# Representing and reasoning about policy for agent-based simulation

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## Contents

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## Unpacking the title

- normative models for intelligent agents
- agent architectures for normative reasoning
- applications in social simulation, security, games, legal reasoning, software engineering, data analytics
- norms ≡ policies ≡ regulations ≡ narratives ≡ requirements
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- abstraction (equational) vs. synthesis (agent-based)
- ...or top-down vs. bottom-up
- approaches emphasize different dimensions

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| accuracy | granularity | fidelity |
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- does a more complex model help understanding of complex systems?
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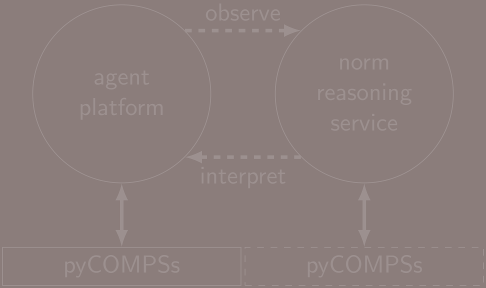
- Agent-based simulation constraints:

$$\begin{aligned}\text{sample size} &= \text{memory}\\ \text{serialization} &= \text{time}\\ \text{parameter range} + \text{dimensions} &= \text{time to sweep}\\ \text{simple (individual) models} &= \text{fidelity?}\end{aligned}$$

- Map to HPC? Overheads of many small tasks
- HPC opportunity: fidelity++ ⇒ better fit + all above



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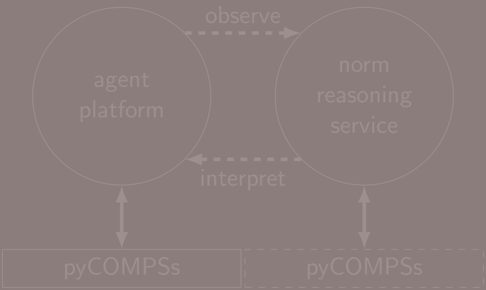

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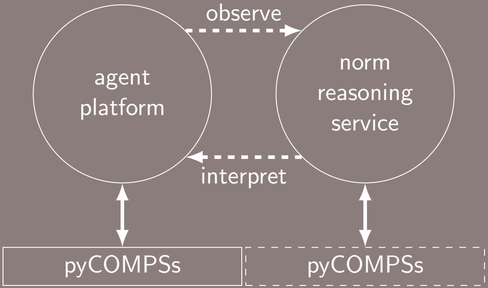

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- capture (in)formal contextualized expectations of behaviour
  - what ought (not) to be true
  - what permissions (P) or prohibitions (F) hold
  - what obligations (O) hold
  - deontic logic (Wright 1951) of F, P, O
- ⇝ knowledge representation as norms
- ⇝ governance of agents in multiagent systems
- ⇝ governance of actors in socio-cognitive technical systems

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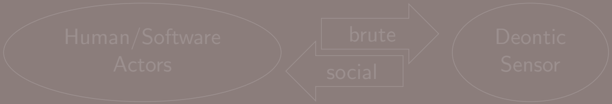
- inspiration: { economics (North 1991) / social sciences (Harré et al. 1972) / social policy (Ostrom 1990) }
  - norm = constraint on action in a context
  - norm = part of policy or regulation or requirement
  - institution = set of norms
  - institution = policy or regulations or requirements
  - associates action with (institutional) consequences
- constitutive norms (Searle 1995):

  brute facts $\rightsquigarrow$ social facts
- counts-as (Jones et al. 1996):

  real-world event $\rightsquigarrow$ institutional event



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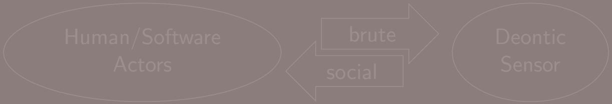

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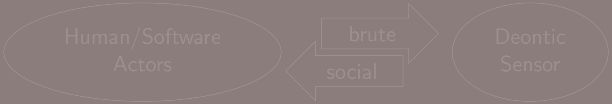

