

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

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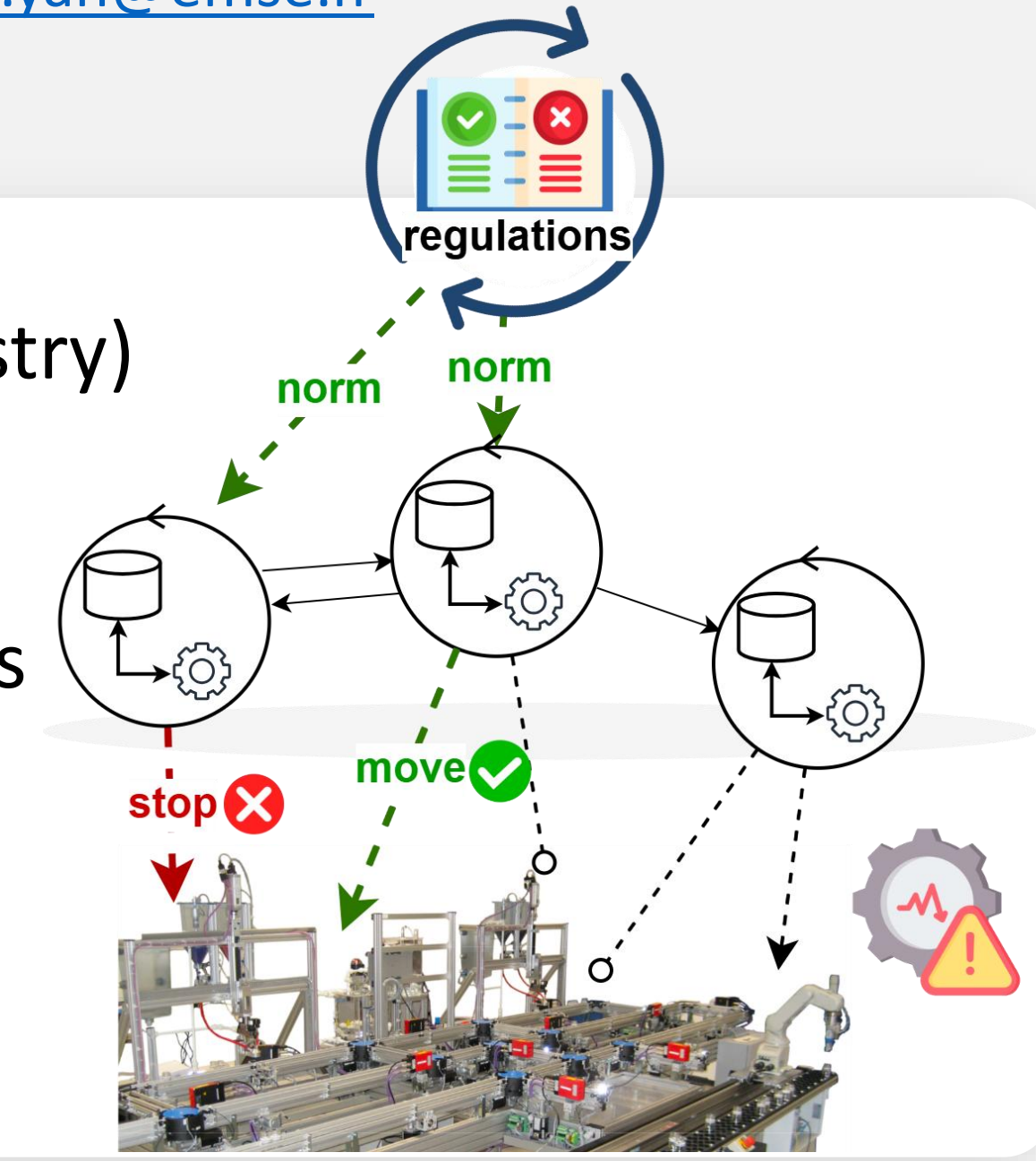
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Motivation & Objective

