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universität OLDENBURG

SuMoCoS
Sustainability and Mobility
in the Context of Smart Cities

Semantic Technologies for Smart Cities

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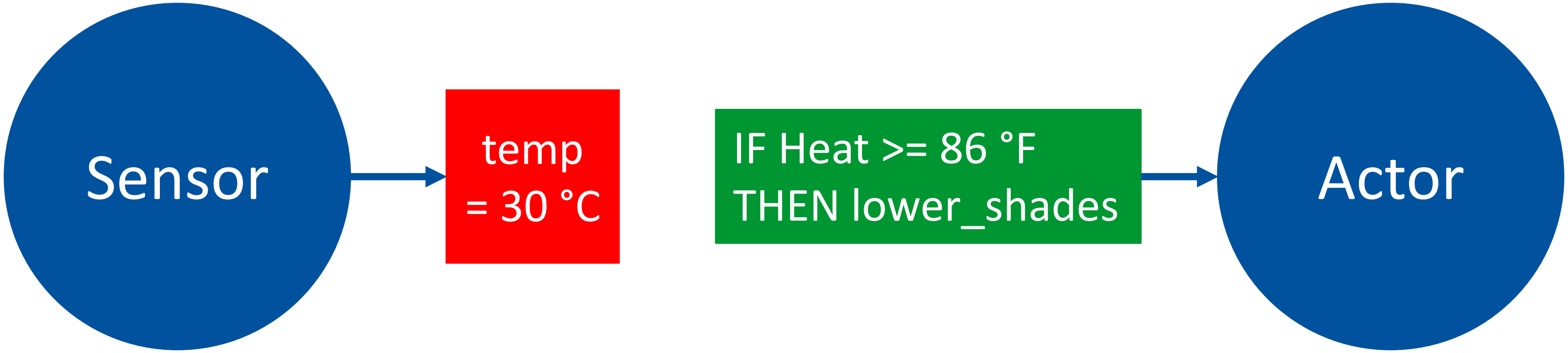
Tashkent, October 7-11, 2019

https://uol.de/se?sumocos

Motivation



Sensor

temp = 30 °C

IF Heat >= 86 °F
THEN lower_shades

Actor

temp = 30 °C ⚡ Heat >= 86 °F

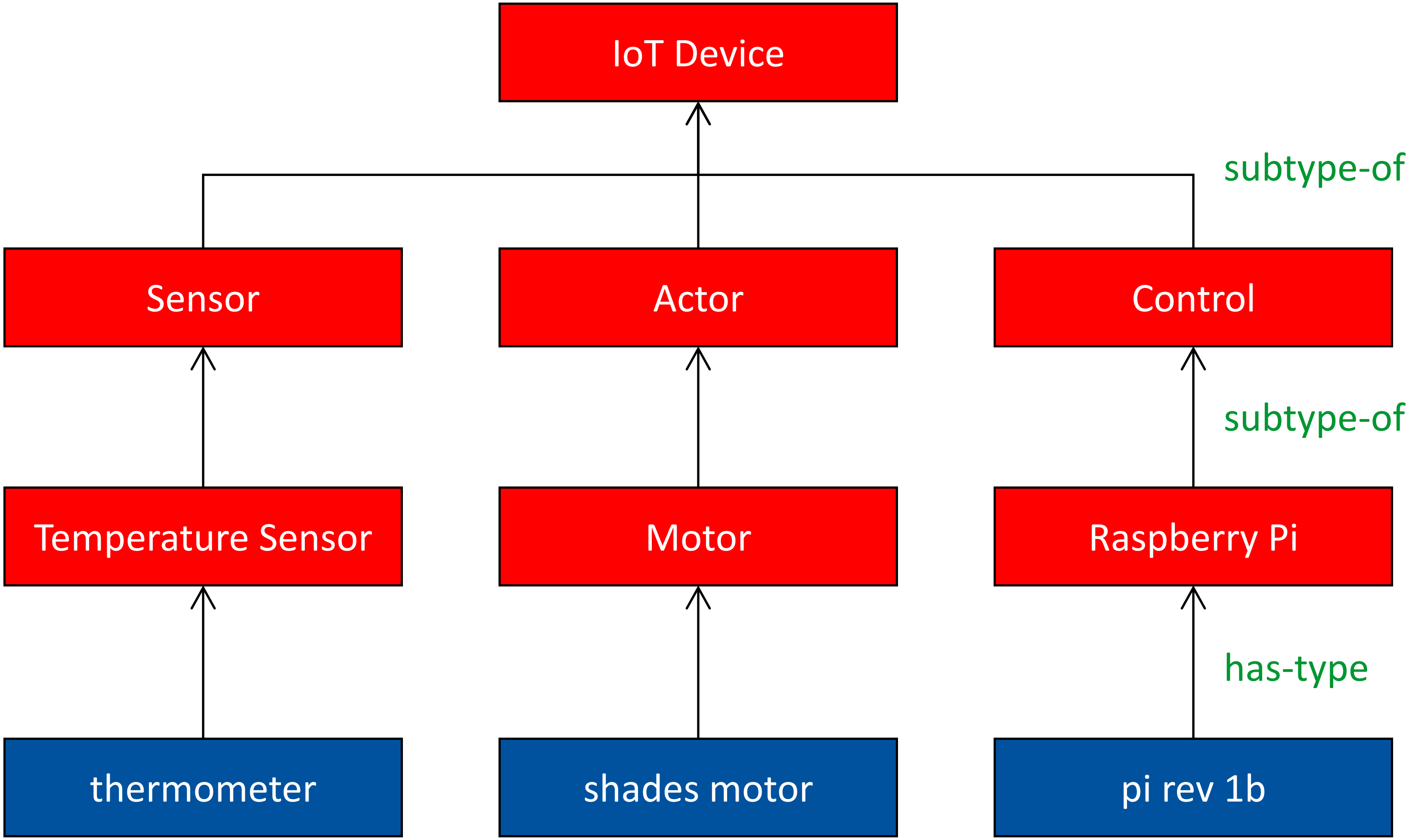
Semantic Technologies

- Knowledge Management
  - Knowledge Representation
    - Ontologies
    - Taxonomies
  - Knowledge Inference

