Penn Engineering

PRECISE

PENN RESEARCH IN EMBEDDED COMPUTING AND INTEGRATED SYSTEMS ENGINEERING

"Building safe, smart, and efficient embedded systems for applications in life-critical control, communication, and computation."

http://precise.seas.upenn.edu

The Future of CPS

We established the Penn Research in Embedded Computing and Integrated Systems Engineering (PRECISE) center in 2008 to leverage our members' expertise in the theoretical and engineering foundations of cyber-physical systems (CPS). The center serves as the convergence of related research efforts by affiliated faculty spanning the CPS domain. In the short time since its creation, our genesis has flourished into a multi-million dollar research center yielding diverse scientific developments. Currently, PRECISE researchers are actively collaborating with CPS application-area experts to develop next generation medical systems, automotive systems, green energy buildings, and consumer electronics.

Cyber-physical systems (CPS) are physical and engineered systems which coordinate computing and communication to interact with the physical world. CPS requires an integration of computer science, control theory, and embedded systems. These domains combine to transform the world with technologies that save lives (e.g., medical devices), respond in real-time (e.g., collision avoidance in automobiles), and use less resources (e.g., energy efficient buildings).

PRECISE strives to provide an enriching and integrative environment that fosters interaction among students, researchers, visitors, faculty, and CPS industry leaders. In doing so, we seek not only to improve the world around us but also to cultivate a workforce that is well-poised to face the future research and development challenges of the CPS field.

Thank you for taking the time to explore PRECISE. I extend a personal invitation for you to visit the center and meet with me and our faculty to learn more about our cutting-edge endeavors in CPS research, innovation, and education.

Sincerely,

Insup Lee

Insup Lee, Ph.D.
Director, PRECISE Center
University of Pennsylvania

PRECISE's Research Foci

Safe Autonomy

We are witnessing a revolutionary shift toward consumer-based autonomous systems. Yet, providing safety guarantees for some of these systems is both essential and notably underdeveloped, as demonstrated by recent fatal accidents involving autonomous vehicle failures. At PRECISE, we are developing novel approaches to assure safety of autonomous systems, as well as new autonomy algorithms that are more amenable to assurance.

Medical Cyber-Physical Systems

From 1985 to 2005 the FDA recorded nearly 30,000 deaths and 600,000 injuries due to medical device failures. At PRECISE, we focus on the development of high-confidence medical device software (e.g., cardiac pacemakers and infusion pumps). PRECISE's goal is to develop a device-modeling approach for testing, validation, and verification in clinically-relevant environments.

Wireless Industrial Automation

Time- and safety-critical automation systems are at the heart of infrastructure such as oil refineries, automated factories, and power plants. While there are convincing economic arguments for using wireless monitoring in these environments, current approaches do not provide stability for closed-loop control or performance guarantees. PRECISE is exploring flexible network architectures and radical distributed approaches to bring wireless control to production systems.

Automotive Cyber-Physical Systems

In 2010, 20.3 million vehicles were recalled in the United States. Increasingly, these recalls are the result of buggy software controlling safety-critical functionality. At PRECISE we focus on designing next-generation programmable automobiles that will enable remote diagnostics, remote software updates, and traffic congestion management.

Energy-Efficient Buildings

Energy is becoming an increasingly valuable and environmentally-sensitive resource. At PRECISE we are developing scheduling algorithms for control systems to improve the energy efficiency of homes and buildings. Inputs like weather, time-of-day, human occupancy, and other plant dynamics influence energy-minimal scheduling which must still maintain human comfort.

Formal Verification of Cyber-Physical Systems (CPS)

To ensure reliability of CPS, a promising approach relies on designing formal models and checking them against correctness requirements using analysis tools. At PRECISE we are developing new modeling formalisms, algorithms for efficient analysis, and tools based on these theoretical foundations. Benefits of these tools are demonstrated by real-world case studies drawn from a range of applications spanning nearly all of PRECISE's research interests.

