# On shape and its semantics in BIM

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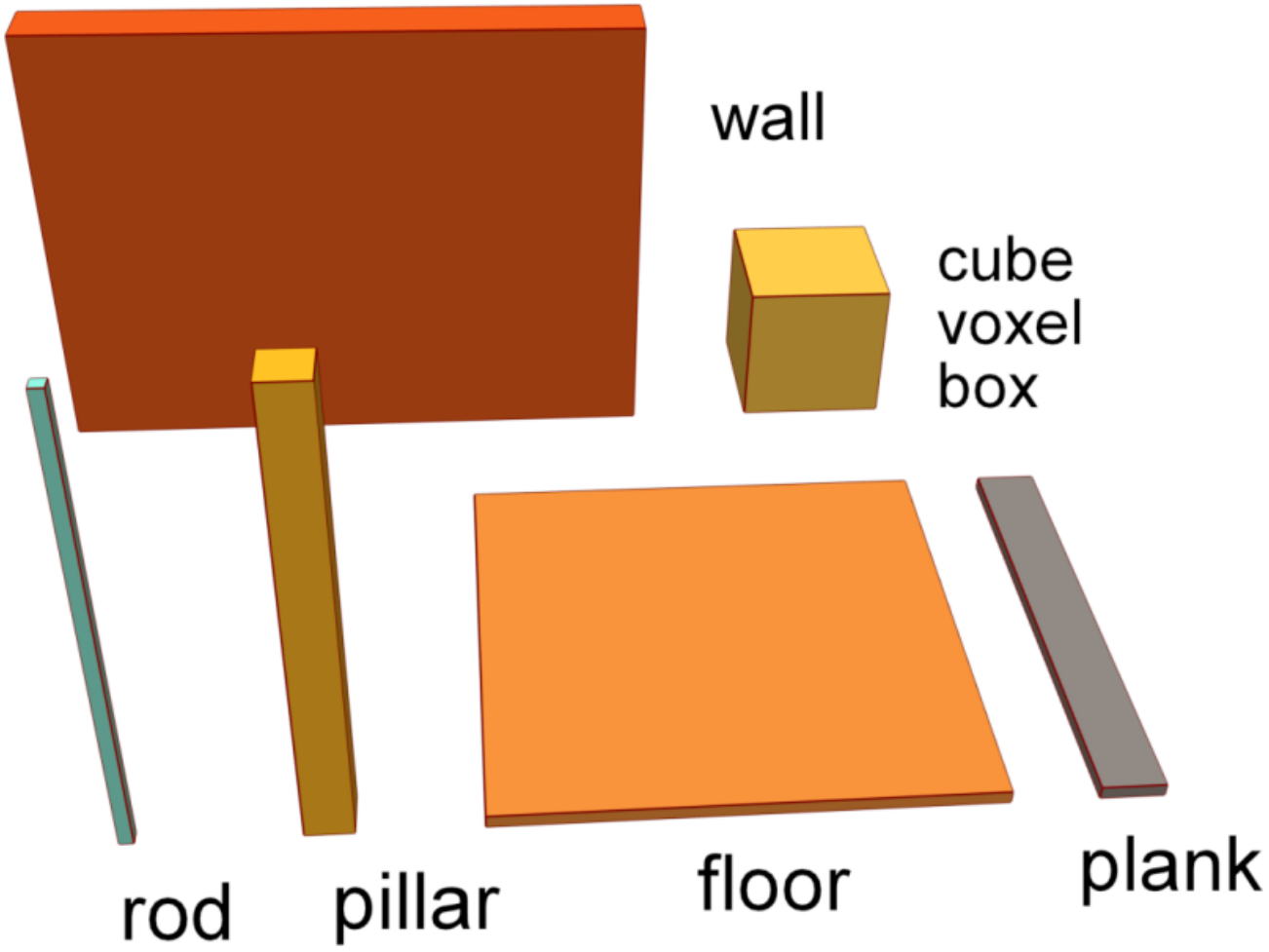
# Background: Visual Computing

- „The objective of Visual Computing is to obtain an *editable* digital representation of the real world.“

  Hans-Peter Seidel (MPI Saarbrücken)

- Editable: What are suitable DoFs?
  - 3D from measuring (sampling)
  - 3D from 3D modeling (digitally born)
- Re-parametrization problem:
  20 ways to parameterize a box...

# Boxes have many roles – same data, different semantics



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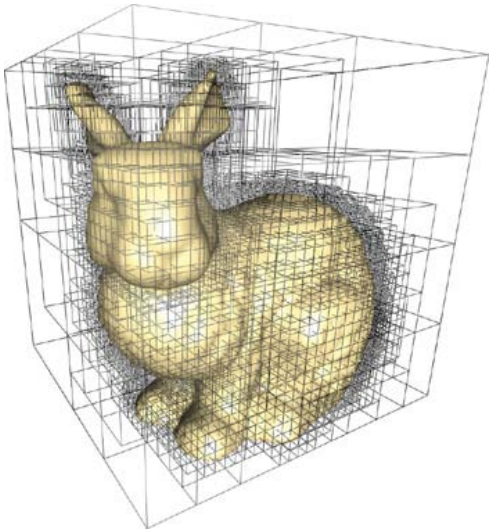
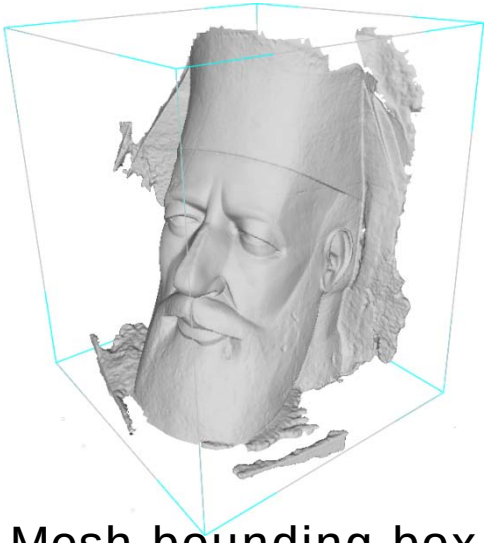
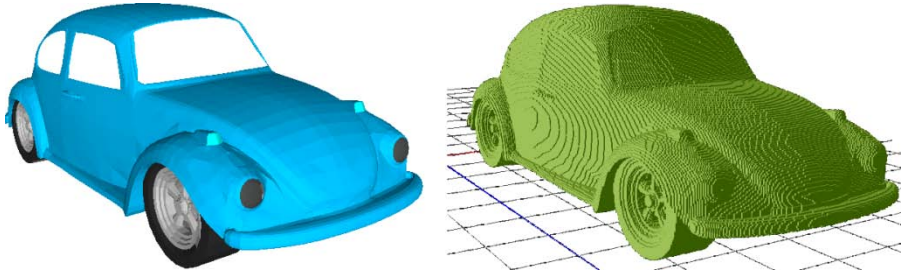


Octree from
GPU Gems 2



Mesh bounding box
(Arc3D / Meshlab )

Voxel worlds from Minecraft

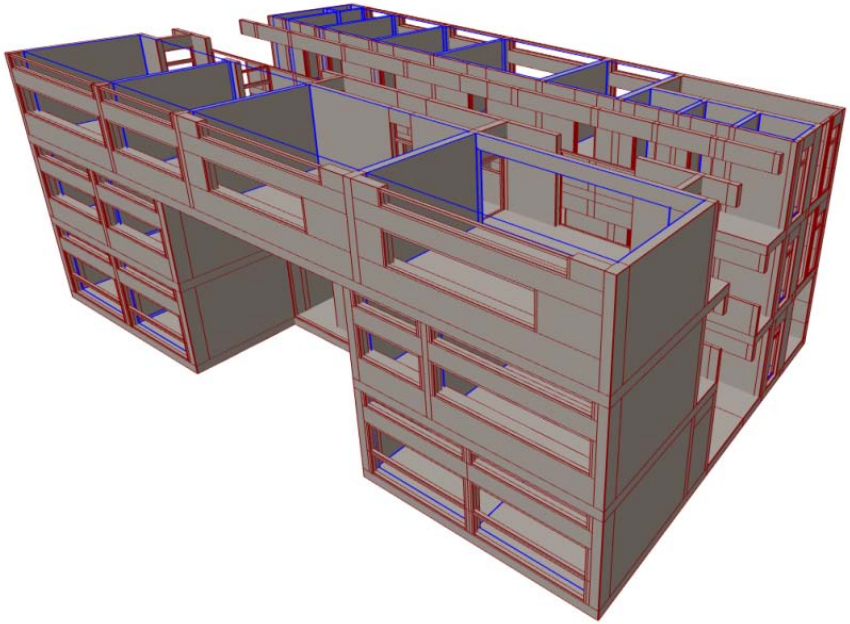


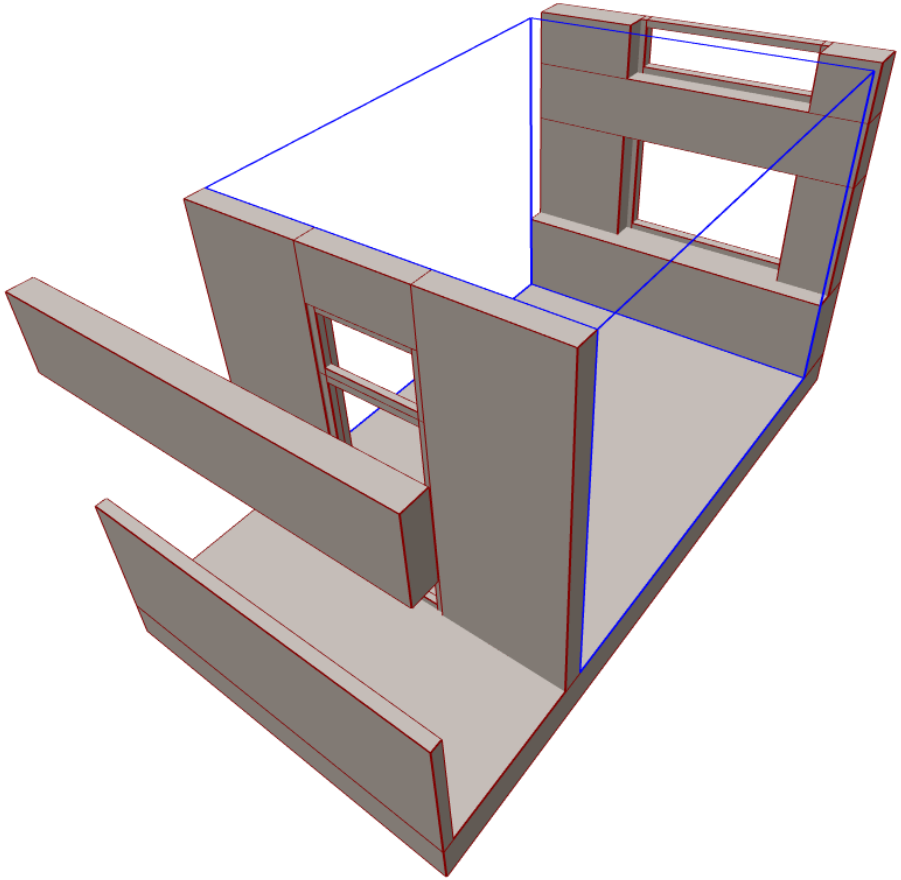
Voxelizer used in METADESIGNER

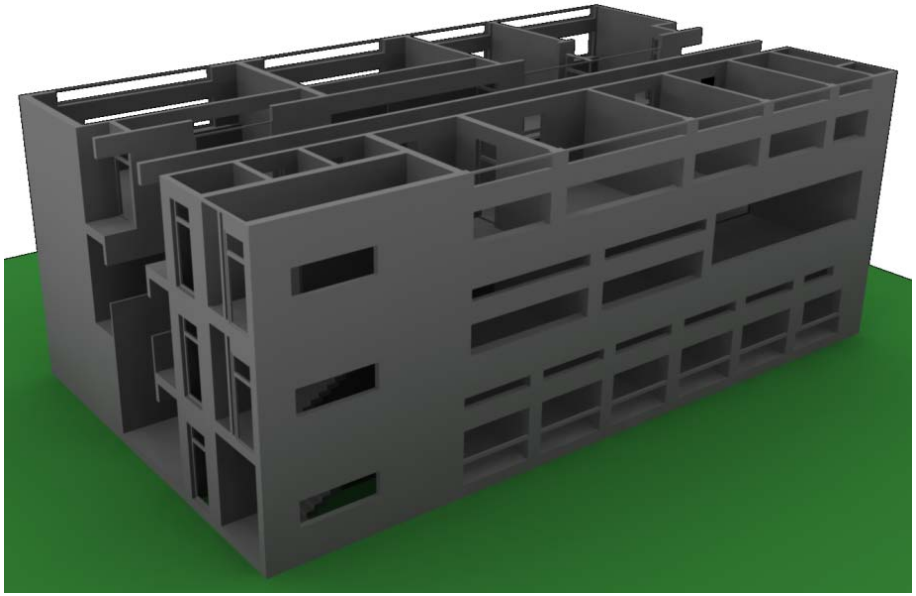
# Attempts to formalize a Box

- Numerous possible parametrizations
  - 20 ways to parameterize a box…
  - (pMin,pMax) or (pCenter,rad), …
- Box in general position:
  6+3 = 9 degrees of freedom (DoF)
  - Minimal but not convenient
- Better but with 4×3 + 3×2 = 18 DoF:
  $(p,e_x,e_y,e_z,(x_0,x_1),(y_0,y_1),(z_0,z_1))$
- An unsolvable problem in standardization!

# Living in a Box



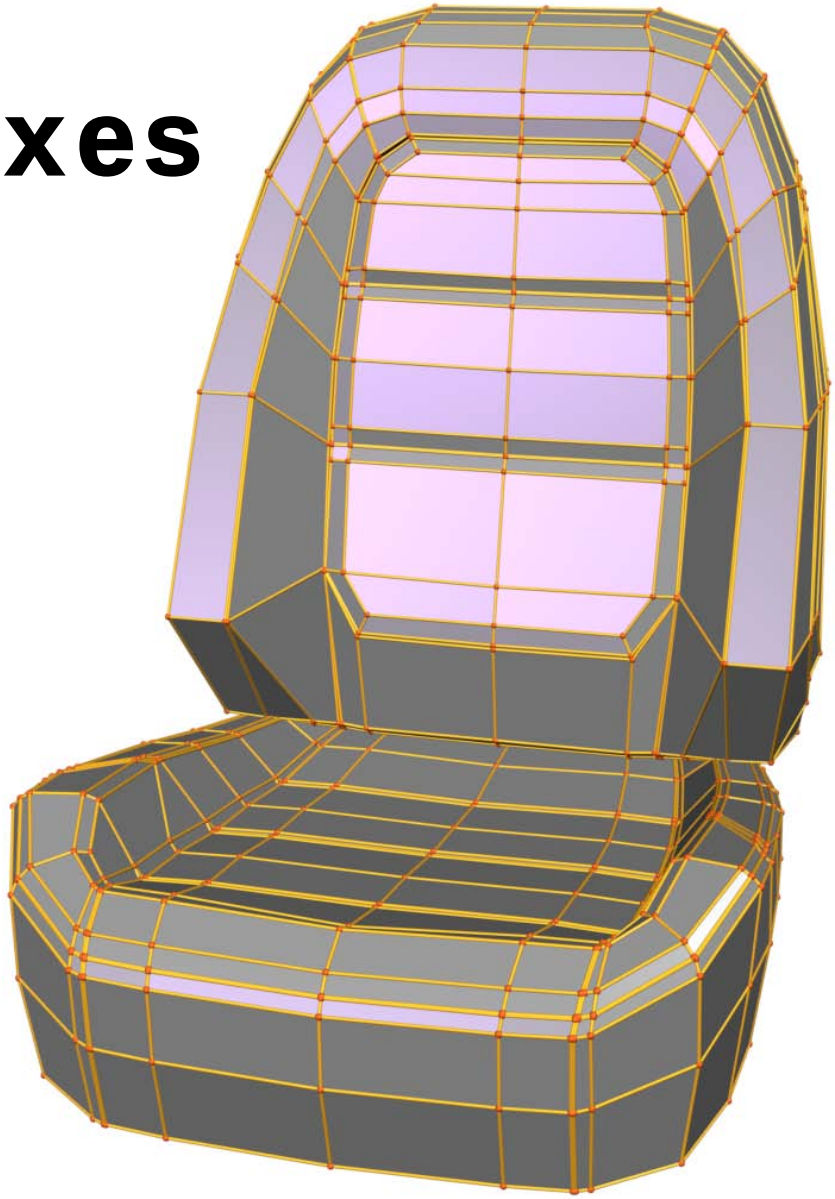




# Thinking beyond the Box

# High-quality Boxes

- Faces are
  - mostly planar
  - nearly rectangular
- High quality control meshes are
  - extremely regular
  - as sparse as possible



Malte Schult, Volkswagen AG

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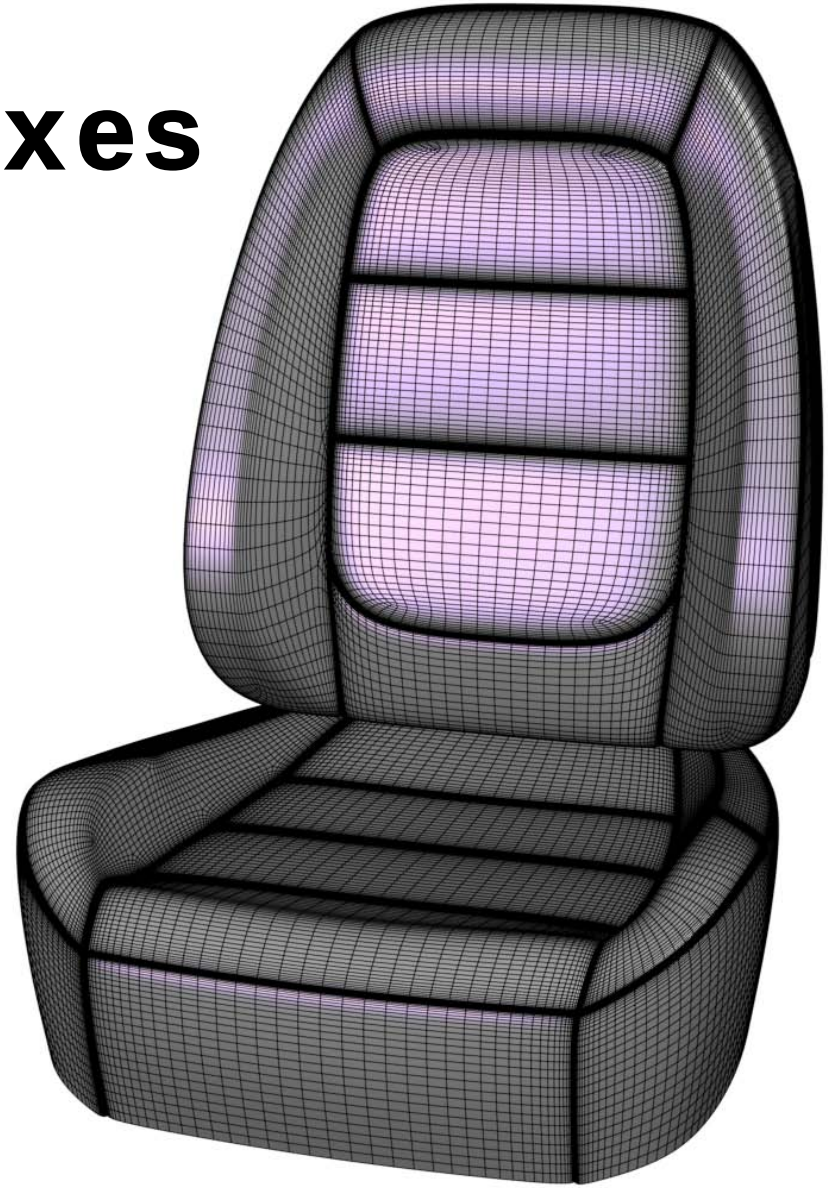

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# The Role of Semantics

- **Information = Data + Semantics**
- **Data**: Bit stream
- **Semantics**: Meaning of the bits

- Esoteric? – No!
- Semantic gap: „The meaning of x“
  - `int x;`
  - `double x;`
  - `string x;`

# The Role of Semantics

- **Data** is indisputable fact
- **Semantics** is (usually) interpretation
  - $0.000\overline{1100}_{\text{binary}}$ interpreted as $0.1_{\text{decimal}}$
- Typical approach: Obtain “precise” semantics through formalization
  - E.g., mathematical notation
- But often this only shifts the problem
  - E.g., XML specifies syntax, not semantics

# Variability of Semantics

- Variable vs. invariable semantics
  - „this number is an integer“
  - „this object is a chair“
- Shape modeling: much variability!
- „Semantics as a view“ approach
  - Semantics not inherent part of an object, but only attributed to an object
- Consequence: Switch the 3D-model on the fly, depending on semantic view

# What is BIM?

- **Building Information Modeling**
- Def: BIM is PDM+PLM for buildings
  - **PDM**: Product Data Management
  - **PLM**: Product Lifecycle Management
- BIM is an integrated data repository
  - for building design, simulation, construction, and maintenance
  - to share data with all the stakeholders consistently and sustainably (60+ years)

# What is BIM?

- Building Information Modeling is much more than CAD drawings
  - Bid and contract documents
  - Price lists, Bills of Materials (BOMs)
  - Specifications
  - Cable lists and labels
  - Timelines and Project management
  - Installation and maintenance guides
  - … (growing)

# Why should ISPRS care about BIM?

www.CityGML.org

- From remote sensing to urban reconstruction
  - 20+ years of city modeling...
- Still unsolved research questions:
  1. Quality metric for urban reconstruction: How good is a 3D city model?
  2. Comparison of urban reconstructions: Is city model A better than city model B?
- Hard to measure progress of the field!

