Linked Building Data and Ontologies

Summer School of Linked Data in Architecture and Construction

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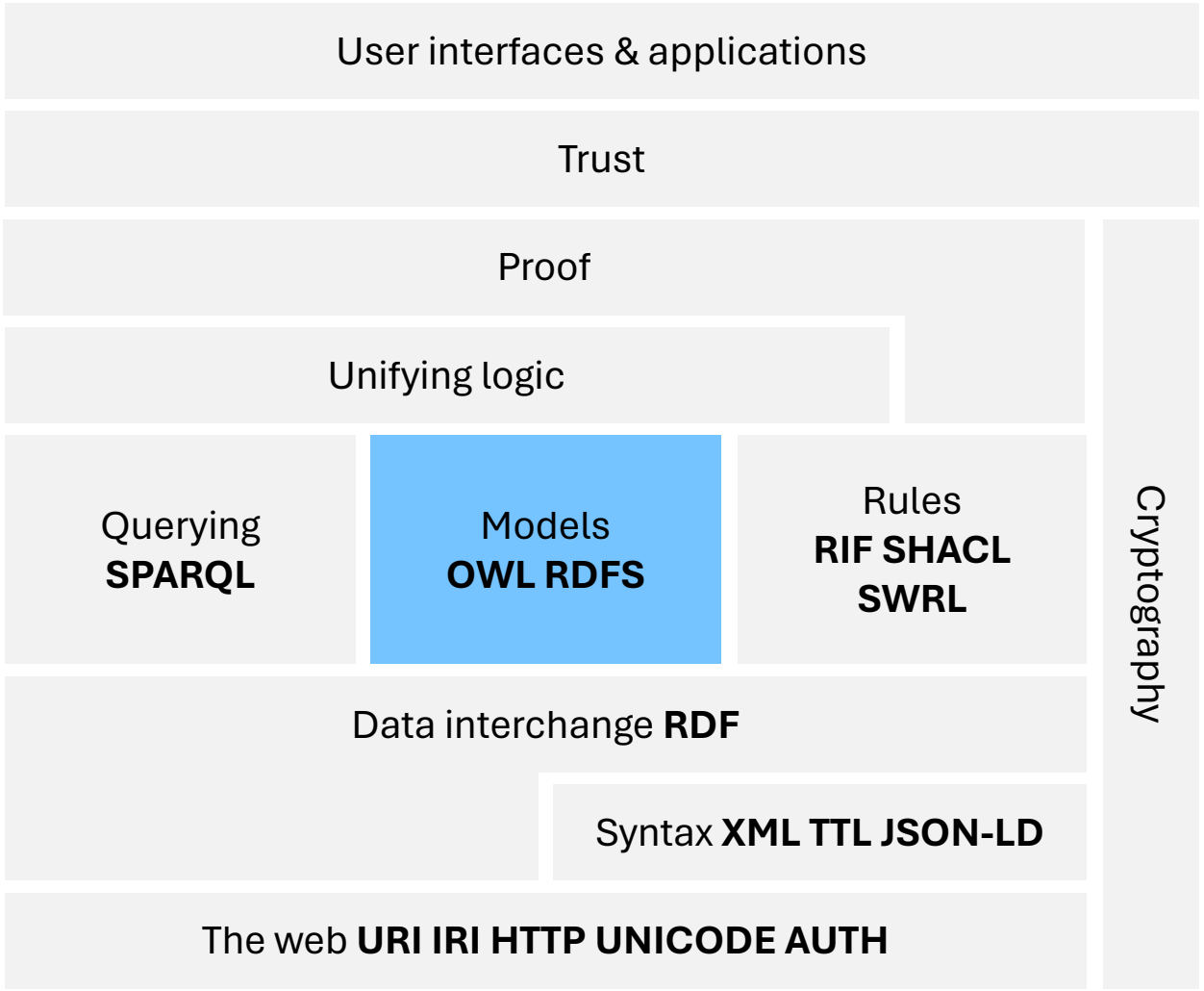
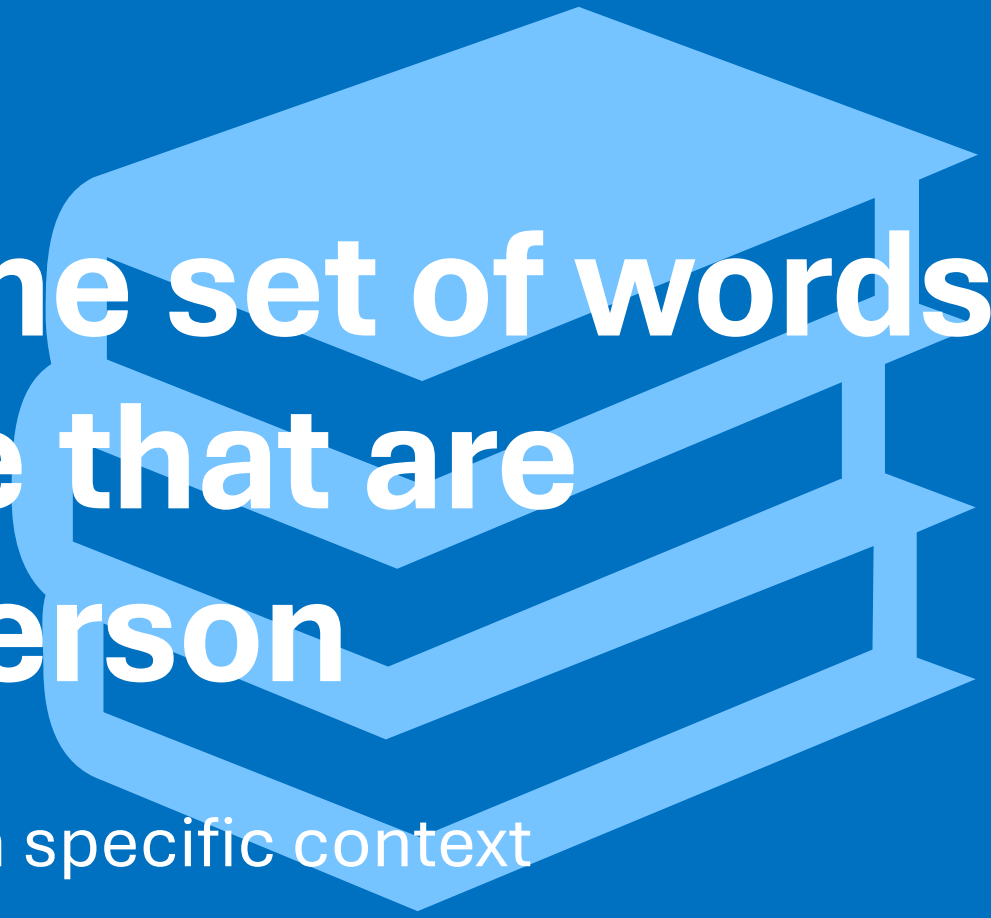
In this lecture, you'll learn:

- What an ontology is
- Why we use ontologies
- Basics of ontology engineering
- The difference between Abox and Tbox
- Open World Assumption and the basics of reasoning
- Common ontologies in the AEC industry
- Practical tips and tools to kickstart your ontology development!

Ontology languages in semantic web stack



A vocabulary is the set of words within a language that are familiar to that person



Classify **terms** that can be used in a specific context

Classify **relationships** between terms

Define **constraints** on using those terms

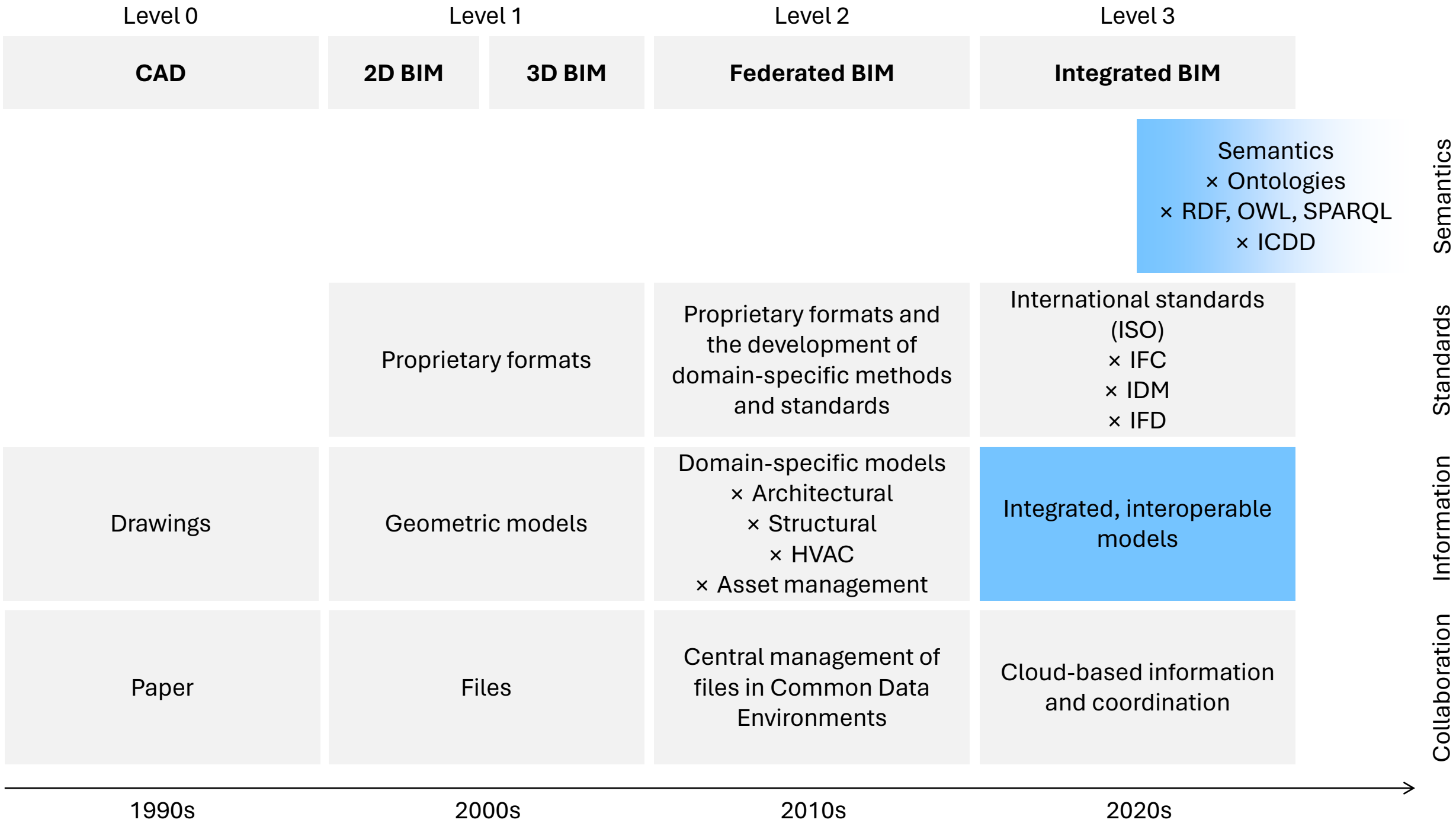
H. Sack. “Linked Data Engineering: 3.1 Vocabularies and Ontologies”

An ontology is a formal, explicit specification of a shared conceptualization

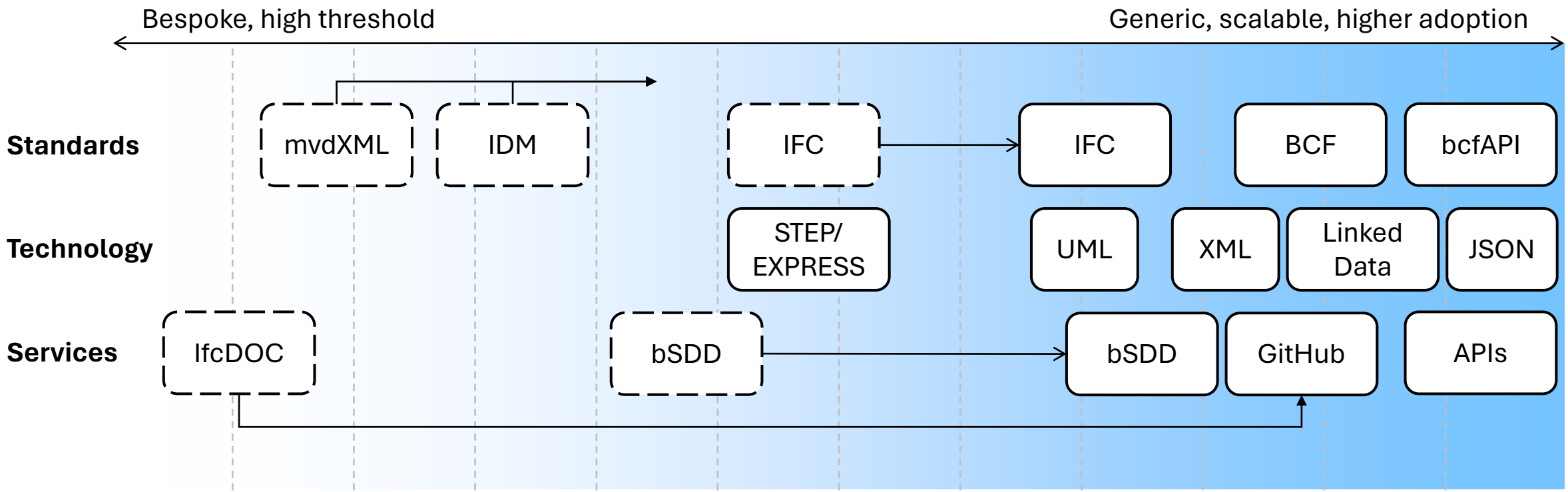
R. Studer, V. R. Benjamins, and D. Fensel. “Knowledge Engineering: Principles and methods”. In: Data & Knowledge Engineering 25.1-2 (1998), pp. 161–197. doi: 10.1016/S0169-023X(97)00056-6.

An ontology is a formal, explicit specification of a shared conceptualization

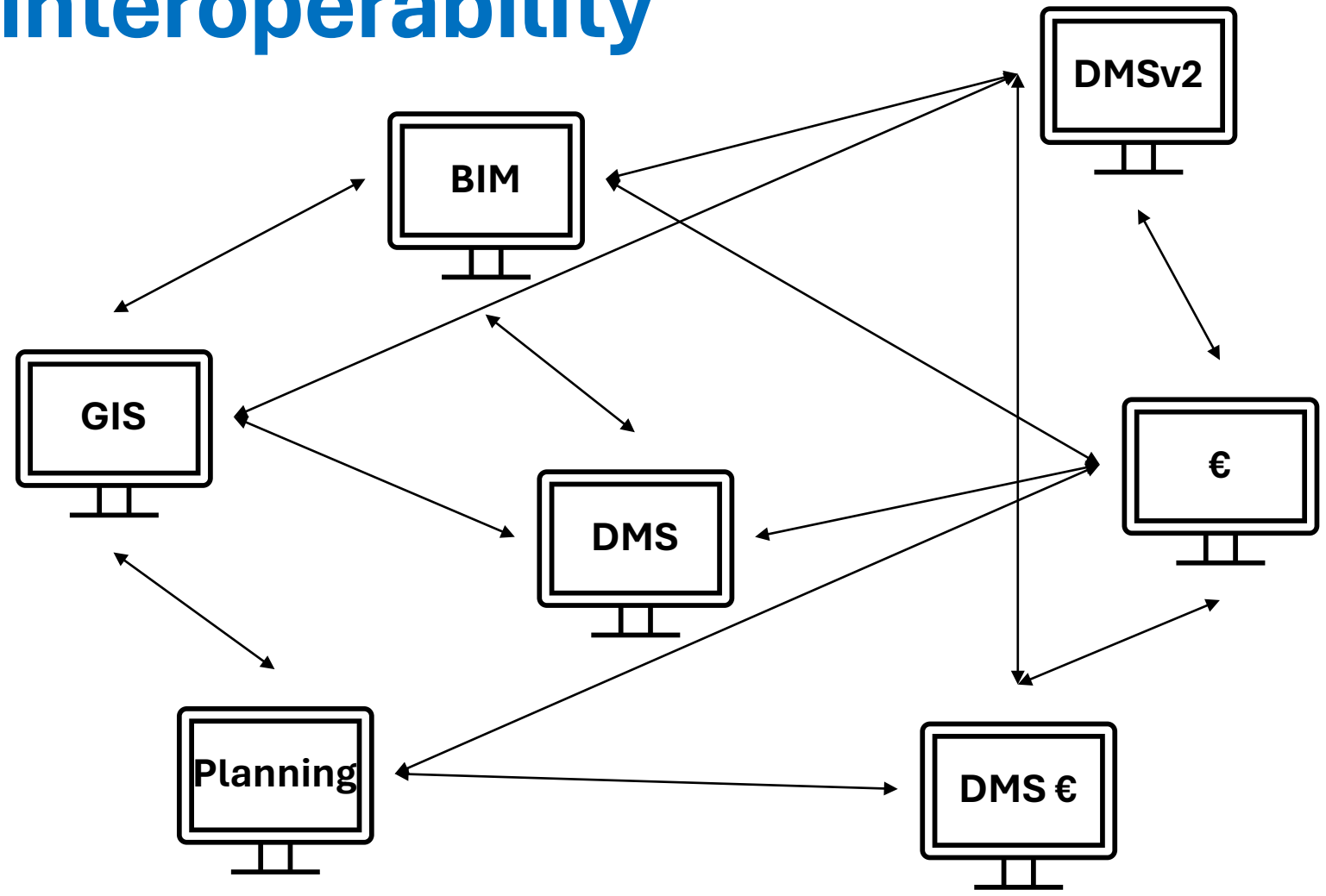
Conceptualization	An abstract model of something in the world that we want to represent
Explicit	All concepts in a domain are defined using formal logics supported by languages in the semantic web stack
Formal	Machine-understandable
Shared	Created for and agreed on by multiple users


