Ontology-based generation of optimization problems for building energy management

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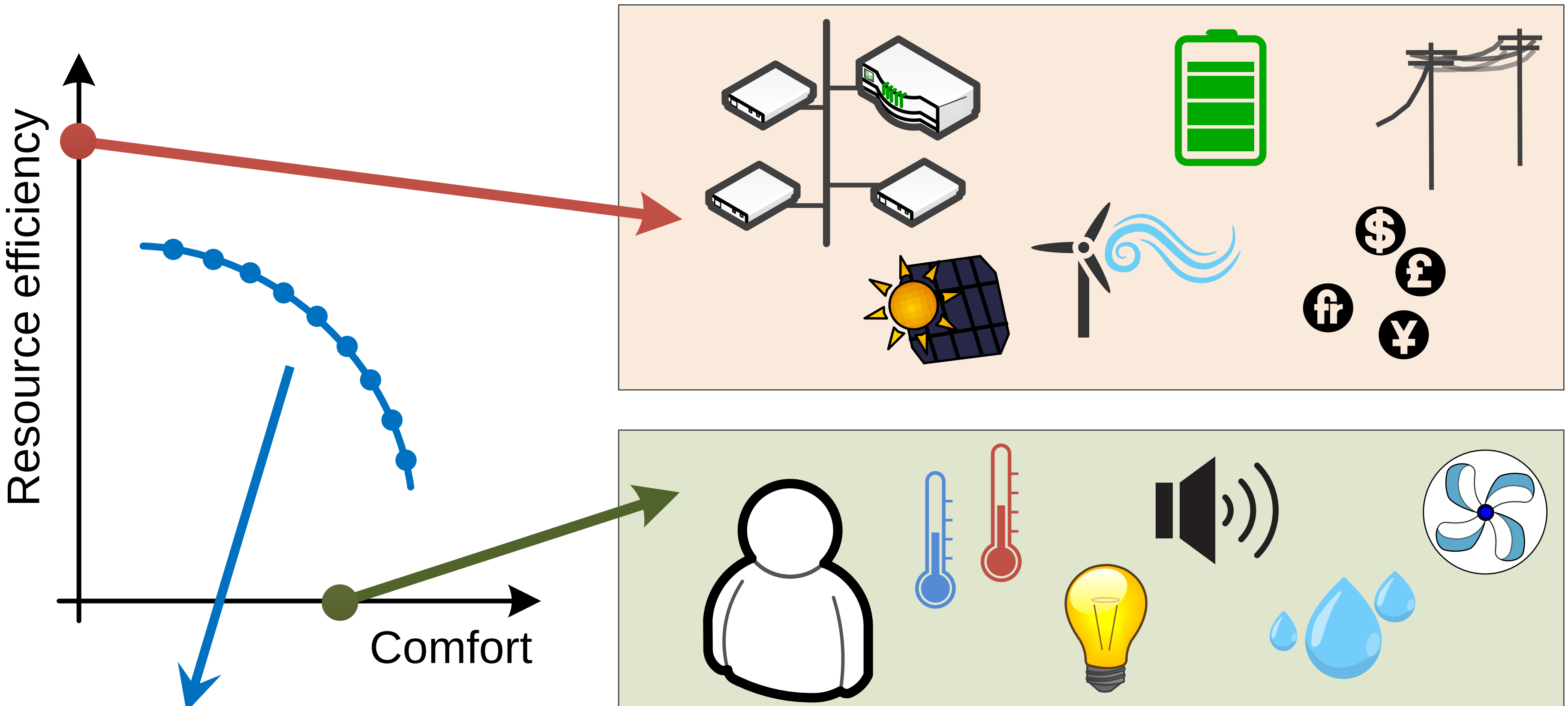
Contents

Motivation

- Reduce energy demand of buildings
  - Constructional measures
  - Operational measures

- Building energy management system (BEMS)
  - Trade-off between comfort and energy needs
  - Supported by building automation
  - Focused on different domains
  - Strategies based on heuristics and exact methods
  - Building-specific design

