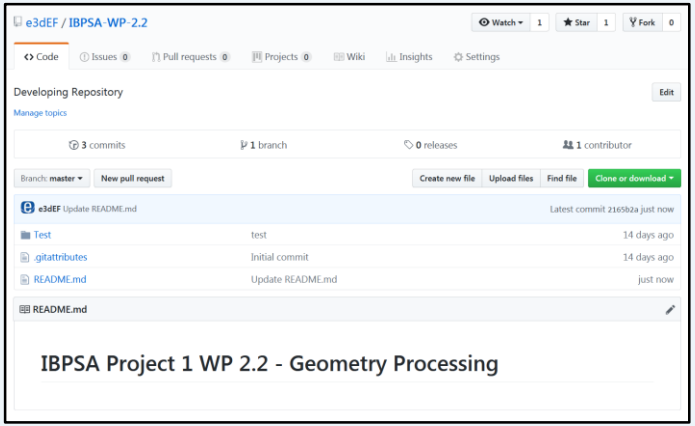
Open Source Sharable Environment Team (@2018-10-01 10:00:00 am ;-)

- E. Fichter **(RWTH Aachen)**
- C. Waluga **(LiNear)**
- J. O'Donnell **(University College Dublin)**
- J. Lin **(Tsinghua University)**
- G. Giannakis **(Technical University of Crete)**
- V. Bazjanac **(Stanford University)**

Current Tasks

Open Source Sharable Environment Team

- E-Mail Distribution List
- Git Repository IBPSA-WP-2.2
  (Contact Eric Fichter)



Current Tasks

Testing Team

- K.-H. Häfele **(Karlsruhe Institute of Technology)**
- Whoever wants to join …

To Do's

Whole Team

- Review of space boundary algorithms
- Summary of algorithms in a joint publication
- Clarification of conditions/constraints within the BIM to SIM workflow (level of detail, objects of interest, design requirements for IFC, etc.)

To Do's

Whole Team

- Define the working environment
- Setup the working environment
- Testing basic geometrical and topological explorer algorithms

Testing Team

- Providing an IFC example file with all available entities
- Providing further IFC examples from easy to complex

IBPSA Project 1

Break-Out

Task 2: Building and City Quarter Models
WP 2.2: Building Information Modeling

Christoph van Treeck
Eric Fichter

IFC Libraries

IFC libraries supporting IFC versions 2x3 and 4 as well as extraction of geometric data

Library	Language	License	Modeling kernel
IfcOpenShell	C++, Python	LGPL, Open source	OpenCascade
IfcPlusPlus	C++	MIT, Open source	OpenSceneGraph
IFC Engine DLL	C++	AGPL, Closed Source	Embedded
xBIM Toolkit	C# (C++)	CDDL, Open Source	OpenCascade
apstex IFC Framework (IFC Tools Project)	Java	Free for research	Embedded
Not usable: STEPcode, JSDAI, pythonifc, ifcsdk, GeometryGymIFCExamples, IfcScript, Ifc-dotnet			

Sharable Environment Team: J. Lin - "IfcOpenShell, IFC Engine, XBIM"

