A Framework for Semantic Discovery on the Web of Things

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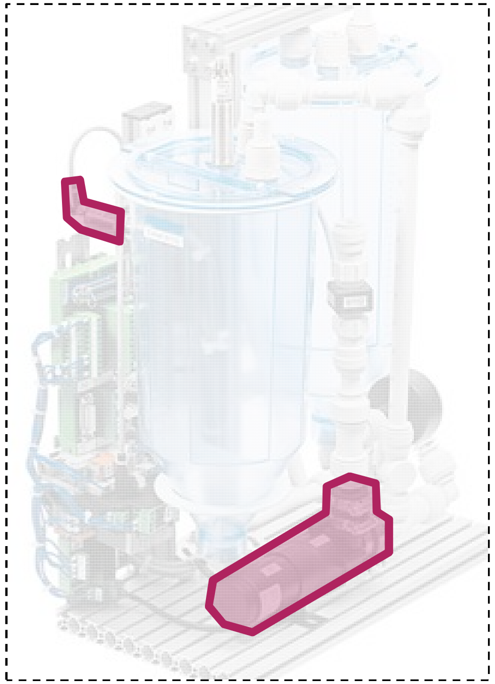
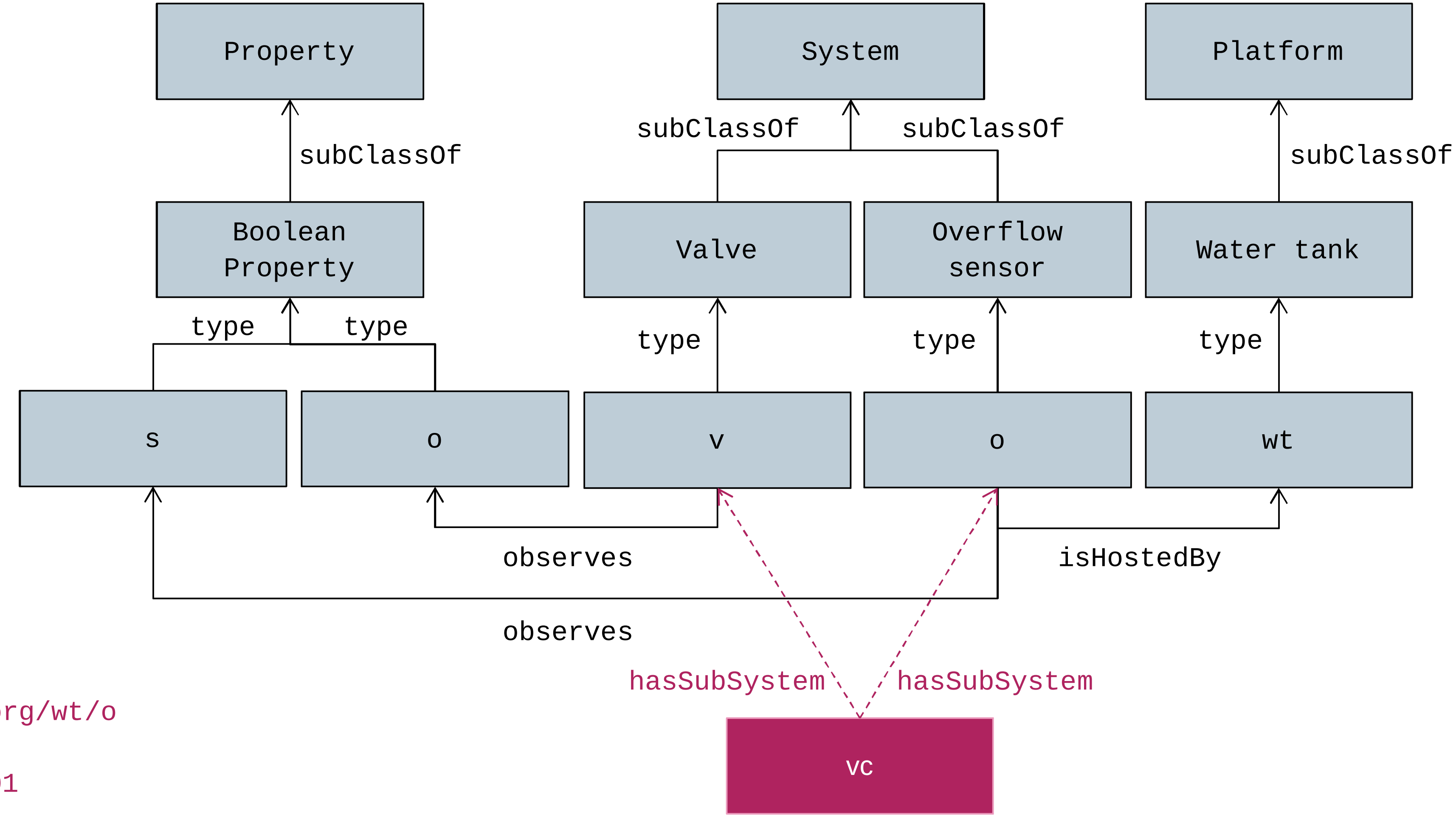
Introduction






```
def overflow = GET coap://example.org/wt/o
if (overflow)
then PUT coap://example.org/v/s 0x01
```