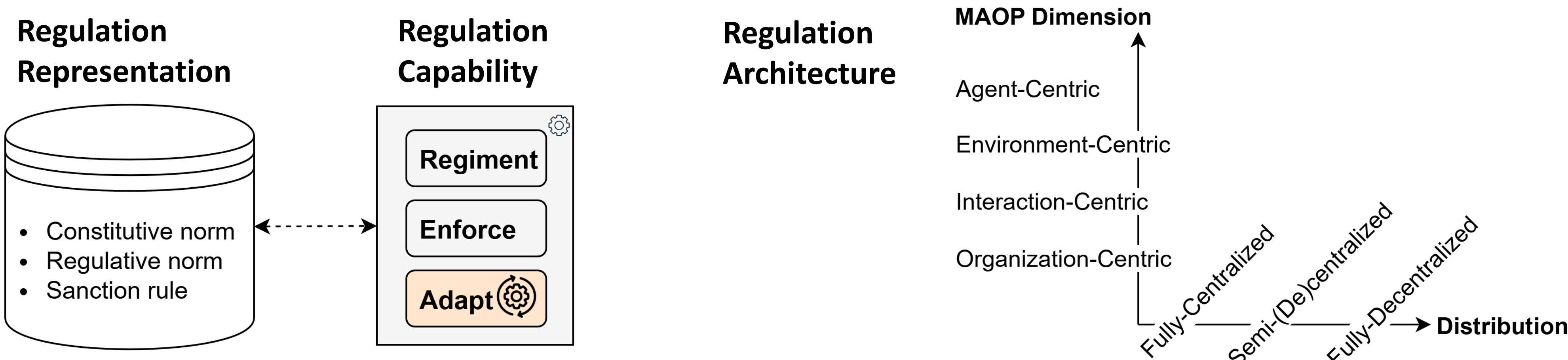
Multi-Agent Systems (MAS) offer the foundations to tackle complex processes in open and dynamic environments (e.g., industry)

→ 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

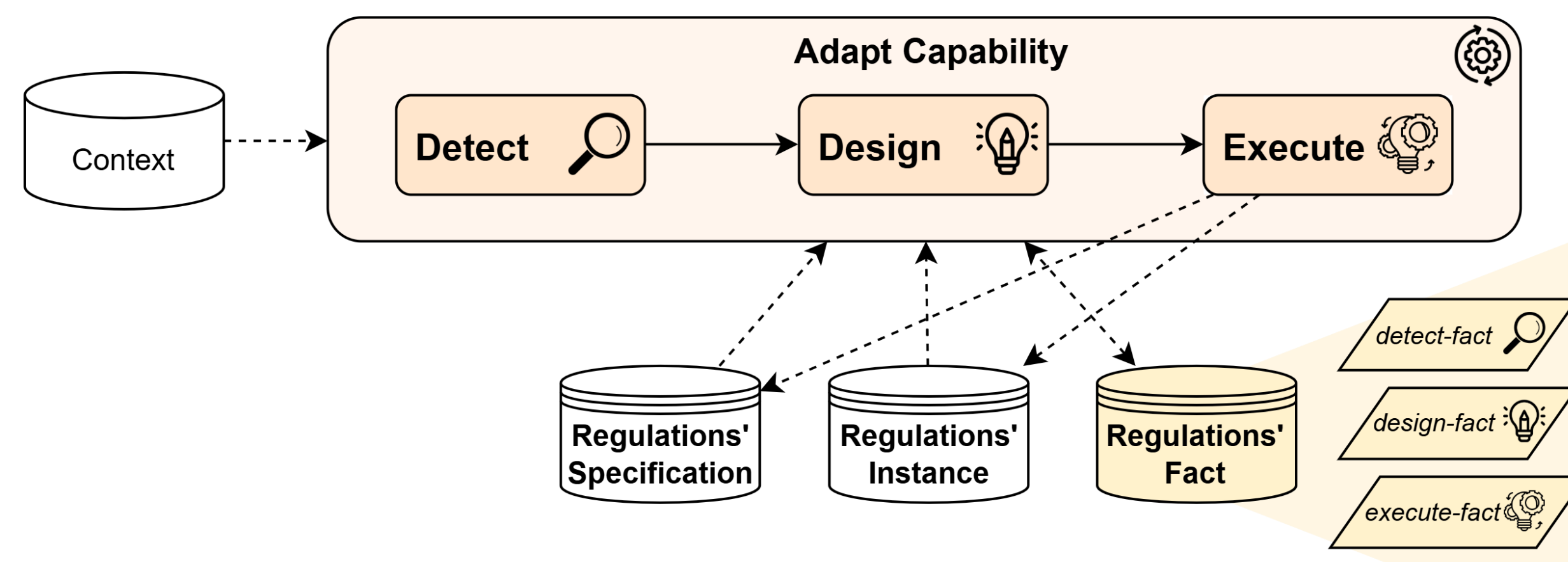
Objective: Design a *self-adaptive regulation management system* in normative MAS



