Modeling and Verification of Cyber-Physical Systems

Overview

Cyber-physical systems (CPS) result from a tight integration of computing and networking technologies with the physical world. Such systems are at the heart of technological innovations in diverse industries such as aerospace, automotive, manufacturing, robotics and healthcare. For example, algorithms are improving fuel efficiency, driving experience and safety in cars. Manufacturing, healthcare and aerospace systems are undergoing similar transformations. Auditing or checking the correctness of these systems is a grand challenge problem. This course gives the necessary background in formal methods, automated deduction and control theory to introduce the participants to the state-of-the art techniques in modeling and analysis of CPS. The substance of this course provides the scientific basis for regulations and standards that make vehicles and autonomous systems safer, more secure and can also help them meet privacy and fairness expectations.

Objectives

The primary objectives of the course are as follows:

- Introduce participants to the fundamentals of modeling cyber-physical systems (CPS) consisting of both discrete and continuous dynamics through several examples.
- Provide an overview of design automation and verification problems and the related decidability and complexity results.
- Expose the participants to state-of-the-art algorithms and tools for analyzing CPS.
- Provide exposure to practical applications of modeling and verification through case studies.

Schedule	**January 01 – January 05, 2018, covering 15 hours lectures and 8 hours tutorials.** **Number of participants for the course will be limited to seventy.**
Who Should Attend	▪ Executives, engineers and researchers from manufacturing, service and government organizations including R&D laboratories. ▪ Students from CSE/ECE/EE/IT at all levels (BTech/MSc/MTech/PhD) and Faculty from reputed academic institutions and technical institutions.
Fees	The participation fee for taking the course is as follows: **Participants from abroad : USD 500** **Industry/ Research Organizations: INR 8000** **Faculty from Academic Institutions: INR 4000** **Indian Students: INR 1000** The above fees include all instructional material and internet facility. The participants will be provided with twin sharing accommodation on payment basis at IITG guest house/student hostels.

The Faculty

Dr. Sayan Mitra is an Associate Professor of Electrical and Computer Engineering at the University of Illinois at Urbana-Champaign. He also holds affiliate positions at the Department of Computer Science and at the Coordinated Science Laboratory. His research interests are in formal verification, distributed computing and cyber-physical systems. He holds a PhD from MIT, MSc from the Indian Institute of Science, Bangalore and an undergraduate degree in Electrical Engineering from Jadavpur University, Kolkata. Professor Mitra is recognized as an international leader in formal analysis of cyber-physical systems with more than 70 publications in top tier conferences and journals. He has co-founded a startup company that is looking to commercialize verification technologies for safety-critical autonomous systems like self-driving vehicles.

Dr. Purandar Bhaduri is a Professor at the Department of Computer Science and Engineering at IIT Guwahati, where he has been a faculty since 2004. His research interests are in compositional modeling, analysis and verification of embedded systems. He did his PhD from the Department of EECS, Washington State University, Pullman in 1993, his ME from the Department of CSA, IISc Bangalore in 1987 and his B.Tech from IIT Kanpur in 1985, all in Computer Science. He has over eight years of industry experience, having worked at TRDDC, Pune and Tata Infotech, Mumbai. He also held postdoctoral positions at TIFR Mumbai and Massey University, New Zealand. He has been a Guest Researcher at the Carl von Ossietzky University, Oldenburg and a Visiting Researcher under the DAAD-IIT Exchange of Senior Scientists Program at Technical University of Munich.

Course Co-ordinators

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http://www.gian.iitkgp.ac.in/GREGN
http://www.iitg.ernet.in/pbhaduri/GIAN-CPS

Detailed Course Plan

Day	Session	Time	Topic
01.01.2018 (Monday)		9:30 AM – 10:00 AM	Inauguration function
	Lecture 1 (SM)	10:00 AM – 11:30 AM	Motivation; Modeling Discrete Systems; Automata; HIOA specification Language; Invariants
Day 1	Lecture 2 (PB)	12:00 PM – 1:30 PM	Turing Machines, Languages and Decidability; Complexity classes, P, NP, NL, PSPACE; NL Completeness of Reachability
	Tutorial 1 (SM)	3:00 PM – 5:00 PM	An introduction to modern SMT solvers; DPLL algorithm; Examples from real-time distributed algorithms; Z3 tutorial
02.01.2018 (Tuesday)	Lecture 3 (SM)	9:30 AM – 11:00 AM	Computational Tree Logic (CTL) and CTL model checking
Day 2	Lecture 4 (SM)	11:30 AM – 1:00 PM	Introduction to dynamical systems and hybrid automata; Reachability; Examples and Case studies
	Tutorial 2 (SM)	2:30 PM – 4:30 PM	Reachability analysis with SpaceEx. Case studies on control systems, robotic models
03.01.2018 (Wednesday)	Lecture 5 (SM)	9:30 AM – 11:00 AM	Compositions, abstractions and simulation
Day 3	Lecture 6 (SM)	11:30 AM – 1:00 PM	Timed automata; Timed to rectangular hybrid automata; Undecidable problems
	Tutorial 3 (PB)	2:30 PM – 4:30 PM	Model checking with UPPAAL/HyTech. Real-time systems, air-traffic protocols
04.01.2018 (Thursday)	Lecture 7 (SM)	9:30 AM – 11:00 AM	Stability verification, Dynamical systems, Lyapunov functions; hybrid systems, Multiple Lyapunov functions, dwell time
Day 4	Lecture 8 (SM)	11:30 AM – 1:00 PM	Simulation-driven Verification
	Tutorial 4 (SM)	2:30 PM – 4:30 PM	C2E2 Tutorial; Case studies on autonomous vehicle maneuvers, cardiac cell models
05.01.2018 (Friday)	Lecture 9 (SM)	9:30 AM – 11:00 AM	Automatic controller synthesis and quantized control
Day 5	Lecture 10 (SM)	11:30 AM – 1:00 PM	Verification of machine learning and other advanced research topics
	Examination	2:30 PM – 4:30 PM	Course Assessment Test (Optional) for participants who need a grade card for the course.

* (SM: Dr. Sayan Mitra, PB: Dr. Purandar Bhaduri)