# CityGML-based businesses – small but growing sector

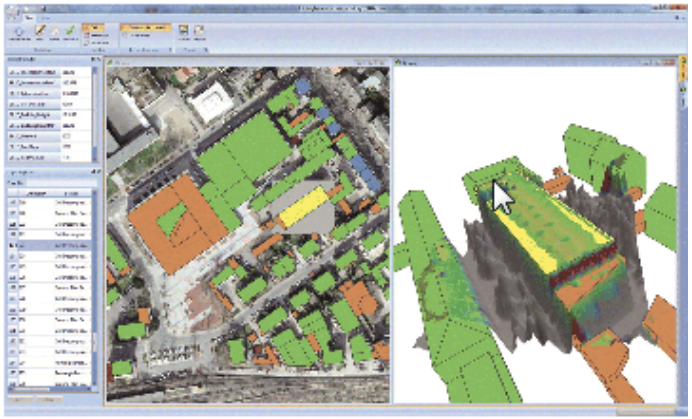
Example: http://www.virtualcitysystems.de

virtualcitySYSTEMS

COMPANY SOLUTIONS PRODUCTS TRAINING REFERENCES

## LoD2 Building Derivation Bavaria

The Bavarian Office for Surveying and Spatial Information (LVG) set the goal of building an extensive 3D building database of the LoD2 for the more than 8 million buildings located in Bavaria confirmed in the land register. In this project, the LVG decided to use our BuildingReconstruction software system. The significant selection criteria for this project, were the possibility of being able to create a 3D building completely based on the floor plans, the high rate of initial recognition as well as the high efficiency when editing the building. In addition virtualcitySYSTEMS had already implemented a variety of client-specific customizations and workflow optimizations for the Bavarian LVG, e.g. the derivation of ALKIS-compliant components from LoD2 building models.



CityGML

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# But compared to BIM:

The **IFC** format is supported by

# Why should ISPRS care about BIM?

- Much larger than 3D city modeling: **The European building construction industry**
- This tanker moves towards BIM
  - It took 20 years to make it move
  - But now **IFC uptake** is hard to stop
  - And IFC will remain in place for long!
- Considerable IT in the background of every new construction project!

# Why should ISPRS care about BIM?

- Efficient building construction will soon rely critically on the availability of BIM
  - Highly optimized industrial processes!
- **City of Graz:**
  - Population: 240.000
  - Number of buildings: ~ 60.000
- **Europe-28:**
  - Population 505.000.000
  - Number of buildings: ~ 126.000.000

# BIM Reality Check:

*„BIM im Klartext“*

David Gubler, Dipl. Arch. ETH
CEO of ArchiMedia Schweiz AT (Vectorworks)

http://www.computerworks.ch/fileadmin/Downloads/Produkte/Vectorworks/bim/BIM_im_Klartext_Gubler.pdf

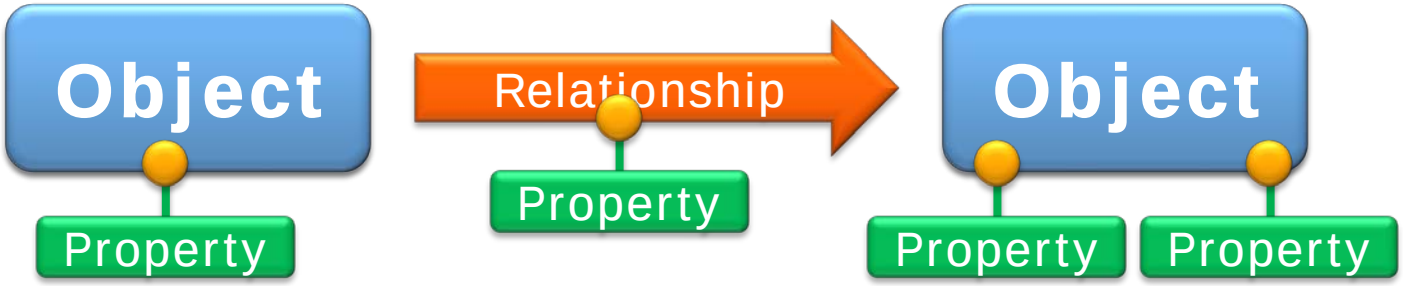
# The BIM Backbone: IFC

- **Industry Foundation Classes**
  - „*STEP for buildings*“, ISO 16739:2013
  - Platform-neutral, vendor-neutral
  - Object-based file format (Express & XML)
- Developed by www.buildingsmart.com
  - Was: IAI (Alliance for Interoperability)
- Danish government: IFC compulsory for publicly aided building projects
  - Investors demand sustainable IT (money!)

# What is IFC?

- IFC is a file format (→ later)
- IFC is a „database“, or better:
- IFC is a data model

- Entitity-Relationship Models:



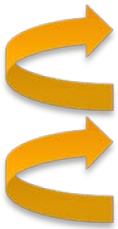

- Like subject-predicate-object phrase
  - „Floor contains room“

# Why should ISPRS care about IFC?

- It will not go away (in medium term)
  - Good support by commercial tools
- IFC is extremely useful as exchange format for geometric algorithms:
  - Points, vectors, directions
  - Transformations
  - Various 2D/3D Geometric primitives
- How do you store the results of your methods and algorithms today?

# IFC – Quick introduction

- Entity-Relationship model based on STEP with hundreds of object-oriented entities
  - Building element: IfcWall
  - Geometry element: IfcExtrudedAreaSolid
  - Basic construct: IfcCartesianPoint



- Central concepts (a) **Objects**, (b) **Relationships**, (c) **Properties**
  - Are „rooted entities“, i.e., derived from IfcRoot
  - Have GUID (Globally Unique IDentifier)
  - Have Revision, Name, Description

# (a) IfcObjectDefinition

- **IfcTypeObject**
  - Common product type with common shape
- **IfcObject** can answer the six fundamental questions ("Five Ws and One H"):
  - „Who?“ IfcActor People, organizations
  - „When?“ IfcProcess Task, event, procedure
  - „Where?“ IfcProduct Physic. locations/elements
  - „What?“ IfcGroup Example: electrical circuit
  - „Why?“ IfcControl Rules: time, cost, order
  - „How?“ IfcResource Material, labor, equipment

# (b) IfcRelationship

- The five fundamental relationships between objects are:
  - IfcRelDecomposes whole-part, floors-rooms
  - IfcRelAssigns service: task consumes labor
  - IfcRelConnects floor connected to beam
  - IfcRelAssociates external references
  - IfcRelDefines instance-of: e.g. product type

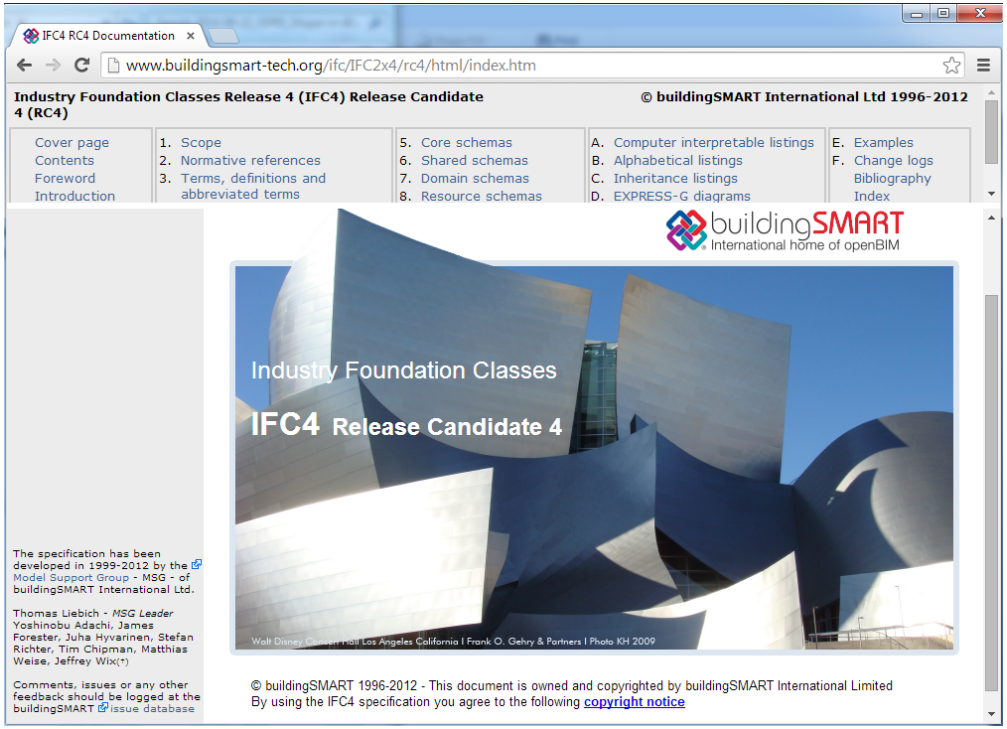
# (c) IfcPropertySet

- Single value (number, float), or array of values, or dictionary of values
- PSet_...: Many predefined property sets
- PSet_AudioVisualApplianceTypeProjector
  - ProjectorType
    - P_ENUMERATEDVALUE: OTHER, NOTKNOWN, UNSET.
  - VideoResolutionWidth
    - P_SINGLEVALUE / IfcInteger
  - VideoResolutionHeight
    - P_SINGLEVALUE / IfcInteger
  - VideoResolutionMode
    - P_TABLEVALUE / IfcIdentifier / IfcLabel

# IFC: The definitive voice

http://www.buildingsmart-tech.org/ifc/IFC2x4/rc4/html

- First hit when searching simply for „***ifc 4 documentation***“



IFC4 RC4 Documentation

www.buildingsmart-tech.org/ifc/IFC2x4/rc4/html/index.htm

**Industry Foundation Classes Release 4 (IFC4) Release Candidate 4 (RC4)**

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The specification has been developed in 1999-2012 by the Model Support Group - MSG - of buildingSMART International Ltd.

Thomas Liebich - *MSG Leader*
Yoshinobu Adachi, James Forester, Juha Hyvarinen, Stefan Richter, Tim Chipman, Matthias Weise, Jeffrey Wix(†)


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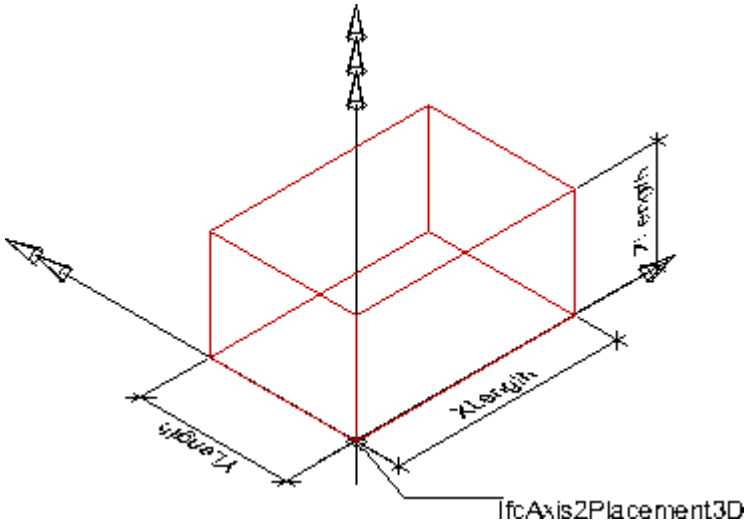
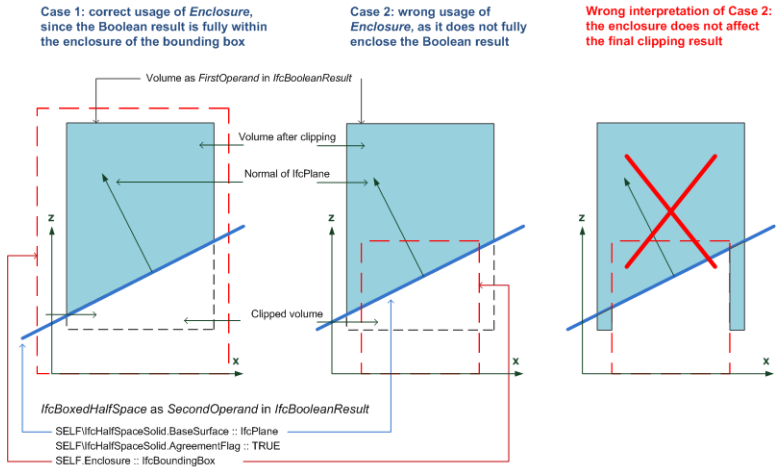
# IFC: Geometry Repesentations

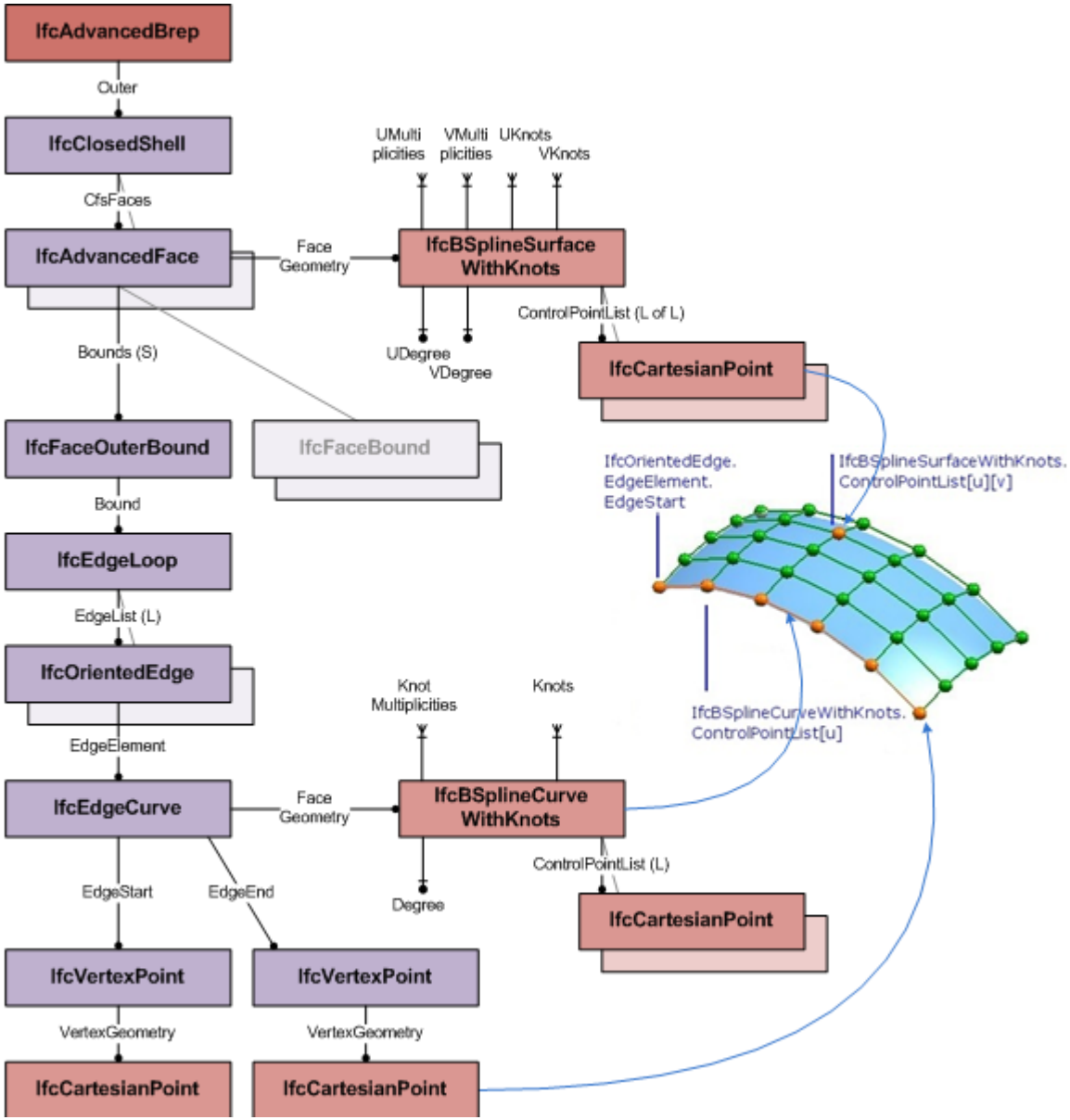
8.8.2.1 **IfcBooleanOperator**
8.8.2.2 IfcBooleanOperand
8.8.2.3 IfcCsgSelect
8.8.2.4 IfcGeometricSetSelect
8.8.3.1 **IfcAdvancedBrep**
8.8.3.2 IfcAdvancedBrepWithVoids
8.8.3.3 **IfcBlock**
8.8.3.4 IfcBooleanClippingResult
8.8.3.5 IfcBooleanResult
8.8.3.6 **IfcBoundingBox**
8.8.3.7 **IfcBoxedHalfSpace**
8.8.3.8 IfcCartesianPointList
8.8.3.9 **IfcCartesianPointList3D**



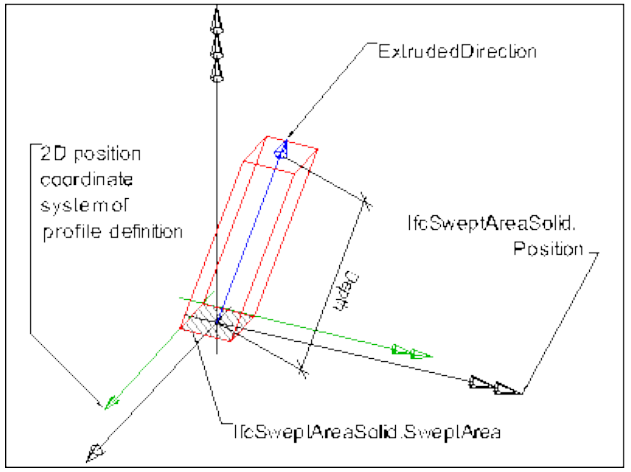
# Advanced BRep

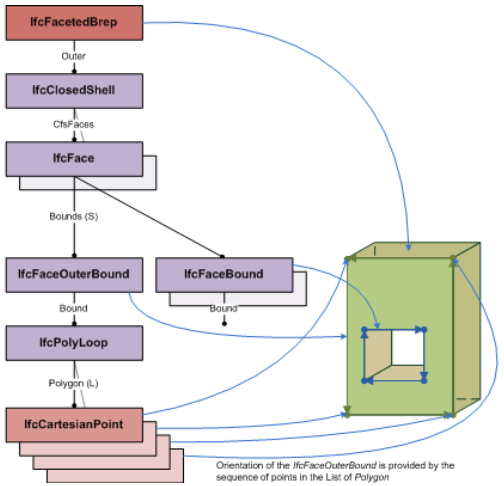
- „to support increasing number of applications that define & exchange **B-rep** models based on **NURBS“**