Related Work

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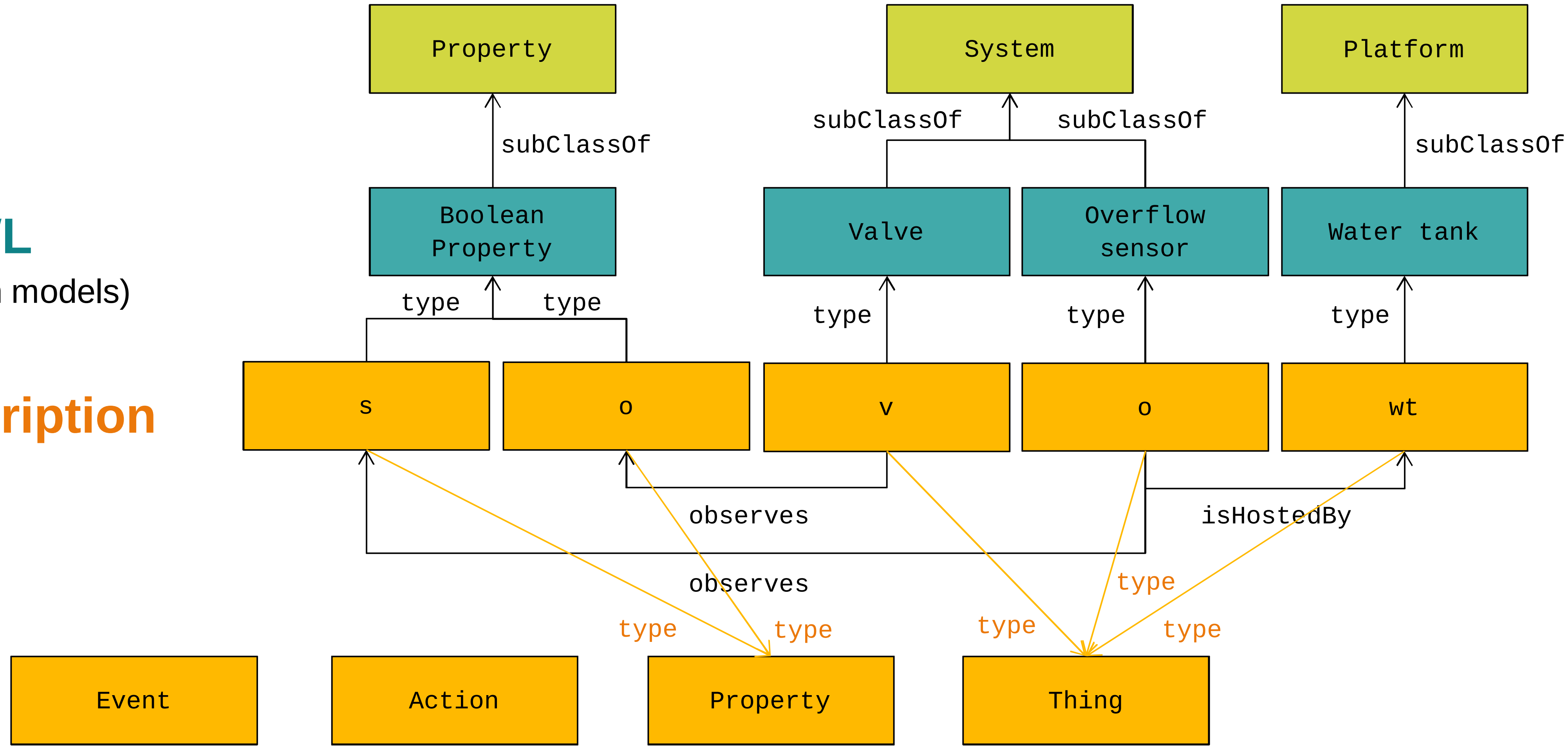
eCl@ssOWL
(and other domain models)

