COMPUTER AND CONTROL ENGINEERING

CRT/DAUIN - Data-Driven and Sustainable Solutions for Distributed Systems

Funded By	Dipartimento DAUIN FONDAZIONE CRT CASSA DI RISPARMIO DI TORINO [P.iva/CF:06655250014]
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Context of the research activity	Recent advances in cyber-physical systems are expected to support advanced and critical services incorporating computation, communication, and intelligent decision making. The research activity aims to leverage advanced analytics, machine learning, and optimization techniques, to enhance the efficiency, resilience, and sustainability of distributed systems. Key focus areas include reducing energy consumption while using distributed learning techniques and optimizing resource allocation.
	Two research questions (RQ) guide the proposed work: RQ1: How can we design and implement on local and larger-scale testbeds effective autonomous solutions that integrate the network information at different scopes using recent advances in supervised and reinforcement learning? RQ2: To scale the use of machine learning-based solutions in cyber-physical systems, what are the most efficient distributed machine learning architectures that can be implemented at the edge of such systems? The final target of the research work is to answer these questions, also by evaluating the proposed solutions on small-scale emulators or large-scale virtual testbeds, using a few applications, including virtual and augmented reality, precision agriculture, or haptic wearables. In essence, the main goals are to provide innovation in decision, planning, responsiveness, using centralized and distributed learning integrated with edge computing infrastructures. Both vertical and horizontal integration will be considered. By vertical integration, we mean considering learning problems that integrate states across hardware and software, as well as states across the network stack across different scopes. For example, the candidate will design data-driven algorithms for planning the deployment of IoT sensors, tasks

Objectives	scheduling, and resources organization. By horizontal learning, we mean using states from local (e.g., physical layer) and wide area (e.g., transport layer) as input for the learning-based algorithms. The data needed by these algorithms are carried to the learning actor by means of newly networking protocols. Aside from supporting resiliency with the vertical integration, solutions must offer resiliency across a wide (horizontal) range of network operations: from close-edge, i.e., near the device, to the far-edge, with the design of secure data-centric resource allocation (federated) algorithms. The research activity will be organized in three phases: Phase 1 (1st year): the candidate will analyze the state-of-the-art solutions for cyber-physical systems management, with particular emphasis on knowledge-based network automation techniques. The candidate will then define detailed guidelines for the development of architectures and protocols that are suitable for automatic operation and (re-)configuration of such deployments, with particular reference to edge infrastructures. Specific use-cases will also be defined during this phase (e.g., in virtual reality, smart agriculture). Such use cases will help identifying ad-hoc requirements and will include peculiarities of specific environments. With these use cases in mind, the candidate will also design and implement novel solutions to deal with the partial availability of data within distributed edge infrastructures. Results of this work will likely result in conference publications. Phase 2 (2nd year): the candidate will consolidate the approaches proposed in the previous year, focusing on the design and implementation of mechanisms for vertical and horizontal integration of supervised and reinforcement learning. Network, and computational resources will be considered for the definition of proper allocation algorithms, with the objective of energy efficiency. All solutions will be implemented and tested. Results will be published, targeting at least one journal publication. Phase 3 (3rd year): the consolidation and the experimentation of the proposed approach will be completed. Particular emphasis will be given to the identified use cases, properly tuning the developed solutions to real scenarios. Major importance will be given to the quality offered to the service, with specific emphasis on the minimization of latencies in order to enable a real-time network automation for critical environments (e.g., telehealth systems, precision agriculture, or haptic wearables). Further conference and journal publications are expected. The research activity is in collaboration with Saint Louis University, MO, USA and University of Kentucky, KY, USA, also in the context of some NSF grants. The contributions produced by the proposed research can be published in conferences and journals belonging to the areas of networking and machine learning (e.g. IEEE INFOCOM, ICML, ACM/IEEE Transactions on Networking, or IEEE Transactions on Network and Service Management) and cloud/fog computing (e.g. IEEE/ACM SEC, IEEE ICFEC, IEEE Transactions on Cloud Computing), as well as in publications related to the specific areas that could benefit from the proposed solutions (e.g., IEEE PerCom, ACM MobiCom, IEEE Transactions on Industrial Informatics, IEEE Transactions on Vehicular Technology).

Skills and competencies	The ideal candidate has good knowledge and experience in networking and machine learning, or at least in one of the two topics. Availability for spending

for the development of the activity	periods abroad (mainly but not only at Saint Louis University and/or University of Kentucky) is also important for a profitable development of the research topic.