GROPYUS

Building on Data: Semantic Modelling of 3D Geometry at Scale.

geof3D: SPARQL geometric functions for co-designing buildings

Our pillars
Creating a new residential product

AFFORDABLE

High-quality homes that are both affordable and inclusive.

SUSTAINABLE

Future-ready buildings with social and sustainable impact.

ASPIRATIONAL

Scalable housing concept for lasting value and strong returns.

Our team
Experts across the board

Our team of experts in the fields of **engineering**, **construction**, **technology** and more is the basis for our success story. At the forefront are three founders with an impressive track record and the IPO of two billion-dollar technology companies (DAX, MDAX).

500
Employees

digital, interdisciplinary and united by the will to change.

300M
Funding

contribute to growth and development of scalable solutions.

~3,500
Apartments

yearly capacity based on digital, industrial processes.

65
Projects

in the GROPYUS pipeline as a general contractor in Germany and Austria.

How we work
Buildings at scale

We create timber-based homes turn-key from one hand.

Software-based we develop technically ready-to-connect building elements. The focus is on combining standardization and customization for time and cost efficiency.

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What we offer
Highest value for money per building

Optimal utilization of the plot
for maximum living space

Shortened construction time
and reliable processes

Individual planning
with fixed costs

Digital operation system
for efficient administration

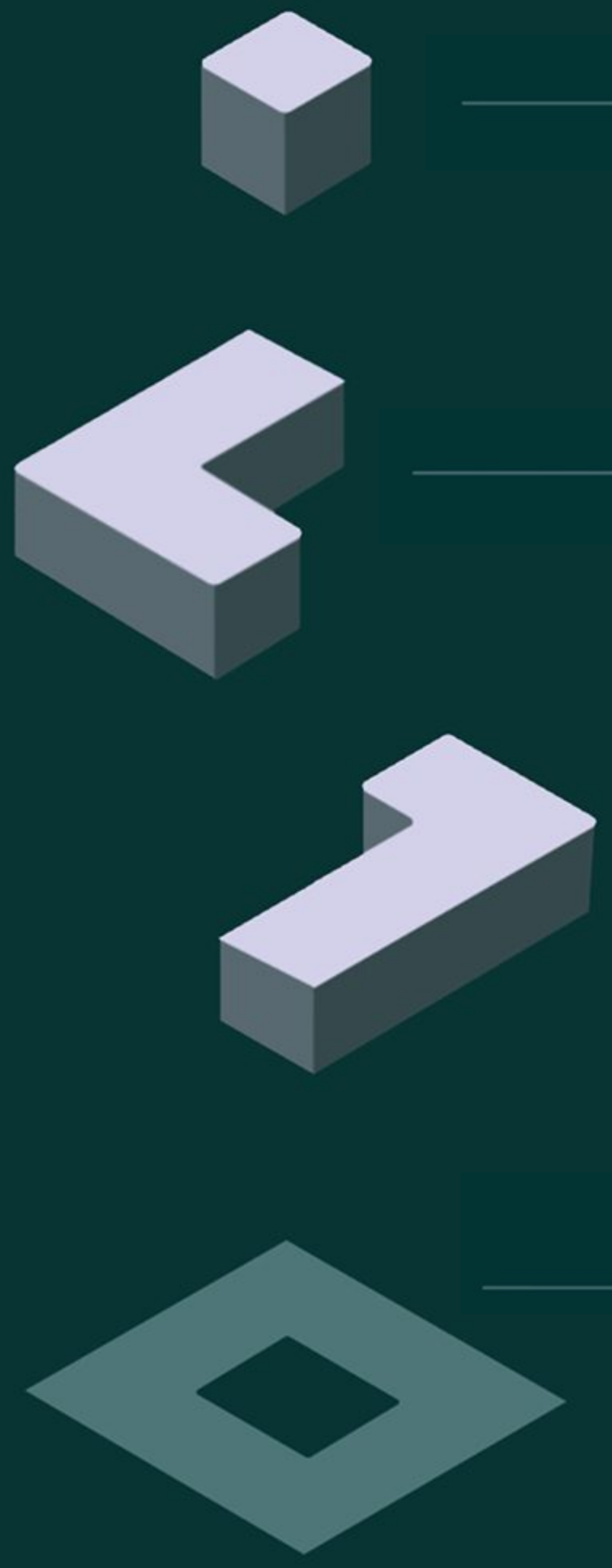
ESG-compliant
construction method

Increase value of the building
through resident-focused services

Our process
A finished building in four steps—on a digitalized base

With our digitized approach, an apartment building is erected on our platform from the very beginning.

In real-time, all the data collected during development forms the robust backbone for production, assembly and sustained building operation. This enables us to ensure end-to-end transparency, continuous analysis and zero-error control of all processes.



Planning

Our digital building system supports efficient planning and optimal land use.

Production

We scale and accelerate industrial production at our dedicated smart factory.

Construction

On-site assembly is straightforward, fast, and predictable.