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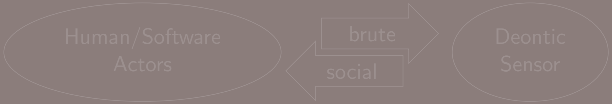

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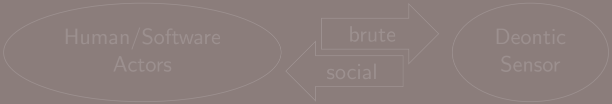

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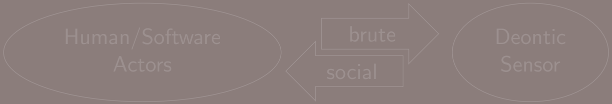

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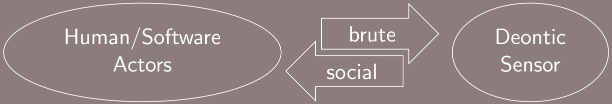

## Actions change the (institutional) world

- counts-as: $\mathcal{G}: \text{external action} \xrightarrow[\text{if(conditions)}]{\text{generates}} \text{institutional action}$

- institutional facts represented by fluents
  1. fluent $\Rightarrow$ true if present, false otherwise

     $$\mathcal{C}^{\uparrow}: \text{action} \xrightarrow[\text{if(conditions)}]{\text{initiates}} \text{fluent}$$

  2. inertial fluent:

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     good for facts true for a period with start and finish actions

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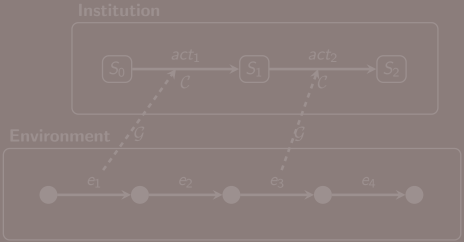
## Making it work

- mathematical model:
  sets + relations $(\mathcal{G}, \mathcal{C}) \rightsquigarrow$ labelled transition system

$$\Delta \xrightarrow{e_1} S_1 \xrightarrow{e_2} S_2 \xrightarrow{e_3} \dots$$

- conceptual model:




- generalizes to multiple, connected institutions

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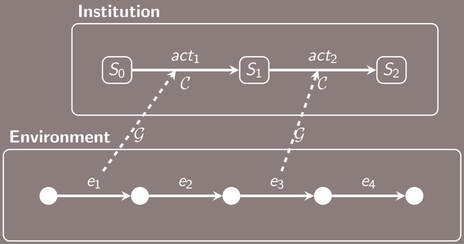


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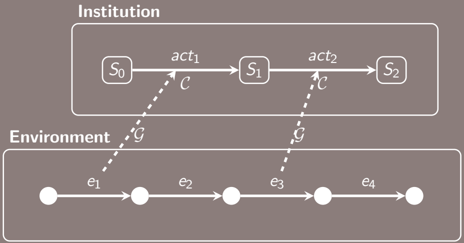


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- computational model:

  InstAL $\xrightarrow{\text{translator}}$ AnsProlog $\xrightarrow{\text{clingo}}$ answer sets $\xrightarrow{\text{visualisers}}$

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- python API to clingo (answer set solver, C++)
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- visualization tools generate images from traces

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  InstAL $\xrightarrow{\text{translator}}$ AnsProlog $\xrightarrow{\text{clingo}}$ answer sets $\xrightarrow{\text{visualisers}}$

- python front-end
- compiler: InstAL to Answer Set Programming
- python API to clingo (answer set solver, C++)
- answer sets delivered in JSON
- visualization tools generate images from traces

## Contents

## AI software siloes

- agent platform package =
  agent behaviour + environment + [institution(s)]
  see Aldewereld et al. (2016) for survey
- institutions absent or optional extra
- environment interface standard Behrens et al. (2011)
- buy the package: can't build platform from components

