INDIN 2024

The 22nd IEEE International Conference on Industrial Informatics INDIN 2024,August 17-20,2024, Beijing, China.

Tutorial Proposal

Title of the Proposal: Functional verification of Cyber Physical Systems: From Theory to Practices

- Presenter(s):
Dr. Nilotpal Chakraborty

- Brief description:
Cyber-Physical System (CPS) integrates digital or cyber components with physical objects (e.g. robotic machines, autonomous vehicles) and data with various capabilities of communication, data generation, data processing, computation, decision making, and action. These systems are increasingly pervading their ways to all parts of our lives where applications range from agriculture and healthcare to energy, manufacturing and social networks. Advances in CPS will enable new capabilities and improved adaptability, scalability, and usability that will far exceed those current embedded systems. Therefore, there is a need to create an integrated ecosystem for convergence among all stakeholders towards CPS technology development and practical implementations. This tutorial is intended to cover primarily the functionalities of and analysis of CPS. In particular, we will cover the safetyness and liveness properties of CPS, which ensure that the system behaves correctly and as per the requirements of the design. For example, in a self-driving car, a safety property would be that the car does not collide with obstacles or pedestrians. On the other hand, Liveness property ensures that the car continues to make progress towards its intended goal, which is reaching the destination.

Upon completion of this tutorial, the audience will be having the capability to:
1. Understand the fundamentals of Cyber Physical Systems.
2. Analyze the safetyness of CPS using Boolean logic and expressions, safety invariants, Binary Decision Diagrams, and obtain Reduced Ordered Binary Decision Diagrams for CPS
3. Learn about Linear Temporal Logic and Buchi Automata for the Liveness properties of CPS.
4. Case studies on real-world CPS applications using state-of-the-art CPS modeling languages.

- Duration:
4 hours

- **Outline:**
The tutorial will cover the following topicss:

I. Introduction to Cyber-Physical Systems (CPS) A. Definition and Components of CPS B. Applications and Importance in Various Domains
II. II. Fundamentals of CPS Analysis A. Understanding Safety and Liveness Properties B. Importance of Safety and Liveness in CPS C. Examples of Safety and Liveness Requirements in CPS.
III. Analyzing Safety in CPS A. Boolean Logic and Expressions for Safety Analysis B. Safety Invariants: Definition and Usage C. Binary Decision Diagrams (BDDs)

for Safety Verification D. Obtaining Reduced Ordered Binary Decision Diagrams (ROBDDs) for Efficient Analysis

IV. Ensuring Liveness in CPS A. Introduction to Linear Temporal Logic (LTL) B. Buchi Automata for Liveness Verification C. Application of LTL and Buchi Automata in CPS.

V. Case Studies on Real-world CPS Applications A. Overview of State-of-the-Art CPS Modeling Languages B. Analysis of CPS Applications in Agriculture, Healthcare, Energy, Manufacturing, and Social Networks C. Challenges and Solutions in Real-world CPS Implementations

VI. Conclusion and Future Directions A. Recap of Key Concepts Learned B. Importance of Safety and Liveness in CPS Development C. Future Trends and Challenges in CPS Analysis and Implementation D. Encouragement for Further Exploration and Learning in CPS

-**Brief CV:**

Dr. Nilotpal Chakraborty: Currently working as an Assistant Professor in Computer Science and Engineering at the Indian Institute of Information Technology Guwahati. He has obtained his PhD in Computer Science and Engineering from the Indian Institute of Technology Patna in 2019. He has worked as a Postdoctoral Researcher at Department of Computer Science, Aalborg University, Denmark, and at EMAX Group, Belgium, as an IT Solution and Innovation Expert. His research interests include Scheduling and Optimization in smart grid and electric vehicles, AI and Blockchain for Cyber Physical Systems.
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- **Relevant publications:**

1. Rajeev Alur, Principles of Cyber Physical Systems, the MIT Press.
2. Edward Lee and Sanjit Seshia, Introduction to Embedded Systems —A Cyber-Physical Systems Approach, PHI
3. N. Chakraborty, A. Mondal, and S. Mondal, "Intelligent Scheduling of Thermostatic Devices for Efficient Energy Management in Smart Grid," in IEEE Transactions on Industrial Informatics, vol. 13, no. 6, pp. 2899-2910, Dec. 2017, DOI: 10.1109/TII.2017.2695241.
4. N. Chakraborty, A. Mondal, and S. Mondal, "Efficient Scheduling of Nonpreemptive Appliances for Peak Load Optimization in Smart Grid," in IEEE Transactions on Industrial Informatics, vol. 14, no. 8, pp. 3447-3458, Aug. 2018, DOI: 10.1109/TII.2017.2781284.
5. N. Chakraborty, A. Mondal, and S. Mondal, "Multiobjective Optimal Scheduling Framework for HVAC Devices in Energy-Efficient Buildings," in IEEE Systems Journal, vol. 13, no. 4, pp. 4398-4409, Dec. 2019, DOI: 10.1109/JSYST.2019.2933308.
6. N. Chakraborty, A. Mondal, and S. Mondal, "Efficient Load Control Based Demand Side Management Schemes Towards a Smart Energy Grid System," in Elsevier Sustainable Cities and Society, vol. 59, August 2020, 102175, DOI: https://doi.org/10.1016/j.scs.2020.102175
7. N. Chakraborty, A. Mondal and S. Mondal, “Scheduling Interdependent Smart Appliances with Mixed-Preemption Policy for Peak Load Minimization,” in IETE Journal of Research, 66:6, 797-805, December 2020, DOI: 10.1080/03772063.2020.1775140
8. N. Chakraborty, A. Mondal, and S. Mondal, "Intelligent Charge Scheduling and Eco-Routing for Electric Vehicles: A Multi-Objective Heuristic Approach," in Elsevier Sustainable Cities and Society, 2021, 102820, DOI: https://doi.org/10.1016/j.scs.2021.102820.
9. P. K. Saha, N. Chakraborty, A. Mondal, and S. Mondal, "Optimal Sizing and Efficient Routing of Electric Vehicles for a Vehicle-on-Demand System," in IEEE Transactions on Industrial Informatics, Accepted June 2021, DOI: 10.1109/TII.2021.3091597

10. 10. P. K. Saha, N. Chakraborty, A. Mondal and S. Mondal, "Intelligent Real-Time Utilization of Hybrid Energy Resources for Cost Optimization in Smart Microgrids," in IEEE Systems Journal, vol. 18, no. 1, pp. 186-197, March 2024, doi: 10.1109/JSYST.2024.3352617