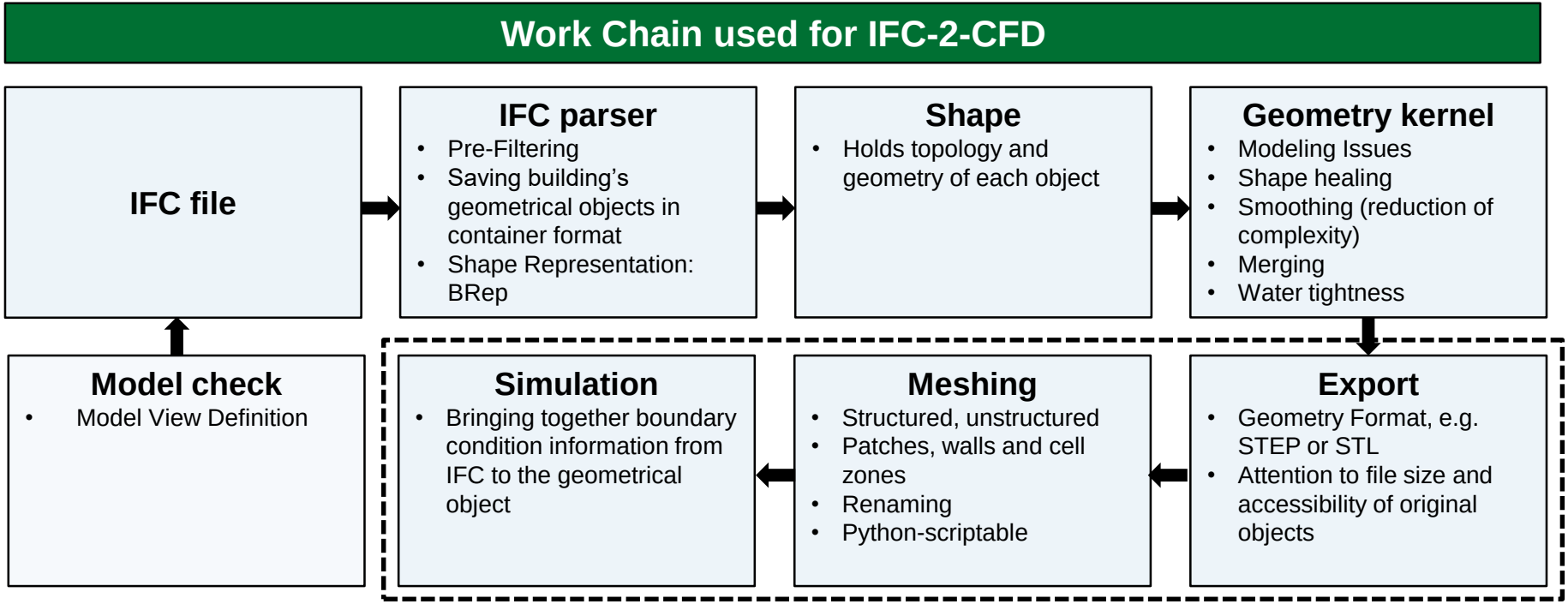
Geometric Modeling Kernel

Most popular kernels licensed for more than one CAD software

Library	License
ACIS	Proprietary
C3D	Proprietary
Parasolid	Proprietary
OpenCascade	LGPL, Open source
pythonOCC (OpenCascade wrapper)	LGPL, Open source
Further suggestions?	
One software only: Catia, Granite, Shape Manager (Autdesk, based on ACIS)	

Coordination Meeting: K. Häfele "Open source backup kernel"

Tool Chain

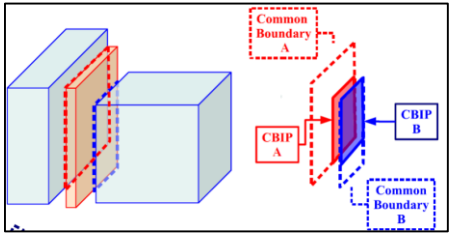

Work Chain used for IFC-2-CFD
IFC file
IFC parser
• Pre-Filtering
• Saving building's geometrical objects in container format
• Shape Representation: BRep
Shape
• Holds topology and geometry of each object
Geometry kernel
• Modeling Issues
• Shape healing
• Smoothing (reduction of complexity)
• Merging
• Water tightness
Model check
• Model View Definition
Simulation
• Bringing together boundary condition information from IFC to the geometrical object
Meshing
• Structured, unstructured
• Patches, walls and cell zones
• Renaming
• Python-scriptable
Export
• Geometry Format, e.g. STEP or STL
• Attention to file size and accessibility of original objects

Space boundary algorithm without graphs

G.N. Lilis et al., Automatic generation of second-level space boundary topology from IFC geometry inputs, Automation in Construction (2016), http://dx.doi.org/10.1016/j.autcon.2016.08.044

Common Boundary Intersection Projection Algorithm

- Parsing: Classification stage of geometrical entities of interest (walls, windows, …) to *Constructions*, *Openings* and *Volumes*
- BRep: Boundary Surface Extraction (BSE) of Constructions (IfcProduct) and Opening Construction Subtractions of Openings
- Common Faces: Common Boundary Intersection of different combinations (e.g. shared face of Construction and Opening) using Clipping functions
- 2nd level space boundaries: Boundary Intersection Projection

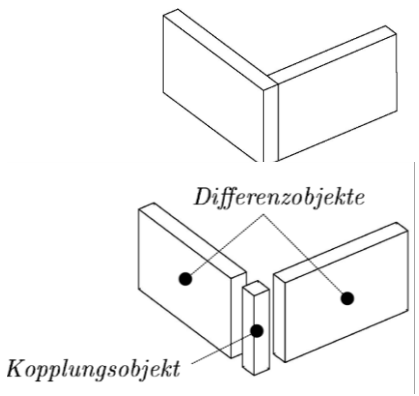


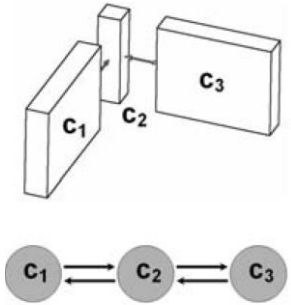
- Save in IFC file: IfcRelSpaceBoundary2ndLevel

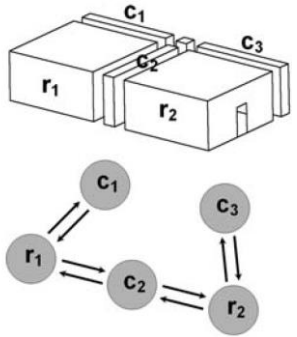
Space boundary algorithm with graphs

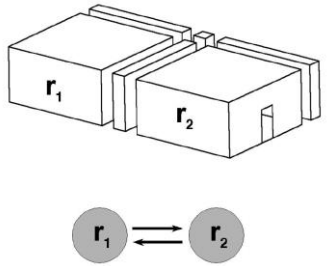
C. Van Treeck: Dissertation. Gebäudemodell-basierte Simulation von Raumluftströmungen