Motivation

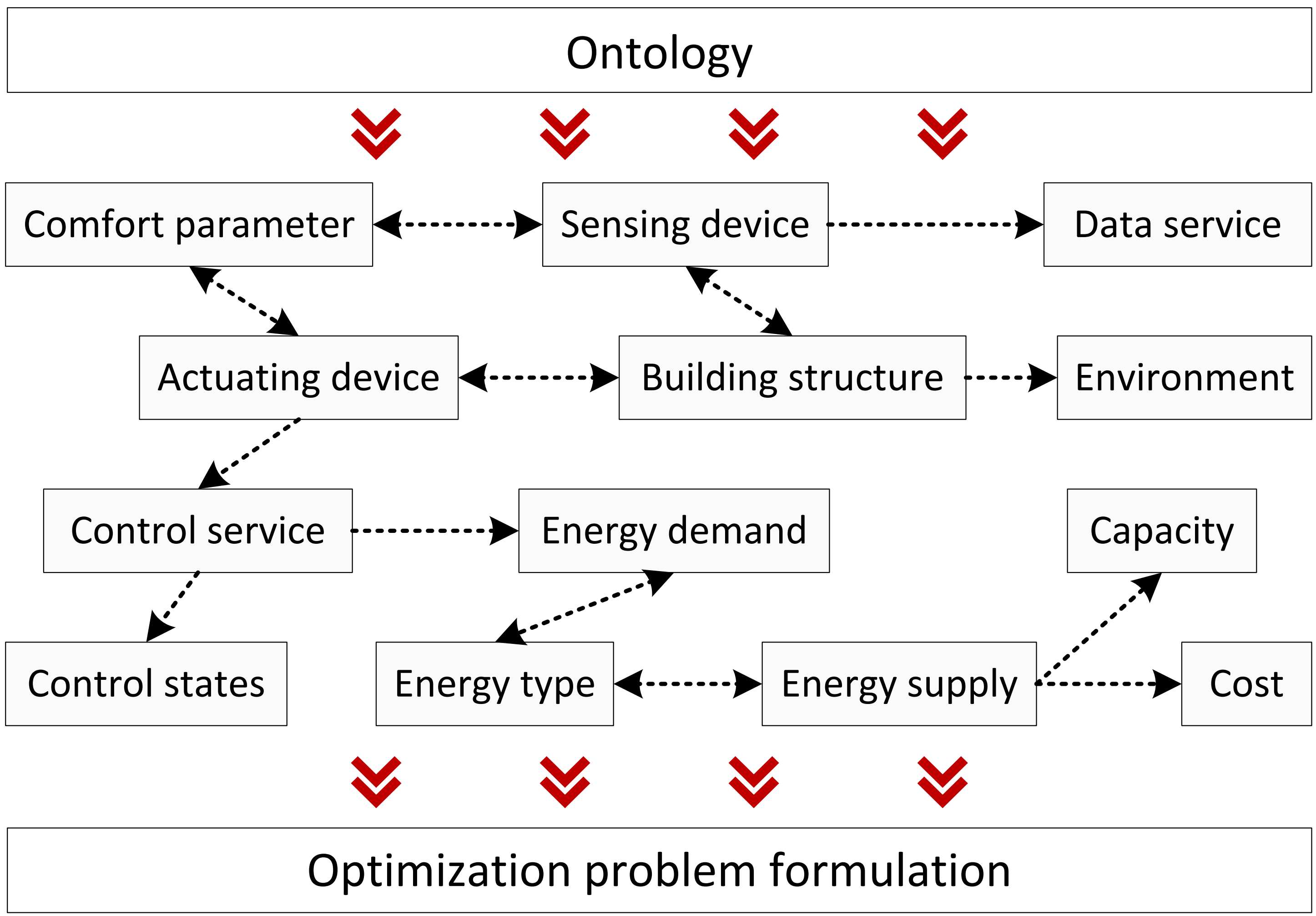


$$\min \sum_{t=1}^{n} F_t \quad \text{where} \quad F_t = \omega \cdot c_t + (1 - \omega) \cdot e_t$$

Motivation

- **General problem**
  - High building-specific design effort by domain experts
  - Limited reuse of developed models
- **Contribution**
  - Expert knowledge modeled in ontology
  - Machine-readable semantics
  - Automatic extraction process
  - Mapping to objective function and constraints
  - Reduction of manual design effort
  - Basis for further processing

Ontology-based information extraction



Automatic problem formulation

1. Mapping to objective function and its variables

$$min \sum_{t=1}^{n} F_t \quad \text{where} \quad F_t = \omega \cdot c_t + (1-\omega) \cdot e_t$$

$$c_t = \sum_{p} \sum_{z} m_{pz} \cdot \lambda_{tp} \cdot o_{tz} \cdot (v_{tpz}(\boldsymbol{l}_t, \boldsymbol{i}_t) - r_{tpz})^2$$