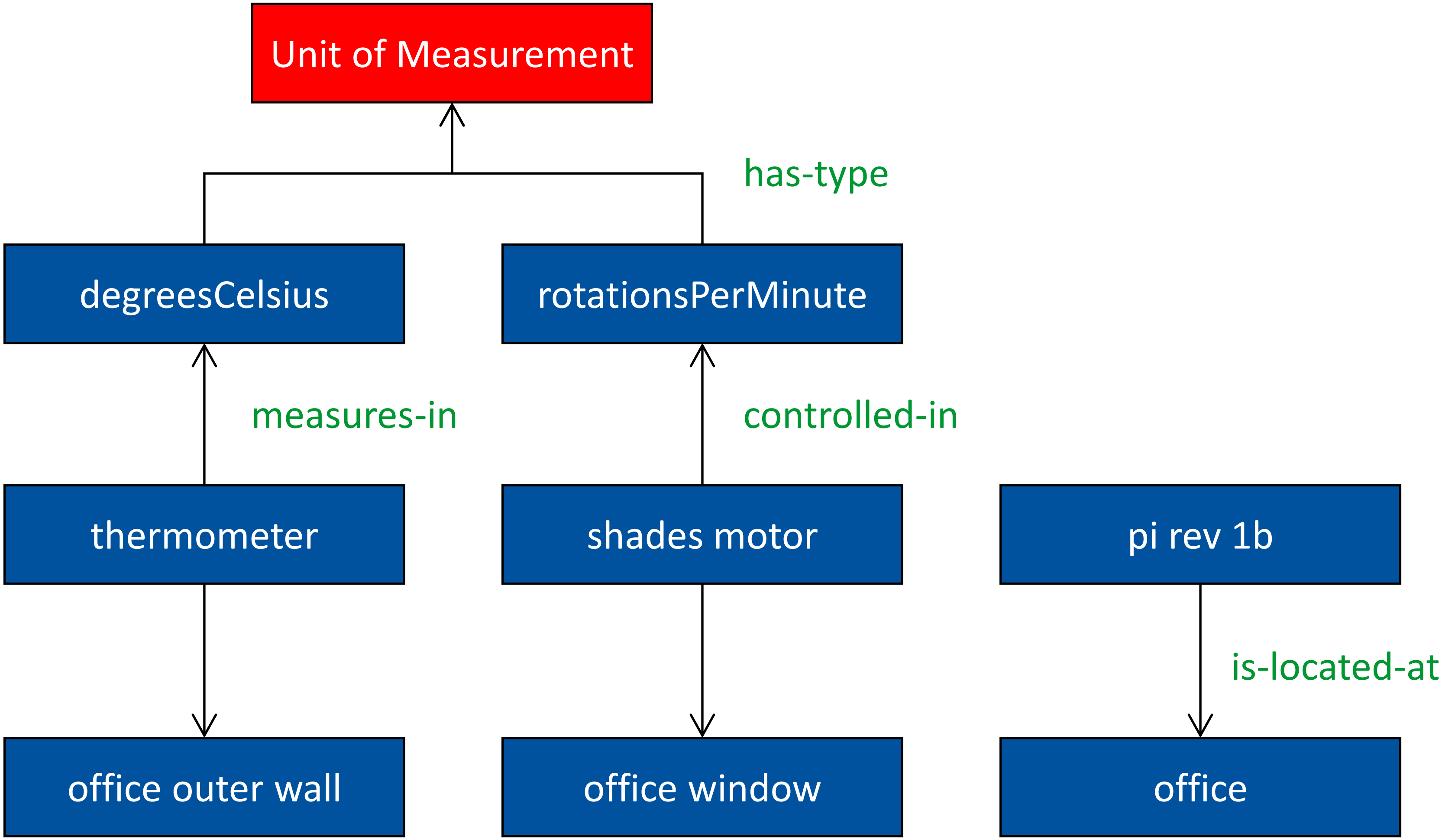
Ontologies

- Describe Concepts, Individuals and their Relationships
- Concepts represent abstract types, such as *Temperature* or *UnitOfMeasurement*
- Individuals represent concrete data, such as *20°* or *degreesCelsius*
- Relationships represent connections between
  - concepts, such as Temperature *is-a* Measurement (specialisation)
  - individuals, such as 20° *is-measured-in* degreesCelsius
  - individuals and concepts, such as 20° *has-type* Temperature

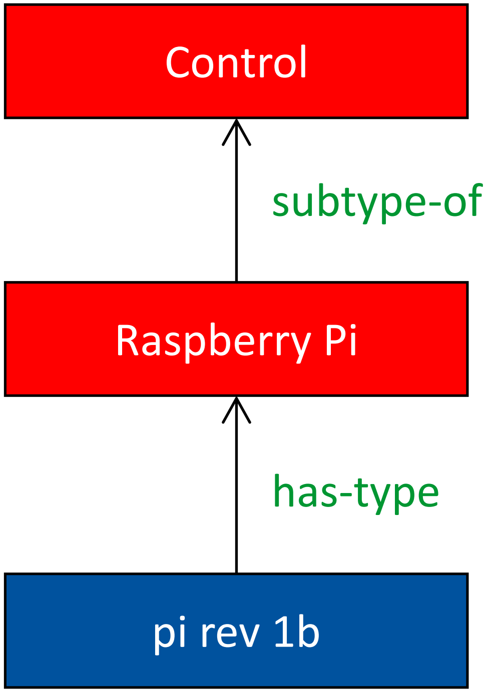
Ontologies: Example



Ontology: Example (continued)



Foundation in Logics



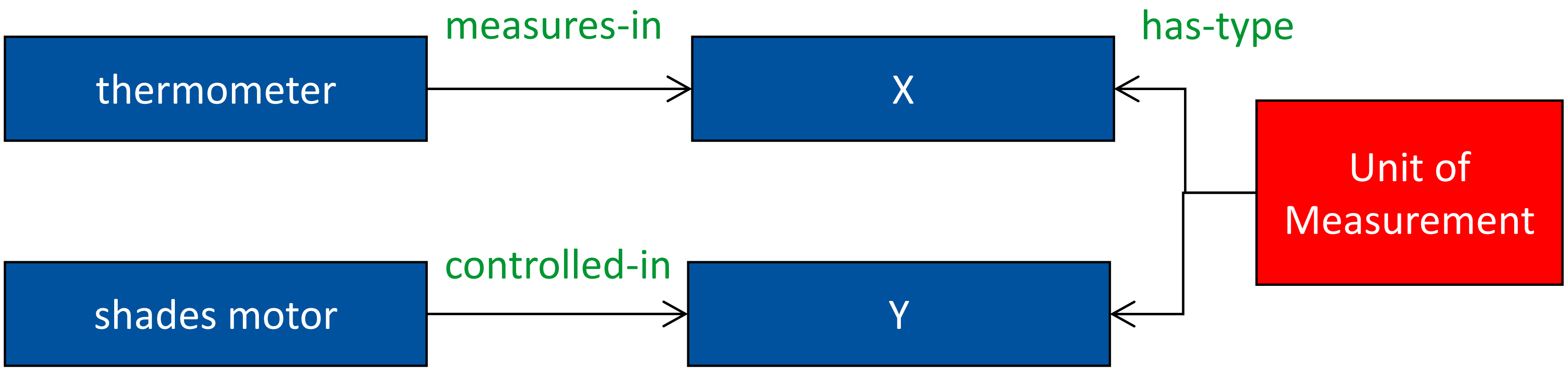
```
Raspberry Pi ⊑ Control

Raspberry Pi(pi rev 1b)
```