Boolean Operation	Component graph	Object graph	Room Graph









IfcOpenShell

IfcOpenShell
the open source ifc toolkit and geometry engine

Parsing

▼ IfcProject	0NZEjs0C1…	Projektnummer
▼ IfcSite	2$Rp4l1Vn…	Oberfläche:817241
▼ IfcBuilding	0NZEjs0C1…	
▼ IfcBuildingStorey	0NZEjs0C1…	-01_OKFD
IfcColumn	0xjJbAECb…	IPE-Stütze:IPE550:799602
IfcWallStandardCase	00kSc73mv…	Basiswand:Fertigteilsockel 25:808252
IfcWallStandardCase	00kSc73mv…	Basiswand:Fassade 25:808253
IfcSlab	3SPxLeY$L…	Sohle:Magerbeton_50:817250
IfcFooting	0P_lGFhfrE…	Wandfundament:Wandfundament:9…
IfcFooting	0P_lGFhfrE…	Wandfundament:Wandfundament:9…
IfcSlab	3rcs$yJHj6…	Sohle:Magerbeton_50:940185
IfcWallStandardCase	0IMUoRRL…	Basiswand:STB 25.0:940862
IfcWallStandardCase	0IMUoRRL…	Basiswand:STB 25.0:940955
IfcSlab	0IMUoRRL…	Geschossdecke:FB Halle 1:941048
IfcWallStandardCase	18221KPlz…	Basiswand:Fertigteilsockel 25:942996
▼ IfcWallStandardCase	18221KPlz…	Basiswand:Fassade 25:942997
IfcOpeningElement	0Ou9idlcvF…	Basiswand:Fassade 25:942997
IfcFooting	18221KPlz…	Wandfundament:Wandfundament:9…
IfcFooting	18221KPlz…	Wandfundament:Wandfundament:9…
IfcSlab	23kaYs_A1…	Sohle:Magerbeton_50:961353
IfcSlab	3ciFeWklH…	Sohle:Magerbeton_50:962150
IfcSlab	3ciFeWklH…	Sohle:Magerbeton_50:962660
▼ IfcBuildingStorey	0NZEjs0C1…	00_UKFB
▼ IfcWallStandardCase	00kSc73mv…	Basiswand:Fertigteilsockel 25:807998
IfcOpeningElement	0_OGQHB…	Basiswand:Fertigteilsockel 25:807998
IfcOpeningElement	0_OGQHB…	Basiswand:Fertigteilsockel 25:807998
IfcOpeningElement	0_OGQHB…	Basiswand:Fertigteilsockel 25:807998
▼ IfcWallStandardCase	00kSc73mv…	Basiswand:Fassade 25:807999
IfcOpeningElement	2orxNh93r…	Basiswand:Fassade 25:807999
IfcOpeningElement	24R2qa3Oj…	Basiswand:Fassade 25:807999
IfcOpeningElement	2NUvn9y39…	Basiswand:Fassade 25:807999
IfcOpeningElement	0_OGQHB…	Basiswand:Fassade 25:807999
IfcWallStandardCase	00kSc73mv…	Basiswand:Fertigteilsockel 25:808094
▼ IfcWallStandardCase	00kSc73mv…	Basiswand:Fassade 25:808095
IfcOpeningElement	1UCMr2B1…	Basiswand:Fassade 25:808095
IfcOpeningElement	3iTppyQy9…	Basiswand:Fassade 25:803892
IfcWallStandardCase	00kSc73mv…	Basiswand:Fertigteilsockel 25:808355
▼ IfcWallStandardCase	00kSc73mv…	Basiswand:Fassade 25:808356
IfcOpeningElement	0_OGQHB…	Basiswand:Fassade 25:808356
▼ IfcWallStandardCase	18221KPlz…	Basiswand:Fertigteilsockel 25:941559
IfcOpeningElement	0b1aWiS0r…	Basiswand:Fertigteilsockel 25:941559
IfcOpeningElement	1lRkr4dcH2…	Basiswand:Fertigteilsockel 25:941559
IfcOpeningElement	3Z0EzVL8f…	Basiswand:Fertigteilsockel 25:941559
IfcOpeningElement	3f_bvwEiLC…	Basiswand:Fertigteilsockel 25:941559
IfcOpeningElement	3zjK8uvLn…	Basiswand:Fertigteilsockel 25:941559

Pset_WallCommon
- **ThermalTransmittance**: 0.625 *(IfcThermalTransmittanceMeasure)*
- **LoadBearing**: False *(IfcBoolean)*
- **IsExternal**: True *(IfcBoolean)*
- **Reference**: b'Fassade 25' *(IfcIdentifier)*
- **ExtendToStructure**: False *(IfcBoolean)*