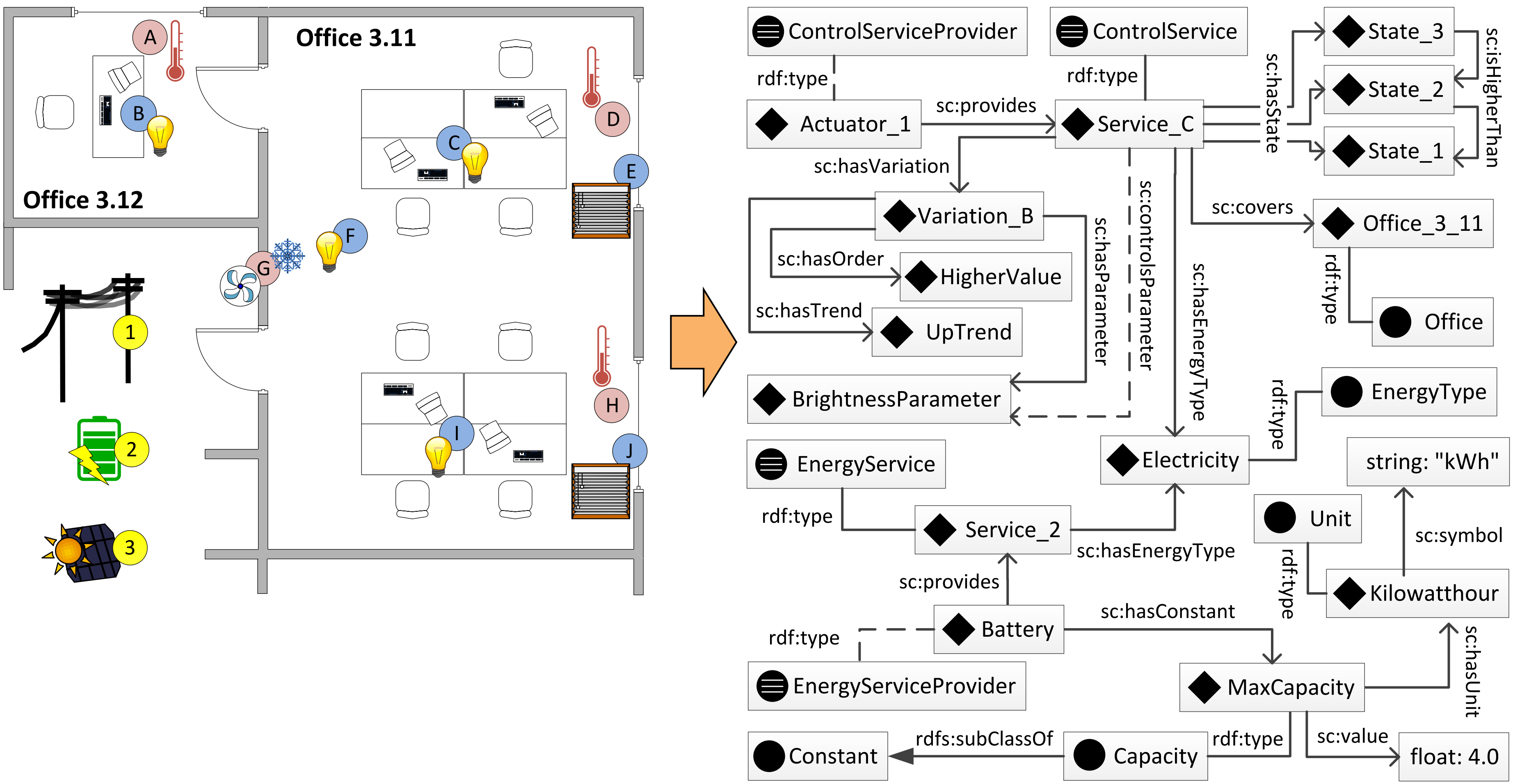
$$e_t = \sum_{g} \sum_{y} j_{gy} \cdot q_{ty} \cdot f_{ty} \cdot s_{ty} \cdot d_{tg}(\boldsymbol{l}_t, \boldsymbol{i}_t)$$

Automatic problem formulation

2. Mapping to constraints
   - Device-specific constraints (e.g. capacities)
   - Comfort-specific constraints (e.g. thresholds)
   - Default constraints for energy objective
     - Flow conservation (storages)
     - Positive storage levels
     - …
   - Examples

$$
\begin{aligned}
b_{(t-1)y} + l_{ty} \cdot a_y - s_{ty} \cdot u_y - w_y &= b_{ty} & \forall t, y \\
l_{ty} + s_{ty} &\leq 1 & \forall t, y \\
b_{ty} &\geq 0 & \forall t, y
\end{aligned}
$$

Case study and discussion



Case study and discussion

- Run extraction process based on SPARQL queries

```
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX colibri: <https://[...]/colibri.owl#>

SELECT ?device ?service ?energytype
WHERE
{
  ?service colibri:covers ?zone.
  ?service colibri:controlsParameter ?param.
  ?param rdf:type ?type.
  ?device colibri:provides ?service.
  OPTIONAL {?service colibri:hasEnergyType ?energytype}.
  FILTER (?zone = <http://www.example.org/Office_3_11>) .
  FILTER (?type = colibri:BrightnessParameter)
}
```

- Initialize control variables (e.g. p=1 for temperature)
- Create data structures for constants (e.g. occupancy)
- Map control variations (e.g. light of Service C)
- Create threshold constraint (e.g. CO_2)

Case study and discussion

- Advantages compared to traditional BEMS design
  1. Available machine-readable semantics
     - Reuse, publish, share, link, reasoning
  2. No manual development of optimization problem
     - But modeling effort to populate ontology
  3. Combined expert knowledge of different domains
     - Possible synergy effects

Conclusion

- **Ontology-based optimization problem generation**
  - BEMS design based on abstract ontology
  - Expert knowledge in machine-readable form
  - Automatic extraction and mapping process
  - Basis for further processing
- **Outlook**
  - Implementation of optimization on top
  - Extensions for white and brown goods
  - Flexibility trading in the smart grid

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Thank you!

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