



Integrated representation of building service systems: Topology extraction and TUBES System Ontology

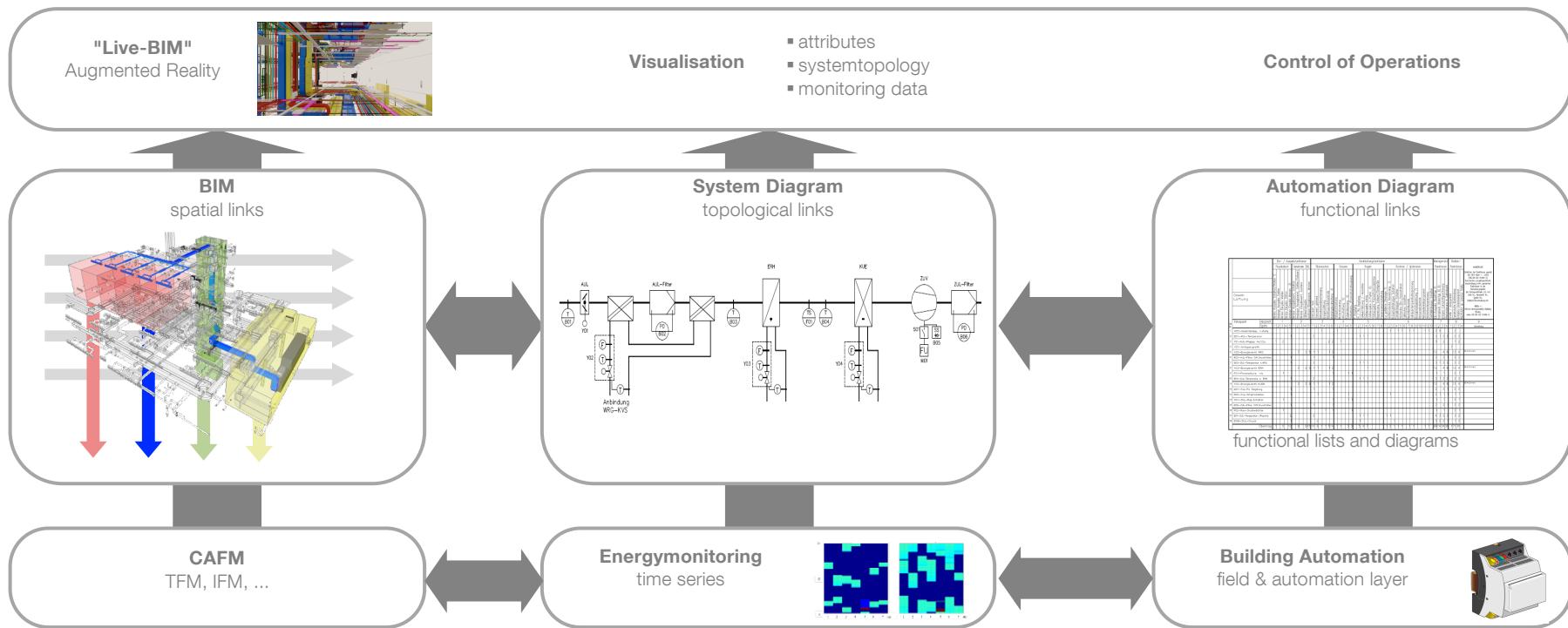
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RWTH Aachen University

Agenda

- Motivation
- TUBES System Ontology 0.1
- Topology Extraction from IFC to RDF
- TUBES System Ontology 0.2

Motivation

Motivation – „Big Picture“



Challenge: Complexity management

Can these questions be answered?

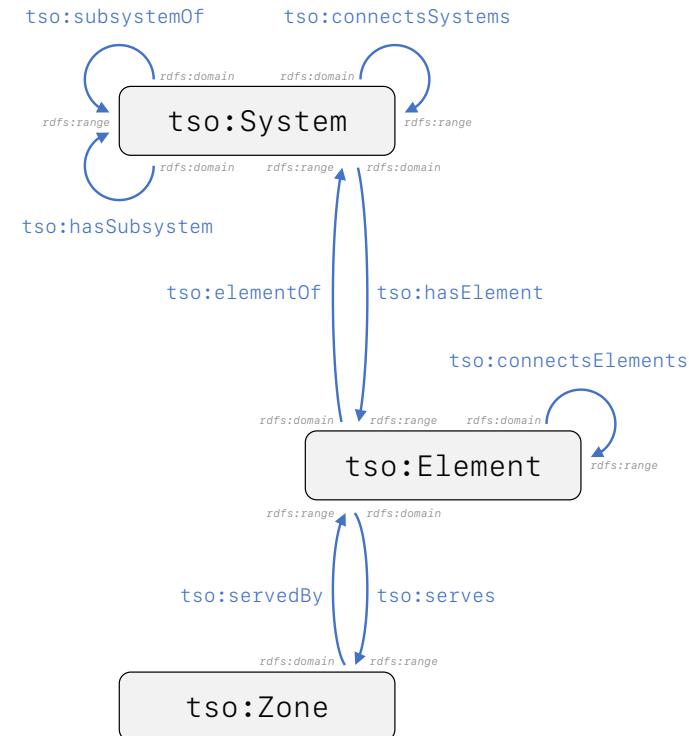
- How many building service systems are in the model?
- Which building service systems are included?
- How are these systems interconnected?
- Are these systems completely modelled?
- etc.



