Safe Learning-Based Control for Mobile Robots

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Wednesday, April 25th, 4:30 PM
EQUAD Rm J223

Traditionally, planning, control and decision making algorithms have been designed based on a-prior knowledge about the system and its environment, including models of the system dynamics and maps of the environment. This approach has enabled successful system operation in predictable situations, where the models are a good approximation of the real system behavior. However, if detailed models are not available, control systems are typically designed to be conservative against the unknown, which may cause drastic performance losses. To achieve safe and efficient system behavior in the presence of uncertainties and unknown disturbances, we aim to enable systems to learn during operation and adapt their behavior accordingly. However, classical learning methods, while often successful, do not provide formal guarantees for system safety and performance. In this talk, I will present approaches for safety-guaranteed learning, which combine learning methods with formal results of control theory in order to produce provably safe approaches to real-time system control. Our work is motivated by applications in the field of robotics such as mobile manipulators, and self-flying and -driving vehicles. In contrast to their early industrial counterparts, these robots are envisioned to operate in increasingly complex and uncertain environments, alongside humans, and over long periods of time. We use Gaussian Processes (GPs) as a tool to model uncertainties and gradually learn unknown effects from data. We investigate how GPs can be combined with robust, nonlinear and predictive control approaches to achieve guaranteed safe, high-performance system behavior. Examples include automatic, safe controller tuning for aerial vehicles and experience-based speed improvement for self-driving vehicles. Finally, I will describe a number of promising future directions of research within the framework of safety-guaranteed learning, including experience recommendation for long-term operations in changing conditions, safe reinforcement learning, resource-constrained learning and control, and transfer learning between robots.

Angela Schoellig is an assistant professor at the University of Toronto Institute for Aerospace Studies, an associate director of the Centre for Aerial Robotics Research and Education at U of T, and an instructor of Udacity's flying-car nanodegree program. She conducts research at the interface of robotics, controls, and machine learning. Her goal is to enhance the performance, safety, and autonomy of robots by enabling them to learn from past experiments and from each other. She is a recipient of a Sloan Research Fellowship (US/Canada-wide award, one of two in robotics); a Canadian Ministry of Research, Innovation & Science Early Researcher Award; and a Connaught New Researcher Award. She is one of MIT Technology Review's Innovators Under 35 (2017), one of Robohub's "25 women in robotics you need to know about (2013)," winner of MIT's 2015 Enabling Society Tech Competition, a 2015 finalist in Dubai's $1 million "Drones for Good" competition, and the youngest member of the 2014 Science Leadership Program, which promotes outstanding scientists in Canada. Her PhD was awarded the ETH Medal and the 2013 Dimitris N. Chorafas Foundation Award (one of 35 worldwide).