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LIMOS
LABORATOIRE D'INFORMATIQUE, DE MODÉLISATION ET D'OPTIMISATION DES SYSTÈMES

Governing Sociotechnical Systems: A Normative MAS Approach

Luis Gustavo Nardin
gnardin@emse.fr

IMT – Data Analytics and AI

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Introduction

- Human society is invariably becoming more **dependent on** information technologies

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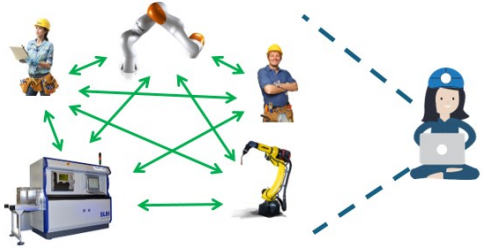
Example: Flexible Industrial Manufacturing

- Lot-size one manufacturing
- Repurposed on-the-fly



Factory workers and artificial agents working towards shared goals

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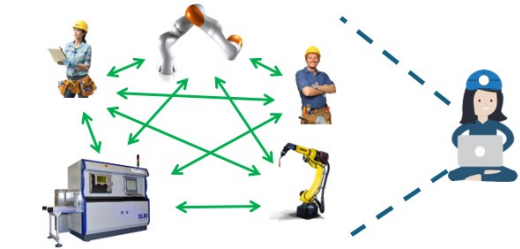

Factory workers and artificial agents working towards shared goals

- **Resilience**: the system avoids and recovers from unexpected events
- **Flexibility**: the system adapts to different situations
- **Sustainability**: the system adapts to sustainability regulations
- **Trustworthiness**: human beings trust and understand the system

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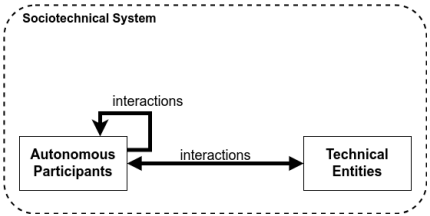

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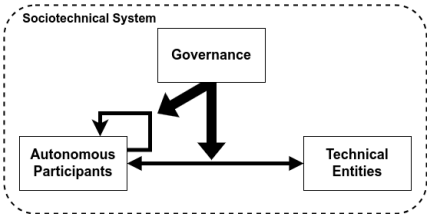

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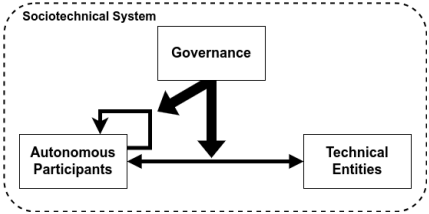

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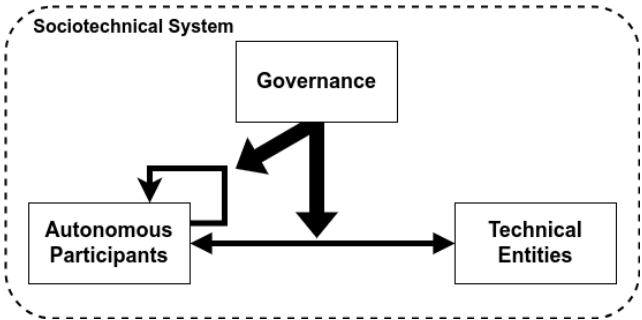
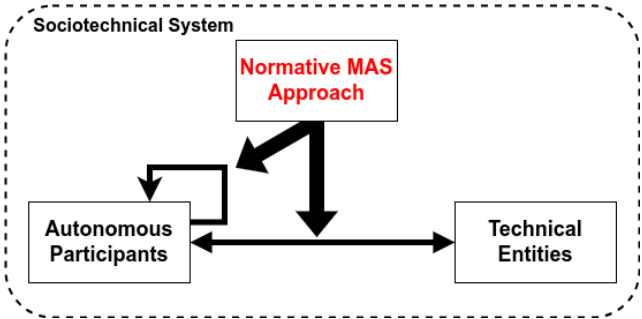
- The success of STS relies on effective **governance**, which pertains to how interactions are controlled (Balke & Villatoro, 2012)
- Governance should maintain a balance between
  - **autonomy** and **flexibility** observed in social systems
  - **predictability** expected in technological systems

Question



How can we govern these sociotechnical systems interfering the least with the autonomy of their participants?

