

# Self-Adaptive Regulation Mechanisms for a Trustworthy and Sustainable Industry of the Future

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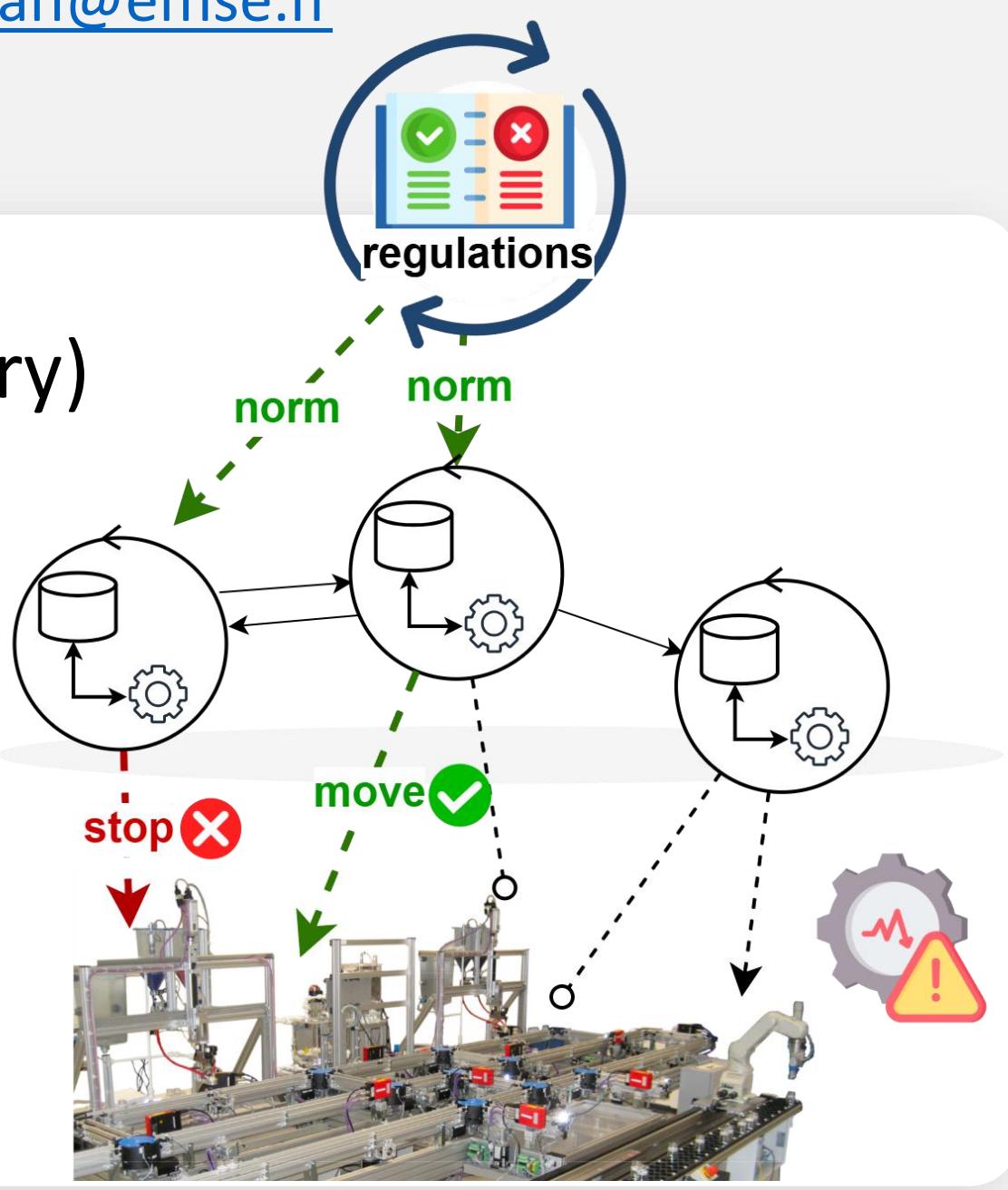
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## Motivation & Objective