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- refactoring: make norm reasoning a separate component
- design pattern: blueprint for deontic sensors
- resource-oriented architecture: deploy as RESTful services
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- $\leadsto$ institution re-use
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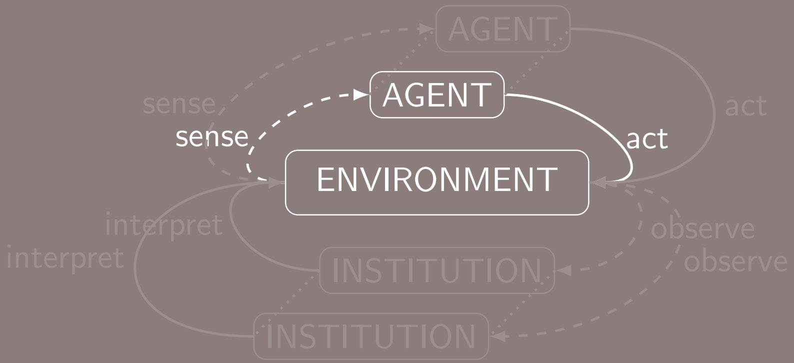
# Sense-Act + Observe-Interpret



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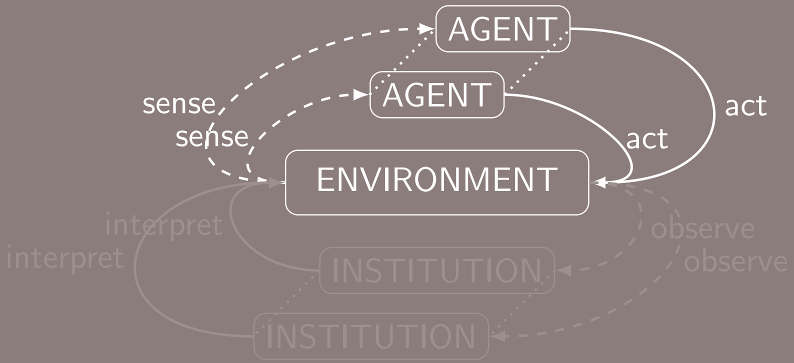

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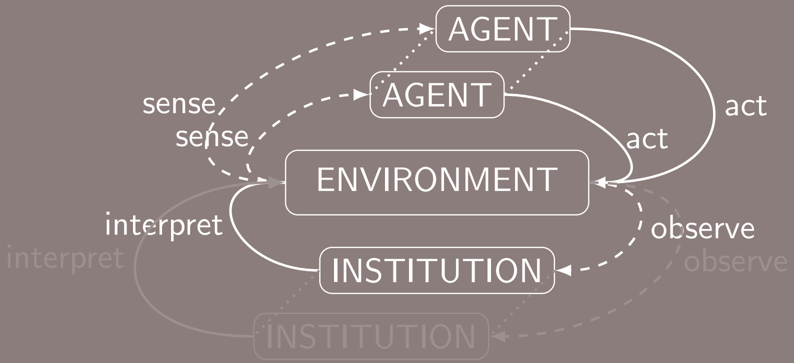