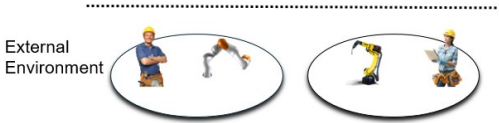
Hypothesis



- **Multiagent Systems** (MAS) enhance decentralization and flexibility by enabling agents to autonomously manage dynamic events
- **Normative mechanisms** guide autonomous agents' behavior while enabling trustworthiness (e.g., transparency)

Multiagent Systems : Multiagent Oriented (MAO) Approach

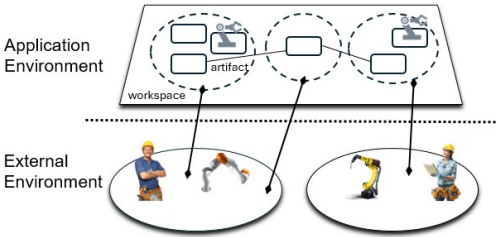
(Ciortea et al., 2018; Boissier et al., 2020)



Multiagent Systems : Multiagent Oriented (MAO) Approach

(Ciortea et al., 2018; Boissier et al., 2020)

- **Environment** : Shared medium providing the conditions for agents to exist and act



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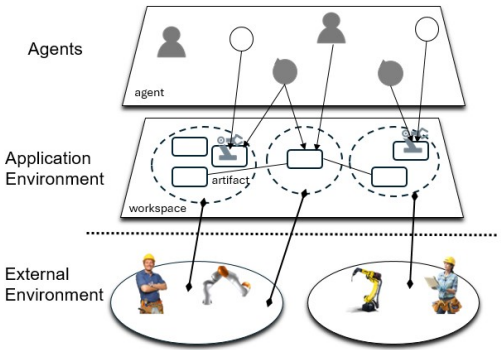

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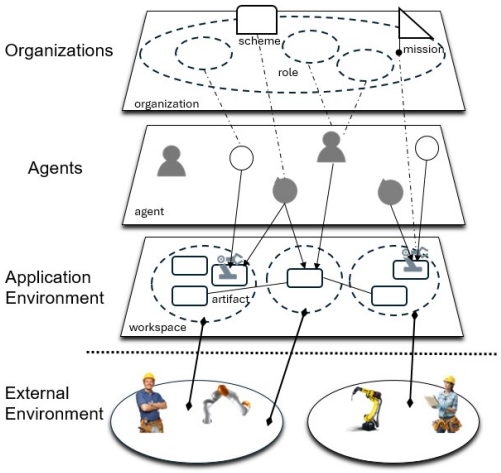

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- **Agent** : Autonomous decision-making entities able to react to events while pursuing goals and performing actions to achieve them
- **Organization** : Abstractions to declare and make accessible to agents their collective structure and functioning in a shared environment

Normative Multiagent Systems

Normative Multiagent System is a multiagent agent system wherein agents behaviors are regulated by norms and sanctions

Norms

- Represent the **standards of proper or accepted behavior** that each agent in a system **expects** from others
- **Rules of conduct** prescribing how members of a group **ought to behave** in a given situation according to the **majority of its members** (Ullmann-margaret, 1977)

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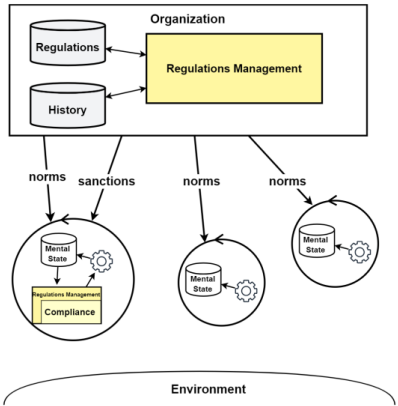
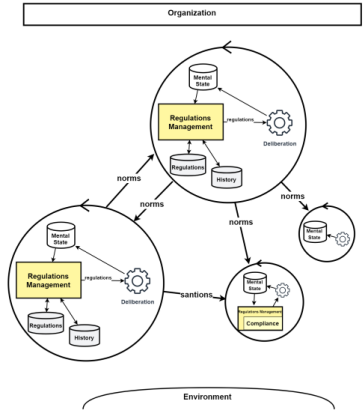
Sanctions

- Represent **reaction to a norm** compliance or violation
- Not all reactions can count as sanctions (Gibbs, 1966)

Regulation Management Mechanisms



Organization-Centric Perspective



Agent-Centric Perspective

(Yan, 2024)

Requirements for Agent-Centric Perspective

1. Language to express agents' expected behaviors and enforced behaviors
2. Normative agent architecture to enforce the agents' expected behaviors?