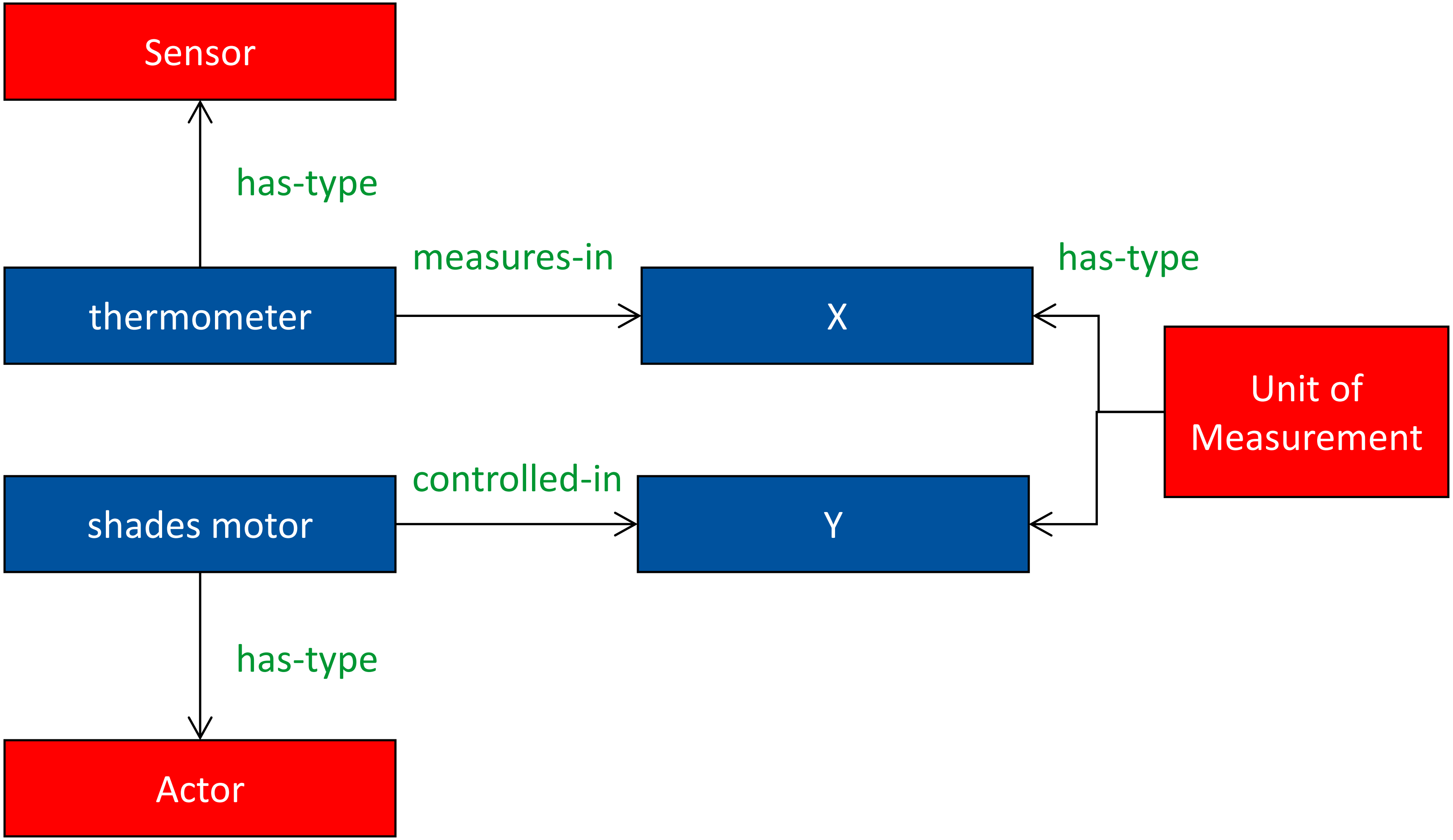
Inference

- Create new facts from existing facts and rules
- Automatic classification,
  e.g., determine type based on attributes
- Find inconsistencies