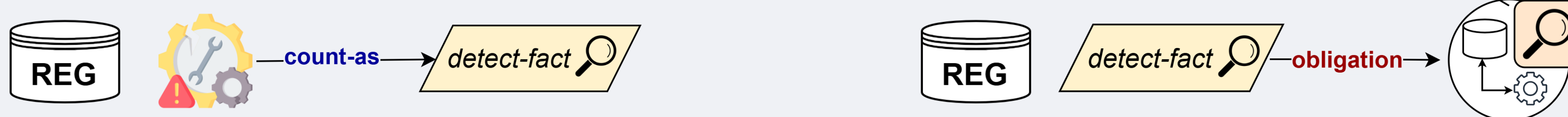
RQ1: What are the core elements of a *regulation management* system? [4]



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

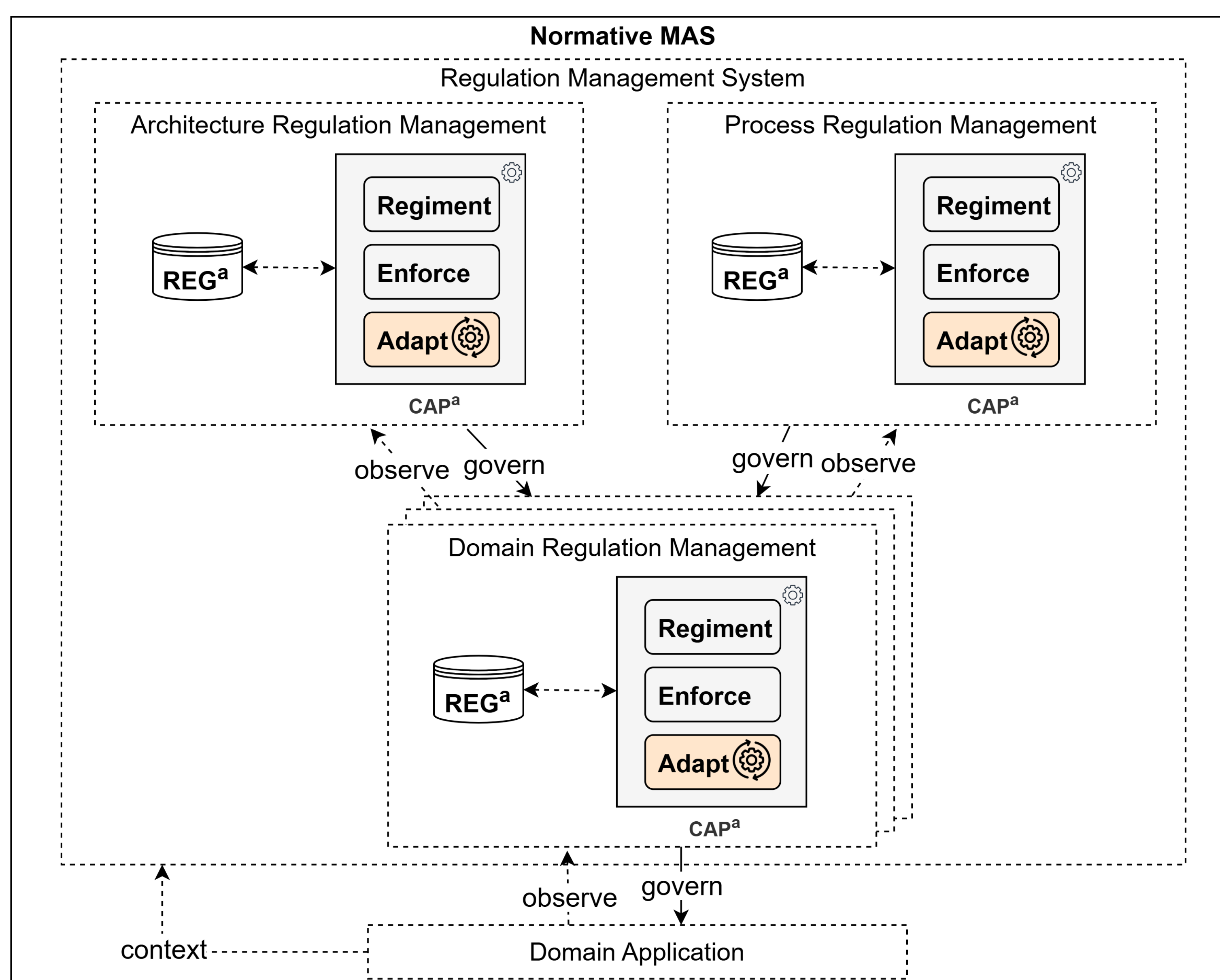


→ **Constitutive norms** for creating *adaptation facts* stating the corresponding adaptation requirement