TUBES System Ontology 0.1

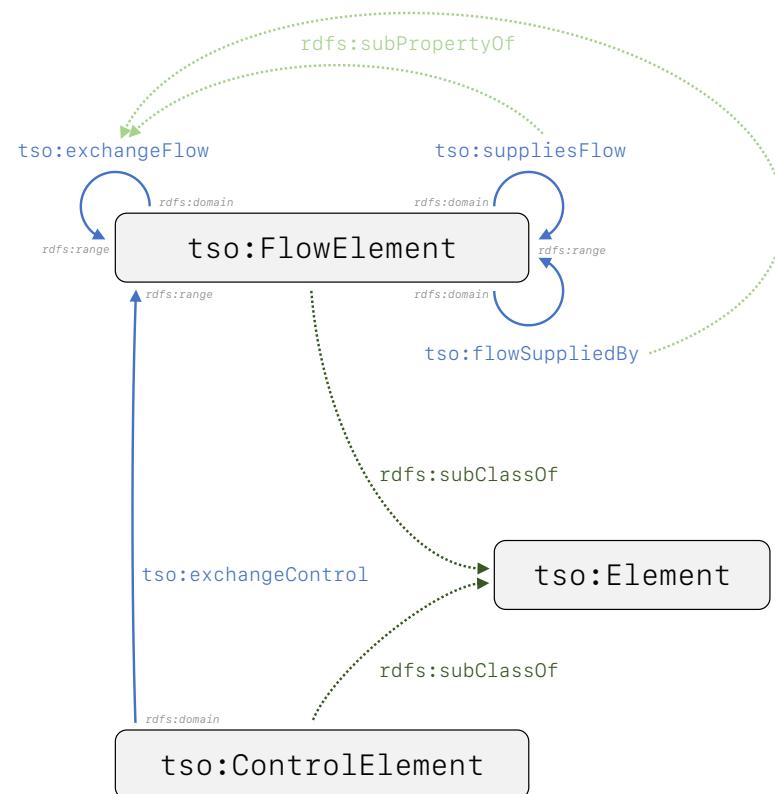
TUBES System Ontology 0.1

- Open, minimal ontology
- 5 Classes, 12 Object Properties
- Explicitly defines the topology of interconnected building service system and their components
- Alignment to BOT (Building Topology Ontology)

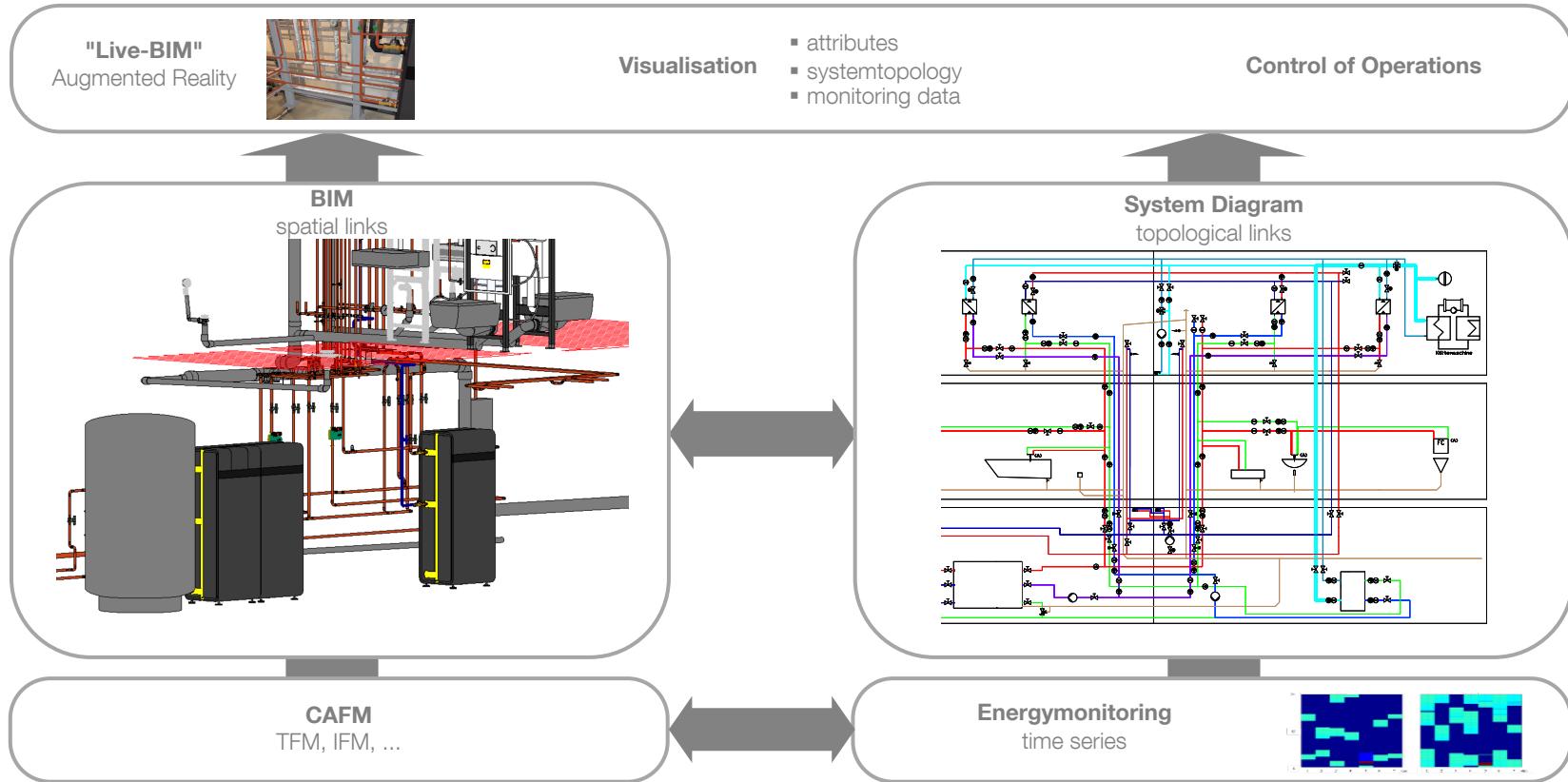


TUBES System Ontology 0.1

- Elements can be differentiated being part of the flow or part of the control
- Differ between the exchange of a flow by `tso:exchangeFlow` and the exchange of a control by `tso:exchangeControl`
- A directed flow can be defined by `tso:suppliesFlow` and `tso:flowSuppliedBy`