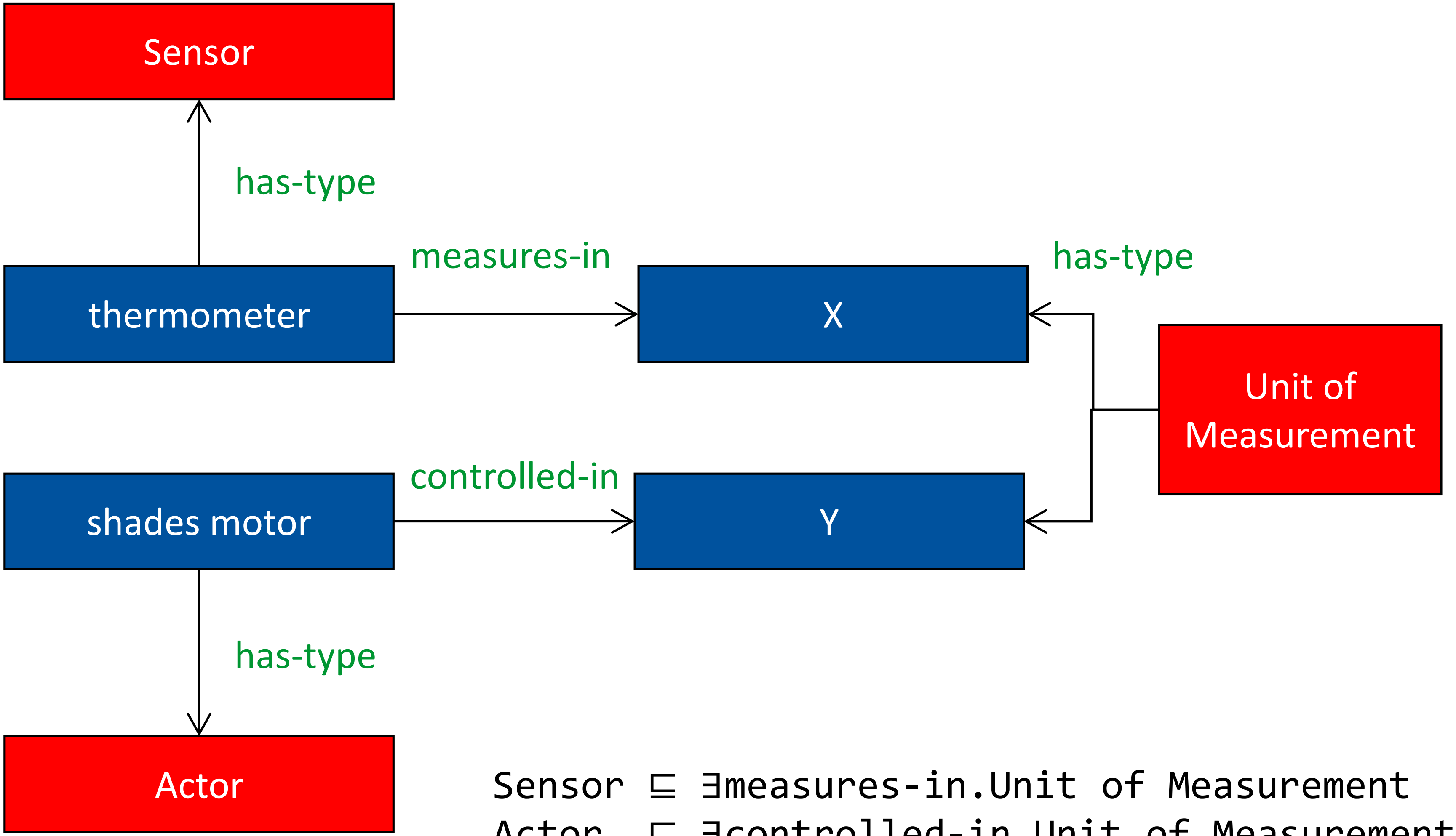
Automatic Classification: Example



Automatic Classification: Example

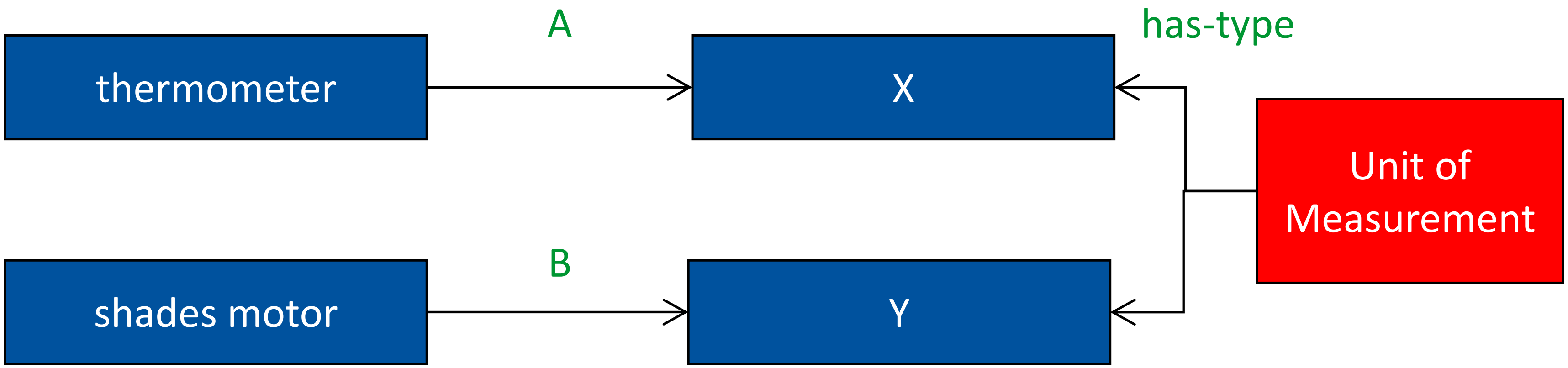


Automatic Classification: Example

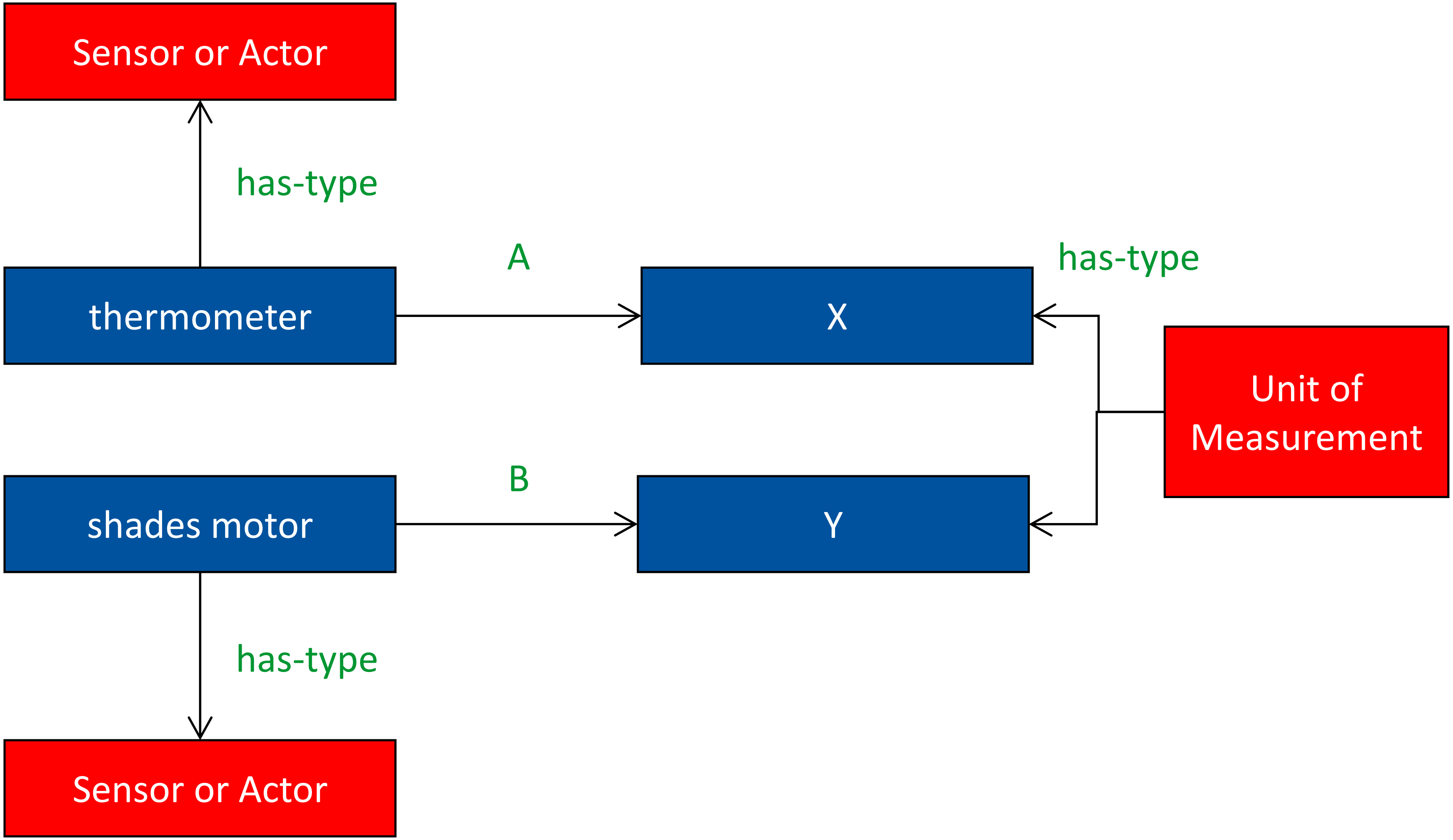


```
Sensor ⊑ ∃measures-in.Unit of Measurement
Actor  ⊑ ∃controlled-in.Unit of Measurement
```

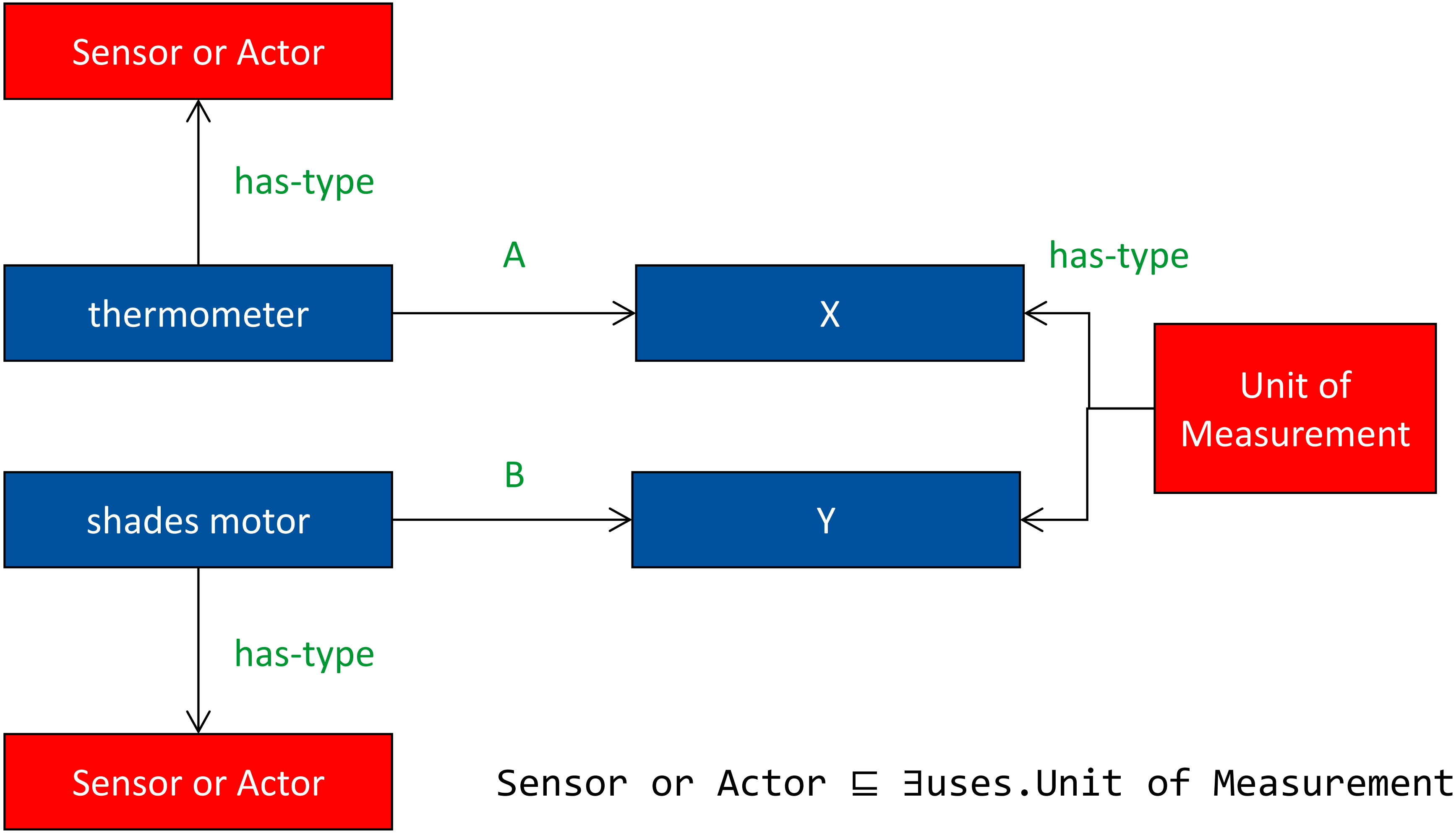
Automatic Classification: Example (2)



