Doctoral thesis

«Risk-aware control synthesis for temporal logic specification with safety guarantees»

CDD 36 months - ENSTA Paris, Palaiseau
The project is funded by CIEDS

Job description

The modern defense challenges involve intensive research into cyber-physical systems whose behavior must adhere to complex specifications. This thesis aims to develop controllers that satisfy by construction specifications outlined by temporal logic formulas, particularly signal temporal logic formulas (STL) **[RDS+15]**.

The language described by STL is quite comprehensive. For example, using STL formalization, one can assign the following tasks to a drone exploring an area:

(i) Travel from point A to point B before your battery runs out.
(ii) Accomplish this within one hour.
(iii) Visit areas C and D along the way.
(iv) Always avoid obstacles while moving.

Unfortunately, computing a controller to ensure the desired behavior may become intractable within a reasonable timeframe, especially when considering robustness to model uncertainties. To synthesize controllers in real-time, it may be necessary to tolerate slight deviations from the specification while prioritizing controllers that minimize the risk of violation **[SLD+20]**. However, certain requirements must always be maintained. In the example provided, points (ii) and (iii) may not be critical to satisfy, but requirements (i) and (iv) are essential because we don't want to lose the drone. In this project, we additionally propose the use of a monitoring system that substitutes (if needed) unsafe actions with less efficient but fail-safe alternatives **[AD14, GMAF18]**.

Hence, the thesis goals are to develop controllers respecting specifications given by signal temporal logic formulas (STL) relying on the notion of the risk while ensuring that hard safety constraints are always satisfied. The controllers then should be tested on the robotics platforms of U2IS lab.

References

[AD14] Matthias Althoff and John M. Dolan. Online verification of automated road vehicles using reachability analysis. IEEE Transactions on Robotics, 30(4):903–918, 2014.

[GMAF18] Thomas Gurriet, Mark Mote, Aaron D Ames, and Eric Feron. An online approach to active set invariance. In 2018 IEEE Conference on Decision and Control (CDC), pages 3592–3599. IEEE, 2018.

[JADS+20] Julien Alexandre Dit Sandretto, Alexandre Chapoutot, Pierre-Loïc Garoche. Towards a Set-based Signal Temporal Logic. 2020. ⟨hal-03084701⟩

[SLD+20] Sleiman Safaoui, Lars Lindemann, Dimos V. Dimarogonas, Iman Shames, and Tyler H.Summers. Control design for risk-based signal temporal logic specifications. IEEE Control Systems Letters, 4(4):1000–1005, 2020.

[RDS+15] Vasumathi Raman, Alexandre Donzé, Dorsa Sadigh, Richard M. Murray, and Sanjit A. Seshia. Reactive synthesis from signal temporal logic specifications. HSCC '15, page 239–248, New York, NY, USA, 2015.

Main activities

- **Perform an Extensive Literature Review**: Conduct a comprehensive literature review to gain a deep understanding of control synthesis for risk-based signal temporal logic specifications with safety guarantees.
- **Conduct In-Depth Research**: Engage in rigorous research to advance the field, building upon the findings in the papers [SLD+20] and [RDS+15].
- **Test the Developed Controller**: Evaluate the developed controller on robotics platforms to validate its effectiveness and applicability.
- **Collaborate with Fellow Researchers**: Collaborate with other researchers in the field to leverage collective expertise and insights.
- **Present Research Findings**: Share research results at prominent control theory and robotics conferences, such as CDC, IFAC WC, ECC, ACC, HSCC, and ICRA.
- **Publish Research**: Aim to publish at least one research paper in a reputable journal.
- **Write and Defend the Doctoral Thesis**: Complete the process by writing a comprehensive doctoral thesis and successfully defending it to obtain your Ph.D. degree.

Laboratory

The Computer Science and Systems Engineering Laboratory (U2IS) is developing research in the field of design and reliability of systems integrating autonomous decision-making processes with applications in intelligent transport, robotics, defense and energy. The laboratory brings together

the research activities of the ENSTA Paris School in computer science, robotics, vision, embedded systems, signal and image processing and hybrid system design and analysis.

Required skills

We are looking for candidates who have an engineering degree or a master's degree (Master 2) in the field of control theory, applied mathematics or computer science.

- rigorous knowledge in control engeniring, optimization, and numerical calculus;
- proficiency in programming languages such as Python and C++;
- proficiency in spoken and written English;
- Research experience (e.g., internships) is a plus.

Profile

Master's degree (Master 2) or equivalent. Salary according to the legal regulations. A 36-month position available from October 2023. **European Union nationality is required (United Kingdom and Norway are accepted). Non-European Union nationality may be accepted upon verification.**

Application

Please send your **CV and a cover letter** in a single PDF file to the following email address:
- Julien Alexandre dit Sandretto (alexandre@ensta.fr)
- Elena Ivanova (elena.ivanova@ensta-paris.fr).