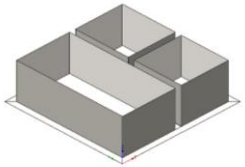


Figure 133 — Space boundary at first level

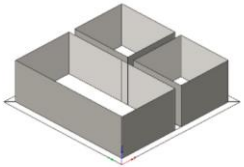


Figure 134 — Space boundary at second level

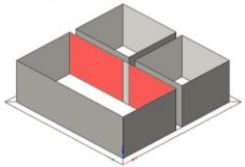


Figure 135 — Space boundary at second level type A

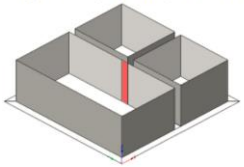


Figure 136 — Space boundary at second level type B

- Direct and inverse attributes callable

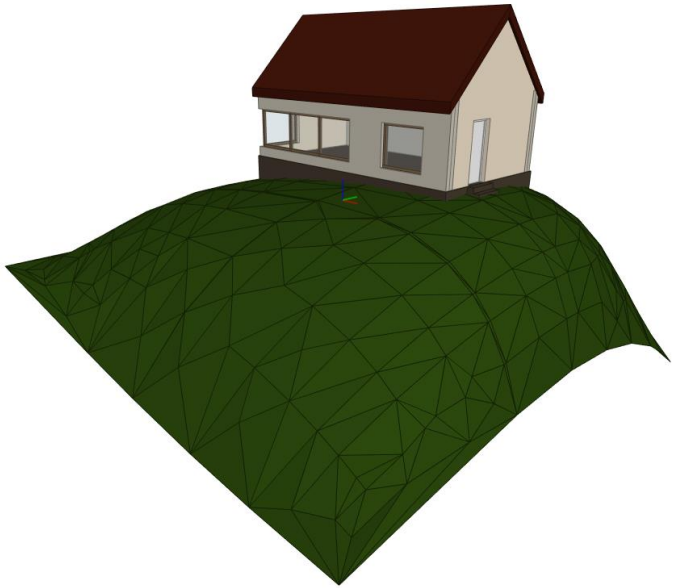
```
#76511=IfcRelSpaceBoundary('0F8DHwVIWaA92A8pankadM',#12,'2ndLevel','2a',#20909,#15042,#76510,.PHYSICAL.,.INTERNAL.)
#15042=IfcWallStandardCase('2XPyKWY018sA1ygZKgQPtU',#12,'Wand-Int-ERDG-4',$,$,#14983,#15037,'BC6F0F70-6195',$)
#20909=IfcSpace('347jFE2yX7IhCEIALmupEH',#12,'4',$,$,#20819,#20904,'Schlafzimmer',.ELEMENT.,$,$)
```

IfcOpenShell

IfcOpenShell
the open source ifc toolkit and geometry engine

Writing to file

```
443         // This window will be placed at five locations within the building. A list of placements is
444         // created and is iterated over to create all window instances.
445         IfcSchema::IfcLocalPlacement::list::ptr window_placements (new IfcSchema::IfcLocalPlacement::list);
446         window_placements->push(file.addLocalPlacement(storey_placement, 2*-1770-430-930,   -45, 400));
447         window_placements->push(file.addLocalPlacement(storey_placement,   -1770-430-930,   -45, 400));
448         window_placements->push(file.addLocalPlacement(storey_placement,        -430-930,   -45, 400));
449         window_placements->push(file.addLocalPlacement(storey_placement,        3000-930,   -45, 400));
450         window_placements->push(file.addLocalPlacement(storey_placement, -4855+45, 885-930, 400, 0, 0, 1, 0, 1, 0));
451
452         for (IfcSchema::IfcLocalPlacement::list::it it = window_placements->begin(); it != window_placements->end(); ++it) {
453
454                 // Create the window at the current location
455                 IfcSchema::IfcLocalPlacement* place = *it;
456                 IfcSchema::IfcWindow* window = new IfcSchema::IfcWindow(guid(), file.getSingle<IfcSchema::IfcOwnerHistory>(),
457                         null, null, null, place, 0, null, 1600, 1860
458 #ifdef USE_IFC4
459                         , IfcSchema::IfcWindowTypeEnum::IfcWindowType_WINDOW
460                         , IfcSchema::IfcWindowTypePartitioningEnum::IfcWindowTypePartitioning_SINGLE_PANEL
461                         , null
462 #endif
463         );
464                 file.addBuildingProduct(window);
```



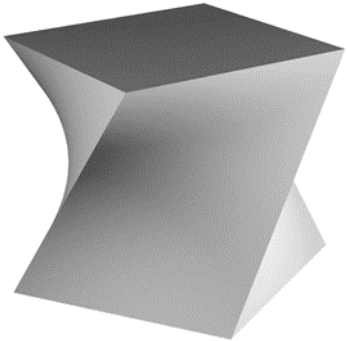
IfcOpenShell

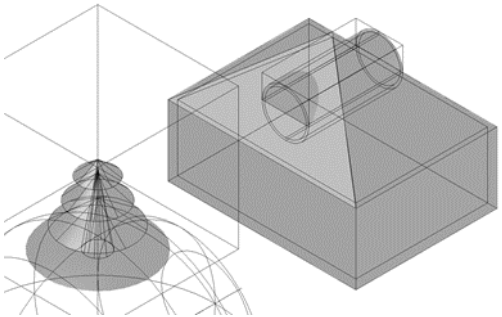
IfcOpenShell
the open source ifc toolkit and geometry engine

