LDAC2025 - Linked Data in Architecture and Construction

LDAC WORKSHOP 2025

11th July 2025

TARGET-X

Co-funded by the European Union

6GSNS

LDAC2025 - Linked Data in Architecture and Construction

5G-Enabled Augmented Reality for Dynamic Interaction with Linked Building Data and Voxelised Spaces

11th July 2025

Chu Han Wu, Brell-Cokcan Sigrid

TARGET-X

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XR for deconstruction planning

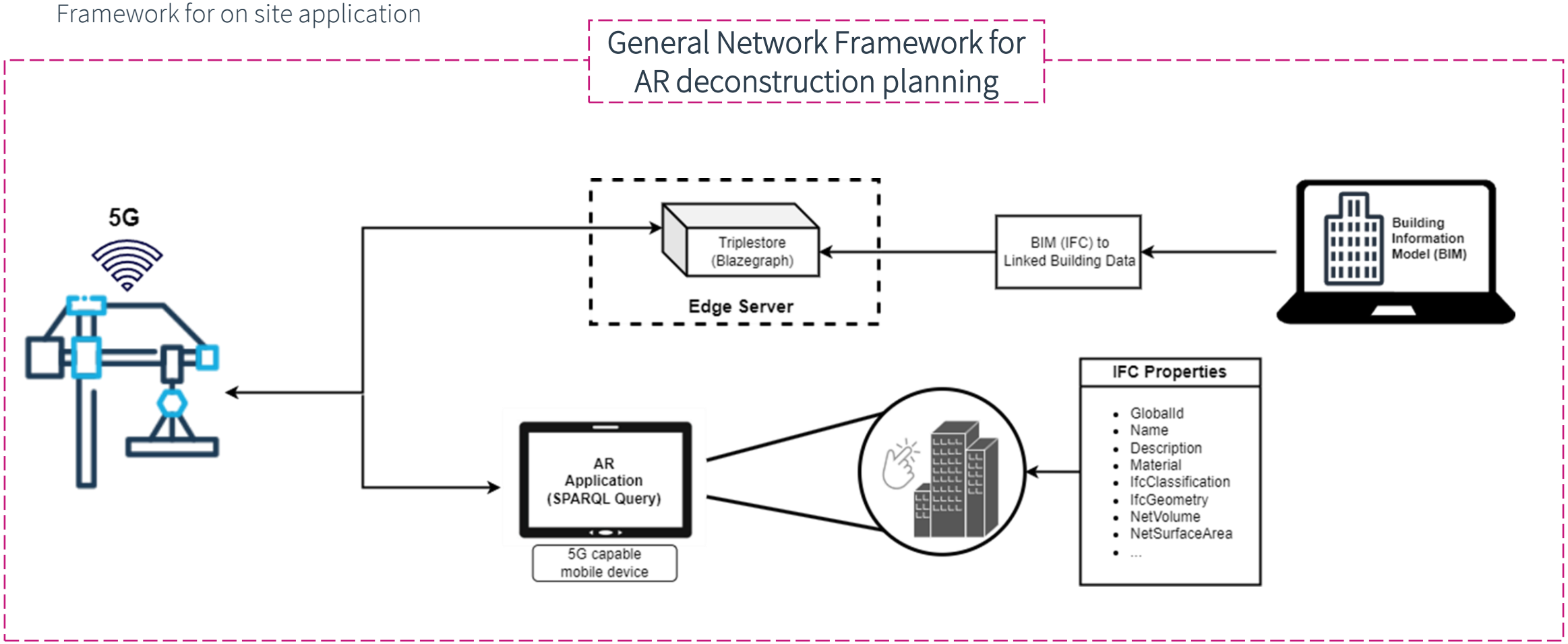
Framework for on site application

Research Questions

1. How can AR be employed to effectively visualize BIM-derived RDF data, including both mesh geometry and associated metadata directly on-site?
2. How can AR facilitate dynamic querying and real-time updates of BIM-derived data from a triplestore to support construction decision-making?
3. How can voxelised space, enriched with semantic attributes, enhance dynamic spatial reasoning and planning within construction workspaces?

XR for deconstruction planning

Framework for on site application



XR for deconstruction planning

Use case: Restage structure from TARGET-X

IFC Model

As-Built Structure

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XR for deconstruction planning