Operation

Our Building Operation System offers easy management and additional income.

geof3D
SPARQL geometric functions for co-designing buildings

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Full length article

geof3D: SPARQL geometric functions for co-designing buildings

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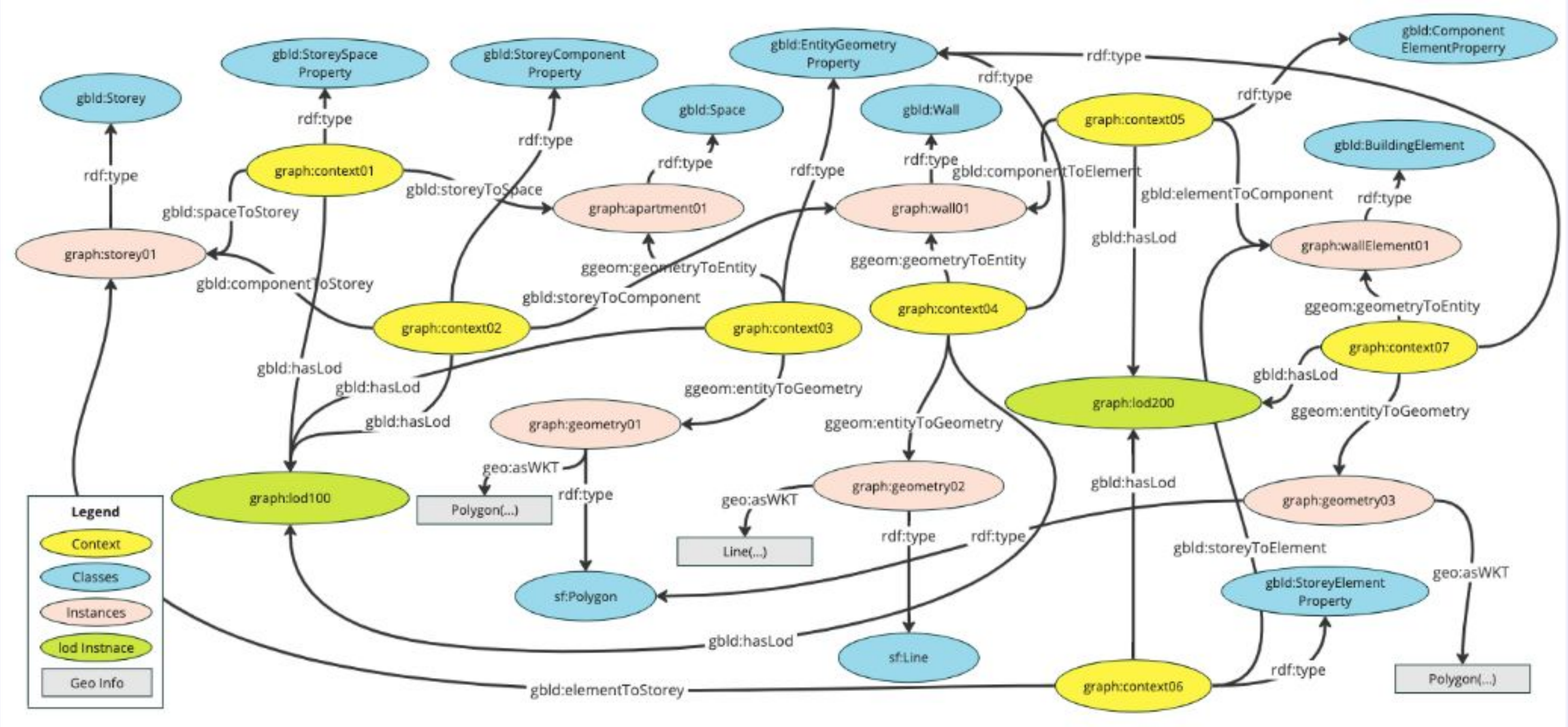
`geof3d: a sparql:extension .`
enabling:

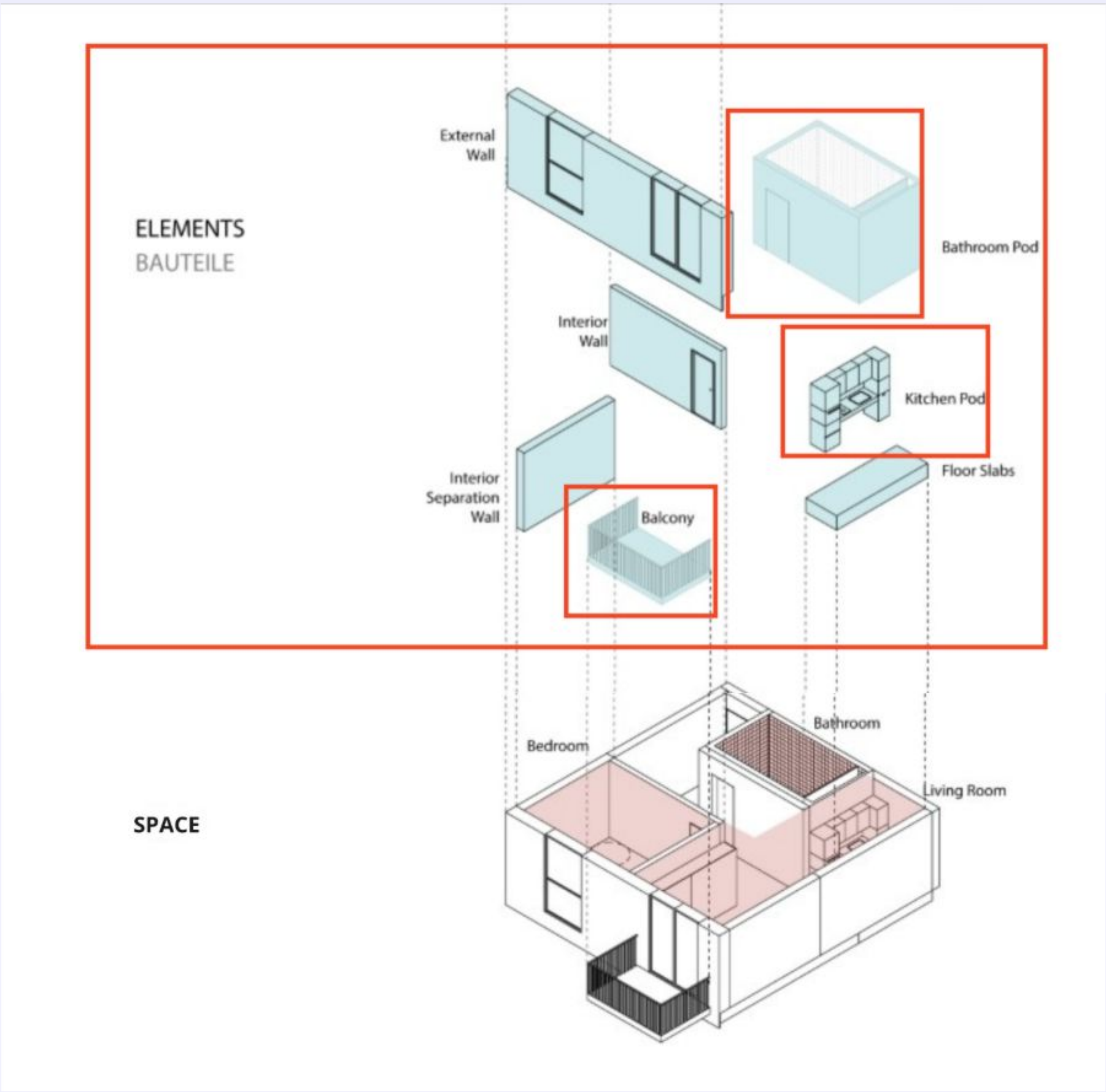
- 3D measurements,
- topological relations,
- Boolean operations,
- affine transformations, directly inside RDF triple stores