# IFC: Geometry Repesentations

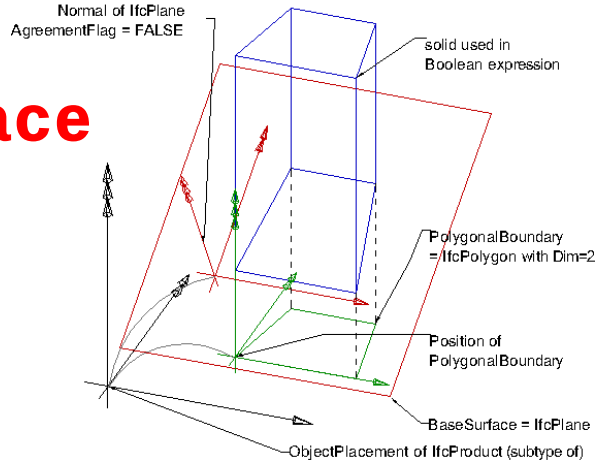
8.8.3.10 IfcCsgPrimitive3D
8.8.3.11 **IfcCsgSolid**
8.8.3.12 **IfcExtrudedAreaSolid**
8.8.3.13 IfcExtrudedAreaSolidTapered
8.8.3.14 **IfcFaceBasedSurfaceModel**
8.8.3.15 **IfcFacetedBrep**
8.8.3.16 IfcFacetedBrepWithVoids
8.8.3.17 IfcFixedReferenceSweptAreaSolid
8.8.3.18 IfcGeometricCurveSet
8.8.3.19 IfcGeometricSet
8.8.3.20 **IfcHalfSpaceSolid**
8.8.3.21 IfcManifoldSolidBrep

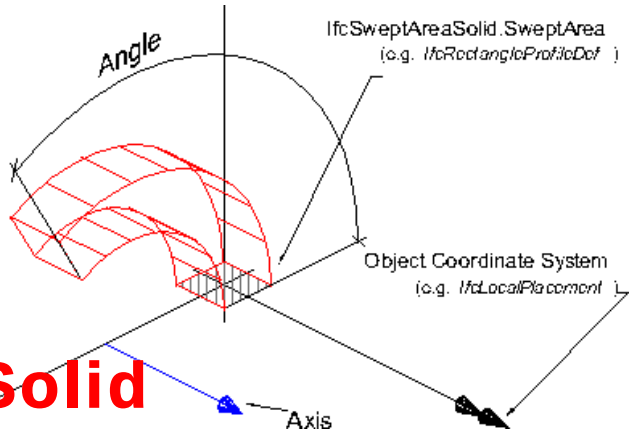


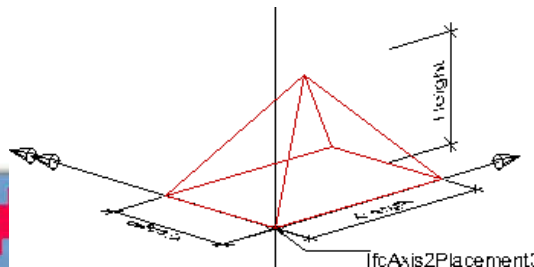



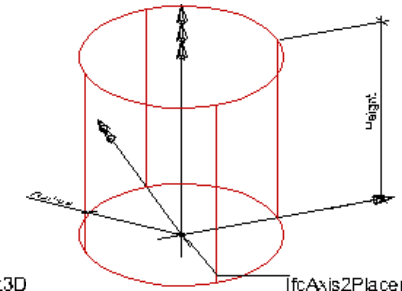
# IFC: Geometry Repesentations

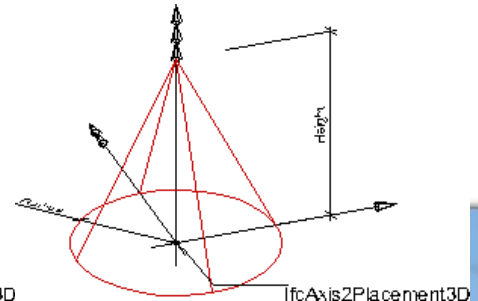
8.8.3.22 **IfcPolygonalBoundedHalfSpace**
8.8.3.23 **IfcRectangularPyramid**
8.8.3.24 **IfcRevolvedAreaSolid**
8.8.3.25 IfcRevolvedAreaSolidTapered
8.8.3.26 IfcRightCircularCone
8.8.3.27 IfcRightCircularCylinder
8.8.3.28 IfcSectionedSpine
8.8.3.29 IfcShellBasedSurfaceModel
8.8.3.30 IfcSolidModel
8.8.3.31 **IfcSphere**
8.8.3.32 **IfcSurfaceCurveSweptAreaSolid**



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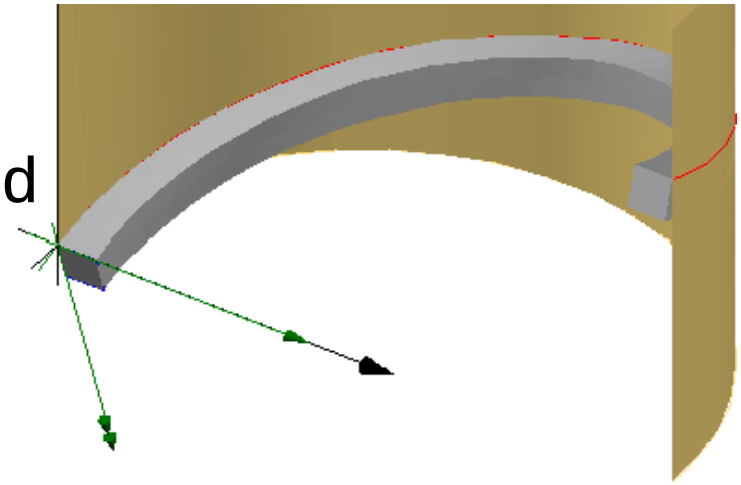


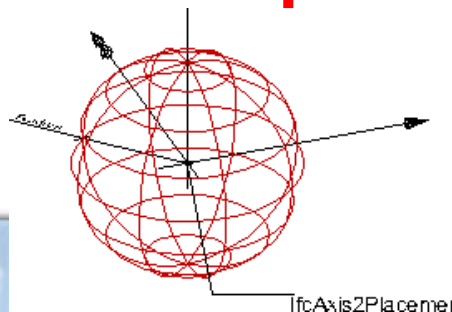
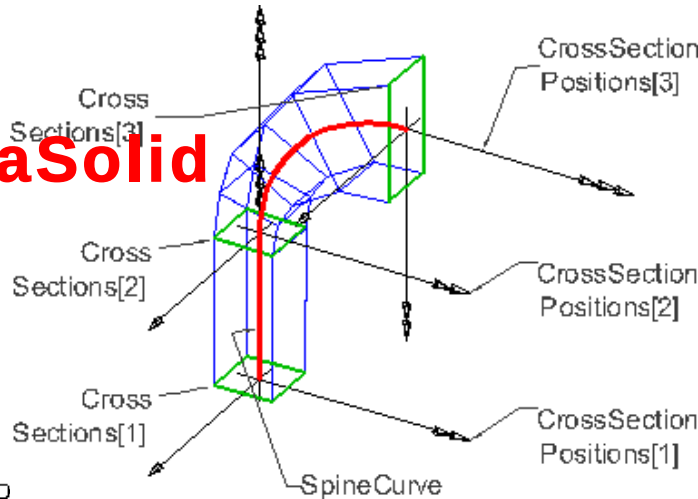
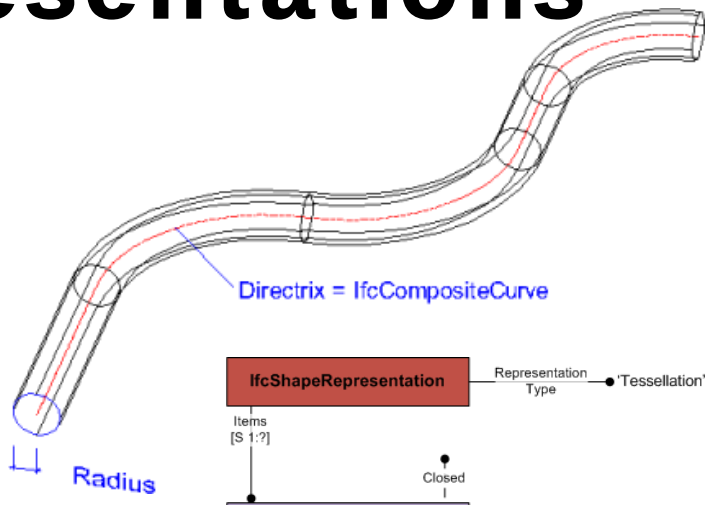


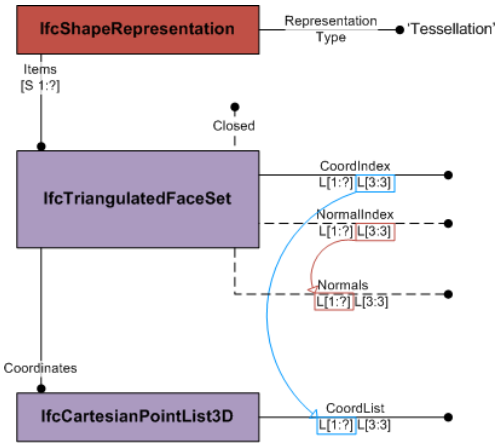

Figure 307 — Surface curve wept area solid results

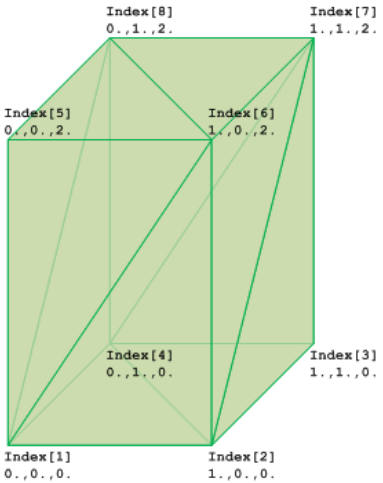


# IFC: Geometry Repesentations

8.8.3.33 **IfcSweptAreaSolid**
8.8.3.34 **IfcSweptDiskSolid**
8.8.3.35 IfcSweptDiskSolidPolygonal
8.8.3.36 **IfcTessellatedFaceSet**
8.8.3.37 IfcTessellatedItem
8.8.3.38 **IfcTriangulatedFaceSet**
8.9.2.8 **IfcCurveOnSurface**
8.9.2.9 IfcTrimmingSelect
8.9.3.1 IfcAxis1Placement
8.9.3.2 IfcAxis2Placement2D
8.9.3.3 IfcAxis2Placement3D
8.9.3.4 IfcBoundaryCurve



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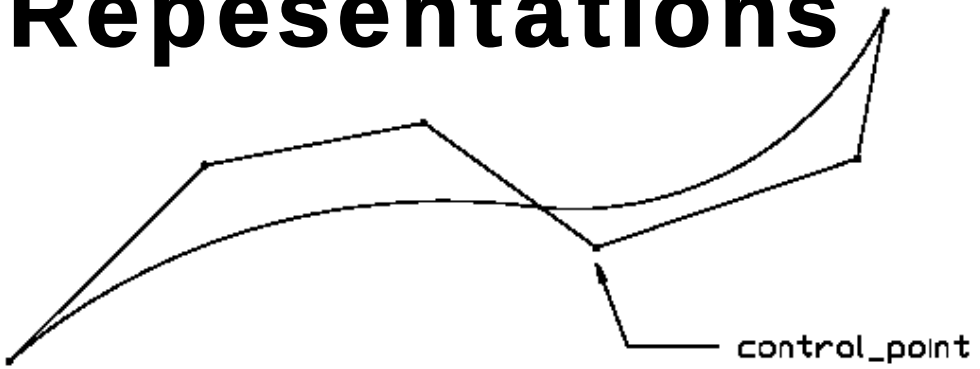
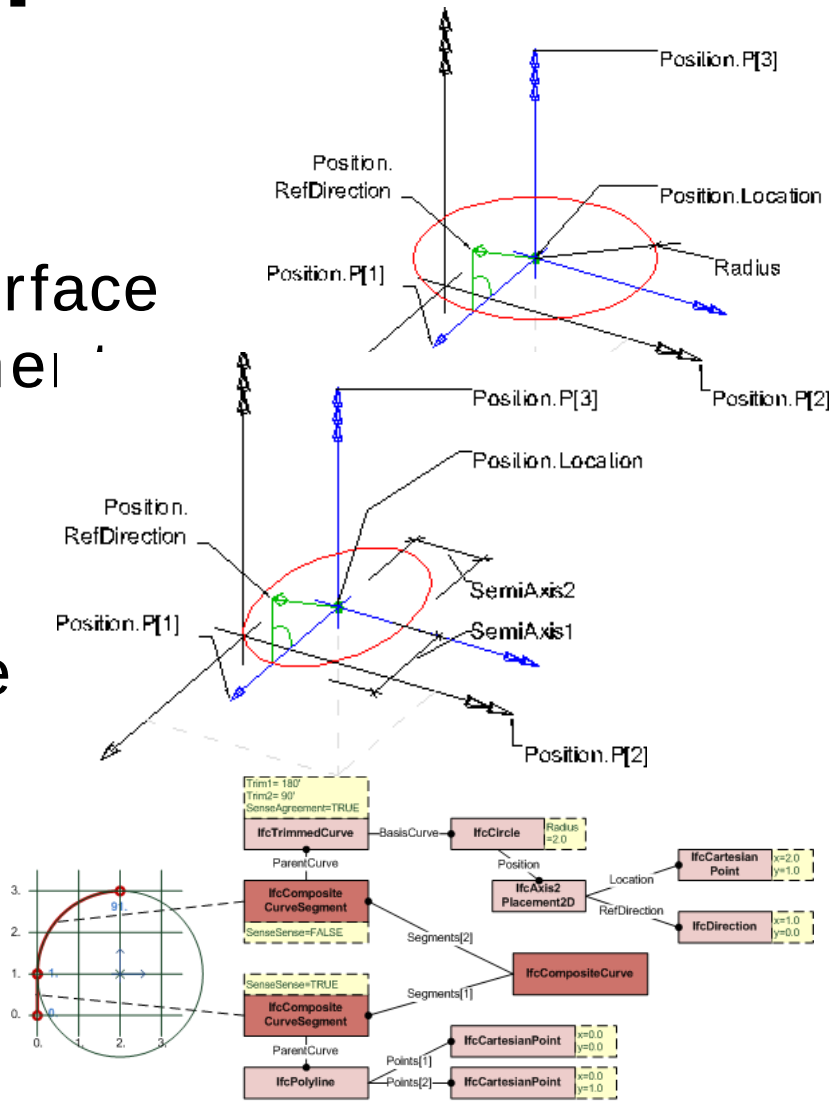



8.9.3.5 IfcBoundedCurve
8.9.3.6 IfcBoundedSurface
8.9.3.7 **IfcBSplineCurve**
8.9.3.8 IfcBSplineCurveWithKnots
8.9.3.9 **IfcBSplineSurface**
8.9.3.10 IfcBSplineSurfaceWithKnots
8.9.3.11 **IfcCartesianPoint**
8.9.3.12 IfcCartesianTransformationOperator
8.9.3.13 IfcCartesianTransformationOperator2D
8.9.3.14 IfcCartesianTransformationOperator2DnonUnif.
8.9.3.15 **IfcCartesianTransformationOperator3D**
8.9.3.16 IfcCartesianTransformationOperator3DnonUnif.

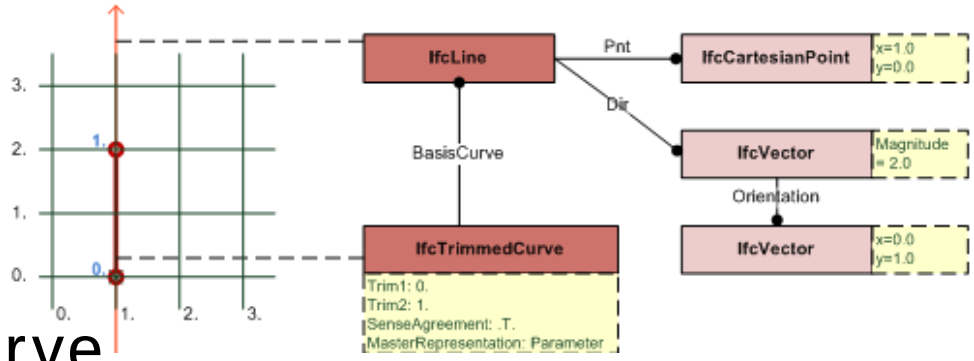
# IFC: Geometry Repesentations

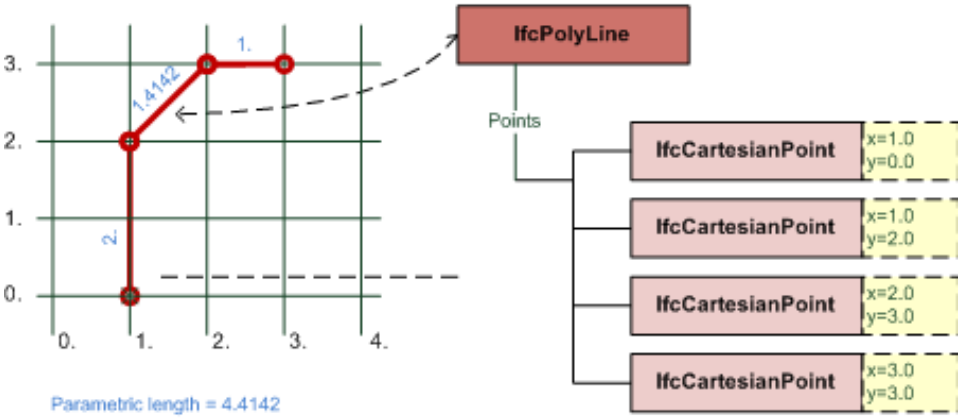
8.9.3.17 **IfcCircle**
8.9.3.18 IfcCompositeCurve
8.9.3.19 IfcCompositeCurveOnSurface
8.9.3.20 IfcCompositeCurveSegme
8.9.3.21 **IfcConic**
8.9.3.22 IfcCurve
8.9.3.23 IfcCurveBoundedPlane
8.9.3.24 IfcCurveBoundedSurface
8.9.3.25 **IfcCylindricalSurface**
8.9.3.26 **IfcDirection**
8.9.3.27 IfcElementarySurface
8.9.3.28 **IfcEllipse**



# IFC: Geometry Repesentations

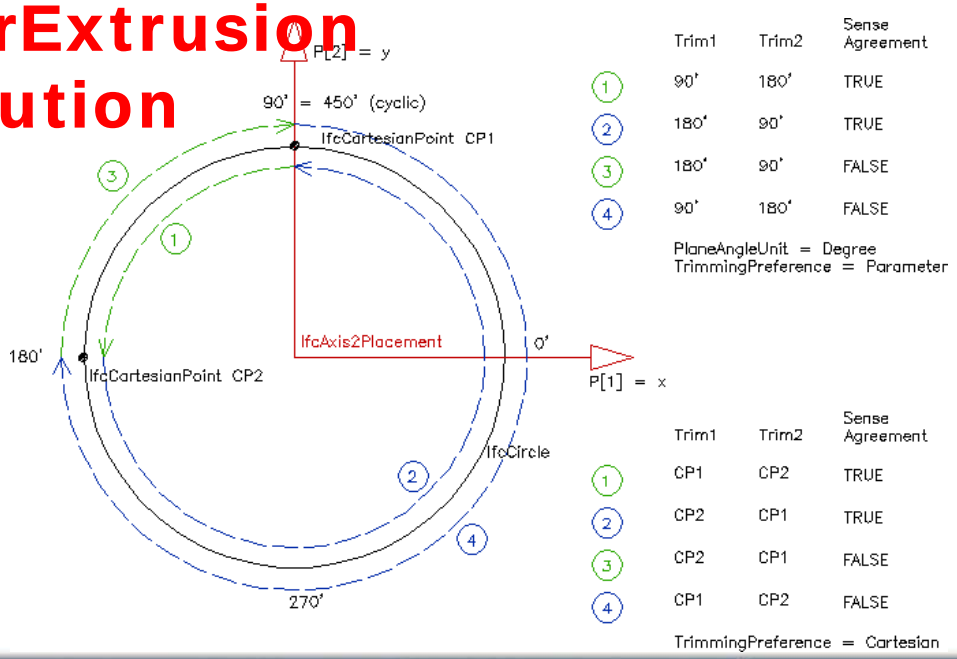
8.9.3.29 IfcGeometricRepresentationItem
8.9.3.30 **IfcLine**
8.9.3.31 **IfcMappedItem**
8.9.3.32 **IfcOffsetCurve2D**
8.9.3.33 IfcOffsetCurve3D
8.9.3.34 IfcOuterBoundaryCurve
8.9.3.35 IfcPcurve
8.9.3.36 IfcPlacement
8.9.3.37 **IfcPlane**
8.9.3.38 **IfcPoint**
8.9.3.39 **IfcPointOnCurve**
8.9.3.40 **IfcPointOnSurface**
8.9.3.41 **IfcPolyline**



