A Normative Agent-Centric Approach to Regulate Manufacturing Process

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SeReCo Autumn Workshop 2024,
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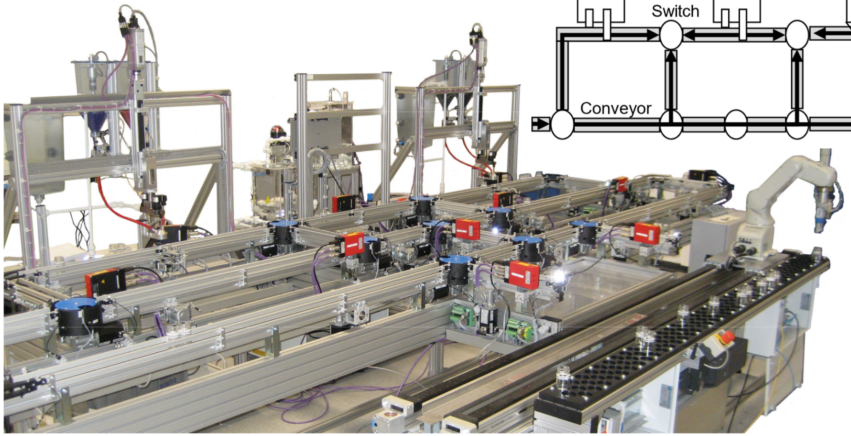
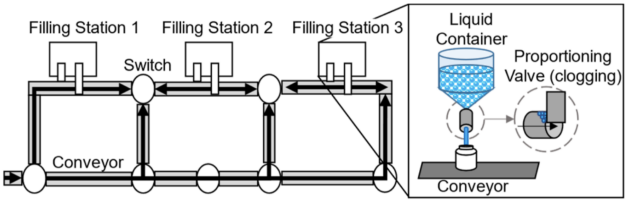
Next in Line...

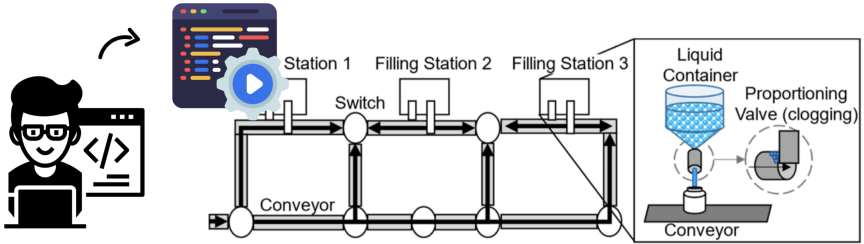
Case Study: Laboratory Plant *myJoghurt* [12]





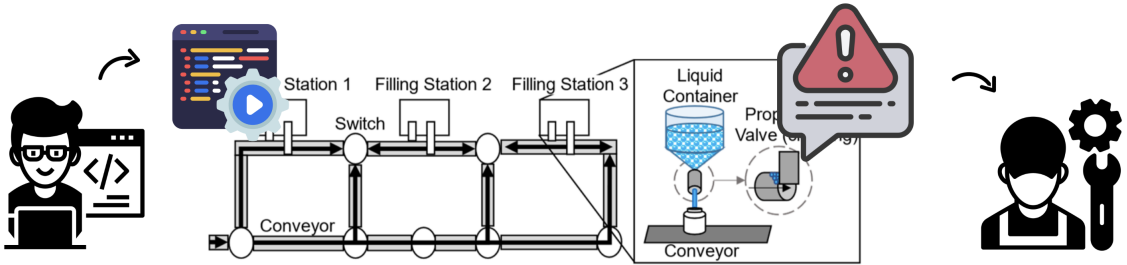
Current Main Limitations in Manufacturing Systems

- Too prescriptive: designers must *prescribe* all situations and exceptions to be handled



Current Main Limitations in Manufacturing Systems

- Too prescriptive: designers must *prescribe* all situations and exceptions to be handled
- Inflexible: it requires manual interventions to *recover* from unexpected events and *adapt* to changing situations



Objective

Hypothesis:

- **Multi Agent Systems (MAS)** enhance decentralization and flexibility in manufacturing by enabling agents to autonomously manage dynamic events
- **Normative mechanisms** guide agent's behavior while enabling self-regulation and adaptation