Level 0
Level 1
Level 2
Level 3
CAD
2D BIM
3D BIM
Federated BIM
Integrated BIM
Semantics
× Ontologies
× RDF, OWL, SPARQL
× ICDD
Proprietary formats
Proprietary formats and the development of domain-specific methods and standards
International standards (ISO)
× IFC
× IDM
× IFD
Drawings
Geometric models
Domain-specific models
× Architectural
× Structural
× HVAC
× Asset management
Integrated, interoperable models
Paper
Files
Central management of files in Common Data Environments
Cloud-based information and coordination
Semantics
Standards
Information
Collaboration
1990s
2000s
2010s
2020s

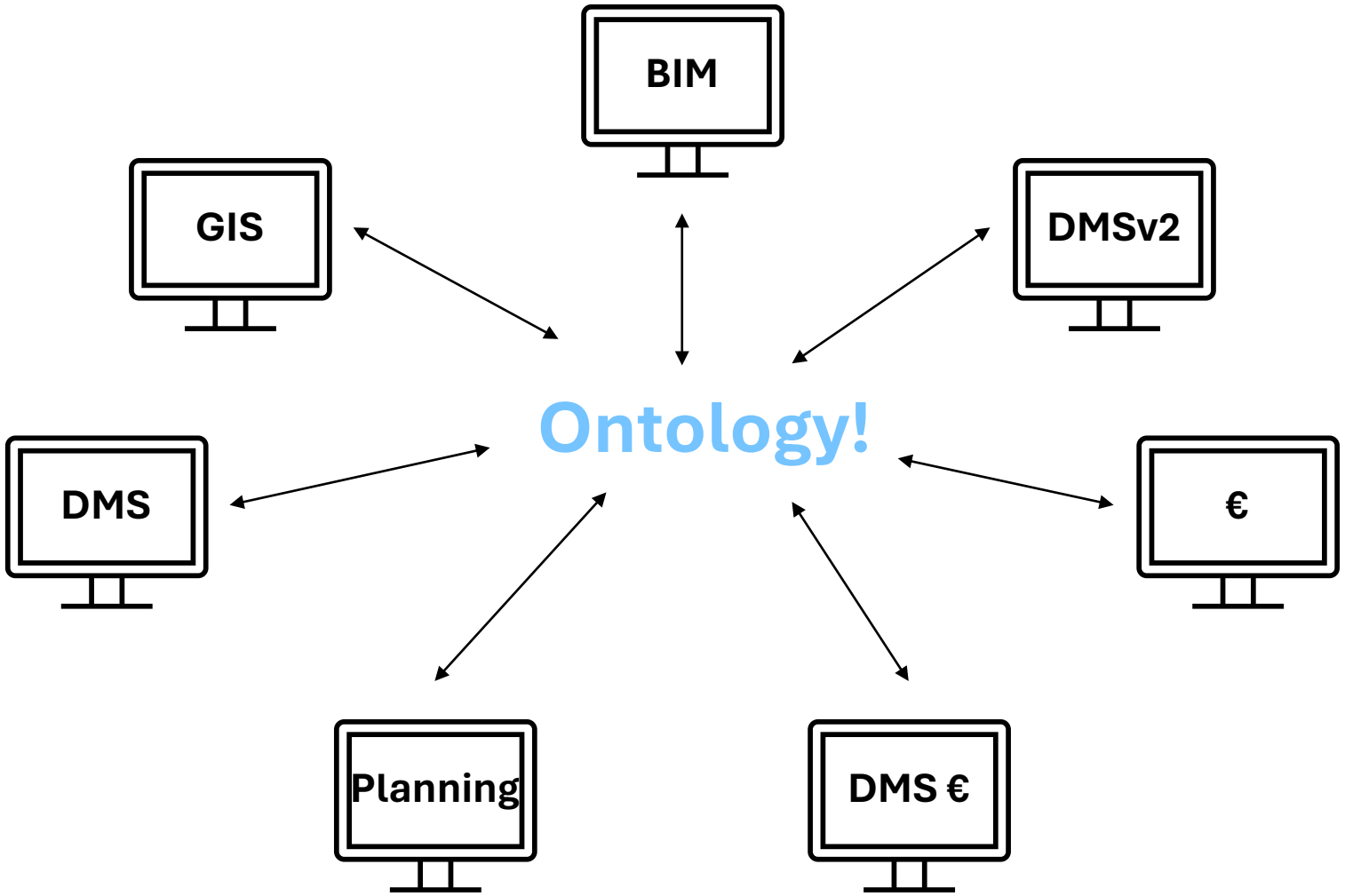
Developments in buildingSmart



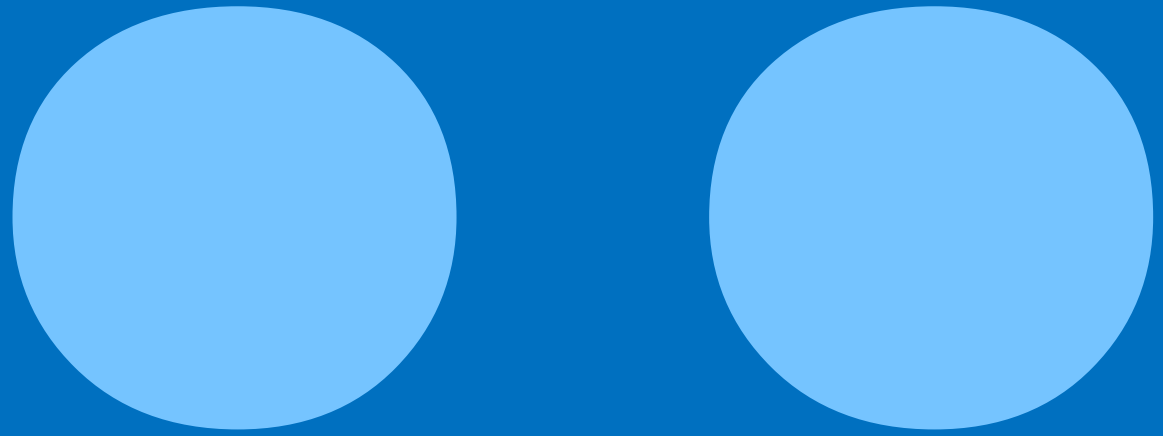
Semantic interoperability



Semantic interoperability



How to represent an ontology?



Ontologies are represented using

Classes

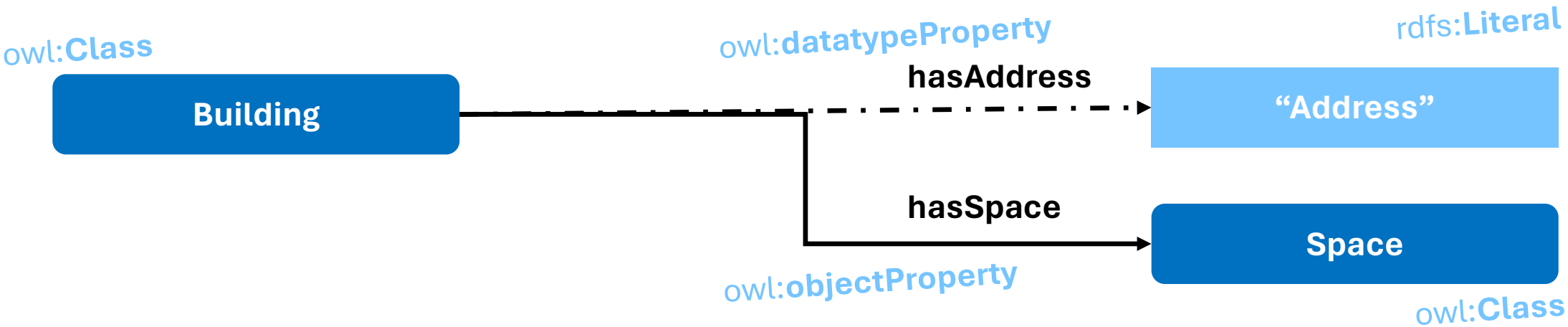
Abstract representation of a real-world concept

Relationships

Relationship between two classes or between a class and a literal

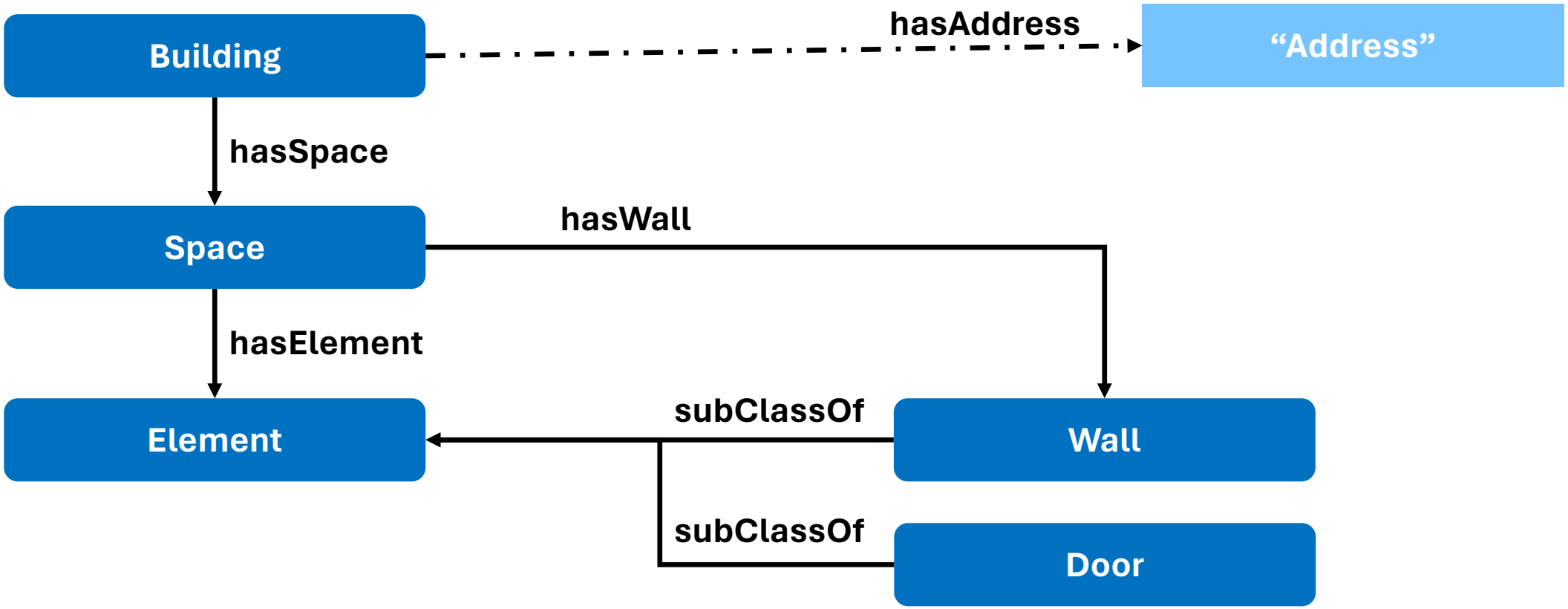
Literals

Data values, such as strings, booleans or integers



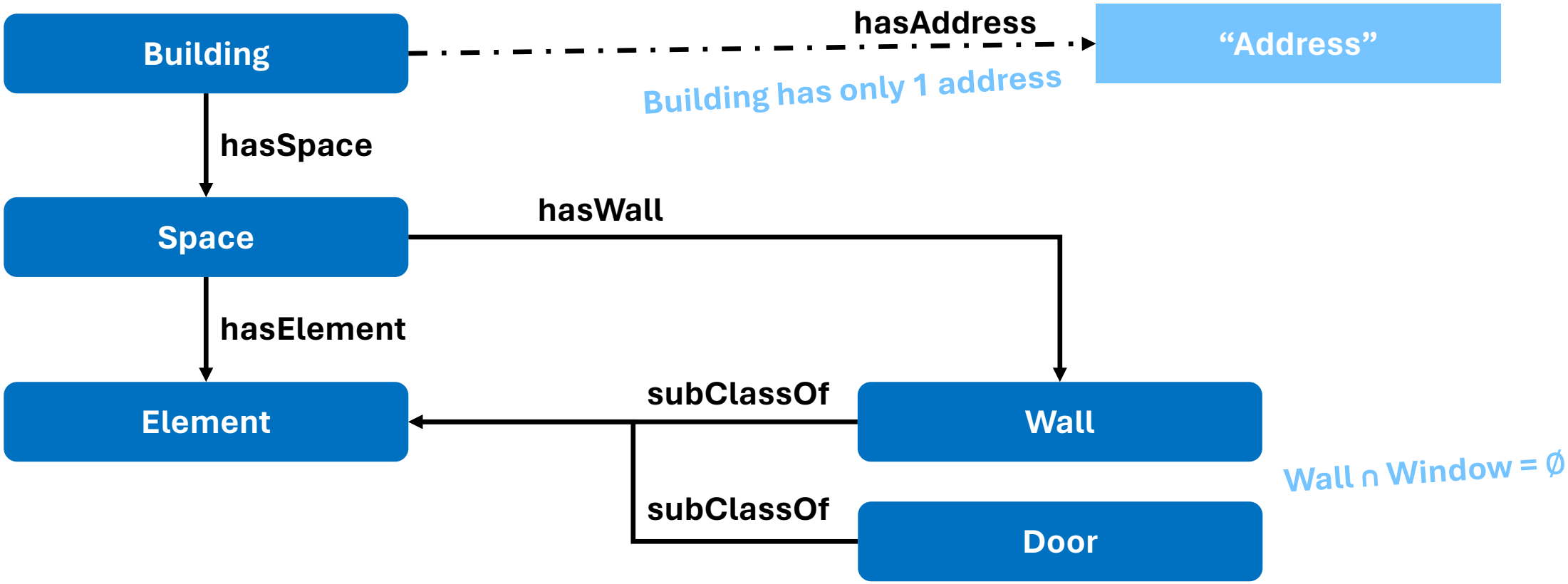
Slightly more complex ontology structures

Classes can have **sub-classes**



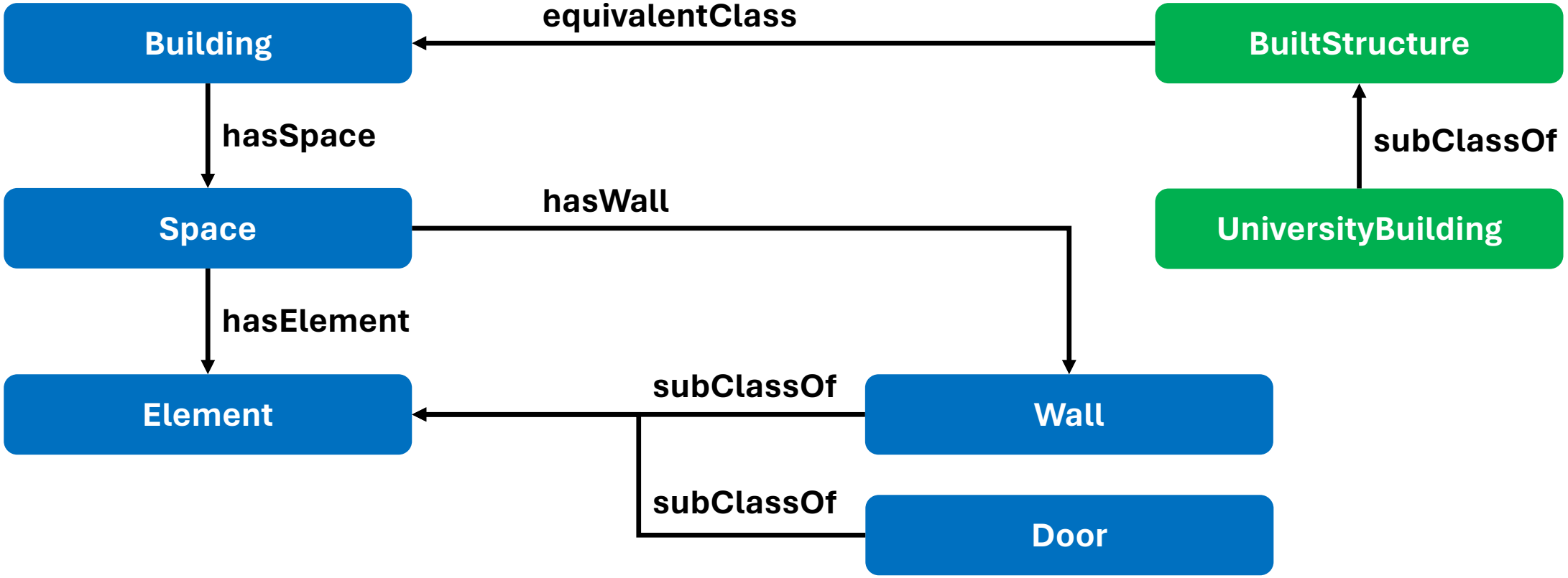
Slightly more complex ontology structures