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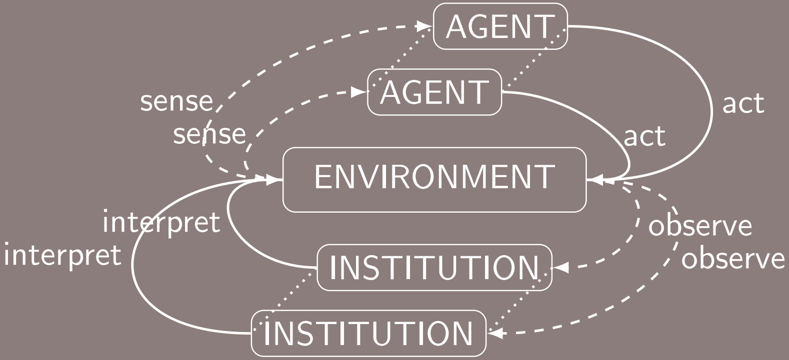
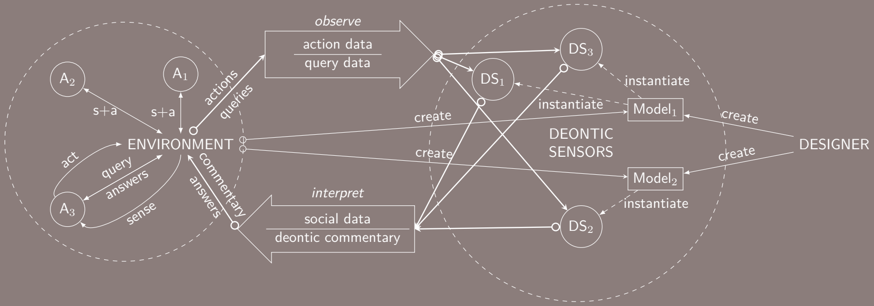
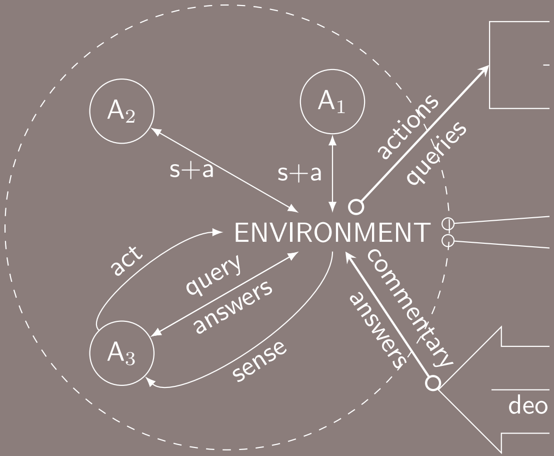


# Deontic Sensors Architecture

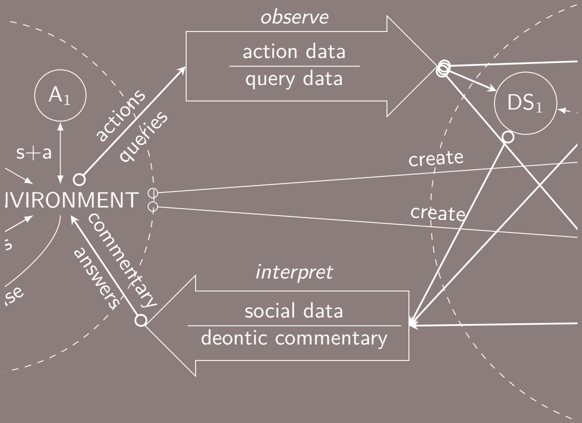



resource-oriented architecture (ROA) pattern for normative reasoning services (Padget et al. 2018)

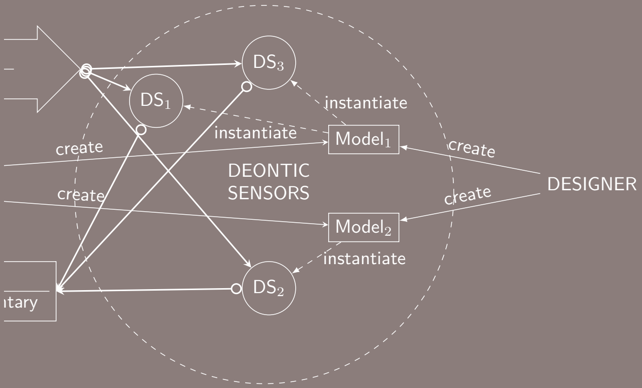
# Architecture: environment and agents



# Architecture: observe-interpret



# Architecture: deontic sensors



## ROA endpoints

1. → `POST /model/`

   *Create model from specification*

   ← `/model/`*X*

2. → `POST /model/`*X*`/instance/`

   *Create instance of model X with* `POST` *data*

   ← `/model/`*X*`/instance/`*Y*

3. → `POST /model/`*X*`/instance/`*Y*`/query/`

   *Create a query of instance Y with* `POST` *data*

   ← `/model/`*X*`/instantiate/`*Y*`/query/`*Z*

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## Instantiating the pattern