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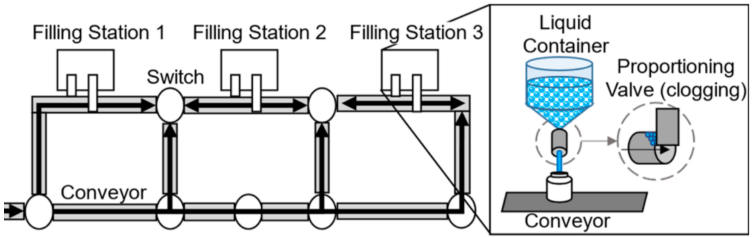
Objective

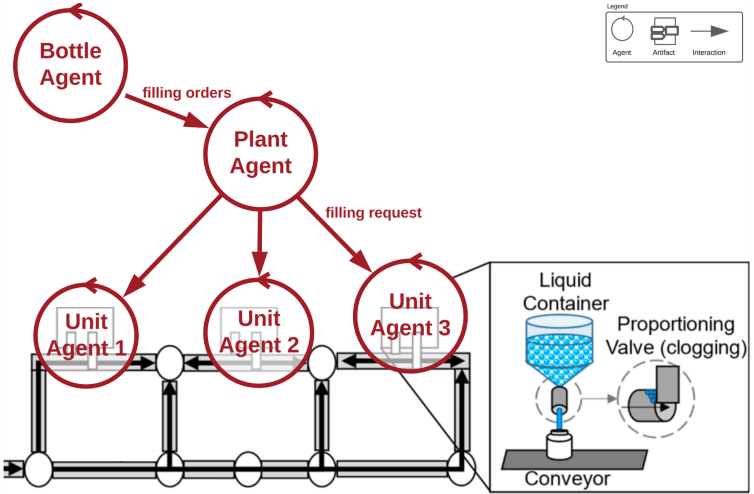
Design mechanisms for MAS to enable self-regulation and regulations self-adaptation for a trustworthy and sustainable Industry of the Future

Next in Line...

Multi-Agent Oriented Design & Programming



Multi-Agent Oriented Design & Programming



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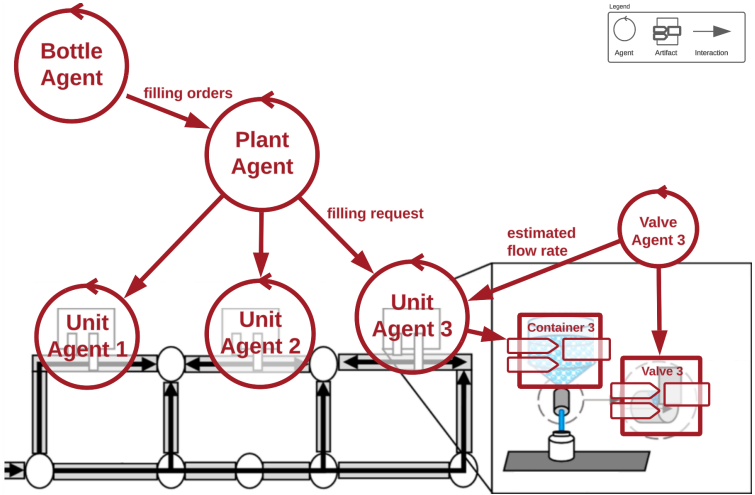


Research Questions

Design mechanisms for MAS to enable **self-regulation** and regulations **self-adaptation** for a trustworthy and sustainable Industry of the Future

Research Questions

1. How to express agent's expected behaviors and enforced behaviors?
2. How to enforce agents' expected behaviors?

State of the Art: Representation of Regulations

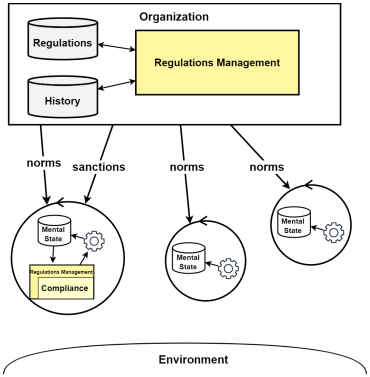
1. How to express agent's expected behaviors and enforced behaviors?