Rules can be defined for classes and relationships



Connecting ontologies

Relationships can connect classes from two ontologies

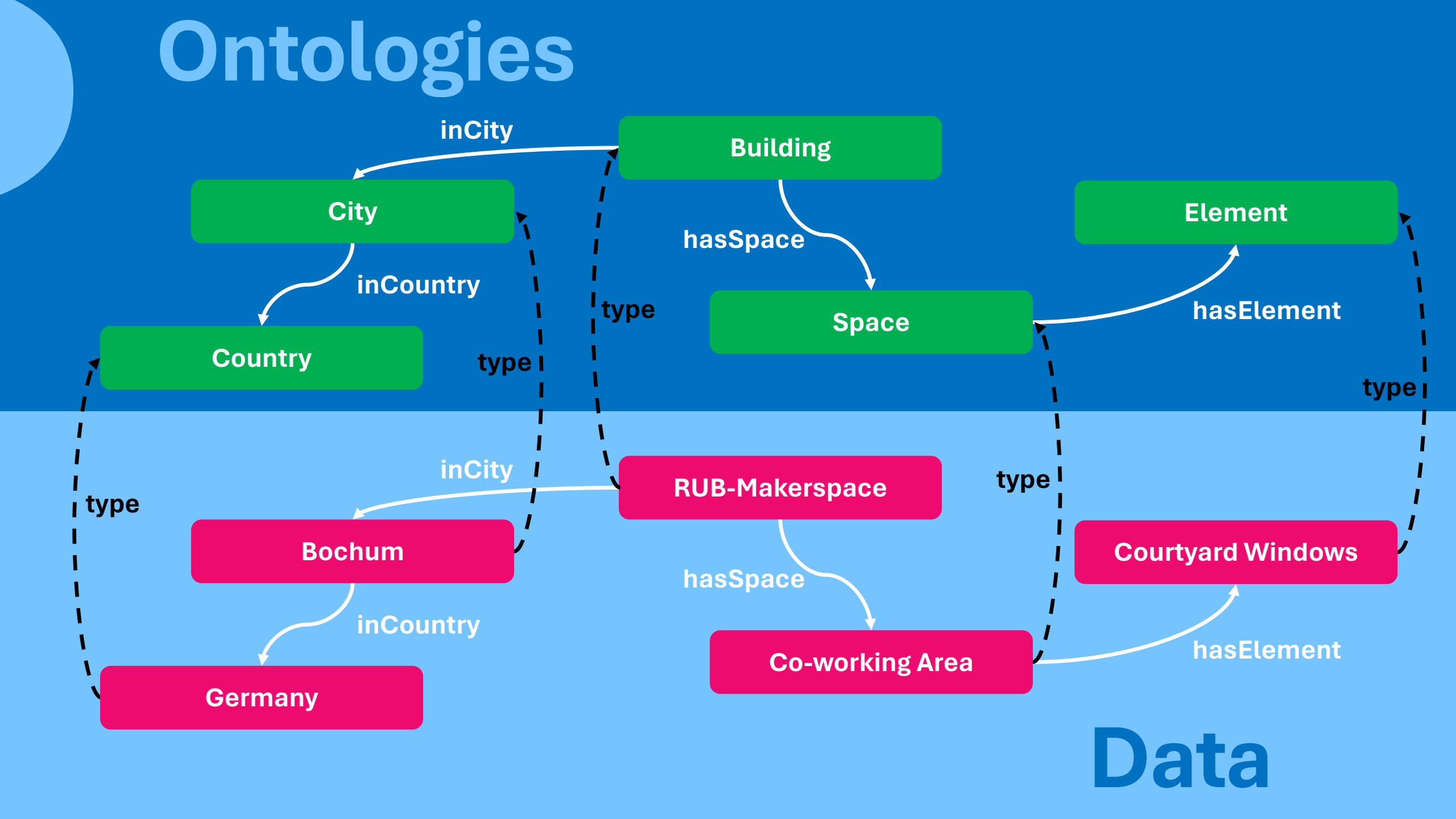


Ontologies

VS

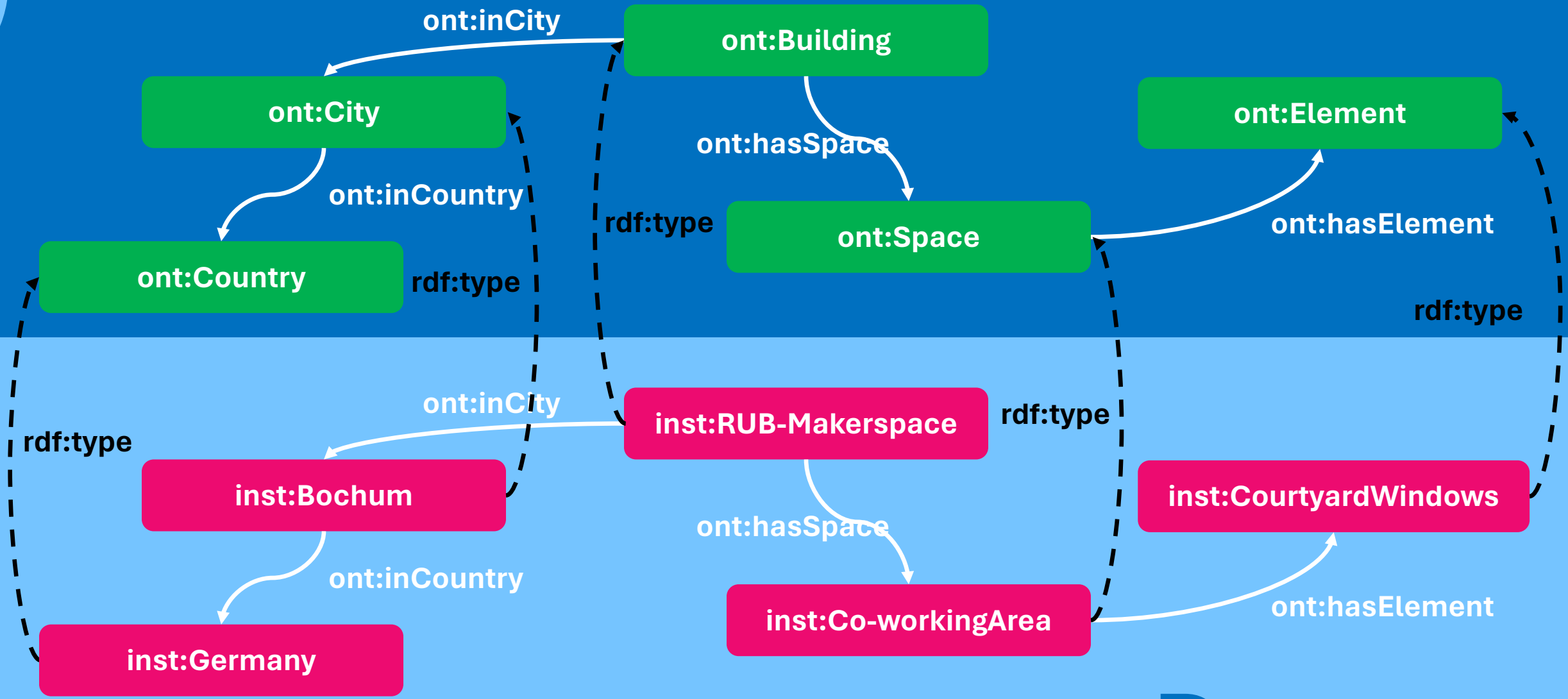
Data

Ontologies



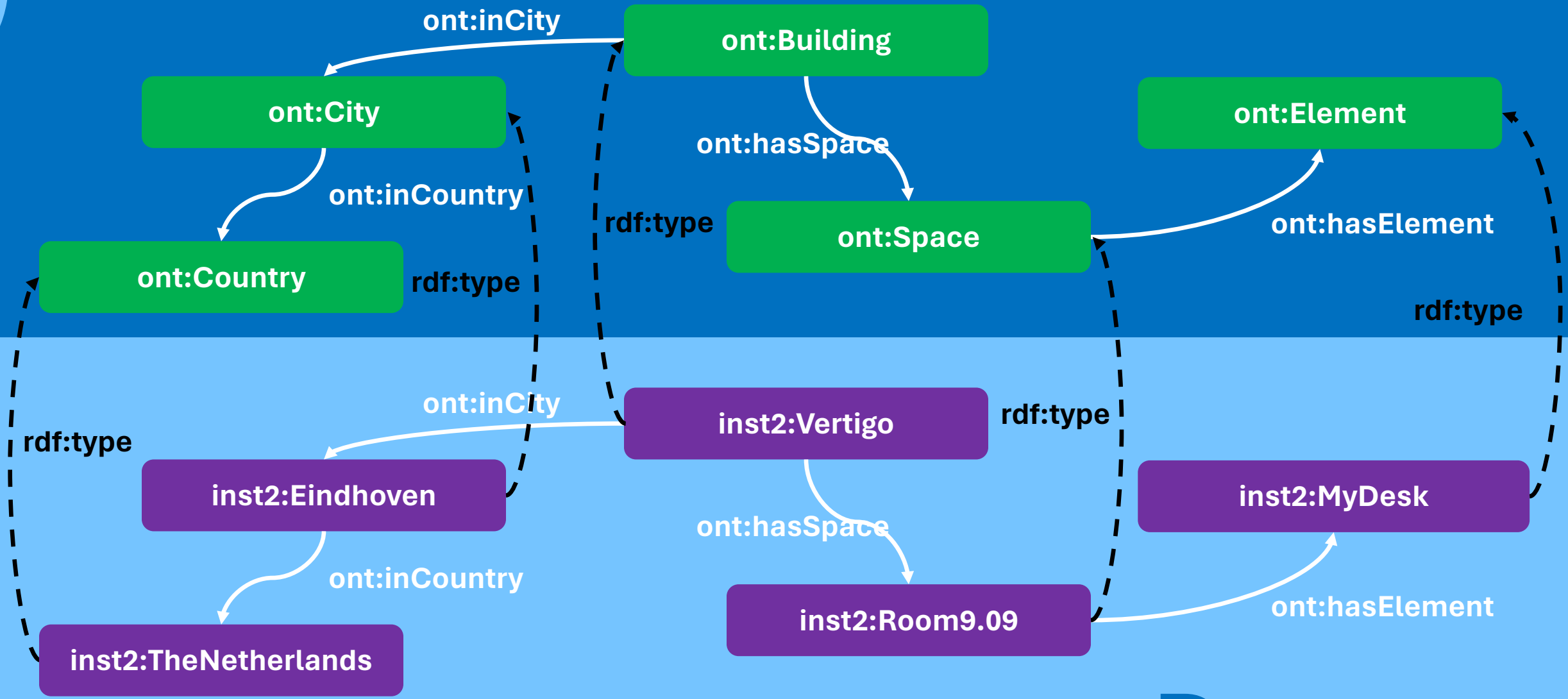
Data

Ontologies



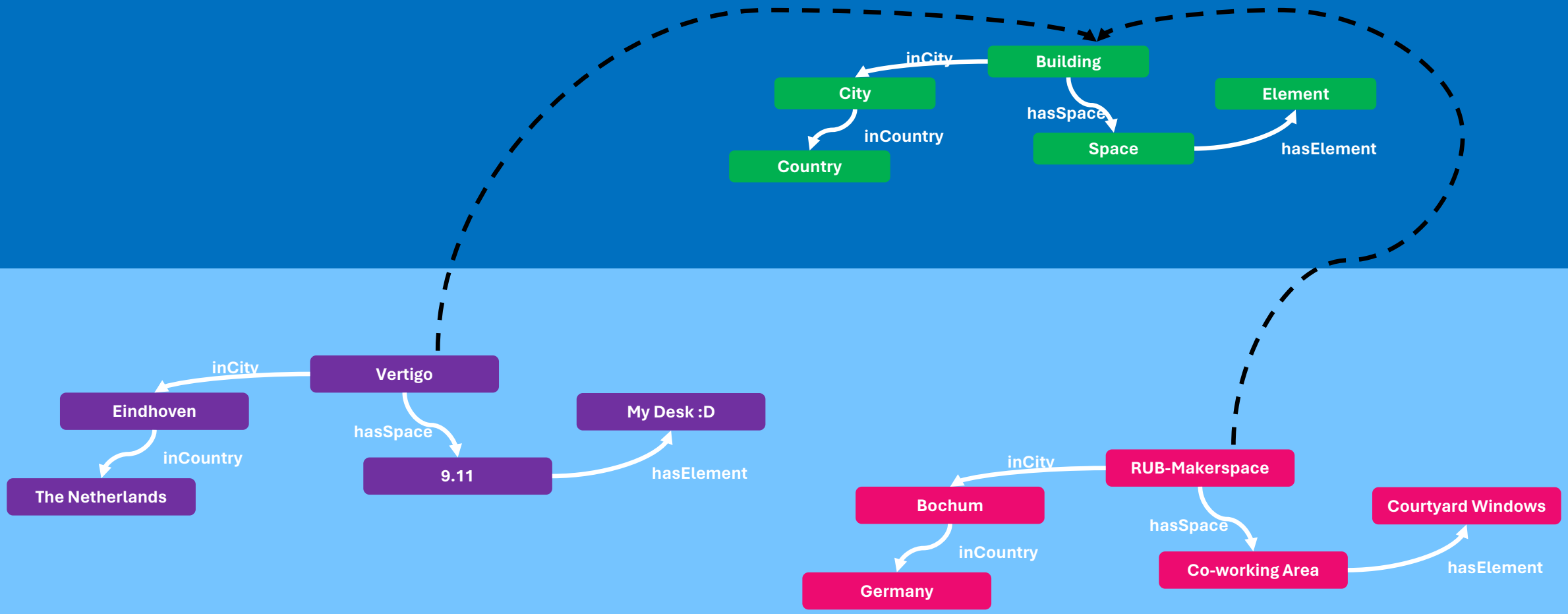
Data

Ontologies



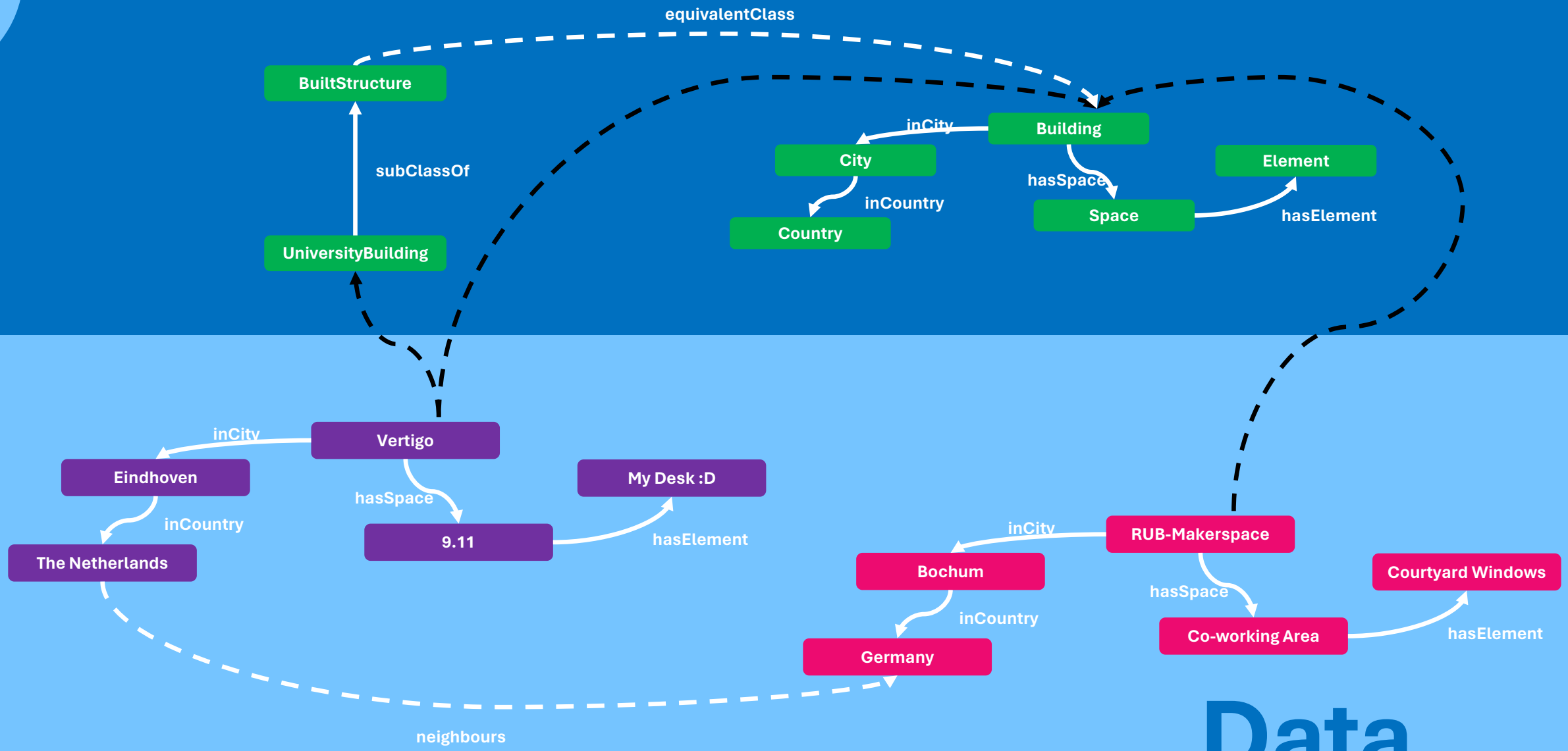
Data

Ontologies



Data

Ontologies



Data

Ontologies

- **Abstract representation of concepts**
- Terminology box (Tbox)
- Ontologies, Vocabularies, Taxonomies, Object type libraries (OTL), dictionaries, masterdata
- Happens in **ontology editors**, such as Stanford Protégé

- **Unique real-world phenomena (or ‘things’)**
- Assertion box (Abox)
- Instances, or data
- Ontologies and Data are represented in different files
- Happens in **graph databases**, such as GraphDB

Data

Open world assumption

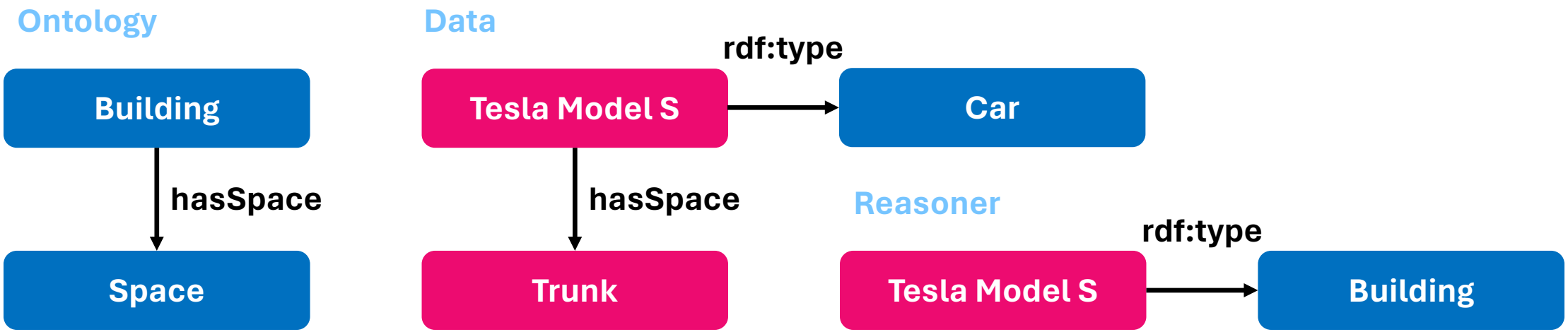
and a bit of reasoning

An example with rdfs:Domain

- Relationships can have a **domain** and **range**, stating the **expected** class-membership of the subject and the object of a triple
- If **hasSpace** has a **domain** Building and a **range** Space, a reasoner would do the following, even if you didn't explicitly specify this in the Data

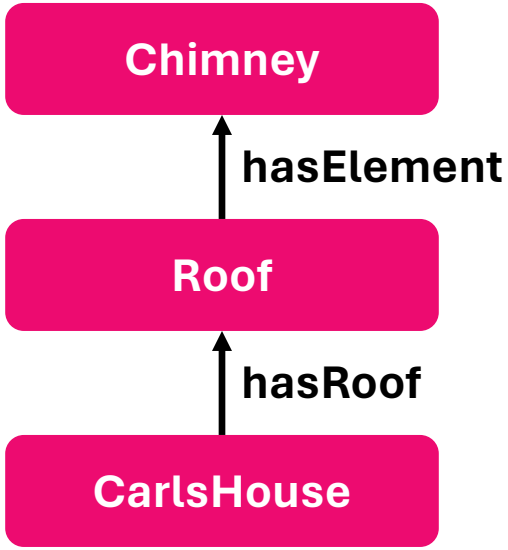
An example with rdfs:Domain

× Be careful!