- agent platform: Jason (Bordini et al. 2007)
  - Belief-Desire-Intention (BDI) agent architecture
  - means-end reasoning
  - open-minded commitment
- normative reasoning: InstAL (Padget et al. 2016a)
  - InstAL: **Inst**itutional **A**ction **L**anguage
  - builds model in Answer Set Prolog
  - symbolic model checking
    - single event $\rightarrow$ new model state: +/- FPO +/- domain facts
    - multiple events $\rightarrow$ alternative model states
- InstAL as a service:
  - python Flask for RESTful API
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1. replace Celery with pyCOMPSs
2. replace Flask (RESTful) API with conventional API
3. extend agent platform Controller to
   - send actions to InstAL
   - receive interpretations from InstAL
   - publish interpretation for agents to perceive
4. extend agent reasoning to account for normative percepts

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# Contents

## InstAL declarations

Different types of declarations:

```
type Industry;
exogenous event discharge(WWTP,Mass);
violation event illegalDischarge(WWTP,Mass);
inst event iDischarge(WWTP,Mass);
fluent highMercury(Mass);
obligation fluent obl(
   iInform(Industry,WWTP,Mass),          % event
   iRelease(Industry,WWTP,Mass),         % deadline
   failureToInform(Industry,WWTP,Mass)); % violation
```

# InstAL rules

Generates, initiates and terminates rules:

```
discharge(WWTP,Mass) generates iDischarge(WWTP,Mass)
   if treated(WWTP,Mass,Treatment);
discharge(WWTP,Mass) generates illegalDischarge(WWTP,Mass)
   if not treated(WWTP,Mass,Treatment);
discharge(WWTP,Mass) generates illegalDischarge(WWTP,Mass)
   if highMercury(Mass);
illegalDischarge(WWTP,Mass) initiates illegalBecause(untreated,
    WWTP,Mass)
   if not treated(WWTP,Mass,Treatment);
illegalDischarge(WWTP,Mass) initiates illegalBecause(
    high_mercury,WWTP,Mass)
   if highMercury(Mass);
iDischarge(WWTP,Mass) terminates treated(WWTP,Mass,Treatment)
   if treated(WWTP,Mass,Treatment), not highMercury(Mass);
iPerform(WWTP,Mass,Treatment) initiates treated(WWTP,Mass,
    Treatment)
   if treating(WWTP,Mass);
initially
highMercury(m2),
signedContract(wwtp1,i1),
obl(iInform(i1,wwtp1,M),iRelease(i1,wwtp1,M),failureToInform(i1,
    wwtp1,M))
```

## Sample run

- grounding specification:

```
Industry: i1 i2
Mass: m1 m2
Reason: untreated high_mercury
Treatment: tk
WWTP: wwtp1 wwtp2
```