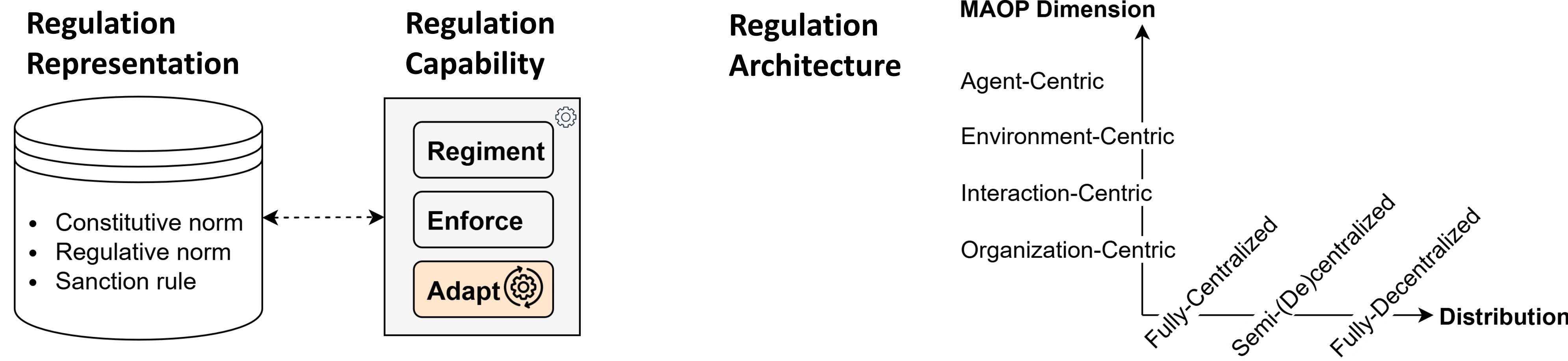
**Multi-Agent Systems (MAS)** offer the foundations to tackle complex processes in open and dynamic environments (e.g., industry)

→ Regulations are integrated in the normative MAS to guide agents' behaviors, but ensuring that these agents behave in *trustworthy* and *sustainable* ways requires effective **self-adaptive regulation mechanisms** to cope with dynamic environments

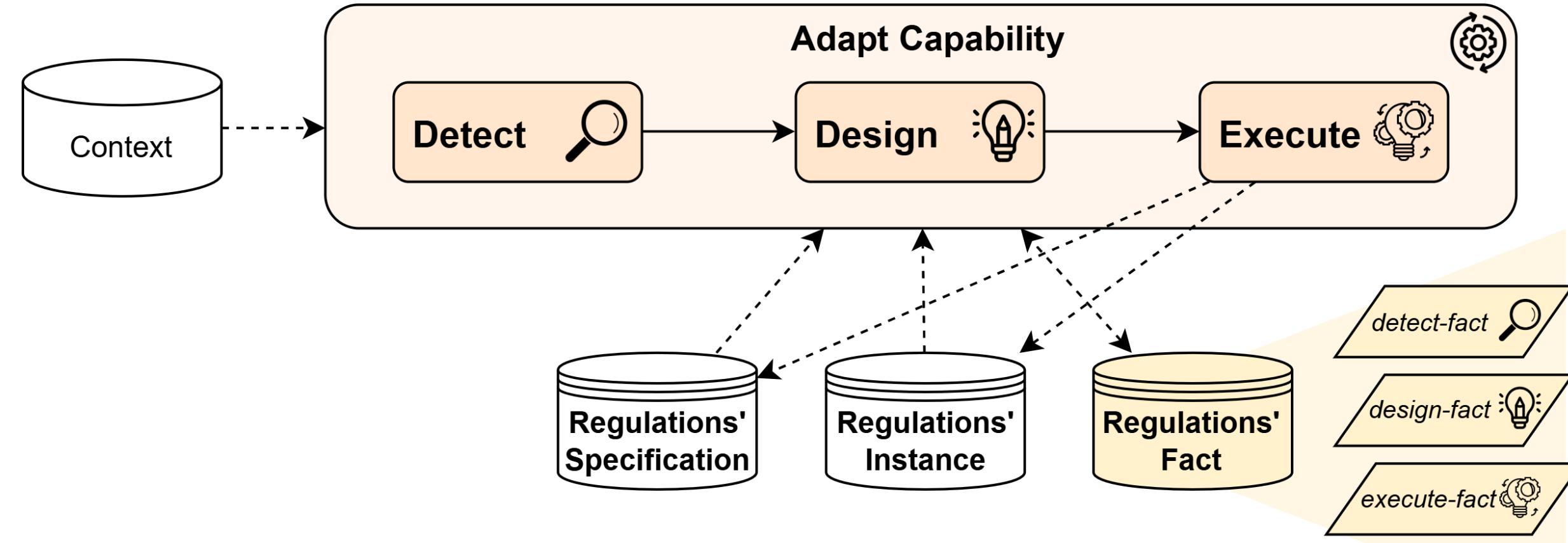
**Objective:** Design a *self-adaptive regulation management system* in normative MAS