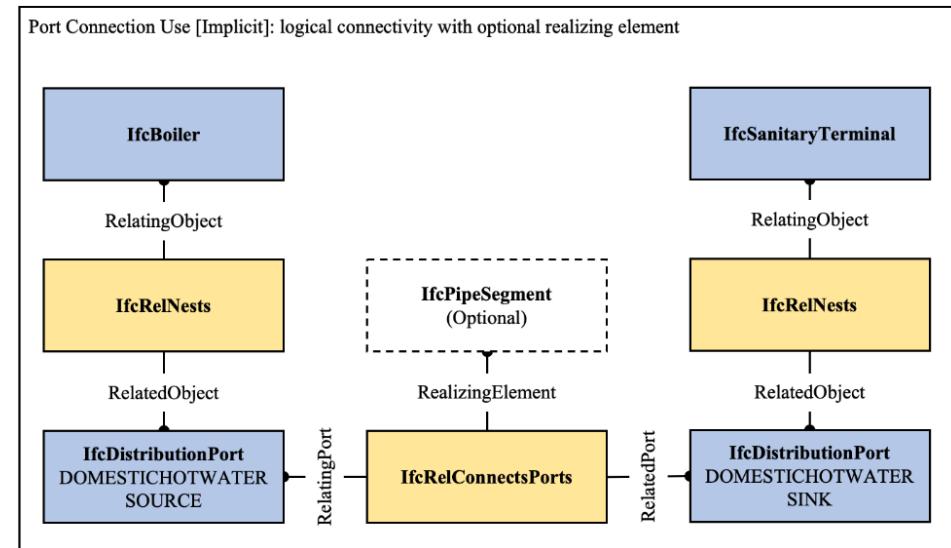
Use-Case: ViegaCUBE



Topology Extraction from IFC to RDF

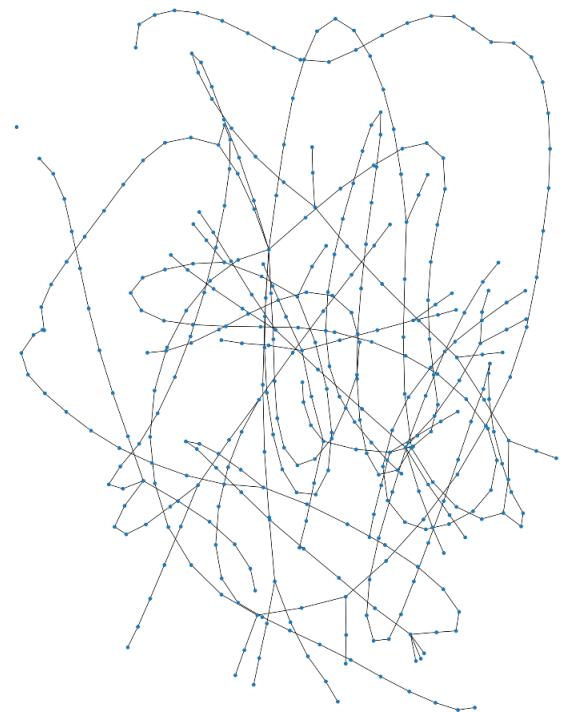
Topology Extraction – IFC

- Spatial links via the geometric representation and the location of objects
- Topological links via IfcDistributionPort
- IfcDistributionPort has attributes regarding its system, type and flow direction
 - source, sink, sourceandsink
 - cable, cablecarrier, duct, pipe
 - 42 system definitions



Topology Extraction – IFC2GRAPH

- Code in python3 using ifcopenshell and networkX
- Iterate over all IfcDistributionElements and IfcBuildingElementProxies
- Analyse all ports and export their topological connections
- Set up a directed and an undirected graph with the given data



Topology Extraction – IFC2GRAPH (Spatial Algorithms)

- What about unassigned ports?
- Use of the rtree package to set up a spatial tree using the geometric positioning of the DistributionPorts and corresponding elements
- k-nearest neighbours/intersection queries to find possible matches which fits the same type
- Export to BCF



