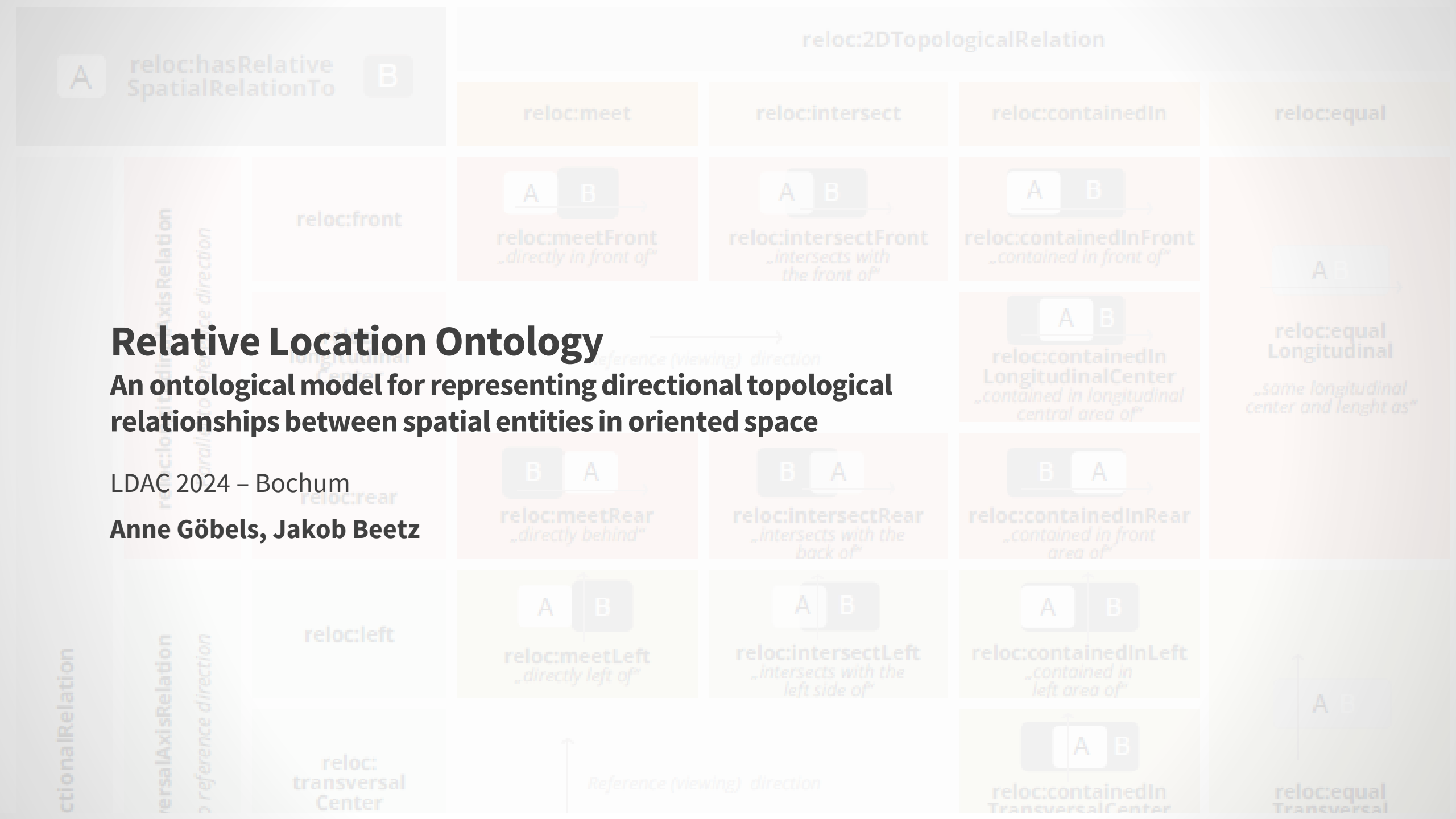


Relative Location Ontology

An ontological model for representing directional topological relationships between spatial entities in oriented space

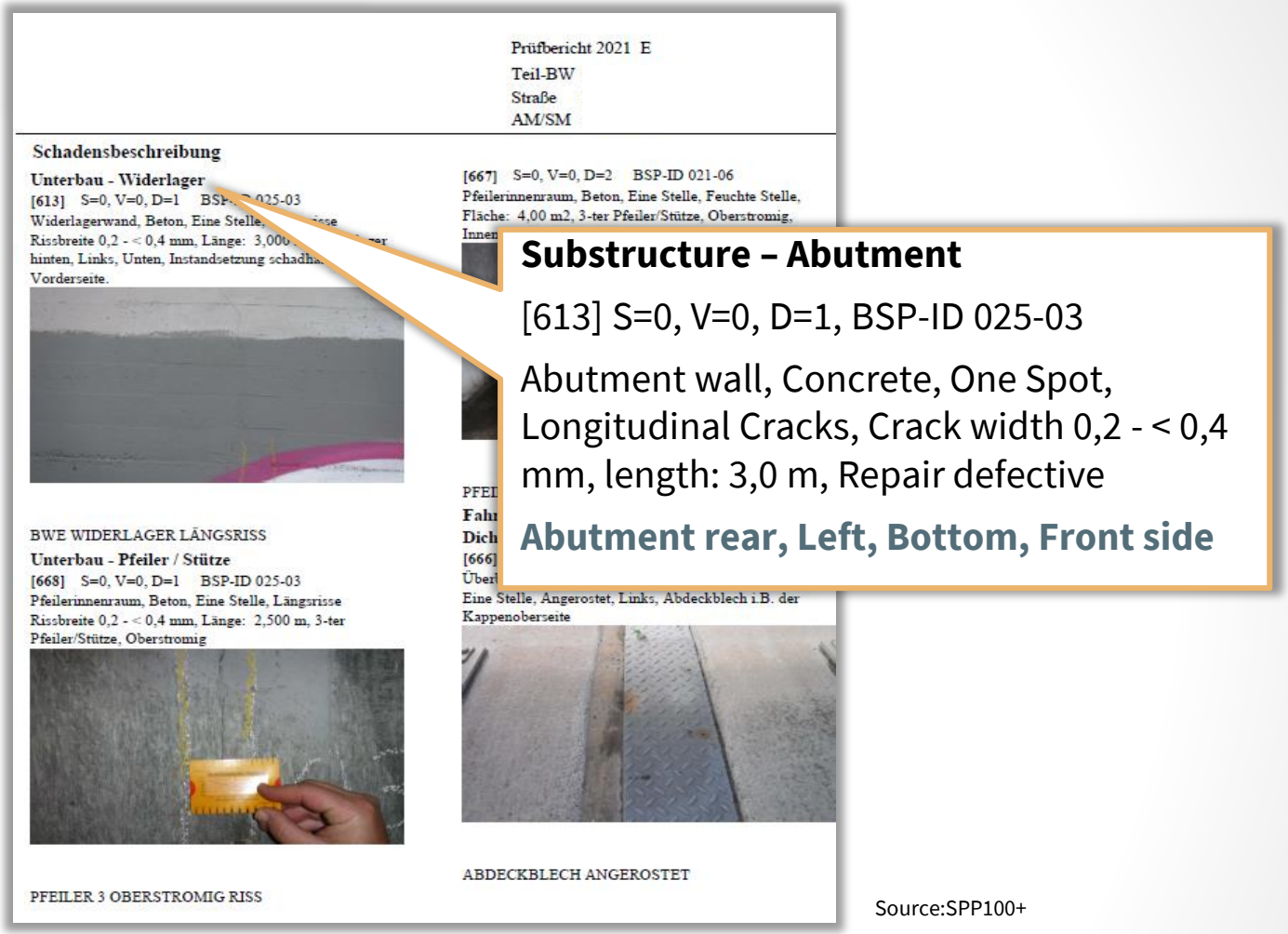
LDAC 2024 – Bochum

Anne Göbels, Jakob Beetz

Introduction

Context - Legacy Bridge Maintenance Data

- **No geometric representation**
- **Natural- Language-Based description of damage and component locations**
- **Using relative spatial references → dependent on viewing direction**
- **Based on implicit spatial (domain) knowledge**
- **Not comprehensively analysable**
- **Large amounts of data : ~ 40,0000 data sets**



Prüfbericht 2021 E
Teil-BW
Straße
AM/SM

Schadensbeschreibung

Unterbau - Widerlager

[613] S=0, V=0, D=1 BSP-ID 025-03
Widerlagerwand, Beton, Eine Stelle,
Rissbreite 0,2 - < 0,4 mm, Länge: 3,000
hinten, Links, Unten, Instandsetzung schadha
Vorderseite.