# IFC: Geometry Repesentations

8.9.3.42 **IfcRationalBSplineCurveWithKnots**
8.9.3.43 **IfcRationalBSplineSurfaceWithKnots**
8.9.3.44 **IfcRectangularTrimmedSurface**
8.9.3.45 IfcReparametrisedCompositeCurveSegment
8.9.3.48 IfcSurface
8.9.3.49 **IfcSurfaceOfLinearExtrusion**
8.9.3.50 **IfcSurfaceOfRevolution**
8.9.3.51 **IfcSweptSurface**
8.9.3.52 IfcTrimmedCurve
8.9.3.53 **IfcVector**



# IFC: Geometry Repesentations

8.9.4 Functions
8.9.4.1 IfcBaseAxis
8.9.4.2 IfcBuild2Axes
8.9.4.3 IfcBuildAxes
8.9.4.4 IfcConstraintsParamBSpline
8.9.4.5 **IfcCrossProduct**
8.9.4.6 IfcCurveDim
8.9.4.7 IfcCurveWeightsPositive
8.9.4.8 **IfcDotProduct**
8.9.4.9 IfcFirstProjAxis
8.9.4.10 IfcGetBasisSurface
8.9.4.11 **IfcListToArray**

# IFC: Geometry Repesentations

8.9.4.12 **IfcMakeArrayOfArray**
8.9.4.13 **IfcNormalise**
8.9.4.14 **IfcOrthogonalComplement**
8.9.4.15 IfcSameAxis2Placement
8.9.4.16 **IfcSameCartesianPoint**
8.9.4.17 IfcSameDirection
8.9.4.18 IfcSameValue
8.9.4.19 **IfcScalarTimesVector**
8.9.4.20 IfcSecondProjAxis
8.9.4.21 IfcSurfaceWeightsPositive
8.9.4.22 **IfcVectorDifference**
8.9.4.23 **IfcVectorSum**

**AND NOW...**
**Let us look at the real thing!**

```
...
#3582=IFCCARTESIANPOINT((0.027506,-0.015881,3.512124));
#3583=IFCCARTESIANPOINT((0.036525,-0.00026,3.519595));
#3584=IFCCARTESIANPOINT((0.037268,0.001027,3.512124));
#3585=IFCPOLYLOOP((#3582,#3583,#3584));
#3586=IFCFACEOUTERBOUND(#3585,.T.);
#3587=IFCFACE((#3586));
#3588=IFCCONNECTEDFACESET((#137,#143,#149,#155,...
        #3497,#3503,#3509,#3515,#3521,#3527,#3533,#3539,
        #3545,#3551,#3557,#3563,#3569,#3575,#3581,#3587));
#3589=IFCFACEBASEDSURFACEMODEL((#3588));
...
#8490=IFCSHAPEREPRESENTATION(#11,'Body',
        'SurfaceModel',(#3589,#7623,#8489));
#8495=IFCREPRESENTATIONMAP(#8494,#8490);
#8496=IFCDIRECTION((1.,0.,0.));
#8497=IFCDIRECTION((0.,1.,0.));
#8498=IFCCARTESIANPOINT((0.,0.,0.));
#8499=IFCDIRECTION((0.,0.,1.));
#8500=IFCCARTESIANTRANSFORMATIONOPERATOR3D(#8496,
        #8497,#8498,1.,#8499);
#8501=IFCMAPPEDITEM(#8495,#8500);
```

```
#16=IFCOWNERHISTORY(#14,#15,$,.ADDED.,0,$,$,1154093502);
...
#3584=IFCCARTESIANPOINT((0.037268,0.001027,3.512124));
#3585=IFCPOLYLOOP((#3582,#3583,#3584));
#3586=IFCFACEOUTERBOUND(#3585,.T.);
#3587=IFCFACE((#3586));
#3588=IFCCONNECTEDFACESET((#137,#143,...,#3581,#3587));
#3589=IFCFACEBASEDSURFACEMODEL((#3588));
#8490=IFCSHAPEREPRESENTATION(#11,'Body',
      'SurfaceModel',(#3589,#7623,#8489));
#8495=IFCREPRESENTATIONMAP(#8494,#8490);
#8501=IFCMAPPEDITEM(#8495,#8500);
#8502=IFCSHAPEREPRESENTATION(#11,'Body',
      'MappedRepresentation',(#8501));
#8503=IFCPRODUCTDEFINITIONSHAPE($,$,(#8502,#8507));
#8504=IFCBUILDINGELEMENTPROXY('12j$tPqrLBrAqXzDPTuAWe',
      #16,'Strassenlaterne','3D Triple Globe Lamp from ADT
      DesignCenter, corrected in Rhino (normal and degenerated
      triangles)','',#131,#8503,$,$);
...
#8514=IFCRELDEFINESBYPROPERTIES('11SEWqMPrCE8$tDLY0bOLq',
      #16,$,$,(#8504),#8513);
```

# Does using IFC already mean you have a BIM?

- IFC allows much freedom in the use of semantic information
- Consequence: Variety of „incompatible“ IFC formats / recommended usages
  - Various varieties to encode the „same“ model
- Great variations between software packages
  - **Roundtrip** generally not possible:
    Open in Revit → in ArchiCAD → in Revit → Save should theoretically yield the identical file
- Note:

> There is no such thing as „the“ 3D-model of a building!

# IFC Exchange Test

- IAI Forum Denmark, [illegible]or 2006
- The import and export of the [illegible]


| ArchiCAD 9 - IFC 2x Add-on Build 46041 | | |
|---|---|---|
| Simple Geometry | ✓ | |
| Complex Geometry | ! | - the wall is only recognized as an object |
| Object Type | ✓ | - wall object. |
| Composite Wall | ✓ | |
| Relations | ✓ | |
| Properties | ✓ | |

- Conclusion:
  - The certification does not prove that the import and export will work without problems even in a simple model

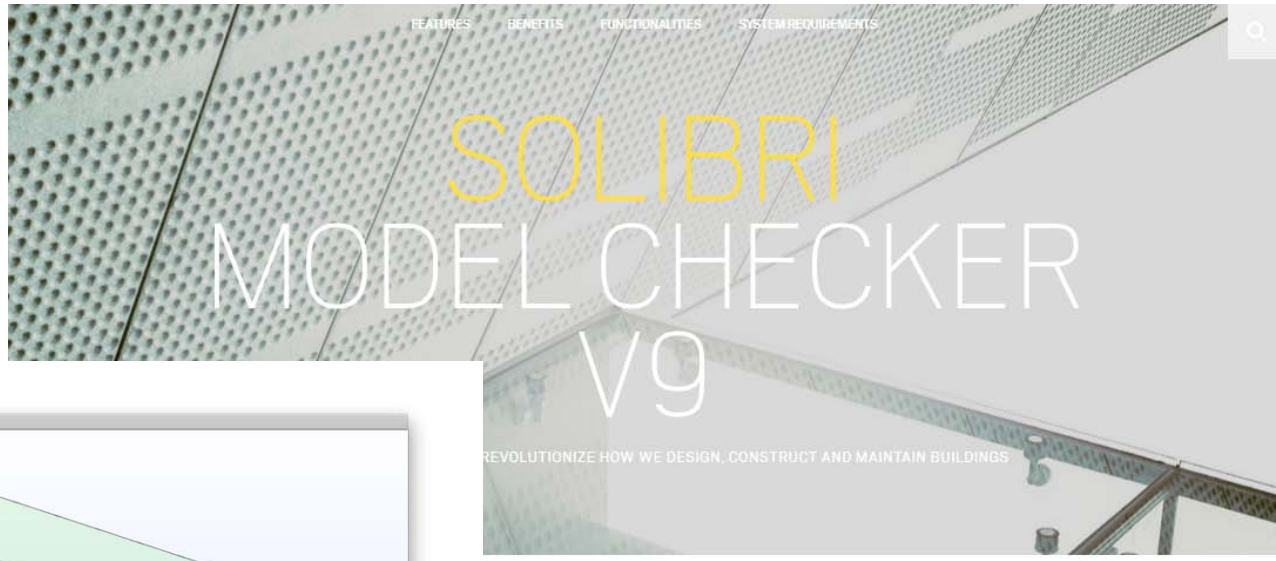
Ten Years of IFC Development - Arto Kiviniemi

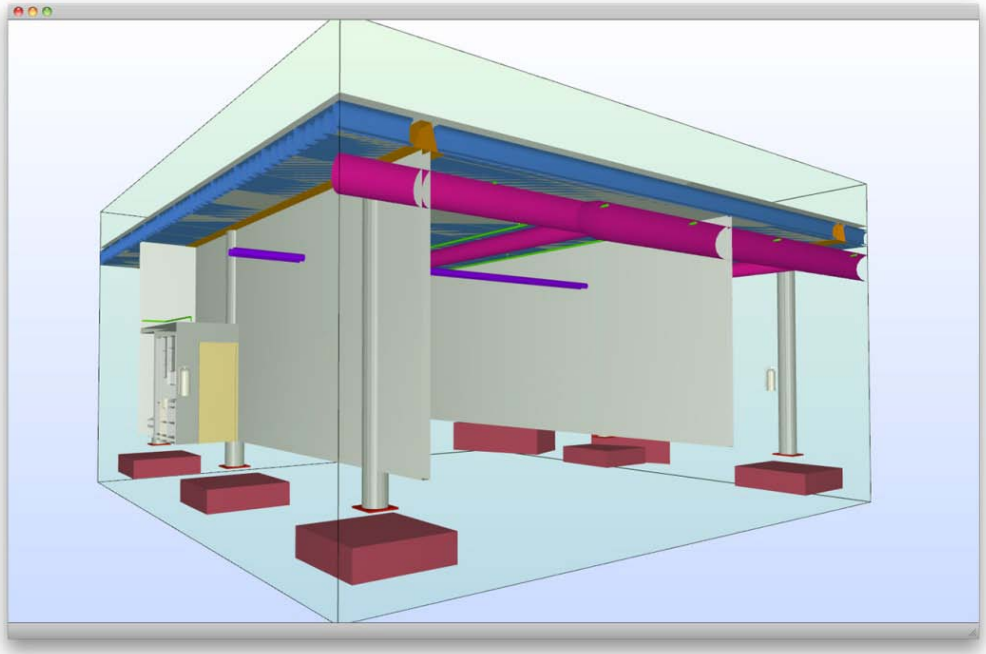


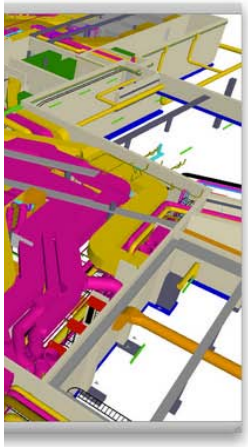
© Fraunhofer

# Answer: Solibri Model Checker

- Check only *fitness for purpose*
  - E.g. *Clash detection*





Features

Solibri Model Checker (SMC) is our flagship product. Here are few reasons that make it unique to the market

**SECOND GENERATION CLASS DETECTION**

Automatically analyze and group clashes according to severity. Find relevant problems quickly and easily. Investigate the quality of your BIM files.

**DEFICIENCY DETECTION**

**VERIFY MATCHING ELEMENTS IN ARCHITECTURAL & STRUCTURAL DESIGNS**

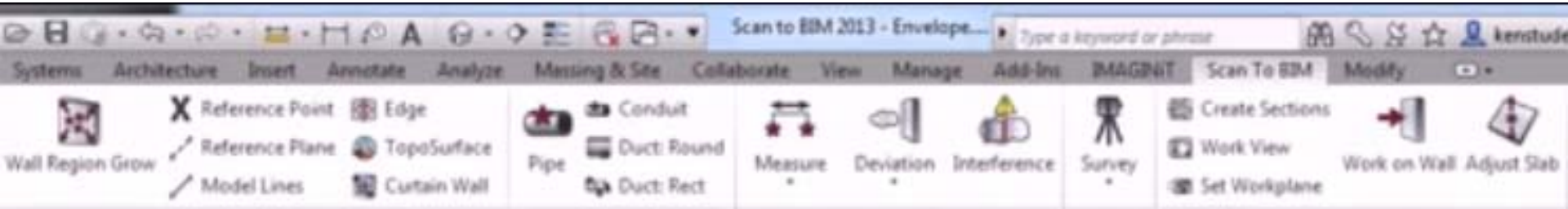
**MANAGING CHANGE ORDERS OR DESIGN VERSIONS**

# Does using IFC already mean you have a BIM?

- IFC allows much freedom in the use of semantic information
  - You CAN describe wall material layers
  - You do not HAVE TO describe wall materials
  - No wall materials → No energy efficiency simul.
- Useful concept: „**Fitness for purpose**“
  - Semantic information: There is no free lunch...
  - You may start with a „stupid“ IFC model...
    - All in one geometry node, minimal semantics
    - But avoid „dummy semantics“ - Missing information is better than wrong information!
  - ..and successively enhance semantic information

# The inverse problem: Scan to BIM (Pointcloud to IFC)

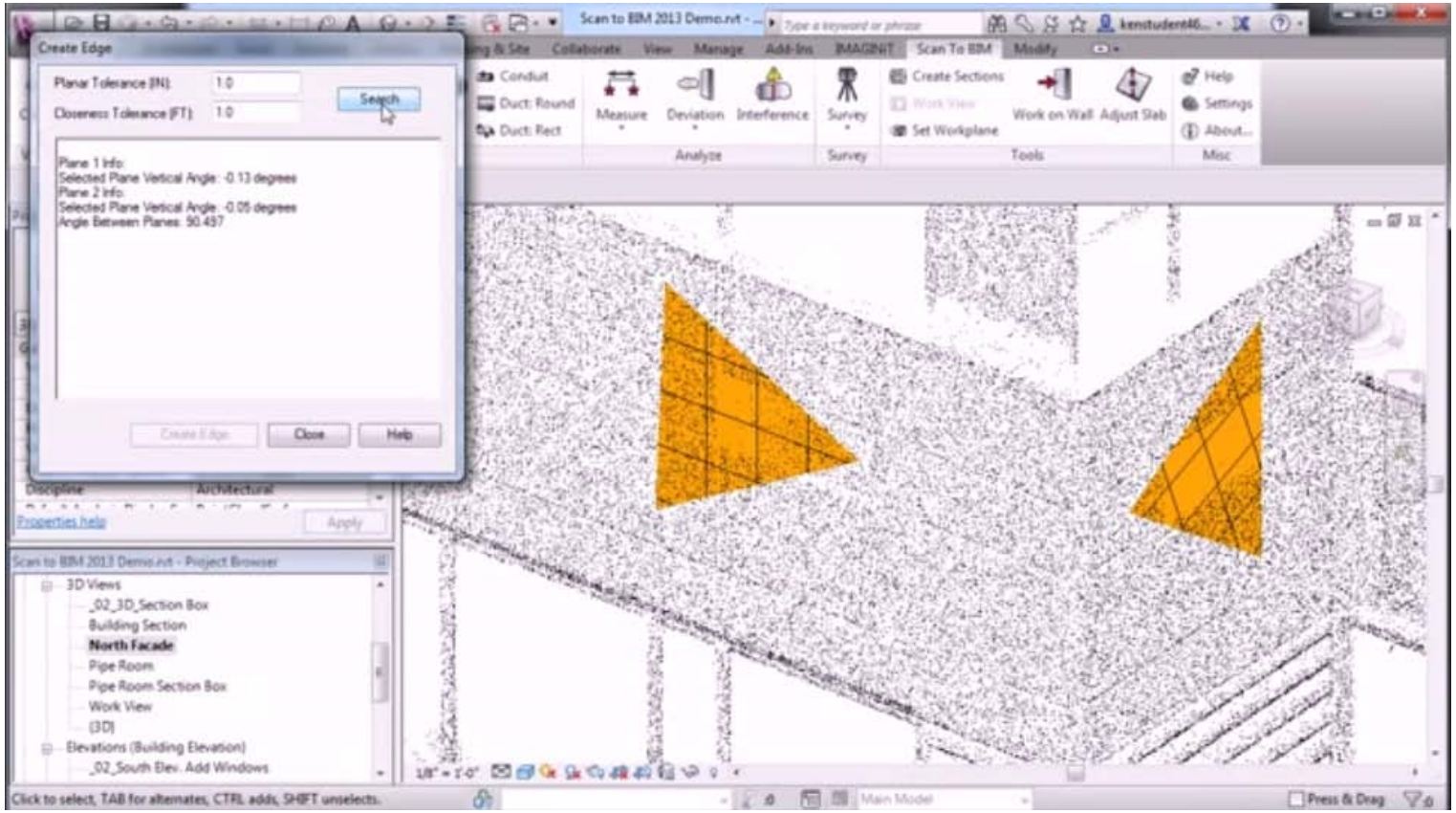
- Wide field of research
  - „Inverse parametric/procedural modeling“
  - Automatic shape understanding




- Commercial plugins for Autodesk Revit
  - E.g. IMAGINiT Technologies „Scan to BIM“
  - (Semi-)interactive, not automatic!