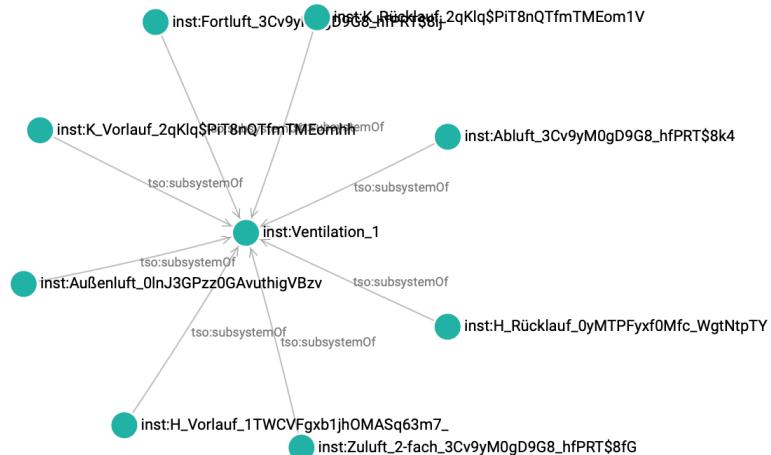
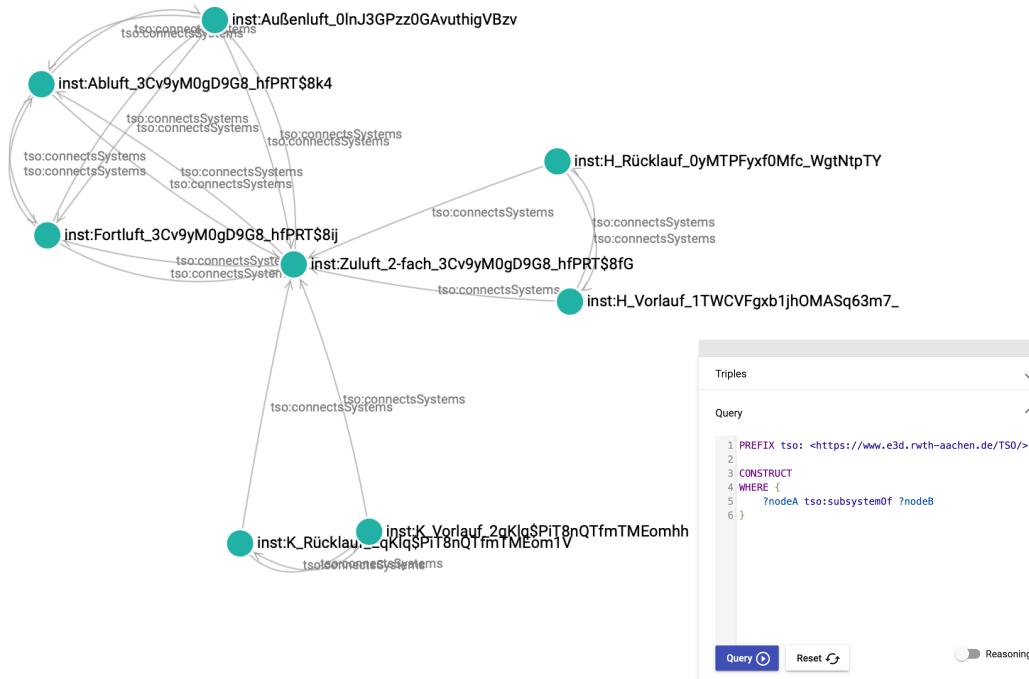
Topology Extraction – GRAPH

- Use of regular expressions to map existing IfcSystems
- Implementing search algorithms to identify further systems based on their topological connection and the exchange of flow
- Aggregation of nodes by the number of neighbours and their value to lower the complexity



Topology Extraction – GRAPH2RDF

- Using rdflib to convert the graphs and the additional system information to RDF

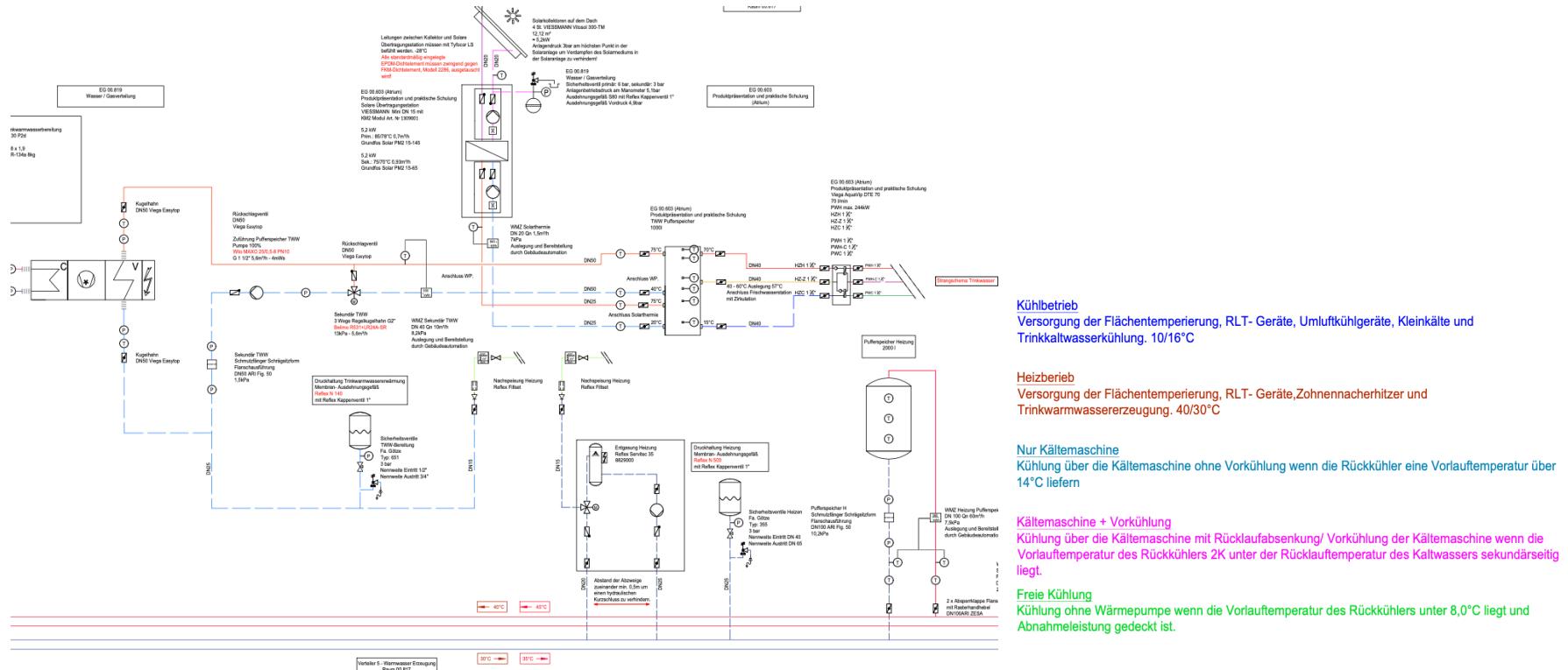


TUBES System Ontology 0.2

Viega World



Viega World



Integrated representation of building service systems

W3C LBD CG – 23th February 2021

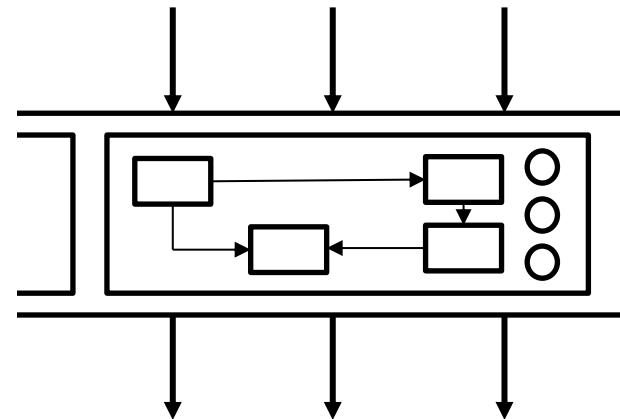
What is a System?