BWE WIDERLAGER LÄNGSRISS

Unterbau - Pfeiler / Stütze

[668] S=0, V=0, D=1 BSP-ID 025-03
Pfeilerinnenraum, Beton, Eine Stelle, Längsrisse
Rissbreite 0,2 - < 0,4 mm, Länge: 2,500 m, 3-ter Pfeiler/Stütze, Oberstromig

PFEILER 3 OBERSTROMIG RISS

[667] S=0, V=0, D=2 BSP-ID 021-06
Pfeilerinnenraum, Beton, Eine Stelle, Feuchte Stelle,
Fläche: 4,00 m2, 3-ter Pfeiler/Stütze, Oberstromig,

[666]
Eine Stelle, Angerostet, Links, Abdeckblech i.B. der Kappenoberseite

ABDECKBLECH ANGEROSTET

Substructure – Abutment

[613] S=0, V=0, D=1, BSP-ID 025-03

Abutment wall, Concrete, One Spot, Longitudinal Cracks, Crack width 0,2 - < 0,4 mm, length: 3,0 m, Repair defective

Abutment rear, Left, Bottom, Front side

Source:SPP100+

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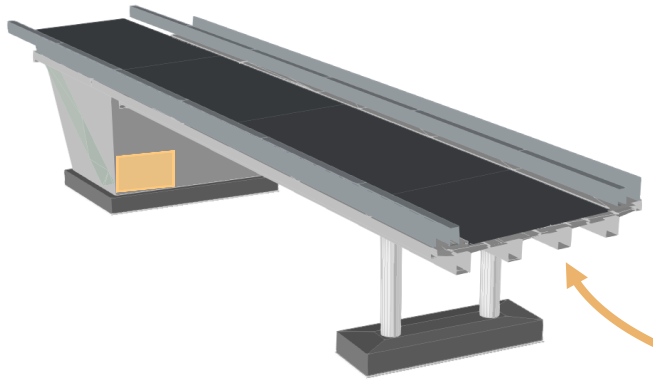

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Abutment rear, Left, Bottom, Front side

Map information to asset (model)

Understand spatial reference system (direction)

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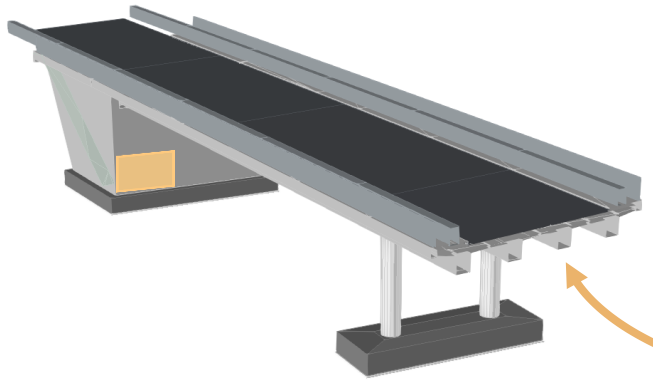
→Implement automatic processing
→Machine-readable data structure



Substructure – Abutment

[613] S=0, V=0, D=1, BSP-ID 025-03

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Map information to asset (model)

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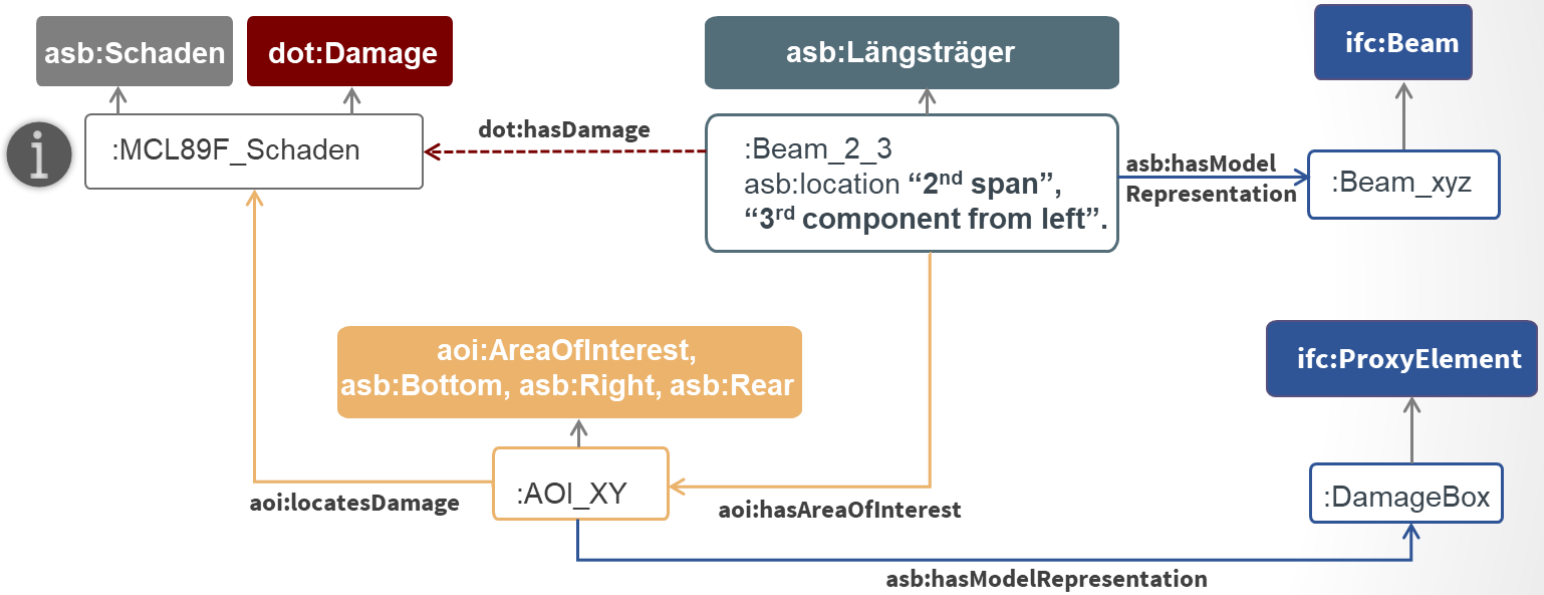
Introduction
Previous Work

- Conversion into RDF
- Using DOT to implement object-oriented damage modelling
- Using AOI Ontology to represent damage area location



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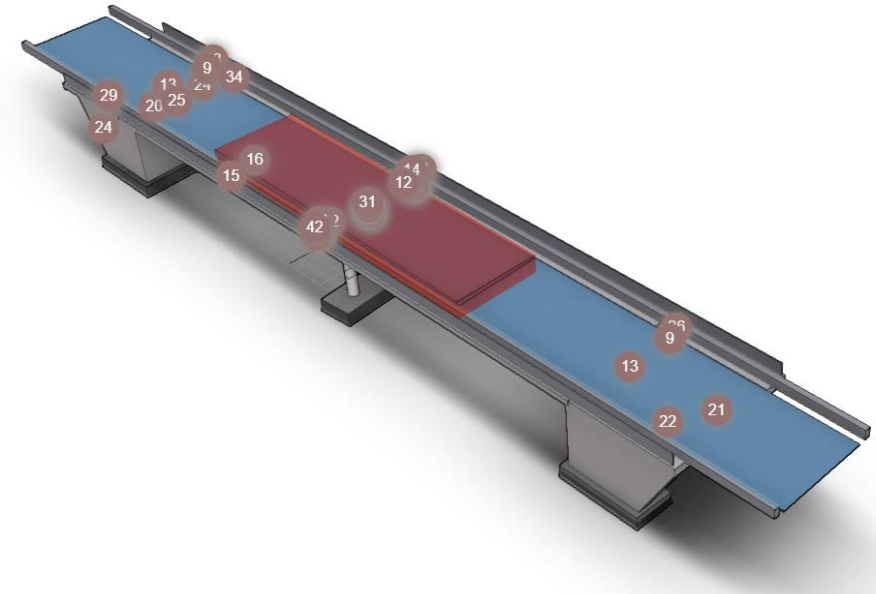
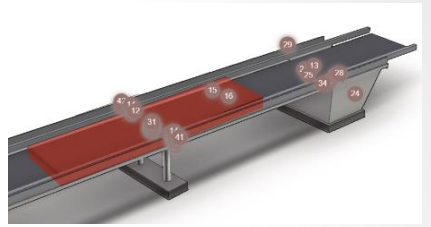
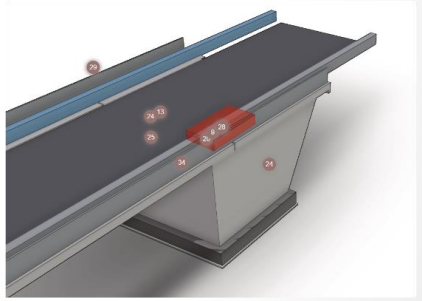
- Conversion into RDF
- Using DOT and AOI Ontology to implement object-oriented damage modelling
- Use of IFC model for spatial representation of component and damages







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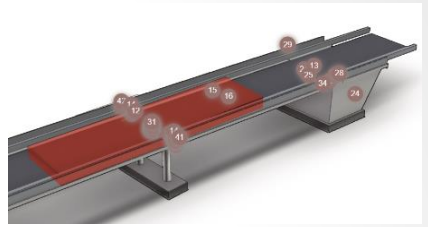
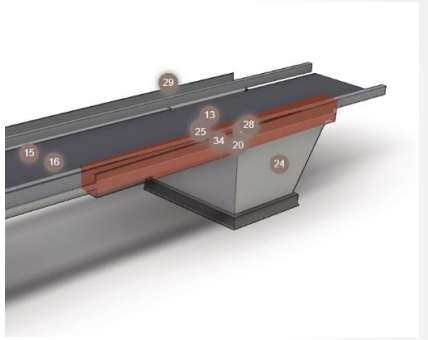
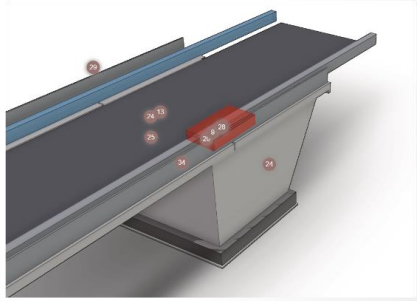
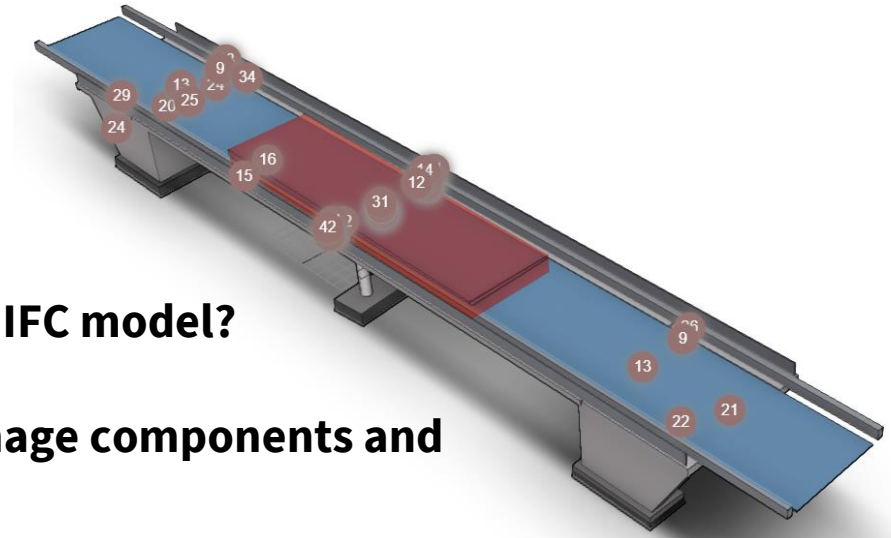