Backend preparation and first XR application 2023

Conversion of IFC to LBD

IFC raw data

```
DATA;
#1=IFCORGANIZATION($,'Autodesk Revit 2025 (ENG)',$,$,$);
#2=IFCAPPLICATION(#1,'2025','Autodesk Revit 2025 (ENG)','Revit');
#3=IFCCARTESIANPOINT((0.,0.,0.));
#4=IFCCARTESIANPOINT((0.,0.));
#5=IFCDIRECTION((1.,0.,0.));
#6=IFCDIRECTION((-1.,0.,0.));
#7=IFCDIRECTION((0.,1.,0.));
#8=IFCDIRECTION((0.,-1.,0.));
#9=IFCDIRECTION((0.,0.,1.));
#10=IFCDIRECTION((0.,0.,-1.));
#11=IFCDIRECTION((1.,0.));
#12=IFCDIRECTION((-1.,0.));
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#14=IFCDIRECTION((0.,-1.));
#15=IFCPERSON($,'','wuG46KQ',$,$,$,$,$);
#16=IFCORGANIZATION($,'','',$,$);
#17=IFCPERSONANDORGANIZATION(#15,#16,$);
#18=IFCOWNERHISTORY(#17,#2,$,.NOCHANGE.,$,$,$,1719932951);
#19=IFCSIUNIT(*,.LENGTHUNIT.,$,.METRE.);
#20=IFCAXIS2PLACEMENT3D(#3,$,$);
#21=IFCDIRECTION((6.123233995736766E-017,1.));
#22=IFCGEOMETRICREPRESENTATIONCONTEXT($,'Model',3,1.0000000000000001E-005,#20,#21);
#23=IFCGEOMETRICREPRESENTATIONSUBCONTEXT('Axis','Model',*,*,*,*,#22,$,.GRAPH_VIEW.,$);
#24=IFCGEOMETRICREPRESENTATIONSUBCONTEXT('Body','Model',*,*,*,*,#22,$,.MODEL_VIEW.,$);
#25=IFCGEOMETRICREPRESENTATIONSUBCONTEXT('Box','Model',*,*,*,*,#22,$,.MODEL_VIEW.,$);
#26=IFCGEOMETRICREPRESENTATIONSUBCONTEXT('FootPrint','Model',*,*,*,*,#22,$,.MODEL_VIEW.,$);
#27=IFCPROJECT('29Y0IaItr2Y9Sy1NEj1BW2',#18,'Project Number',$,$,'Project Name','Project Status',(#22),#891317);
#28=IFCCLASSIFICATION('CSI (Construction Specifications Institute)','1998',$,'Uniformat');
```

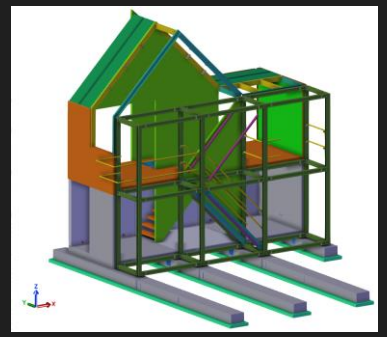

IFCtoLBD

Linked Building Data

```
inst:buildingelement_f8b9725e-9584
        props:guid                      "025M0Dimf438IBfJvt$G_z" ;
        lbd:containsInBoundingBox       inst:buildingelement_2f957744;
        rdf:type                        bot:Element ;
        props:volume                    0.000010701 ;
        lbd:description                 "" ;
        lbd:containsInBoundingBox       inst:buildingelement_be2bab7d;
        lbd:containsInBoundingBox       inst:buildingelement_4b3208cf;
        props:lengthRelevant            true ;
        props:length                    87.00000000000001 ;
        props:materials                 "Stahl" ;
        props:material                  "Stahl" ;
        props:partType                  "xd_10" ;
        props:netSurfaceArea            0.021822 ;
        props:type                      "3D-Objekt5CSweep" ;
        props:detailObject              false ;
        props:layer                     "0" ;
        props:isNegative                false ;
```

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XR for deconstruction planning

Base64 encoding and decoding of meshes

Encoded and Decoded Base64

Encoded	Decoded
diAxLjAwMCAxLjAwMCAxLjAwMAp2IC0xL	v 1.000 1.000 1.000
jAwMCAxLjAwMCAxLjAwMAp2IC0xLjAwMC	v -1.000 1.000 1.000
AtMS4wMDAgMS4wMDAKdiAxLjAwMCAtMS4	v -1.000 -1.000 1.000
wMDAgMS4wMDAKdiAxLjAwMCAxLjAwMCAt	v 1.000 -1.000 1.000
MS4wMDAKdiAtMS4wMDAgMS4wMDAgLTEuM	v 1.000 1.000 -1.000
DAwCnYgLTEuMDAwIC0xLjAwMCAtMS4wMD	v -1.000 1.000 -1.000
AKdiAxLjAwMCAtMS4wMDAgLTEuMDAwCmY	v -1.000 -1.000 -1.000
gMSAyIDMKZiAxIDMgNApmIDUgNiA3CmYg	v 1.000 -1.000 -1.000
NSA3IDgKZiAxIDUgOApmIDEgOCA0CmYgM	f 1 2 3
iA2IDcKZiAyIDcgMwpmIDEgNSA2CmYgMS	f 1 3 4
A2IDIKZiA0IDggNwpmIDQgNyAzCg==	f 5 6 7
	f 5 7 8
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	f 1 8 4
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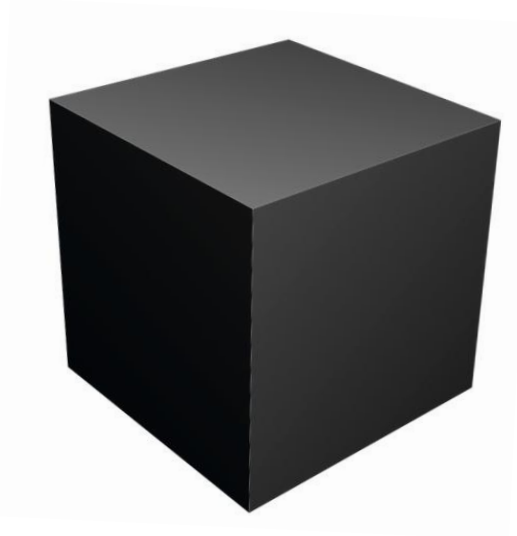
	f 4 8 7
	f 4 7 3



