CERCIRAS Summer School 2022 on Time Predictability, Energy Budgeting, Simulation-based Analysis of complex systems, and Mixed-Criticality Systems

Technical Program

- **Venue**: Faculty of Economics, Business and Tourism @ Split, HR
- **Dates**: from Monday, 19 September until Saturday, 24 September
- **Capacity**: up to 26 students (in full-board double-room accommodation), with grant from CERCIRAS covering travel and subsistence.
- **Program synopsis**: see table below, where the X.Y topic identifier denotes the topic number X (the school features **four** lecture topics) and the slot Y in each lecture series (each lecture series has **four** 90-minute slots, which alternate theory and hands-on practice).
- **Optional exams**: for students who needs a “pass mark” from the school, on-site exams will be organized in the morning of the last day, where per-student per-lecture-topic assignments will be reviewed by the corresponding instructors.
- **Other program features**:
  - the participating students will present their current research work and projects in a Poster Session that will take place in the evening of Tuesday;
  - a keynote talk (speaker and topic to be defined as yet) will be delivered in the evening of Wednesday;
  - an diversion excursion (destination to be defined as yet) will take place in the afternoon of Friday.

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Lecture Series 1: Time-predictable Multicore Computer Architecture

Instructors: Martin Schoeberl and Luca Pezzarossa, Technical University of Denmark

- Martin Schoeberl received his PhD from the Vienna University of Technology in 2005. From 2005 to 2010 he has been Assistant Professor at the Institute of Computer Engineering. He is now Professor in real-time computer architecture at the Technical University of Denmark. His research interest is on hard real-time systems, time-predictable computer architecture, and real-time Java. Martin Schoeberl has been involved in a number of national and international research projects: EOPARD, CJ4ES, T-CREST, RTEMP, the TACLe COST action, and PREDICT. He has been the technical lead of the EC funded project T-CREST. He has more than 100 publications in peer reviewed journals, conferences, and books.
- Luca Pezzarossa is Assistant Professor at the Technical University of Denmark in the field of cyber-physical embedded system. His main research interests include reconfigurable systems, FPGA-based acceleration, hardware- software co-design, on-chip/off-chip interconnects, and real-time systems. He also have carried out work on the topic of compilation and execution of domain-specific languages in the context of digital microfluidics for biochemical applications.

Outline

To enable static worst-case execution time analysis we need time-predictable processors, communication, and memory architectures. Standard processors, optimized for average-case performance, are hardly predictable for the timing analysis. Especially multicore architectures introduce additional inference between tasks executing on different cores. In this class, we will explore alternative computer architectures where time-predictability is the main design criteria. We contrast the classic design paradigm of "Make the common case fast and the uncommon case just correct" with the time-predictable design paradigm of "Make the worst case fast and the whole system analyzable". As example, we will explore the Patmos/T-CREST architecture including hands-on exercises for such an architecture.

The course will enable you to understand the timing analysis issues with standard processors and give you an idea how this issues can be solved with the appropriate architecture. In addition, the course will also touch upon the topic of time-predictable reconfigurable on-chip interconnects for multicore architectures. You will build basic knowledge using the open-source T-CREST platform, which you can also use and extend for your research.

Slot 1 (Lecture): Time-predictable computer architecture, Martin Schoeberl

We will explore how to build a time-predictable processor that is an easy target for worst-case execution time analysis. Besides the basic architecture we will learn how to build a memory hierarchy for a multicore processor (including caches, time-predictable memory arbitration, and controller) with bounded memory access time.

Slot 2 (Laboratory): The T-CREST multicore processor, Martin Schoeberl

The initial exercises are intended to make you familiar with the Patmos processor and the T-CREST tool chain, including worst-case execution time analysis. We will use a cycle-accurate simulation of Patmos/T-CREST. The tools are relative easy to install on a Ubuntu Linux, but we will also provide a VM with all tools installed.

Slot 3 (Lecture): Reconfigurable time-predictable interconnects, Luca Pezzarossa

In this lecture, we will explore the fundamental concepts for time-predictable on chip interconnects. We will investigate how statically scheduled networks-on-chip can be used to efficiently move data between the nodes of a multicore processor in a predictable manner. Furthermore, we will see how fast run-time reconfiguration can be used to increase the flexibility of such interconnects.

Slot 4 (Laboratory): Message-passing using the Argo 2 Network-on-Chip, Luca Pezzarossa

In this laboratory session, we will implement and test a simple multicore application using the time-predictable network-on-chip Argo 2. We will define a suitable schedule, implement message passing of data tokens between nodes, and use reconfiguration to change the schedule at run-time.

Lecture Series 2: Energy Consumption and Optimization of Software

Concept: Maja Hanne Kirkeby, Roskilde University, Denmark, João Paulo Fernandes, University of Porto, Portugal

Instructors: Maja Hanne Kirkeby, Roskilde University, Denmark, Bernado Santos, University of Porto, Portugal, Maria B. Mikkelsen, Roskilde University, Denmark

Short Bios to be provided.

Outline

The lecture series will provide students with

- knowledge about what affects the energy consumption of software
- skills in measuring the energy consumption of software
- knowledge about statistical analysis of energy consumption measurements
- ability to evaluate and compare the energy consumption of software.

