2nd Summer School of Linked Data in Architecture and Construction, Cercedilla - Spain

Hackathon Final Presentation | Team 3

Integration of trajectory-based data into 4D BIM Semantic Digital Twin

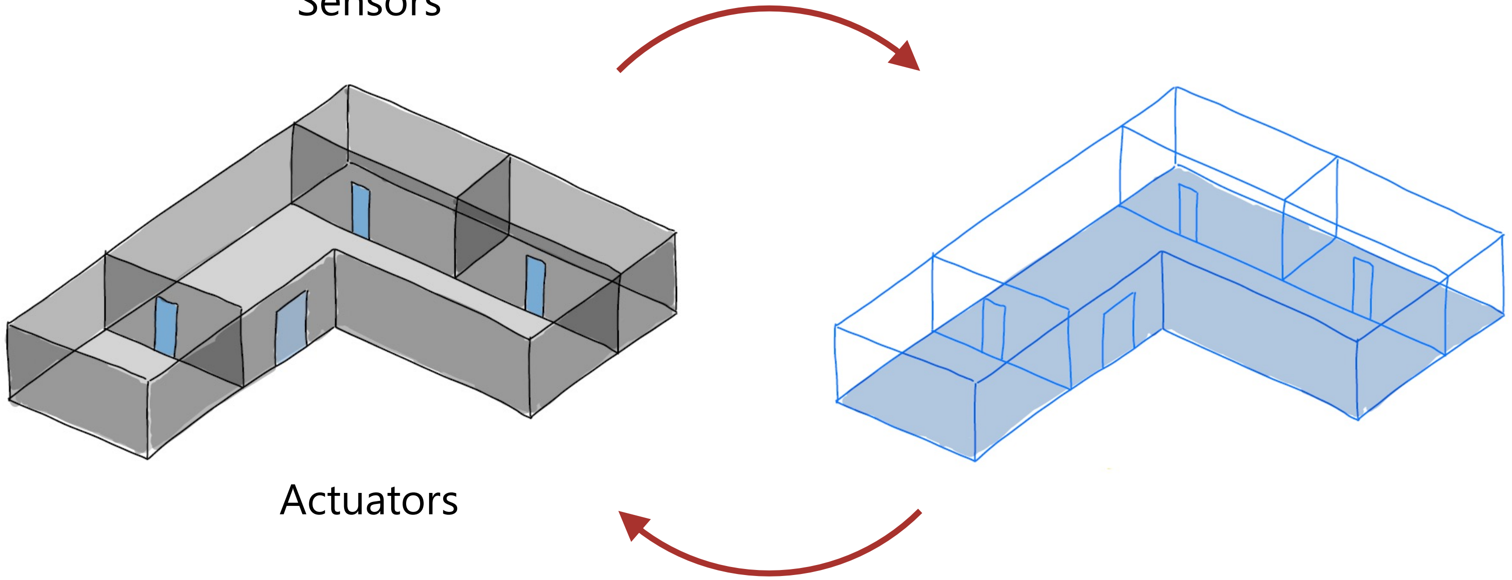
Digital Construction Twin

Physical entity

Virtual entity

Sensors

Real-world actions

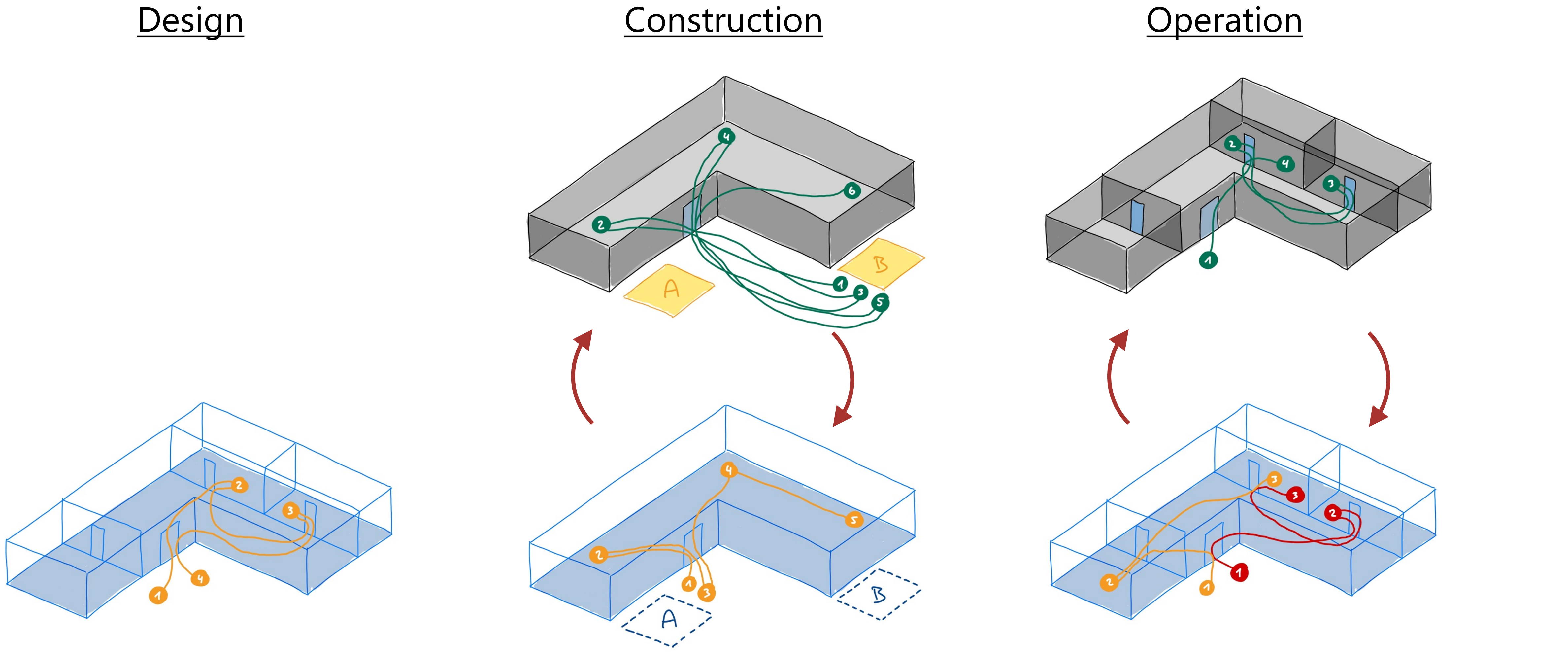


Simulations

Actuators

Bi-directional information flow

Trajectory-based data in construction



Challenges of handling trajectory data within digital twins

- Digital Twins have the potential to provide deep insights and suggest predictive performance improvements across project phases
- Trajectory data can be a valuable source of information for these DT application

- A large amount of trajectory data coming from multiple sources in various formats
  - Simulation software for intent optimization in the design phase
  - Real-time retrieval software from construction phase
  - Predictive and non-predictive analyses for decision making in operational phase

- **We must link this data** to enrich the existing data on the building (IFC), resources (workers, equipment), … **providing corresponding interoperable trajectory information**
- Injection of this information into DT simulations to achieve several benefits:
  - **Health & safety** during work execution (avoidance of hazardous areas)
  - **Waste reduction** during equipment usage (fuel, electricity, spare parts, …)
  - **Energy efficiency** during usage (occupation-based HVAC control)

Challenge details

Focus on digital twin application in the construction phase.