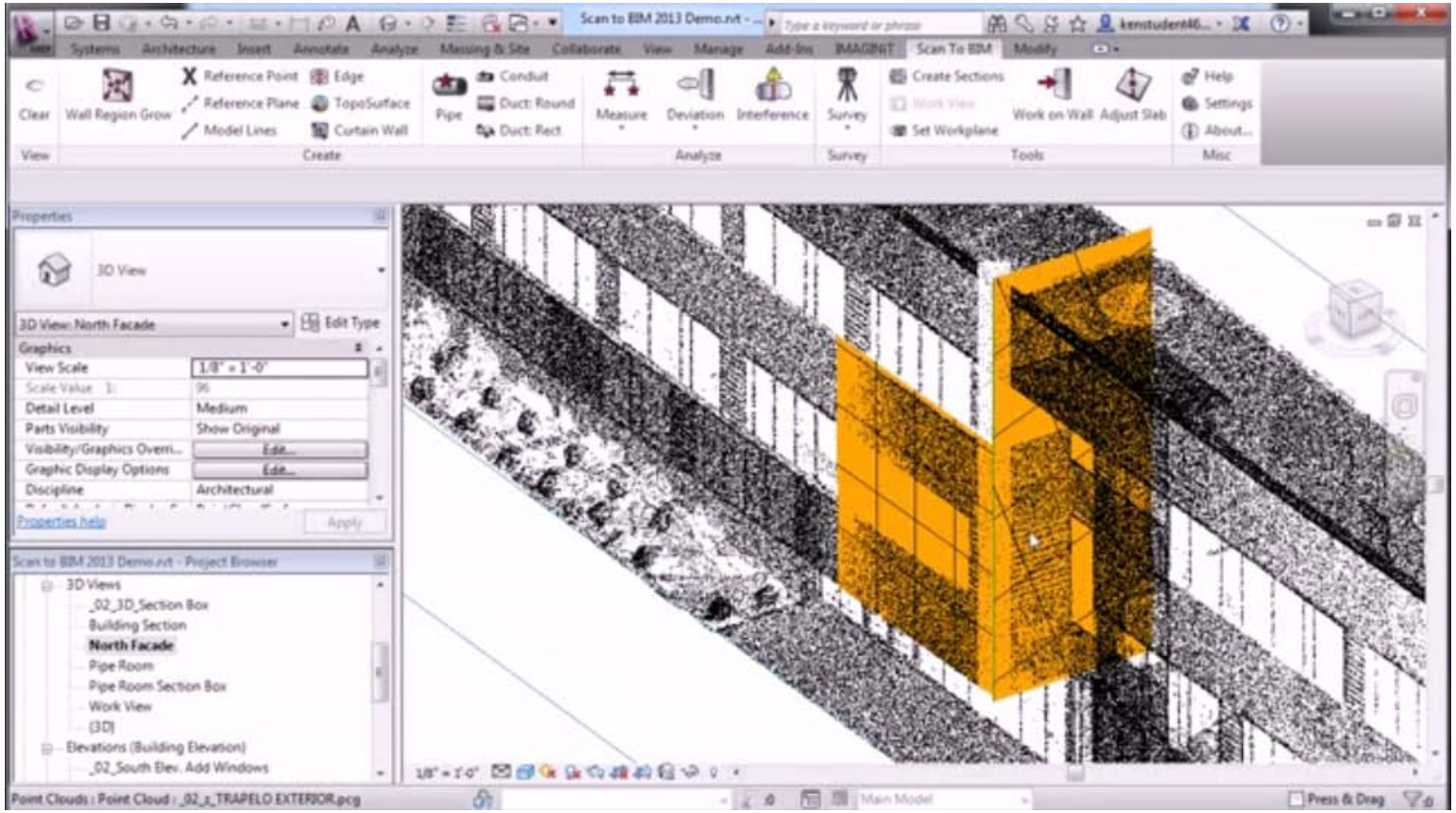
# IMAGINiT „Scan To BIM“

- Wall growing: Plane from 3 points
- Edge tool: Intersect planes



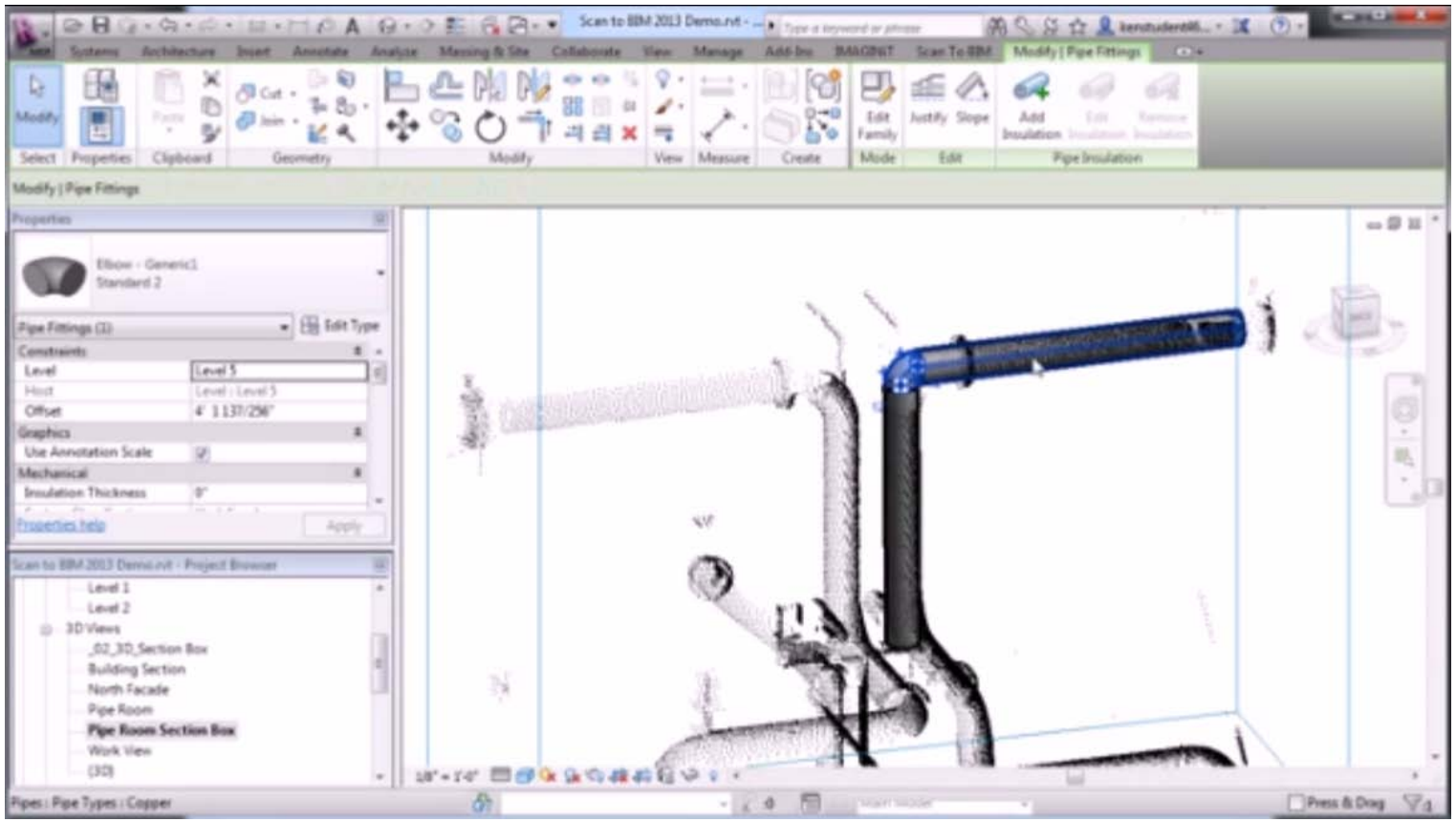
# IMAGINiT „Scan To BIM“

- Wall growing: Plane from 3 points
- Edge tool: Intersect planes

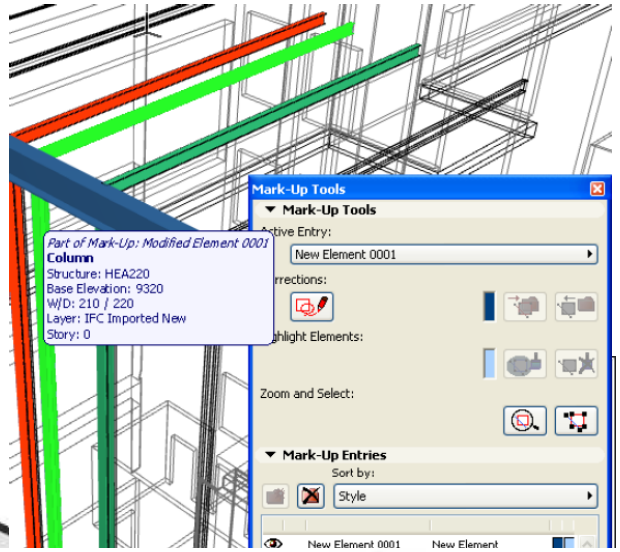


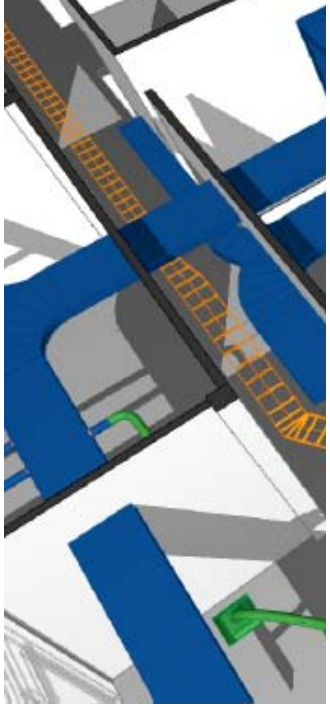
# IMAGINiT „Scan To BIM“

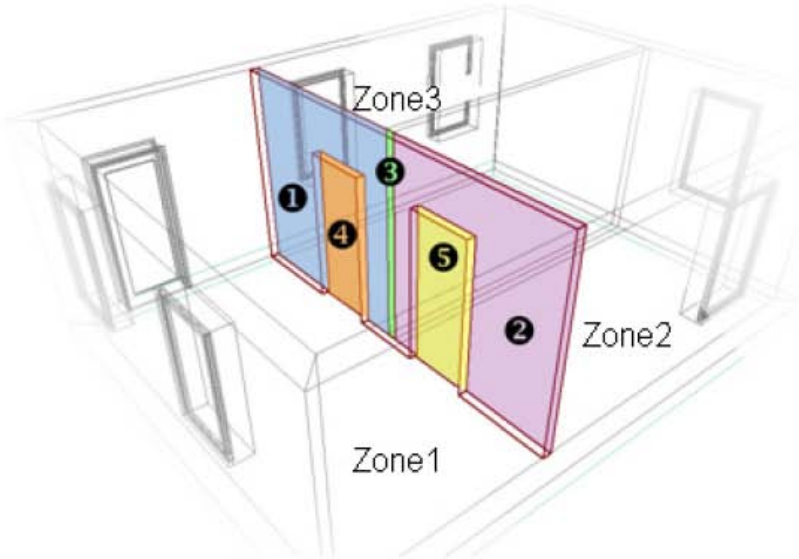
- Pipe tool: Fitting of cylinders
- Length of cylinder: When connected



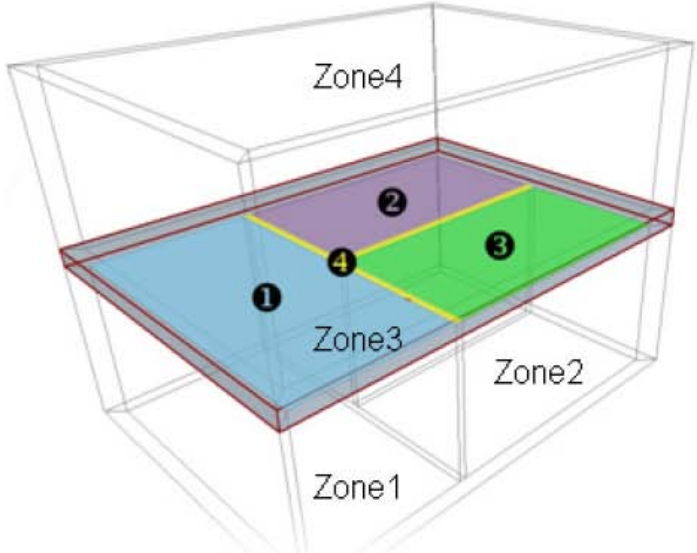
# Scan to BIM: Vast field of research






**Space Boundaries (defined by Walls):**
1 - Wall part defined by Zone3
2 - Wall part defined by Zone2
3 - Wall part cut by connected wall
4 and 5 - Area defined by door opening



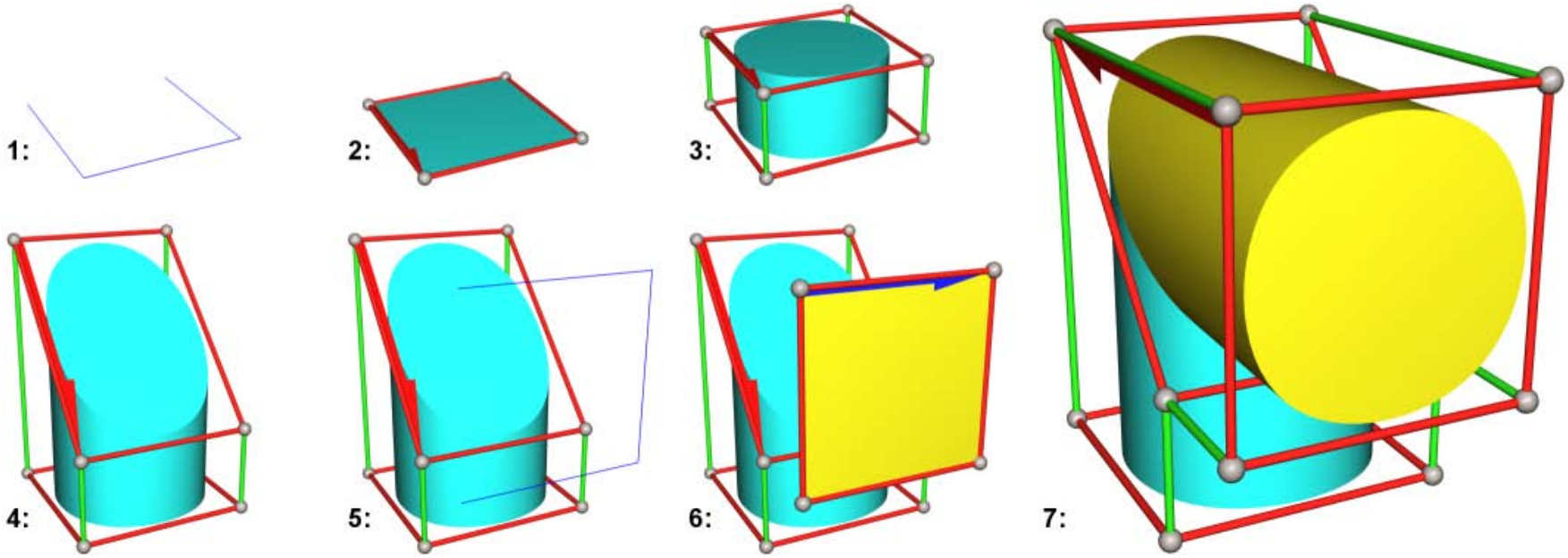

**Space Boundaries (defined by Slab):**
1 - Slab part defined by Zone1
2 - Slab part defined by Zone3
3 - Slab part defined by Zone2
4 - Slab part without thermal convection

# Parametric vs. procedural shape modeling

- **Parametric Modeling**
  - Large but fixed set of so-called **features**
  - *Geometric (CAD) feature* consists of
    - Set of parameters + Geometric objects
    - And *compiled* evaluation function param→geo !
  - Associativity: Parameters can be linked
- **Procedural modeling**
  - Underlying script language
  - Shape programming, rules
  - User can define/program new features

[http://en.wikipedia.org/wiki/Generative_Modelling_Language]

# Generative Modeling Language




```
1: (0,0,-2) (1,1,0) 2 quad
2: /cyan setcurrentmaterial 5 poly2doubleface
3: (0,1,1) extrude
4: (0,0,1) (1,0,1) normalize 0 project_ringplane
5: (2,0,0) (0,1,-1) 2 quad
6: /yellow setcurrentmaterial 5 poly2doubleface
7: 0 bridgerings
```

# Formwerkstatt 3D-Configurator

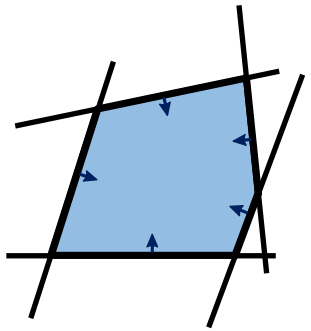
- ☑ Constructions
- ☑ Design shapes
- ☑ Shape changes
- ☑ Client-side 3D
- ☑ Direct 3D interaction
- ☑ Predictible
- ☑ Inexpensive
- ☑ 3D printing
- ☑ Knowledge protection

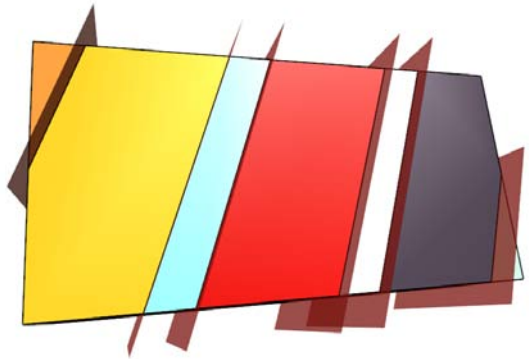
Install http://www.generative-modeling.org/GenerativeModeling/Software/ActiveGML2-2.1.1.612.msi

Go! | 100 100 3 Gothic-Window.create | Rim

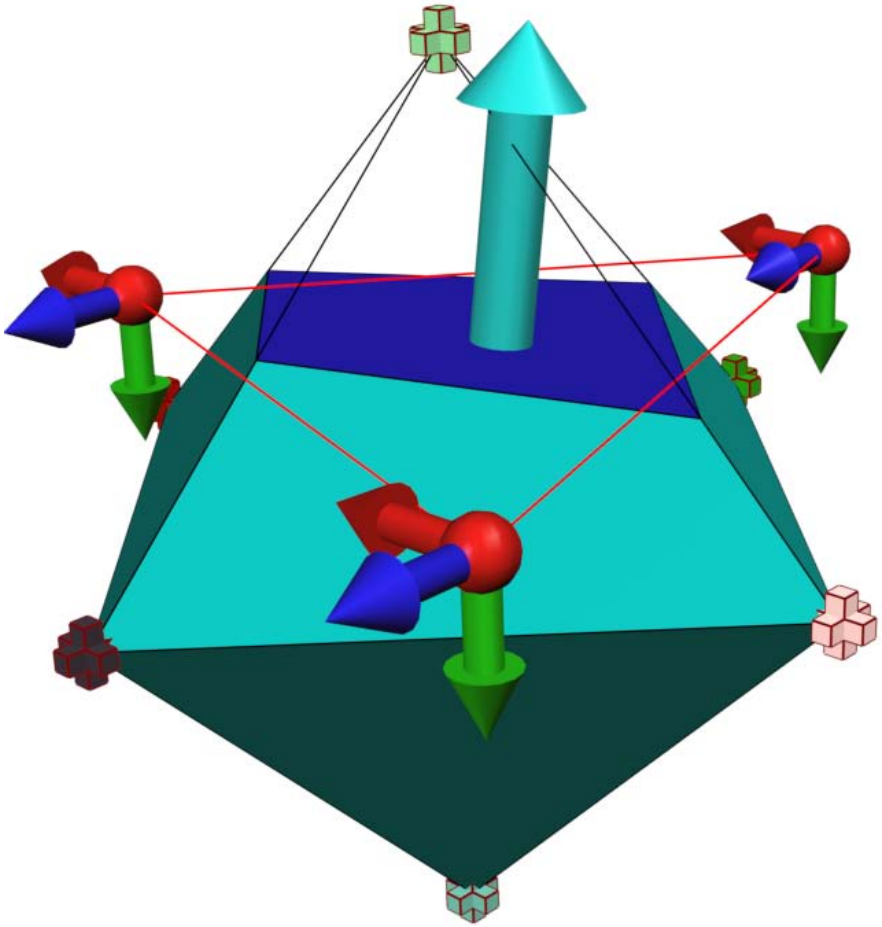
# Convex Polyhedra (CPs)

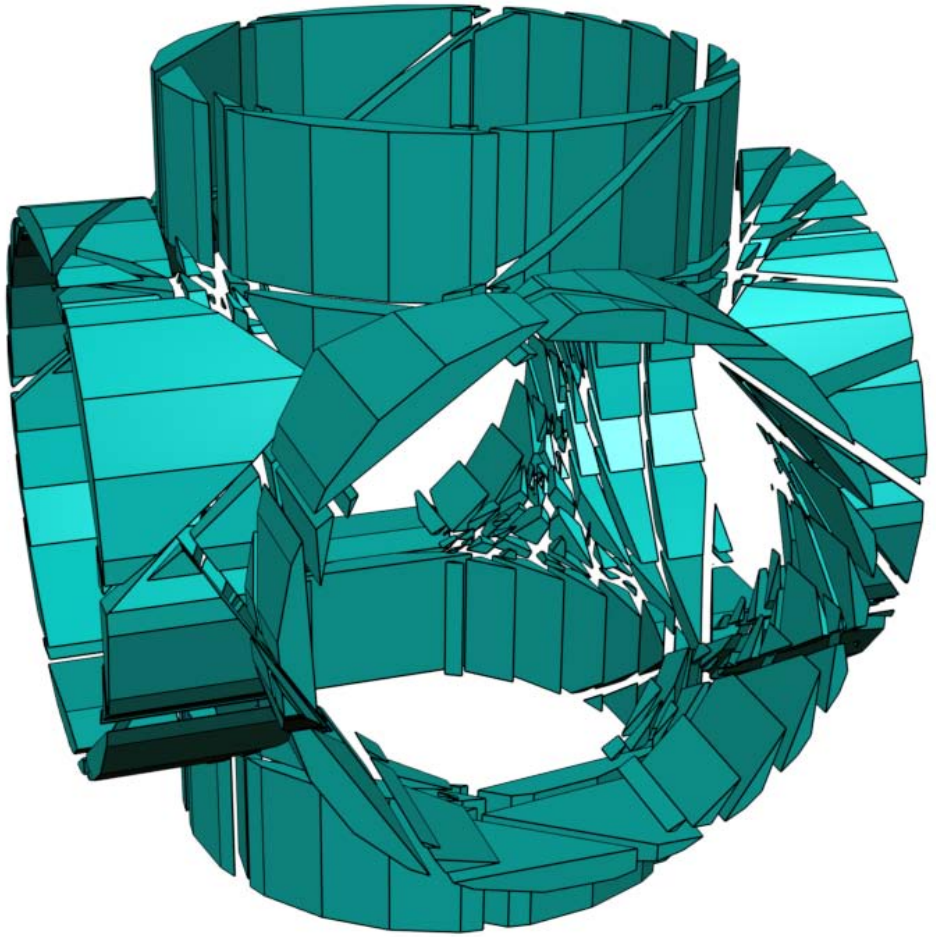
- Volumetric entity (scope): intersection of half-spaces → convex polyhedron
- Half-Space: Oriented plane
  - 2 points with order in 2D
  - 3 points with order in 3D
- Split operation to split scope with plane(s):
  - Split = add plane



