ARTIFICIAL INTELLIGENCE

DM 351 PNRR - Symbolic and data-driven verification of Cyber-physical Systems

Funded By
UNIVERSITÀ DEGLI STUDI DI PADOVA [Iva/CF:00742430283] and Ministero dell'Università e della Ricerca - MUR [Iva/CF:96446770586]. Scholarship funded by MD 351/2022 – M4C1 – Inv. 4.1 – Research on Recovery and Resilience Plan topics (RRP). CUP: E12B22000760005

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Context of the research activity
Cyber-physical systems communicate with each other and interact with the users and the physical world via sensors and actuators, in a feedback loop where physics affects computation and vice versa. This complexity and heterogeneity substantially increase the challenges for the development of reliable systems.

This research proposal envisions the combination of verification strategies coming from symbolic and data-driven AI to overcome the limitations of current tools and methodologies.

Objectives
The role of computers in modern societies is changing rapidly. The increase in computational power paired with the decrease of size, costs and energy consumptions of computers favoured the emergence of a whole class of new applications which go beyond the traditional boundaries of computation. In most of these applications, such as smart buildings, smart grids, smart cities, autonomous vehicles, cyber security, and health-care wearables, computational devices communicate with each other and interact with the physical world via sensors and actuators, usually with feedback loops where physics affects computation and vice versa.

The complexity and heterogeneity of such cyber-physical systems, originating from combining what in the past have been separate worlds, tend to substantially increase the challenges in the development of reliable large-scale cyber-physical systems.

A large family of mathematical languages, techniques, and tools, going under the collective name of Formal Methods, has been developed by computer science to help engineers in the development of reliable systems. Nowadays, they are standard practice in many ICT industries for the development of hardware and software systems and are becoming a vital aspect in the design of safety-critical cyber-physical systems, including robotics and automation systems. Their value has been demonstrated in several industrially relevant case studies from vehicle platooning protocols, to audio control protocol, collision avoidance protocol for aircrafts, verification of adaptive cruise control and medical robotics systems.

Data-driven methods based on machine learning, reinforcement learning,
Bayesian inference and Monte Carlo simulations provide a set of automatic data analysis techniques with which models can be learned from data. In the context of cyber-physical systems, they have been successfully applied for condition monitoring, predictive maintenance, image processing and diagnosis.

The main objective of this research proposal is the development of a verification framework that integrates model-based formal methods with data-driven learning algorithms in a feedback loop where the learner is used to provide a model to the verifier, and the result of the verification is used to improve the learning of the model.

The integrated verification framework will be implemented and validated with respect to an appropriate set of benchmarks, to exhibit the distinctive features of the approach and evaluate the performance of the toolkit. Case studies from smart-manufacturing and industrial cybersecurity will be used to test the toolkit on real application scenarios.

The research project will include a secondment period at a foreign academic institution and/or at a company, selected among the partners of the Department of Mathematics of the University of Padua.

Skills and competencies for the development of the activity

- Ability to model and formulate problems in a mathematically precise way.
- A background in at least one of the two topics of the proposal: symbolic AI and/or data-driven AI.
- Interest in learning logic, automata theory, formal methods, machine learning and coding.