Motivation
Buildings are more than graphs




```
ex:Building_A
   a ex:Building ;
   ex:name ”Apartment Building A" ;
   geo:hasGeometry ex:Building_A_Geometry .

ex:Building_A_Geometry
   a geo:Geometry ;
   geo:asWKT """
   POLYGON((
      0 0,
      20 0,
      20 15,
      0 15,
      0 0
   ))
   """^^geo:wktLiteral
```



RDF Representation of Geometry
Key Concepts

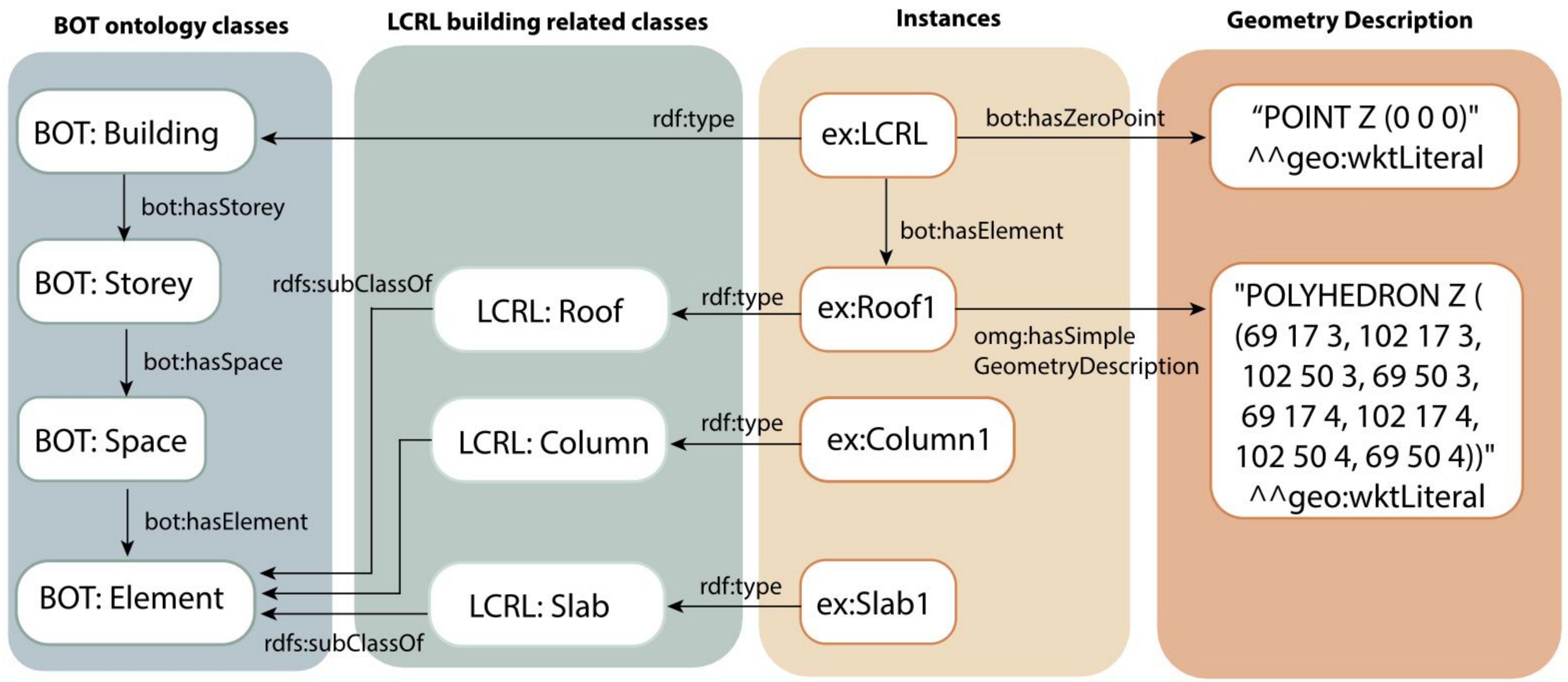
- WKT with Z-coordinates
  - RDF Literals
  - markup language for vector geometry objects

- Ontology alignment
  - W3C GeoSPARQL
  - ifcOWL
  - BOT ontology
  - LCRL ontology
  - …

Well-known Text (WKT)

WKT representation of 3D geometries.