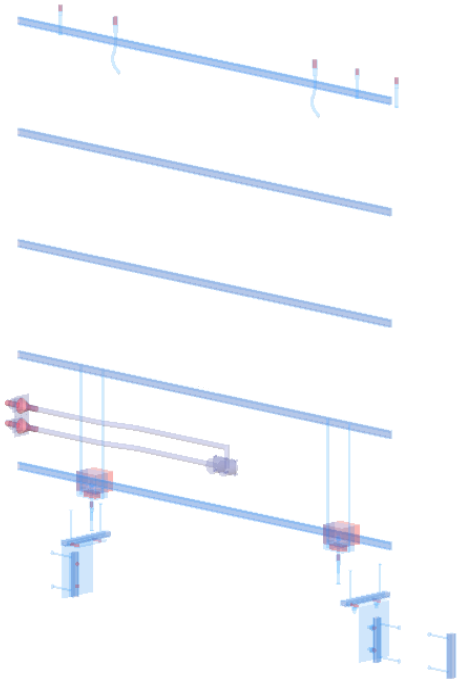
XR for deconstruction planning

Example query and result

Query

```
PREFIX inst: <https://www.target-x.com/>
PREFIX fog: <https://w3id.org/fog#>
PREFIX beo: <https://pi.pauwel.be/voc/buildingelement#>
PREFIX omg: <https://w3id.org/omg#>
SELECT DISTINCT ?inst ?encoded
WHERE {    ?inst omg:hasGeometry ?instG .
        ?instG fog:asObj_v3.0-obj ?encoded. }
```

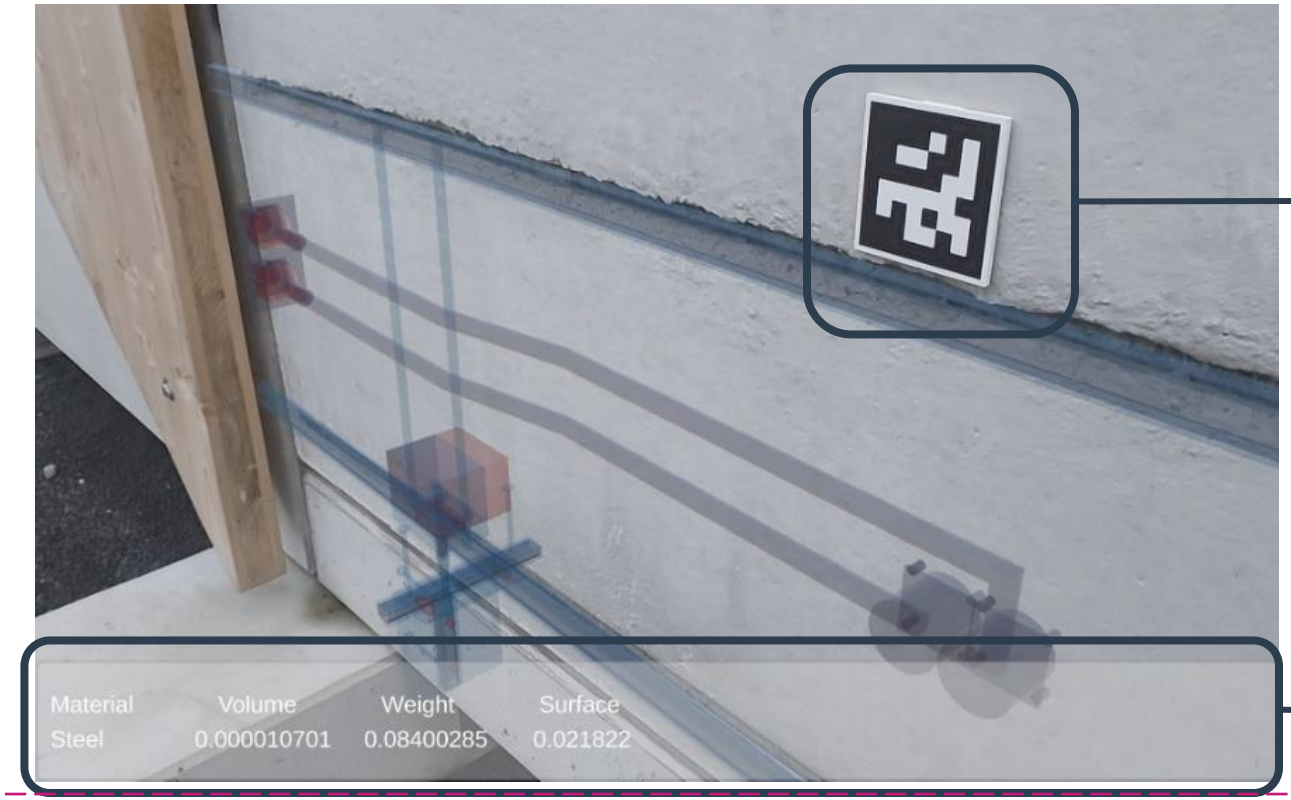
Result



XR for deconstruction planning

AR application in action

Screenshot of the AR application



Fiducial Marker

Result of the query

XR assisstant for deconstruction planning

Example use case of the AR application

- Visual anchors attached to the demonstrator
- Selection of building element
- Query building element information from the edge server