A system is a model of a whole which is isolated from the world or a supersystem, which may consist of interconnected components or sub-systems and has links between attributes such as inputs, outputs and states.

hierarchical concept

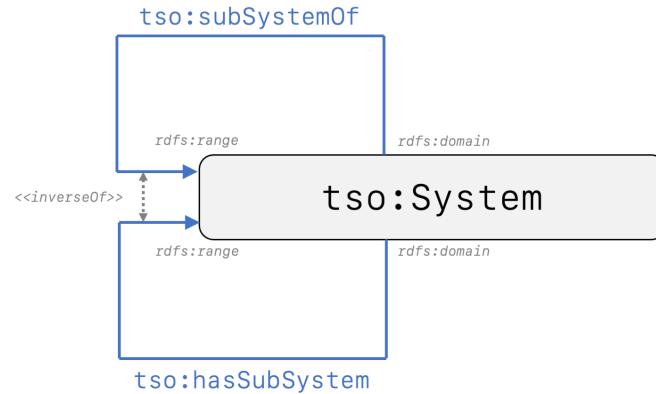
structural concept

functional concept



Hierachichal concept

A system is a model of a whole which is isolated from the world or a supersystem...



Structural concept

A system is a model of a whole [...] which may consists of interconnected components or sub-systems ...

Whats the difference between a system and a component?

Component vs. System

A system is a model of a whole which is isolated from the world or a supersystem, which may consists of interconnected components or sub-systems and has attributes such as inputs, outputs and states.

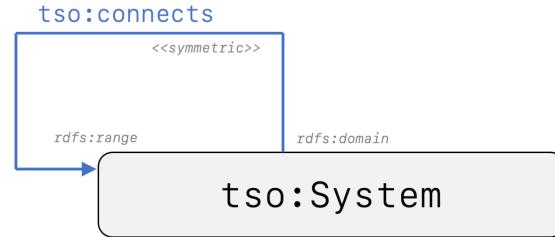
A component is a model of a whole which is isolated from the world or a supersystem, which may consists of interconnected components or sub-systems and has attributes such as inputs, outputs and states. The boundary which isolates the component from the world is defined by the manufacturer with regards to the product aspect.

Components describe the product-related view at aggregated functional aspects in one entity with a given boundary.

A component can be described as a system.

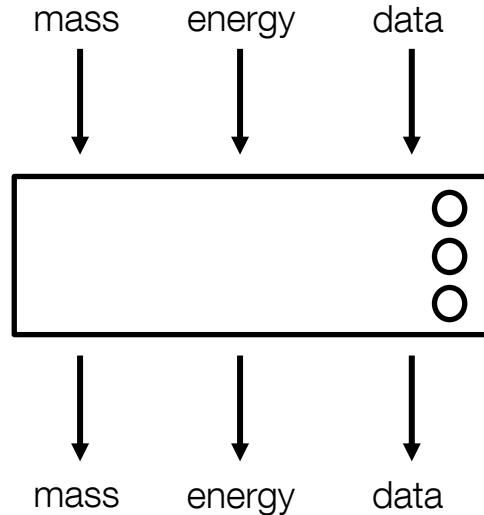
Structural concept

A system is a model of a whole [...] which may consists of interconnected components or sub-systems ...



Functional concept

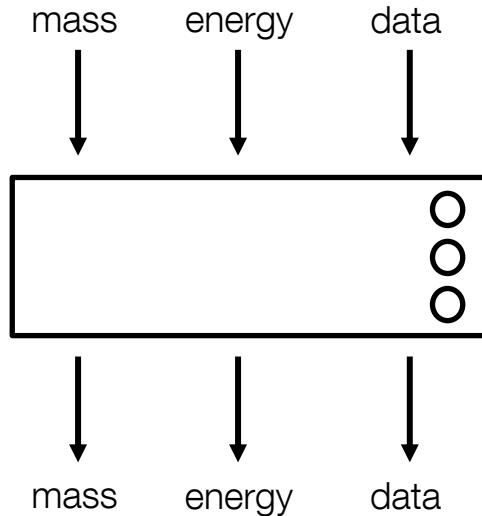
A system is a model of a whole [...] which has attributes such as inputs, outputs and states.



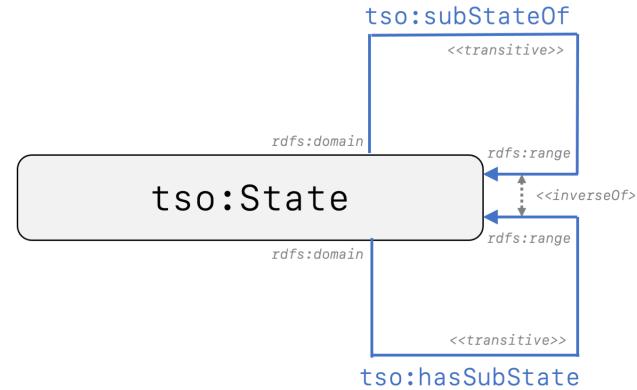
- mass
 - fluid
 - liquid
 - gas
 - solid
- energy
 - thermalEnergy
 - electricalEnergy
 - mechanicalEnergy
- data

Functional concept

A system is a model of a whole [...] which has attributes such as inputs, outputs and states.