Geometry

Implemented Classes (state of 2016)

- IfcAdvancedBrep
- IfcAdvancedBrepWithVoids
- IfcAdvancedFace
- IfcAxis1Placement
- IfcAxis2Placement2D
- IfcAxis2Placement3D
- IfcBSplineCurveWithKnots
- IfcBSplineSurfaceWithKnots
- IfcBlock
- IfcBooleanClippingResult
- IfcBooleanResult
- IfcBoundaryCurve
- IfcBoundingBox
- IfcBoxedHalfSpace
- IfcCartesianPoint
- IfcCartesianPointList2D
- IfcCartesianPointList3D
- IfcCartesianTransformationOperator2D
- IfcCartesianTransformationOperator2DnonUniform
- IfcCartesianTransformationOperator3D
- IfcCartesianTransformationOperator3DnonUniform
- IfcCircle
- IfcClosedShell
- IfcCompositeCurve
- IfcCompositeCurveOnSurface
- IfcCompositeCurveSegment
- IfcConnectedFaceSet
- IfcCsgSolid
- IfcCurveBoundedPlane
- IfcCurveBoundedSurface
- IfcCylindricalSurface
- IfcDirection
- IfcEdge
- IfcEdgeCurve
- IfcEdgeLoop
- IfcEdgeCurve
- IfcEdgeLoop
- IfcEllipse
- IfcExtrudedAreaSolid
- IfcExtrudedAreaSolidTapered
- IfcFace
- IfcFaceBasedSurfaceModel
- IfcFaceBound
- IfcFaceOuterBound
- IfcFaceSurface
- IfcFacetedBrep
- IfcFacetedBrepWithVoids
- IfcFixedReferenceSweptAreaSolid
- IfcGeometricCurveSet
- IfcGeometricSet
- IfcHalfSpaceSolid
- IfcIndexedPolyCurve
- IfcLine
- IfcLoop
- IfcMappedItem
- IfcOffsetCurve2D
- IfcOffsetCurve3D
- IfcOpenShell
- IfcOrientedEdge
- IfcOuterBoundaryCurve
- IfcPath
- IfcPcurve
- IfcPlane
- IfcPointOnCurve
- IfcPointOnSurface
- IfcPolyLoop
- IfcPolygonalBoundedHalfSpace
- IfcPolyline
- IfcRationalBSplineCurveWithKnots
- IfcRationalBSplineSurfaceWithKnots
- IfcRectangularPyramid
- IfcRectangularTrimmedSurface
- IfcReparametrisedCompositeCurveSegment
- IfcRevolvedAreaSolid
- IfcRevolvedAreaSolidTapered
- IfcRightCircularCone
- IfcRightCircularCylinder
- IfcSectionedSpine
- IfcShellBasedSurfaceModel
- IfcSphere
- IfcStyledItem
- IfcSubedge
- IfcSurfaceCurveSweptAreaSolid
- IfcSurfaceOfLinearExtrusion
- IfcSurfaceOfRevolution
- IfcSweptDiskSolid
- IfcSweptDiskSolidPolygonal
- IfcTriangulatedFaceSet
- IfcTrimmedCurve
- IfcVector
- IfcVertex
- IfcVertexLoop
- IfcVertexPoint

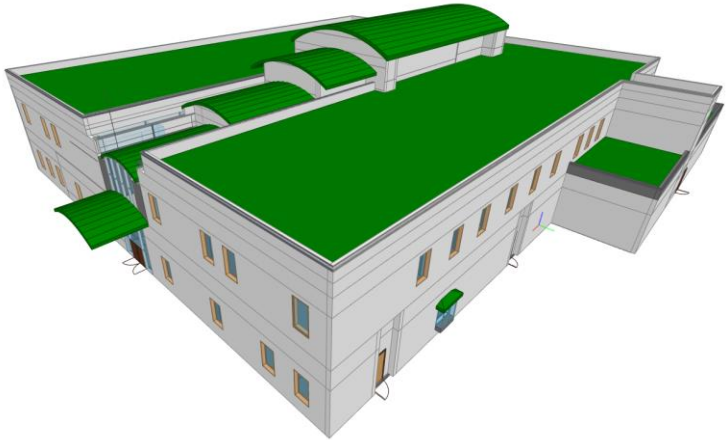




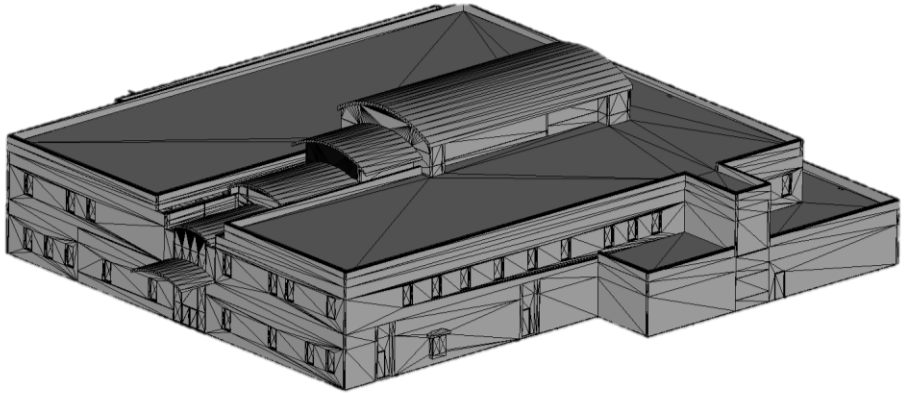
http://blog.ifcopenshell.org/

IfcOpenShell
the open source ifc toolkit and geometry engine

Some basic conversion tests to other file formats (.obj, .stp, .igs)