The Open World Assumption (OWA)

- The assumption that a statement can be true, even if it is not known to be true.
- Different from the **Closed World Assumption**: statements that are not known to be true are considered false.

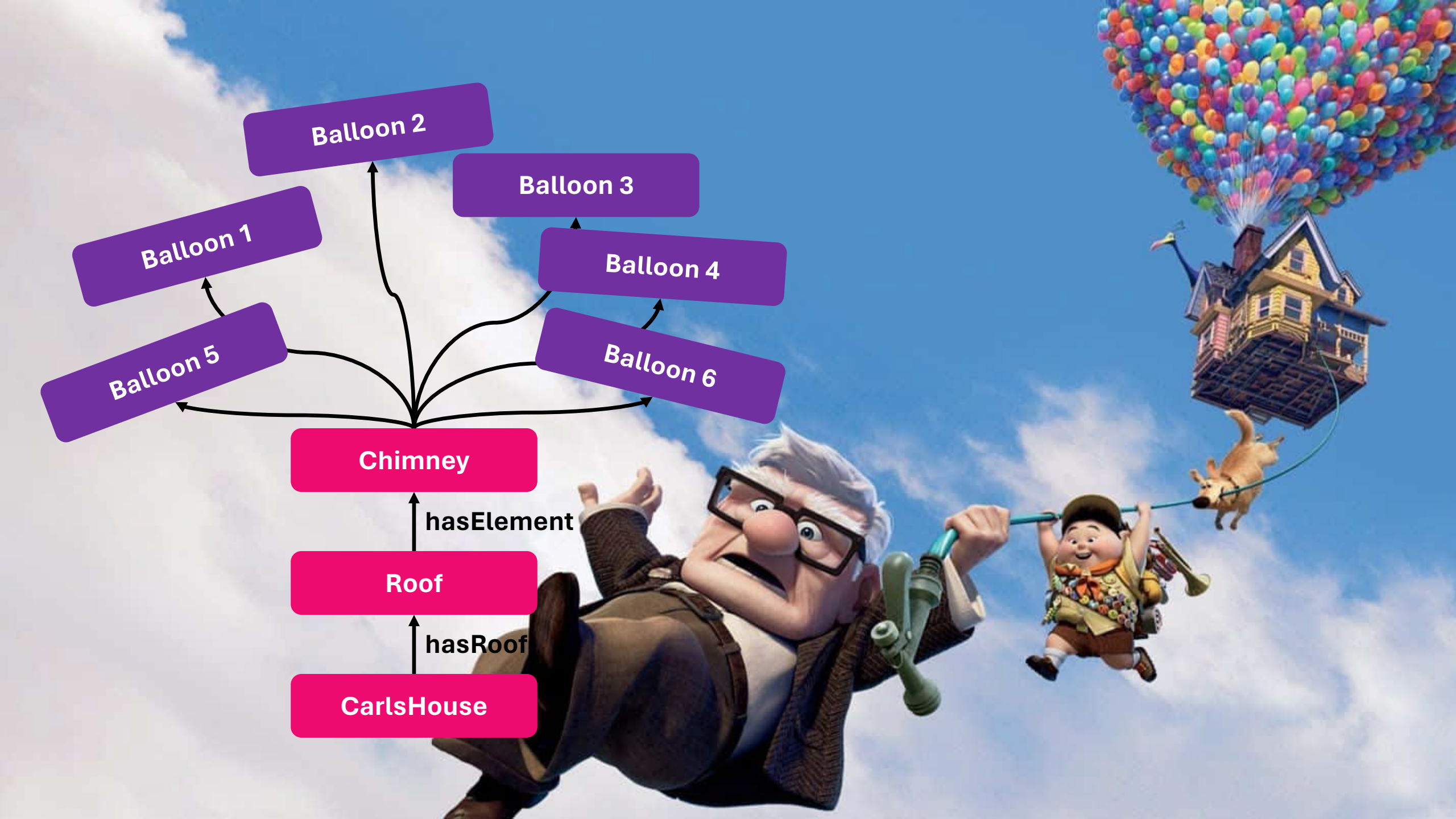


Query

Can CarlsHouse fly?

CWA: No

OWA: We don't know, but possibly yes


Balloon 2
Balloon 3
Balloon 1
Balloon 4
Balloon 5
Balloon 6
Chimney
hasElement
Roof
hasRoof
CarlsHouse

The Open World Assumption (OWA)

- × Mimics the real world
- × We, in the AEC industry, very often deal with incomplete information
- × OWA assumes that information is incomplete by default
- × We allow others to extend our knowledge graphs
- × However, be careful, because houses can fly, and cars can be buildings…
- × Rule checking requires a CWA (SHACL)

Linked Building Data Ontologies

Where it all begun...

Ontology Specification Draft

language **en**

ifcOWL ontology (IFC4_ADD2_TC1)

IRI:
https://standards.buildingsmart.org/IFC/DEV/IFC4/ADD2_TC1/OWL

Date:
February 9, 2019

Authors:
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Imported Ontologies:
express
list

Download serialization:
Format JSON LD | Format RDF/XML | Format N Triples | Format TTL

Abstract

This ifcOWL ontology is automatically generated from the EXPRESS schema 'IFC4_ADD2_TC1' using the 'IFC-to-RDF' converter developed by Pieter Pauwels (pipauwel.pauwels@ugent.be), based on the earlier versions from Jyrki Oraskari (jyrki.oraskari@aalto.fi) and Davy Van Deursen (davy.vandeursen@ugent.be). The ontology is identical to the ontology that is generated from the EXPRESS schema 'IFC4_ADD2_TC1.exp' using the 'genOnto' converter developed by Walter Terkaj (ITIA-CNR, walter.terkaj@itia.cnr.it).

Web address: https://standards.buildingsmart.org/IFC/DEV/IFC4/ADD2_TC1/OWL Namespace: https://standards.buildingsmart.org/IFC/DEV/IFC4/ADD2_TC1/OWL

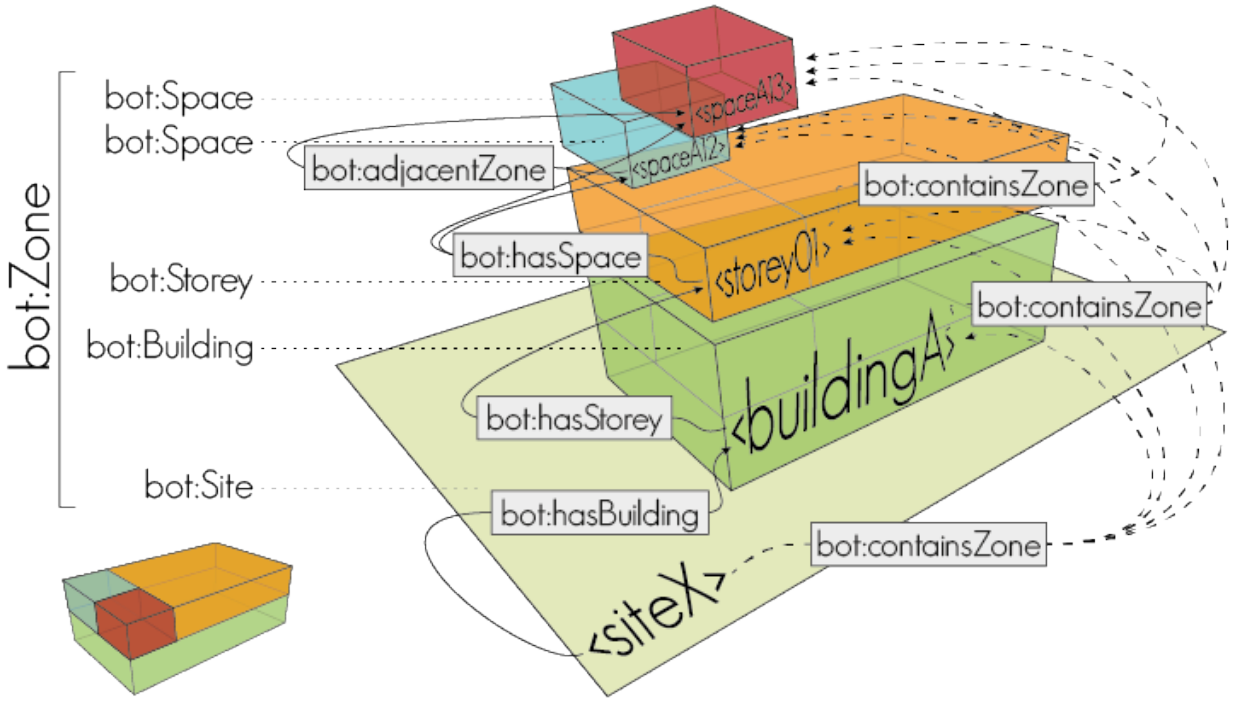
Table of contents

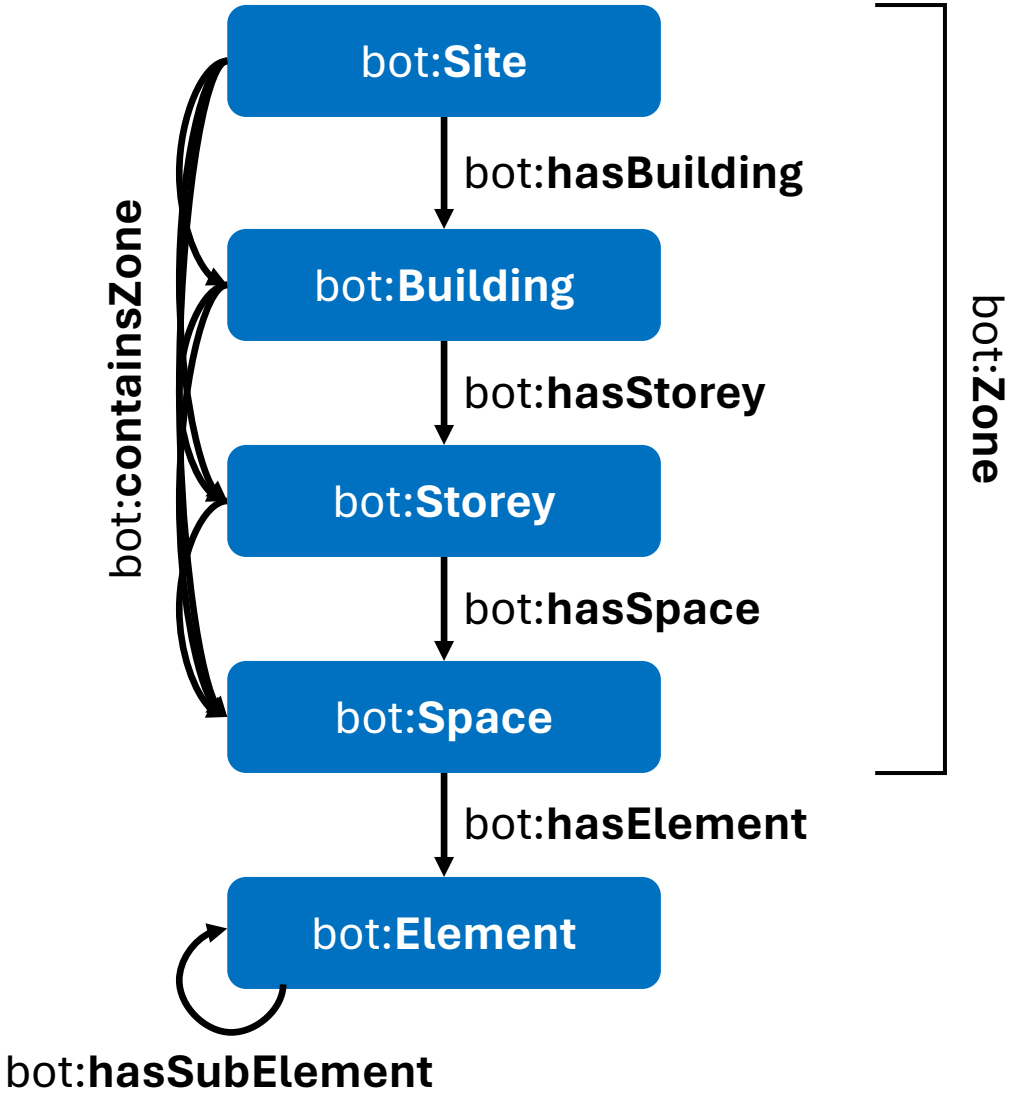
… to where we are now

- **Modular**, small, lightweight ontologies
- Plug-and-play
- Core ontologies representing basic building information
- Domain-specific ontologies representing specific knowledge