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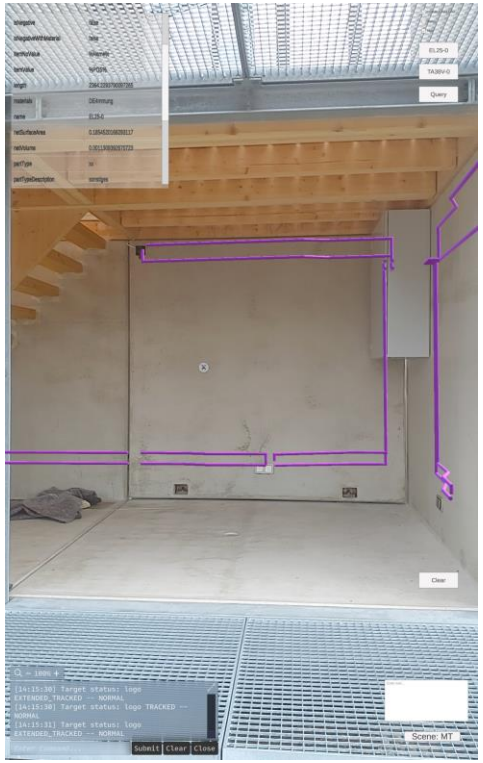
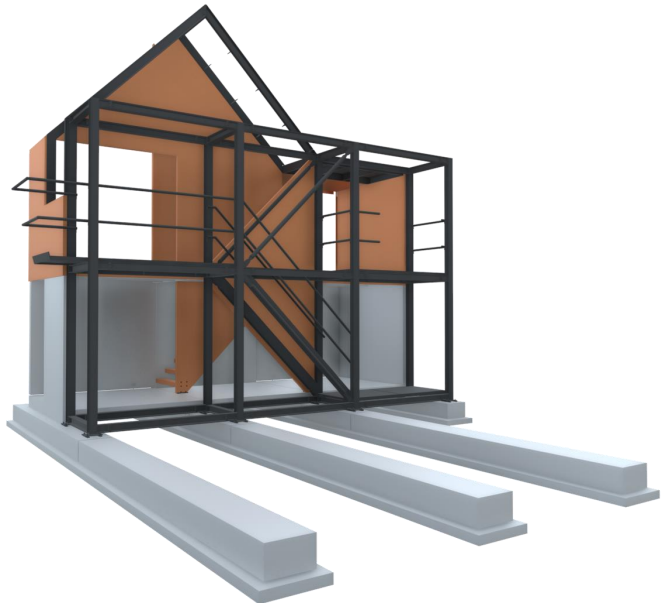
App output for different materials and building elements



» Result: Quality of the query results can only be as good as the initial BIM model

Bridging the physical and virtual spaces

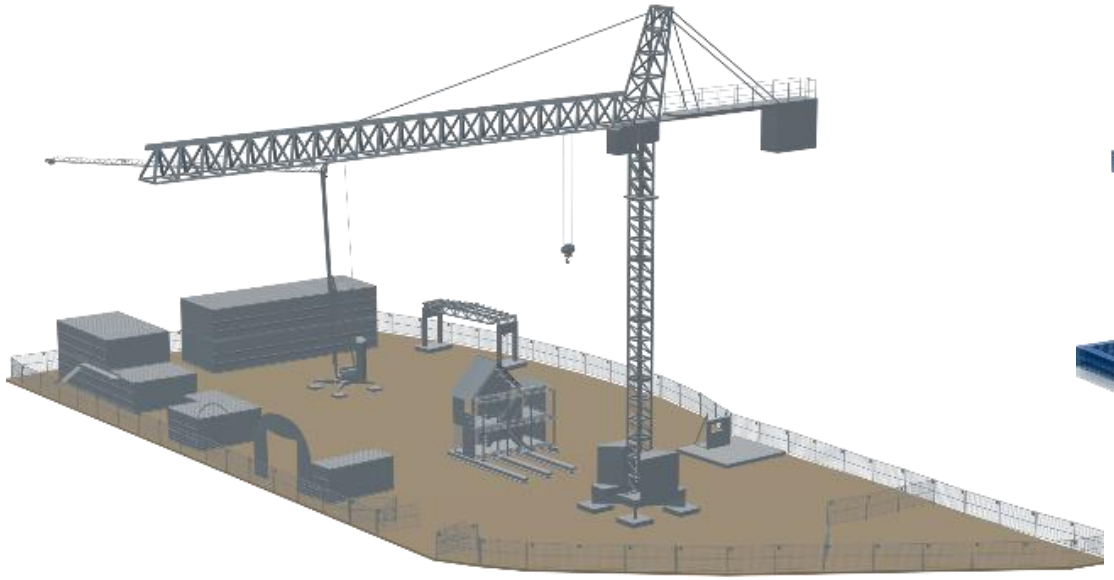
Using AR as user interface to bridge the gap between physical and virtual environment