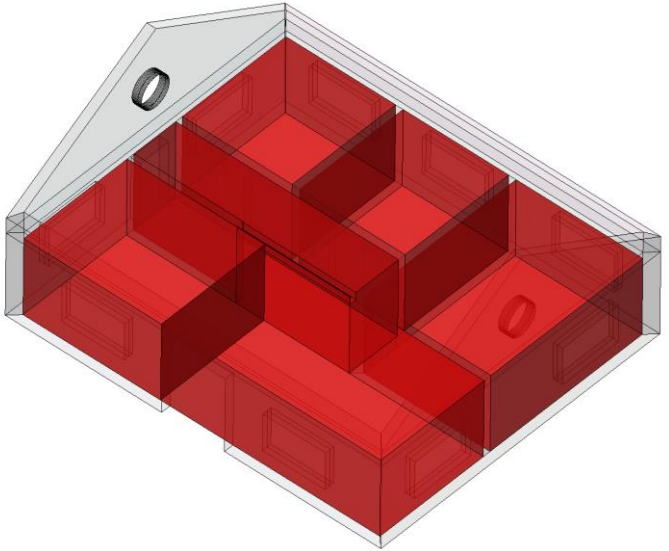
IFC file | .ifc



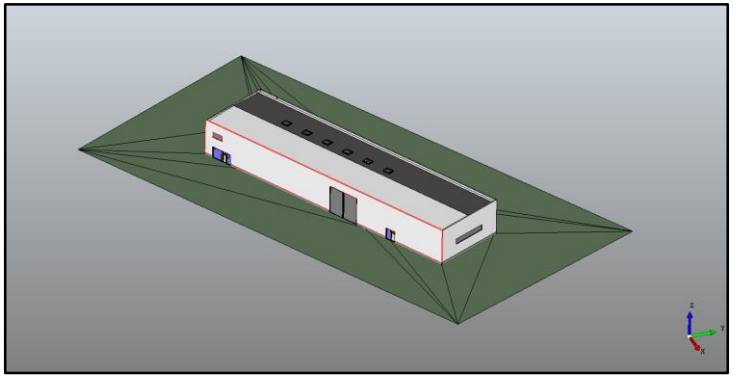
Object File | .obj

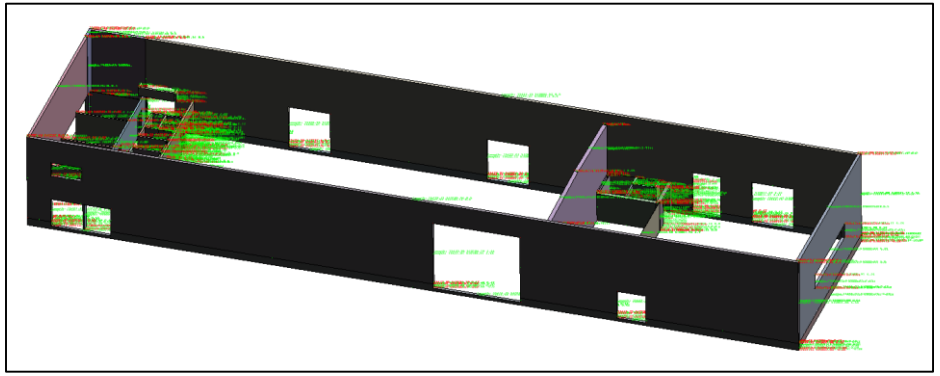
Creation of Brep Shapes

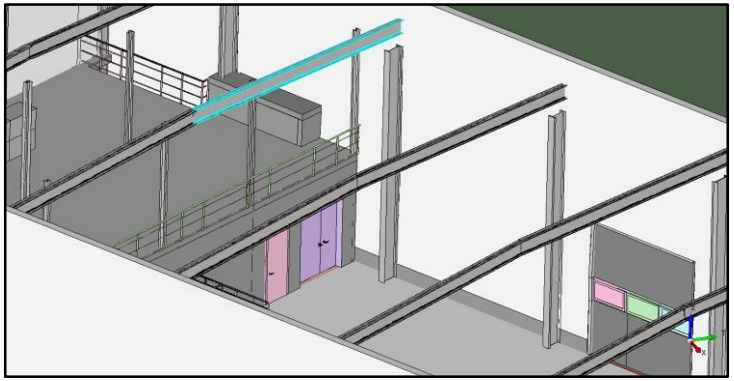
- Shapes can be created for further use in OpenCascade, also for abstract represantions as IfcSpaces
- There are some options to include e.g. IfcConnectedFaceSets or IfcOpeningElement