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

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**

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

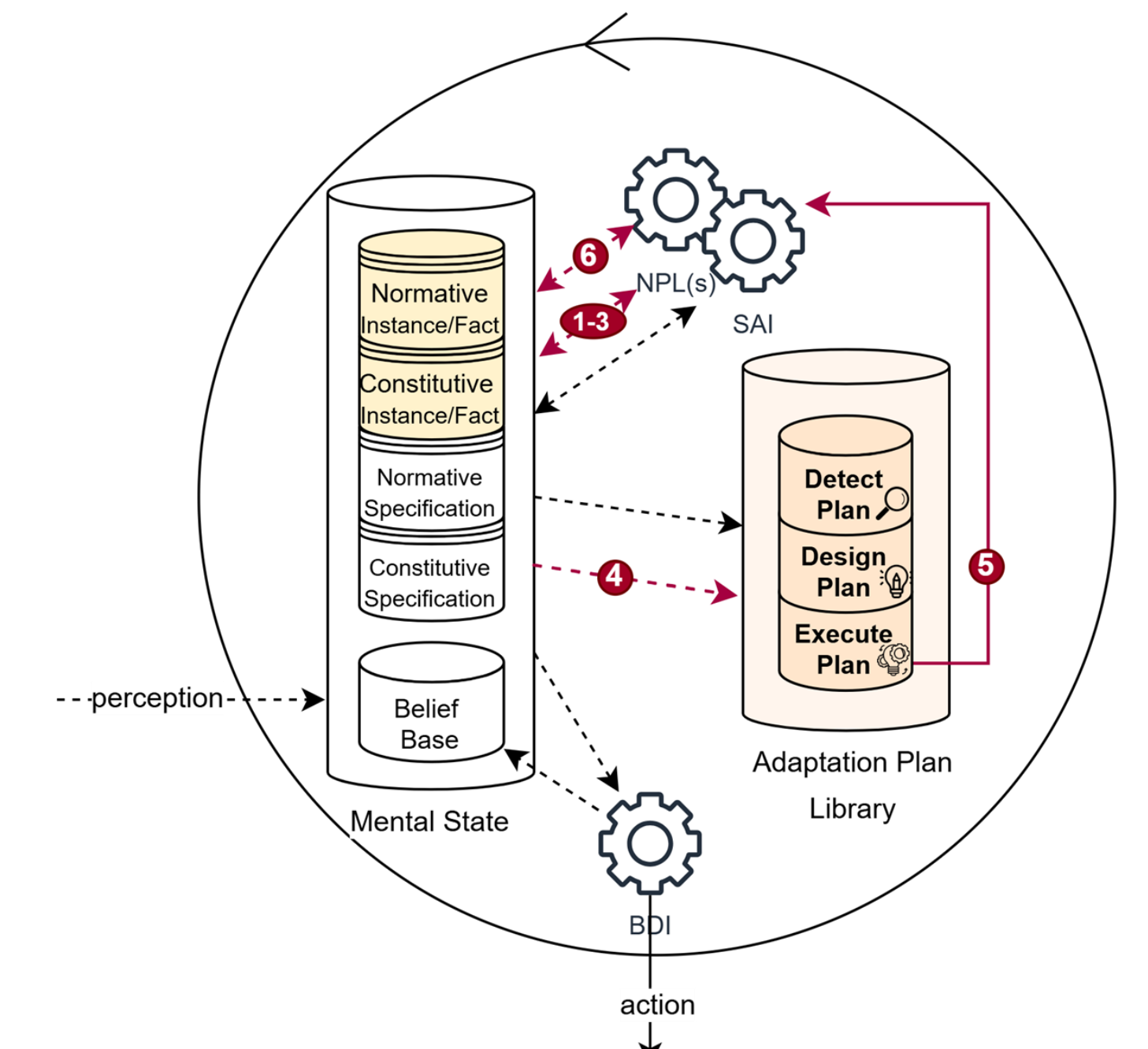
Regulation Representation

- Situated Artificial Institutions **SAI** [2] for programming constitutive norms
 $id : x \text{ count-as } y \text{ while } c$
- Normative Programming Language **NPL(s)** [3] for programming regulative norms and sanction rules