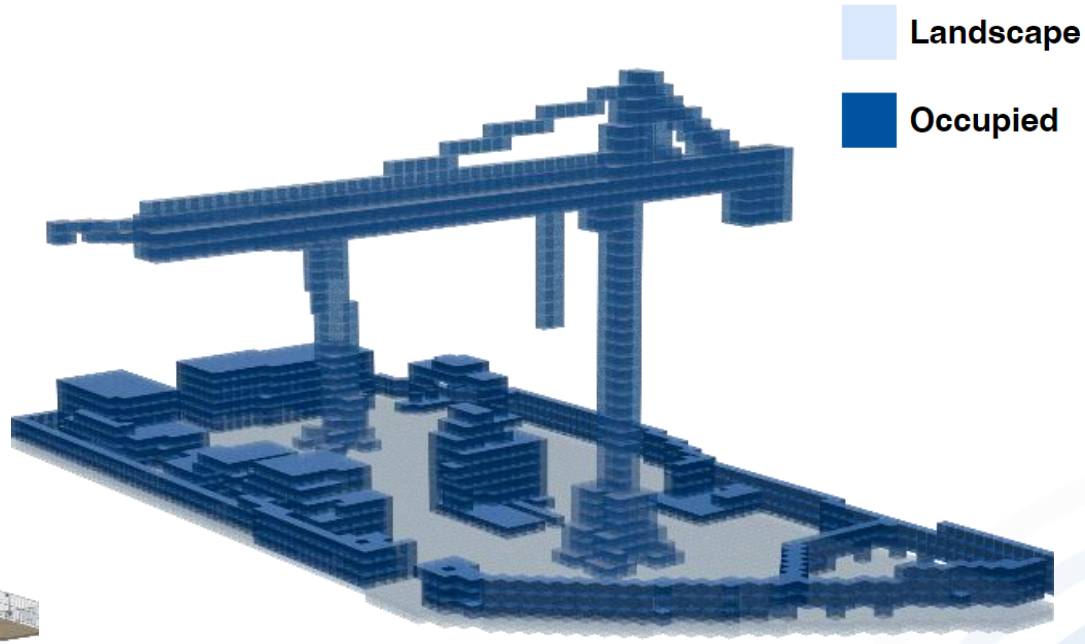


Spatial-Temporal Description via Voxelisation of Spaces

Voxelisation of the construction site: A shared understanding of the spaces

Voxelisation of construction site





Spatial-Temporal Description via Voxelisation of Spaces

Voxelisation of the construction site

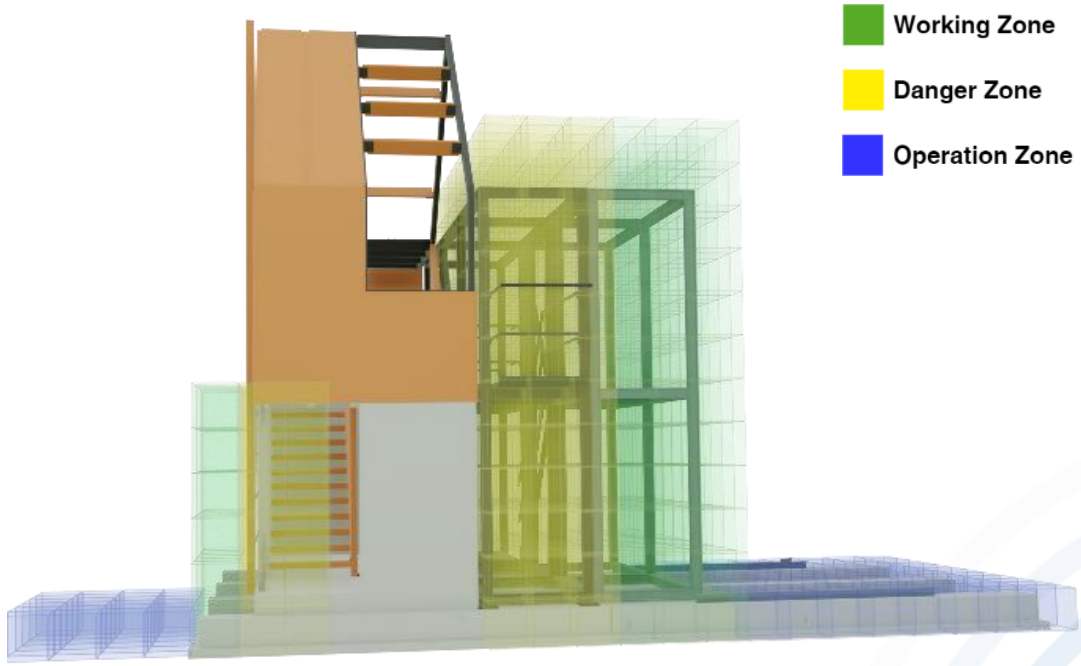
Use Case

- Two processes ongoing at the same time
- Define working zone depending on the IFC information

Spatial-Temporal Description via Voxelisation of Spaces

Voxelisation of the construction site

Working Area Definition



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Spatial-Temporal Description via Voxelisation of Spaces

Voxelisation of the construction site

Example Voxel Instance

```
inst:Voxel_051004 a vxl:Voxel ;
    vxl:guid "051004-xyz789-2025" ;
    vxl:layer "Layer_3" ;
    vxl:process inst:Deconstruction_ConcreteWall ;
    vxl:plannedTime "2025-02-01T09:00:00Z"^^xsd:dateTime ;
    vxl:space vxl:GroundFloor ;
    vxl:position [vxl:x 7 ; vxl:y 15 ; vxl:z 3] ;
    vxl:size [vxl:width 1.0 ; vxl:height 1.0 ; vxl:length 1.0] ;
    vxl:relatedTo inst:buildingelement_f8b9725e-9584 ;
    prov:wasGeneratedBy inst:VoxelPlanningSystem ;
    vxl:entryTime "2025-01-31T08:00:00Z"^^xsd:dateTime ;
    vxl:startTime "2025-02-01T09:00:00Z"^^xsd:dateTime ;
    vxl:endTime "2025-02-01T11:00:00Z"^^xsd:dateTime .
```