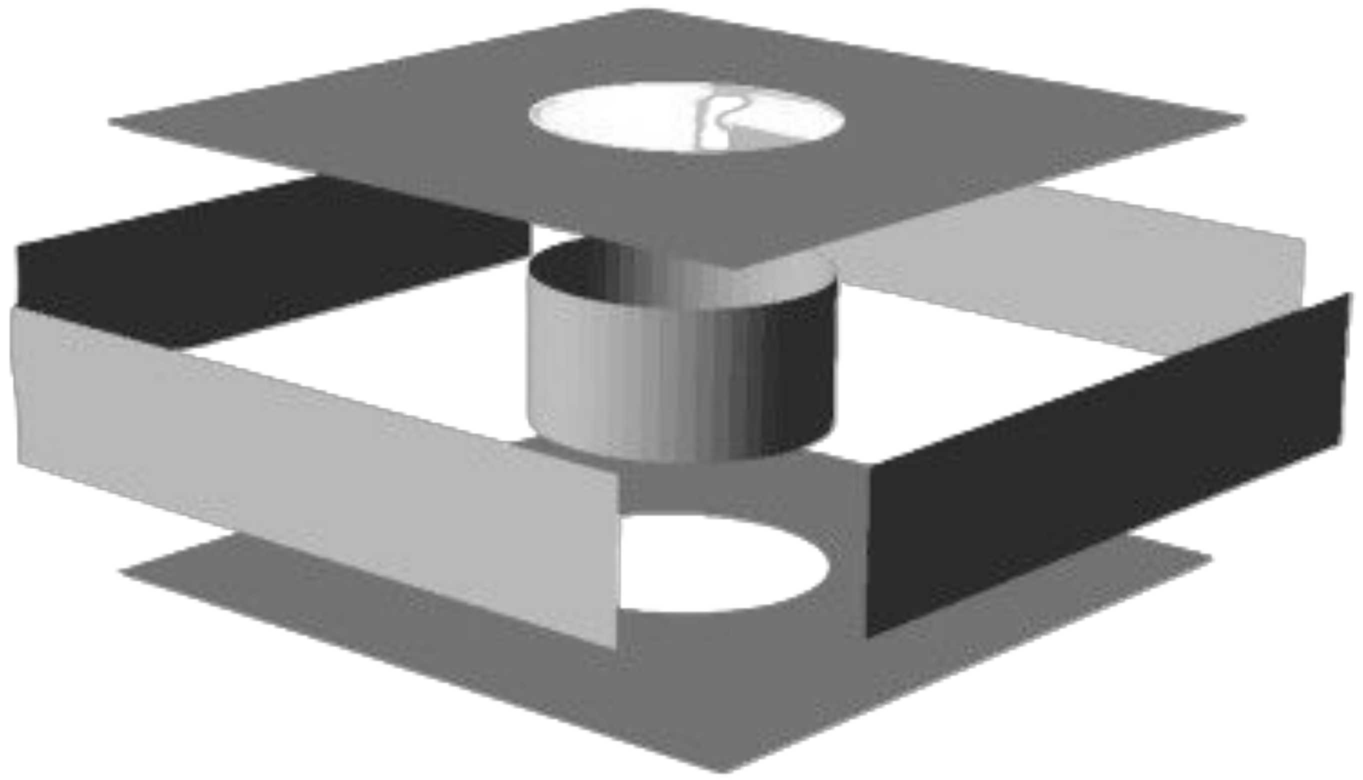
WKT type	Description
POINT Z (x y z)	A single 3D point.
LINESTRING Z (x_1 y_1 z_1, . . . , x_n y_n z_n)	A connected sequence of points forming a 3D line.
POLYGON Z ((x_1 y_1 z_1, . . . , x_n y_n z_n, x_1 y_1 z_1))	A closed 3D surface defined by points.
POLYHEDRALSURFACE Z	A 3D object composed of triangular and quadrilateral faces.
TIN Z (Triangulated Irregular Network)	A 3D mesh representation where each face is a triangle.