Data sources

- BIM model [IFC] (static)
- Schedule with tasks and processes [XML] (static)
- Work orders [JSON] (static)
- Resource types [CSV] (static)
- Trajectory information from trackers & simulations [JSON] (dynamic)

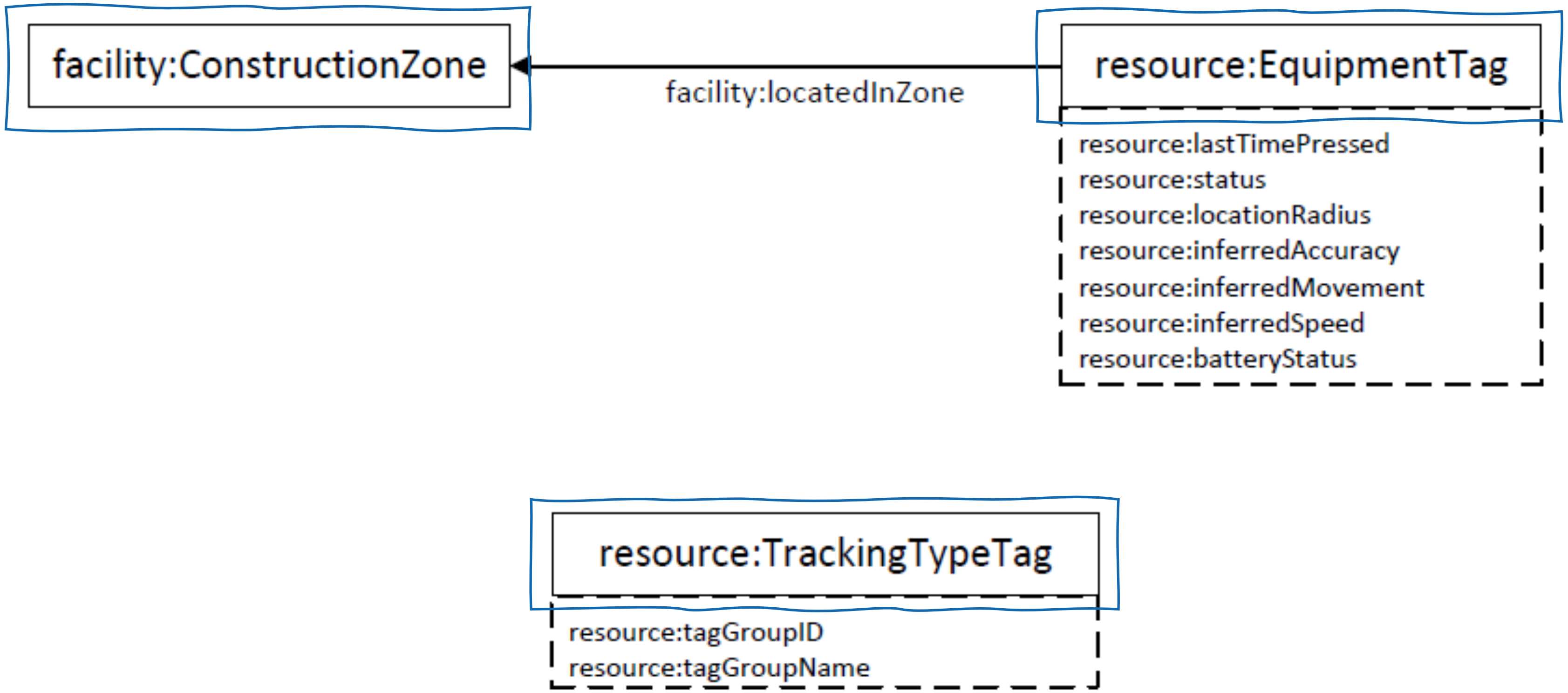
Scripts

- Simulation of trajectory points of resources

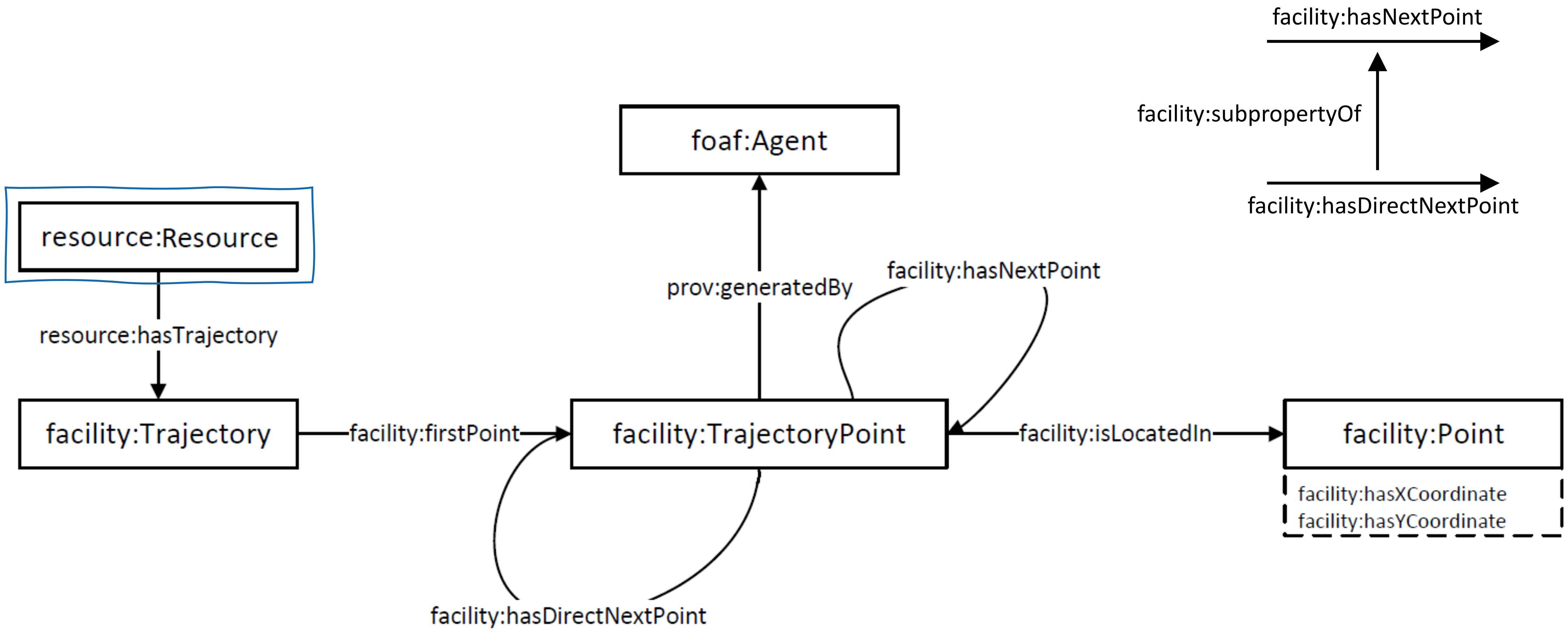
Tackling the challenge

1. Ontology extension to additionally model trajectory information
2. Mapping of JSON data to RDF via Helio (*great tool btw!*)
3. Injection of the RDF data into the GraphDB triple store
4. Modification of simulation script to provide multiple trajectory points
5. Development of scripts for …
   – extracting data from the GraphDB triple store via SPARQL queries
   – visualization of trajectories produced by specific resources on top of an IFC element floorplan