Language	Expected behaviors	Enforced behaviors
NPL, 2011	**obligations, permissions, prohibitions**	-
NoA, 2002	obligations, permissions, prohibitions	-
N-2APL, 2012	obligations and prohibitions	**sanction**

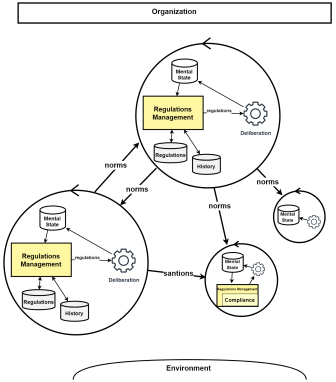
Extend NPL to NPL(s) with sanctions as a first-class abstraction

State of the Art: Mechanisms for Regulations

2. How to enforce agents' expected behaviors?



Organization-Centric Perspective

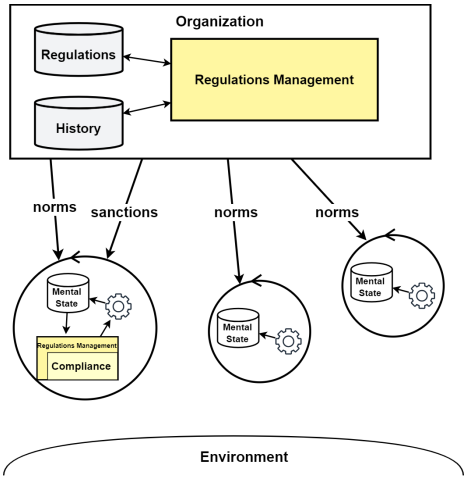


Agent-Centric Perspective

Organization-Centric Perspective on Managing Regulations

Organization-Centric Perspective:
mechanisms and representations are inside the organization, external to the agents

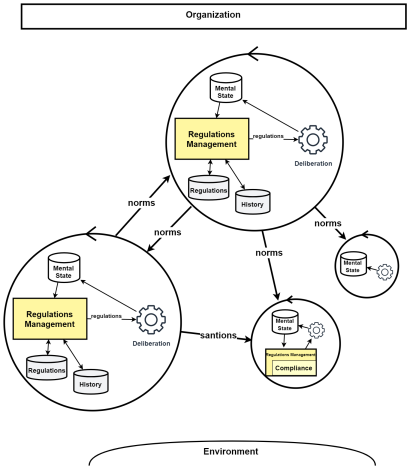
- ✓ Single point of control
- ✓ Consistency in the representation and application of the regulations
- × Agents have limited autonomy to manage regulations
- × Impractical in highly distributed systems



Agent-Centric Perspective on Managing Regulations

Agent-Centric Perspective: mechanisms and representations are internal to the agents

- ✓ Agents are autonomous to manage regulations
- ✓ Efficient in adapting to changes by addressing local needs
- ✓ Flexible with highly distributed systems
- ✗ Extra costs for coordination and alignment



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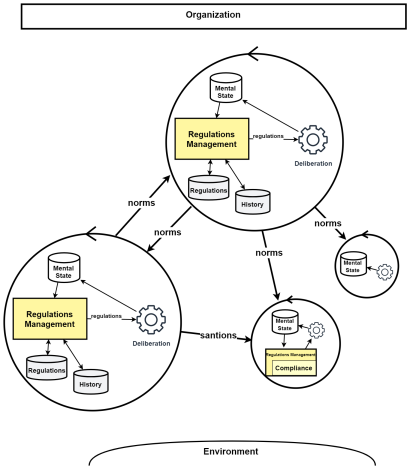


→ In this work, we focus on the agent-centric perspective to manage regulations

State of the Art: Normative Agent Architectures

2. How to enforce agents' expected behaviors?

Agent Architecture	Enforcement Mechanism
López y López et al., 2006	use secondary norms
n-BDI, 2014	always sanctions
AORTA, 2015	trigger another norm or plan
Normative MDP, 2010	inflict a cost for the violation
EMIL-I-A, 2007	**adaptive sanction**

Embed NPL(s) engine into a BDI normative agent architecture to enable agents to enforce their or the other agents' behavior

Proposed Approach

- Extend NPL to NPL(s) with sanctions as a first-class abstraction
- Embed NPL(s) engine into a BDI normative agent architecture to enable agents to enforce their or the other agents' behavior

Next in Line...

