PURDUE UNIVERSITY | College of Engineering

CE 597: Vehicular Cyber-Physical Systems (Spring 2023)

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[Description] Cyber-physical systems (CPS) are a new frontier for computational systems that transform the way people interact with engineered systems, which benefit applications in fields like transportation, aerospace, manufacturing, and health care. This course introduces students to the theoretical and practical foundations of CPS, with an emphasis on their usages in connected and automated vehicles (CAV). Upon finishing the course, students are expected to obtain the basic knowledge of CPS and CAV, and know how to develop a model-based autonomous system to be applied to the transportation system.

[Prerequisites] This course is intended for **graduate students only**. Basic understanding of software engineering, autonomous systems, and internet of things is preferred.

[Topics] This course is planned to cover the following topics:

- **Cyber-physical systems (CPS)**
  - sensors and actuators for physical processes
  - system modeling, model-based design, and digital twins
  - CPS applications in various fields
- **Connected and automated vehicle (CAV) systems**
  - CAV modules: communication, localization, perception, planning, and control
  - mechanism of popular CAV functions: object detection (perception), behavior prediction (planning), and car following (control)
  - CAV applications: personalized/cooperative adaptive cruise control, cooperative lane change, and cooperative driving at intersections
  - edge computing and cloud computing for CAV
- **Advanced simulation technologies for CPS and CAV**
  - X-in-the-loop simulation
  - virtual reality and augmented reality for virtual prototyping
  - agent-based modeling and simulation with game engines
- **State-of-the-art in CPS and CAV industries**
  - Invited talks from guest speakers in industry (software and automotive companies)

[Grading] There will be no written quizzes or exams, and the overall grade of this course will be based on multiple aspects of an independent/collaborative research project (team size<=2). Students are allowed to pick their own project topics related to CPS or CAV.

- Project proposal with literature review: 10%
- Mid-term project report: 20%
- Final project presentation: 30%
- Final project report: 40%

[References] Following textbook and position/survey papers are useful references of this course:

- [CPS] E. A. Lee and S. A. Seshia, "Introduction to Embedded Systems: A Cyber-Physical Systems Approach", 2017, available: https://ziranw.github.io/CE597/Lee_CPS_Book.pdf.
- [DT] C. Schwarz and Z. Wang, "The Role of Digital Twins in Connected and Automated Vehicles", IEEE Intelligent Transportation Systems (ITS) Magazine, 2022.
- [DT] Z. Wang et al., "Mobility Digital Twin: Concept, Architecture, Case Study, and Future Challenges", IEEE Internet of Things Journal., vol. 9, no. 18, 2022.
- [Computing] S. Liu et al.," Edge Computing for Autonomous Driving: Opportunities and Challenges," Proceedings of the IEEE, vol. 107, no. 8, 2019.
- [AV] C. Badue et al., "Self-Driving Cars: A Survey", Expert Systems with Applications, vol. 165, 2021.
- [CAV] A. Eskandarian et al., "Research Advances and Challenges of Autonomous and Connected Ground Vehicles", IEEE Transactions on ITS, vol. 22, no. 2, 2021.
- [Localization] G. Bresson et al., "Simultaneous Localization and Mapping: A Survey of Current Trends in Autonomous Driving", IEEE Transactions on Intelligent Vehicles (IV), vol. 2, no. 3, 2017.
- [Perception] E. Marti et al., "A Review of Sensor Technologies for Perception in Automated Driving", IEEE ITS Magazine, vol. 11, no. 4, 2019.
- [Planning] W. Schwarting et al., "Planning and Decision-Making for Autonomous Vehicles", Annual Review of Control, Robotics, and Autonomous Systems, vol. 1:187-210, 2019, available: https://ziranw.github.io/CE597/schwarting2018.pdf.
- [Planning] B. Paden et al., "A Survey of Motion Planning and Control Techniques for Self-Driving Urban Vehicles", IEEE Transactions on IV, vol. 1, no. 1, 2016.
- [Control] J. Guanetti et al., "Control of connected and automated vehicles: State of the art and future challenges", Annual Reviews in Control, vol. 45, 2018.
- [Control] Z. Wang et al., "A Survey on Cooperative Longitudinal Motion Control of Multiple Connected and Automated Vehicles", IEEE ITS Magazine, vol. 12, no. 1, 2022