- input trace:

```
observed(inform(i1,wwtp1,m2))
observed(release(i1,wwtp1,m2))
observed(receive(wwtp1,i1,m2))
observed(perform(wwtp1,m2,tk))
observed(discharge(wwtp1,m2))
observed(release(i2,wwtp2,m1))
observed(receive(wwtp2,i2,m1))
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# Trace visualization


[{"metadata":{"answer_set_n":1,"answer_set_of":1,"cost":
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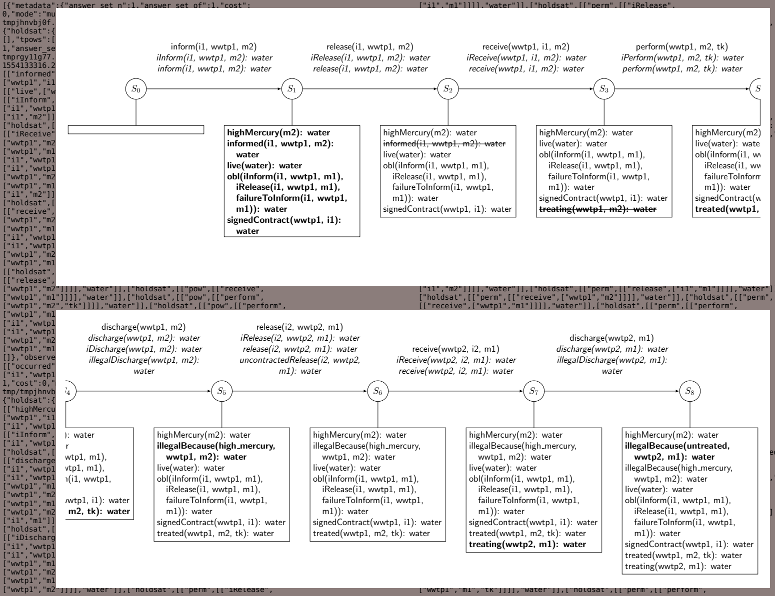
# Trace visualization



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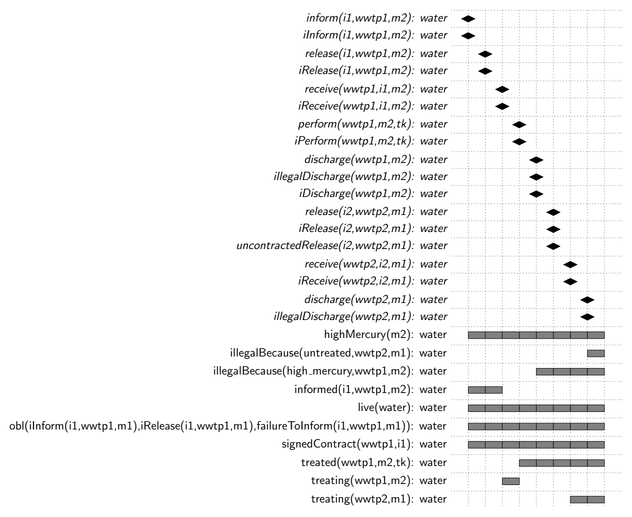


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- semantic representation of policy → model?
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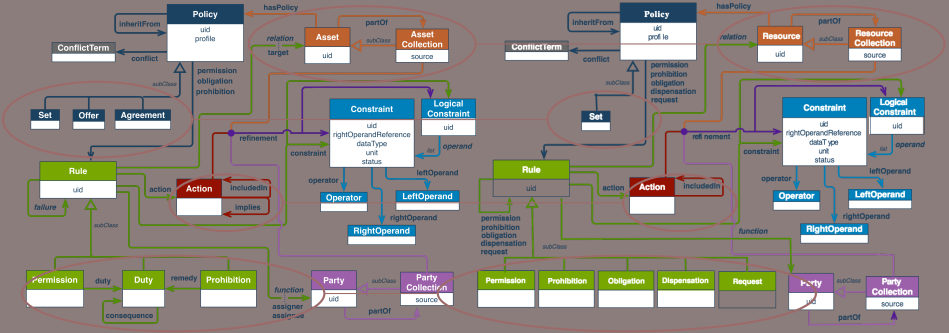

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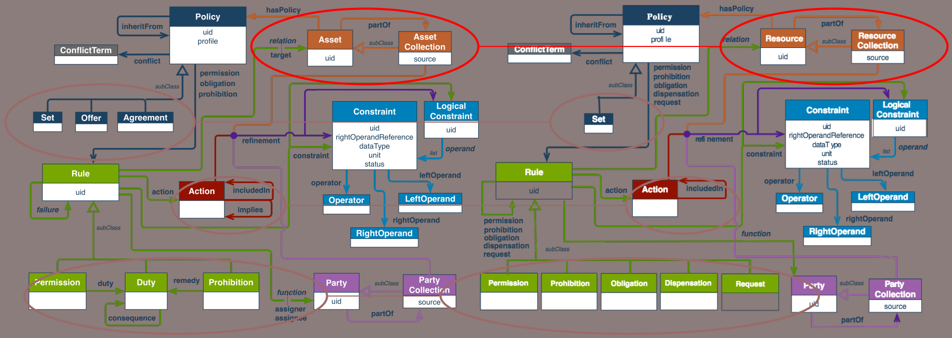

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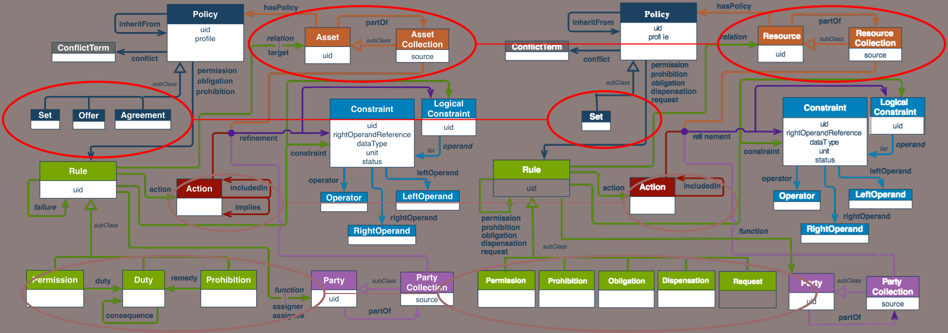

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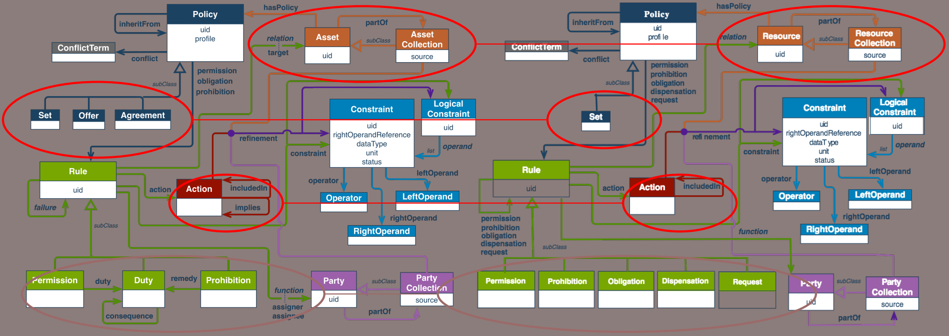

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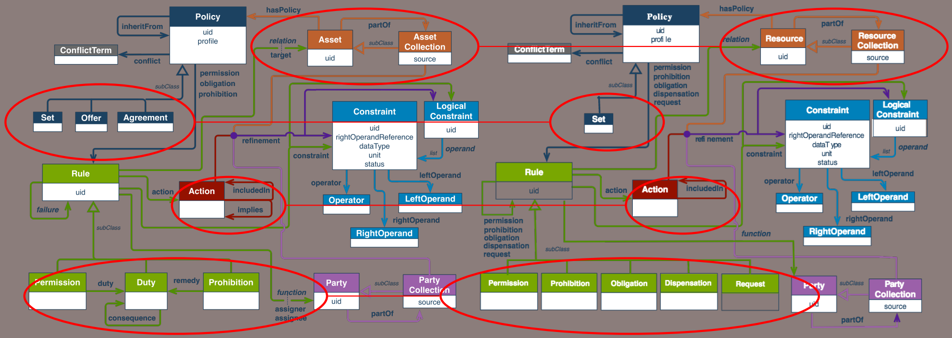

# Example ODRL policy compliance request

```
{
    "@context": "http://www.w3.org/ns/orcp.jsonld",
    "@type": "Set",
    "uid": "http://example.com/policy:01",
    "profile": "http://example.com/odrl:profile:regulatory-
        compliance",

    "request": [{
        "action": "orcp:Transfer",
        "target": "orcp:PersonalData",
        "sender": "http://example.com/TR_Ireland",
        "recipient": "http://example.com/TR_USA",
        "purpose": "orcp:KYC",
        "location": "orcp:USA",
        "legalBasis": "orcp:Consent",
        "constraint": [{
            "leftOperand": "orcp:AppropriateSafeguards",
            "operator": "eq",
            "rightOperand": { "@id": "orcp:BindingCorporateRules
                "  }
        }]
    }]
}
```

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- check business process compliance with GDPR
- H2020 SPECIAL project
- develop ODRL → InstAL translator
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- how to capture policy heterarchies?
- how to revise a policy: which is the master copy?

Acknowledgements: Marina De Vos[1], Sabrina Kirrane[2], Pablo Noriega[3], Charlie Ann Page[1], Ken Satoh[4], Harko Verhagen[5]

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