Automatic Classification: Example (2)

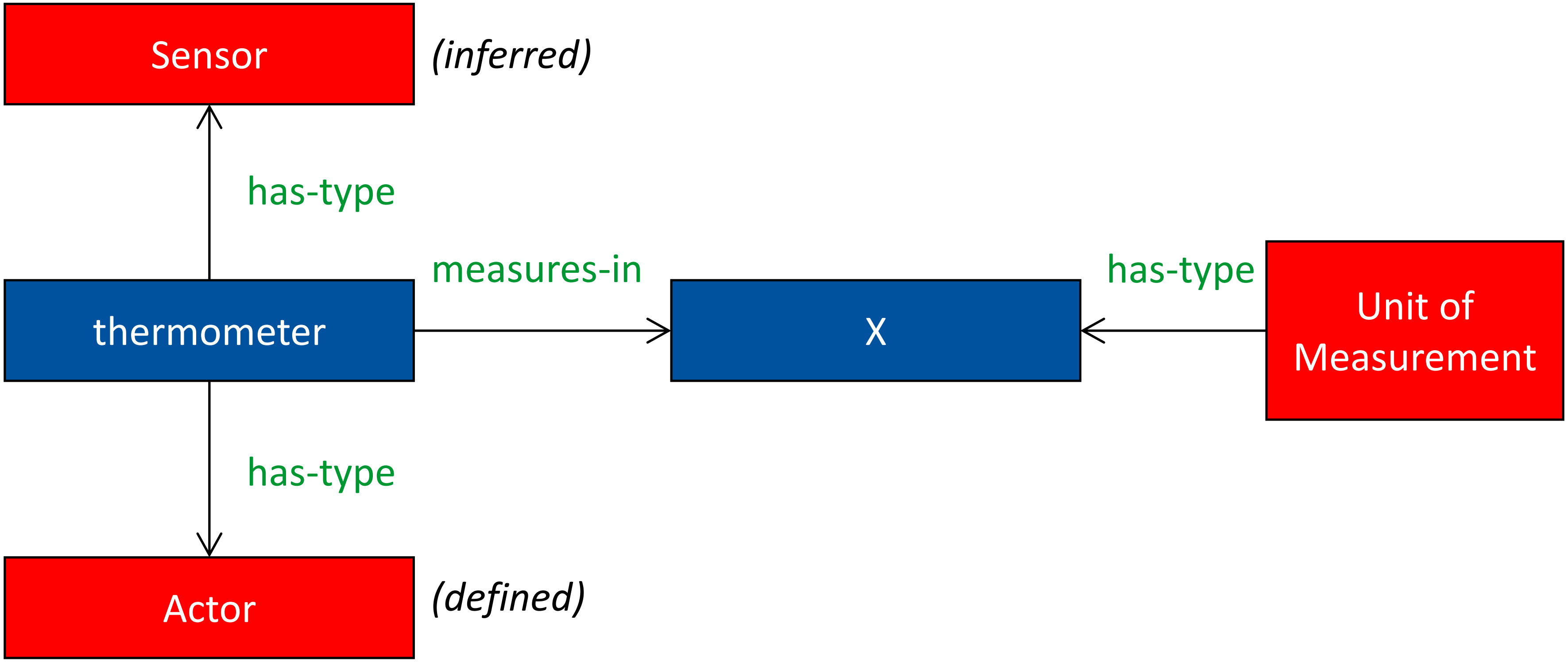


Automatic Classification: Example (2)



Sensor or Actor ⊑ ∃uses.Unit of Measurement

Inconsistency: Example



Sensor

(inferred)

has-type

thermometer

measures-in

X

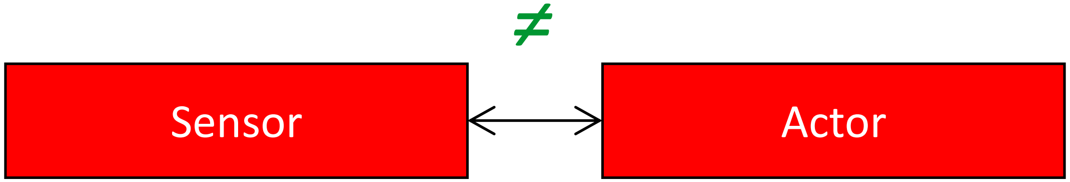
has-type

Unit of Measurement

has-type

Actor

(defined)