@prefix **bot**: <https://w3id.org/bot#>

Building Topology Ontology BOT





Building Topology Ontology BOT

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@prefix bot: <https://w3id.org/bot#>
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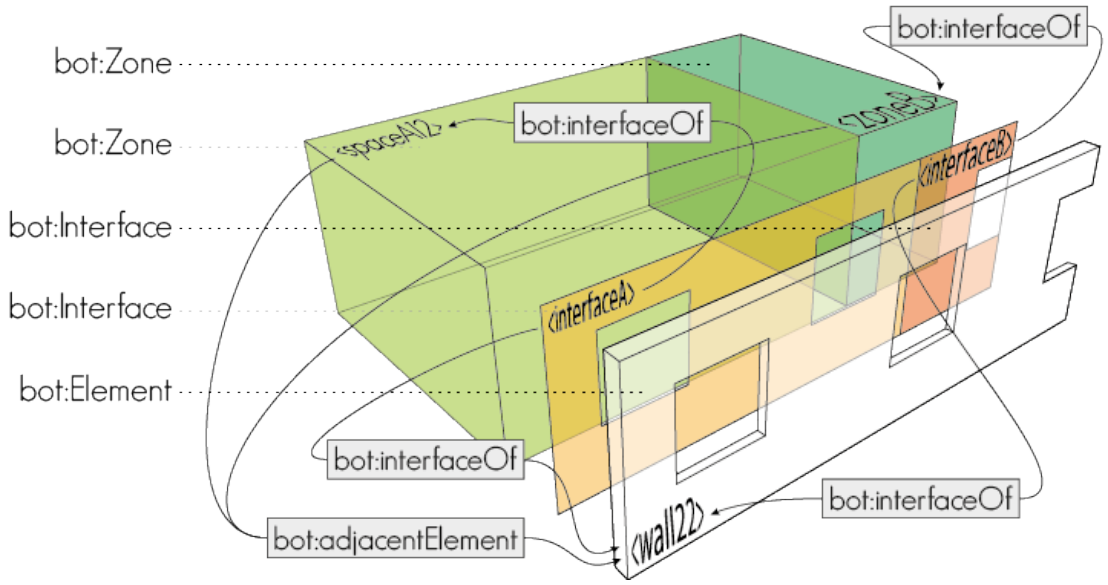
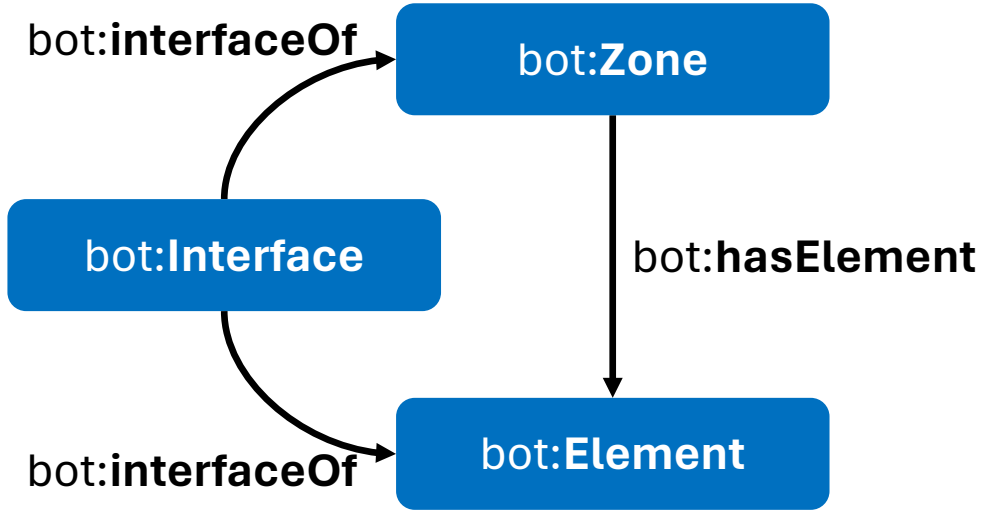
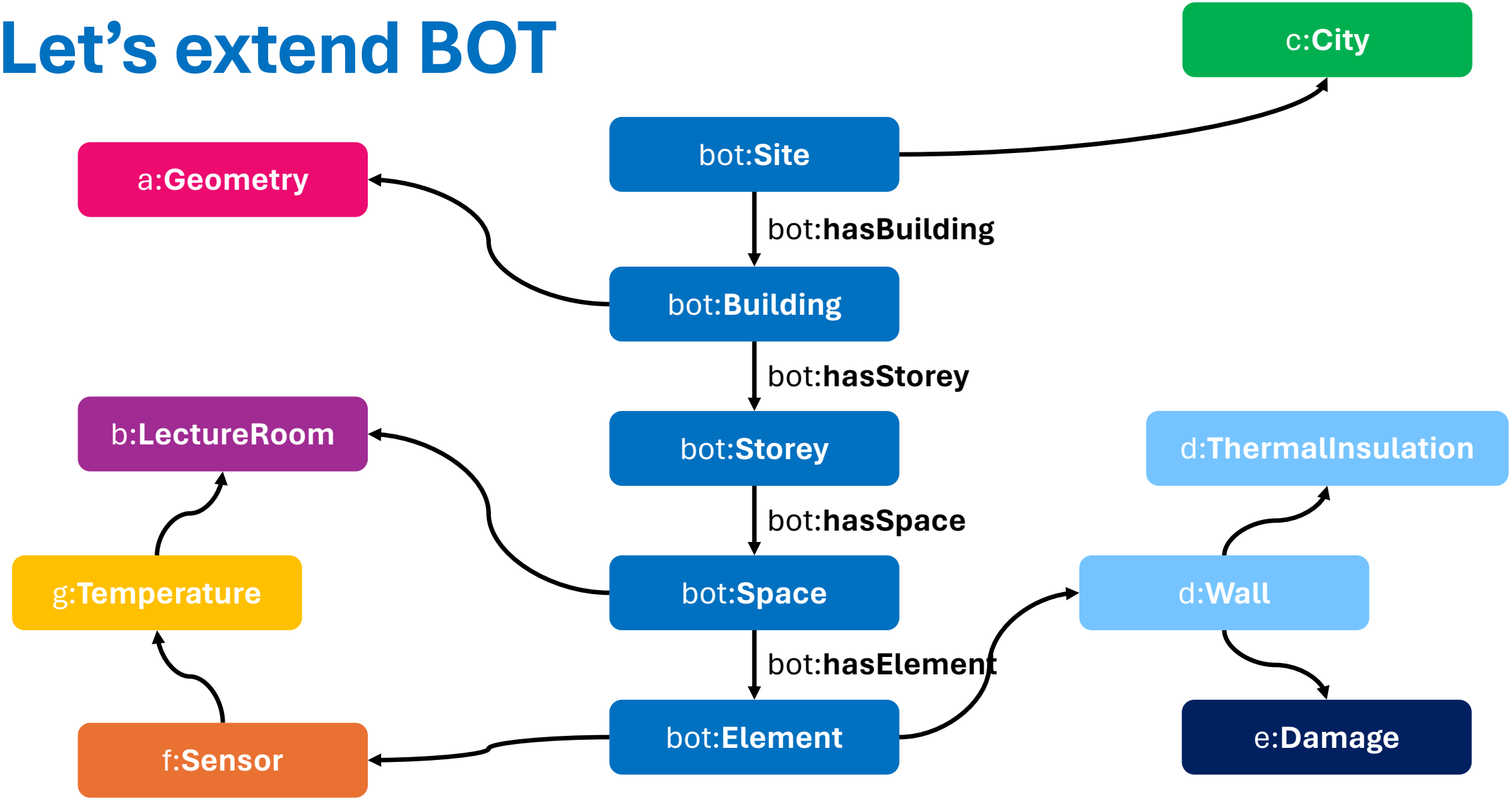
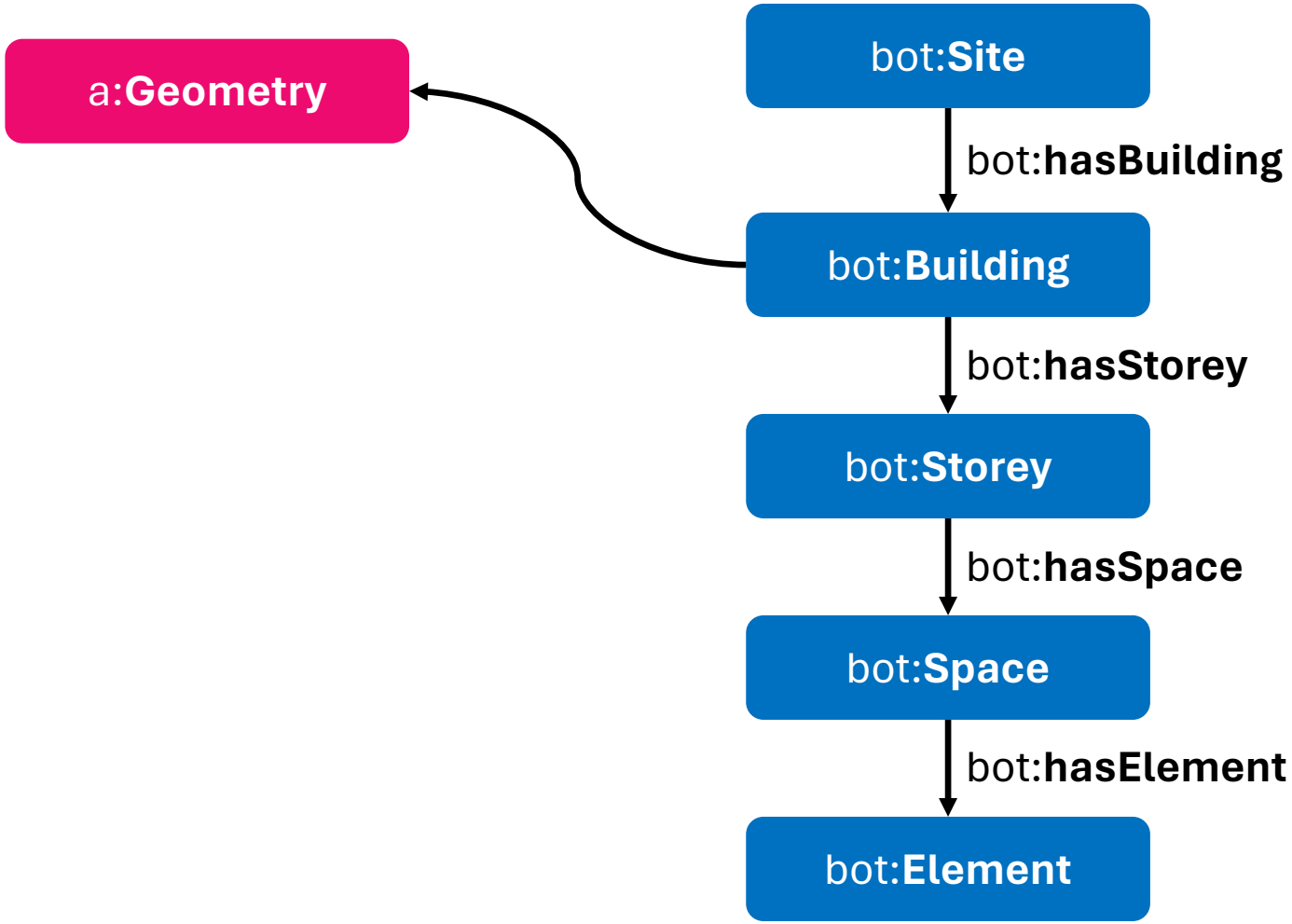