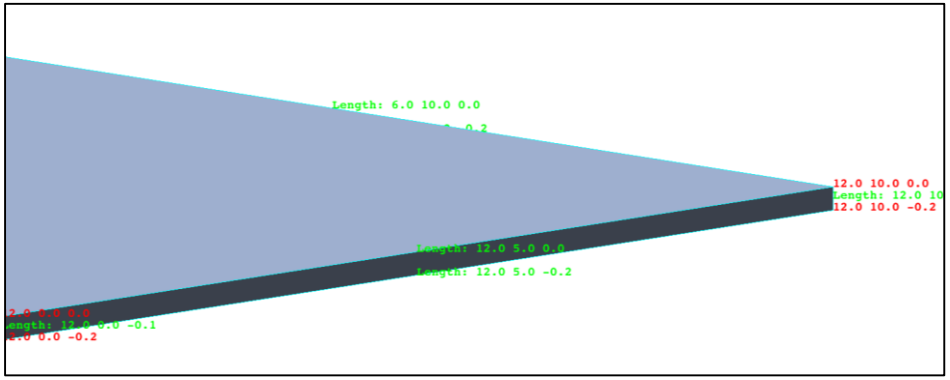


Geometrical Information









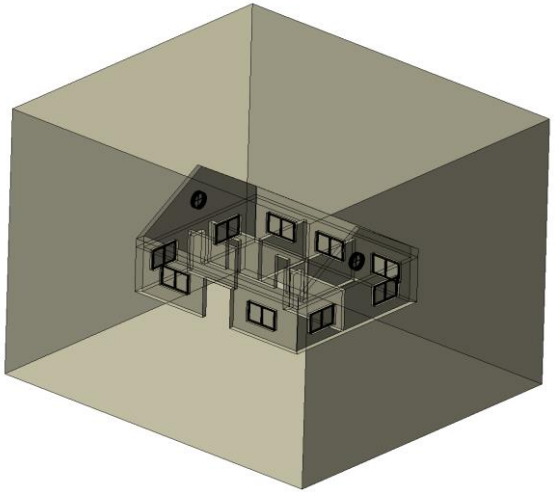
Geometrical Smoothing and product filtering

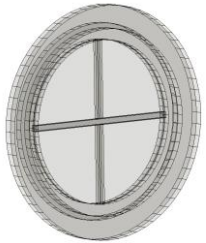
Needs to be done for high performance and speed as well as robustness

- IFC file:
  - Filtering using IfcOpenShell (semantical data, hierarchy of IFC file)
  - …
- Geometry:
  - Oriented bounding box
  - ...

Boolean Operations

- Boolean Operations, which allow creating new shapes from the combinations of source shapes. For two shapes *S1* and *S2*:
  - *Common* contains all points that are in *S1* and *S2*;
  - *Fuse* contains all points that are in *S1* or *S2*;
  - *Cut* contains all points in that are in *S1* and not in *S2*