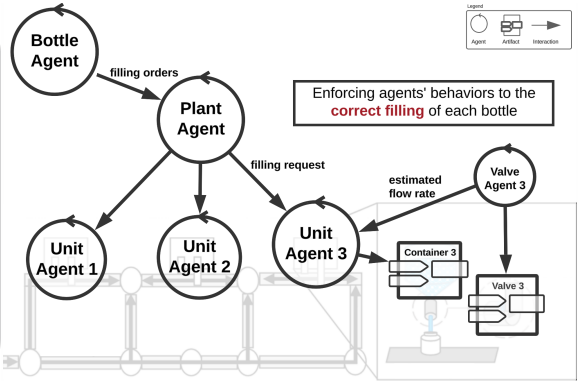
NPL

```
norm <id> : <when>
-> obligation(<who>, <while>, <what>, <deadline>) .
```

Example

```
norm n1: fill_bottle(LQ,X,MN,MX) &
    .my_name(U)
-> obligation(U, n1, fill(LQ,X,MN,MX),
    level(X,L) & (L<MN | L>MX)).

norm n2: level(V,X,L) & .my_name(U)
-> obligation(U, n2, update_factors(V,X,L),
    deviation_factor(X, "negative", _)).
```



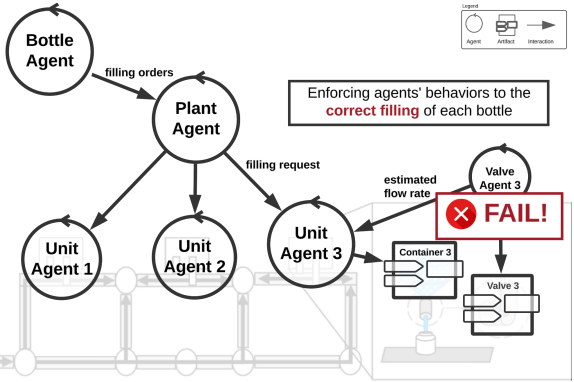
NPL(s) - Sanction Rule

```
norm <id> : <when>
-> obligation(<who>, <while>, <what>, <deadline>)

    [if fulfilled: <sanction-rule>*]
    [if unfulfilled: <sanction-rule>*]
    [if inactive: <sanction-rule>*] .
```

Example

```
norm n2: level(V,X,L) & .my_name(U)
-> obligation(U, n2, update_factors(V,X,L),
    deviation_factor(X, "negative", _))
if unfulfilled: s1(V,X), s2(V,X).
```

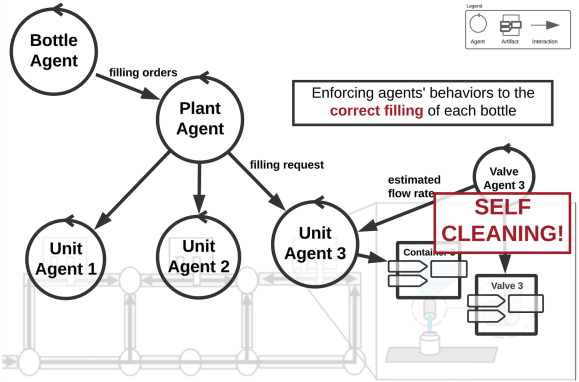


NPL(s) - Sanction

```
sanction-rule <id>(<args>): <when>
  -> sanction(<who>, <what>) .
```

Example (Self Cleaning)

```
sanction-rule s2(V,X):
    learning_factor(V,X,_,_,_,C) &
    threshold(_,T) & C>=T
   -> sanction(V, self_cleaning(X)).
```

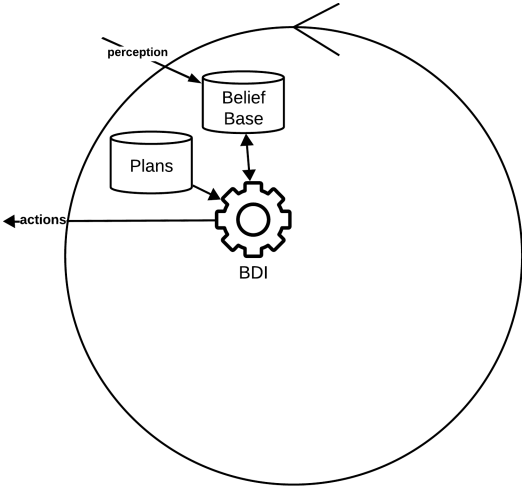


Id	Sanctioner	Target	Sanction	Condition
S2	unit	valve	Activate the **self-cleaning** procedure	The violation occurs three consecutive times

Next in Line...