$$\text{norm } id : \varphi \rightarrow \psi \text{ [if } \phi : sr_i(args)].$$
$$\text{sanction-rule } sr_i(\text{args}): \rho \rightarrow \text{sanction}(\alpha, \gamma).$$

Agent-Centric Regulation

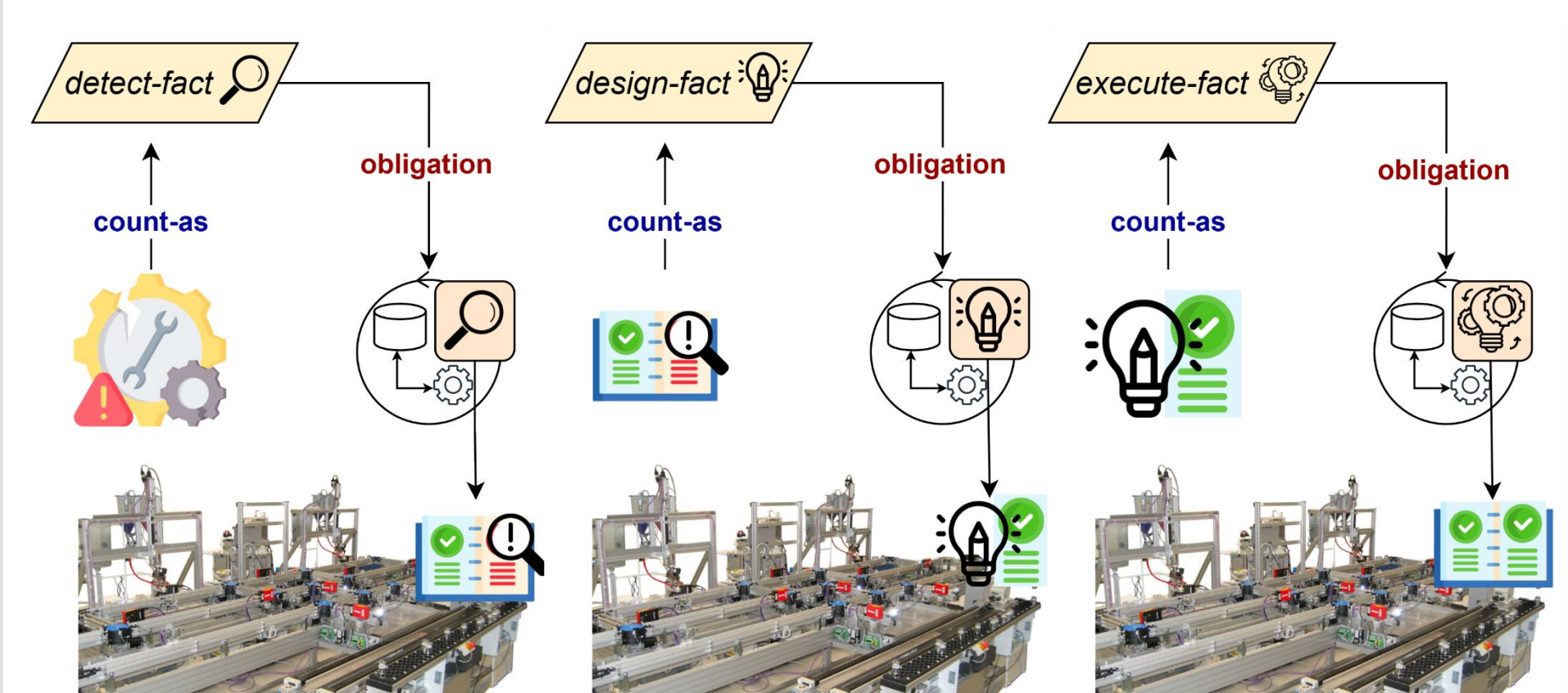
BDI agent architecture in JaCaMo [1] integrated with SAI and NPL(s) engines and the adaptation capability



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

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.