

## 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:**

Specification and validation of dynamic constraints into  
an artificial intelligence programming language for  
virtual reality and mixed-reality simulation environment

**Keywords:** Distributed Artificial Intelligence, Programming Language, Run-Time Constraint,  
Virtual Environment, Microscopic Simulation

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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 and UB has created the CIAD staff. Part of the CIAD activities us supported by the multiagent and simulation research group whose head is Prof. Dr. S. Galland.

The core activity of CIAD in relation with this PhD subject is concerned with computer programming 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 that constitute a base blocks for the other research projects of the team. The scientific works 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. In the context of this PhD subject, 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

**Simulation** is an inseparable step in the design process which contributes to detecting earlier design flaws or non-compliance with requirements for a system. In this, the simulation helps reduce design and production costs and ensure a better triplet quality / cost / time. Integrating simulation for complex product design requires redesigning business processes and more generally the product life cycle. On the other hand, the heterogeneity of different trades / specialties involved in production requires taking into account the heterogeneity of models and their interactions.

In this context, microscopic simulation of a population of interacting entities remains a major challenge. In the last decade, many works have been devoted to the study of collective behaviors and their inherent emergent properties such as spontaneous organizations of pedestrians into lines, oscillations at gates, etc. Agent-Based Simulation (ABS) is one of the approaches to support microscopic simulation. Agent-based modeling allows complex behaviors of various interacting entities to emerge from a set of simple individual rules. Phenomena such as human crowds, vehicles fleets, flocks of birds, schools of fish, and complex biological systems of cells are good examples of how systems with simple goals can demonstrate complex emergent behaviors as a result of interactions between neighboring agents (local to global). ABS can therefore be regarded as an appropriate approach for pedestrian simulation and the study of associated emergent phenomena.

The aim of this thesis is to exploit the experience capitalized in application fields (e.g. traffic simulation, intelligent transport systems) in order to transpose this integration of simulation to

within the design process in the field of land vehicles and more specifically for testing and validating embedded algorithms.

The main objective of the research work entrusted to the doctoral student is to guarantee a high level of realism, precision and performance of the environment in which the system being validated and its user will be immersed. Simulation platform in a virtual environment are generally used for the training of drivers or other types of operators who require to work on the target equipment. In this type of platform, the embedded software is not the real software but simplified versions, on the other hand, the virtual environment in which the system is immersed is simulated with finesse to ensure the immersion of the human user.

In this context, several generic research questions arise, e.g.:

- **How to validate the behaviors of the system's components against dynamic and run-time constraints?**
- **What are the appropriate models and simulator architecture for reproducing and handling the dynamics of the systems?**

These questions are refined in the context of this PhD subjects, and are described into the following section.

### 3. Goals of the PhD Works

This PhD subject aims at providing tools to researchers and engineers in order to specify and implement dynamic constraints for multiagent systems in the context of simulation of systems.

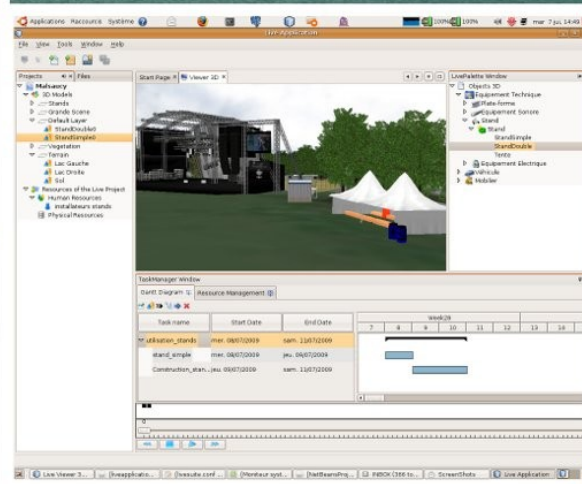
Depending on the open research questions at the time of the start of the PhD thesis, and the background of the PhD candidate, the research questions that may be tackled by the PhD candidate are:

- **How to specify goal, time and spatial constraints into an agent-based model?**
- **How to specify goal, time and spatial constraints into an agent programming language?**
- **How to validate the specified goal, time and spatial constraints during the execution of the agents into a microscopic agent-based simulator?**
- **What are the concepts to be included into the modeling meta-model and the programming language for implementing an agent-based simulator?**
- **What is the best software architecture for simulating complex systems with semantically enriched environment?**

The scientific fields that are supposed to be explored by the PhD students: agent-oriented simulation, agent-oriented software engineering, agent programming language, and parallel programming.

**Machine learning methods and data-driven artificial intelligence are outside the scope of this PhD thesis.**

The goal of the PhD thesis is to extend the existing tools, such as the open-source framework **SARL** ([www.sarl.io](http://www.sarl.io)) and the free **Unreal Engine** in order to create a simulation environment that could be used for mobile entity simulation. Examples of screenshots of the existing simulator (Jasim simulator, created by CIAD) could be found below:



#### 4. Data Management and European GDPR

No data source that are covered by the GDPR will be used in this thesis.

Only synthetic data, i.e. automatically generated by computer models, will be used into the simulation scenarios.

#### 5. Expected Background for the Candidates

This section lists the expected background for the candidates:

- **Computer programming with object-oriented paradigm (mandatory knowledge)**
- **Object-oriented programming language, e.g. Java or C# (mandatory knowledge)**
- Artificial Intelligence and Multiagent Systems
- Microscopic agent-based simulation tools, e.g. Gama, Rhapsody Repast.
- Programming language theory, computer language grammars and compilers

#### 6. 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

### Year 2 (Months 13-24)

- Elaboration of the agent-based models : metamodel, agent architectures, simulator architecture.
- 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 on data from a virtual smart city.
- 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

## 7. Possible connections with academic partners

The works that will be done in this PhD research may open cooperations with several national and international partners. Each of them may be concerned by specific research topics that are mentioned below:

- **Prof. Xiaowei TU** / Shanghai University / China: Modeling of electronic system behaviors for simulation
- **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: Simulation of intelligent transport systems
- **Prof. Eric MATSON** / Purdue University / USA: Human-agent interaction models

## 8. 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**.