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1. Audience and Duration
This tutorial is for anyone interested in the state-of-the-art technology for developing embedded, real-time, and cyber-physical systems. The focus is on functional reactive programming, RTL (real-time logic)-based formal verification, response time analysis, and power-aware scheduling. Knowledge of basic operating systems and architecture concepts are assumed. The duration is two hours.

2. Tutorial Description
The use of sophisticated digital systems to control complex physical components in real-time has grown at a rapid pace. These applications range from traditional stand-alone systems to highly-networked cyber-physical systems (CPS), spanning a diverse array of software architectures and control models. Examples include automobile adaptive braking, industrial robotic assembly, medical pacemakers, autonomous (ground, air, and sea) vehicular travel, remote surgery, physical manipulation of nano-structures, and space exploration. Since all these applications interact directly with the physical world and often have humans in the loop, we must ensure their physical safety.

Obviously, the correctness of these embedded systems and CPSs depends not only on the effects or results they produce, but also on the time at which these results are produced. For example, when the driver of a car applies the brake, the anti-lock braking controller analyzes the environment in which the controller is embedded (car speed, road surface, direction of travel) and activates the brake with the appropriate frequency within fractions of a second. Both the result (brake activation) and the time at which the result is produced are important in ensuring the safety of the car, its driver and passengers. In a CPS consisting of a multitude of
vehicles and communication components with the goal to avoid collisions and reduce traffic congestions, formal safety verification and response time analysis are essential to the certification and use of such systems.

In battery-operated real-time systems such as sensors in a CPS, conserving energy is of critical importance. Power-aware scheduling plays a key role in ensuring uninterrupted operation of these systems between battery recharges or energy-harvesting.

This tutorial covers the following topics:

1. Introduction to embedded/real-time and cyber-physical systems;
2. Functional reactive programming
3. Formal specification methodology and requirements analysis;
4. Analysis tools for performance evaluation;
5. System decomposition, multiprocessor scheduling, and resource partitioning;
6. Development tools;
7. Real-time operating systems;
8. Formal analysis, verification, and validation techniques based on Real-Time Logic (RTL);
9. Power-aware scheduling;
10. Response time analysis;
11. Optimization and synthesis; and
12. Case studies of actual systems (such as the timing analysis of the X-38 Space Station Crew Return Vehicle Avionics consisting of a fault-tolerant distributed system of a network of processors).

3. Instructor’s Biography

Albert M. K. Cheng is Professor and former interim Associate Chair of the Computer Science Department at the University of Houston (UH). His research interests center on the design, specification, modeling, scheduling, and formal verification of real-time, embedded, and cyber-physical systems, green/power/thermal-aware computing, software engineering, knowledge-based systems, and networking. He is the founding Director of the UH Real-Time Systems Laboratory. He received the B.A. with Highest Honors in Computer Science, graduating Phi Beta Kappa at age 19, the M.S. in Computer Science with a minor in Electrical Engineering at age 21, and the Ph.D. in Computer Science at age 25, all from The University of Texas at Austin, where he held a GTE Foundation Doctoral Fellowship. He has served as a technical consultant for many organizations, including IBM and Shell, and was also a visiting professor in the Departments of Computer Science at Rice University and at the City University of Hong Kong. He is a co-founder of ZapThru.com, where he is currently the Chief Technology Advisor.

Dr. Cheng is the author/co-author of over 170 refereed publications in leading journals (including IEEE Transactions on Computers, IEEE Transactions on Software Engineering, and IEEE Transactions on Knowledge and Data Engineering) and top-tier conferences (including RTSS, RTAS, RTCSA, ICESS, ICPADS, ISLPE, LCN, ICMCS, COMPSAC, AINA, PADL, IPPS, IPDPS, and ICPP), and has received numerous awards, including the U.S. National Science Foundation Research Initiation Award and the Texas Advanced Research Program Grant. He has been invited to present seminars, tutorials, panel positions, and keynotes at over 80 conferences, universities, and organizations. He is and has been on the technical program committees (including several program chair positions) of over 200 conferences, symposia, workshops, and editorial boards (including the IEEE Transactions on Software Engineering 1998-2003 and the IEEE Transactions on Computers 2011-present). Dr. Cheng is the author of the popular senior/graduate-level textbook entitled Real-Time Systems: Scheduling, Analysis, and Verification (Wiley), 2nd printing with updates, 2005. He is a Senior Member of the IEEE and has been nominated to become an IEEE Fellow in 2012; an Honorary Member of the Institute for Systems and Technologies of Information, Control and Communication (INSTICC); and a Fellow of the Institute of Physics (IOP).

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Selected References