Let’s extend BOT

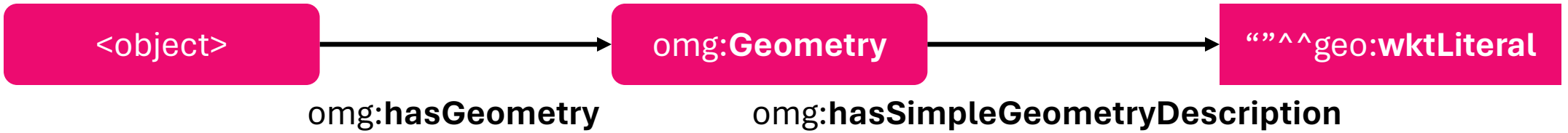


Let’s extend BOT *with geometry*

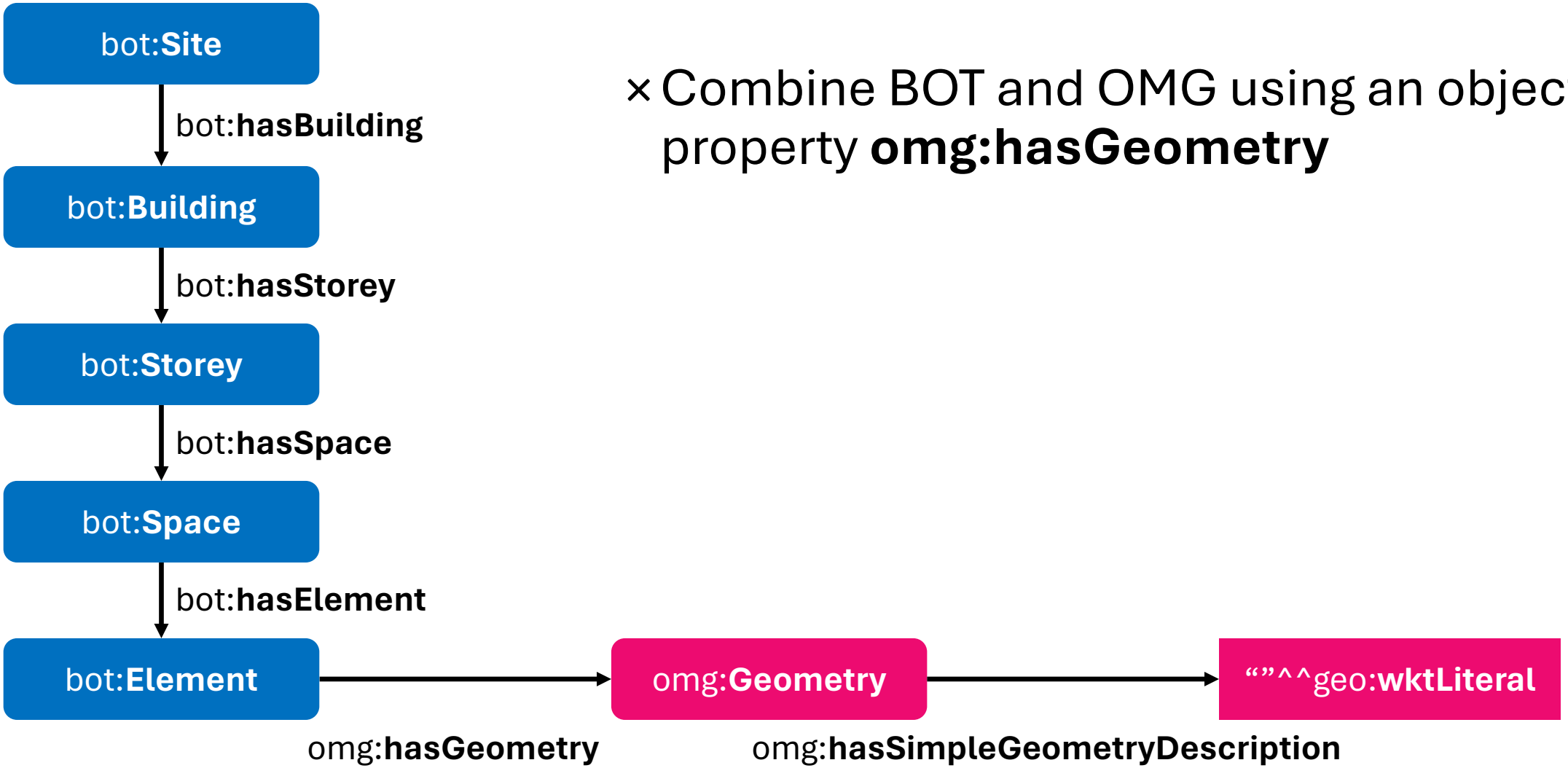


@prefix **omg**: <https://w3id.org/omg#>

Ontology for Managing Geometry OMG

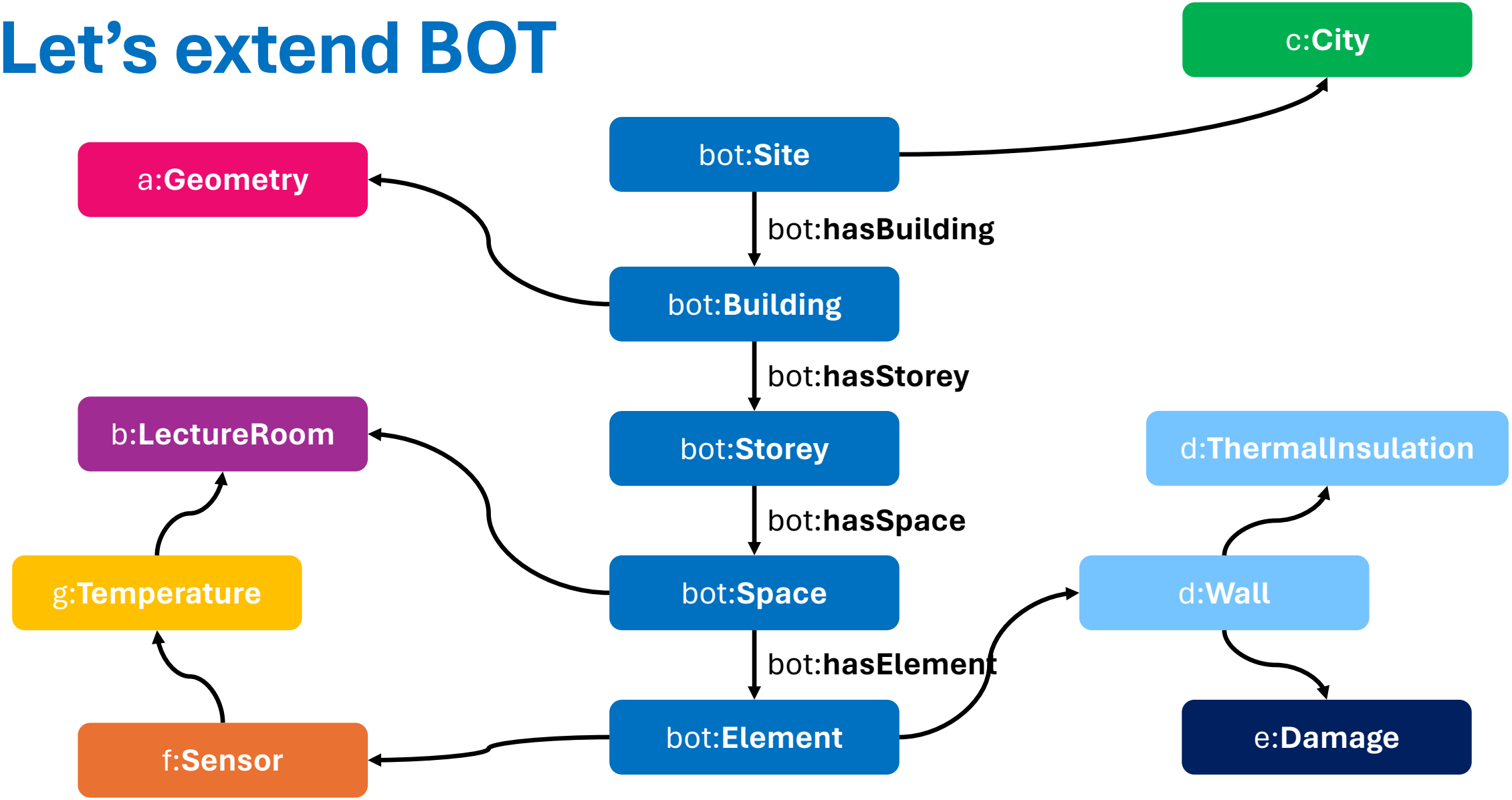


Ontology for Managing Geometry OMG

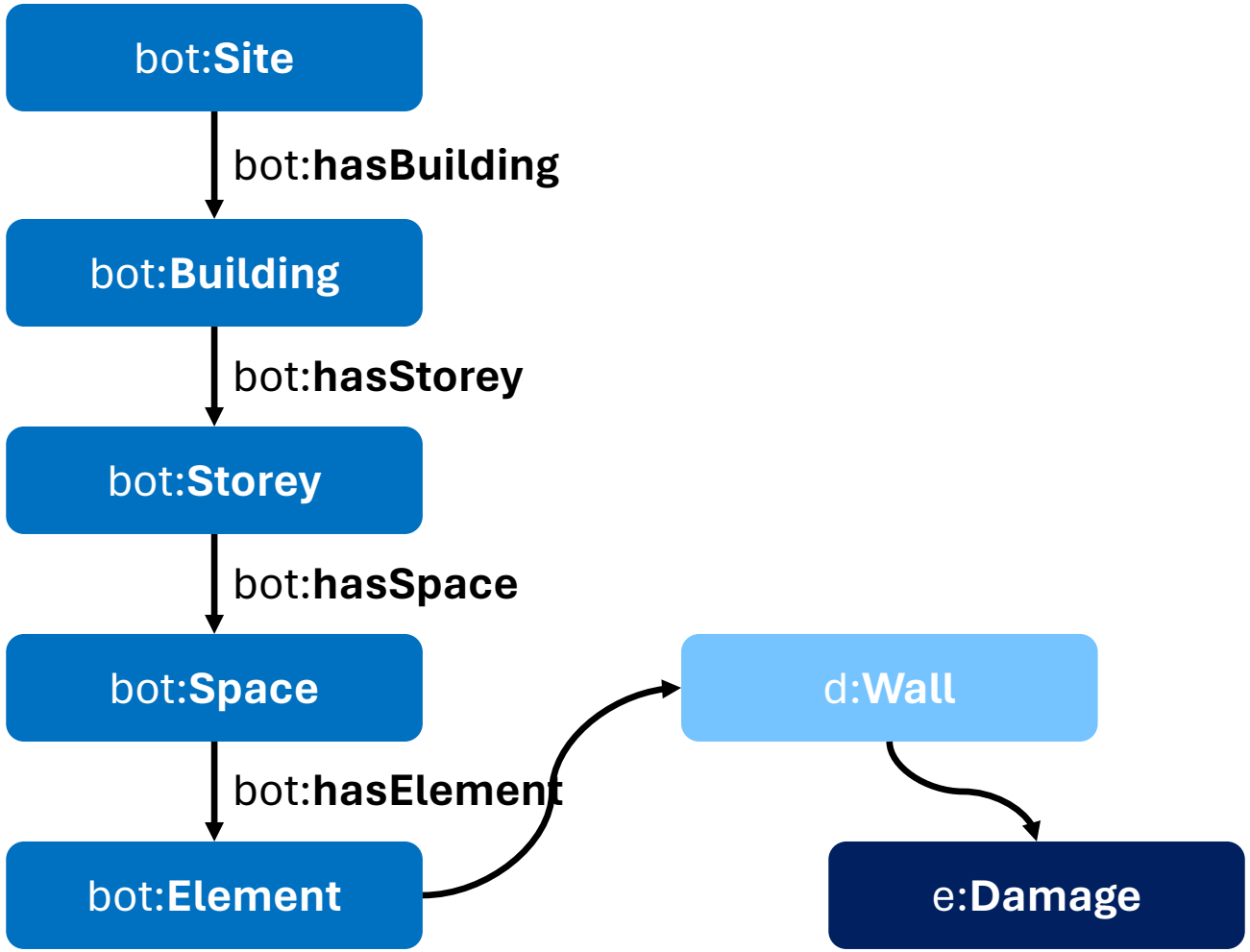


× Combine BOT and OMG using an object property **omg:hasGeometry**

Let’s extend BOT

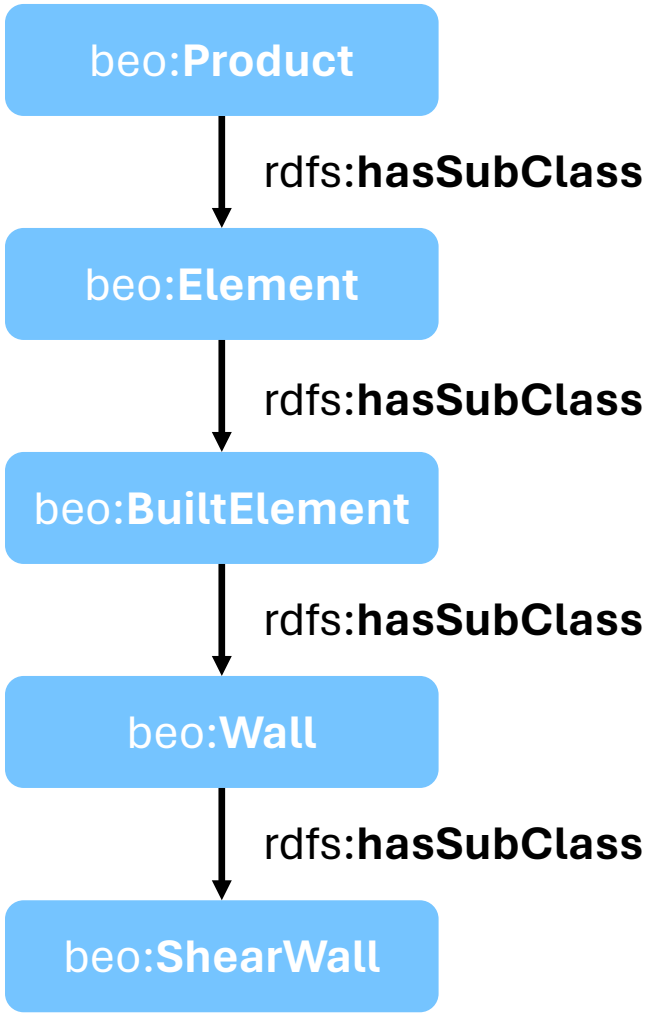


Let’s extend BOT *with specific elements*



@prefix beo: <https://w3id.org/beo#>

Built Element Ontology BEO



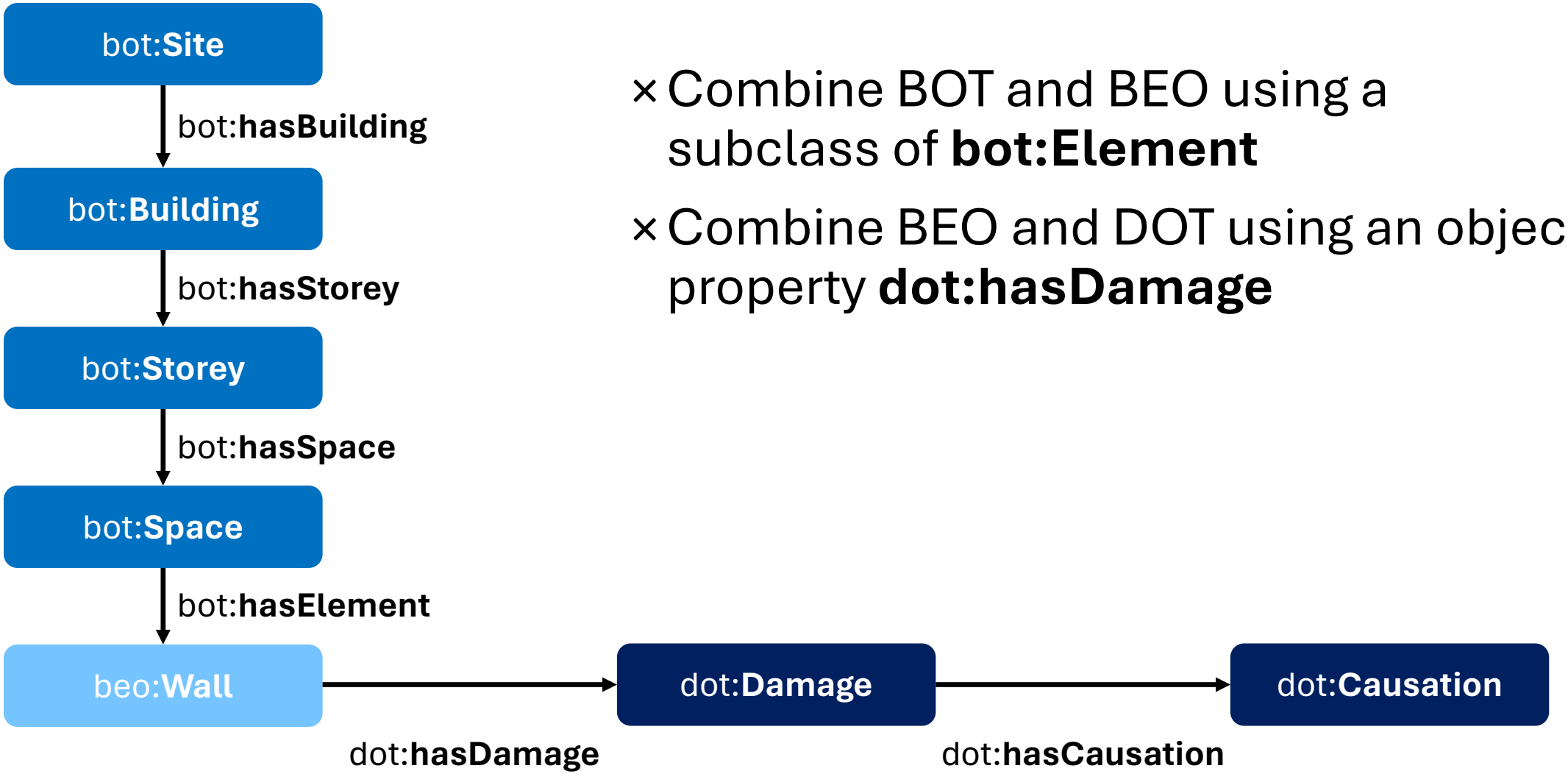
Classes

Above Track Above-Ground Facility Above-Waterline Part Abutment Abutment Assembly Access point Accessory Assembly Achor Plate Active Cooled Beam Actuator Adiabatic Air Washer Adiabatic Atomizing Humidifier Adiabatic Compressed Air Nozzle Humidifier Adiabatic Pan Adiabatic Rigid Media Humidifier Adiabatic Ultrasonic Humidifier Adiabatic Wetted Element Air Conditioning Unit Air cooled Chiller Air Handler Air Particle filter Air Release Valve Air Station Air Terminal Air Terminal Box Air Vehicle Air-cooled Condenser Air-to-Air Heat Recovery Alarm Alarm Panel Ammeter Amplifier Anchor Bolt Anchorage Anchoring Bar Antenna Anti-Arcing Device Antivacuum Valve Approach Channel Approach Slab Apron Arch Arch Segement Arched Bridge Armour Armour Unit Assisted Electric Humidifier Assisted Natural Gas Humidifier Assisted Propane Humidifier Assisted Steam Humidifier Assited Butane Humidifier Audio Signaling Device Audio-visual Appliance Audiovisual Outlet Automaton Awning Axial-yield Damper Backdraft Damper Backfill Balancing Damper Ballasted Course Balustrade Bar Tendon Barrel Roof Barrier Beach Base Isolator Base Plate Base Slab Base Station Controller Base Transciever Station Baseband Unit Basin Bath Battery Beacon Beam Beam Grid Bearing Bed Bell Below Ground Facility Below-Waterline Part Belt Conveyor Belt Drive Bending-yield Damper Berth Berting Structure Bicycle Crossing Bided Bird Cage Bird Protection Blade Blast Damper Blocking Device Boiler Bollard Bolt Boom Barrier Booster Bore Pile Borehole Brace Braced Frame BRACKET Break Pressure Tank Breakglass Button Breakwater Breeching Inlet Bridge Bridge Part Bucket Conveyor Building Building Element Part Building Element Proxy Built Element Bumper Buoy Burner Bus Bar Segment Bus Stop Butterfly Roof Cable Arranger Cable Bracket Cable Carrier Bend Cable Carrier Connector Cable Carrier Fitting Cable Carrier Junction Cable Carrier Segment Cable Carrier Transition Cable Connector Cable Entry Cable Exit Cable Fanout Cable Fitting Cable Junction Cable Ladder Segment Cable Segment Cable Stayed Bridge Cable Transition Cable Tray Segment Cable Trunking Segment Caisson Caisson Foundation Camera Canal Cantilever Bridge Capacitor Capacitor Bank Cargo Vehicle Carriageway Catenary Wire Ceiling Central Island CentralReserve Centrifugal Forward-Curved Fan Centrifugal Airfoil Fan Centrifugal Backward-Inclined Curved Fan Centrifugal Radial Fan Chain Chair Chamber Changeover Valve Check Rail Check Valve Chiller Chimney Chopper Chord CHP Chute Conveyor Cill Level Circuit Breaker Circulator Pump Cistern Cladding CO Sensor CO2 Sensor Coated Tendon Cohesion Pile Coil Collar Column Combined Control Element Combined Flow Instrument Combined Transformer Commissioning Valve Communication Outlet Communication Terminal CommunicationsAppliance Compact Fluorescent Lamp Compensator Compressed Air Filter Compression Isolator Compressor Computer Condenser Conductance Sensor Conductor Segment Conduit Segment Constant Flow Terminal Box Construction Zone Consumer Unit Contact Sensor Contact Wire Segment Contactor Control Damper Control Panel Controller Convector Conveyor Segment CooledBeam CoolingTower Cope Level Coping Core Core Course Core Segment Cornice Counterweigth Coupler Coupling Course Cover Plate Covering Cowl Crane Way System Crash Cushion Crest Cross Bracing Culvert Culvert Bridge Current Transformer Curtain Panel CurtainWall Curved Run Stair Curved Stair Flight Cyclonic Intercepter Cylindrical Bearing Damper Damping System Data Junction Box Data Outlet DC Motor Deck Deck Assembly Deck Segment DeepFoundation Dehumidifier Derailer Desk Diabolo Diaphragm Diffuser Dilatation Panel Dilation Track Dimmer Switch Direct Drive Direct Evaporative Packaged Rotary Air Cooler Direct Evaporative Random Media Air Cooler Direct Evaporative Rigid Media Air Cooler Direct Evaporative Slingers Packaged Air Cooler Direct Expansion Brazed Plate Evaporator Direct Expansion Evaporator Direct Expansion Shell-and-Tube Evaporator Direct Expansion Tube-in-Tube Evaporator Direct Vaporative Washer Direction Source Light Fixture DiscreteAccessory Dishwasher Disk Bearing Dispatching Board Display Distribution Board Distribution Element Distribution Frame DistributionChamberElement DistributionControlElement DistributionFlowElement Diverting Valve Dome Roof Door Double Check Valve Double Regulating Valve Double Return Stair Dowel Draw-Off Cock Driven Pile Dropper Dry Dock Duct Bend Duct Connector Duct Entry Duct Exit Duct Fitting Duct Junction Duct Obstruction Duct Segment Duct Transition DuctSilencer DX Cooling Coil Dynamic Compressor Dynamically Compacted Soil E-Utran Node B Earth Leaker Circuit Breaker Earthing Switch Earthquake Sensor Earthworks Element Earthworks Fil Edge Bar Edge Beam Elastic Cushion Elastomeric Bearing Electric Actuator Electric Cooker Electric Flow Storage Device Electric Flow Treatment Device Electric Generator Electric Heating Coil Electric Motor Electric Time Control ElectricAppliance Electromagnetic Tripping Unit Electronic Filter Electronic Tripping Unit Element Element Assembly ElementComponent Elemented Wall Elevator Embankment Emergency Stop End Suction Pump Energy Meter EnergyConversionDevice Engine Engine Generator Entrance Works ESCALATOR Evaporative Cooled Condenser Evaporative Cooler Evaporator Expansion Joint Device Expansion Tank External Combustion Motor Facility Facility Part Facility Part Common Fan Fastener Faucet Fax Feed and Expansion Tank Feed-Air Unit Fence Fender Fiber Segment Fiber Tube File Cabinet Filler Filter Fitter Course Finned Tube Bundle Fire Damper Fire Hoserel Fire Hydrant Fire Monitor Fire Safety Zone Fire Sensor Fire Suppression Terminal FireSmoke Damper Fixed End Anchor Fixed Plate Counter Flow Exchanger Fixed Plate Cross Flow Exchanger Fixed Plate Parallel Flow Exchanger Flange Plate Flashing Flat Roof Flat-oval Silencer Flexible Duct Segment Flexible Pavement Flexible Pipe Segment Floating Controller Floating Dock Flooded Shell and Tube Evaporator Floor Slab Floor Trap Flopr Waste Flooring Flow Moving Device Flow Segment Flow Sensor Flow Storage Device Flow Terminal Flow Treatment Device FlowController FlowFitting FlowInstrument FlowMeter Fluorescent Lamp Flushing Valve Footing Footing Beam Foreign Object Detection Sensor Formed Duct Foundation Framework Bridge Free Form Roof Free Form Stair Flight Freestanding Electric Heater Freestanding Fan Freestanding Water Cooler Freestanding Water Heater Freezer Frequency Meter Frequency Transformer Friction Damper Friction Pile Fridge-Freezer Frog Frost Sensor Fume Hood Exhaust Damper FurnishingElement Furniture Fuse Disconnector Gable Roof Gambrel Roof Gas Cock Gas Detection Panel Gas Heat Coil Gas Meter Gas Sensor Gas Tap Gate Gatehead Gateway Gateway GPRS Node Support Geographic Element Geomodel Geoslice Geotechnical Assembly GeotechnicalElement GeotechnicalStratum Girder Girder Bridge Girder Segment Glue Gravity Damper Gravity-relief Damper Grease Interceptor Grid Grille Gross Floor Area Grouted Soil Grouting Duct Guard Rail Guardrail Guide Bearing Guiding Structure Gully Sump Gully Trap Gusset Plate Gutter Half Set of Blades HALF TURN RAMP Half Turn Stair Half Winding Stair Halogen Lamp Hand Dryer Hand Operated Actuator Handrail Hard Shoulder Harmonic Filter Hatstone Beam Hauling Gear Heat Exchanger Heat Pipe Heat Recovery Chiller Heat Sensor Hermetic Compressor High Pressure Mercury Lamp High Pressure Sodium Lamp High-Waterline Hip Roof Hipped Gable Roof Hollowcore Beam Hoserel Humidifier Humidistat Humidity Sensor Hydraulic Actuator Hydrofit Hydronic Coil Impact Protection Device Indentifier Sensor Indicator Panel Indirect Direct Combination Indirect Evaporative Cooling Tower or Coil Cooler Indirect Evaporative Package Air Cooler Indirect Evaporative Wet Coil Induction Motor Inductor Inductor Bank Inspection Chamber Inspection Pit Insulation Insulation Element Insulator Intelligent Peripheral Intercepter Interference Zone Internal Combustion Motor