Normative Programming Language NPL(s)

Norm

```
norm <id> : <when>
  -> obligation(<who>, <while>, <what>, <deadline>)
     [if fulfilled: <sanction-rule>+]
     [if unfulfilled: <sanction-rule>+]
     [if inactive: <sanction-rule>+] .
```

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```

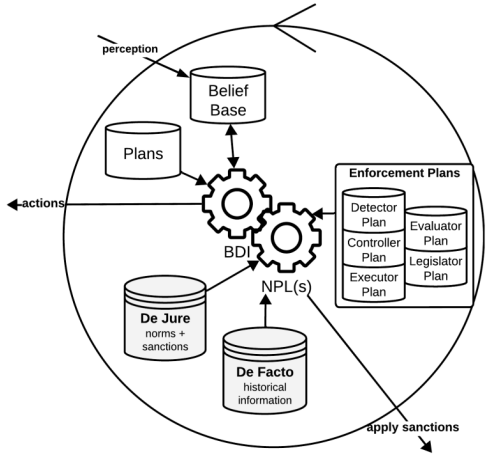
Sanction Rule

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

(Yan et al., 2024)

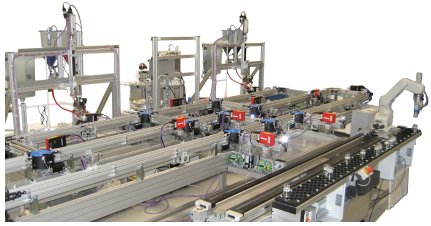
Normative Agent Archietcure

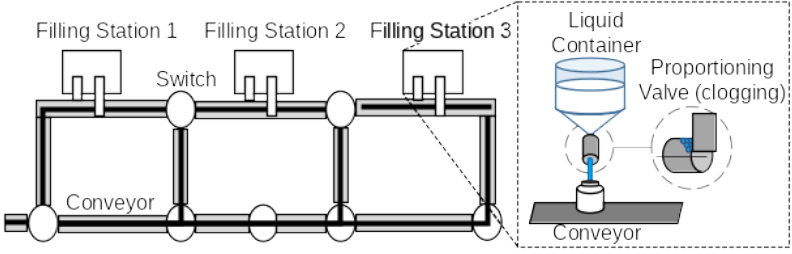
- BDI JaCaMo agent architecture
- NPL(s) Engine
- Repositories
  - De Jure
  - De Facto
- Enforcement Plans
  - Detector
  - Evaluator
  - Executor
  - Controller
  - Legislator



(Yan et al., 2024)

Increase Robustness of Production Automation





(Land et al., 2023)

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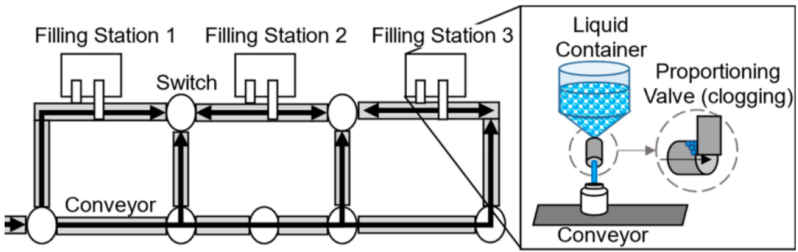

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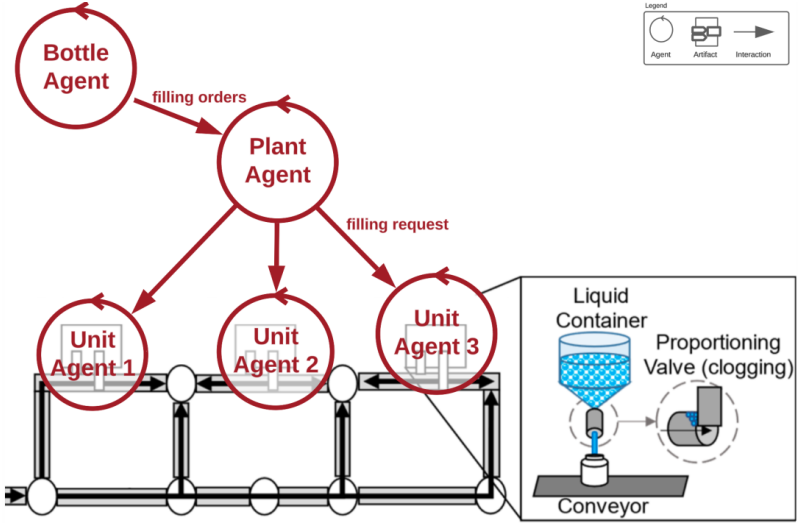