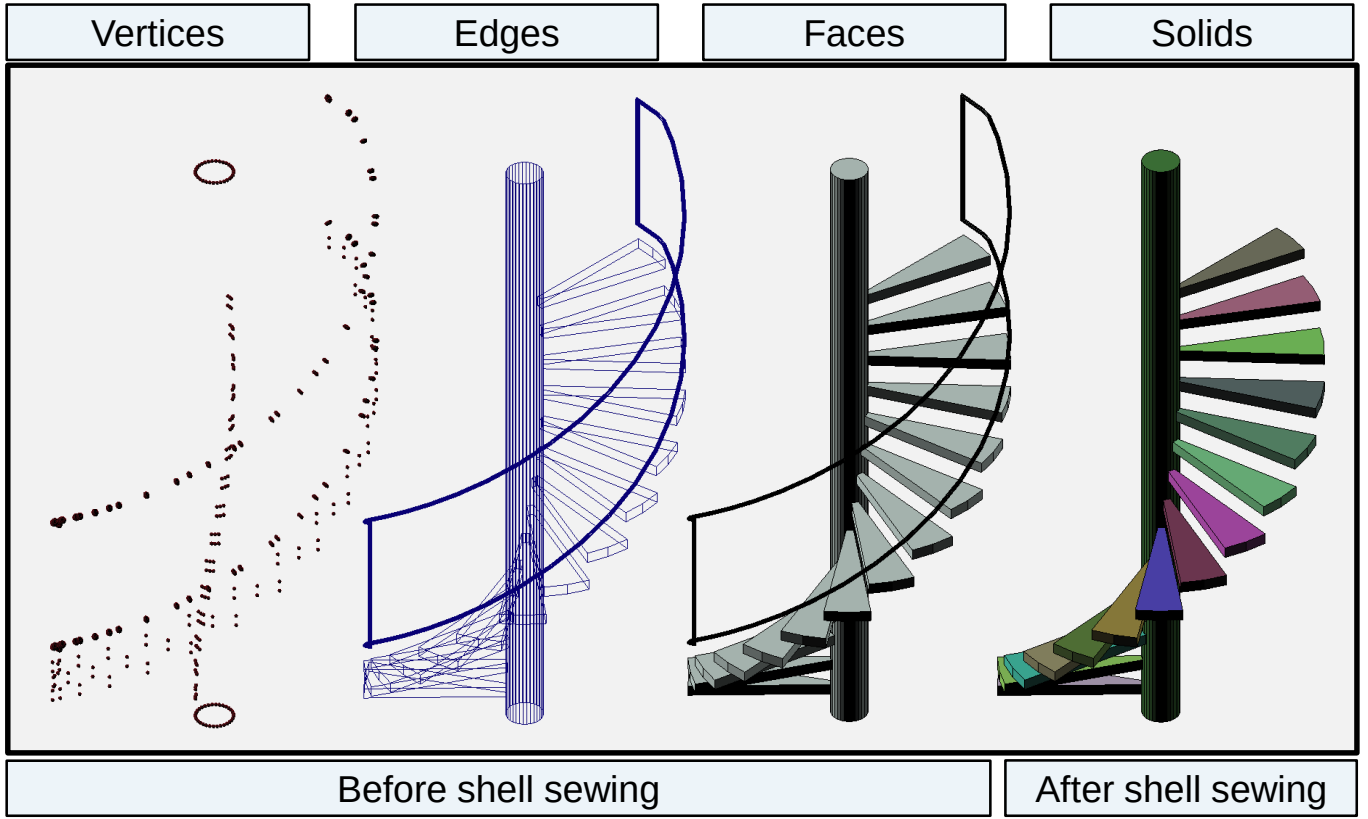




- Negative of walls and windows
- Fail for non-sewed shells

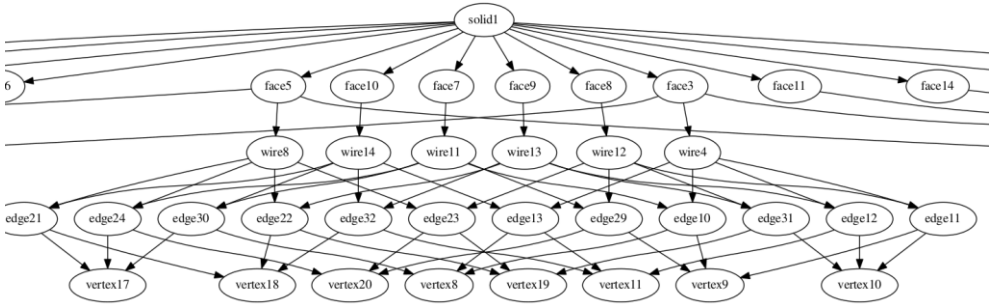
Topological Elements

- Staircase and its topological elements

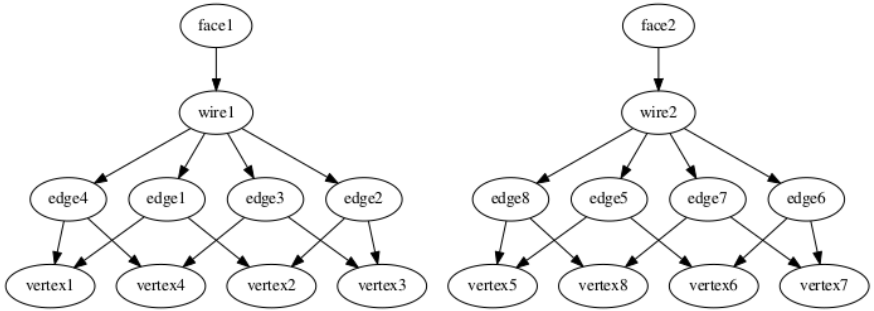


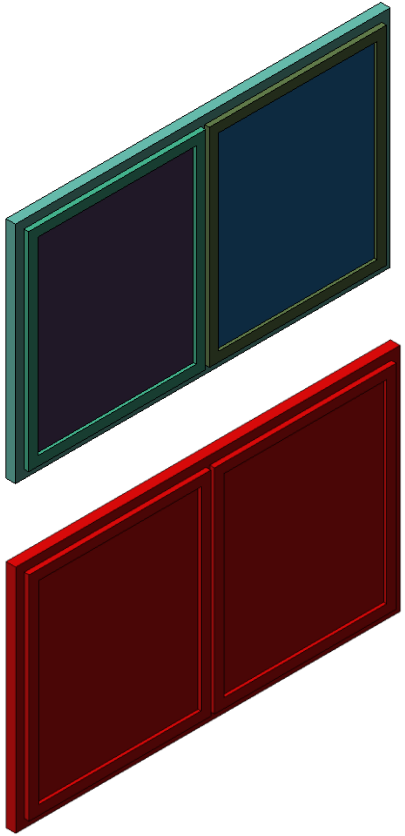
Sew shells

Sewed shells
66 faces
156 edges



Unsewed shells
66 faces
312 edges





Tests

- Connection between building elements using *fuse* and check for *intersection*