Solid Modelling
Key Concepts

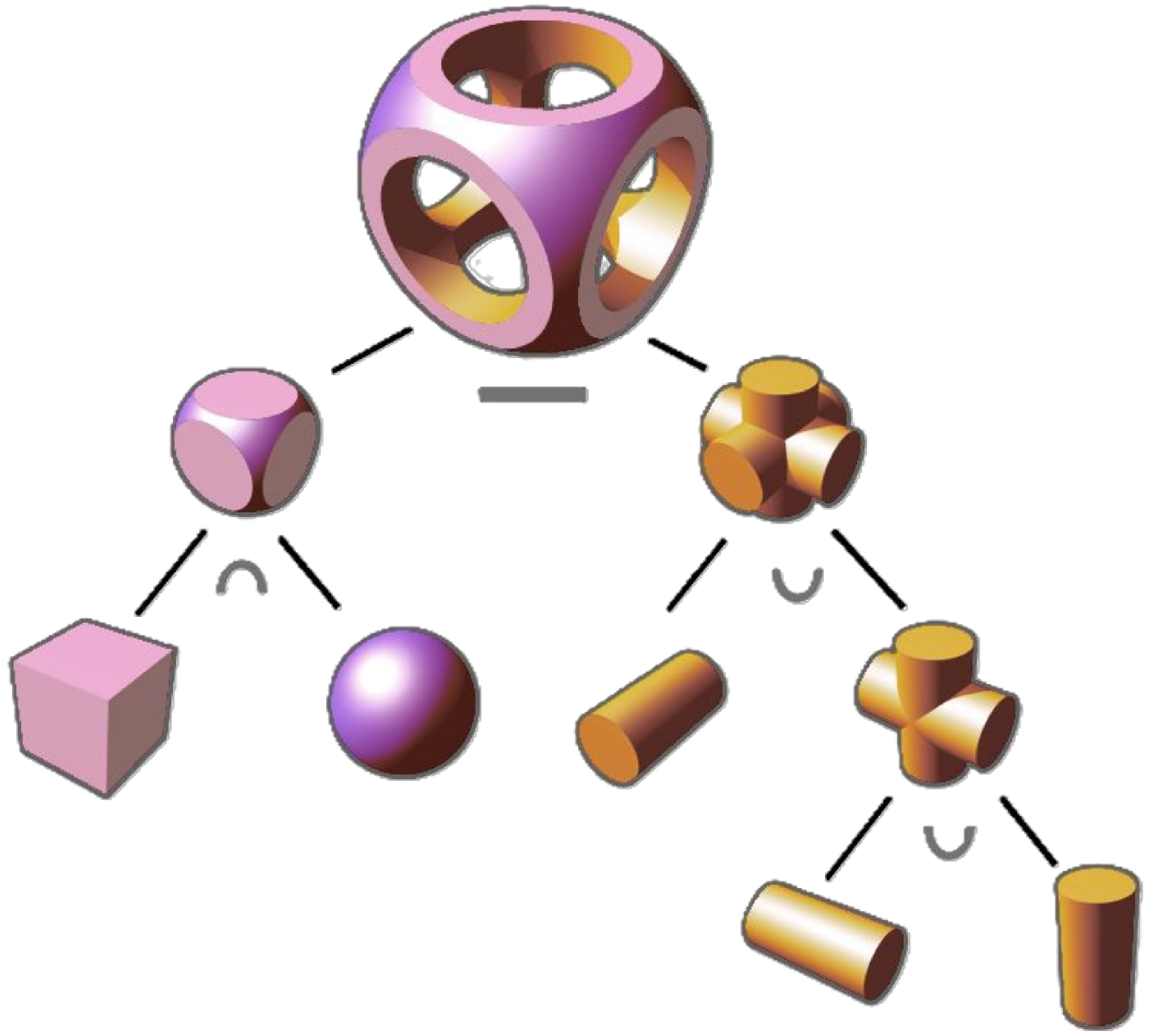
Boundary Representation (B-REP)

- aggregation of boundary surfaces which enclose solid
- complex boundaries approximated as wireframes/mesh



Constructive Solid Geometry (CSG)

- based on simple 3D primitives
  - boxes, cones, spheres, ...
- primitives are combined using Boolean operators
  - union, difference, intersection
  - represented as a Boolean tree



Local Reference-point geometries

- elements have individual reference points (instead of geo-location)
- comparing element data demands reference points to be aligned

The Semantic Web Geometry Gap

Semantic Web technologies lack native 3D geometry support

AEC industries rely on 3D geometry

no native support in RDF and SPARQL

Existing approaches:

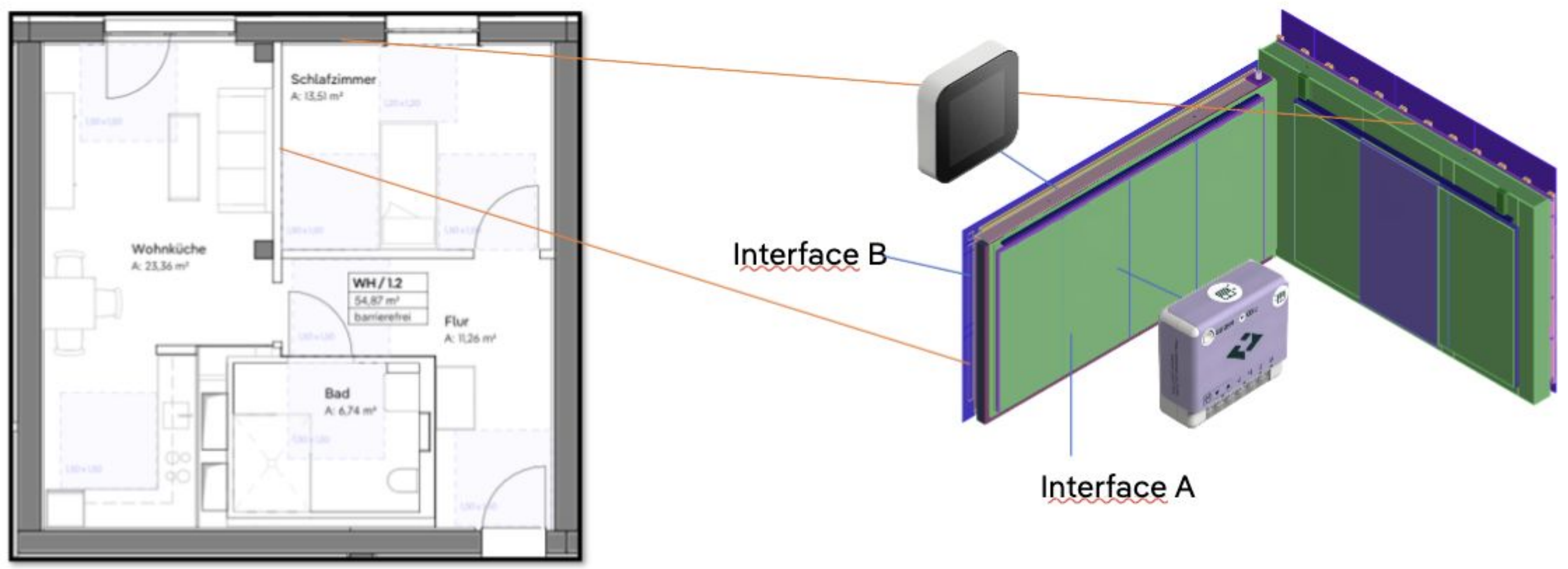
- *reduce geometry to 2D,*
- *offload computation to spatial databases (PostGIS), or*
- *require external geometry pipelines*