? **Spatial Bridge representation without IFC model?**

! **Semantic modelling of bridge and damage components and their spatial relations**

Introduction
Existing approaches

- **BOT Ontology** (https://w3id.org/bot#)
  - offers contains / intersect / adjacent relationship for elements and zones
- **BROT Ontology** (https://w3id.org/brot#)
  - Used for bride component modelling
  - Spatial relations: contains / adjacent for zones and components
  - Located above / located below
- **DOT Ontology** (https://w3id.org/dot#)
  - Topological relations / Aggregation
- **AOI Ontology** (https://w3id.org/aoi#)
  - Damage Area Position
  - Sub-Part of Component
  - Direction-independent location classes

§ 3.4.2.5 bot:adjacentElement ⊑ bot:hasElement

IRI: https://w3id.org/bot#adjacentElement

a OWL Object Property

adjacent element - Relation between a zone and its adjacent building elements, bounding the zone.

Sub property of	bot:hasElement
Disjoint object properties	bot:intersectingElement

§ 3.4.2.6 bot:intersectingElement ⊑ bot:hasElement

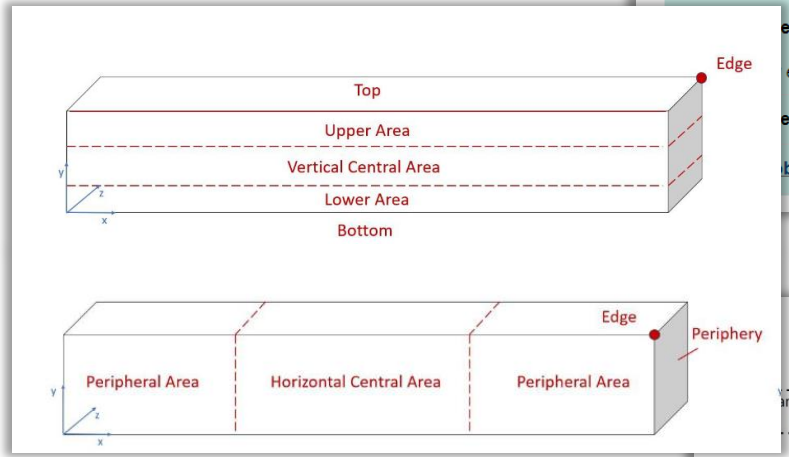
IRI: https://w3id.org/bot#intersectingElement

ect Property

element - Relation between a Zone and a building Element that intersects it.

erty of	bot:hasElement
bject properties	bot:adjacentElement

Rasmussen, M. H., Pauwels, P., Hviid, C. A., & Karlshøj, J. (2017). Proposing a Central AEC Ontology That Allows for Domain Specific Extensions.



Hamdan, A.-H., & Scherer, R. J. (2020).
Areas of Interest—Semantic description of component locations for damage assessment.

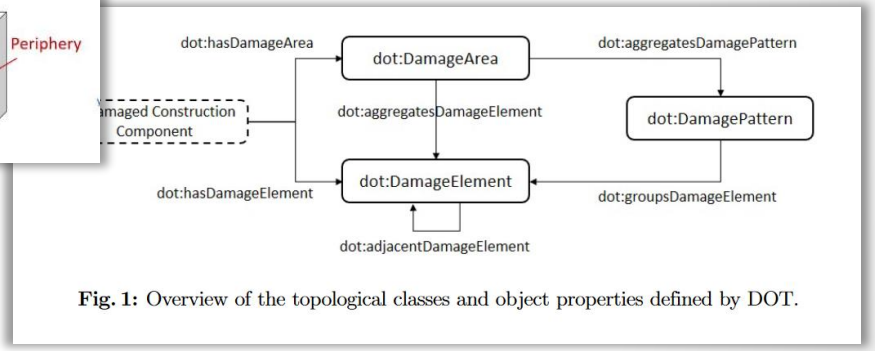


Fig. 1: Overview of the topological classes and object properties defined by DOT.

Hamdan, A.-H., Bonduel, M., & Scherer, R. J. (2019).
An ontological model for the representation of damage to constructions.

