Title: Cyber-physical control systems

Abstract: Cyber-physical systems (CPS) integrate sensing, computation, actuation and networking into physical objects and the environment for the purpose of more efficient, robust and resilient operations. Applications of CPS range from energy and transportation to healthcare and manufacturing. In this course we will discuss some essential topics on how to design cyber-physical control systems.

The first day of the course will present how to incorporate formal design specifications into the control synthesis problem for CPS. In particular, it will be shown how receding horizon control laws can be computed under temporal logic constraints. Such constraints naturally arise for instance in the control of autonomous vehicles, which might interact with each other and the environment in a complex manner. A particular application we will consider is shared-autonomy systems, where a vehicle is jointly steered by a human operator and automatic control under provable safety guarantees.

In the second day of the course, we will first introduce some methods for how to design wirelessly networked CPS. It will be shown how network protocols and control algorithms can be co-designed and how the framework scales to large systems and multi-hop networks. As CPS are vulnerable to cyber-attacks, we will also discuss how to build secure CPS. In particular, when cyber and physical components are tightly interconnected, it will be argued that traditional IT security focusing only on the cyber part does not provide appropriate solutions. Modeling the objectives and resources of the adversary together with the plant and control dynamics is shown to be essential. The consequences of common attack scenarios, such as denial-of-service, replay, and bias injection attacks, can be analyzed using the proposed framework.

Finally, we will present a CPS application in transportation consisting of connected vehicles acting as mobile sensors and actuators, enabling traffic predictions and control at a scale never before possible. Specifically, we will discuss how a new freight transport technology based on automated truck platoons can be the backbone for such a system. Both theoretical and experimental results on the control and coordination of truck platoons will be presented. How such platoons influence traffic flows by acting as a moving bottleneck will be discussed together with data-based traffic models suitable for designing novel traffic control systems.