Ontology extension



Ontology extension



Mapping of trajectory data to RDF

```
<#assign jpath=handlers("JsonHandler")>
<#assign dataset=providers(type='FileProvider',
file='/Users/salva/Dropbox/cogito/summer_school/trajectory_files/simulation_trajectory.json')>
@prefix rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#> .
@prefix rdfs: <http://www.w3.org/2000/01/rdf-schema#> .
@prefix data: <https://data.cogito.iot.linkeddata.es/resources/> .
@prefix xsd: <http://www.w3.org/2001/XMLSchema#> .
@prefix facility: <https://cogito.iot.linkeddata.es/def/facility#> .
@prefix resource: <https://cogito.iot.linkeddata.es/def/resource#> .
@prefix geo: <http://www.w3.org/2003/01/geo/wgs84_pos#> .
<#list jpath.filter('$.tagdata', dataset) as tagdata>
data:TrackingTag_[=jpath.filter('$.tagId', tagdata)]
   a resource:Resource ;
   a resource:TrackingTag ;
   a resource:EquipmentTag ;
   facility:isUsedIn data:Project_[=jpath.filter('$.assignedProjectId', tagdata)] ;
   resource:resourceId '[=jpath.filter('$.tagId',tagdata)]'^^<http://www.w3.org/2001/XMLSchema#string> ;
   resource:lastTimePressed '[=jpath.filter('$.lastSeen',tagdata)]'^^<http://www.w3.org/2001/XMLSchema#time> ;
   resource:locationRadius [=jpath.filter('$.locationRadius',tagdata)] ;
   resource:inferredAccuracy [=jpath.filter('$.locationRadius',tagdata)] ;
   resource:inferredMovement [=jpath.filter('$.locationRadius',tagdata)] ;
   resource:inferredSpeed [=jpath.filter('$.locationRadius',tagdata)] ;
   resource:batteryStatus [=jpath.filter('$.locationRadius',tagdata)] ;
   resource:hasTrajectory data:Trajectory_[=jpath.filter('$.tagId', tagdata)] .
<#if tagdata?index==0>
data:Trajectory_[=jpath.filter('$.tagId', tagdata)]
   a resource:Trajectory ;
   facility:hasFirstPoint facility:Traject_Point_[=tagdata?index].
</#if>
```

Mapping of trajectory data to RDF

```
facility:Traject_Point_[=tagdata?index]
   a facility:Trajectory ;
   <#list jpath.filter('$.tagdata',dataset) as nextPoint>
   <#if nextPoint?index gt tagdata?index>
   facility:hasNextPoint facility:Traject_Point_[=nextPoint?index] ;
   </#if>
   <#if nextPoint?index == tagdata?index && nextPoint?is_last>
   facility:hasDirectNextPoint data:Point_0 ;
   <#elseif nextPoint?index == tagdata?index && !nextPoint?is_last>
   facility:hasDirectNextPoint data:Point_[=nextPoint?index+1] ;
   </#if>
   </#list>
   facility:isLocatedIn data:Point_[=tagdata?index] .

facility:Point_[=tagdata?index]
   a resource:Point ;
   a geo:Point ;
   <#list jpath.filter('$.xy_location', tagdata) as points>
   <#if points?is_first>
   facility:hasXCoordinate '[=points]'^^<http://www.w3.org/2001/XMLSchema#float> ;
   <#else>
   facility:hasYCoordinate '[=points]'^^<http://www.w3.org/2001/XMLSchema#float> ;
   </#if>
   </#list>
   <#list jpath.filter('$.coordLocation', tagdata) as points>
   <#if points?is_first>
   geo:lat '[=points]'^^<http://www.w3.org/2001/XMLSchema#float> ;
   <#else>
   geo:lon '[=points]'^^<http://www.w3.org/2001/XMLSchema#float> .
   </#if>
   </#list>
</#list>
```

SPARQL Queries

Get IFC element zone

```
PREFIX resource: <https://cogito.iot.linkeddata.es/def/resource#>
PREFIX props: <https://w3id.org/props#>
PREFIX facility: <https://cogito.iot.linkeddata.es/def/facility#>
SELECT DISTINCT ?s WHERE {
    ?s props:hasCompressedGuid  "22O7WvOu1F3RpVxpkqDC6M" .
}
```

Retrieve boundaries of IFC element zone

```
PREFIX resource: <https://cogito.iot.linkeddata.es/def/resource#>
PREFIX props: <https://w3id.org/props#>
PREFIX facility: <https://cogito.iot.linkeddata.es/def/facility#>
SELECT DISTINCT ?s ?boundary ?firstPointx ?firstPointy ?locationPoint2 ?nextPointsx ?nextPointsy WHERE
{
    ?s props:hasCompressedGuid  "22O7WvOu1F3RpVxpkqDC6M" .
    ?s facility:hasBoundaries ?boundary .
    ?boundary facility:hasFirstPoint ?firstPoint .
    ?firstPoint facility:hasNextPoint ?nextPoint .
    ?firstPoint facility:isLocatedIn ?locationPoint .
    ?locationPoint facility:hasXCoordinate ?firstPointx .
    ?locationPoint facility:hasYCoordinate ?firstPointy .
    ?nextPoint facility:isLocatedIn ?locationPoint2 .
    ?locationPoint2 facility:hasXCoordinate ?nextPointsx .
    ?locationPoint2 facility:hasYCoordinate ?nextPointsy .
}
```