Thing Description



Related Work

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	Web linking	CRUD management	RDF data model	Compact messages	Vocabulary integration
HYPER/CAT	✓	✓	✓		
IETF Resource Directory	✓	✓		✓	
THINGWEB Thing Directory	✓	✓	✓	✓	✓

thingweb/thingweb-directory

Preliminaries

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Description Logic (DL)

A DL knowledge base KB is a set of `subClassOf` and `subPropertyOf` axioms between DL concept expressions like `C`, `{a}`, `(r some C)`, `(s only D)`. `C`, `D` are concept names, a is a named individual and `r`, s are role names.

Boolean conjunctive query (BCQ)

A BCQ Q is a conjunction of DL axioms with variables. A solution to Q against KB is a set of axioms S s.t. for every axiom α in S, KB $\models$ α and there exists a mapping μ from variables to concept, role or individual names in KB. We also denote S as μ(Q).

Preliminaries

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Query Abduction

Let KB be a knowledge base and Q a BCQ. Abduction is the problem of finding a knowledge base KB' s.t. there exists a mapping μ where, $KB \cup KB' \vDash \alpha$ but $KB \nvDash \alpha$, for every α in μ(Q).

Integrity constraint

Let Q, Q' be BCQs. An integrity constraint for an abduction problem is a rule $Q \rightarrow Q'$, which is said to be met if, for every solution μ(Q) against $KB \cup KB'$, $KB \cup KB' \vDash \alpha'$ (α' in μ(Q')).