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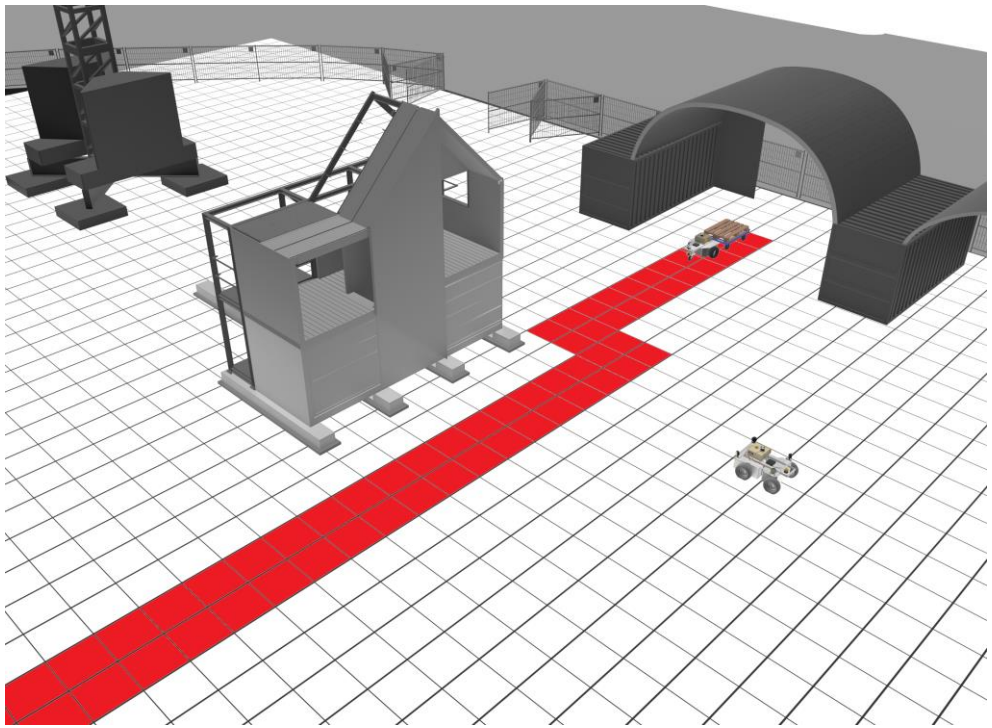
Spatial-Temporal Description via Voxelisation of Spaces

Voxelisation of the construction site

Robot navigation for T1

Path



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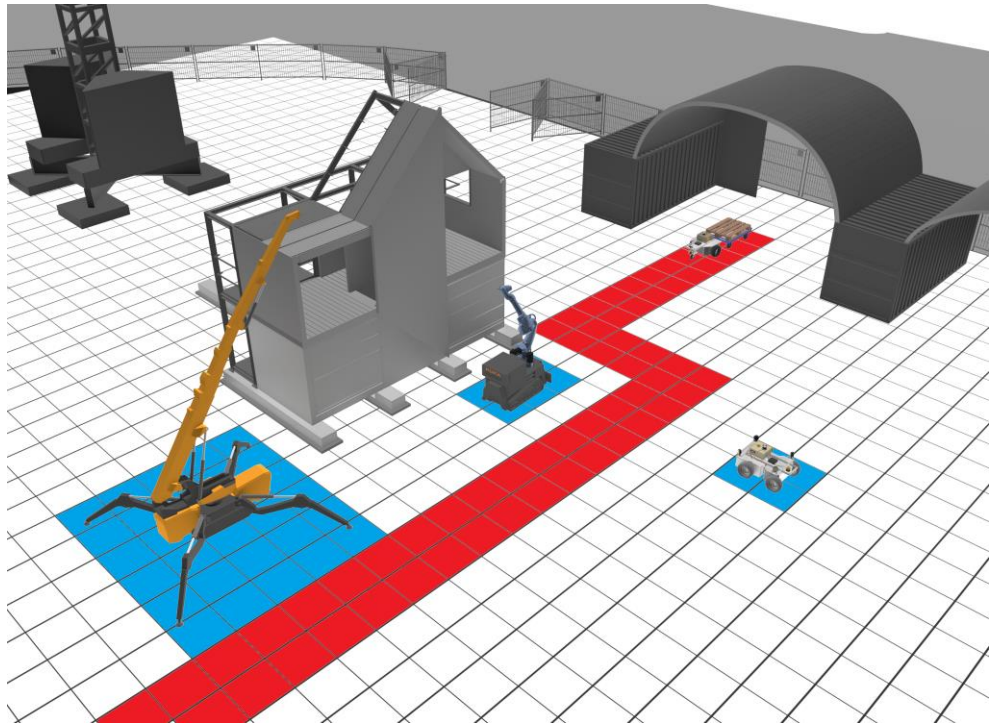
Layering Semantic Information robotic navigation

