Thesis Subject

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

Keywords: Multiagent Systems, Normative Systems, Responsible AI, Industry of the Future

- **Employer:** MINES Saint-Étienne, an IMT graduate school
- **Laboratory:** LIMOS UMR 6158
- **Location:** Saint-Étienne, France
- **Contract and duration:** PhD fixed term contract of 36 months
- **Start date:** Aimed to start in October 2023
- **Application deadline:** Open until filled
- **Supervisors**
    - Prof. Olivier Boissier – MINES Saint-Étienne – France, Thesis Director
    - Prof. Jaime Simão Sichman – University of São Paulo – Brazil, co-supervisor
    - Dr. Luis Gustavo Nardin – MINES Saint-Étienne – France, co-supervisor

Scientific Context

The digital transformation of manufacturing industries provides a nurturing environment for the adoption of more autonomous and (self-)adaptive technologies that can quickly and flexibly respond to endogenous and exogenous changes. In the context of the Industry of the Future, manufacturing industries are increasingly envisaged as a network of intelligent production machines, achieving greater and more reliable production efficiency by means of inter-machine coordination [4]. Besides being flexible, they are also expected to be trustworthy. The Industrial Internet Consortium (IIC) express trustworthiness in terms of safety, security, privacy, reliability and resilience aspects [2] of manufacturing systems. Complying to sustainable regulations is also a strong requirement by contributing to cope with three sustainability pillars (i.e., economic, environmental and social) translated into regulations (i.e., laws, standards, policies and rules) that will differ depending on where the manufacturing industry is located.

Multiagent system (MAS) is a promising foundation for such technologies. MAS is able to represent and control these complex industrial ecosystems [5] by representing machines as agents who are responsible for the machines' control and operation.

To achieve a balance between the individual agents' autonomy and the overall manufacturing system's expected behavior, it becomes imperative the governance of these systems. Governance enforces the behavior of agents within the system [1] by establishing a set of norms describing behaviors agents are expected to perform [7] and a set of sanctions describing the negative and positive reactions, or consequences, to potentially any violation of or compliance with the norms [6].

The NAIMAN ANR-FAPESP project has the objective to develop a new generation of autonomous systems for regulating manufacturing systems by the integration of normative concepts (i.e. norms and sanctions) as proposed and defined in the Normative Multiagent Systems domain [8,3]. Two prototypical demonstrators will be developed targeting two different industrial process: product-centric manufacturing and zero-defect manufacturing.

Thesis Objectives

In the context of the NAIMAN project, the thesis aims **to develop models and mechanisms based on normative multiagent systems to regulate manufacturing systems for enhancing their trustworthiness and sustainability in the context of the Industry of the Future**.

The aim is that agents deployed in manufacturing systems are regulated by norms that define what is expected from them when interacting and cooperating with other agents for executing their tasks and achieving their goals. Agents' local decisions, however, may deviate from these expected behavior what may impact the global execution of the manufacturing system. Hence, **this thesis focus on proposing models and mechanisms based on the normative approach to regulate the actions of these agents and nudge their decisions to achieve not only their individual's, but also the desired global manufacturing system's, goals**. These models and mechanisms will need to deal with two aspects. First, they have to enable agents to reason about the norms and the possible consequences of complying with or violating such norms (i.e., sanctions) in order to decide their actions. Second, these models and mechanisms have to enable the monitoring of the environment and the enforcement of the norms, i.e., application of sanctions (i.e., rewards and punishments) depending on the agents's actions and their consequences.

We understand that trustworthy systems, in particular trustworthy MAS manufacturing systems, have (1) to enable human oversight of the system's operations, (2) to provide a transparent and understandable way for human beings to inspect the system's automated decisions, and (3) to make the systems accountable for their automated decisions. Going beyond the state of the art of models and mechanisms available in the normative multiagent domain for regulating manufacturing systems, **the thesis focuses on enriching regulation mechanisms to make their automated decisions transparent and understandable for human beings, thus easy to oversight and to assign accountability**.

Additionally, **the thesis focuses also on ensuring that the proposed regulation mechanisms are flexible and can adapt to comply with the different sustainability regulations depending on the location of the manufacturing systems**.

Summary of Objectives and Expected Results

- Identify the sufficient and necessary requirements for regulation mechanisms in manufacturing systems
- Assess the state-of-the-art on normative multiagent systems mechanisms and propose a classification for these systems in the light of the identified requirements
- Develop a regulation mechanism enabling trustworthiness and sustainability in manufacturing systems
- Demonstrate the effectiveness of the regulation mechanism in enabling trustworthiness and sustainability in the context of the Industry of the Future

Responsibilities

Besides developing research and achieve the thesis objective, the candidate will:

- Participate in project meetings
- Co-supervise interns in the scope of the project
- Contribute to the writing of scientific articles
- Contribute to the writing of project deliverables
- Disseminate the work's results in seminars, conferences, workshops, etc.

Workplace

The PhD student will join the *SIC axis* of the *Laboratory of Informatics, Modelling and Optimization of the Systems* (UMR CNRS 6158 LIMOS), a CNRS laboratory. The PhD will be hosted at within the *Informatique et Systèmes Intelligents* (ISI) department of the *Institut Henri Fayol* of MINES Saint-Étienne, an IMT graduate school, in Saint-Étienne. The PhD student will be fully integrated to the ANR-FAPESP Normative Artificial Intelligence for regulating MANufacturing (NAIMAN) project, thus demanding regular interactions with international project partners.

Candidate's profile

- Master Degree or equivalent in Computer Science, Artificial Intelligence or related discipline
- Good level of English, oral and written
- Good interpersonal skills (e.g., able to work in groups, proactive, autonomous)
- Skill in programming language and artificial intelligence
- Preference for candidates with knowledge on
    - Java
    - Multiagent systems
    - Normative systems

Conditions

The PhD funding is offered on a full-time basis for a period of 36 months with a starting date aimed at October 2023 (temporary contract), the candidate will be employed by MINES Saint-Étienne.

How to apply

Interested candidates should submit the documents listed below by email to gnardin@emse.fr with the subject **PhD NAIMAN 2023**

- Motivation Letter
- Resume/CV
- Master's degree transcript
- Reference(s) contact information or Letter(s) of recommendation (Optional)
- Link to a public Git/SVN/Mercurial repository containing previous projects (Optional)

Further information

For any further information on the PhD position, please contact Dr. Luis Gustavo Nardin (gnardin@emse.fr).

References

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[5] Karnouskos, S., Leitao, P., Ribeiro, L., & Colombo, A. W. (2020). Industrial agents as a key enabler for realizing industrial cyber-physical systems: Multiagent systems entering industry 4.0. In *IEEE Industrial Electronics Magazine*, 14(3), 18–32. DOI: 10.1109/MIE.2019.2962225.

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