Semantic Discovery Framework

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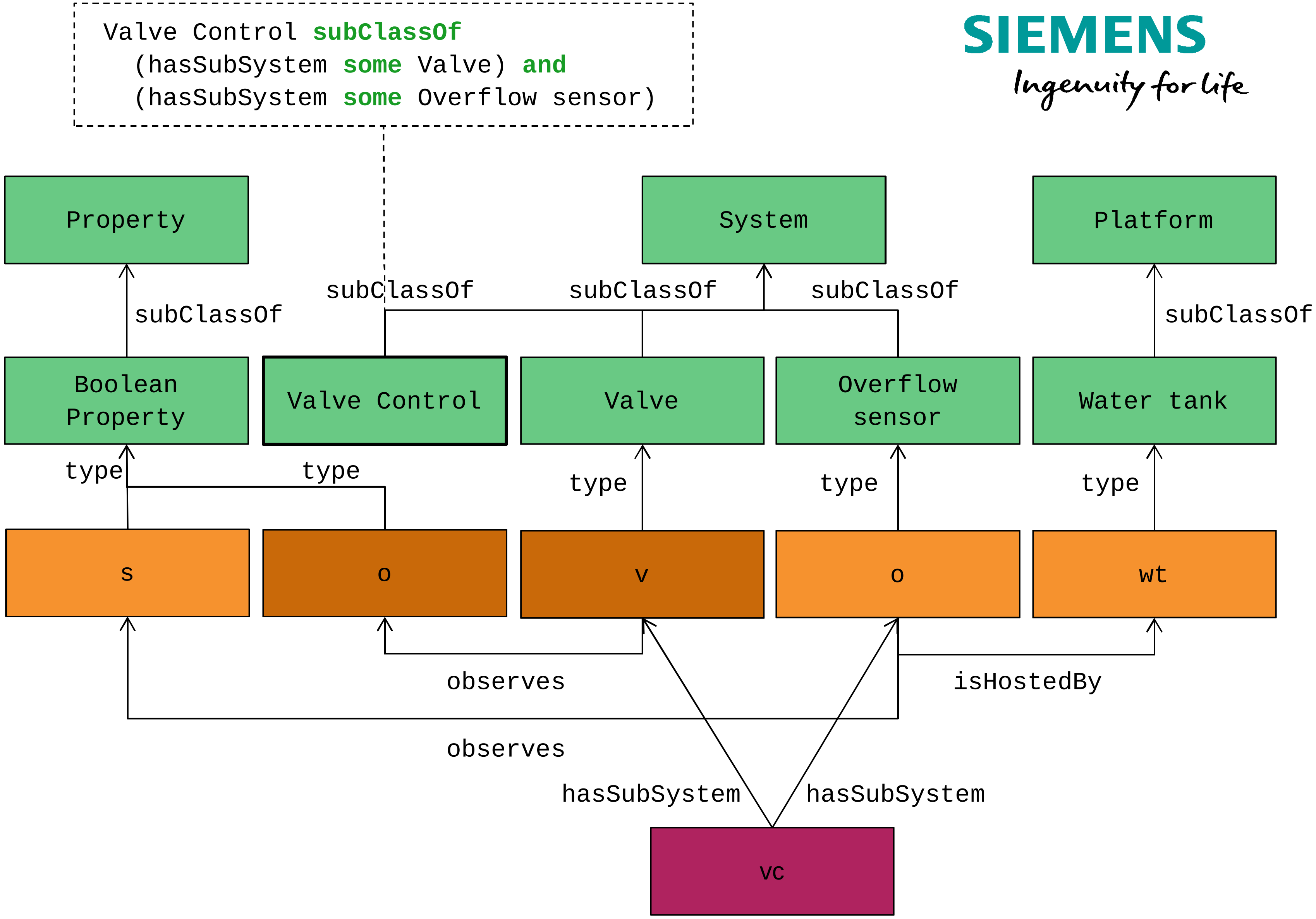
Semantic Discovery for the Web of Things

Let $\mathbf{A_1}$, $\mathbf{A_2}$, … $\mathbf{A_n}$ be (ABox) Thing Descriptions and `C` be an arbitrary set of DL (CBox) axioms. WoT semantic discovery is the abduction problem where

- KB = $\mathbf{A_1} \cup \mathbf{A_2} \cup \ldots \mathbf{A_n} \cup$ `C`,
- `Q` = `{?a}` **`subClassOf`** `System` and
- only ABox axioms are abducible
- against a set of integrity constraints `IC`.