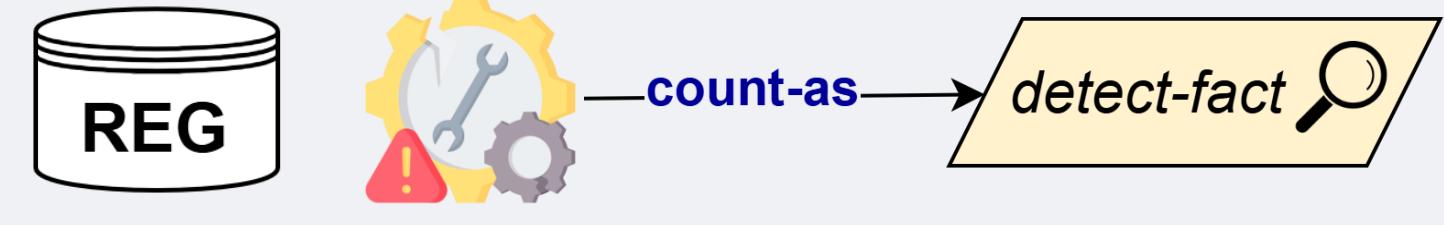
RQ1: What are the core elements of a *regulation management* system? [4]



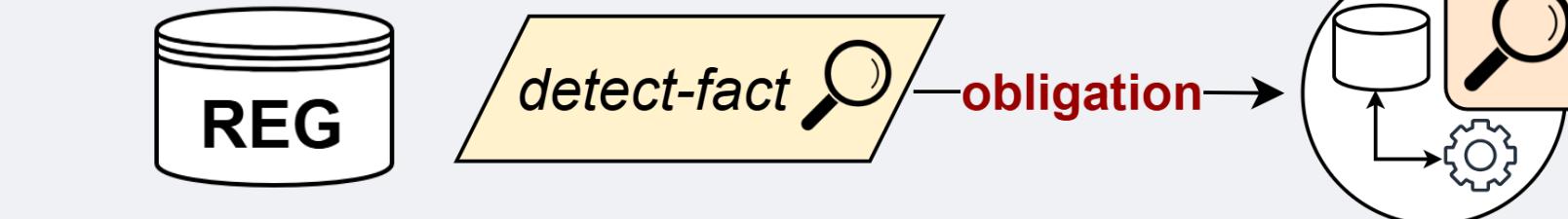
RQ2: What are the core elements for enabling *adaptation* in the regulation management system?



**Approach:** Use the same regulation management concepts and engine for enabling regulation adaptation



→ **Constitutive norms** for creating *adaptation facts* stating the corresponding adaptation requirement



→ **Regulative norms** for guiding agents in the *adaptation* capabilities of the adaptation process