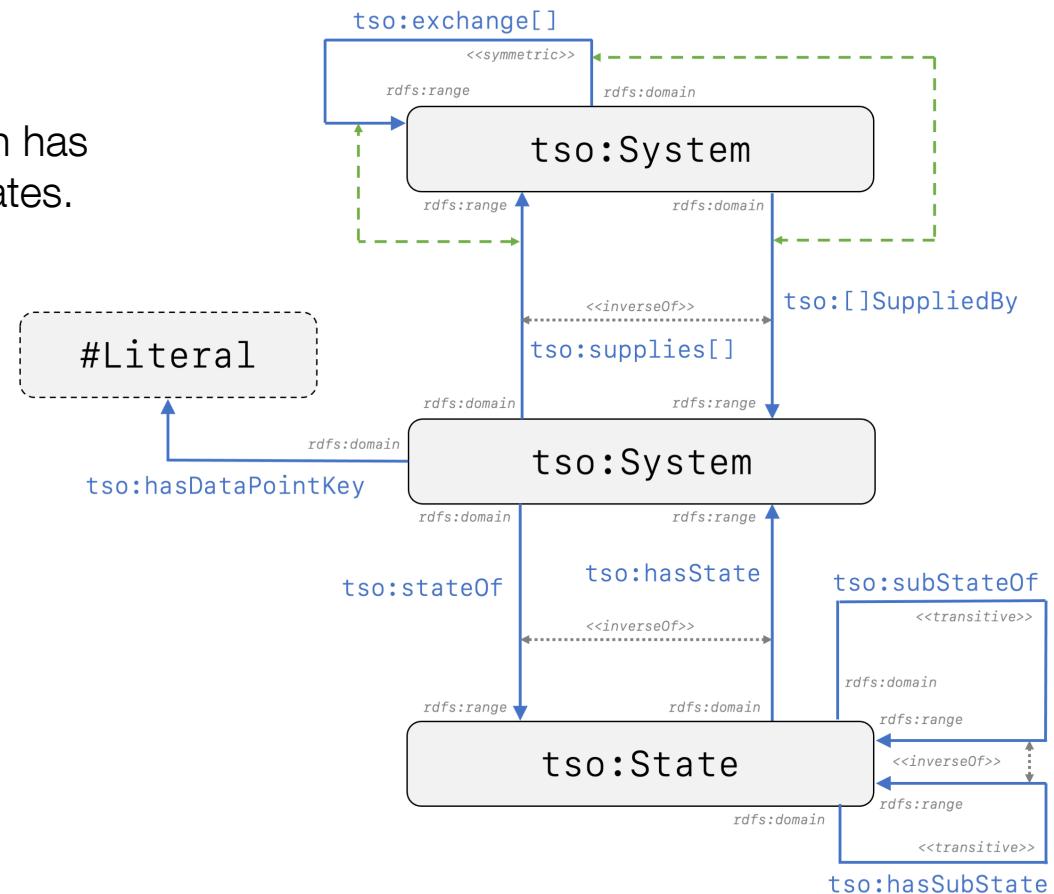
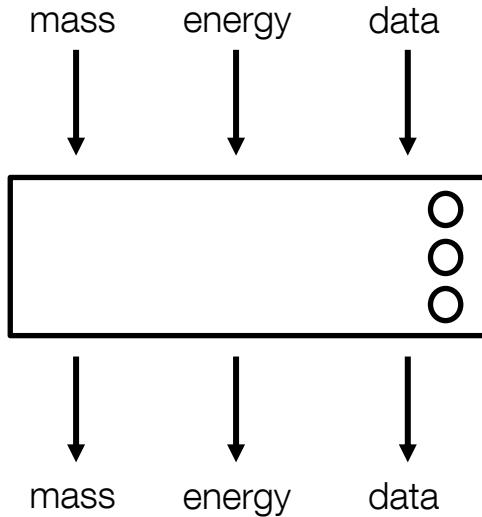


A state defines the internal condition of a planned or abstract system. This includes specific aspects as on, off, open or closed as well as general aspects such as outdoor-air-operation, mixed-air-operation or heating-operation.