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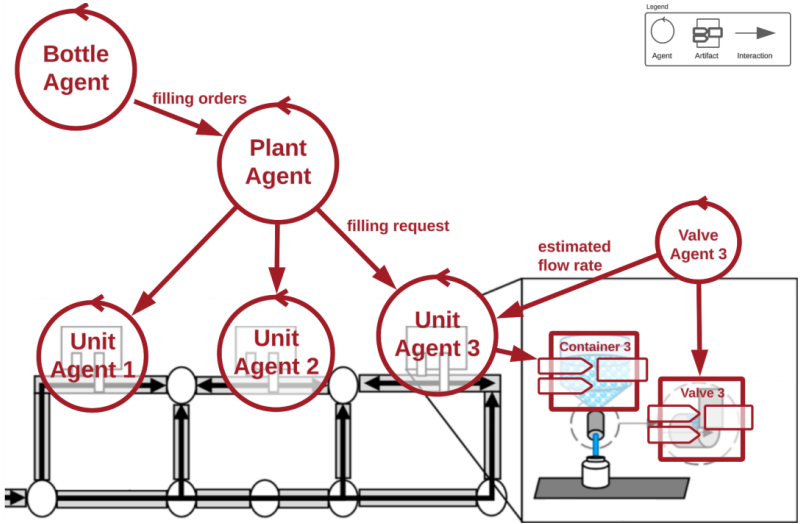
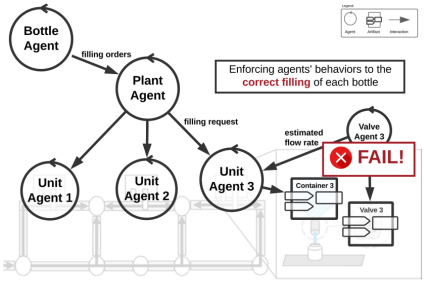


(Yan et al., 2024)

Increase Robustness of Production Automation

Norm 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) .
```



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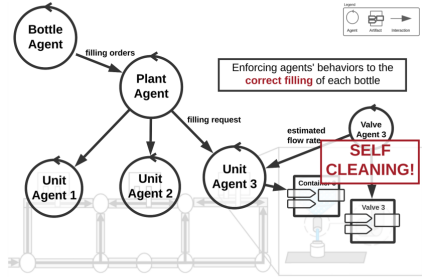
Increase Robustness of Production Automation

Sanction-Rule Example

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



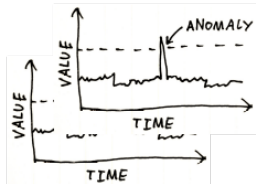
Id	Sanctioner	Target	Sanction	Condition
S2	unit agent	valve agent	Activate **self-cleaning** procedure	The violation occurs three consecutive times

(Yan et al., 2024)

Zero-Maintenance Production Line

Product Anomaly

Production Line Anomaly



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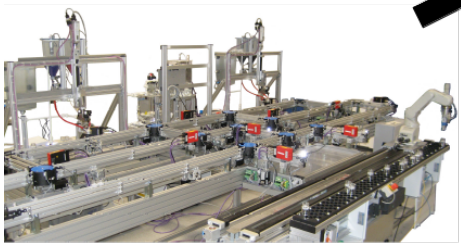

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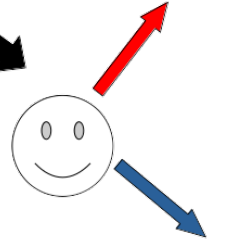
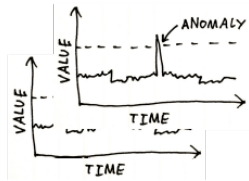


Self-Clean

Production Line Anomaly



Future Work

- Explore how normative systems can support **transparency** and **explainability**
- Investigate **self-adaptation** on norms and sanctions
- Explore different domain applications like the regulation of **automated software development**

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Thank you!