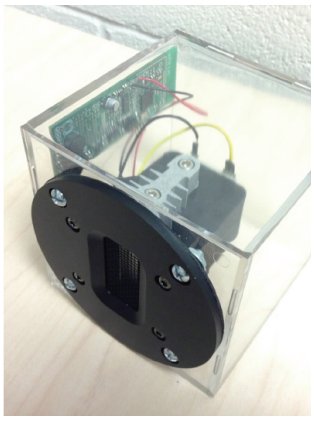
Cyber-Physical Systems

Electrical & Computer Engineering









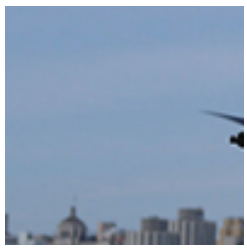
More and more devices are becoming embedded with sensors and gaining the ability to communicate. We are seeing a new paradigm in computing where sensing, computation, and control are tightly coupled with the physical environment. We will soon live in a world where trillions of devices interact with billions of smartphones and servers that are able to sense and control the utmost aspects of our lives. If orchestrated correctly, the economic and societal potential of these systems will transform far reaching application domains including critical infrastructure monitoring, healthcare, transportation, defense systems, entertainment, mobile robotics, manufacturing, smart buildings and citywide energy optimization.

Design of these systems requires research at the intersection of multiple disciplines, including; embedded systems, control theory, sensors, perception, computer networks, and machine learning. The term Cyber-Physical System (CPS) refers to this next generation of engineered system where the emphasis is on the strong linkage between computation and the physical world. ECE's deep roots in the fundamental areas that comprise CPS, paired with a highly collaborative College of Engineering, makes for one of the most extensive CPS research portfolios in the world.

Faculty are currently working on projects with ambitious goals; designing safer cars, disaster rescuing robots, buildings that consume zero-net energy, technology to improve the lives of the disabled, and sensors to monitor the health of everything from bridges to our aging population.

In order to realize these goals, ECE faculty grapples with the following research questions: How should devices in communicate? What should power them? How should data be represented and how do we extract meaningful information? Where should information be stored? What changes do we need to make to our current internet? Will they operate safely and securely? Solutions in this space will help lead industries towards an unprecedented level of automation and improved efficiency as Cyber-Physical Systems evolve in complexity and scale.

Our challenge is in providing the design paradigms, abstractions and methodologies that enable predictable, analyzable and enforceable operation across a wide variety of applications. ECE contributes key expertise in multiple crosscutting research areas and it leverages the strengths available at CMU in a number of ongoing and planned initiatives, including the Quality-of-Life Technology Center, the Scott Energy Institute, the US-DOT funded T-SET Transportation Center, and CyLab.



Electrical & Computer ENGINEERING

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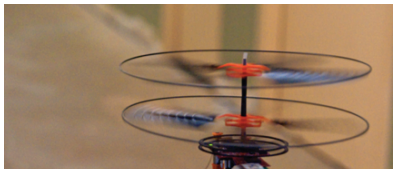
ECE expertise

Cyber-Physical Systems (CPS) at ECE is comprised of a mixture of technical areas and application domains briefly described below.

Real-time and dependable embedded systems

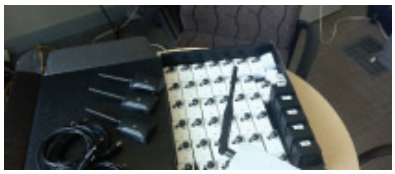


In complex sensing and control systems, there are often requirements where the correctness of a result is only useful if it is produced before a certain timing deadline. Ongoing embedded research in ECE spans from designing hardware, communication protocols and operating systems with principled timing properties, to the specification of application requirements and system robustness testing. *Contact: Phil Koopman.*

Networking and distributed controls

It is becoming increasingly important to be able to model and analyze the interaction between sensing, communication and computing infrastructure to enable robust/reconfigurable design of decision-making mechanisms at scale and across networked devices. ECE researchers in this area are working on a wide variety of topics including the synthesis and verification of embedded control software, optimization of energy systems and analysis of networked embedded controls. *Contact: Bruce Krogh.*

Wireless sensor networking



We are now beginning to see practical wireless sensor network deployments making their way to industry. ECE researchers in this space are tackling the next set of challenges associated with ultra low-power networking, system architectures and ontologies for accessing, storing and analyzing sensor data streams at scale. *Contact: Pei Zhang.*

Security

Network connected devices are increasingly finding themselves in critical infrastructure where the threat of hackers causing malfunctions and outages can quickly escalate to a Hollywood-scale worst-case scenario. ECE research in this area focuses on approaches for detecting malicious attacks, guaranteeing continuity of operations and ultimately reconfiguring and restoring full functionality through use of formal methods. *Contact: Bruno Sinopoli.*

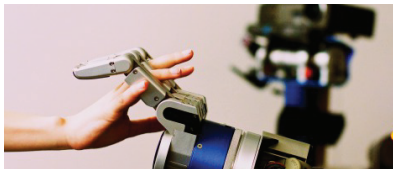
Critical infrastructure monitoring

To avoid costly failures and provide 21st century infrastructure, ECE researchers in close collaboration with the Civil and Environmental Engineering Department are working to deliver an electronic "nervous system" that can collect and analyze sensor data to enable better decision-making. Our research helps to provide sensor data-driven awareness of the usage and condition of infrastructure (both for components and the entire network), and proactive, intelligent decision support and control of these systems over their lifetime. *Contact: Anthony Rowe.*

Intelligent transportation

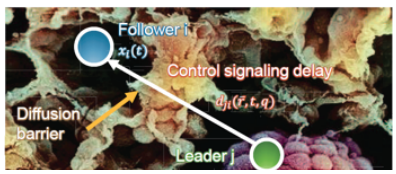
Transportation is on the verge of a technology-fueled renaissance. Smart traffic lights will be used to make Intersections safer, vehicles will coordinate to reduce congestion and automatic surface monitoring will lead to well-maintained roads. Sensors and actuators within vehicles will assist the driver by performing continuous around-the-vehicle sensing, looking ahead, communicating and notifying of unsafe conditions and even intervening when necessary. *Contact: Raj Rakumar.*

Quality-of-life technology



ECE faculty currently lead an NSF Engineering Research Center (QoLT) focused on the development of intelligent systems that help older adults and people with disabilities to live more independently. The center addresses the needs of everyday living by prototyping personal assistive robots, and cognitive / behavioral coaches through research rooted in human-system interaction. *Contact: Dan Siewiorek.*

Bio-CPS



Miniature devices voyage inside the human body for diagnostic and drug delivery purposes is no longer a wild dream. Indeed, one can develop synthetic gene circuits and tiny micro-robots to treat of infectious diseases or cancer, as well as vaccines, cell therapies, and regenerative medicine approaches. Ongoing research within ECE, targets a variety of topics including theoretical foundations, molecular and nano-networking, intra- and inter-cellular dynamics. *Contact: Radu Marculescu.*