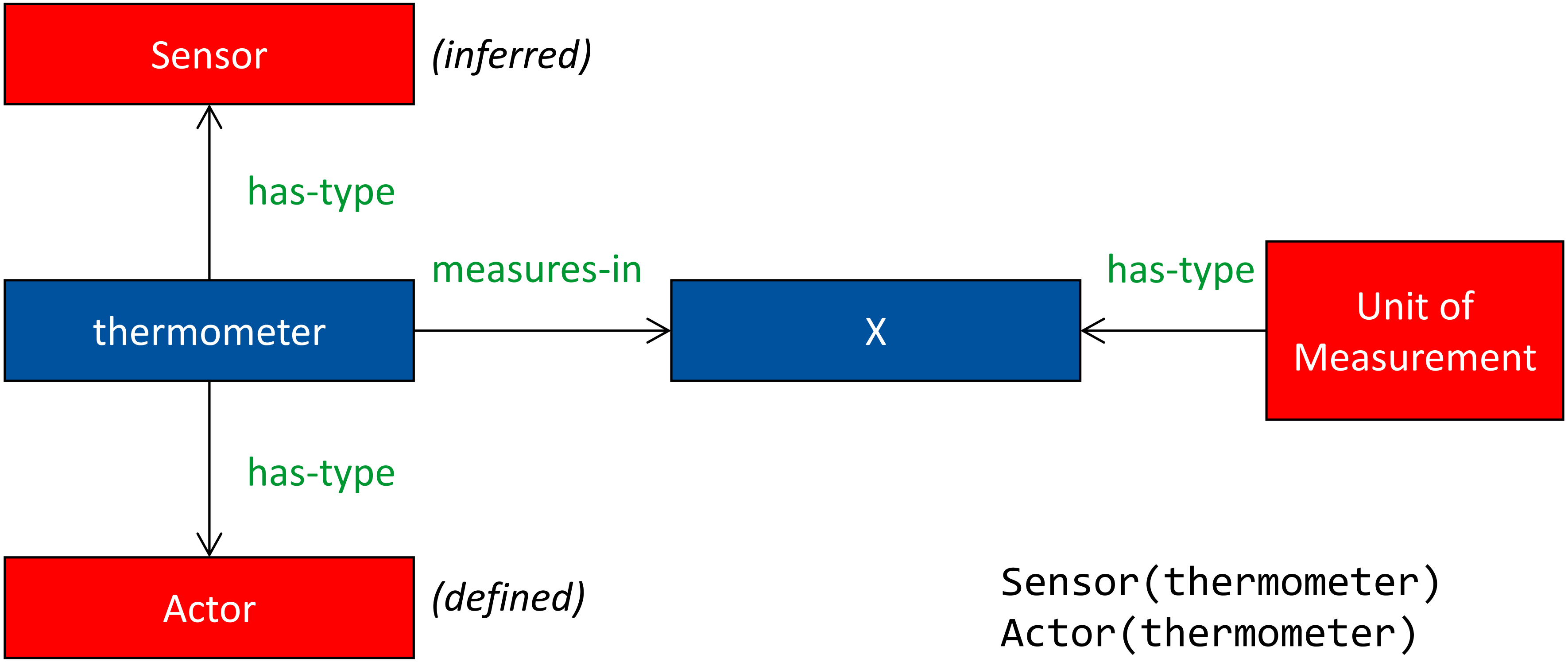


≠

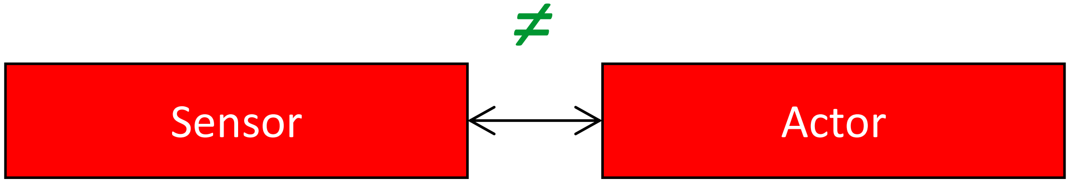
Sensor

Actor

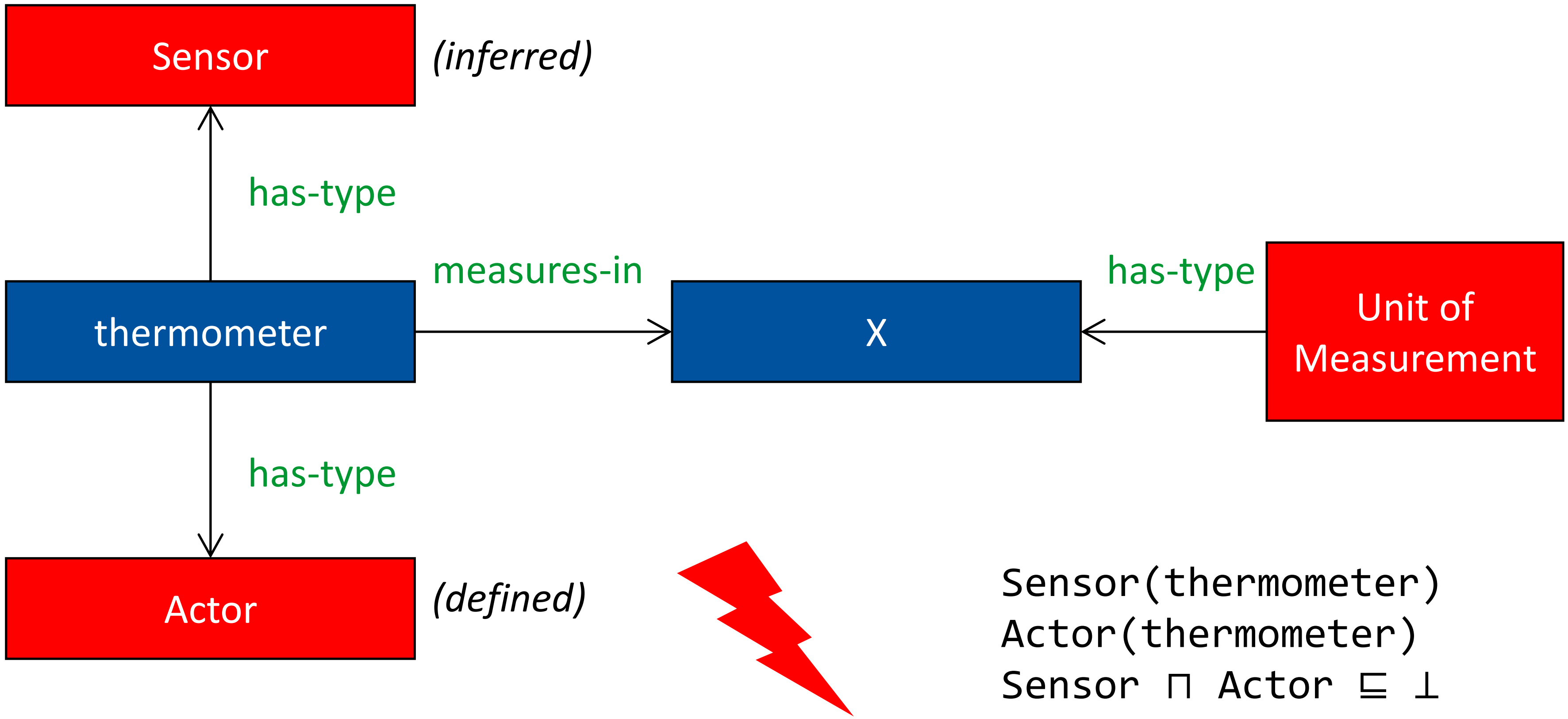
Inconsistency: Example



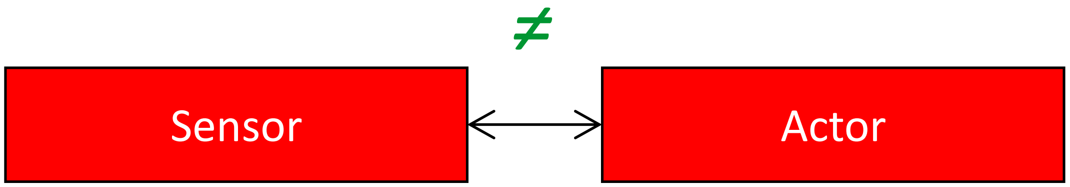
Sensor(thermometer)
Actor(thermometer)
Sensor ⊓ Actor ⊑ ⊥