Normative Agent Architecture

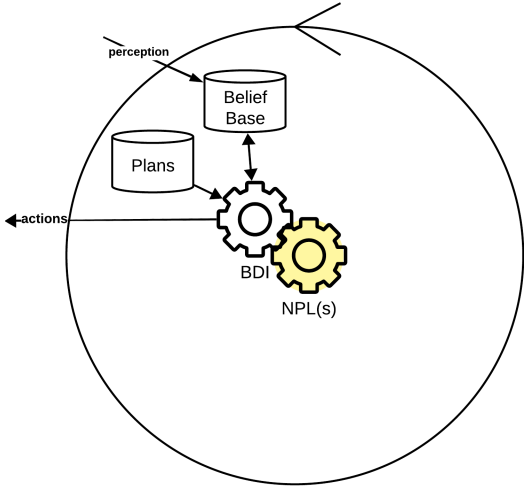
BDI JaCaMo agent architecture



Normative Agent Architecture

We extend the BDI JaCaMo agent architecture by integrating:

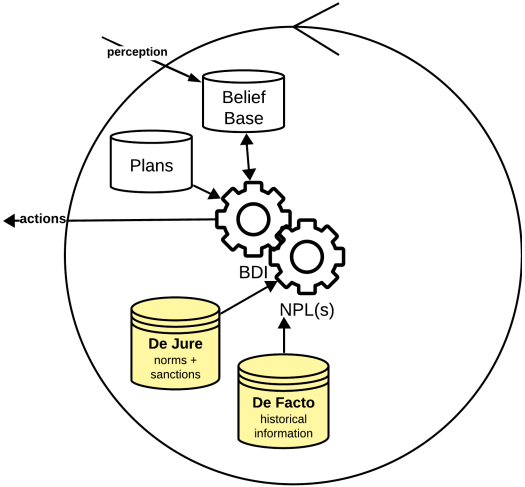
- **NPL(s) Engine**



Normative Agent Architecture

We extend the BDI JaCaMo agent architecture by integrating:

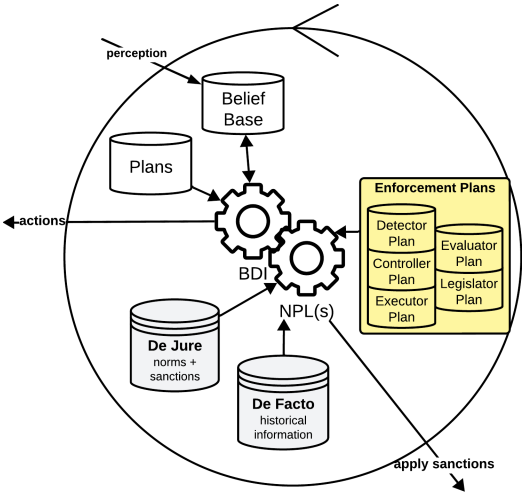
- **NPL(s) Engine**
- **De Jure**
- **De Facto**



Normative Agent Architecture

We extend the BDI JaCaMo agent architecture by integrating:

- **NPL(s) Engine**
- **De Jure**
- **De Facto**
- **Enforcement Plans**:
  - Detector
  - Evaluator
  - Executor
  - Controller
  - Legislator