Intersection Inverter Ion Concentration Sensor IP Network Equipment Isolating Valve Jalouise Jet Grouting Pile Jetty Joist Beam Junction Junction Box Kerb Keypad Kitchen Machine Ladder Lamp Landfield Landing Slab Launch Recovery Facility Layby LED Lamp Leeward Side Level Crossing Level Sensor Lifting Gear Ligature Light Light Sensor LightFixture Lightning Zone Lightdome Line Tensioner Line-Side Line-Side Part Lineside Electronic Unit Lintel Liquid Terminal Loading Arm Lock Louvre Low-Waterline Magenetic Mooring Device Main Bar Manhole Mansard Roof Manual Pull Box Manufacturing Part Marine Defence Marine Facility Marine Part Marine Vehicle Marker Mast Master Unit Mechanical Fastener Mechanical Forced Draft Cooling Tower Mechanical Induced Draft Cooling Tower Medical Device Member Membrane Metal Halide Lamp Meter Chamber Microphone Microwave Mimic Panel Mirror Mixed Signaling Device Mixing Valve Mobile Switching Center MobileTelecommunicationsAppliance Modem Molding Momentary Switch Mooring Device Mooring Hooks Mortar Motor Connection Motor Control Centre Movable Wall Movement Sensor Moving Walkway MSC Server Mullion Multiposition Controller Nail Nail Plate Natural Draft Cooling Tower Navigation Channel Navigation Element Navigational Area Network Appliance Network Bridge Network Hub Obstacle Sensor Occupancy Zone Odor Filter Oil Filter Oil Interceptor Oil Meter Oil Retention Tray OLED Lamp Open Type Compressor Optical Cable Segment Optical Line Terminal Optical Network Unit Outlet Oxygen Generator Oxygen Plant Packet Control Unit Pad Footing Panel PANEL STRENGTHENING Parapet Parking Parking Bay Partitioning Wall Passing Bay Passive Cooled Beam Pavement Pavement Course Pavilion Roof Paving Slab Pedestrian Crossing Petrol Interceptor PH Sensor Phase Angle Meter Photocopier Pictoral Pier Pier Assembly Pier Cap Pier Segment Pier Stem Pier Stem Segment Pilaster Pile Pile Cap Pipe Bend Pipe Conector Pipe Entry Pipe Exit Pipe Fitting Pipe Junction Pipe Obstruction Pipe Segment Pipe Transition Plain Track Plate Plate Heat Exchanger Plate Member Player Plumbing Wall Pneumatic Actuator Point Machine Locking Device Point Machine Mounting Device. Point Source Light Fixture Polyphase Motor Port Post Pot Power Factor Meter Power Junction Box Power Outlet Precast Panel Pressure Gauge Pressure Reducing Valve Pressure Relief Valve Pressure Sensor Pressure Vessel Printer Product Programmable Controller Projector Propellor Axial Fan Proportional Controller Protection Protection Course Protective Device Protective Device Tripping Unit Pump Punching Bar Purlin Pylon Pylon Assembly Quarter Turn Ramp Quarter Turn Stair Quarter Winding Stair Quay Rack Rail Radiactivity Sensor Radiation Sensor Radiator Radio Block Center Rafter Rail Rail Brace Rail Fastening Rail Joint Rail Lubrication Rail Mechanical Equipment Rail Mechanical Equipment Assembly Rail Pad Railing Railway Railway Crocodile Railway Crossing Railway Detonator Railway Substructure RailwayPart Rain Sensor Rainbow Roof Rainwater Hopper Ramp RampFlight Recharger Reciever Reciprocating Compressor Recording Equipment Rectangular Silencer Rectifier Refrigerator Refuge Island Register Regulating Valve Reinforced Soil Reinforcement Ring Reinforcing Bar Reinforcing Element Reinforcing Mesh Reinforcment Unit Relay Relief Damper Reluctance Synchronous Motor Remote Radio Unit Remote Unit Repeater Replaced Soil Reservation Zone Residual Current Circuit Breaker Residual Current Switch Residual Current Tripping Unit Retaining Wall Revetment Rigid Duct Segment Rigid Frame Rigid Pavement Rigid Pipe Segment Rivet Road Road Part Road segment Roadside Roadside Part Roadway Plateau Rocker Roller Roller Compacted Soil Rolling Piston Rolling Stock Roof Roof Drain Roof Slab Roofing Covering RoofTop Unit Rope Rotary Compressor Rotary Vane Compressor Rotary Wheel Round Silencer Roundabout Router Rubber Damper Run-around Coil Loop Safety Cage Sanitary Terminal Sanitray Fountain Scanner Screw Screw Conveyor Scroll Compressor Security Cut-off Valve Security Lightning Security Zone SEGMENT Selector Switch Semi-hermetic Compressor Sensor Service GPRS Support Node Shading Device Shear Bar Shear Connector Shear Wall Shear-yield Damper Shed Roof Sheet Shelf Shell and Coil Evaporator Shell and Tube Exchanger Shelter Ship Transfer ShipLift Shiplock Shipyard Shoe Shoulder Shower Shutter Sidewalk Sidewalk Slab Sign Signal Assembly Signaling Device Single Screw Compressor Single Stage Compressor Sink Siren Site Skirting Board Skylight Slab Slab Field Sleeper Sleeving Sliding Chair SLIPWAY Slope Fill Smoke Damper Smoke Sensor Snow Depth Sensor Sofa Soft Shoulder Solar Collector Solar Device Solar Panel Solid Stratum Solid Wall Sound Absorption Sound Sensor Space Space Bar Space Heater Spark Gap Spatial Element Spatial Structure Element Spatial Zone Speaker Speed Regulator Spherical Bearing Spiral Ramp Spiral Ramp Flight Spiral Stair Spiral Stair Flight Splice Plate Split Case Pump Spoil System Spool Sprandel Spring Isolator Sprinkler Stack Terminal Stair StairFlight Standalone Generator STANDCOLUMN Staple Start and Stop Switch Starter Stay Cable Steam Boiler Steam Heating Coil Steam injection Humidifier Steam Trap Stichl Wire Stiffener Plate Stiffening Rib Stock Rail Stop Cock Storage Area Storage Tank Storey Straight Ramp Flight Straight Run Ramp Straight Run Stair Straight Stair Flight Strainer Strand Stringer STRIP FOOTING Structural Cable Strut Stud Stud Shear Connector Subgrade Subgrade Bed Submersible Pump Subrack Subscriber Server SUBSTRUCTURE Substructure Sump Sump Buster Sump Pump SUPERSTRUCTURE Superstructure Support Pile Supporting Gas Assembly Surcharge Preloaded Soil Surface Structure Suspender Suspension Assembly Suspension Bridge Suspension Cable Switch Board Switch Disconnector Switcher Switching Device Synchronous Motor System Furniture Element T Beam Table Tank Technical Cabinet Telecommand Telephone Telephone Outlet Telephony Exchange Temperature Sensor Tendon Tendon Anchor Tendon Conduit Tendon Conduit Coupler Tendon Coupler Tendon Duct Tension Equipment Tensioning End Anchor TERMINAL Terrain Thermal Tripping Unit Thermal Zone Thermometer Thermosiphon Coil Type Heat Exchanger Thermosiphon Sealed Tube Heat Exchanger Thermostat Thermostatic Actuator Thin Screw Compressor Three Quarter Turn Stair Three Quarter Winding Stair Tiebar Time Delay Time Relay Timelock Toggle Switch Toilet Pan Toll Plaza Topping Track Track Element Track End of Alignment Track Panel Track Part Track Slab Tracked Vehicle Traction Switching Assembly Traffic Calming Device Traffic Island Traffic Lane Train Sensor Transformer Transition Component Transition Section Transport Element Transportation Device Trap door Transponder Transport Unit Trench Trochoidal Compressor Trumpet Trunstile Truss Truss Bridge Tube Axial Fan TubeBundle Tumble Dryer Tuner Tungsten Filament Lamp Turnout Closure Sensor Turnout Heating Turnout Panel Turnout Track Twin Tower Enthalpy Recovery Loops Two Curved Run Stair Two Quarter Turn Ramp Two Quarter Turn Stair Two Quarter Winding Stair Two Stair Run Ramp Two Straight Run Stair Two-position Controller Unitary Control Element UnitaryEquipment UPS Urinal Vacuum Mooring Device Vacuum Station Valve Valve Chamber Vane Axial Fan Variable Flow Pressure Dependant Terminal BOx Variable Flow Pressure Independant Terminal Box Varistor Vegetation Vehicle Vehicle Servicing Vehicle Stop Vending Machine Ventilation Zone Vertical Inline Pump Vertical Turbine Pump Vertically Drained Soil Vessel Vibration Damper Vibration Isolator Viscous Damper Visual Signaling Device Void Stratum Voltage Limiter Voltage Transformer Voltmeter Voltmeter Peak Voltmeter RMS Wall Wall Stud Wash Hand Basin Washing Machine Waste Disposal Unit Waste Terminal Waste Trap Water Boiler Water Cooled Chiller Water Cooling Coil Water Filter Water Heating Coil Water Meter Water Stratum Water-cooled Brazed-plate Condenser Water-cooled Condenser Water-cooled Shell Coil Condenser Water-cooled Shell Tube Condenser Water-cooled Tube-in-Tube Condenser Waterfield Waterway Waterway Shiplift Wave Wall Wearing Slab Weather Side Weather Station Web Plate Weld Welded Shell Hermetic Compressor Well Wheel Sensor Wheeled Vehicle Whistle Wind Sensor Winder Stair Flight Window Wire Wire Pair Segment Work Surface Wrapping

@prefix **dot**: <https://w3id.org/dot#>

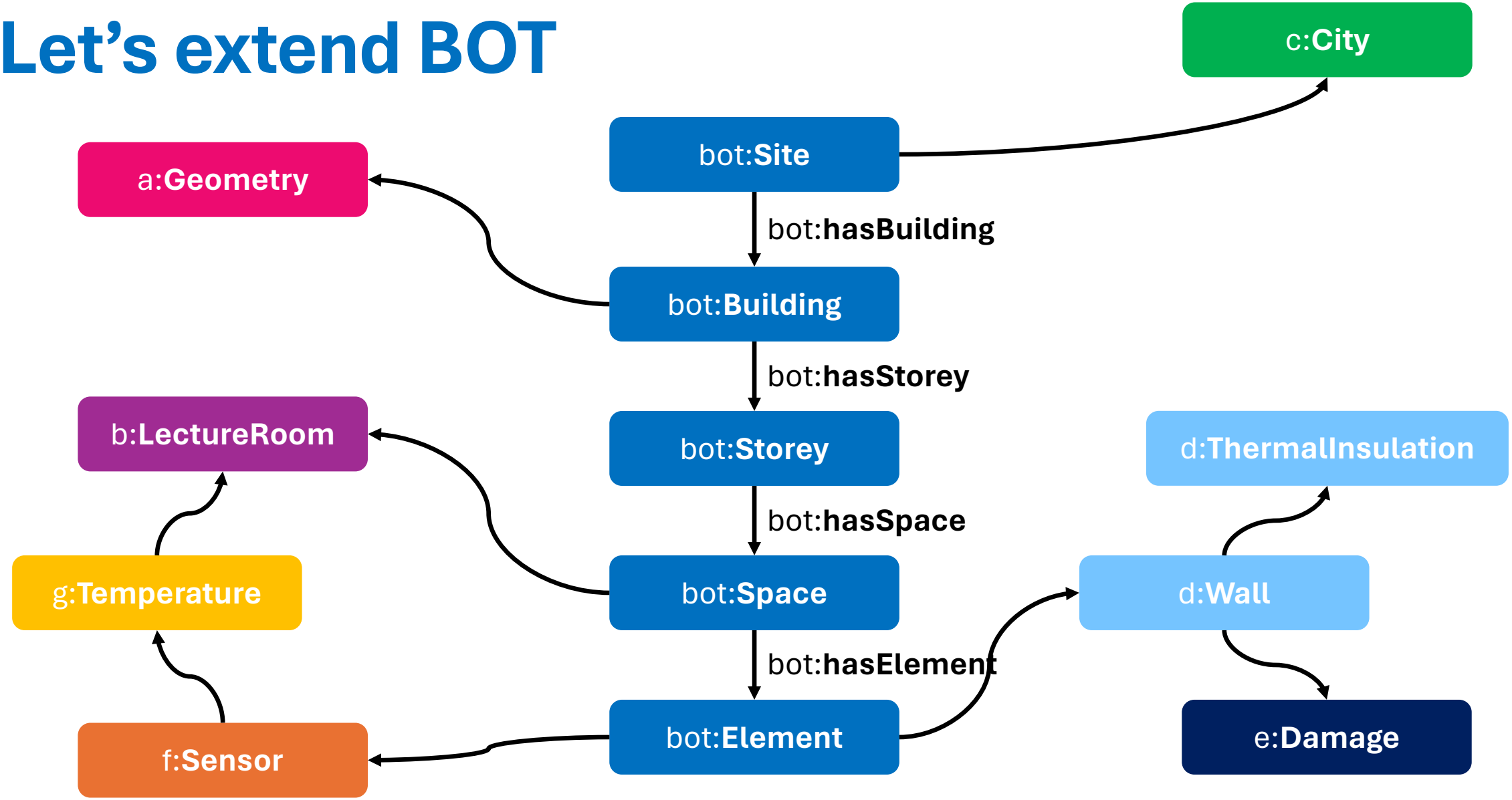
Damage Topology Ontology DOT

Built Element Ontology BEO

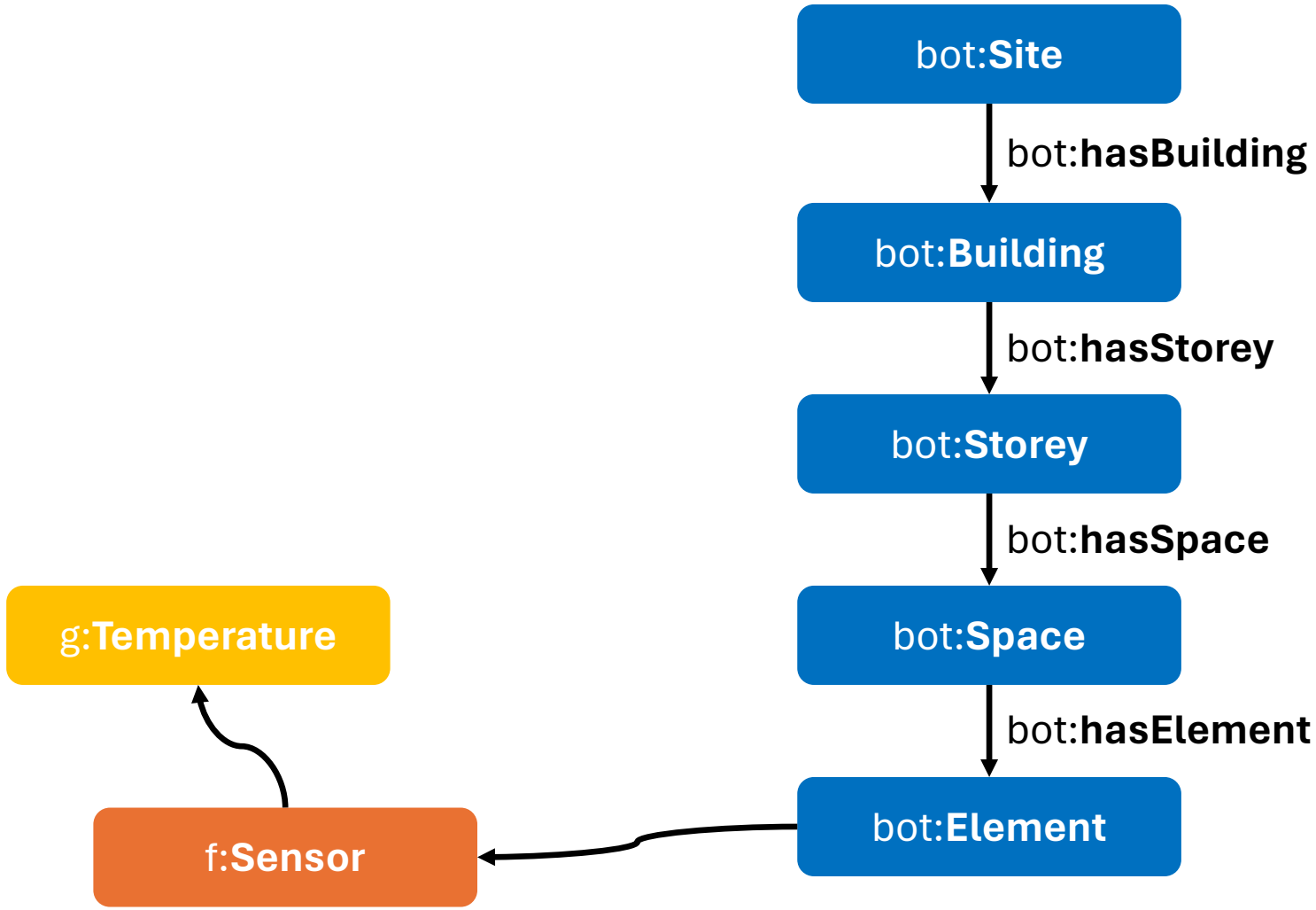


- Combine BOT and BEO using a subclass of **bot:Element**
- Combine BEO and DOT using an object property **dot:hasDamage**