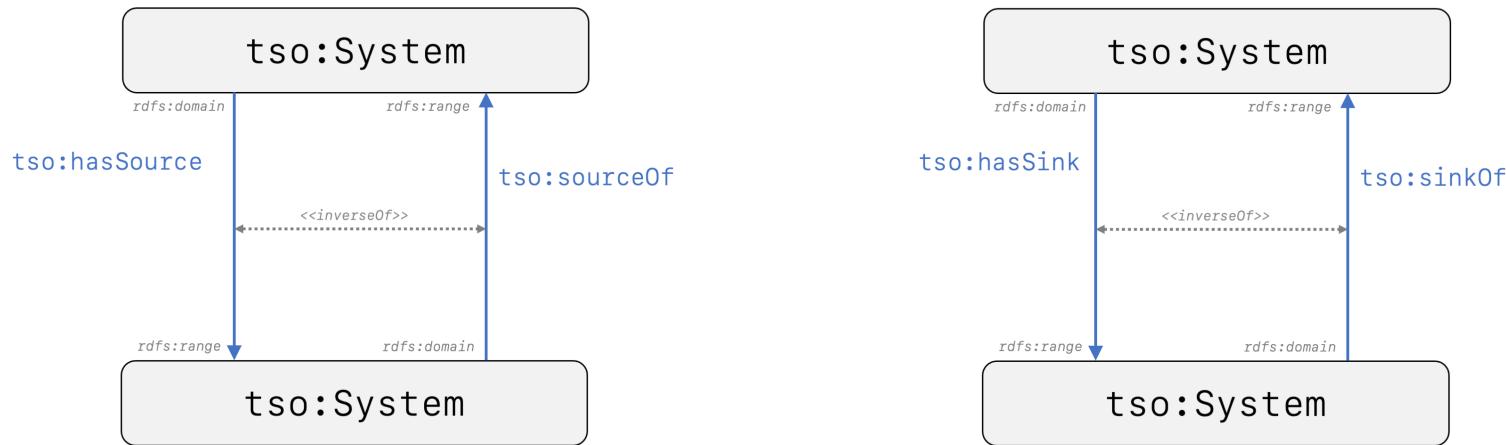


Functional concept

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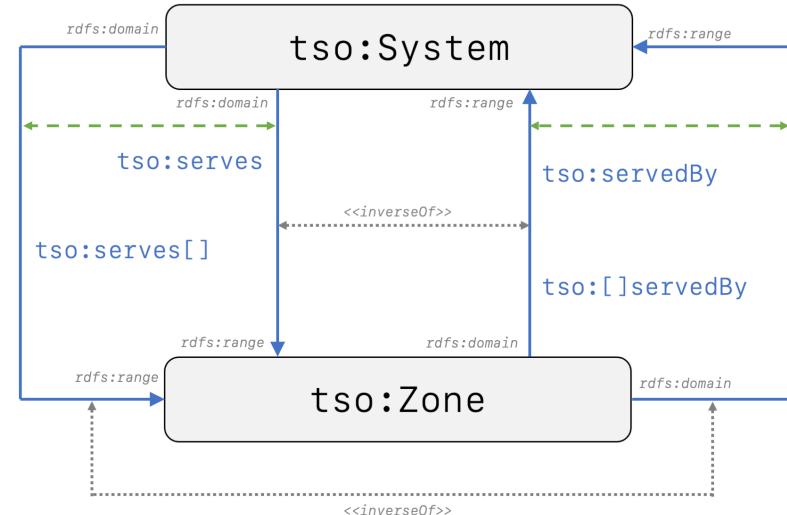
Source and sink of systems



What about spatial elements?

A zone is a part of the physical world or a virtual world that is inherently both located in this world and has a 3D spatial extent. (bot:Zone)

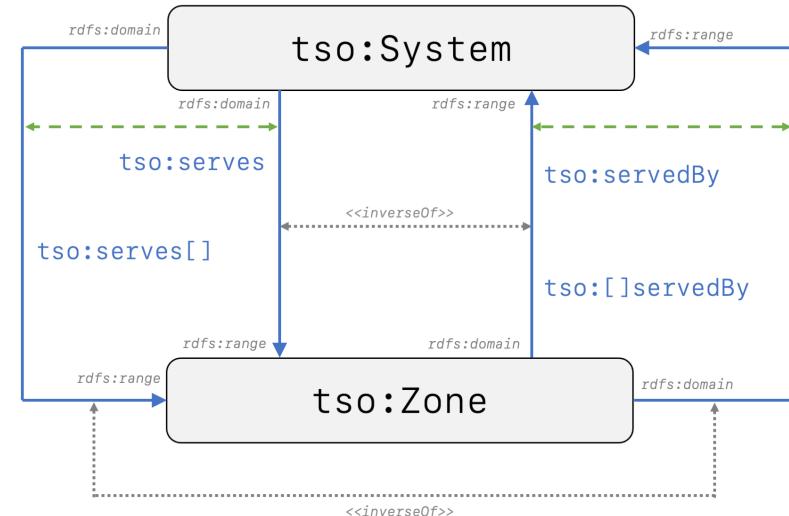
- Zones are served by tso:System
- A tso:System can serve multiple zones
- Zones do not exchange mass, data or energy between each other
- tso:serves can be further detailed to describe „what“ is served



What about spatial elements?

A zone is a part of the physical world or a virtual world that is inherently both located in this world and has a 3D spatial extent. (bot:Zone)

- mass
 - fluid
 - liquid
 - gas
 - solid
 - energy
 - soundEnergy
 - electricalEnergy
 - thermalEnergy
 - lightEnergy
 - mechanicalEnergy
 - data



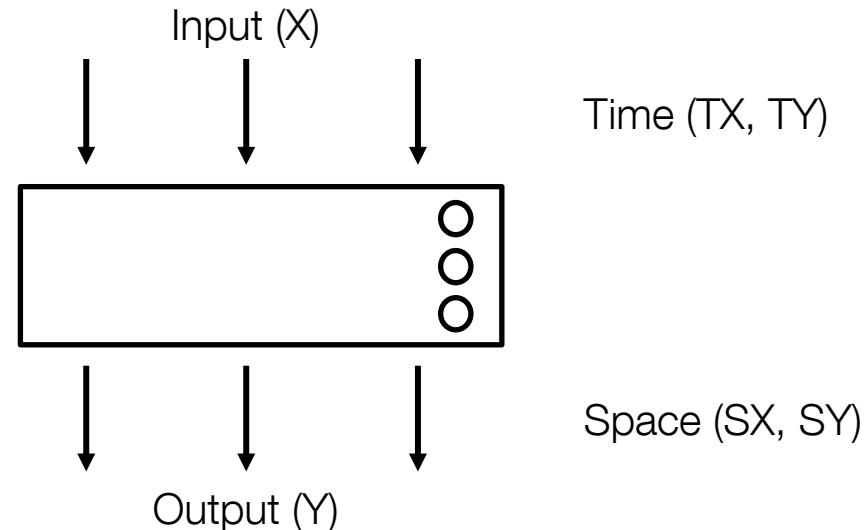
Classification of systems

A system can be classified by the overall function or the technical solution by which the function is fulfilled.