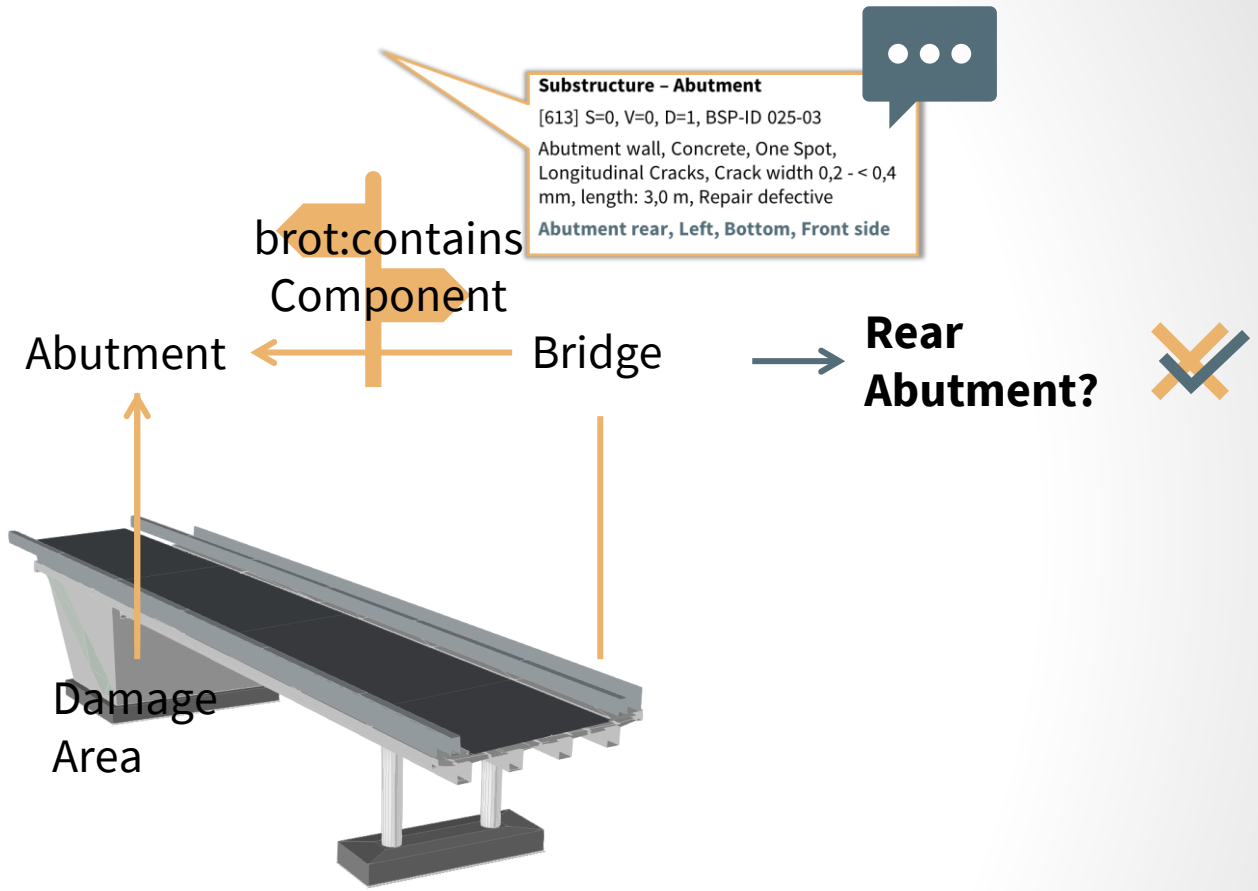
Topological relations ✓

Directional relations ✗

Relative Location Ontology

Gap → Domain & Scope Definition

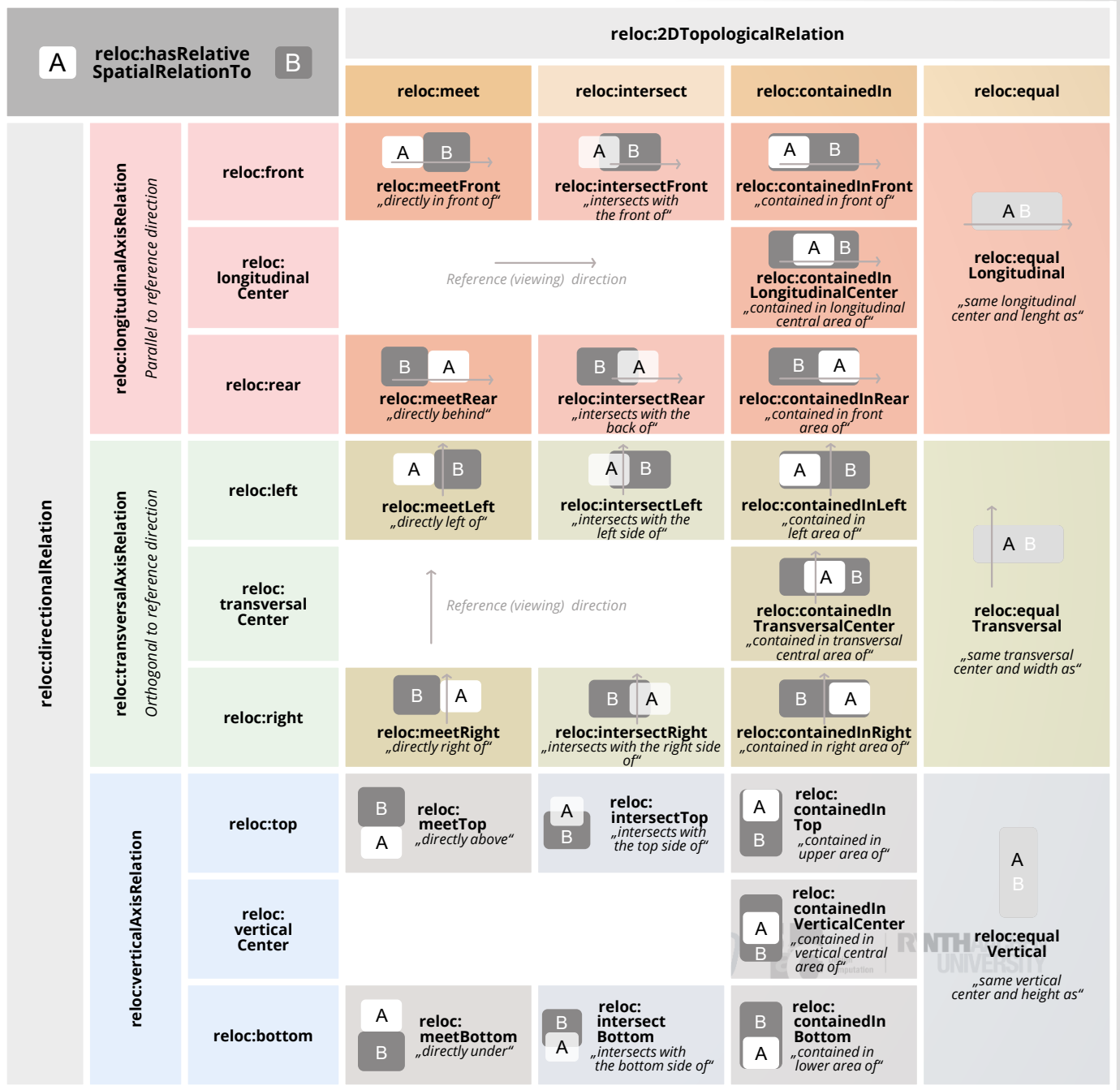
- **Expression of directional relationships**
- **Compliant with NL-description of directional relationships**
- **Geometry-Independent Modelling and Querying of spatial relationships**
- **2D / 3D objects (damage area / component)**



Relative Location Ontology

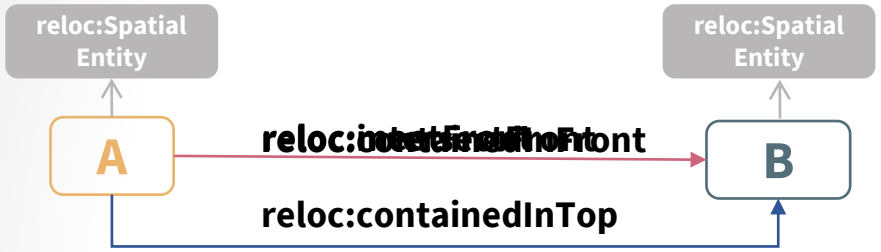
Concept

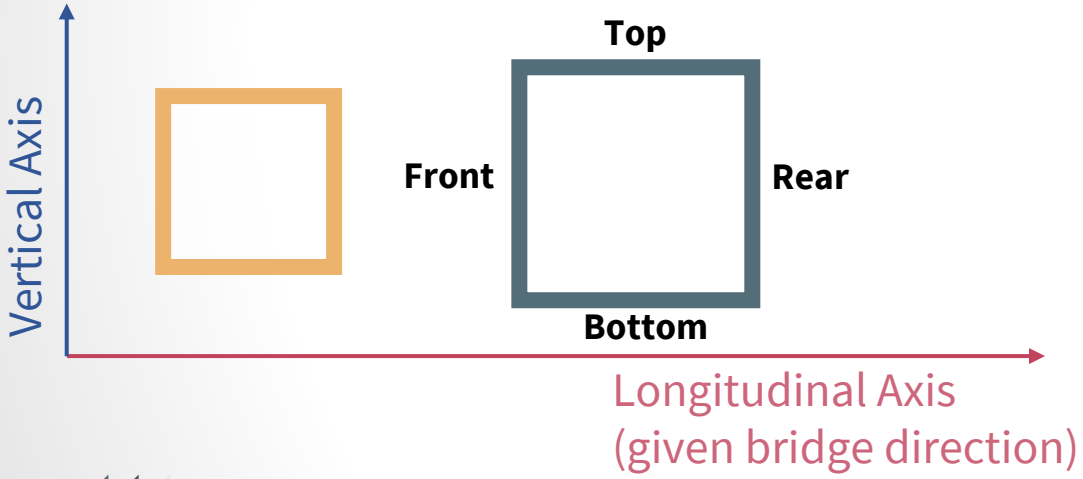
- **prefix reloc:** <https://w3id.org/reloc#>
- **reloc:SpatialEntity**
- **A hasRelativeSpatialRelationTo B**
- **Separate relationship for each axis**
- Combination of
  - Topological &
    - **Meet, Intersect, Contained In, Equal**
  - Directional properties
    - **Long. Axis: Front, Center, Rear**
    - **Trans. Axis: Left, Center, Right**
    - **Vert. Axis: Top, Center, Bottom**
- Implemented as rdfs:subProperty Relationships