Let’s extend BOT



Let’s extend BOT *with sensor data*



@prefix ssn: <https://w3.org/ns/ssn/>

Semantic Sensor Network SSN

@prefix sosa: <https://w3.org/ns/sosa/>

Sensor, Observation, Sample, and Actuator

@prefix ssn: <https://w3.org/ns/ssn/>

Semantic Sensor Network SSN

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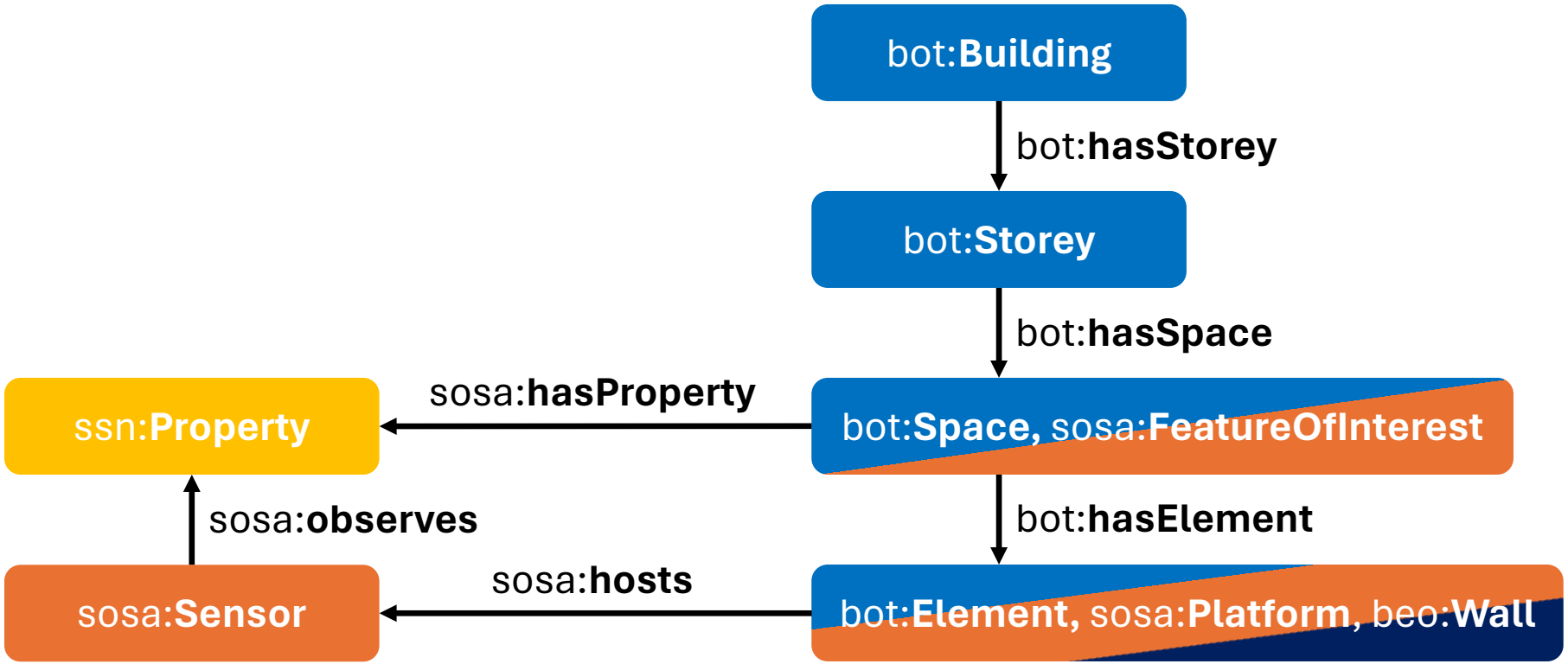
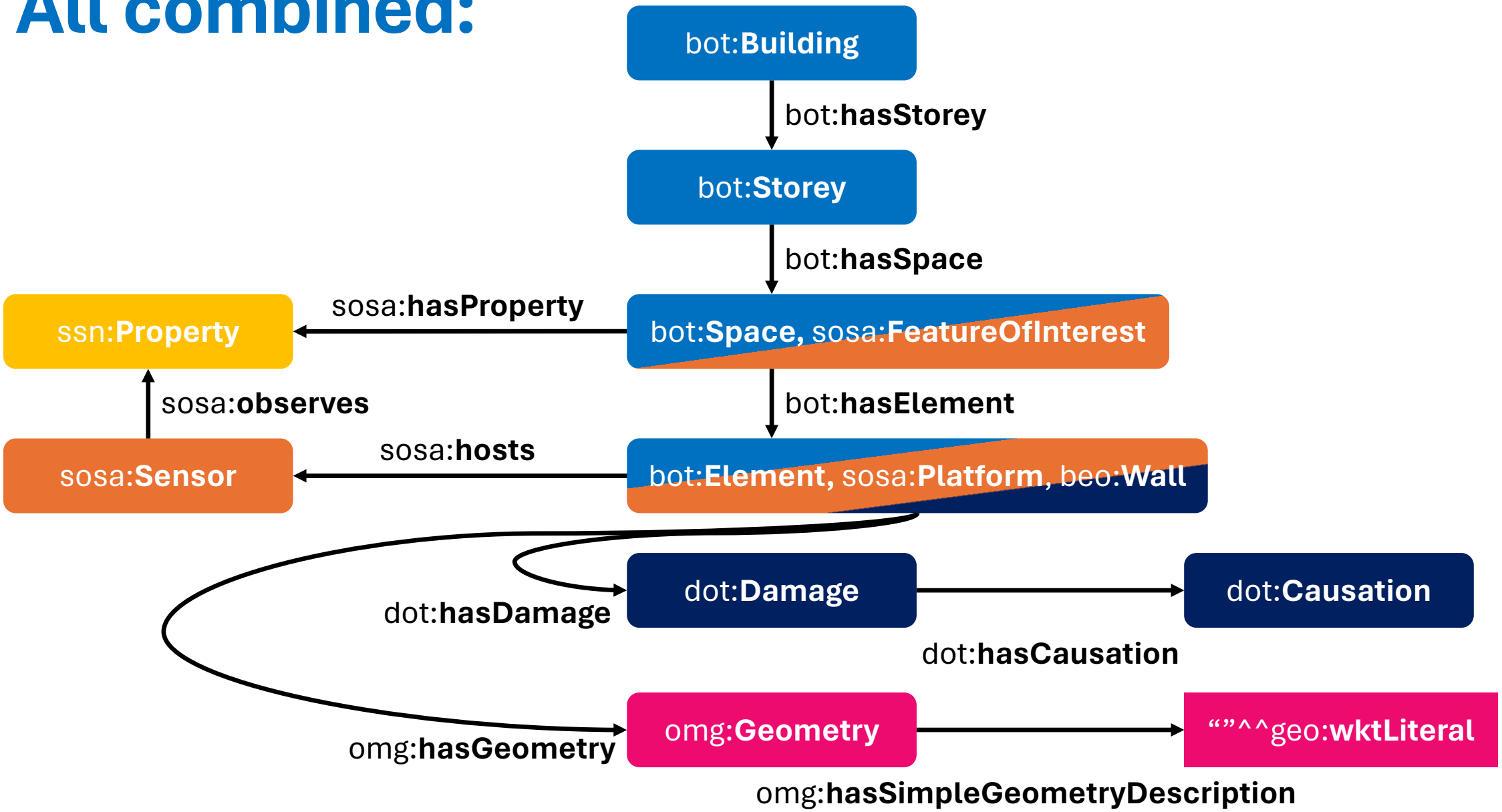
Sensor, Observation, Sample, and Actuator



All combined:



Common LBD ontologies

Buildings: BOT, DogOnt, SAREF4BLDG, REC, ifcOWL
Element taxonomies: BEO
Properties: OPM, BOP
Sensors: SOSA/SSN, SAREF, SEAS, BOP
Geometry: OMG, GeoSPARQL, GOM, FOG
HVAC: Brick
Provenance, metadata: PROV-O, DCAT, DublinCore

… and many, many more!

Ontology alignment

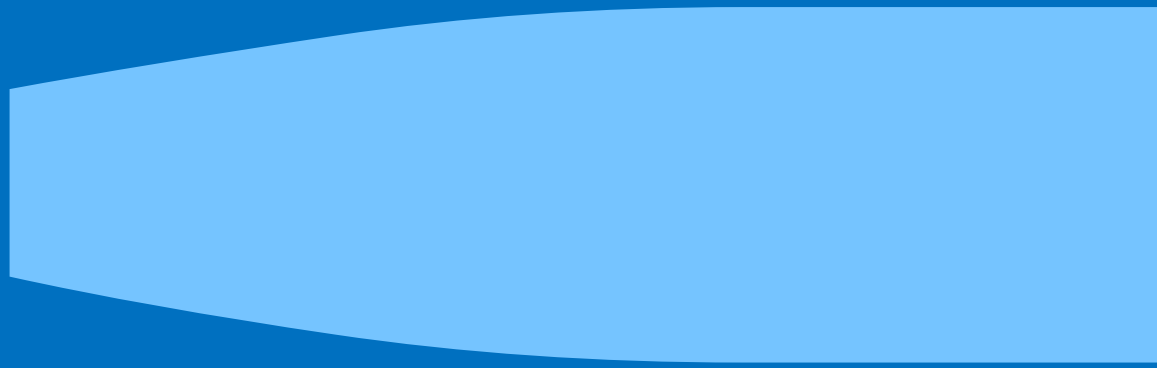
Tbox using formal alignment modules. E.g. Brick and Bot:

```
brick:Building owl:equivalentClass bot:Building .
```

Abox by simply using multiple rdf:type statements:

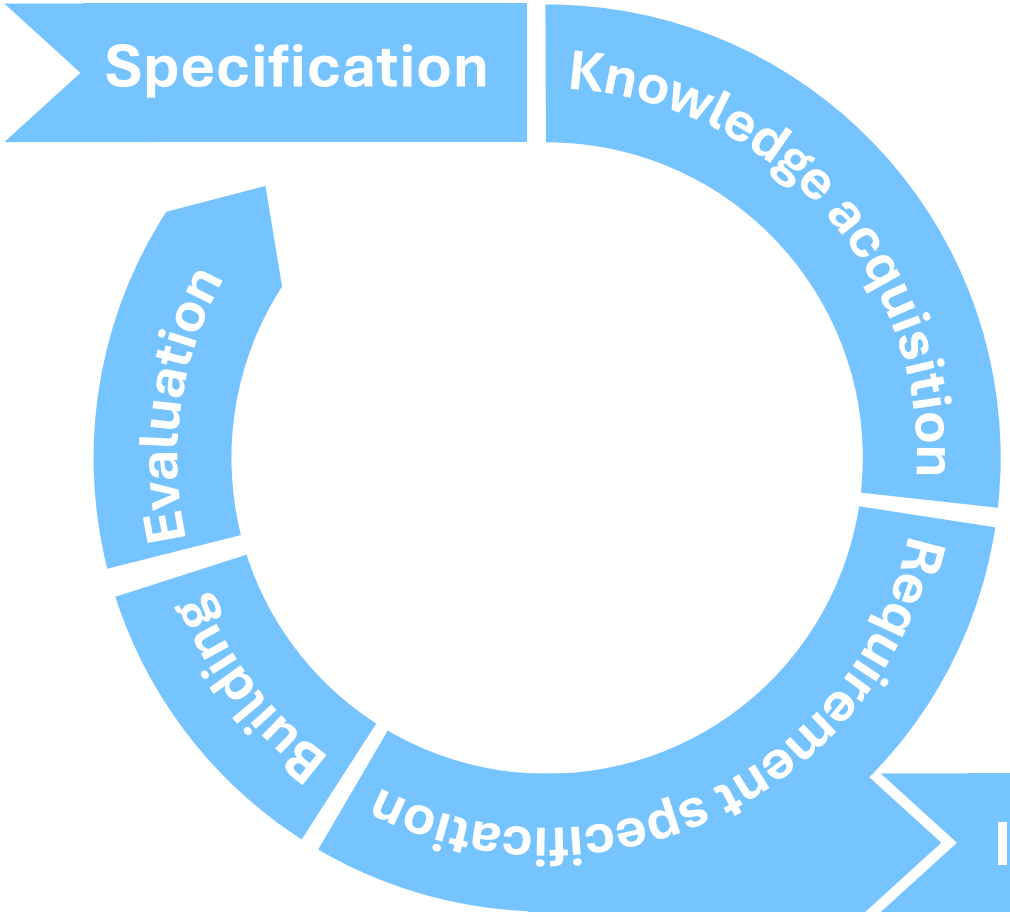
```
inst:RUB-Makerspace
     rdf:type       bot:Building, brick:Building .
```

Practical tips and tools



Ontology design cycle

Donkers et al., 2022.
https://doi.org/10.3390/buildings12101522



1. **Specification**: Determining the scope and purpose of the ontology, including its position in the semantic web landscape. Competency questions are formulated in this phase.
2. **Knowledge acquisition**: Defining the exact domain knowledge that the ontology should cover, based on a literature review.
3. **Requirement specification**: Making a list of classes, instances, object properties, and restrictions. Choices are based on the competency questions and the knowledge acquisition phase.
4. **Building**: Building the ontology using Stanford Protégé 5.5.0.
5. **Evaluation**: Testing the ontology in different use-cases. Testing SPARQL queries to validate the competency questions. Testing the ontology against evaluation criteria. Using the OntOlogy Pitfall Scanner! (OOPS!) to detect common pitfalls in the ontology.
6. **Integration**: Integrating the ontology with existing standards and ontologies.
7. **Documentation and publication**: Creating HTML documentation using WIDOCO. If possible, publish an example dataset, instantiating the ontology, under the CC-BY 4.0 license and provide example queries.

Ontology editors

User interface:

- **Stanford Protégé**
- TopBraid EDG
- Laces Library Manager

Powerpoint:

- Ontology Design Template

UML to OWL:

- Chowlk
- EA-to-RDF

Tips:

- W3C Best Practices
- W3C Cool URIs
- Other W3C standards

Validators

Ontologies

× OOPS!

Instance data

× RDF TTL syntax validator

Publishing ontologies

Making HTML documentation

- WIDOCO
- LODE

Uploading to GitHub: https://github.com/w3c-lbd-cg/bot

Publish using GitHub Pages: https://w3c-lbd-cg.github.io/bot

Publishing ontologies (2)

Claiming a prefix: http://prefix.cc

Claim a w3 perma id: https://github.com/perma-id/w3id.org

Publish the ontology on Linked Open Vocabularies

Publish on bSDD (buildingSmart Data Dictionary)

Talk about it!

Occupant Feedback Ontology

Latest version:
https://w3id.org/ofo#

Authors:
Alex Donkers

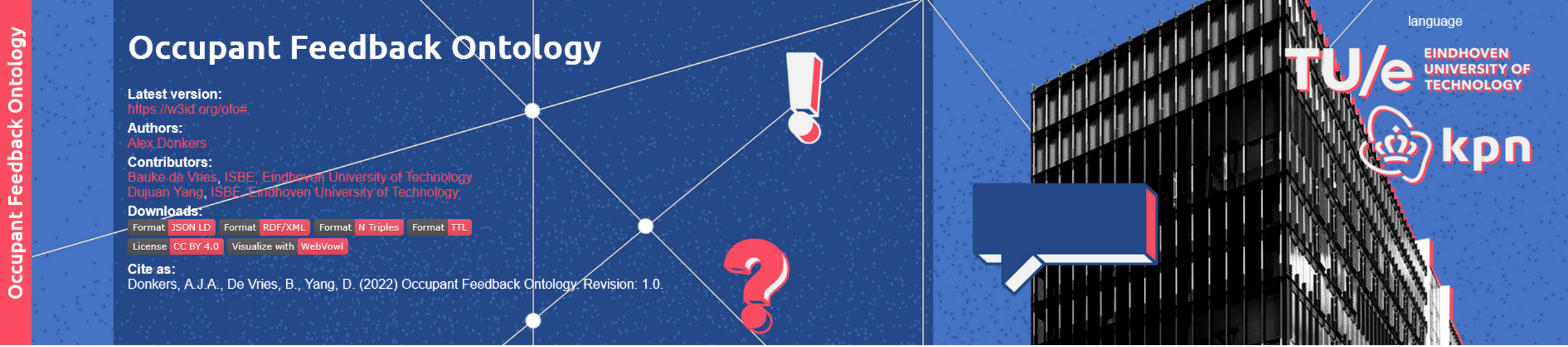
Contributors:
Bauke de Vries, ISBE, Eindhoven University of Technology
Dujuan Yang, ISBE, Eindhoven University of Technology

Downloads:

Format JSON LD | Format RDF/XML | Format N Triples | Format TTL

License CC BY 4.0 | Visualize with WebVowl

Cite as:
Donkers, A.J.A., De Vries, B., Yang, D. (2022) Occupant Feedback Ontology. Revision: 1.0.



Abstract

The aim of the Occupant Feedback Ontology is to semantically describe passive and active occupant feedback and to enable integration of this feedback with linked building data.

Namespace: `https://w3id.org/ofo#`

Suggested prefix: `ofo:`

A small extension module of the ofo:Property class has been created, as this enhances querying possibilities in indoor environmental quality use cases. The extension module is documented at:

Namespace: `https://alexdonkers.github.io/opt#`

The Occupant Feedback Ontology extends the Building Performance Ontology (BOP). Together, these ontologies can help creating rich semantic digital twins that combine sensor data, building properties and occupants and their opinions.

Namespace: `https://w3id.org/bop#`

Table of contents

W3C Linked Building Data Group

If you like to contribute to those ontologies, discuss ongoing developments or learn from other academics and industry professionals, please join our W3C LBD CG.

Triweekly technical meetings with presentations on linked building data.

Linked Building Data and Ontologies

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