The Science of Remulation for Executable Biology

Overview

Executable biology refers to executable computational models that mimic biological processes. Partha's group have recently proposed a refinement for real-time executable biology, where human organs can be transformed into executable models such that these models can operate in real-time with medical devices. The main motivation for such models is that they can be used for the validation of medical devices in a closed-loop without using live human organs. This has significant implications in medicine, biology, computer science, and also biomedical engineering. There are obvious implications for educational software related to this approach.

Closed-loop validation of controllers is well-known using emulation: hardware-in the loop simulation and model-in-the-loop validation. Here either the actual plant or its model may be used to validate the controller in closed-loop. Validation using the actual plant may not be practical in many situations such as live organs. Model-in-the-loop validation of human organs has received limited attention such computational models of organs provide high fidelity at the expense of very long simulation time. We propose the new approach of remulation to overcome these issues. During emulation, the plant exists and the focus is the design of the controller. During remulation, we want to design a plant that can provide real-time response to a black-box controller. Hence, in this setting the plant controller relation ship is reversed and hence remulation is an acronym of reverse emulation. A key requirement while developing remulation models is that the timing of the plant under design must be matched with that of the black-box controller. This design approach is extremely complex as the plant is typically a hybrid system, exhibiting both continuous dynamics and discrete mode switches.

We illustrate remulation by developing executable, real-time models of the cardiac conduction system of the human heart and illustrate the developed model in hardware as a remulated system for the validation of pacemakers.
The tentative schedule of course modules is as under:
Module A: Cyber-physical systems and Formal Methods

Lecture 1-2: This lecture will introduce key tenets of CPS and associated formal methods. It will introduce topics from closed-loop control systems, discrete event control, and real-time systems.

Lecture 3-4: Background on embedded systems. These lectures will provide an overview of the embedded system design flow and the current research questions of relevance to the topic of CPS. Topics covered will include techniques for synthesis, verification and static analysis of embedded systems.

Lecture 5-6: The synchronous approach, These lectures will focus on the well-known synchronous approach and its significance for the design of CPS. We will elaborate on tools such as Esterel, Scade (pure synchronous) and Zelus (hybrid). We will also present the approach used in Simulink / Stateflow from Mathworks.

Lecture 7-8: Pacemaker and Timed Automata. We will present well-known Pacemaker algorithms and illustrate formal modeling and validation of pacemakers using timed automata.

Lecture 9-10: Models of the cardiac conduction system. This will cover a range of models, form very high-fidelity bioengineering (finite element, finite volume) ones to more recent ones developed using timed and hybrid automata. We will illustrate the challenges of such modeling such as scalability, timing and reentrancy. Device specific behaviours such as the restitution interval and how to achieve good restitution will be discussed.

Lab: Remulation-based validation of pacemakers. Here Simulink and Piha will be introduced as tools for comparison and practical Remulation examples will be demonstrated.

For more details, please visit GIAN cell at http://mnit.ac.in.

Dates	**Course Duration**		**:**	**Dec 12 – 16, 2016**
	Last date of Registration		**:**	**Dec 4, 2016**
Modules	**A:**	**Cyber-physical systems and Formal Methods**	**:**	**Dec 12-13, 2016**
	B:	**Pacemaker and Timed Automata**	**:**	**Dec 14, 2016**
	C:	**Models of the cardiac conduction system**	**:**	**Dec 15-16, 2016**
	Number of participants for the course will be limited to fifty. Selection of participants shall be on "First Come First Served" basis only.			

You Should Attend If you are …

- Cardiac physicians particularly interested in cardiac devices such as pacemakers and other ICD devices. These can be members of private / public hospitals.
- Members of the school of medical science and technology at IIT, Kharagpur and similar institutes.
- Computer science, electrical and bio-engineering professors and their graduate students.
- Faculty from reputed academic institutions and technical institutions.

Fees

GIAN Portal registration fee: Rs 500 (mandatory for all participants).

1. Create login and password at http://www.gian.iitkgp.ac.in/GREGN/index
2. Login and complete the Registration Form and select Course(s)
3. Confirm application and pay Rs. 500/- (non-refundable) through online payment gateway.
4. Download "pdf file" of the application form and email it to the Course Coordinator.

Registration Fee (exclusive of GIAN Portal Registration Fee)

Participants from abroad	:	**US $100**
Industry/ Research Organizations	:	**Rs 5000**
Faculty from other Academic Institutions	:	**Rs 3500**
Students from other Academic Institutions	:	**Rs 1000**
Faculty /Students from MNIT and IIIT Kota	:	**Rs 1000**

The above fee includes all instructional materials, computer use for tutorials and free Internet facility. The participants will be provided with accommodation, if available, on payment basis.