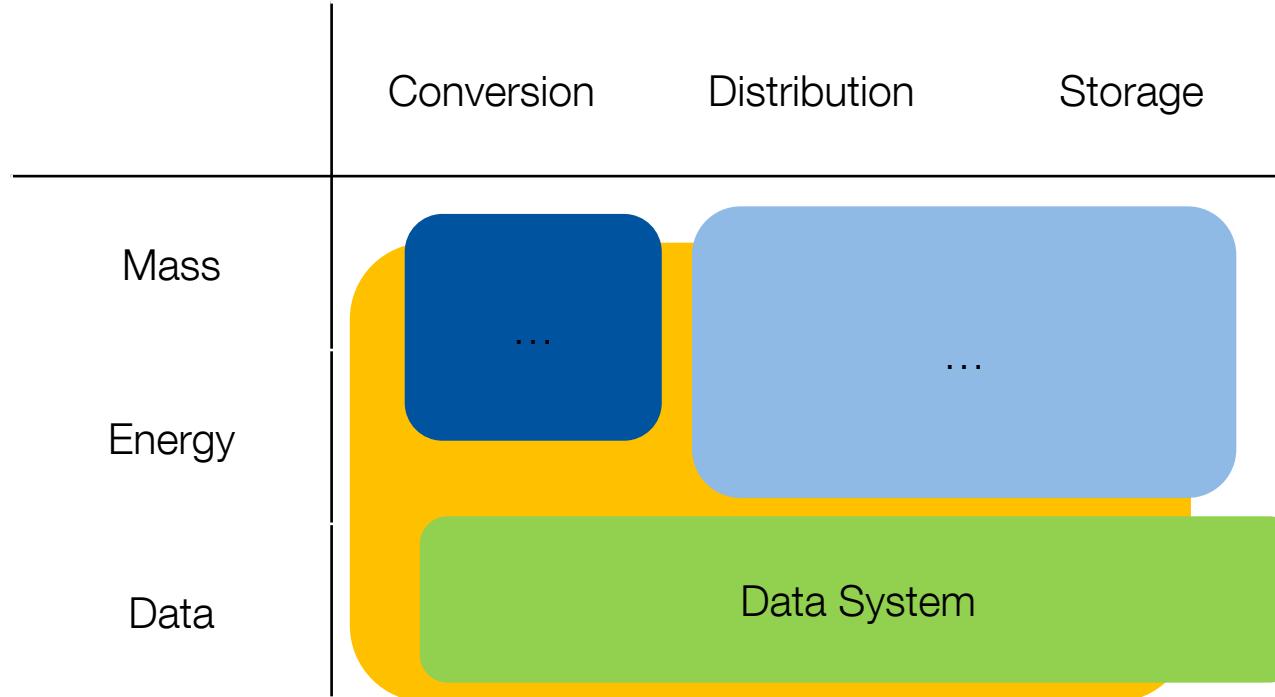
Classification of systems – Technical Solution

A system can be classified by the overall function or the technical solution by which the function is fulfilled.

- $X = Y, SX = SY, TX \neq TY:$
 - StorageSystem
- $X = Y, SX \neq SY, TX = TY:$
 - DistributionSystem
- $X \neq Y$
 - ConversionSystem



Classification of systems – Functional System



Classification of systems

Technical Systems

ConversionSystem

- EnergyConversionSystem
- TreatmentSystem

DistributionSystem

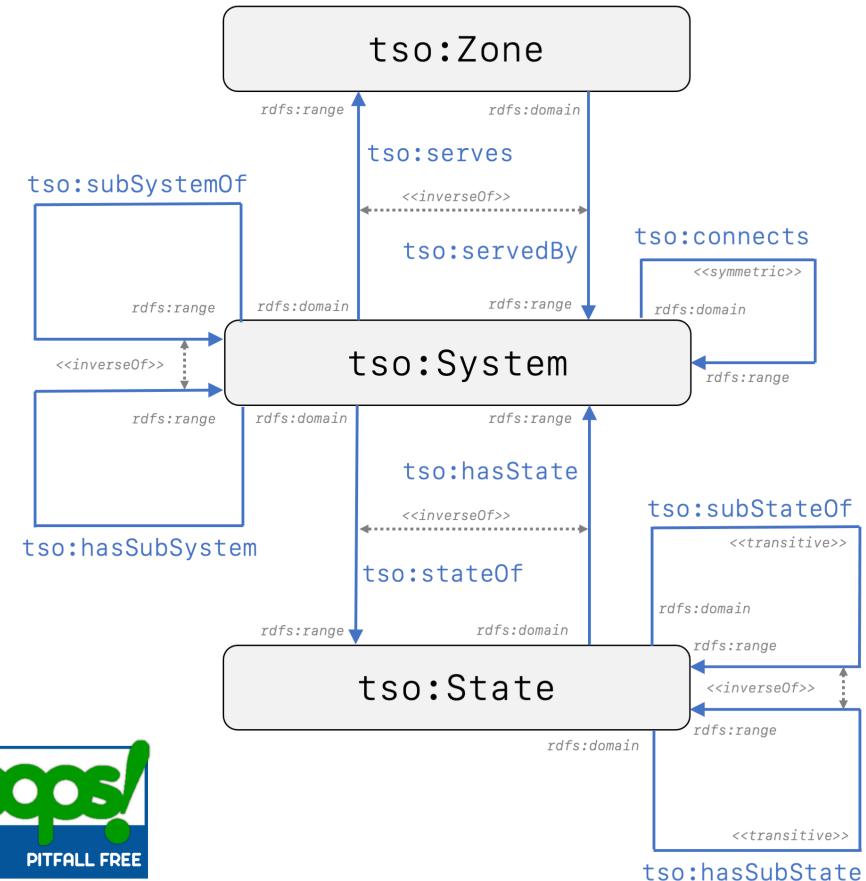
- SupplySystem
- ReturnSystem

StorageSystem

Functional Systems

Overview

- Namespace: <https://w3id.org/tso#>
- Ontology IRI: <https://w3id.org/tso/v0.2/tubes>
- Documentation: <https://rwth-e3d.github.io/tso>
- 21 Classes
- 67 Object Properties
- 1 Datatype Properties
- Proposed Alignment to BOT:
<https://w3id.org/tso/v0.2/AlignmentBOT>



Q&A