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INSTITUT FRANÇAIS India

Job offer – Post-doctorate in Computer Science

Formal Methods & Verification

(*For non-French scientists only*)

Research Project Title: "SMILeS - Synthesis with Multiple objectives, Imperfect information, and Learning in Stochastic systems"
Principal Investigator contact: "Laurent Doyen, LMF – Laboratoire Methodes Formelles, CNRS, ENS Paris-Saclay, 4 avenue des sciences, 91190 Gif-sur-Yvette, France, ldoyen@lmf.cnrs.fr"
Reference Number of the Job Offer: IFI_CEF_26_01

Project Description

- **Keywords :** Reactive synthesis, Stochastic games, Markov decision processes, Beyond worst-case, multiple objectives, synthesis and AI

- **Context :** Due to increasing parallelism, concurrency, and dependency on real-time and stochastic nature of the system and the environment in cyber-physical systems, even relatively small systems exhibit unexpectedly complex behaviours. Such systems may need to satisfy multiple objectives at the same time, they may exhibit stochastic behaviour and operate in uncertain environment. A challenging problem in formal methods research is synthesis, where given a logical specification for a reactive system and a model of the environment, the goal is to automatically construct (synthesize) a system that satisfies the property no matter how the environment behaves.

- The framework of games is a natural paradigm for the synthesis problem, where a correct implementation corresponds to a winning strategy for a player against the environment, with a winning condition defined by the specification. The project aims to address the synthesis problem in a rich model of games, incorporating stochasticity, complex requirements, and imperfect information.

- **Abstract of the Research Project :** The project aims to advance the state of the art for reactive controller synthesis of stochastic systems. A reactive system consists of a network of computing systems trying to achieve their goals through a continued interaction with the environment in which they operate. All cyber-physical systems are predominantly reactive systems that are safety-critical. Examples include control units in automotive, medical, or spaceship applications where safety is of paramount importance and any flaw can be catastrophic. Furthermore, in a variety of scenarios like communication networks, biological events, stock markets, these systems are stochastic in nature and they may function in an unknown environment.

  The central topic of the project is the stochastic synthesis problem where given a specification for a reactive system and a stochastic model of the environment, the goal is to automatically compute (synthesize) a system that always satisfies the specification in a probabilistic or adversarial environment.

- **Scientific Objectives of the Project :** This project has the following three objectives:

  1. Beyond worst-case synthesis - ensure a worst case threshold no matter how the environment behaves as well as a good expectation against the expected behaviour of the adversary.

  2. Multi-objective synthesis - a system may have multiple complex requirements to be satisfied at the same time, for example, maintaining a minimum average battery level (quantitative objective) in a vehicle while maintaining safety and reaching the destination (Boolean objective).

  3. Learning in imperfect information - synthesis of stochastic systems using machine learning techniques in addition to providing formal guarantees when full information is not available about the environment.

- **Methodology and Timeline of the Project :** It is natural to consider synthesizing strategies that ensure both a) some worst case threshold is satisfied no matter how the environment behaves and b) a good expectation is achieved against the expected probabilistic behaviour of the environment. This is called beyond worst-case (BWC) synthesis. Although these objectives have been studied in the context of MDPs, the synthesis problem remains greatly unexplored for

stochastic games. We plan to develop synthesis algorithms for combined worst-case and expected measures of classical objectives such as reachability, parity, and mean-payoff objectives. Extension to finitary variant of those objectives, and quantitative measures like long-run average or energy objectives will be considered as well. We expect to show the decidability of these problems, and we will focus on the design of efficient algorithms.

For the second objective (Multi-objective synthesis), the challenge is to devise a modular approach to synthesis considering the individual objectives. Even in the case of a conjunction of reachability objectives, decidability remains open for stochastic games. We plan to investigate this problem, possibly with additional assumptions that would make the problem tractable.

The third objective pertains to imperfect information when (part of) the structure of the state space is unknown, or the exact transition probabilities are not fixed. We plan to analyze the tractability and complexity of these models and we expect that using learning techniques will be a great advantage over exact methods.

Candidate profile

- Candidates can be all nationalities except French. In case of double nationality (French and another one), the candidate is not eligible. In the context of CEFIPRA, Indian candidates are preferred;
- Applicants must have a PhD degree (or be in the process of obtaining one);
- No competences in French language is required
- Candidate competences: Strong level in Logic, Automata, Games. Good familiarity with Complexity theory, Algorithms, and Probability.
- Candidate know-how: Excellent writing and oral communication skills, including LaTeX. Collaborative and teamwork instinct.
- Expected starting date: 01-01-2026
- Expected duration: 12 months

How to apply ?

Documents to be provided :

i. A cover letter (reasons for the candidature, professional project …) max 2 pages
ii. A copy of the PhD degree or a proof of the PhD program followed (and expected date of defense) max 1 page
iii. A copy of results for previous scholarship (max 3 pages)
iv. A copy of Passport
v. International curriculum vitae (max 2 pages)
vi. Two letters of recommendation: one from any Indian institution and one from the French institution planned to host the candidate –mandatory- (max 2 pages)
vii. All should be submitted within 1 pdf file of no more than 10 pages.

Applications should be submitted to the following email address: msi@institutfrancaisindia.in mentioning the reference number of the Job offer clearly.

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Candidates are requested to contact the French scientific principal investigator of the project before submission.
A recommendation letter from the scientific principal investigator is mandatory.

Benefits:

- Monthly allowance of 2400 euros for Post-Doc
- Travel allowance
- University fee
- Carte de séjour fee
- Campus France management fee
- Registration to the French social security scheme

Selection process:

Selection is made by a dedicated selection committee of at least 4 persons. Decisions will be transmitted by the Embassy of France to CEFIPRA. **No consideration will be given for candidates with no recommendation letter from the French institution.**

Criteria for applicants' selection:

Academic excellence

- Excellence of the Academic background, Academic records, Honors, Letters of support, Participation to international research projects, exchange programmes and conferences.

Motivation and qualities

- Academic maturity: appropriation of the thesis project (stakes and contexts) • Quality of the presentation (oral expression, skills for synthesis, English level) • Maturity of the professional project: capacity to project her/himself within five years in terms of career development.

About CEFIPRA:
Indo-French Center for the Promotion of Advanced Research (CEFIPRA/IFCPAR) is an Indian body which promotes scientific cooperation between France and India in advanced fields of Science and Technology. It is supported by the Department of Science and Technology, Government of India and the Ministry of Europe and Foreign Affairs of the French government