

## SUBJECT FOR THE INSA-UT PHD PROGRAM OF THE CHINA SCHOLARSHIP COUNCIL

**SESSION 2021-2022**

**Institution:** Laboratoire Connaissance et Intelligence Artificielle Distribuées (CIAD, <http://www.ciad-lab.fr>),  
Université de Technologie de Belfort-Montbéliard (UTBM, <http://www.utbm.fr>), France

**Title of the subject:**

### Multiagent oriented programming for robot swarms and human-robot interactions

**Keywords:** Robots swarm, Collaborative robots, Human-multi-robot collaborative teams,  
Distributed Artificial Intelligence, Programming Language, Multiagent systems.

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### 1 Description of the Hosting Institution

The 'Université de Bourgogne Franche-Comté' (UBFC) is a community of universities and high schools with around 56,000 students, located at the Center-East of France. It is composed of 22 geographical sites. UBFC was created April 1<sup>st</sup>, 2015. The founding members are: Burgundy University (uB) , Franche-Comté University (UFC), Université de Technologie de Belfort-Montbéliard (UTBM), High National School of Mechanics and Microtechnics (ENSMM), AgroSup Dijon, Burgundy School of Business (BSB, formerly ESC Dijon).

The 'Université de Technologie de Belfort-Montbéliard' (UTBM) is a public higher education and research institution located in the towns of Belfort, Sévenans and Montbéliard (Franche-Comté, France). The university has 2,555 students for the academic year 2011-2012. UTBM comes from the merging of the National School of Engineers of Belfort (ENIBe) created in 1962, and the department of the University of Technology of Compiègne established in 1985 in Sevenans, becoming "Sévenans Polytechnic Institute" (IPSE) in 1991. UTBM was founded in 1994. It belongs, like the University of Technology of Compiègne, the University of Technology of Troyes, and the University of Technology

of Shanghai, to the Network of the Technology Universities. UTBM is a member of the National Council of the French High Schools, the Conference of Directors of French Engineering Schools, the Conference of University Presidents, founder of the Bourgogne Franche-Comté Research and Education Pole, founding member of the ARC-Europe Project, and member of UT Group. UTBM is authorized by the Ministry of Higher Education and Research to issue engineering diplomas in the following domains: automatic, industrial electronics, IT, mechanical, production systems, mechanical design and ergonomics. UTBM is developing research activities in cohesion with the industrial environment of the north Franche-Comté: Land transport and energy. Seven laboratories research is organized around UTBM.

The **CIAD laboratory** (Laboratoire Connaissance et Intelligence Artificielle Distribuées, <http://www.ciad-lab.fr>) is a multidisciplinary research laboratory that is hosted by UTBM and UB. In 2019, Researchers from UTBM has created the CIAD staff. These Researchers are mostly members of the multiagent research group whose head is Prof. Dr. S. Galland. The members of the CIAD includes 6 full professors, 4 professors, 5 associate professors, 12 contract researchers, 2 research engineers, 2 post-doc and 27 PhD students. Within the CIAD laboratory, the multiagent team investigates the field of Multi-Agent Systems (MAS).

The core activity of CIAD in related with this PhD subject is concerned with computer languages, methods and tools, and aims at defining suitable abstractions, methodologies either formal or semi-formal and tools for engineering multiagent software based on organizational and behavioral theories and constitute a basic building block for the other research projects of the team. The scientific work of the team is organized around three fundamental axes: Agent-Oriented Software Engineering and Formal models, Multiagent-based Simulation, and Agent's architectures. Our main application areas cover Intelligent Transport Systems (ITS), traffic and pedestrian's simulation in virtual environments. Currently, the two following areas draw the attention of the team: Simulation in virtual environments, and the Modelling, simulation and control of multimodal traffic.

The PhD candidate will be hosted on the **campus of Belfort of UTBM**.

## 2 Scientific Context and Problems

Managing multiple robots simultaneously raises many challenges in terms of coordination, control, especially in environments where there's a lack of accurate localization, sensing uncertainty and limited communications, yet there is an overarching mission objective or series of tasks that need to be completed.

In this PhD, you will explore and develop approaches around multi-robot swarming and coordinated formation control for collective exploration/motion/transport, target tracking, and possibly human-swarm interaction.

## 3 Goals of the PhD Works

The main objective of the research work is to develop and ease the development as well as the deployment of collective behaviors for robot swarms. The focus is to facilitate the control of robots swarms performing collective tasks possibly involving humans. The effective and efficient coordination of a robot swarm includes task and motion planning algorithms, control, and robust

sensing in a dynamic uncertain environment. Ideally, these behaviors and algorithms are resilient and able to recover from possible faults and damages experienced by one of the robots of the swarm.

The considered application could be robotic logistics and cooperative payload transportation in distribution centers for packing, automated inventory management, and picking, as well as the last mile delivery including mobile parcel stations and robot-assisted 2-man handling.