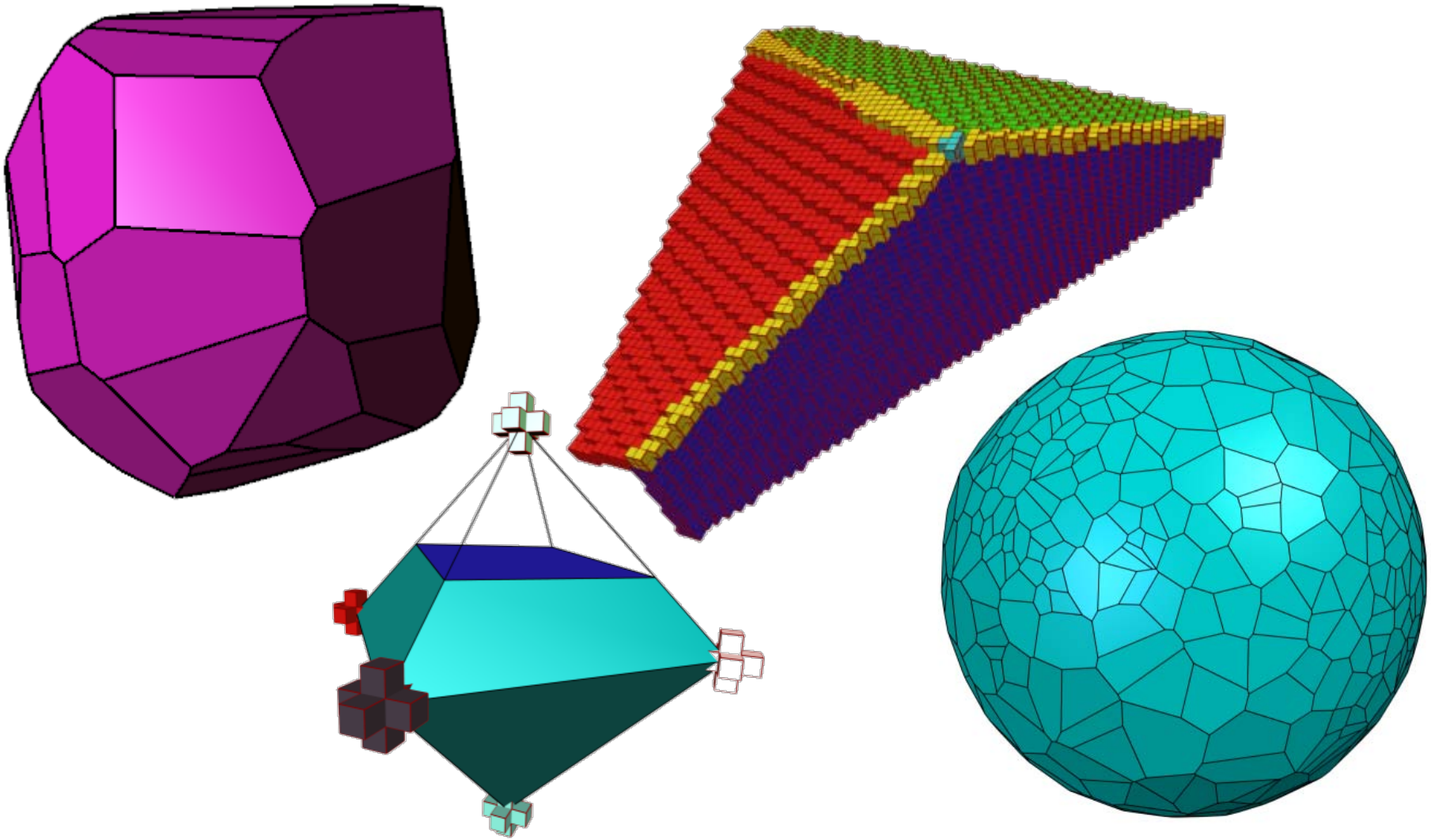


# Convex Polyhedra (CPs)

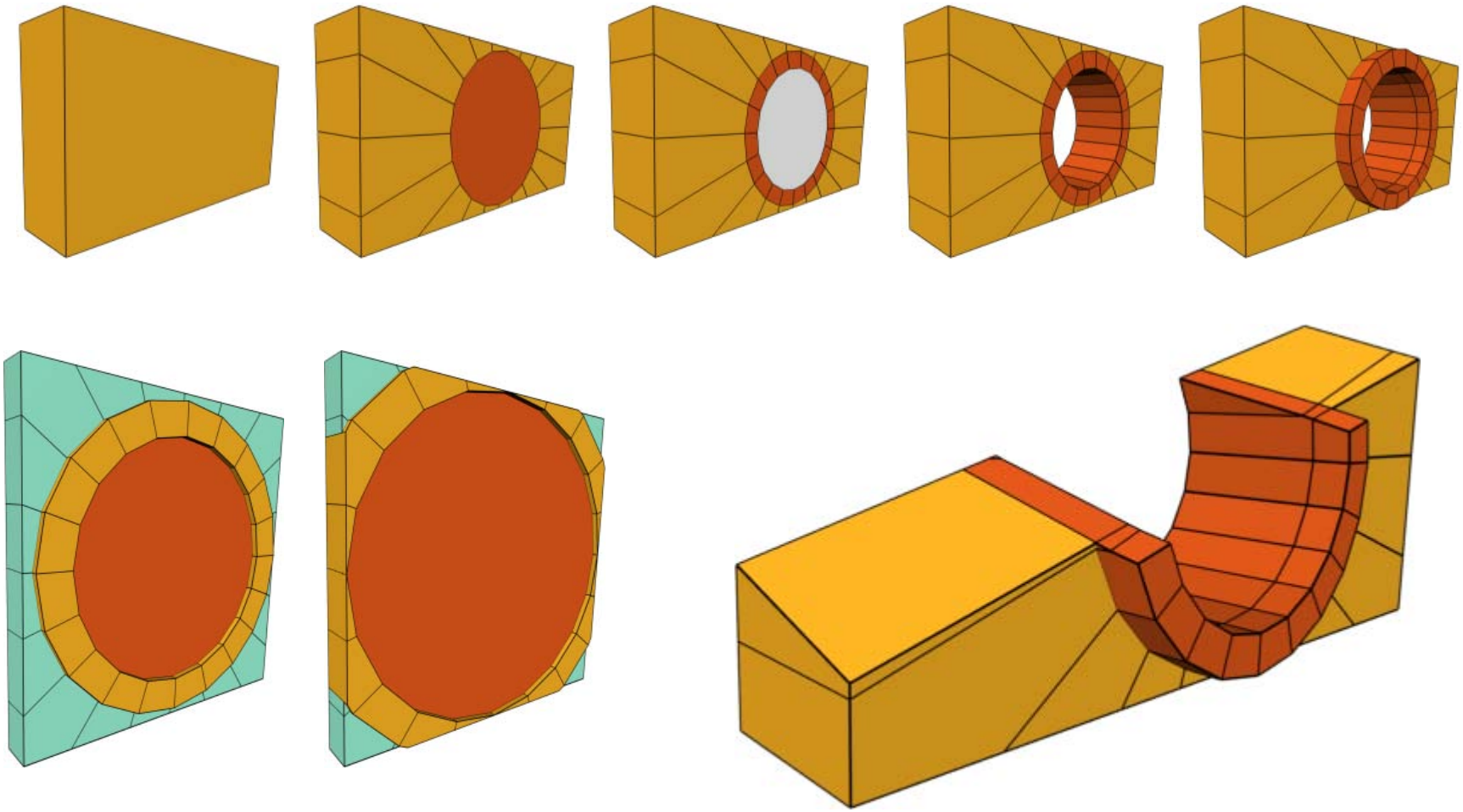




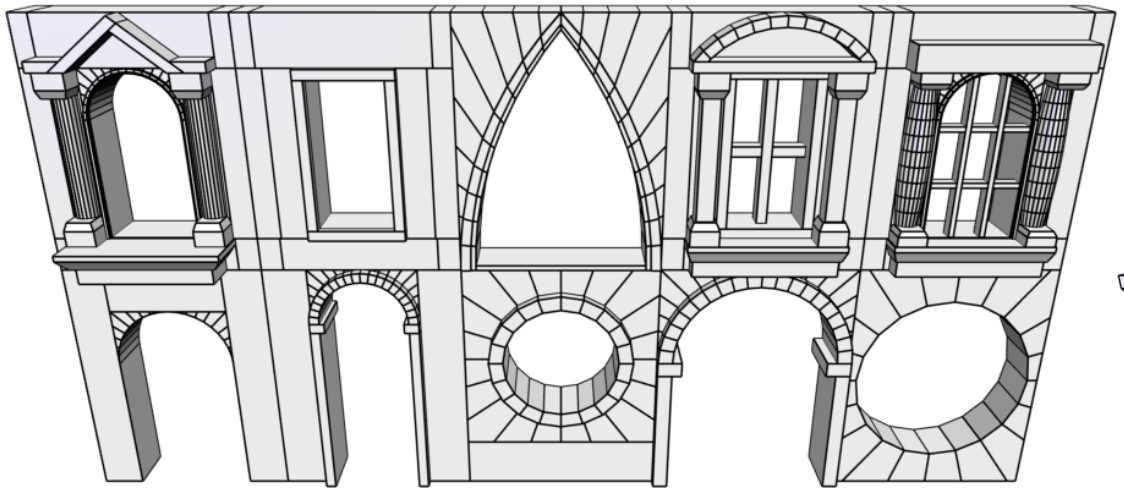
# Convex Polyhedra (CPs)

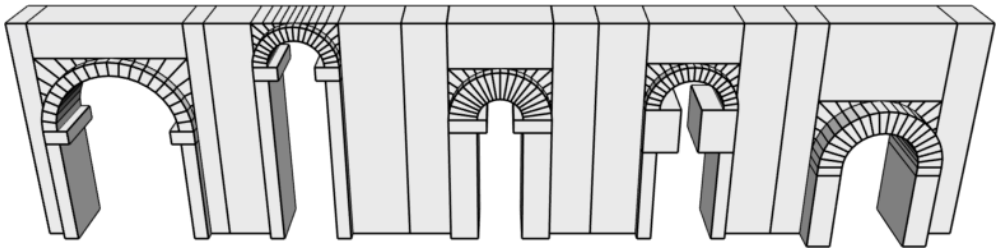


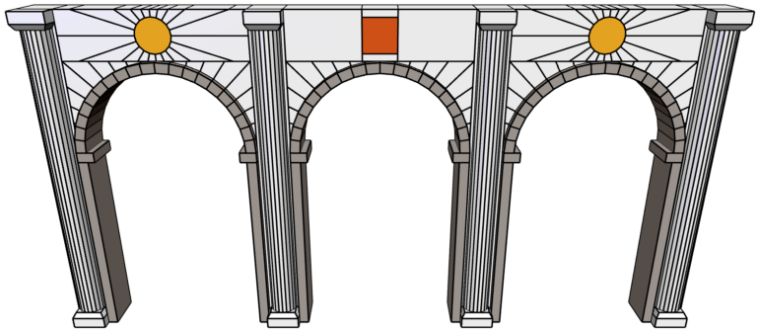
# Convex Polyhedra (CPs)

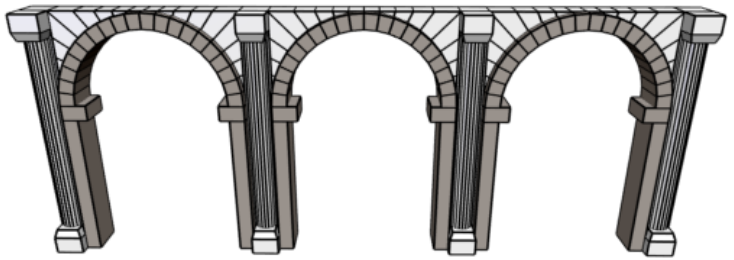


# Terminal rules: Scripted assets





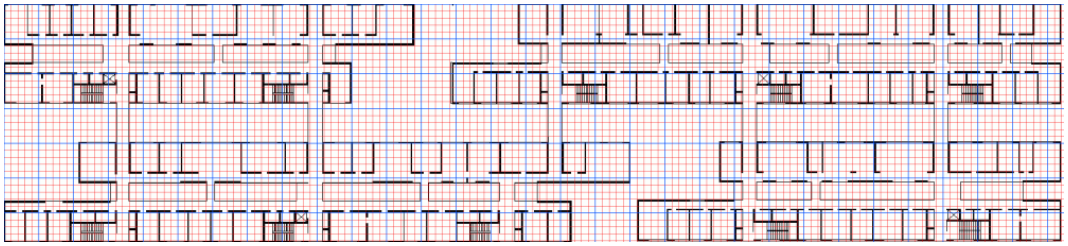


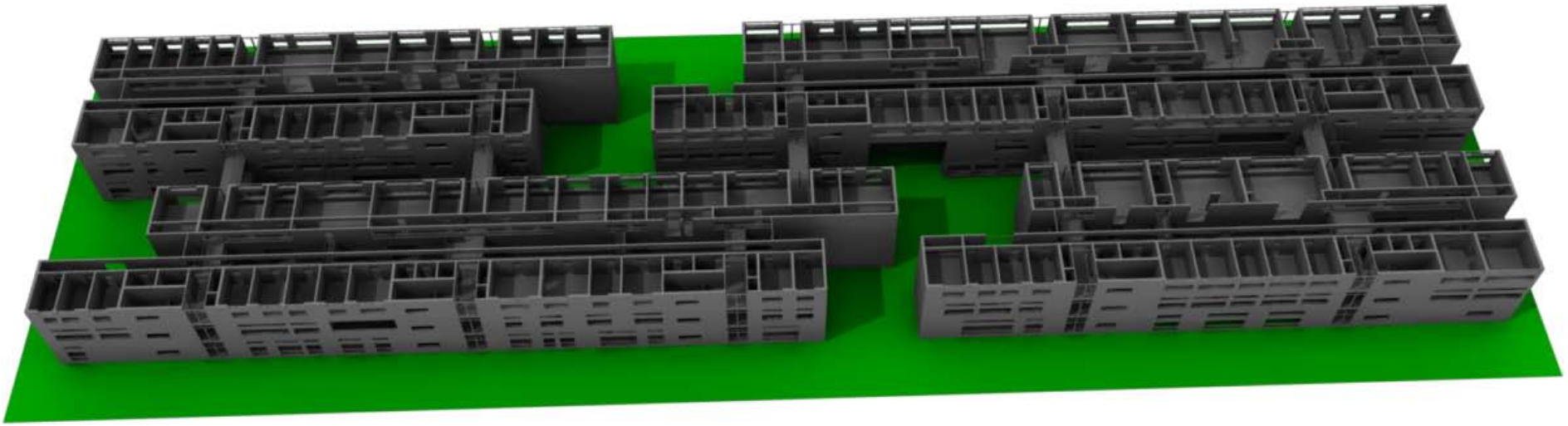


[Hohmann et al., Comp.&Graph. 34(4), 2010]

# The “Qualitative Model”

- All building elements are present, but measurements may be wrong
- Parametrics:
  Add true values anytime later





[CAA 2012]

# Towards a Procedural Reconstruction of the Louvre

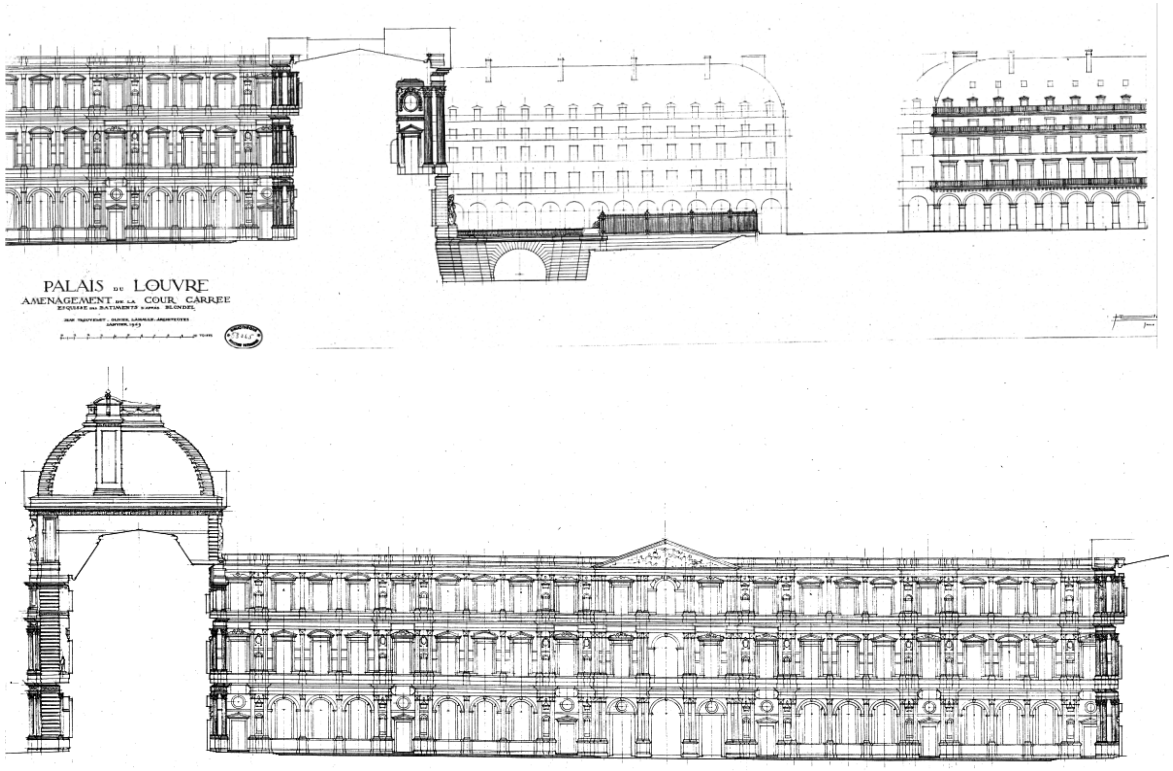
- Bachelor thesis of Martin Pszeida

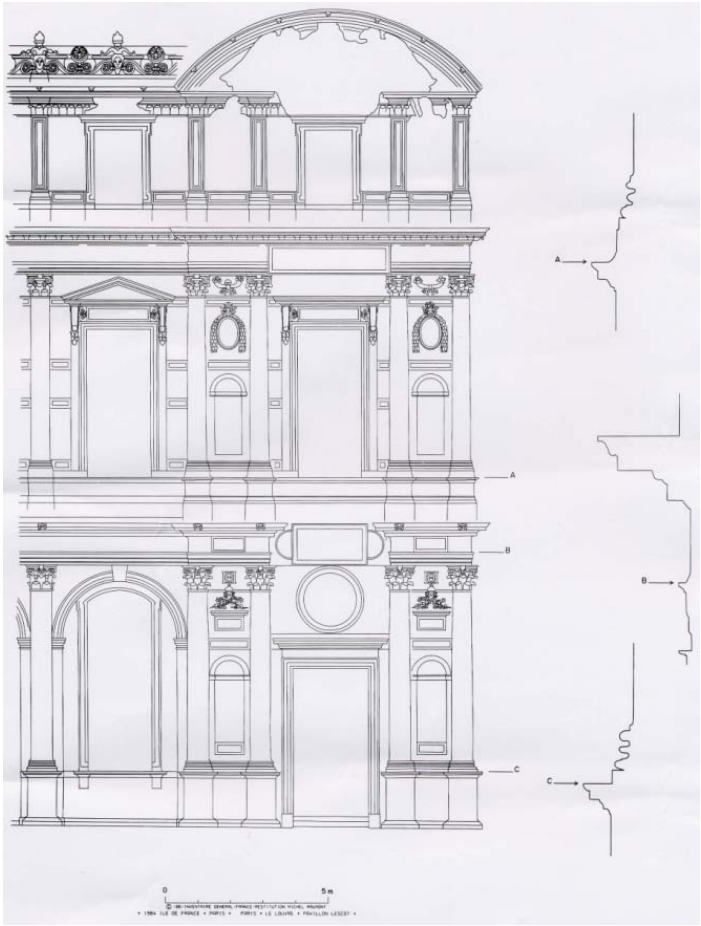
Reconstruction of
Cour Napoléon

[CAA 2012]