Industry Perspective

"As a Toyota employee, I have collaborated with the University of Pennsylvania on embedded systems design since 2005.

The automotive industry is moving away from the traditional idea of isolation between vehicles. Researchers are studying vehicle-to-vehicle and vehicle-to-infrastructure collaboration, thereby introducing system elements that we neither design, nor control. This broader system-to-system view may help us achieve our goals of improving sustainability and safety.

We envision a roadway infrastructure that can broadcast traffic scenarios, allowing vehicles to react accordingly. Our CPS capabilities need to be increased in order to produce the embedded systems we envision.

Finding students trained across CPS disciplines is an ongoing challenge. The skills that PRECISE is providing are essential for the automotive industry's delivery of advanced systems to our customers and to society. The PRECISE center recognizes the needs of our society and is providing the corresponding educational requirements that CPS requires."

Ken Butts, Ph.D.

Executive Engineer, Powertrain Control Department

Toyota Technical Center

"Our first interaction with PRECISE faculty was in 2005 on the Small Business Innovative Research (SBIR) grant called *Run-Time Validation and Verification for Safety-Critical Flight Control Systems*. The PRECISE center research-level tools aided in the guaranteed safety of adaptive (non-deterministic) software. Since that time, researchers and students alike have been instrumental in providing relevant fault-tolerant applications for advanced safety critical certification. More recently, the PRECISE center has contributed to a cross-discipline team to understand and enable the next generation of autonomous unmanned aerial vehicles. These needs were highlighted in the 2010 Science and Technology Report from the Air Force Chief Scientist. Much like Asimov's fictional three laws of robotics, the PRECISE center is aiding in the creation of autonomous robots that 'do no harm.'

PRECISE excels at linking control, communication, and software disciplines for autonomous systems defining the next generation cyber-physical systems."

Matthew Clark

Electronics Engineer

Air Force Research Laboratory, Control Sciences

Wright Patterson Air Force Base

Pioneers of PRECISE

RAJEEV ALUR, Ph.D., *Computer Science*

Interest(s): Model-based design and formal verification

Application domain(s): Embedded control software and real-time decision making

OSBERT BASTANI, Ph.D., *Computer Science*

Interest(s): Machine learning

Application domain(s): Learning-based control and precision medicine

JOE DEVIETTI, PH.D., *Computer Science*

Interest(s): Computer architecture and programming languages

Application domain(s): Security, concurrency and mobile computing

INSUP LEE, Ph.D., *Computer Science*

Interest(s): Real-time embedded systems, CPS safety & security, assurance cases

Application domain(s): Cyber-physical systems, Internet of Medical Things, autonomous systems

RAHUL MANGHARAM, Ph.D., *Electrical and Computer Engineering*

Interest(s): Formal methods, control systems, machine learning

Application domain(s): Autonomous systems, implantable medical devices, energy-efficient smart buildings

MAYUR NAIK, Ph.D., *Computer Science*

Interest(s): Programming languages and software engineering

Application domain(s): Security, concurrency and mobile computing

GEORGE PAPPAS, Ph.D., *Electrical and Computer Engineering*

Interest(s): Embedded control systems, networked control systems, hybrid control systems

Application domain(s): IoT, safe AI and robotics

LINH THI XUAN PHAN, Ph.D., *Computer Science*

Interest(s): Safety, security and performance guarantees for real-time/embedded/cyber-physical systems and distributed systems

Application domain(s): Automotive & avionics systems, IoT, data centers & the cloud

OLEG SOKOLSKY, Ph.D., *Computer Science*

Interest(s): Runtime verification, model-based verification and development

Application domain(s): Medical devices and autonomous vehicles

JAMES WEIMER, PH.D., *Electrical and Computer Engineering*

Interest(s): Medical cyber-physical systems and cyber-physical security

Application domain(s): Health informatics and personalized health