## 4 Expected Background for the Candidates

This section lists the expected background for the candidates:

- **Computer programming with object-oriented paradigm (mandatory knowledge)**
- Strong programming skills, e.g. Java or C#
- Artificial Intelligence and Multiagent Systems
- Robotics, Arduino, Maker
- Bio-inspired solutions, swarm intelligence

## 5 Expected Working Plan

### Year 1 (Months 1-12)

- Do a Systematic Literature Review (SLR) according to the international standards in order to highlight the key research questions in the field of this PhD thesis
- Selection of one or two research questions from the SLR in order to be handled by the PhD candidate.
- Writing and publication of one paper into an international journal of Rank Q1 or Q2 that explains the SLR
- Select a real use case for applying and test the proposed robots swarms behaviors.

### Year 2 (Months 13-24)

- Elaboration of the agent-based behavioral models for robots swarms : metamodel, agent architectures, simulator architecture.
- Identify a way to connect the SARL platform with the controllers embedded in the chosen robots
- Writing and publication of papers into international conferences with ready committee.
- Writing and publication of a paper into an international journals of Rank Q1 or Q2 that explains the proposed models

### Year 3 (Months 25-36)

- Implementation of an experimentation with robots, including the deployment on these robots on a previously identified real use case.
- Writing and publication of papers into an international conference with ready committee.
- Writing and publication of a paper into an international journals of Rank Q1 or Q2 that explains the experiments.
- Preparation of the final PhD document

## Year 4 (Months 37-42)

- Preparation of the final PhD document
- Official oral defense

## 6 Possible connections with academic partners

The works that will be done in this PhD research may open cooperation with several national and international partners. Each of them may open joint contributions on specific fields that are mentioned below:

- Prof. Sebastian Rodriguez, Royal Melbourne Institute of Technology (Australia)
  - SARL metamodel and agent programming language, applied to BDI agents
- Dr. Jean-Michel Ilié, Sorbornes Université (France)
  - Rational action planning for mobile entities
- Prof. Ansar YASAR, Hasselt University (Belgium)
  - Application to transport science and intelligent transport systems
- Prof. Xiaowei TU, Shanghai University (China)
  - Modeling of electronic system behaviors for simulation
- Prof. Eric MATSON, Purdue University (USA)
  - Human-agent interaction models

## 7 Five significant scientific publications related to this PhD subject

- Stéphane GALLAND, Sebastian RODRIGUEZ, Nicolas GAUD. "Run-time Environment for the SARL Agent-Programming Language: the Example of the Janus platform." In International Journal on Future Generation Computer Systems, Elsevier, 2017. ISSN 0167-739X. **IF : 6.125 ; Q1.**
- Stéphane GALLAND, Yazan MUALLA, Igor TCHAPPI HAMAN, Hui ZHAO, Sebastian RODRIGUEZ, Amro NAJJAR and Nicolas GAUD. « Model Transformations from the SARL Agent-Oriented Programming Language to an Object-Oriented Programming Language ». In International Journal on Agent-Oriented Software Engineering (IJ-AOSE), pp. 1-38, 2020. **Q4.**
- Stéphane GALLAND, Sebastian RODRIGUEZ. "Semantic Transformation from SARL Agent-oriented Statements to Java Object-oriented Statements." In International Journal of Artificial Intelligence, vol. 17(2), pp. 139-153, Centre for Environment & Socio-Economic Research Publication, Rank: Q2, 2019. ISSN 0974-0635. **Q2.**
- Yazan MUALLA, Amro NAJJAR, Alaa DAOUD, Stéphane GALLAND, Christophe NICOLLE, Ansar-UI-Haque YASAR, Elhadi SHAKSHUKI. "Agent-based simulation of unmanned aerial vehicles in civilian applications: A systematic literature review and research directions." In Future Generation Computer Systems (FGCS), vol. 100, pp. 344-364, Elsevier, 2019. DOI: 10.1016/j.future.2019.04.051. **IF : 6.125 ; Q1.**
- Igor TCHAPPI HAMAN, Stéphane GALLAND, Vivient corneille KAMLA, Jean-claude KAMGANG, Yazan MUALLA, Amro NAJJAR and Vincent HILAIRE. "A Critical Review of Holonic Technology in Traffic and Transportation Fields." In Int. Journal of Engineering Applications of Artificial Intelligence (EAAI), pp. 1-54, 2020. **IF : 4.201 ; Q1.**
- Xue Zheng, Stéphane Galland, Xiaowei Tu, Qinghua Yang, Alexandre Lombard and Nicolas Gaud. "Obstacle Avoidance Model for UAVs with Joint Target based on Multi-Strategies and

Follow-up Vector Field". In 257-264, pp. Elsevier, Elsevier, 11th International Conference on Ambient Systems, Networks and Technologies (ANT), 2020.