



FOUNDATIONS OF CYBER PHYSICAL SYSTEMS

PROF. SOUMYAJIT DEY

Department of Computer Science and Engineering
IIT Kharagpur

PRE-REQUISITES :

1. Basic Programming Knowledge
2. Engineering Mathematics

INTENDED AUDIENCE : UG/PG students of CSE/EE/ECE

INDUSTRY SUPPORT : Tier 1 Automotive companies:
Robert Bosch Engineering, OEM Automotive companies:
TML, BMW, Daimler, Mahindra etc, Govt Labs like DRDO, HAL

COURSE OUTLINE :

Cyber-physical systems (CPS), which consist of physical systems tightly integrated and/or controlled by software, are ubiquitous in many safety critical domains, including automotive, avionics, railways, healthcare, atomic energy, power, and industrial automation. The principles of design and implementation of cyber-physical systems are remarkably different from that of other embedded systems because of the tight integration of real valued and dense time real time systems with software based discrete automated control. The objective of this course is to develop an exposition of the challenges in implementing a cyber-physical system from a computational perspective, but based equally on the principles of automated control. The course aims to expose the student to real world problems in this domain and provide a walk through the design and validation problems for such systems. With the advent of AI techniques, their increased use in CPS is also a promising growth vertical along with the necessity of safety assurance. In this course we also touch upon concepts of Neural Network based decision making for Continuous Systems while guaranteeing safety and stability using control theoretic constraint solving.

ABOUT INSTRUCTOR :

Prof. Soumyajit Dey is currently an associate professor in the Department of Computer Science and Engineering, IIT Kharagpur. He joined the department in 2013. He did his B.E. in Electronics and Telecommunication Engg. from Jadavpur University, Kolkata, India. He did his Masters and PhD degree in Computer Science and Engg. from IIT Kharagpur, India. He has published 24 peer reviewed journals and 40 International conference papers, some of them in top venues (<http://cse.iitkgp.ac.in/~soumya/pub.html>). He leads the High Performance Real-time Computing Laboratory (HIPRC) in Computer Science and Engg. Dept, IIT Kharagpur, India. His research interests include 1) Real Time / Cyber Physical Systems 2) Automated Reasoning and Programming Languages, 3) GPGPU optimizations. He has served as reviewer in 10 IEEE/ACM transactions and as PC member in DAC, RTSS, VLSI, VDAT, DSD, SPACE conferences. He has also organized special sessions in OSD 2020/21, DATE 2021. He is the winner of best design award in VLSI 2006 and has an honourable mention in VLSI 2019. He serves in the IEEE Technical Committee on CPS and IEEE Control System Society Technical Committee on Hybrid Systems.

COURSE PLAN :

Week 1:

- i. Cyber— Physical Systems (CPS) in the real world: Industry 4.0, Automotive, Building Automation, Medical CPS
- ii. Low power compute platforms for CPS

Week 2: Real time sensing and communication for CPS

- i. Sensors, Actuators
- ii. CAN protocol in automotive systems

Week 3:

- i. Real time task scheduling for CPS
- ii. Worst Case Execution Time, Res ponse time analysis of CPS software

Week 4:

- i. Dynamical System modeling for CPS
- ii. Different notions of stability

Week 5:

- i. Controller Design (using pole placement)
- ii. Delay aware Controller Design

Week 6:

Stability and Control Performance in presence of Platform uncertainties

Week 7:

- i. Lyapunov Stability
- ii. Barrier Functions

Week 8:

Quadratic Program based Controller Design ensuring Safety and Stability

Week 9:

Neural Network (NN) Based Controllers in CPS

Week 10:

Safety of NN enabled CPS: switching between NN and conventional controllers

Week 11:

State Estimation using Kalman Filter and other techniques

Week 12:

i. False Data Injection (FDI) Attack detection in CPS

ii. Attack Mitigation in C