Relative Location Ontology

Concept

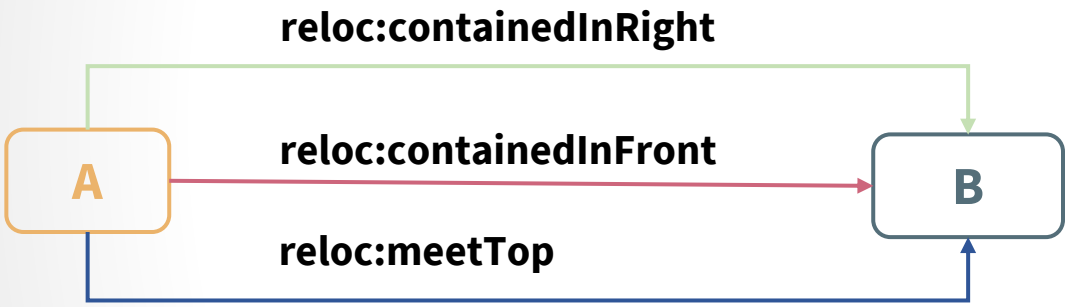


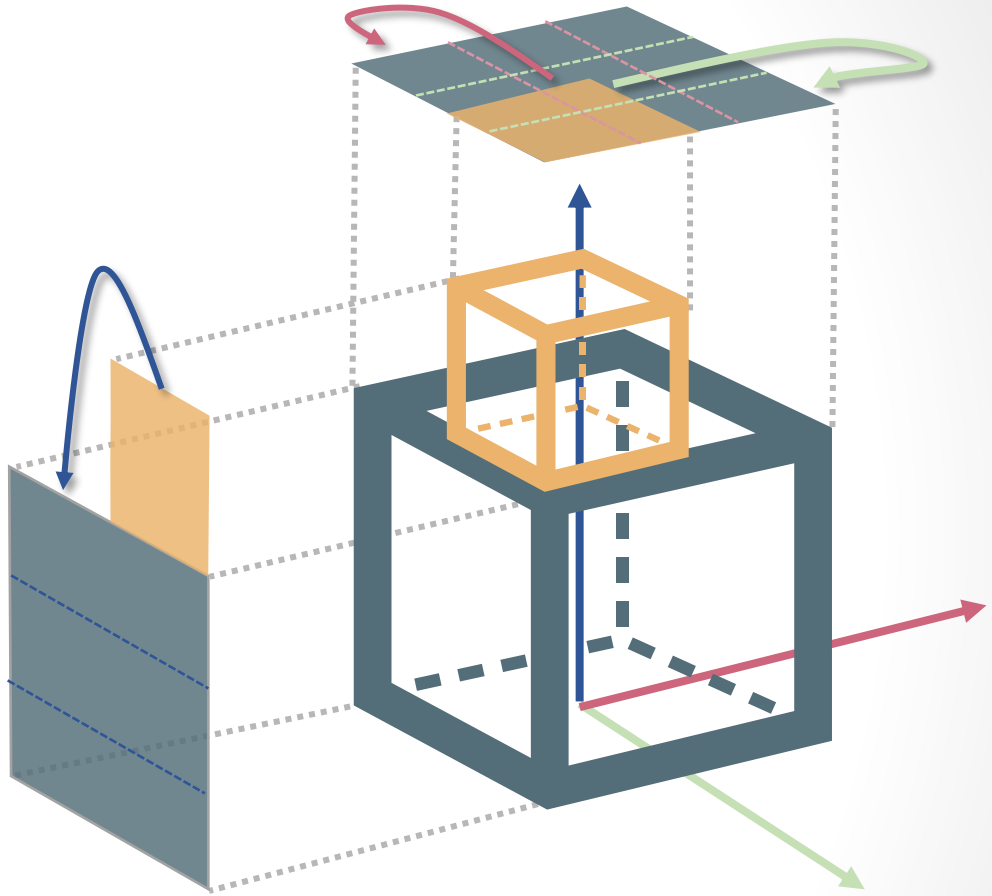


A reloc:hasRelativeSpatialRelationTo B			reloc:2DTopologicalRelation		
			reloc:meet	reloc:intersect	reloc:containedIn
	reloc:longitudinalAxisRelation *Parallel to reference direction*	reloc:front	**reloc:meetFront** *„directly in front of"*	**reloc:intersectFront** *„intersects with the front of"*	**reloc:containedInFront** *„contained in front of"*
		reloc: longitudinal Center	*Reference (viewing) direction*		**reloc:containedIn LongitudinalCenter** *„contained in longitudinal central area of"*
		reloc:rear	**reloc:meetRear** *„directly behind"*	**reloc:intersectRear** *„intersects with the back of"*	**reloc:containedInRear** *„contained in front area of"*

Relative Location Ontology

Concept





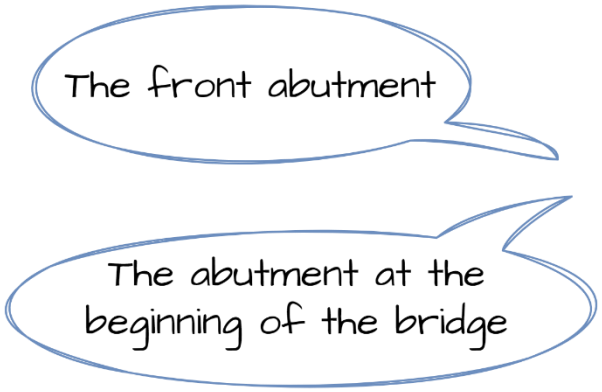
Relative Location Ontology

Integration of natural-language terms/ legacy data

- Label definition of directional properties
- Include alternative NL-terms for the description of a specific location

→ Mapping of NL-text to RELOC properties

→ Enables text-comparison process (e.g., regex filters)

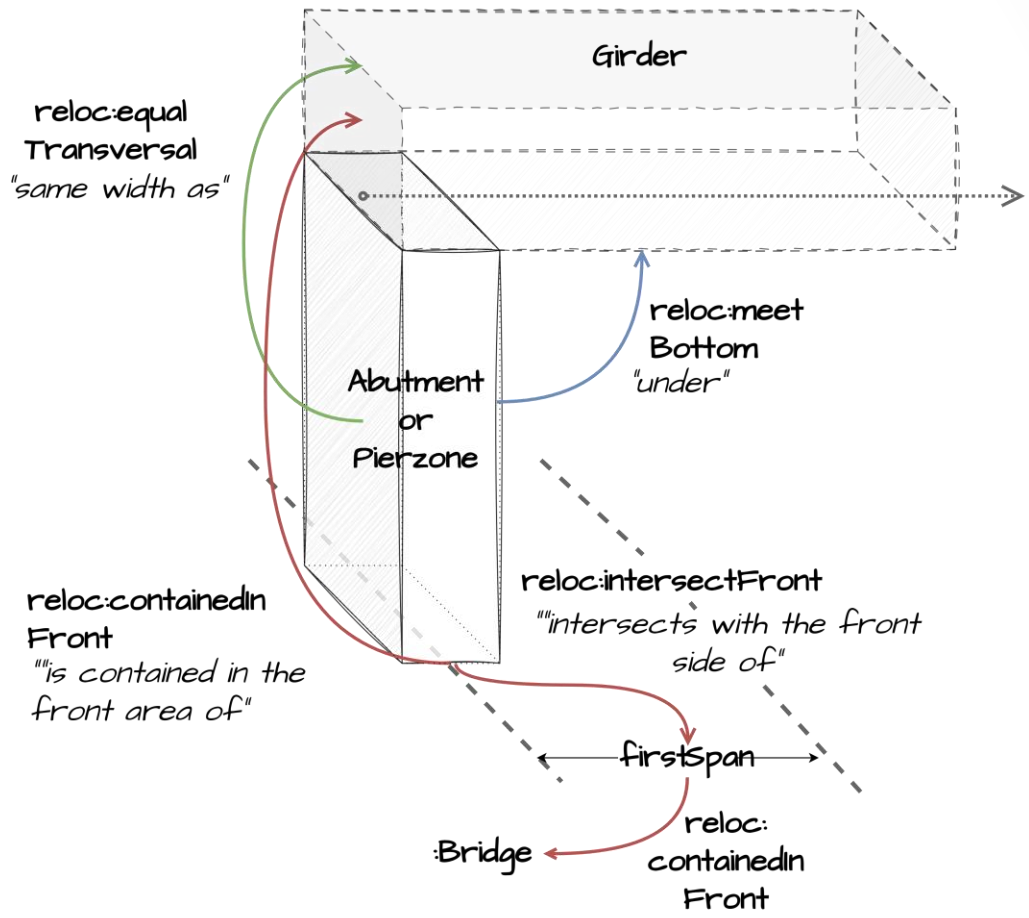



```
reloc:front
        rdf:type  owl:ObjectProperty ;
        rdfs:label  "front"@en ;
        rdfs:label  "Vorne"@de ;
        skos:altLabel  "Anfang"@de, "beginning"@en,
                       "Vorderseite"@de, "front side"@en,
         rdfs:subPropertyOf  reloc:longitudinalAxisRelation .
```

Application

Definition of bridge component relations

- Used RELOC Ontology to model “typical” spatial relations of bridge components
- Explicit expression of implicit domain knowledge
- **Basis for derivation of spatial graph from existing bridge documentation**

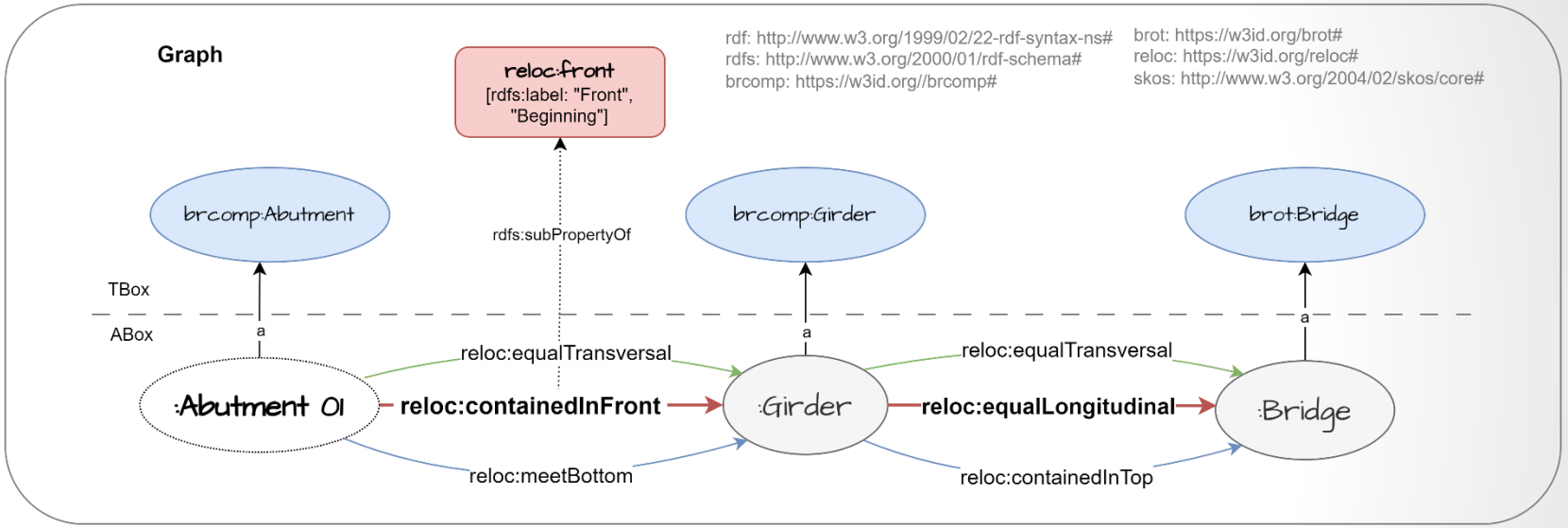


Application

Transfer of legacy damage documentation

```
PREFIX asb: <https://w3id.org/asbingowl/core#>
PREFIX asbkey: <https://w3id.org/asbingowl/keys#>
PREFIX : <http://example.org/>

:Damage613
rdf:type                    asb:Schaden [Damage]
asb:Bauteil [component]     asbkey:Widerlager [Abutment] ;
asb:Ortsangabe [location]   asbkey:Vorne [front] ,
                            asbkey:Vorderseite [front side] ,
                            asbkey:Unten [bottom] ,
                             asbkey:Links [left] .
```