Voxelisation of the construction site

Robot navigation for T2

Path

Occupied

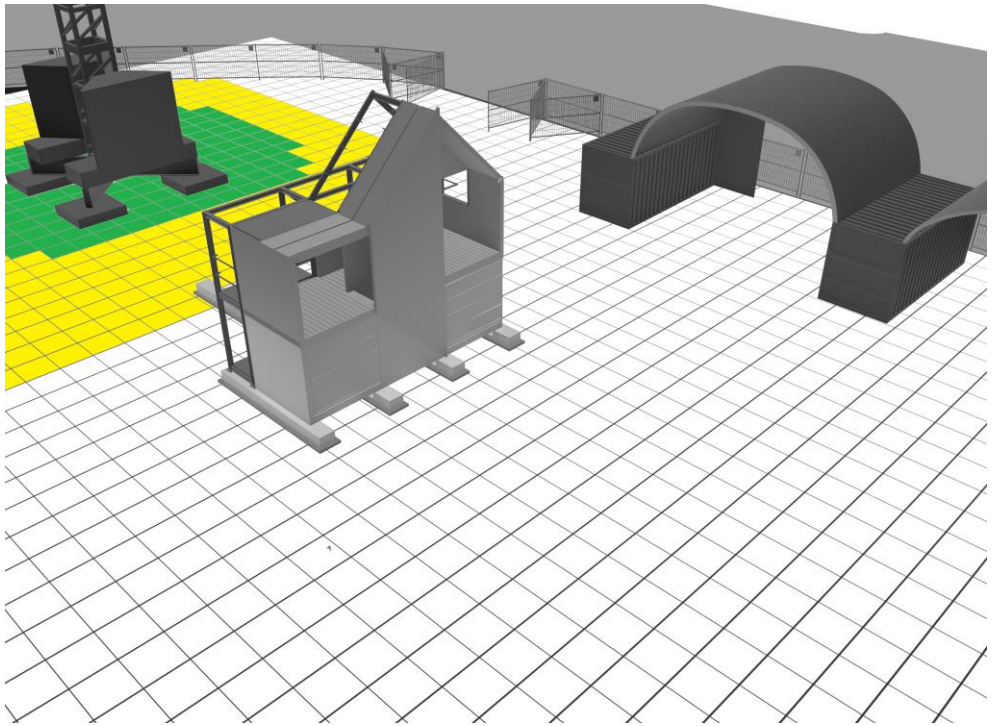


Layering Semantic Information robotic navigation

Voxelisation of the construction site

5G Signal Strength

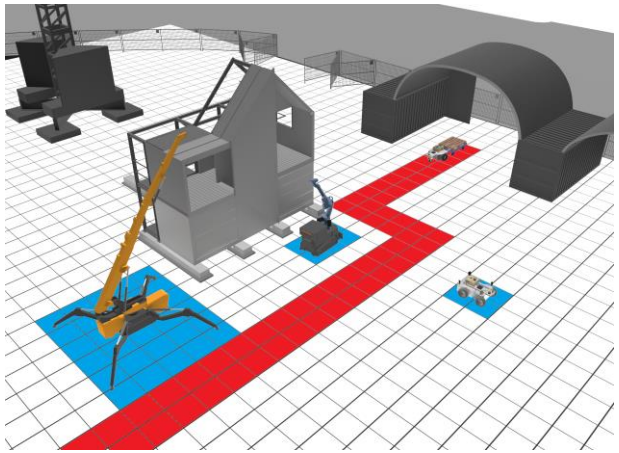
- Strong Signal
- Moderate Signal
- Minimum Signal

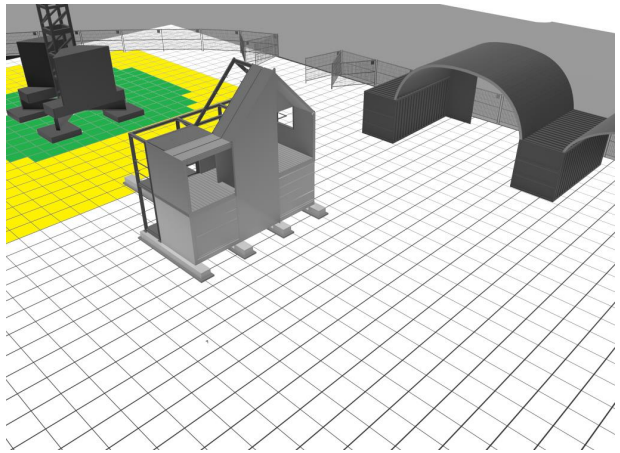


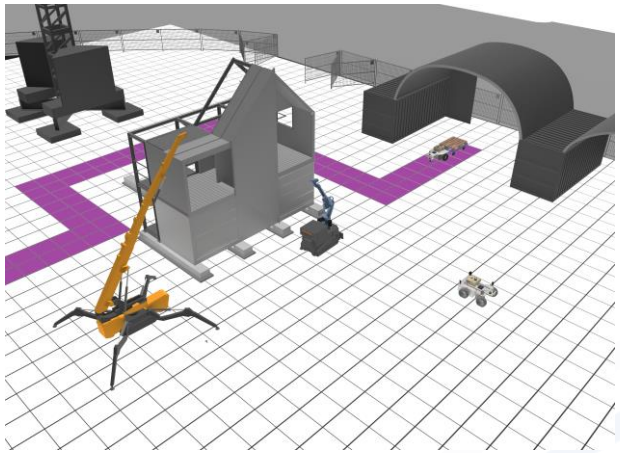
Spatial-Temporal Description via Voxelisation of Spaces