Registration

1. Fees may be paid via Demand Draft in favour of "REGISTRAR (SPONSORED RESEARCH) MNIT Jaipur" payable at Jaipur. OR

   Fees can be paid through National Electronic Funds Transfer (NEFT)

   Account No. : 676801700388
   In name of "REGISTRAR (SPONSORED RESEARCH) MNIT Jaipur"
   Bank : ICICI Bank, Branch MNIT Jaipur
   IFSC Code: ICIC0006768.

   Preferred mode of registration is Demand Draft.
2. Email filled in "Registration Form", scan copy of "Demand Draft/ NEFT Transaction Receipt" and pdf file (downloaded from GIAN Portal Registration) to lavab@mnit.ac.in and vlaxmi@mnit.ac.in. Please mention "GIAN (The Science of Remulation for Executable Biology) in Subject of email on or before December 4, 2016.

The Faculty

Dr. Parthasarathi Roop is a Associate Professor in the Department of Electrical and Computer Engineering, University of Auckland, New Zealand. He completed his PhD in Computer Science and Engineering at the University of New South Wales, Sydney, Australia, a M.Tech at Indian Institute of Technology in Kharagpur, India and a BE degree at Anna University (College of Engineering), Madras, India. Partha had visiting positions in Kiel University, Germany, French National Laboratory of Informatics and Control, and Iowa State University and University of California, Berkeley.

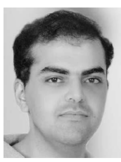
He has co-authored two research monographs and over one hundred papers, which includes a best paper award in embedded systems week (CASES 2013) and has recently received the Mercator professorship from the German Science Foundation (DFG), 2016. He has also received the Humboldt fellowship for experienced researchers in 2009. Partha is an Associate Editor of IEEE embedded systems letters and EURASIP Journal on Embedded Systems. He is in the TPC of leading conferences such as ACM EMSOFT and IEEE RTAS and is the PC co-chair of 19 IEEE ISORC to be held in York in May 2016.
(URL: http://homepages.engineering.auckland.ac.nz/~roop/)

Course Coordinators

Dr. Lava Bhargava
Associate Professor
Department of Electronics and Communication Engineering
Malaviya National Institute of Technology
JLN Marg, Jaipur – 302017, India.
Tel: +91 0141 2713337 (O)
+91-9549654231 (M)
Email: **lavab@mnit.ac.in**

Dr. Lava Bhargava is currently an Associate Professor at Electronics and Communication Engineering Department, Malaviya National Institute of Technology Jaipur, India. His research interests are in the areas of Low power VLSI systems, VLSI physical design, FPGAs. He has been associated with Phase II of VLSI-SMDP (Special Manpower Development Project in VLSI & related project and ICT Academy at MNIT Jaipur. He has published several research articles in various conferences and journals. He has served as TPC member in many International conferences. He is a member of ACM, IEEE and IETE.

Dr. Vijay Laxmi is an Associate Professor at Computer Science and Engineering Department of Malaviya National Institute of Technology Jaipur. She has been teaching in MNIT since 1995. Her research interests include information security. She obtained PhD from University of Southampton, UK under Commonwealth Scholarship and Fellowship Plan. She has guided 12 PhDs and has 125 publications in Journals and Conferences. She has been involved in various R&D projects, some of which are International Collaboration. She is an IEEE and ACM member. She has been a member of TPC of various conferences.



Dr. Avinash Malik is a Lecturer at the University of Auckland, New Zealand. His main research interest lies in programming languages for multicore and distributed systems and their formal semantics/ compilation. He has worked at organizations such as INRIA in France, Trinity College Dublin, IBM research Ireland, and IBM Watson on design and compilation of pro- gramming languages. He holds B.E. and PhD degrees from the University of Auckland.

Dr. Sidharta Andalam is currently a postdoctoral fellow at the University of Auckland, New Zealand. His principle research interests emulating the electrical conduction system of the heart for validation of medical devices such as cardiac pacemakers. He worked at TUM CREATE research centre in Singapore on design, implementation and analysis of distributed safety-critical automotive applications. He holds B.E. and PhD degrees from the University of Auckland.

Dr. Vijay Laxmi
Associate Professor,
Computer Science and Engineering,
Malaviya National Institute of Technology Jaipur
Tel: +91-141-2713333 (O),
+91-141-2713127 (R)
Email: **vlaxmi@mnit.ac.in**