# Louvre: Input material

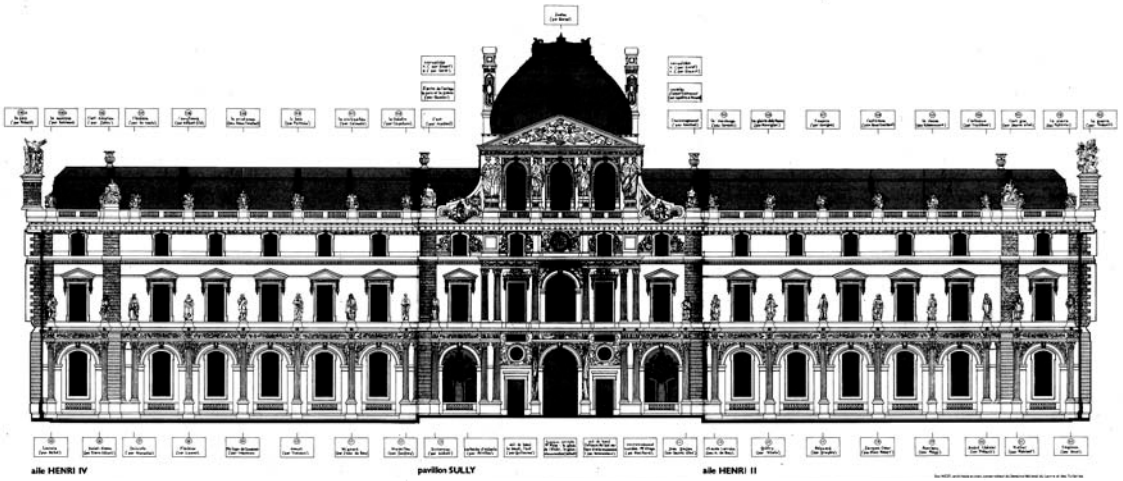
- Scanned plans: Sections, ortho-views

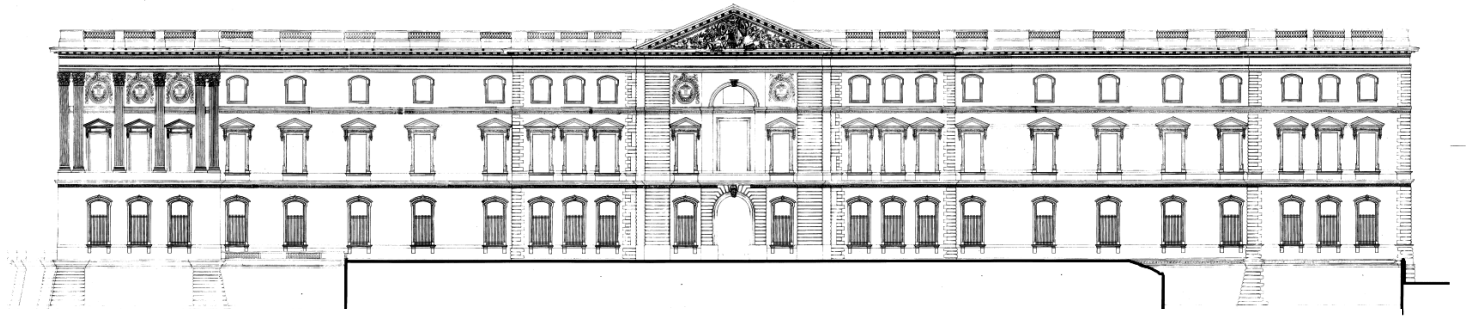


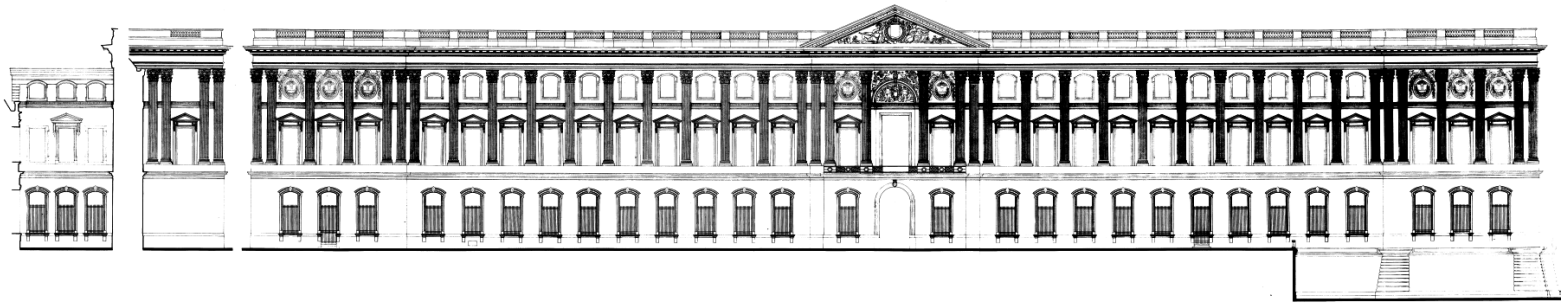



# Louvre: Input material

- West Façade
- North
- South

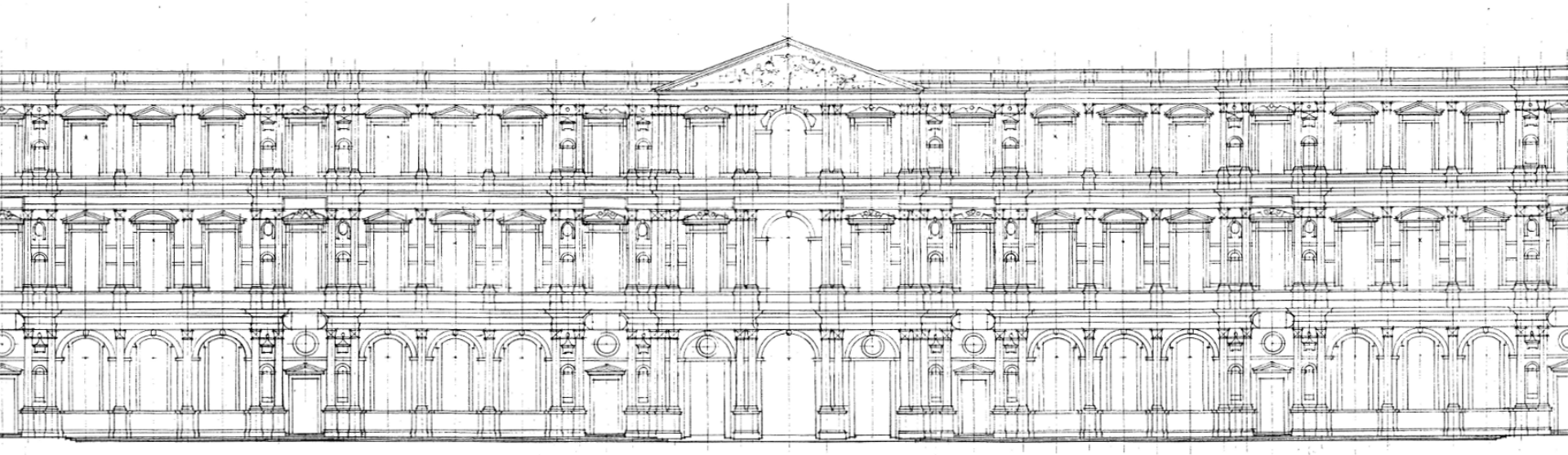




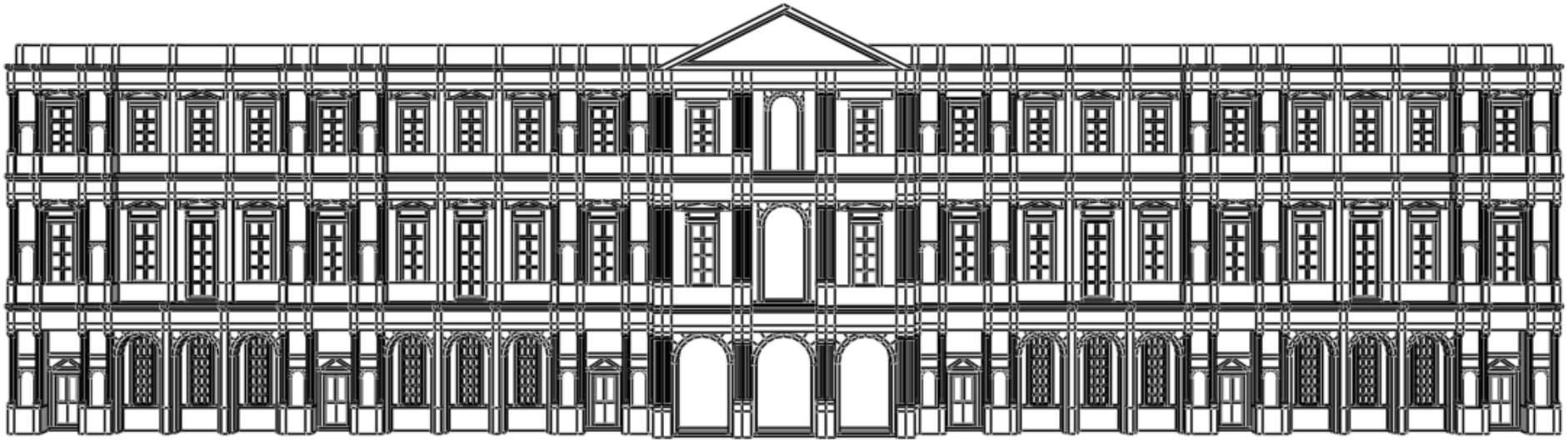
[CAA 2012]

# Split grammars: Hierarchical Box refinement



# Split grammars: Hierarchical Box refinement

- Split rules for boxes
  A → split(xDirection, [1,1,1], **B**)
  **B** → split(yDirection, [1,1], C)
- Finally placing assets (arches, windows, ...)



[CAA 2012]

# Rendered Façade

[CAA 2012]

# Modeling 3D detail

[CAA 2012]

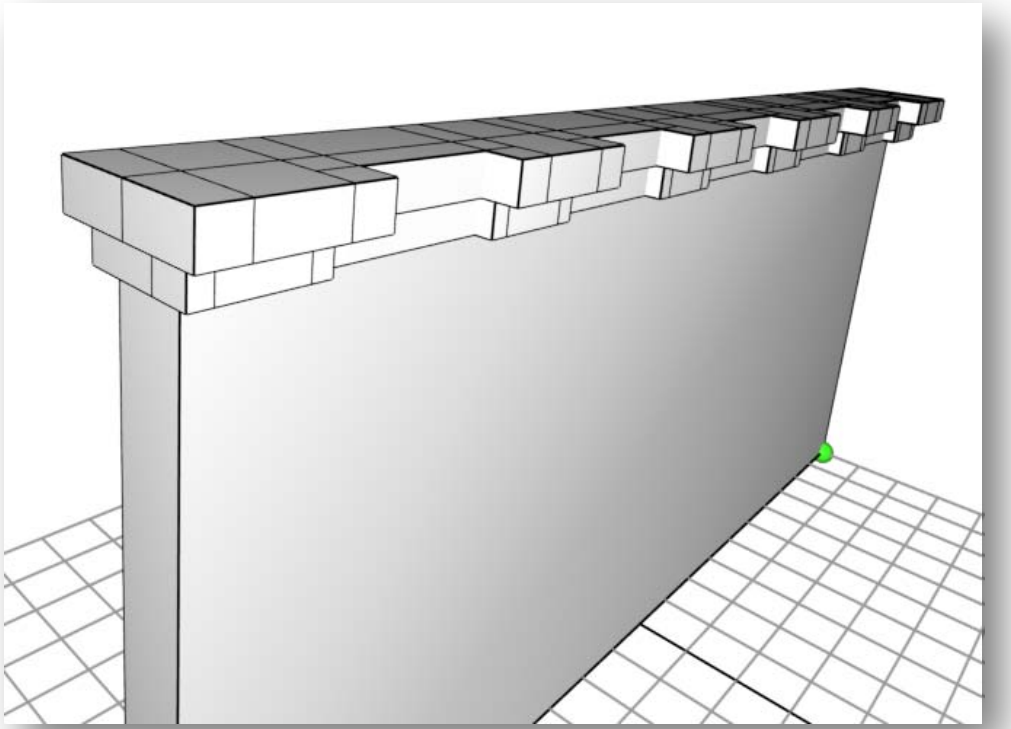
# Modeling 3D detail

- Facade base structure is 2D
- Vaults are modeled using extrusions

[CAA 2012]

# Modeling detail: Ledges

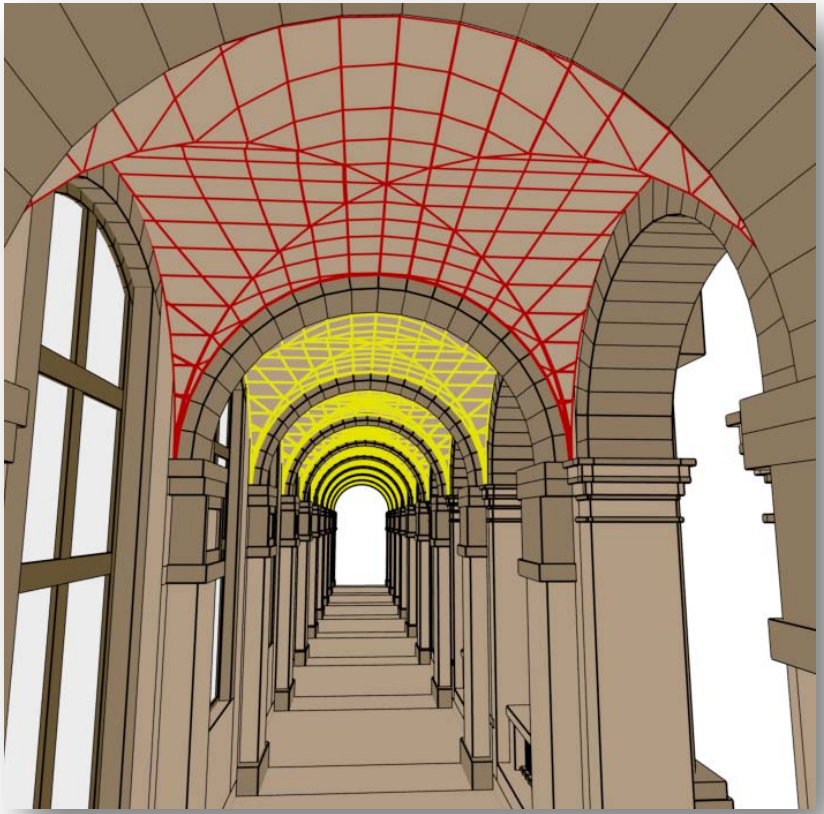
extrude → link → extrude → alternate

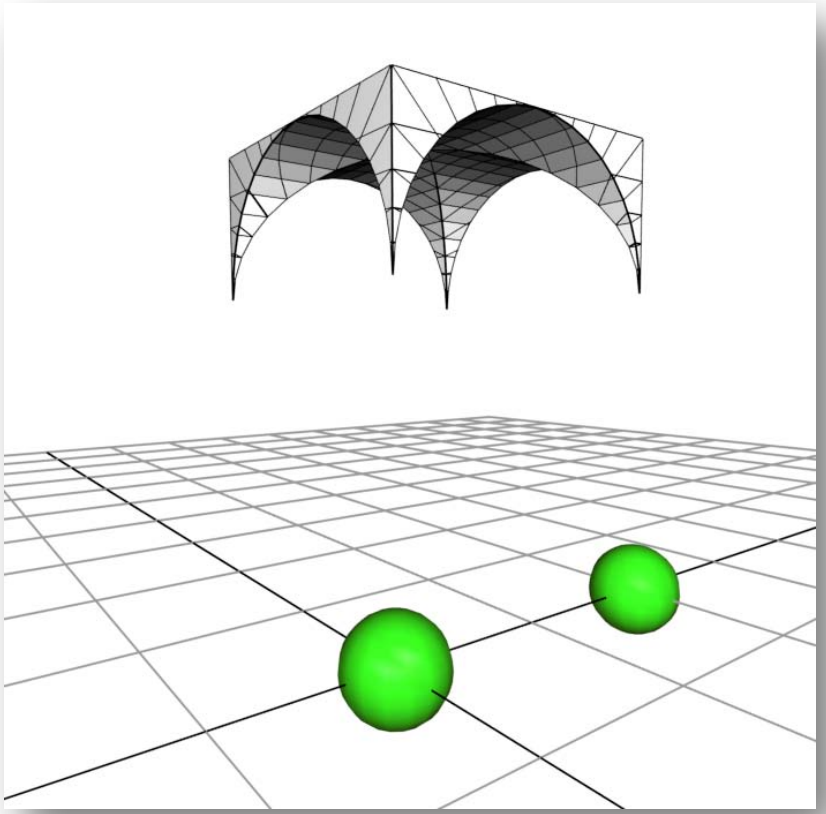


[CAA 2012]

# Modeling detail: Cross vault

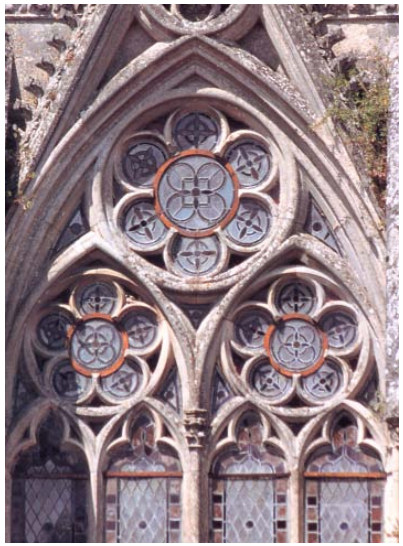
arch → void → arch → void





# What are the future topics?

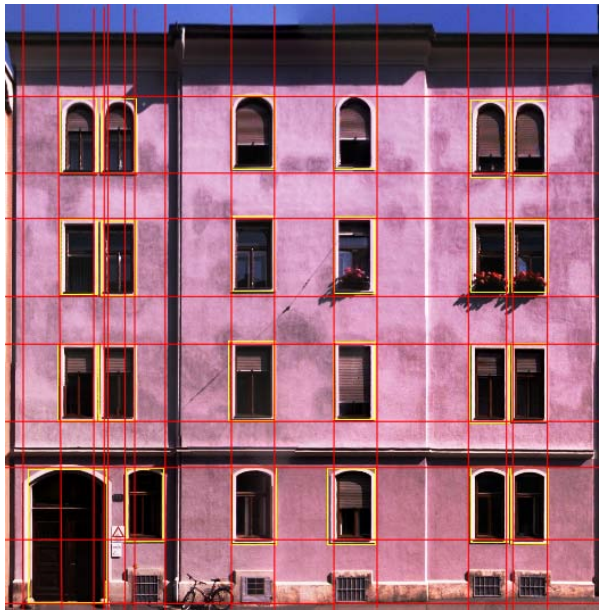
Generative surface reconstruction (inverse)