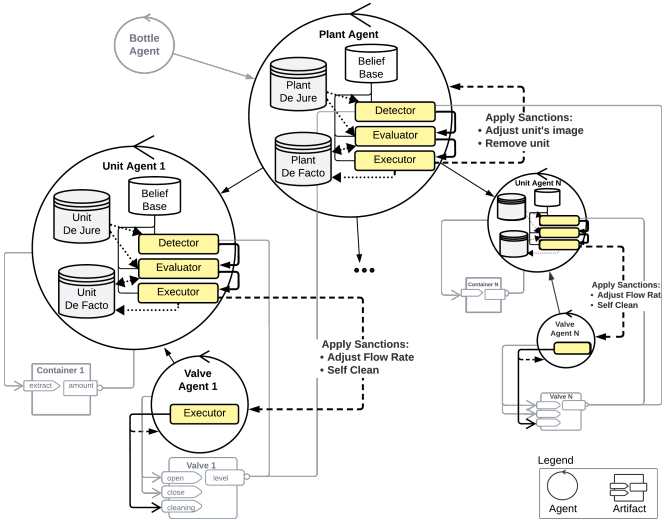


myJoghurt Case Study: Norm and Sanctions

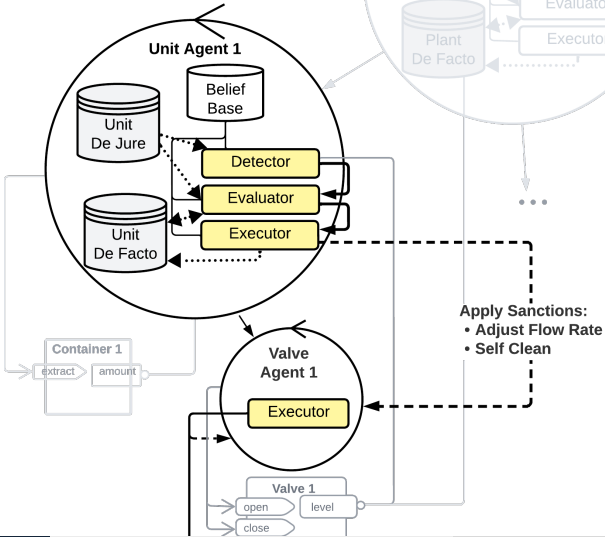
The norms refer to the correct filling of each bottle.

Sanctioner	Target	Sanction	Pre-condition
unit	valve	**Adjust** the estimated **flow rate**	The image is below a threshold
unit	valve	Activate the **self-cleaning** procedure	The violation occurs three consecutive times
plant	unit	**Adjust** the unit agent's **image**	The image is below a threshold
plant	unit	**Remove as an option** for subsequent filling orders	The violation occurs five consecutive times

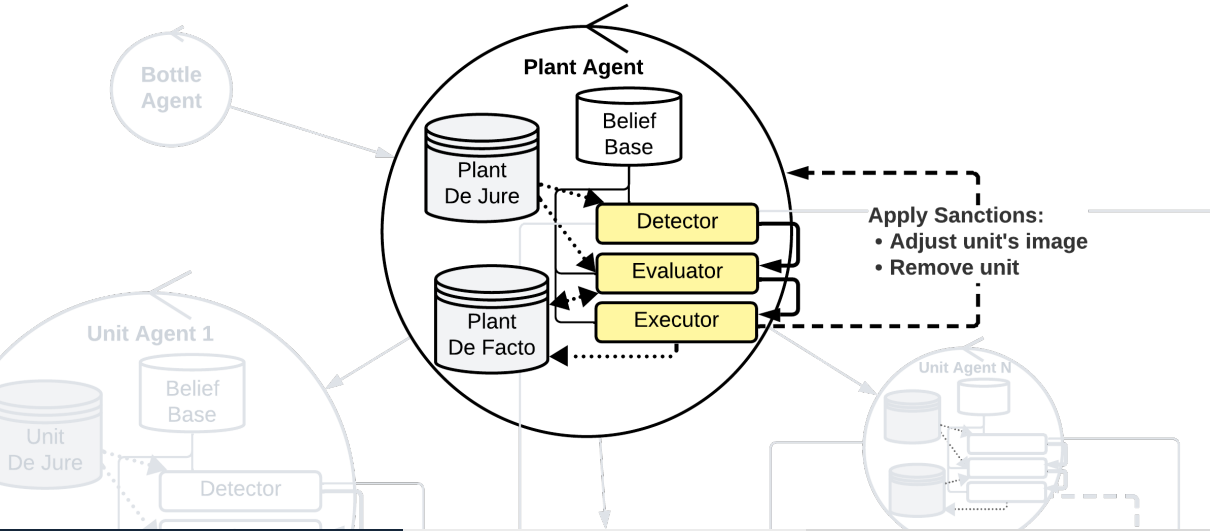
myJoghurt Case Study: MAS Architecture



myJoghurt Case Study: MAS Architecture



myJoghurt Case Study: MAS Architecture



Next in Line...

Conclusions

1. **How to express agent's expected behaviors and enforced behaviors?**

   NPL(s) with the explicit representation of norms and sanctions

2. **How to enforce agents' expected behaviors?**

   Normative agent architecture with a comprehensible and flexible module on norm enforcement and sanctions

→ Illustrate in an *industrial case study*

Future Work

- Investigate self-adaptation on norms and sanctions
- Investigate hybrid perspectives across the MAO dimensions, e.g. by connecting the sanctioning process to the organization [9], or to the environment [6]
- Explore accountability [3] and explainability [16] of the normative functioning

Thank you for your attention!

For further information:

Elena Yan, Luis G. Nardin, Jomi F. Hübner, and Olivier Boissier.
An Agent-Centric Perspective on Norm Enforcement and Sanctions.
International Workshop on Coordination, Organizations, Institutions, Norms and Ethics for Governance of Multi-Agent Systems (COINE@AAMAS2024), May 2024, Auckland, New Zealand.
`https://arxiv.org/abs/2403.15128`.

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