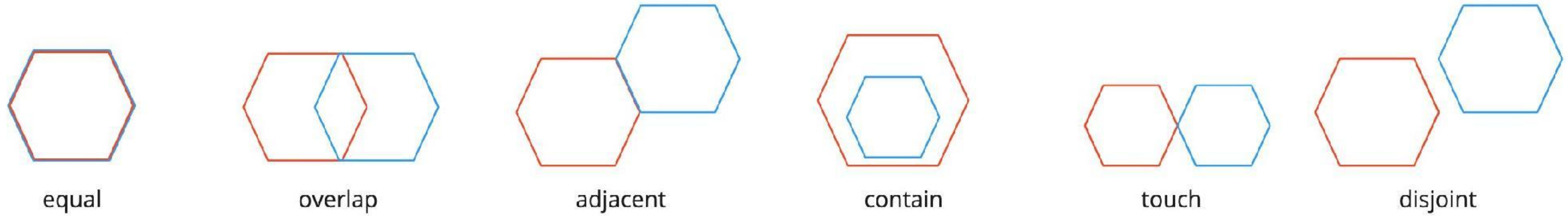
□

- *fragmented workflows,*
- *broken interoperability,*
- *geometry disconnected from reasoning*

In which room is a device located?
Use case

- A semantic answer alone is often unavailable
- Need to determine spatial relationships between walls to derive rooms





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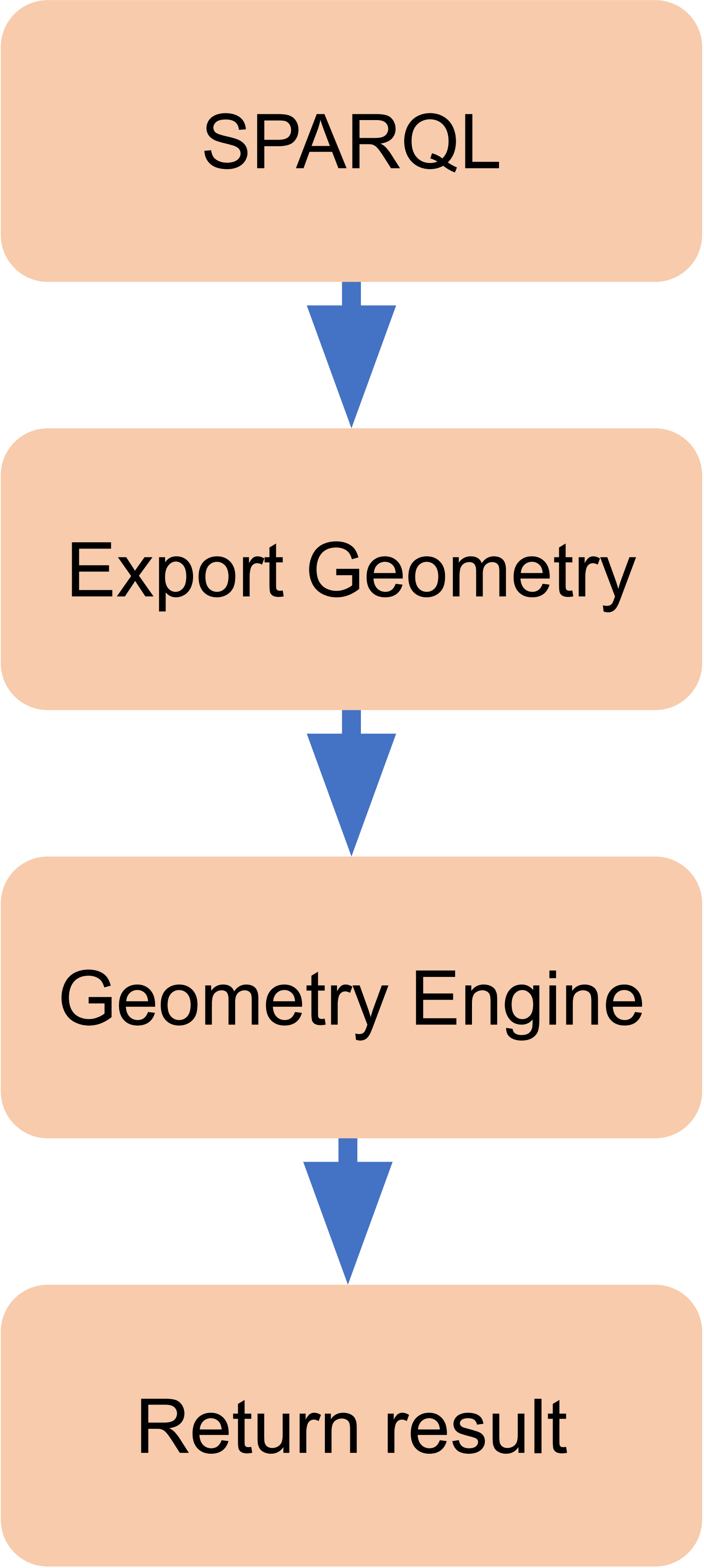
Traditional Workflow
... to answer ”Which room contains the device?"