Inconsistency: Example



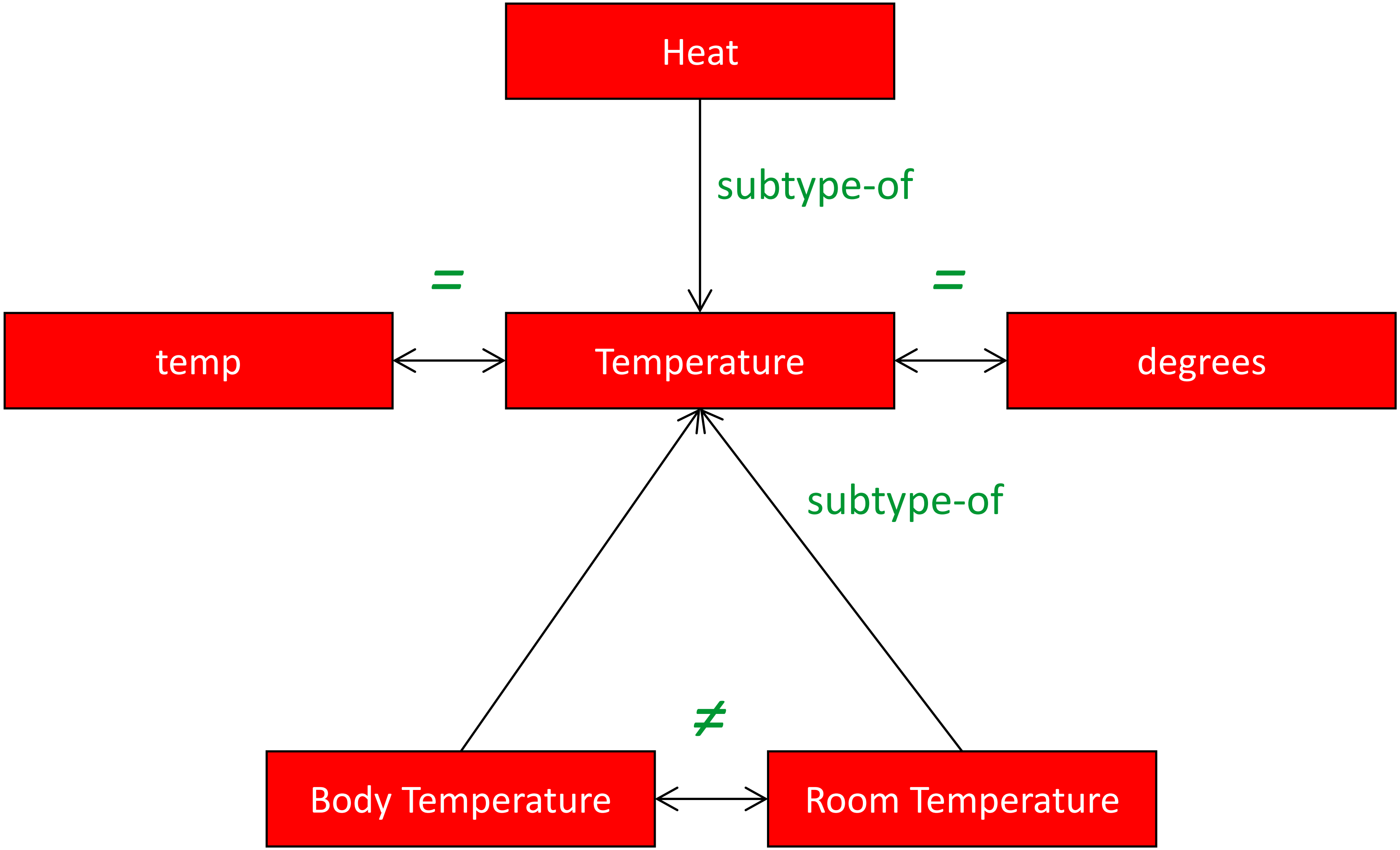
Sensor(thermometer)
Actor(thermometer)
Sensor ⊓ Actor ⊑ ⊥



Ontologies for Smart Cities

- Documentation
- Semantic description of devices
- Thesaurus
  - different devices and domains use different terminology
  - map devices and data

Ontologies for Smart Cities: Example



Heat

subtype-of

=

=

temp

Temperature

degrees

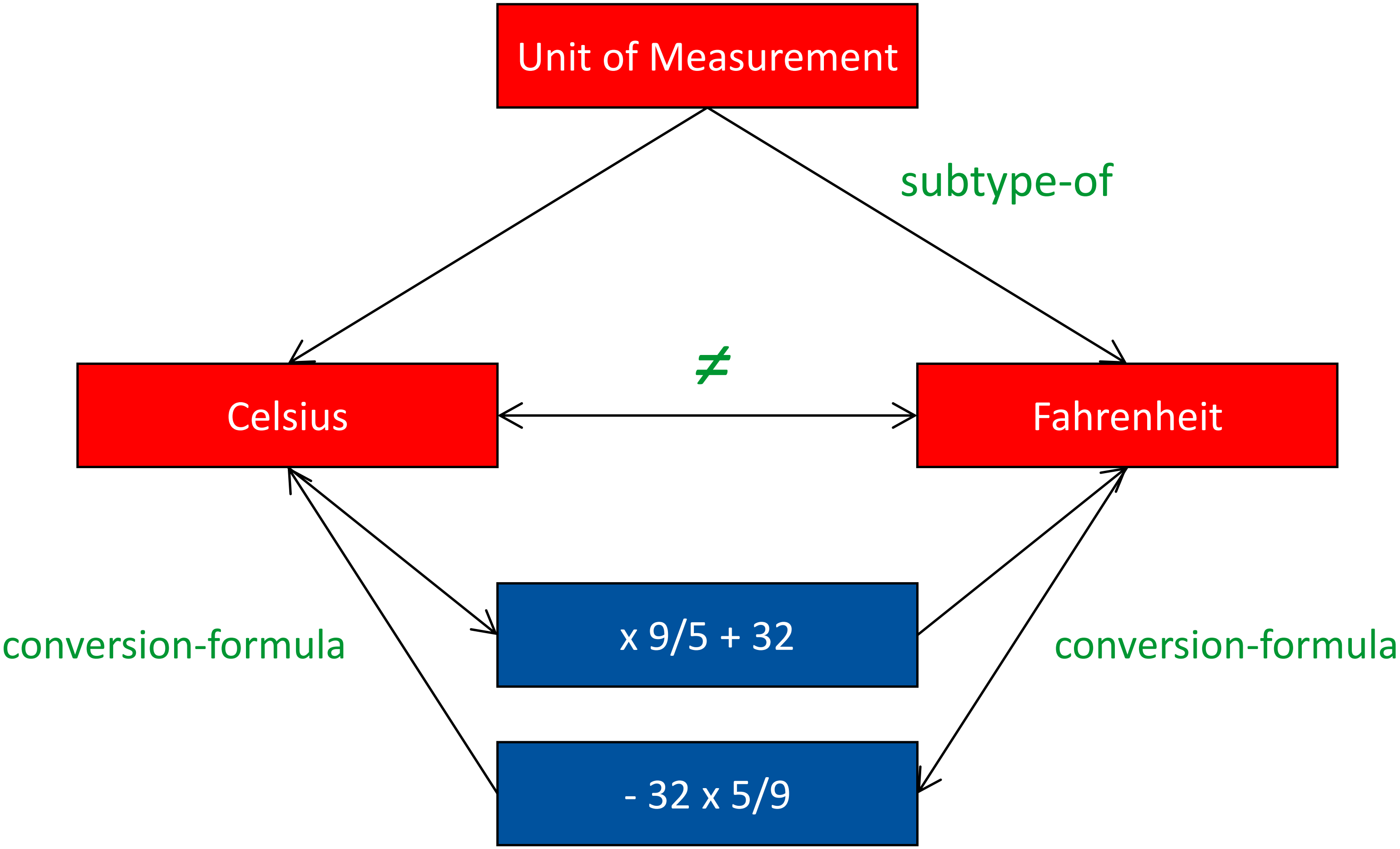
subtype-of

≠

Body Temperature

Room Temperature

Ontologies for Smart Cities: Example (2)