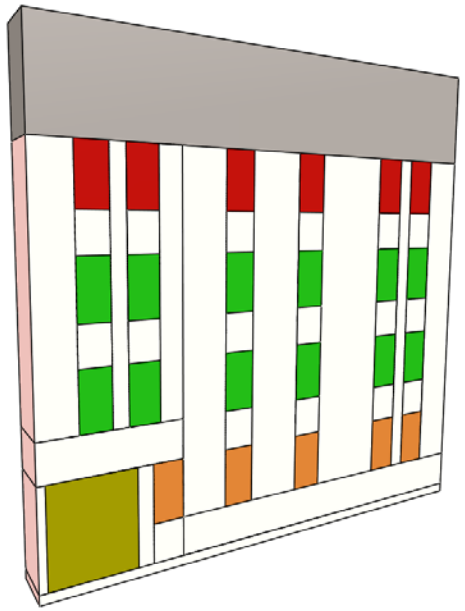


[Riemenschneider et al., CVPR 2012]

# CITYFIT Project (FFG Fit-IT)

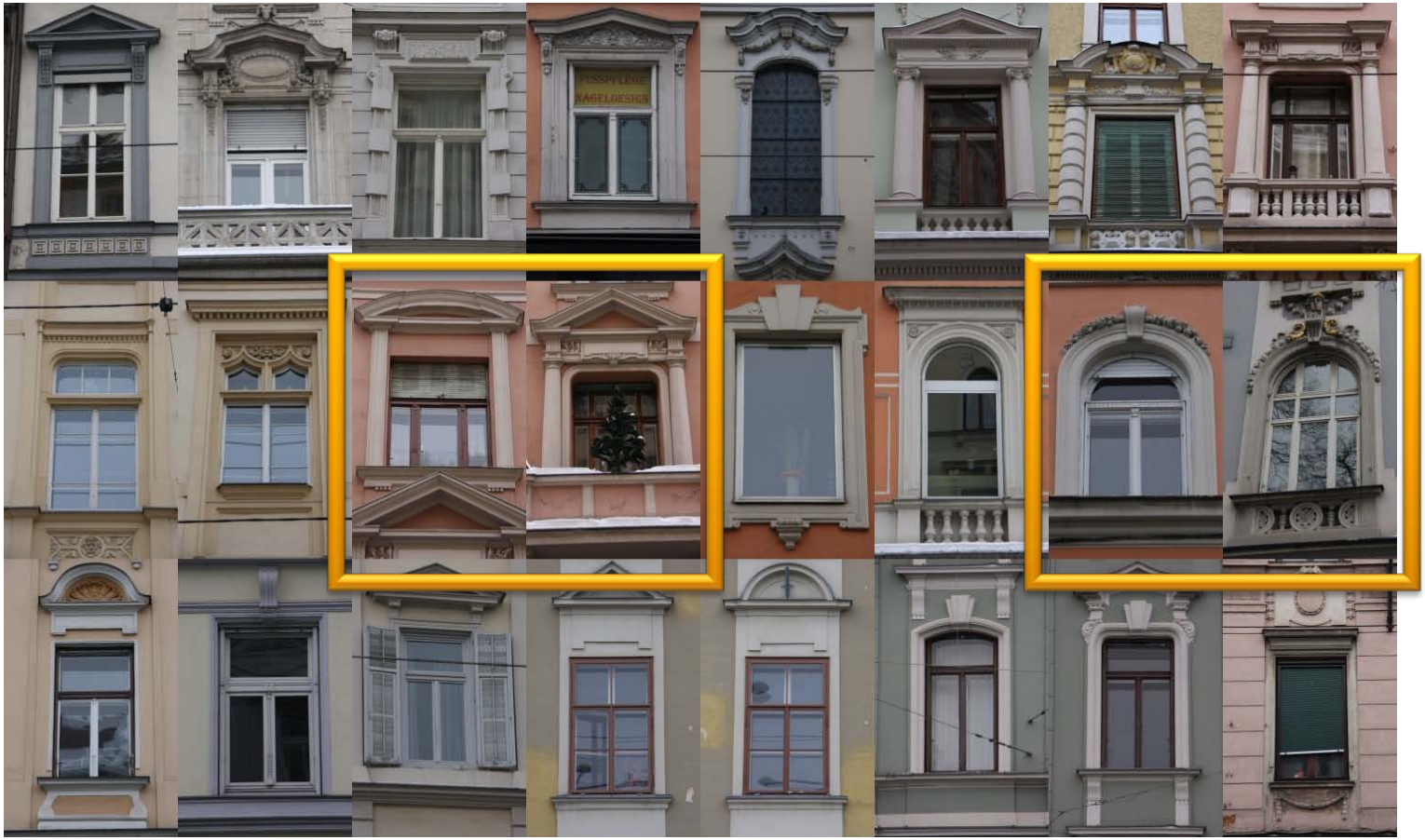
- Automatic façade reconstruction from streetside imagery and LIDAR
  - Cooperation: Microsoft Photogrammetry Graz



[Thaller et al., 3D-ARCH (Trento) 2012]

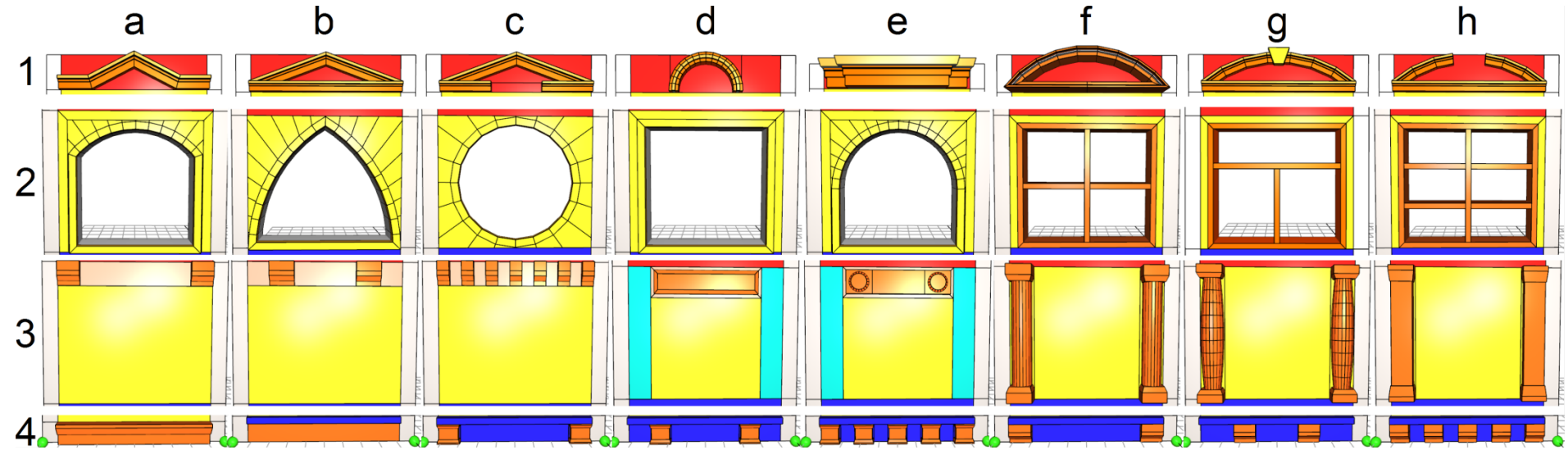
# Creating procedural window building blocks



[Thaller et al., 3D-ARCH (Trento) 2012]

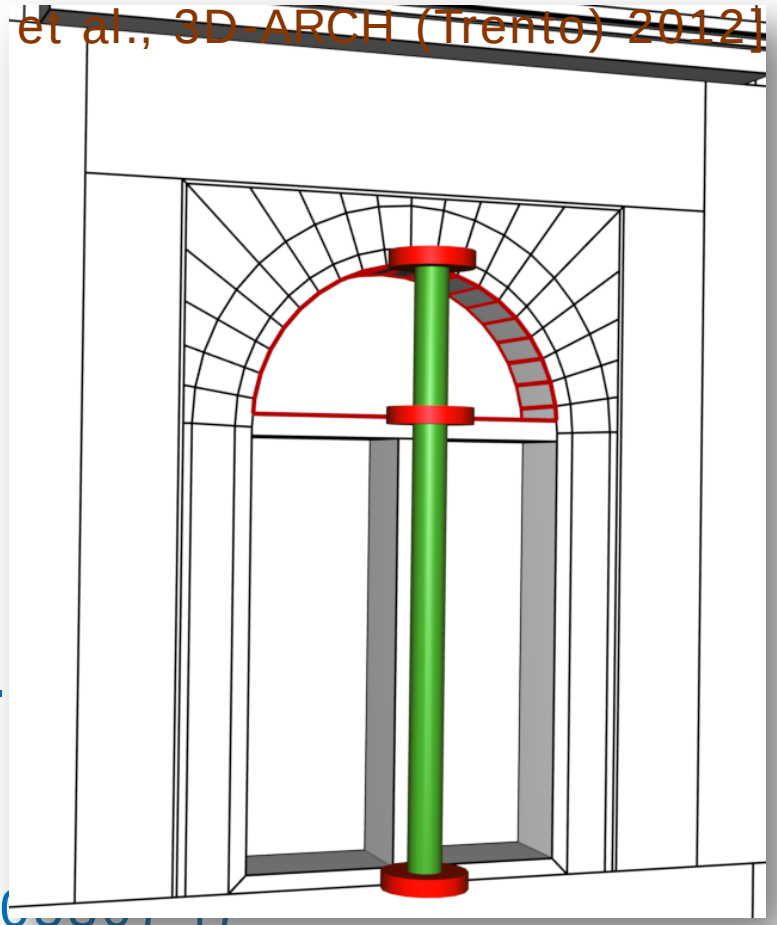
# Procedural Asset Library

- Convex Polyhedra scripted in GML
  - Volumetric & simple: cut = add plane
- One input scope per procedure
  - Scope = set of convex polyhedra



[Thaller et al., 3D ARCH (Trento) 2012]

# Creating the window opening



- **Win.addFrieze**()
- 1: **Win.addPilaster**()
- 1: **frameSplitXZNoBottom**(0.05)
- 1: **arch-a3**(divisions=20, spacing=0.
- 2: **frameSplitXZNoBottom**(0.5)
- 1: **frameSplitXZ**(0.2)
- 1: **split**(Z, Interval=[ -1.4947 -0.5
- **1: hole-rect1**(thickness sides=0.0, thickness top=0.25, thickness bottom=0.0)
- 1: **cross**(thickness vertical=0.25, horizontal splits=0)
- 2: **void**()
- **2: void**()

[Thaller et al., 3D-ARCH (Trento) 2012]

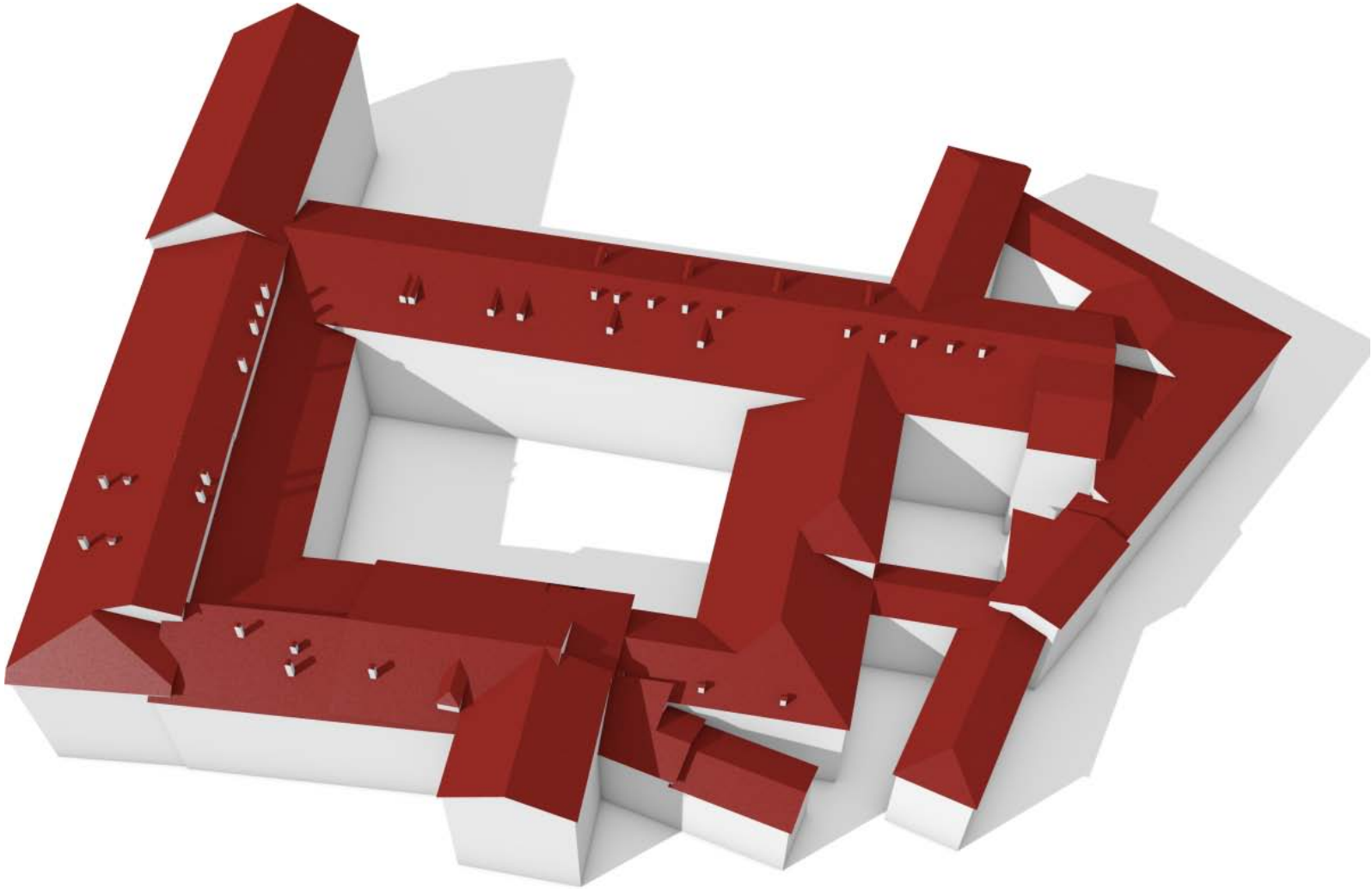
# Results

[Thaller et al., 3D-ARCH (Trento) 2012]

# Variations of blue frame

[Edelsbrunner et al. (submitted)]

# The Roof Modeling Language



[Edelsbrunner et al. (submitted)]

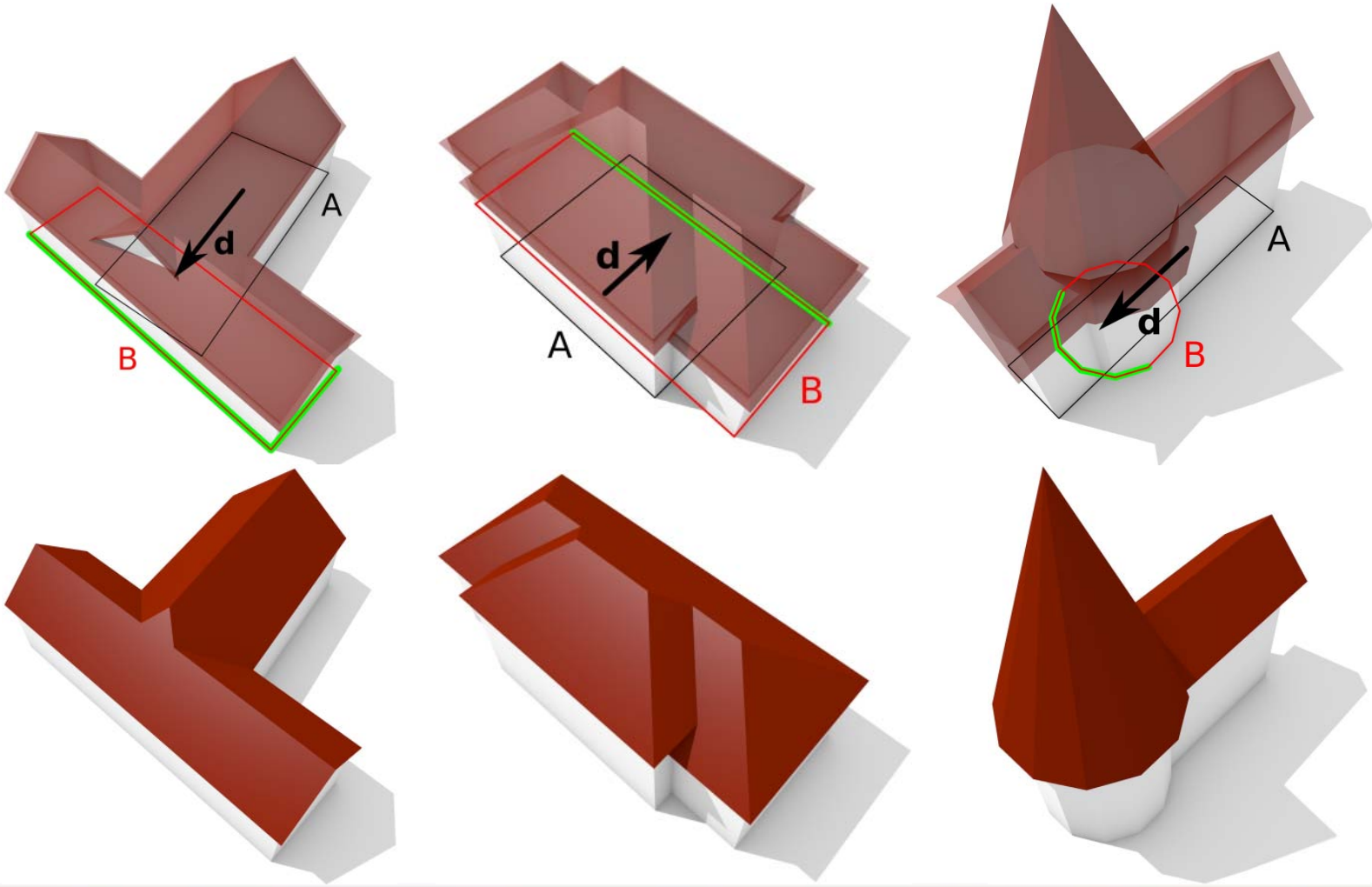
# The Roof Modeling Language

- There is no good standard for describing roofs!
- Parameter **redundancy** minimized
- Any parameter (green) can be changed **independently**
- Without corrupting the roof

```
structure
  parts
    part type=main-axis id=a1
      data
        axis    [(0,0) (25,0)]
      sides
        side type=all
          shape
            angle              40
          distance             10
          overhang             1
          height               20
        side type=across
          shape
            none
```

[Edelsbrunner et al. (submitted)]

# Declarative language, but procedural trimming operations



[Edelsbrunner et al. (submitted)]

# A more complex example

- Intersection removal by successive trimming
  combined with
- Shape grammars for the facades

# Conclusion

- BIM is highly relevant for anybody seriously concerned with digital buildings
- IFC is an advanced technology for the detailed description of real buildings
  - Interesting: Entity-relationship model
  - Simple and complex at the same time
  - For software developers: Export to IFC is easy, selective (geometry) import is easy, support of all IFC features is difficult
- Parametric approach: Fixed set of features
- Inverse BIM is a vast field for R&D

# Conclusion

- The real challenge is inverse procedural modeling
- Especially for Turing-complete rule sets
  - Programming languages
  - Context-sensitive grammars / graph grammars
- Obstacles: Halting problem, and the Incomputability of Kolmogorov complexity
  - Given output data, what is the shortest computer program to generate these data?

# GML Homepage

**www.generative-modeling.org**

**www.havetronic.at**