Research Internship 2021 − 2022

Guaranteed learning-based control of dynamical systems

Work place: Laboratoire des signaux et systemes, CentraleSupelec, Gif-sur-yvette, France

Application:
Master's students with good academic results, a solid background in control theory, and excellent writing and communication in English. Furthermore, experience in machine-learning techniques is preferable.

Keywords: Control theory, Learning-based control.

Context and objectives of the internship: In recent years, machine-learning approaches have made a remarkable impact on the society as they have been successfully employed in many areas including transportation [6], networking [12], healthcare [8], and education [7]. The obtained results have inspired the control community to use machine-learning techniques to design safety-critical Cyber-Physical Systems (CPS) such as surgical robots [4], autonomous vehicles [10, 6, 3] and air traffic collision avoidance systems [9]. Classical approaches for demonstrating the safety of learning-based systems rely on the use of extensive simulation testing, which are usually costly and incomplete. At the same time, recent rare event failures such as the Tesla and Uber [1] autonomous driving crashes, have shown the need for a better understanding of machine-learning algorithms to control complex CPS.

In this context, new approaches based on analytical proofs using control theory and algorithmic proofs based on tools from formal methods are urgently needed. In principle, these new approaches will make it possible to explore all scenarios when verifying or falsifying the safety of learning-based systems, when used for verification purposes. They will also makes it possible to learn guaranteed control policies when used for control purposes.

Hence, the goal of this internship is develop tools for guaranteed learning-based control of dynamical systems. The intern will mainly work on the analysis of control loops including learning-based components, either at the level of the system [2, 5] or at the level of the controller [11]. Stability and performance guarantees of the closed-loop system will be analysed using different tools combining reachability analysis and lyapunov-based approaches.

Duration: 6 months

Supervisors: Adnane SAOUD, Antonio LORIA, Mohamed MAGHENEM.

Contact: The candidate must send to adnane.saoud@centralesupelec.fr the CV and marks of all her/his MSc studies.

References

[1] *US National Highway Traffic Safety Administration. [n. d.]. Investigation PE16-007. https://static.nhtsa.gov/odi/inv/2016/INCLA-PE16007-7876.pdf.* 2016.

[2] Alex Devonport, Adnane Saoud, and Murat Arcak. Symbolic abstractions from data: A pac learning approach. *arXiv preprint arXiv:2104.13901*, 2021.

[3] Tommaso Dreossi, Shromona Ghosh, Alberto Sangiovanni-Vincentelli, and Sanjit A. Seshia. Systematic testing of convolutional neural networks for autonomous driving, 2017.

[4] Daniel A Hashimoto, Guy Rosman, Daniela Rus, and Ozanan R Meireles. Artificial intelligence in surgery: promises and perils. *Annals of surgery*, 268(1):70–76, 2018.

[5] Kazumune Hashimoto, Adnane Saoud, Masako Kishida, Toshimitsu Ushio, and Dimos Dimarogonas. Learning-based symbolic abstractions for nonlinear control systems. *arXiv preprint arXiv:2004.01879*, 2020.

[6] Philip Koopman and Michael Wagner. Autonomous vehicle safety: An interdisciplinary challenge. *IEEE Intelligent Transportation Systems Magazine*, 9(1):90–96, 2017.

[7] Rosemary Luckin. *Machine Learning and Human Intelligence: The Future of Education for the 21st Century.* ERIC, 2018.

[8] Gunasekaran Manogaran and Daphne Lopez. A survey of big data architectures and machine learning algorithms in healthcare. *International Journal of Biomedical Engineering and Technology*, 25(2-4):182–211, 2017.

[9] Amjad Rehman. Machine learning based air traffic control strategy. *International Journal of Machine Learning and Cybernetics*, pages 1–11, 2012.

[10] Ahmad EL Sallab, Mohammed Abdou, Etienne Perot, and Senthil Yogamani. Deep reinforcement learning framework for autonomous driving. *Electronic Imaging*, 2017(19):70–76, 2017.

[11] Adnane Saoud and Ricardo G Sanfelice. Computation of controlled invariants for nonlinear systems: Application to safe neural networks approximation and control. *IFAC-PapersOnLine*, 54(5):91–96, 2021.

[12] Mowei Wang, Yong Cui, Xin Wang, Shihan Xiao, and Junchen Jiang. Machine learning for networking: Workflow, advances and opportunities. *IEEE Network*, 32(2):92–99, 2017.