Unit of Measurement

subtype-of

Celsius

≠

Fahrenheit

x 9/5 + 32

conversion-formula

conversion-formula

- 32 x 5/9

Existing Ontologies for Smart Cities

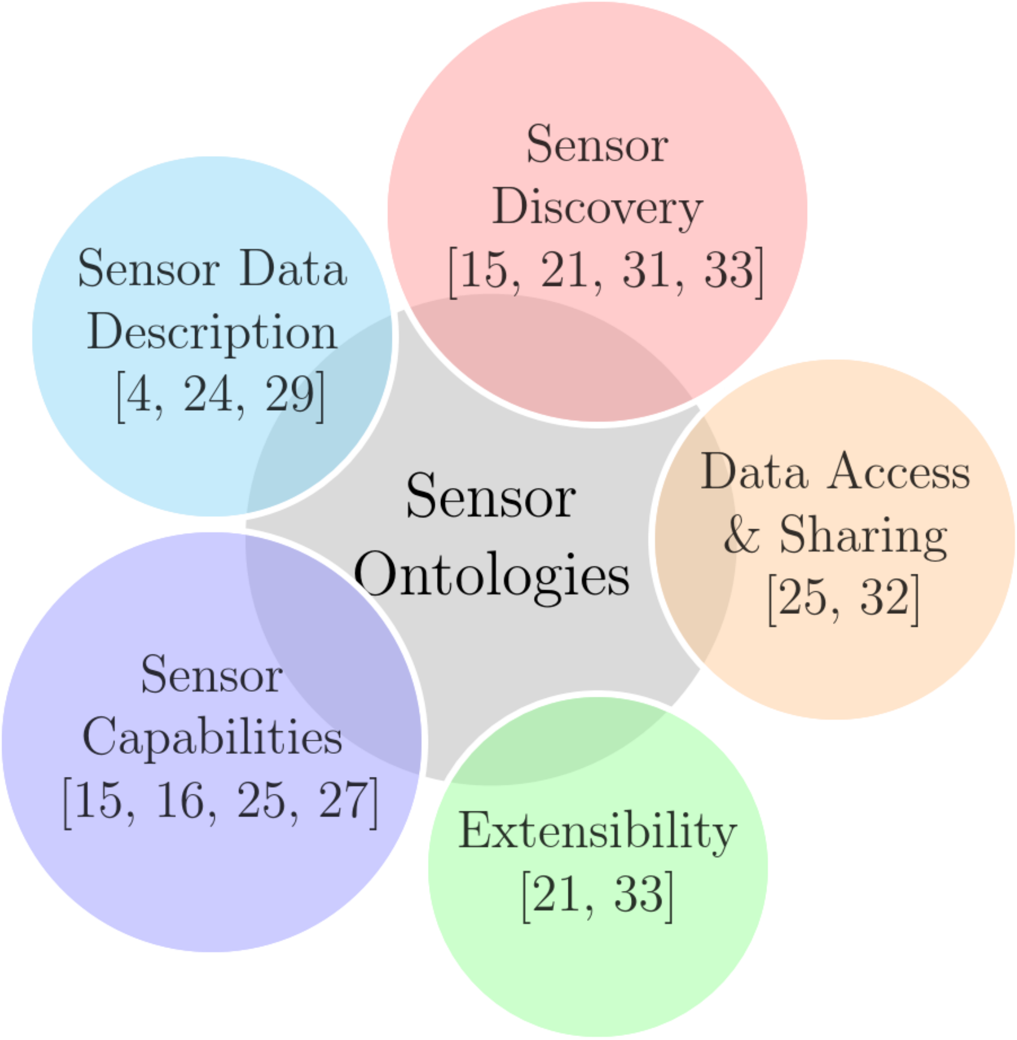

Sensor Discovery [15, 21, 31, 33]
Sensor Data Description [4, 24, 29]
Sensor Ontologies
Data Access & Sharing [25, 32]
Sensor Capabilities [15, 16, 25, 27]
Extensibility [21, 33]

Image taken from Garvita Bajaj, Rachit Agarwal, Pushpendra Singh, Nikolaos Georgantas, and Valerie Issarny: *A study of existing Ontologies in the IoT-domain*. CoRR, 2017.

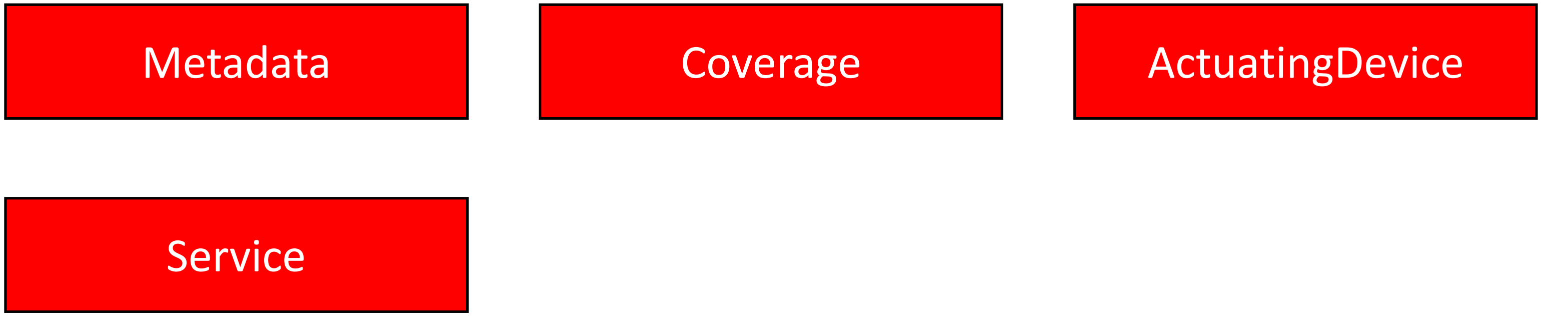
Existing Ontologies for Smart Cities

- Semantic Sensor Network Ontology (SSN)
  - W3C ontology
  - describes sensors, observations and related concepts
  - does not describe domain concepts, time, locations, … (but can be included from other ontologies)

System	Process	SensingDevice
SensorDataSheet	Platform	Deployment

Existing Ontologies for Smart Cities (2)

- IoT-Lite
  - W3C member submission
  - lightweight ontology to represent IoT resources, entities and services
  - instantiation of SSN



Metadata

Coverage

ActuatingDevice

Service

Existing Ontologies for Smart Cities (3)

- OpenIoT
  - describes observations, sensors, locations, and metrics for SLAs
  - instantiation of SSN
- OntoSensor
  - sensor categories, behaviour, functions and meta-data
  - extends SensorML
- OWL-Time
  - specifies date/time information
  - point in time and intervals

Analysis

- Semantic technologies can
  - help with relating various sensors, actors and other devices
    - from different manufacturers
    - from different application domains
    - of different types
  - identify inconsistencies and errors in the system description
- Semantic technologies are
  - often restricted to a single domain (but can be combined)
  - expensive to create (but can be mitigated)

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