1. **Query bridge graph for front abutment**
2. Add damage via reloc properties to found component

SPARQL Query:

1. Component of **type abutment**
2. Related to girder or bridge
3. via a **reloc property**
4. which **directional super-property** has the **label “front”**

:Abutment 01

Application

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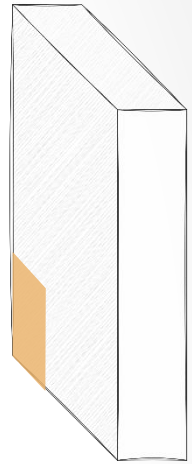
asb:Ortsangabe [location]   asbkey:Vorne [front] ,
                            asbkey:Vorderseite [front side] ,
                            asbkey:Unten [bottom] ,
                            asbkey:Links [left] .
```

Mapping table: [German] legacy terms to reloc properties

Location term	RELOC property
front side	containedInFront
bottom	containedInBottom
left	containedInLeft



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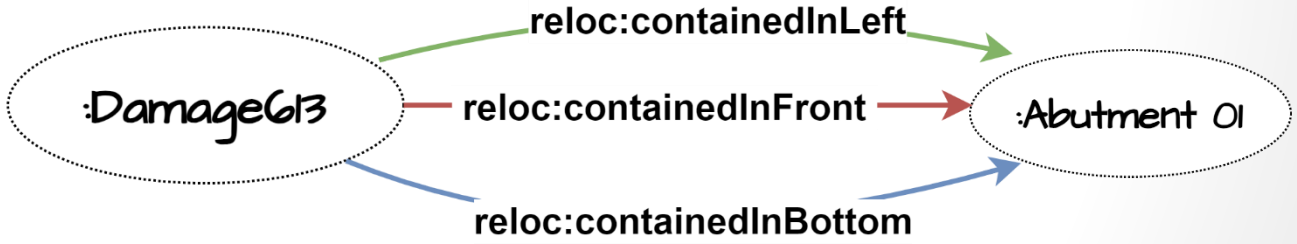
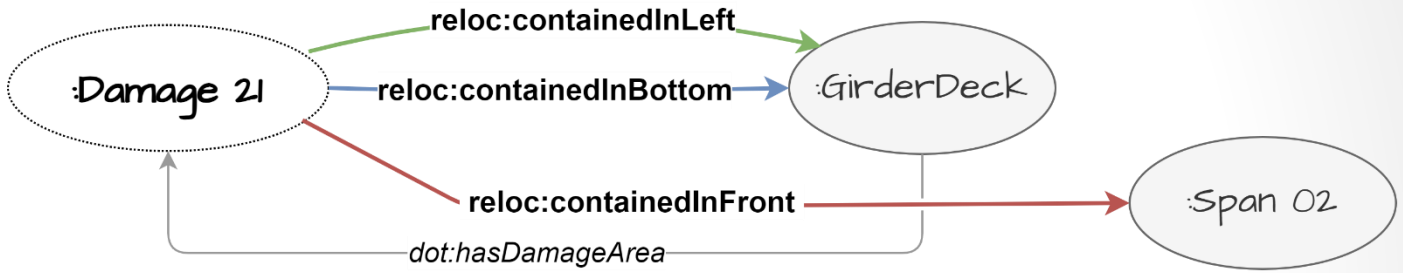
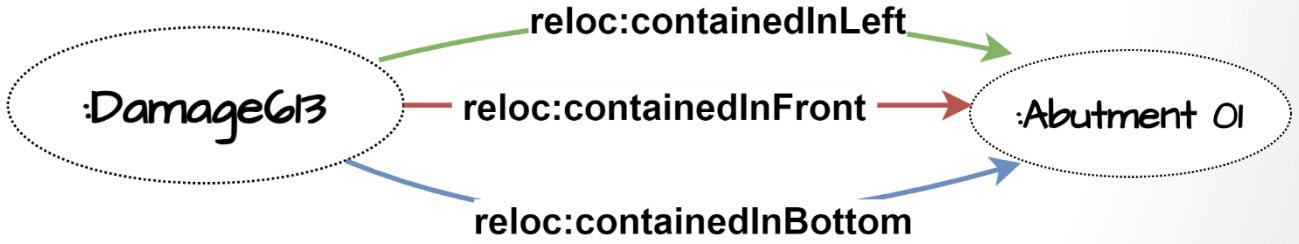


Application

Transfer of legacy damage documentation

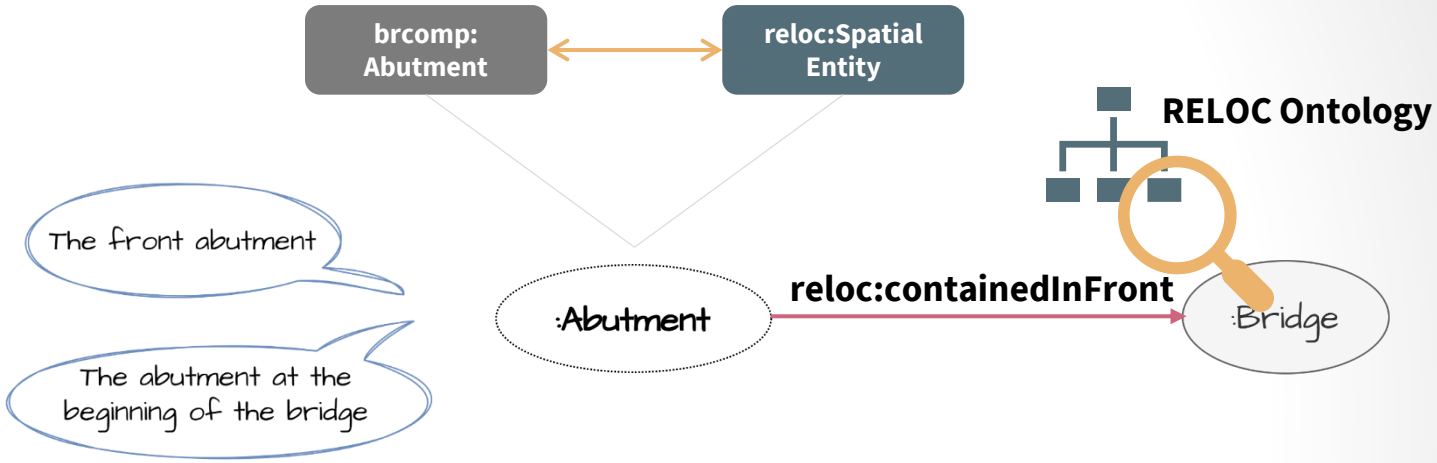
- Possible to use different reference points
- Flexible approach to reflect references to conceptual zones
  - “Damage on the road surface at the beginning of the 2nd span”
  - “Damage on the road surface in the area of the first abutment”