Example



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C SSN, eCl@ssOWL

A_1 Thing Description

A_2 Thing Descripton

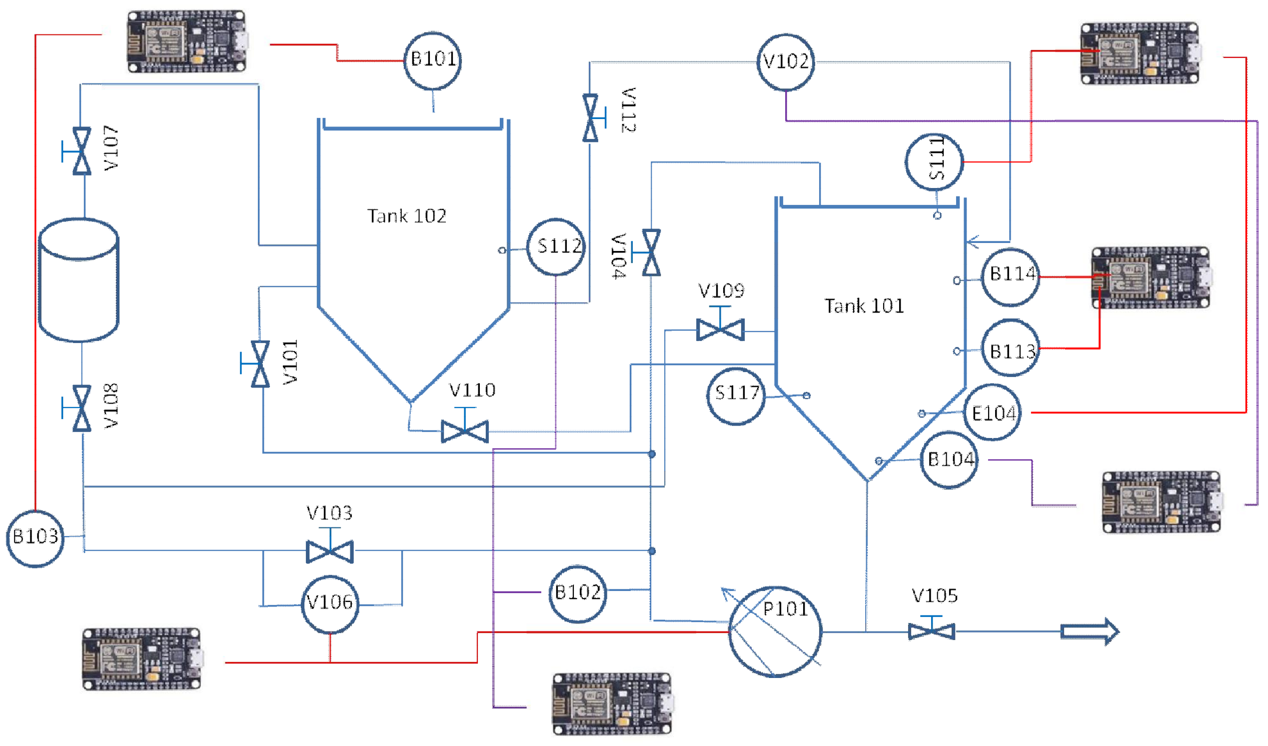
KB' *(discovery result)*

An Abductive Logic Programming Approach (I)

Restricted to the DL family **EL**$^{++}$ (OWL EL):

- Classification in polynomial time by constructing two mappings S, R s.t.:
  - if `D` in S(`C`), then **KB** ⊨ `C` **`subClassOf`** `D`
  - if (`C`, `D`) in R(`r`), then **KB** ⊨ `C` **`subClassOf`** `(r` **`some`** `D)`
- Possible formulation in terms of logic programming
  - By defining an embedding τ to turn DL axioms into FOL
  - Abduction based on the Abductive Logic Programming (ALP) framework

Experiments



B103: Pressure Sensor
V102: Pneumatic Valve
P101: Pump
V101, V103, V104, V105, V107, V108, V109, V110, V112: Valves

B101: Ultrasonic Sensor
E104: Heater
S112, S117 (Not Avail.): Float Switch

B113, B114: Level Sensor
B102: Flow Meter
S111: Float Sensor
S115/S116 : Valve closed/open switch insd. of V102