- Extract geometry
- Run external geometry code
- Re-import result

Problems:

- Complex pipelines
- Synchronization issues
- Loss of declarative querying

geof3D Idea

Knowledge Graph + 3D Geometry + SPARQL

Core contribution

- geof3D extends SPARQL with 3D geometric functions executed directly within the RDF environment

Function Semantics and Typing

Measurement:

Geometry → Scalar

geof3d:volume(?geom)

Relational:

Geometry → Boolean

geof3d:intersects3D(?geomA, ?geomB)

Constructive:

Geometry → Geometry

geof3d:union3D(?geomA, ?geomB)

Transformational:

Geometry → Geometry

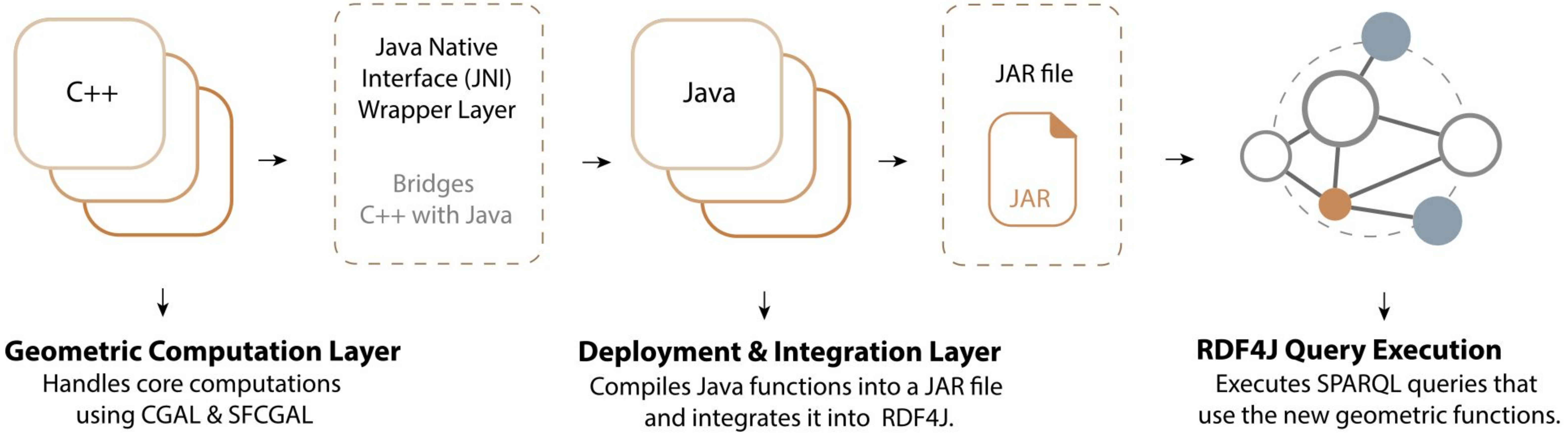
geof3d:translate(?geomA, ?vector)

Function	Signature	Inputs/Outputs
Measurement & Analysis ($G \to \mathbb{R}$ or $G \times G \to \mathbb{R}$)		
Distance3D	$f(G_A, G_B) \to \mathbb{R}$	2 geometries → scalar distance
Area	$f(G) \to \mathbb{R}$	Planar polygon → area
Volume	$f(G) \to \mathbb{R}$	Closed solid → volume
Centroid	$f(G) \to G'$	Solid → centroid (POINT Z)
Relational/Predicate ($G \times G \to \{0,1\}$)		
Within3D	$f(G_A, G_B) \to \{0,1\}$	A inside B?
Covers3D	$f(G_A, G_B) \to \{0,1\}$	A covers B?
IntersectBoolean	$f(G_A, G_B) \to \{0,1\}$	Intersection exists?
UnionBoolean	$f(G_A, G_B) \to \{0,1\}$	Union non-empty?
IsValid	$f(G) \to \{0,1\}$	Valid mesh?
Constructive Boolean ($G \times G \to G'$)		
Intersection3D	$f(G_A, G_B) \to G'$	New geom ($A \cap B$)
Union3D	$f(G_A, G_B) \to G'$	New geom ($A \cup B$)
Difference3D	$f(G_A, G_B) \to G'$	$A \setminus B$ solid
SymDifference3D	$f(G_A, G_B) \to G'$	XOR solid
Transformational/Affine ($G \times v \to G'$)		
Extrude	$f(G, v) \to G'$	Polygon + vector → solid
Translate	$f(G, v) \to G'$	Geometry moved by vector
Rotate	$f(G, \theta) \to G'$	Geometry rotated
Transform	$f(G, M) \to G'$	Affine matrix transform
Negate	$f(G) \to G'$	Vector mirroring

SPARQL functional extension
Architecture

Components

- custom RDF4J SPARQL built-in functions
- functions namespace geof3d: (https://w3id.org/geof3d#)
- JNI bridge connecting to SFCGAL and CGAL (Computational Geometry Algorithms Library)
- backend can be changed if needed



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Integration with Linked Building Data

Compatibility

- BOT ontology
- ifcOWL
- Brick schema
- Digital twins
- Knowledge graphs

- geof3D complements Linked Data pipelines rather than replacing BIM tools

Semantic-Geometric Reasoning

… to answer ”Which room contains the device?"