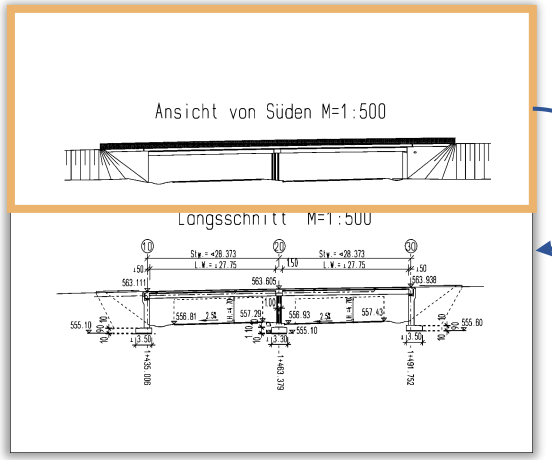




Conclusion

- Enable the **expression of implicit knowledge as explicit spatial statements**
- Enables successful **conversion of NL descriptions** of locations
- Enables **spatial queries of formerly semi-structured text data**
- Modular approach, can be **integrated with other ontology** approaches
- Can be used for **3D assets but also for 2D** documents





reloc:containedInTop

Conclusion

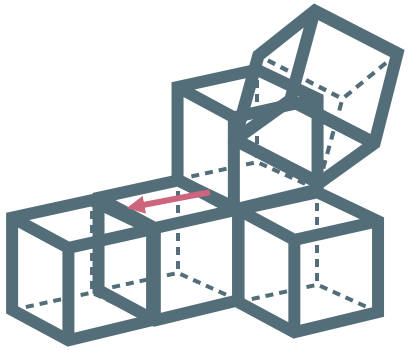
Limitations

- **Simplified representation of spatial relationships**
  - “Box”-thinking of spatial elements
  - orthogonal relations
- **Tested only for bridge maintenance use case**

  → For buildings with less clear orientation it is maybe complicated to use
- **Currently only 3D zones , no surface definitions**

  → placement of 2D damage areas on 3D component not derivable from reloc properties
- **Currently only topological relations**

  ≥ **“meet “ included, no “disjoint” / “near”**



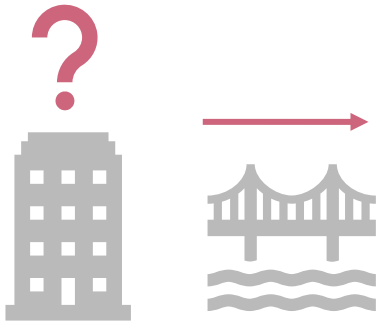


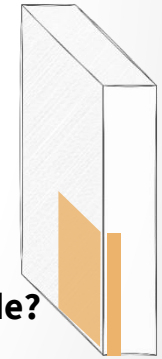
Foto: David Boureau / archello.com

reloc:containedInBottom

reloc:containedInRight

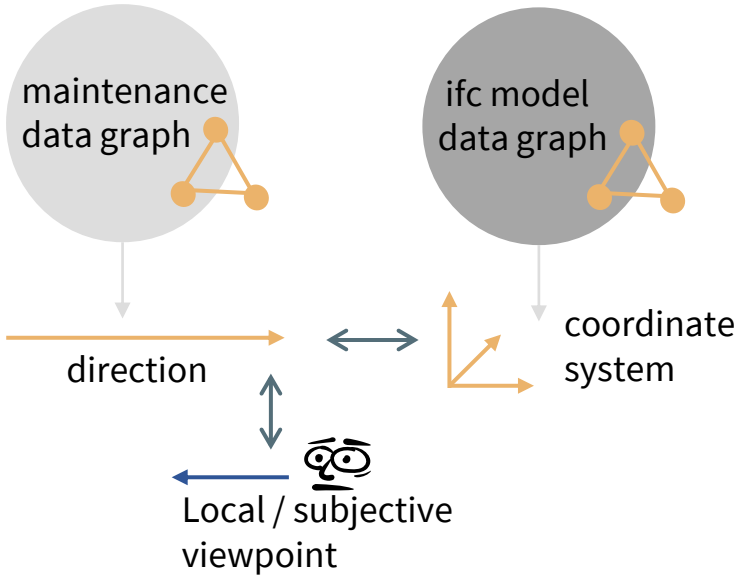
reloc:containedInFront

reloc:containedInFrontSide?



Next steps