B104: Temperature Sensor
V106: Proportional Valve

Experiments

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System type	Definition
Valve control	An open/close or proportional valve is coupled to a water level sensor to avoid overflow. When water level in a tank goes above a certain threshold, the valve opens.
Pump control	A water pump is coupled to a water level sensor to refill a tank when necessary. When water level in a tank goes below a certain threshold, the pump starts.
Heater control	A temperature sensor is coupled to a heater to maintain water at a stable temperature by turning on and off heating (thermostat).
Circuit anomaly detection	A flow meter and a valve are synchronously monitored to detect potential anomaly in a circuit, e.g. when the measured flow is not null but the valve is closed.
Water circulation	A pump and a valve are synchronously activated to keep water flowing in a closed loop, e.g. for cleaning purposes.

Experiments

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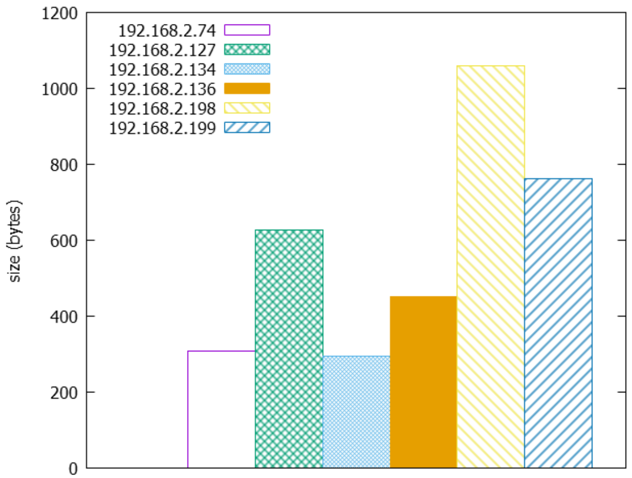
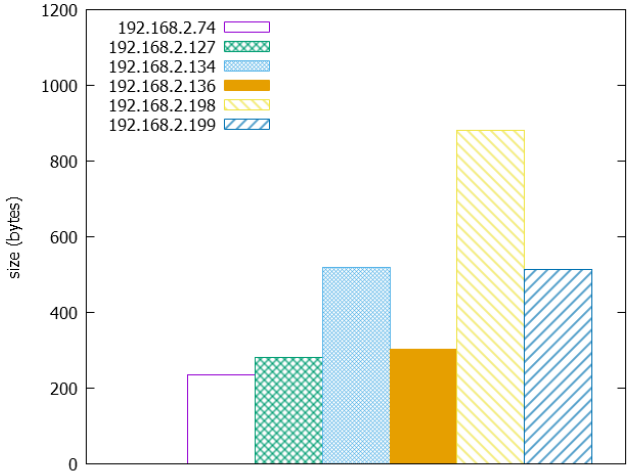
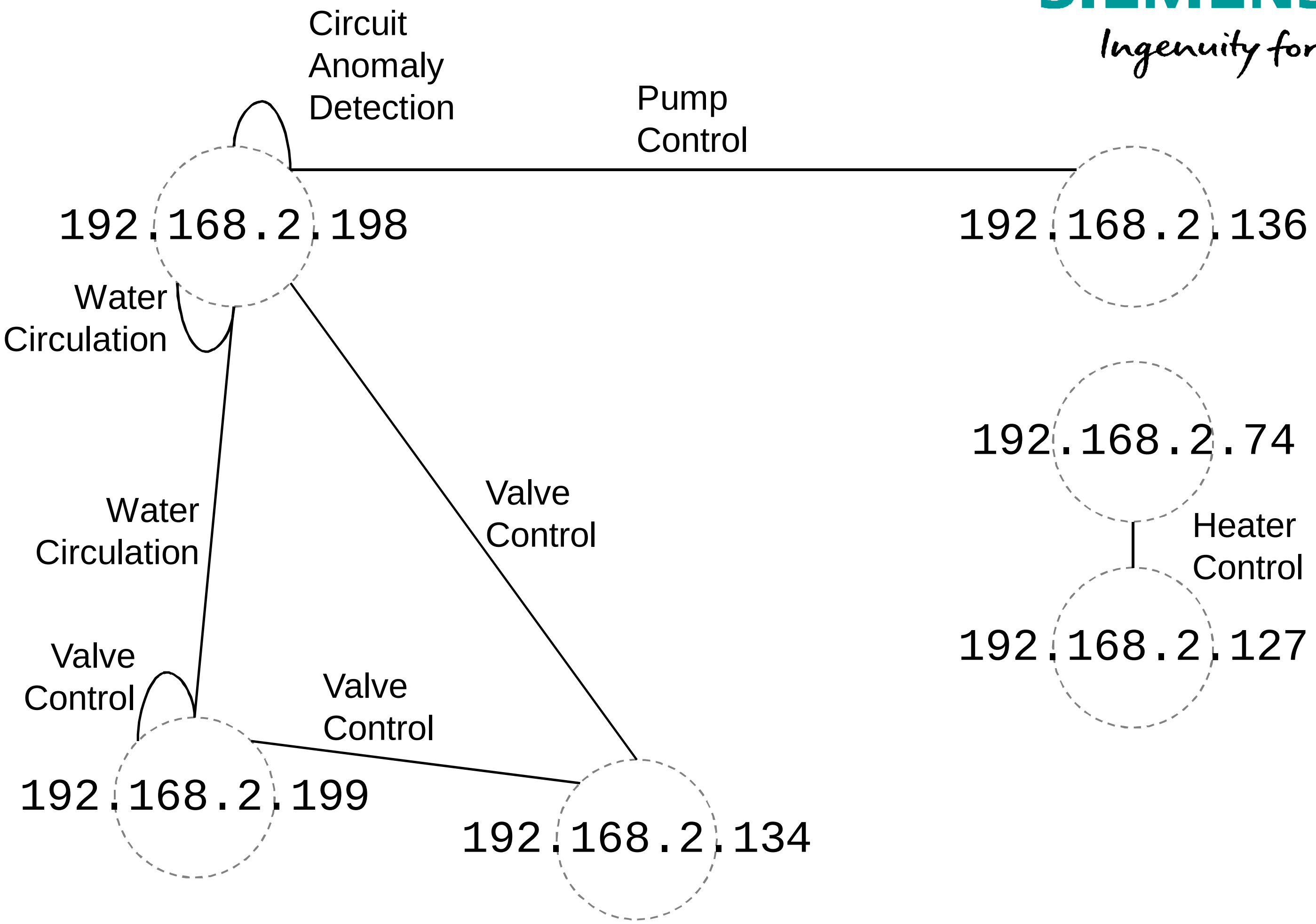