Queries combine:

- Graph Semantics
- Geometric Computations

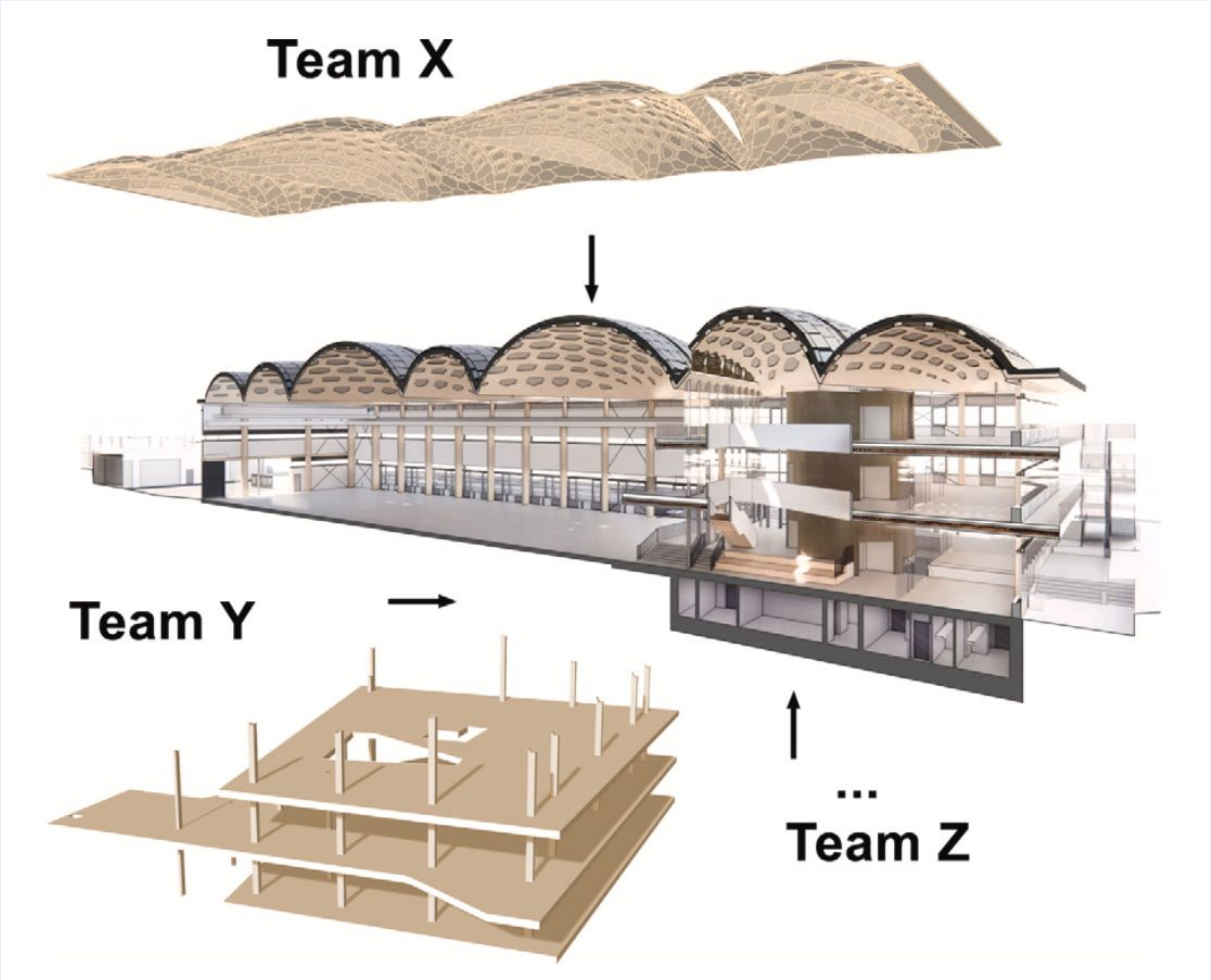
```
SELECT ?room
WHERE {
  :Device123 geo:hasGeometry ?devGeom .
  ?room a bot:Room ;
        geo:hasGeometry ?roomGeom .

  FILTER(
    geof3d:Within3D(
        ?devGeom,
        ?roomGeom
    )
  )
}
```

More Co-Design Scenarios

AEC co-design requires simultaneous semantic and geometric reasoning

- Clash detection,
- Spatial alignment,
- Algorithmic modelling,
- Design coordination,
- Fabrication workflows



Relation to GeoSPARQL

GeoSPARQL strengths

- topological vocabulary
- spatial indexing
- geospatial interoperability

Main limitations

- primarily 2D semantics
- weak support for solids/meshes
- lacks computational geometry operators
- no affine transformations

Feature	GeoSPARQL	geof3D
2D topology	✅	✅
3D solids	Limited	✅
Boolean geometry	❌	✅
Affine transforms	❌	✅
Native SPARQL functions	Partial	Extensive

Future directions

- Standardization (GeoSPARQL 3D extension?)
- Ontology-driven geometry reasoning
- Spatial indexing
- Semantic Digital Twins

Q&A

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Thank You

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Critical Reflection

Standardization challenge
Could geof3D evolve into a GeoSPARQL 3D extension?

Interoperability issue
How portable are custom SPARQL functions?

Scalability
Can RDF stores support large-scale geometry workloads?
Improve the computational performance with spatial indexing?

Semantic implications
Should geometry be:
- literals,
- resources,
- or linked computational objects?