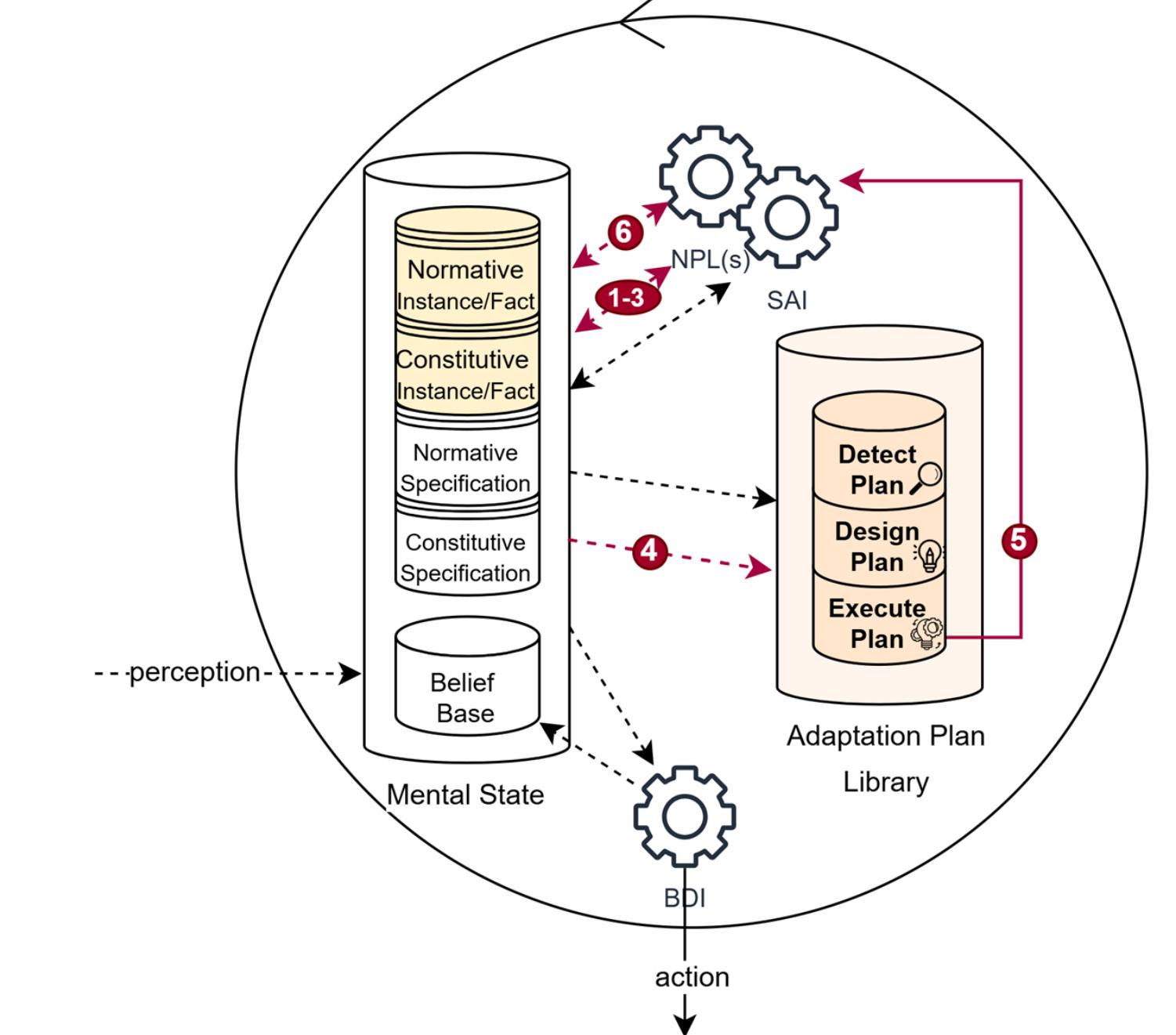
RQ4: How to integrate the self-adaptive regulation management system to support a *sustainable Industry of the Future*?

### Regulation Representation

- Situated Artificial Institutions **SAI** [2] for programming constitutive norms  
 $id : x \text{ count} - \text{as } y \text{ while } c$
- Normative Programming Language **NPL(s)** [3] for programming regulative norms and sanction rules  
norm  $id : \varphi \rightarrow \psi$  [if  $\phi : sr_i(args)$ ].  
sanction–rule  $sr_i(args) : p \rightarrow \text{sanction}(\alpha, \gamma)$ .