- Include viewing direction definition into ontology
  → **enable alignment with other external reference systems**
  → **compute directions from other entry points (local viewing direction)**
- **Enable to represent fuzziness of NL- terms**
- Use NLP for conversion, instead of static mapping table
  → **Open up approach to different text sources**
- Transform >1000 data sets
  → **Test complex spatial queries/inferring of spatial relationships**
- Derive relative coordinates from bridge graph relations, using documented bridge and damage dimensions
  → **Create simple bounding box model**



Thank you for your attention

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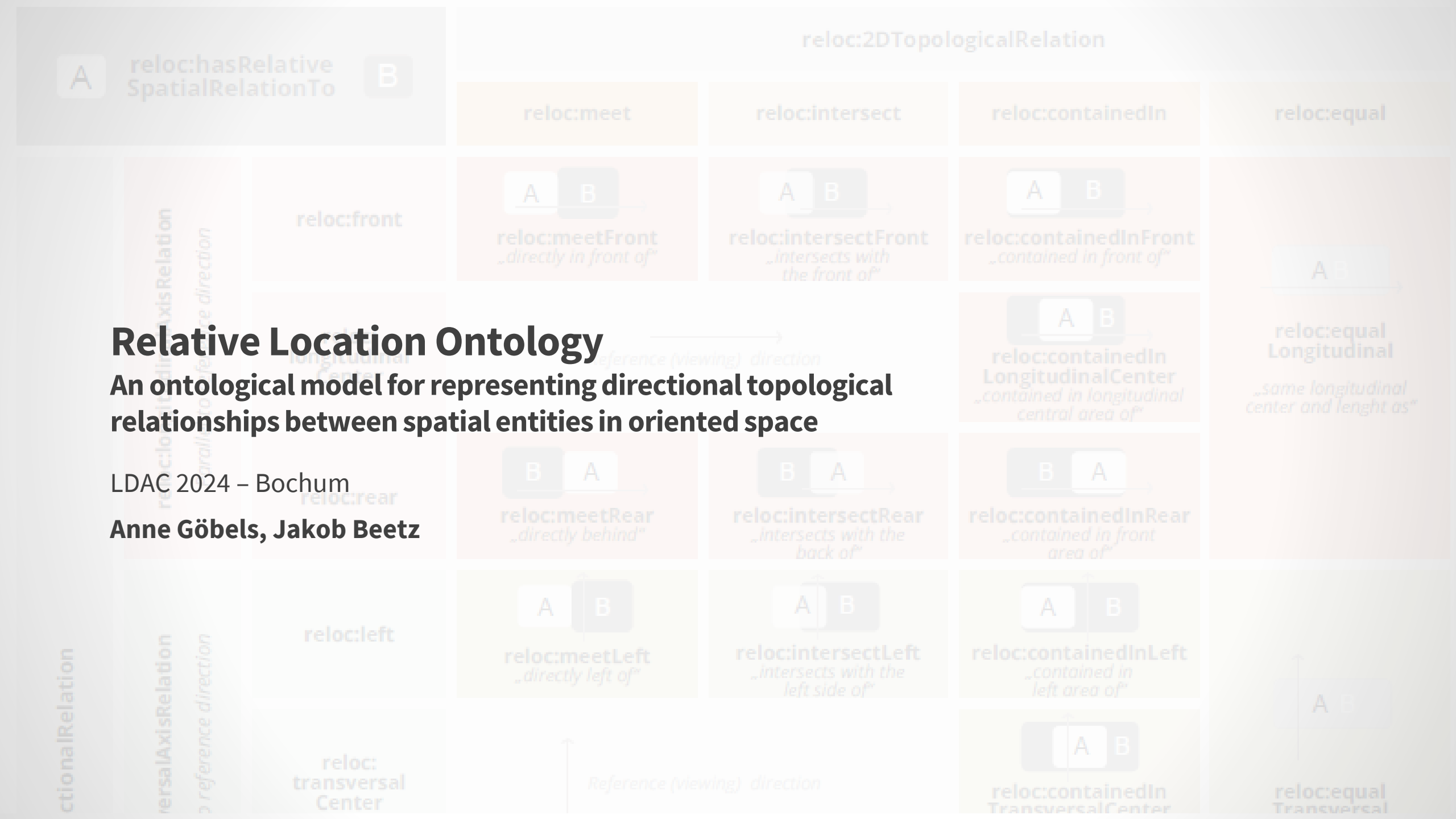


Relative Location Ontology

An ontological model for representing directional topological relationships between spatial entities in oriented space

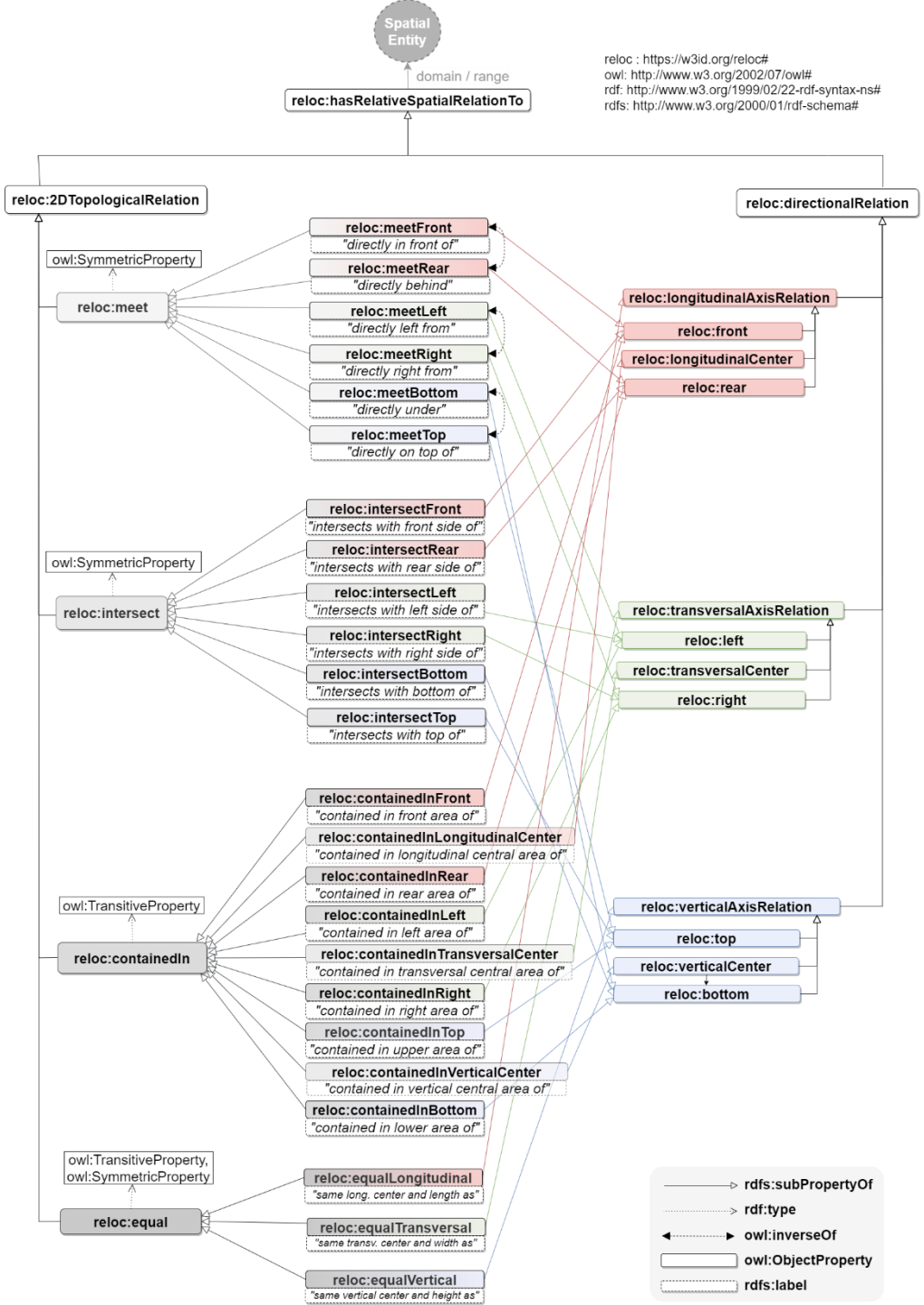
LDAC 2024 – Bochum

Anne Göbels, Jakob Beetz

RELOC Ontology

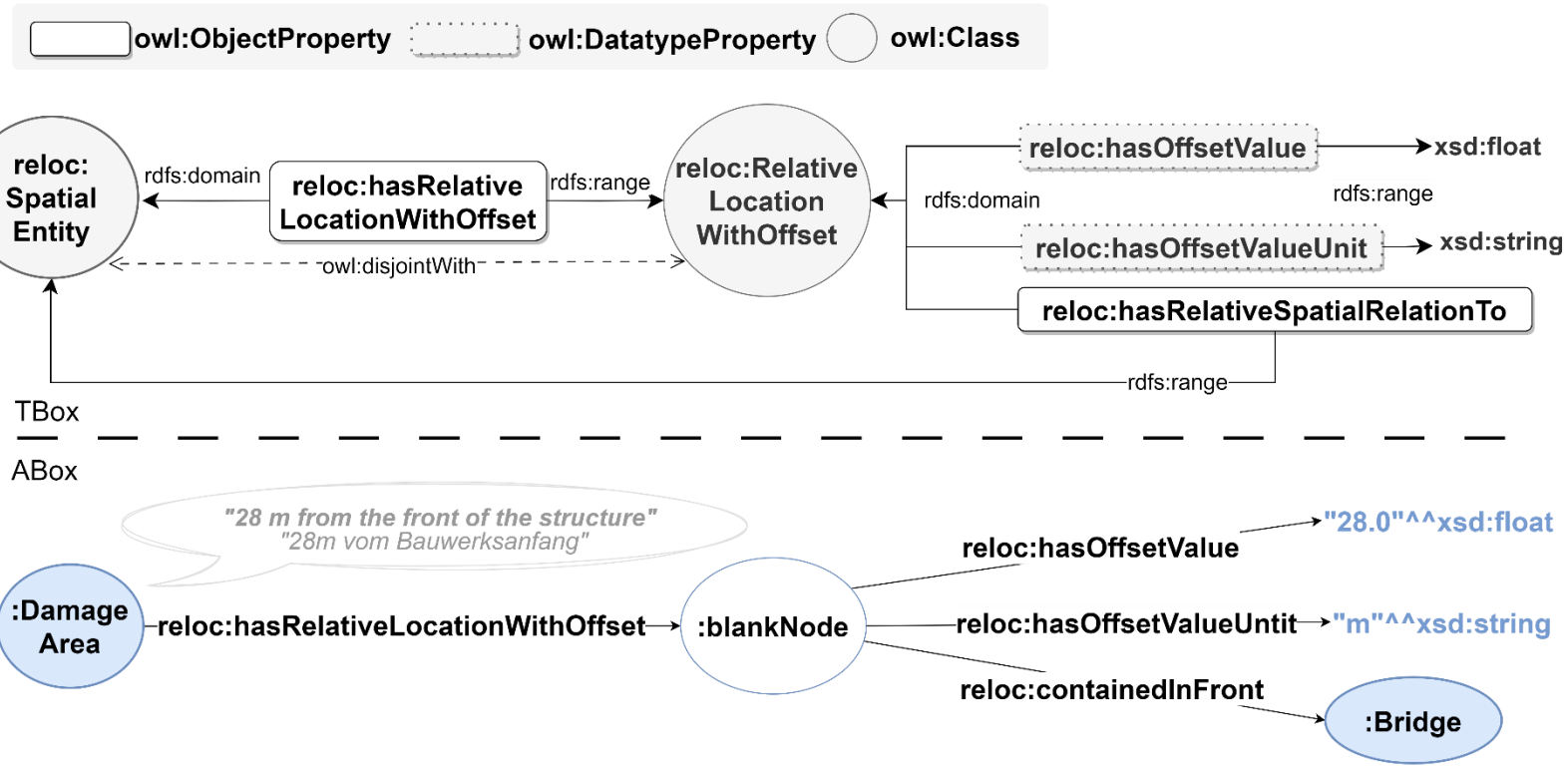
Technical Implementation

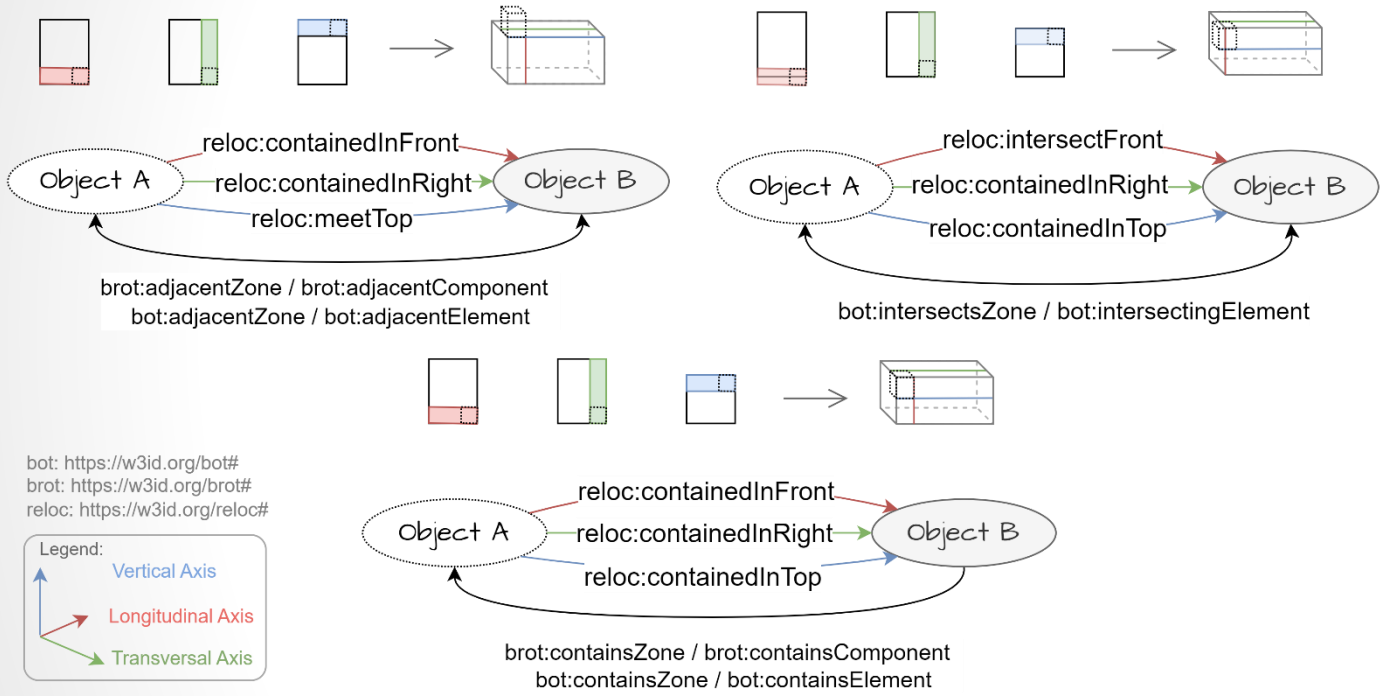
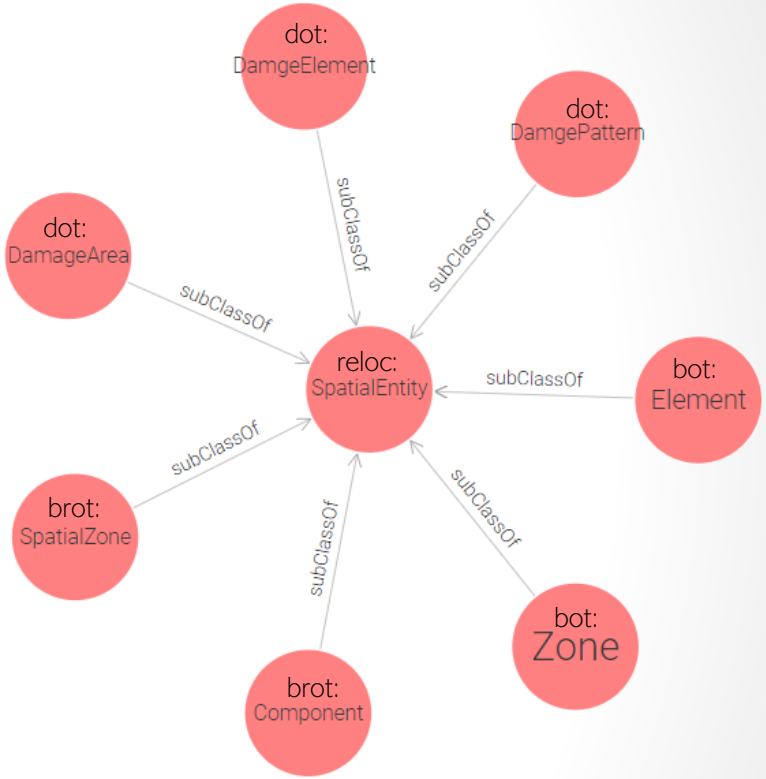
prefix reloc:
<https://w3id.org/reloc#>



Functional Extension

Express defined offset to locations



Application

Alignment with LBD ontologies