SPARQL Queries

Retrieve trajectories of a specific resource

```
PREFIX resource: <https://cogito.iot.linkeddata.es/def/resource#>
PREFIX props: <https://w3id.org/props#>
PREFIX facility: <https://cogito.iot.linkeddata.es/def/facility#>
PREFIX geo: <http://www.w3.org/2003/01/geo/wgs84_pos#>
SELECT DISTINCT ?s ?trajectory ?initalPointX ?initalPointY  ?nextTrajectoryPointX ?nextTrajectoryPointY WHERE {
    ?s resource:resourceId  'e9b870d9-5058-4d4a-802b-3457279524e0'^^<http://www.w3.org/2001/XMLSchema#string> .
    ?s resource:hasTrajectory ?trajectory .
    ?trajectory facility:hasFirstPoint ?firstPoint .
    ?firstPoint facility:hasNextPoint ?nextPoint .
    ?firstPoint facility:isLocatedIn ?initialPoint .
    ?initialPoint facility:hasXCoordinate ?initalPointX .
    ?initialPoint facility:hasYCoordinate ?initalPointY .
    ?nextPoint facility:isLocatedIn ?nextTrajectoryPoints .
    ?nextTrajectoryPoints facility:hasXCoordinate ?nextTrajectoryPointX .
    ?nextTrajectoryPoints facility:hasYCoordinate ?nextTrajectoryPointY .
}
```

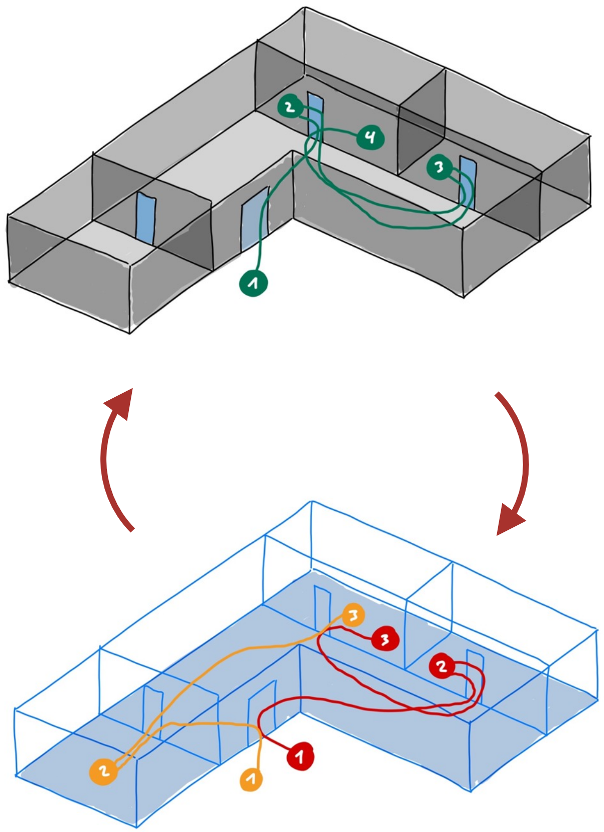
Script presentation

[DEMO TIME]

Impact of our developments

<u>**Technological perspective**</u>

- **Ontology for modelling trajectories** as an addition to existing semantic 4D BIM models
- Enabled injection of dynamic trajectory data from various sources **into a knowledge graph**
- **Exploitation** of specific trajectory information **via SPARQL queries**



<u>**Domain application perspective**</u>

- Trajectory data of caused by resource movements can be **gathered and used across multiple project phases**
- Interoperability allows for automatic data provision for bi-directional **digital twin** applications to improve **health & safety**, **productivity boost**, **resource consumption** and **operational sustainability**

Thank you for your attention!