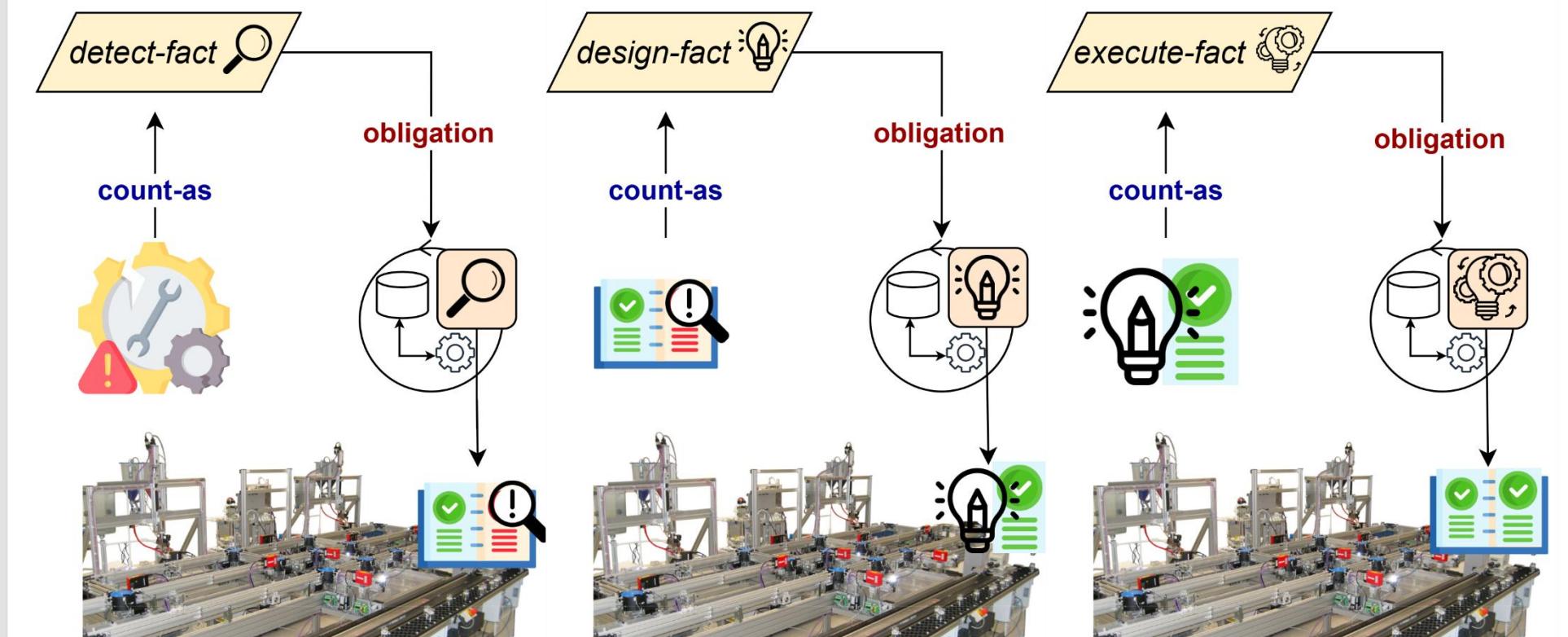
### Agent-Centric Regulation

BDI agent architecture in JaCaMo [1] integrated with SAI and NPL(s) engines and the adaptation capability



Regulation Representation → Agent's beliefs  
Regulation Capability → Agent's plans (enforce and adapt)