Voxelisation of the construction site

Layered information for robot navigation







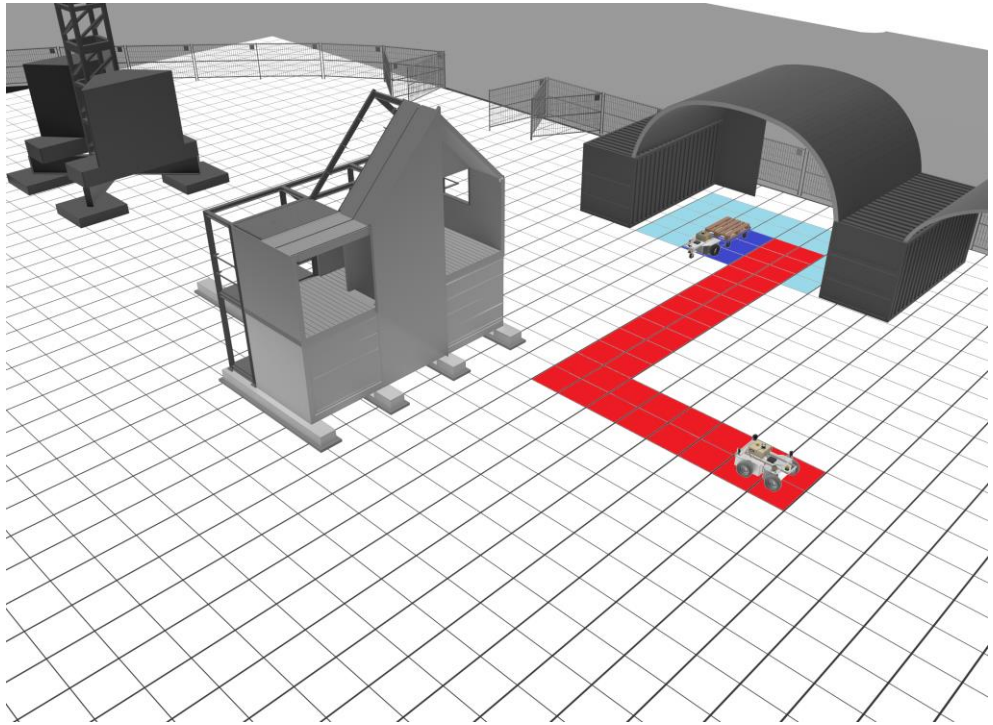
New path

Spatial-Temporal Description via Voxelisation of Spaces

Voxelisation of the construction site

Robot navigation with semantic on different zones

- Path
- Storage zone
- Occupied



Spatial-Temporal Description via Voxelisation of Spaces

Voxelisation of the construction site

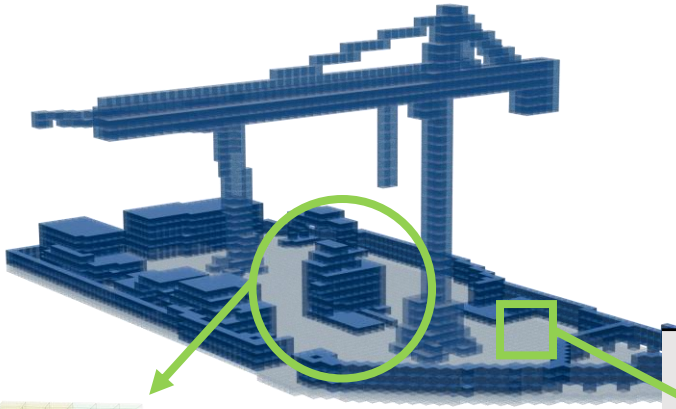
Future Work

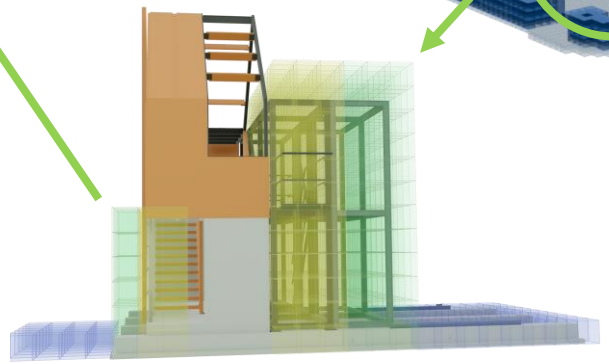
- Fully defining an ontology for voxels in a construction site
  - better capture the semantics, interactions and temporal data required for effective planning, scheduling, and real-time management of construction workflows
  - could potentially be integrated with ontologies that address process descriptions, such as the Internet of construction process ontology.
- Degree and relationships of the adjacent neighbourhood
  - relational information to each of its neighbours can potentially be used to implement rules and constraints to the voxels
- Incorporating different sensors into the system could enhance automated decision-making
- Granularity of the voxels
  - Dimensions of the voxels
  - Implementation of octree and leaf nodes

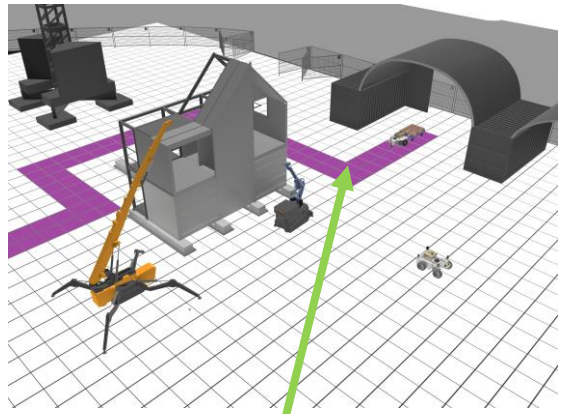
Spatial-Temporal Description via Voxelisation of Spaces

Voxelisation of the construction site

Thank You







```
inst:Voxel_051004 a vxl:Voxel ;
    vxl:guid "051004-xyz789-2025" ;
    vxl:layer "Layer_3" ;
    vxl:process inst:Deconstruction_ConcreteWall ;
    vxl:plannedTime "2025-02-01T09:00:00Z"^^xsd:dateTime ;
    vxl:space vxl:GroundFloor ;
    vxl:position [vxl:x 7 ; vxl:y 15 ; vxl:z 3] ;
    vxl:size [vxl:width 1.0 ; vxl:height 1.0 ; vxl:length 1.0] ;
    vxl:relatedTo inst:buildingelement_f8b9725e-9584 ;
    prov:wasGeneratedBy inst:VoxelPlanningSystem ;
    vxl:entryTime "2025-01-31T08:00:00Z"^^xsd:dateTime ;
    vxl:startTime "2025-02-01T09:00:00Z"^^xsd:dateTime ;
    vxl:endTime "2025-02-01T11:00:00Z"^^xsd:dateTime .
```

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