Size of $\mathbf{A_i}$ for every device i



Size of $\mathbf{E_i}$ for every device i



An Abductive Logic Programming Approach (II)

A knowledge base **KB** with fresh named entities can also be interpreted as a BCQ, which we then denote Q_{KB}.

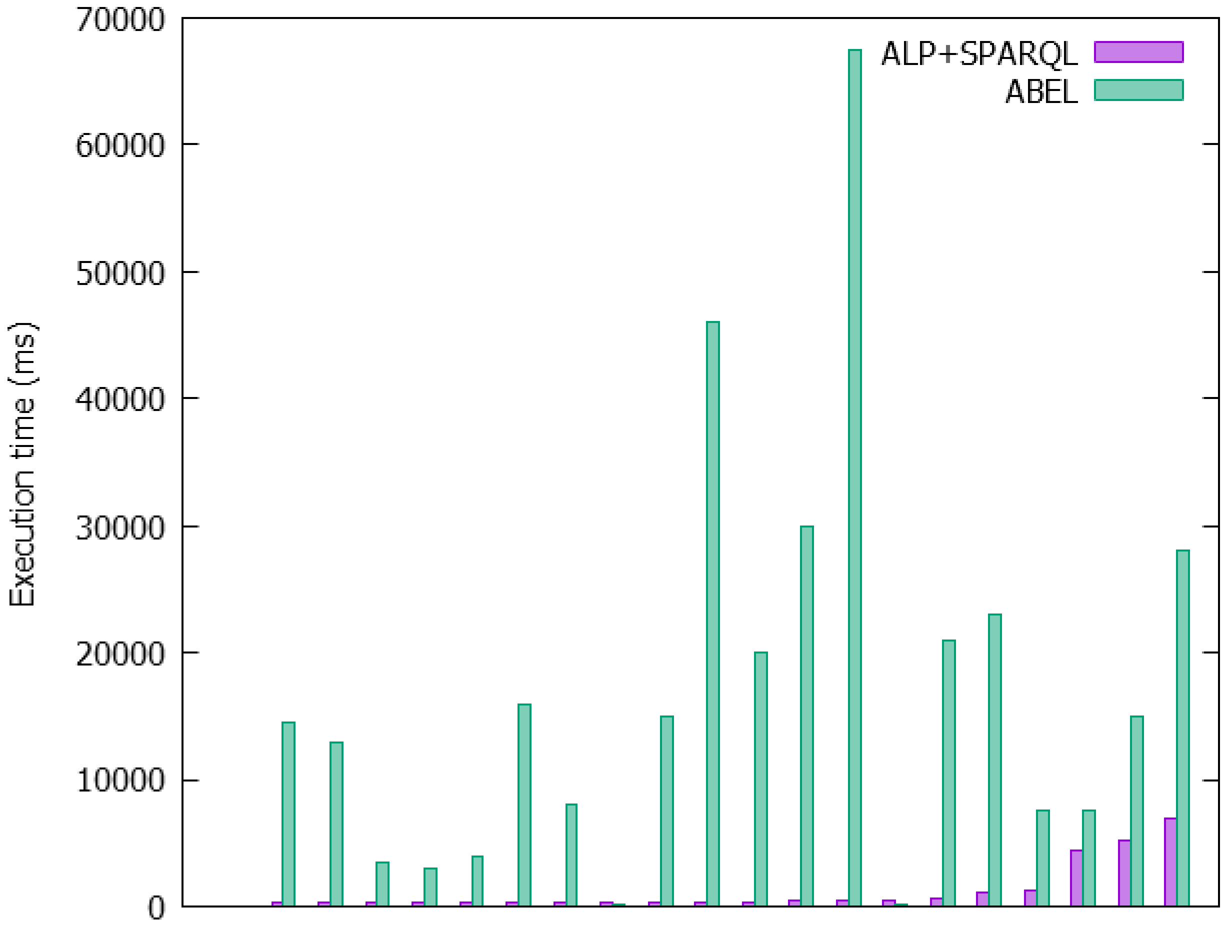
Theorem

If **KB**' is a solution to an abduction problem over $\mathbf{A_1} \cup \mathbf{A_2} \cup \ldots \mathbf{A_n} \cup C$, then there exists **KB**", solution over C only s.t. **KB**' = $\mu(Q_{KB''})$.

SPARQL optimization techniques can then be leveraged:

1. Run ALP on C only;
2. Turn every intermediary solution **KB**" into a SPARQL query $Q_{KB''}$;
3. Find every mapping μ for $Q_{KB''}$ and construct **KB**' as $\mu(Q_{KB''})$.

Experiments



LSTW abduction benchmak (derived from LUBM)

Conclusion

- Reasoning on top of WoT discovery platforms
- Supports the vision of WoT as a large-scale multi-agent system for automation applications
- Adresses scalability too
- Issue: sharing of system specifications (OWL)

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