### Regulation Adaptation



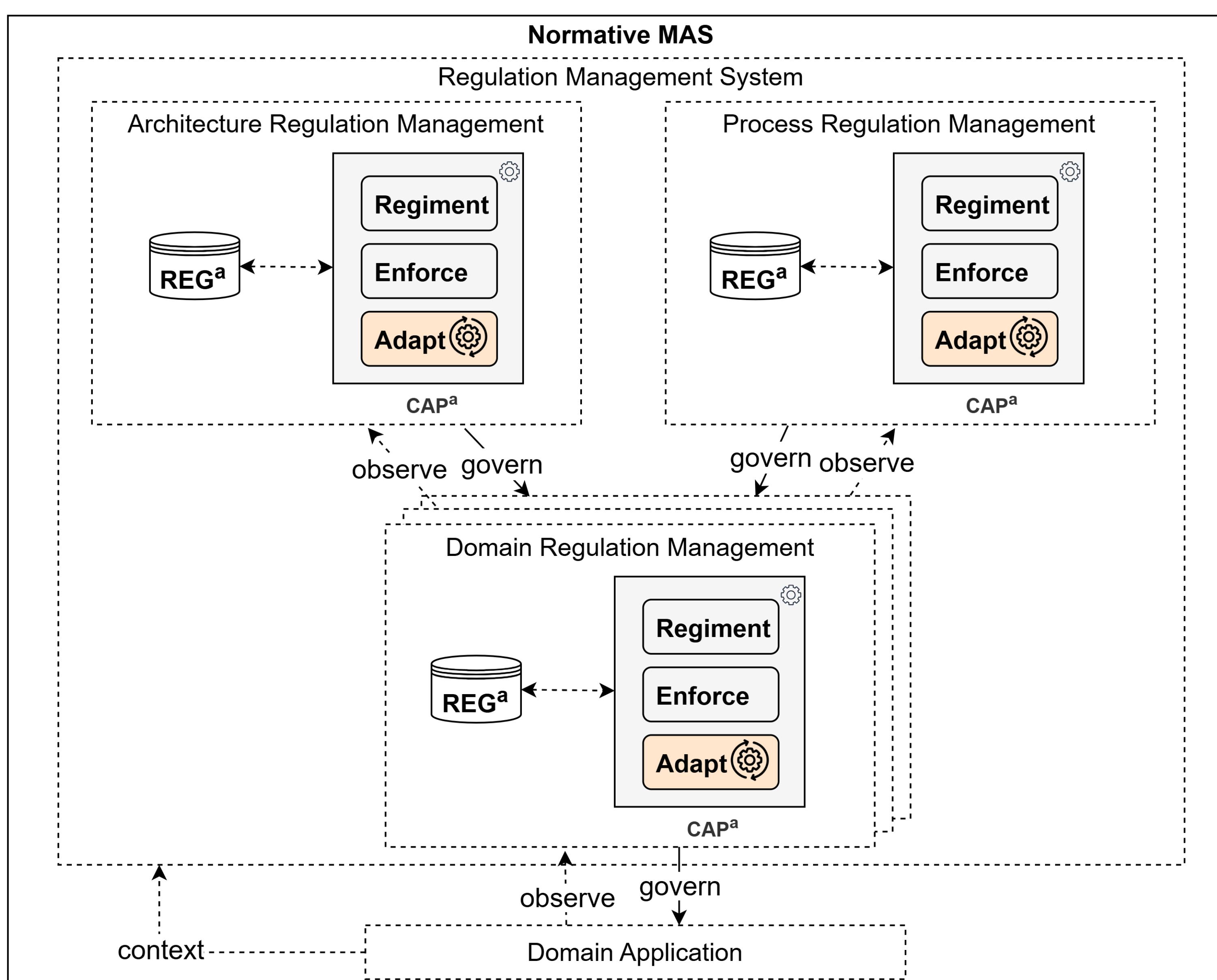
failure count-as detect-fact  
detect-fact → obligation(alice, detect-goal)  
detected count-as design-fact  
design-fact → obligation(bob, design-goal)  
designed count-as execute-fact  
execute-fact → obligation(carlos, execute-goal)

### Future experiments

- Adaptation of the capability process and architecture
- Explainability

Regulation management can be used to govern and **adapt**

- Domain application
- Regulation process
- Regulation architecture



RQ3: How to support *trustworthiness* in the self-adaptive regulation management?

Explaining the agent's mental state at *multiple levels* (i.e., implementation, design, domain) for *different stakeholders* (e.g., developers, designers, end-users) [5]

→ Extend it to **explain** the agent's representation of **regulations** and **regulation management decisions**

## References

- [1] Boissier, O., Bordini, R. H., Hubner, J., & Ricci, A. (2020). Multi-agent oriented programming: programming multi-agent systems using JaCaMo. Mit Press.
- [2] De Brito, M., Hübner, J. F., & Boissier, O. (2019). Coupling the normative regulation with the constitutive state management in Situated Artificial Institutions. The Knowledge Engineering Review, 34, e21.
- [3] Yan, E., Nardin, L. G., Hübner, J. F., & Boissier, O. (2025). An agent-centric perspective on norm enforcement and sanctions. In International Workshop on Coordination, Organizations, Institutions, Norms, and Ethics for Governance of Multi-Agent Systems (pp. 79-99). Cham: Springer Nature Switzerland.
- [4] Yan, E., Nardin, L. G., Boissier, O., & Sichman, J. S. (2025). A unified view on regulation management in multi-agent systems. In International Workshop on Coordination, Organizations, Institutions, Norms, and Ethics for Governance of Multi-Agent Systems.
- [5] Yan, E., Burattini, S., Hübner, J. F., & Ricci, A. (2025). A multi-level explainability framework for engineering and understanding BDI agents. Autonomous Agents and Multi-Agent Systems, 39(1), 9.