Each student will be provided with an Intel-chips laptop provided by Roskilde University's IT department, preinstalled with:

- Ubuntu Server 22.04 LTS
- RAPL (https://github.com/greensoftwarelab/Energy-Languages or a version of it tailored for this lecture series),
- Python: Python 3.9
- Haskell compiler: ghc 8.0.2
- C compiler: gcc 6.2.0

Slot 1 (Lecture): Motivation and Introduction to energy consumption of software, Maja H Kirbeby

- Introduction to ICTs energy consumption and forecasts
- Definitions of energy consumption and energy-efficiency
- Introduction to state-of-the-art research on optimizing software for energy, demonstrating how changes in software can affect energy consumption.

Slot 2 (Lecture and Laboratory): Measuring Energy Consumption, Maja H Kirkeby, Bernardo Santos

- Introduction to energy measuring and energy modelling (exemplifying different methods together with their advantages and disadvantages)
- Introduction to RAPL and to how it can be used to estimate energy consumption
- Hands-on use experience of RAPL to measure energy consumption of example programs written in Haskell, C, Python.

Slot 3 (Laboratory): Using RAPL to measure the energy improvements of programs, Bernardo Santos

- Work on the programs from slot 2 to improve their energy balance. First, following explicit guidance, afterwards doing exploratory changes.
- Throughout all that, always repeating energy-consumption measurements to analyse the actual effects of the applied changes.

Slot 4 (Lecture and Laboratory): Using Python for statistical analysis of experimental results, Maja H Kirkeby, Bernardo Santos

- Introduction to the statistics needed for showing significance of the results
- Building/understanding a Python script with tests for normal distributions, showing significance in case of normal and not-normal distributions.

Lecture Series 3: Simulation and behaviour analysis of complex systems

Instructors: Attila Kertesz and Hamza Baniata, University of Szeged, Hungary

- Attila Kertesz is an associate professor at the Department of Software Engineering, University of Szeged, leading the IoT Cloud research group of the department. He graduated as a program- designer mathematician in 2005, received his PhD degree at the SZTE Doctoral School of Computer Science in 2011, and habilitated at the University of Szeged in 2017. His research interests include the federative management of Blockchain, IoT, Fog and Cloud systems, and interoperability issues of distributed systems in general. He is the leader of the FogBlock4Trust sub-grant project of the TruBlo EU H2020 project, and the OTKA FK 131793 national project financed by the Hungarian Scientific Research Fund. He is also a Management Committee member of the CERCIRAS and INDAIRPOLLNET EU Cost Actions. He has more than 130 publications with more than 1100 citations.
- Hamza Baniata is a research fellow and a PhD candidate at the Doctoral School of Computer Science at University of Szeged, Hungary. He is a member of the IoT-Cloud research group at the Department of Software Engineering, actively contributing to the Fog-Block4Trust sub-grant project of the TruBlo EU H2020 project, the CERCIRAS EU Cost Action, and the OTKA FK 131793 project. He received his B.Sc. degree in Computer and Military Sciences from Mutah University (Jordan, 2010), And his M.Sc. degree with excellence in Computer Science from the University of Jordan (Jordan, 2018). His work experience includes different roles in the domains of ICT and Security, while his current research interests fall in the domains of Security, Privacy and Trust of Blockchain, Cloud/Fog Computing, and Internet of Things systems. Hamza is the main developer of FoBSim and PriFoB which will be used in this lecture series.

Outline

The latest evolution in Information Technology has led to the creation of IoT-Fog-Cloud systems, which combine the Internet of Things (IoT), Cloud Computing and Fog Computing. IoT systems are composed of possibly up to billions of smart devices, sensors and actuators connected through the Internet, and these components continuously generate large amounts of data. Cloud and fog services assist the data processing and storage needs of IoT applications, while Blockchain services can support accountability and verification of certain actions. The location and behaviour of IoT devices can change dynamically, which calls for multicriteria optimization methods to be applied during the execution of these applications. The investigation and detailed analysis of such application and their underlying complex systems can be fostered by simulation solutions.

Basic knowledge of Python programming is required, and a preinstalled Java and Python IDEs for compiling and executing simulations.

Slot 1 (Lecture): Investigating IoT-Fog-Cloud Systems by means of Simulation, Attila Kertesz

General overview of the types and needs of IoT applications, and properties and services of Cloud Computing and Fog Computing. Simulation possibilities of IoT-Fog-Cloud systems will also be reviewed, via the main capabilities of the DISSECT-CF-Fog simulator, through various application scenarios.

Slot 2 (Lecture): Modelling and Realizing Fog-assisted Blockchain Systems, Attila Kertesz

General overview of the types and features of Blockchain systems and applications. Simulation and realization possibilities of Fog-assisted Blockchain systems will also be reviewed, via the main capabilities of the FoBSim simulator, through various application evaluation scenarios.

Slot 3 (Laboratory): The FoBSim simulator: Analysing Fog-assisted Blockchain Systems, Hamza Baniata

General introduction of the architecture and main components of the FoBSim simulator. The inner workings of the simulator will be illustrated through various use cases.

Slot 4 (Laboratory): PriFoB: a Blockchain-based Credential Management Service, Hamza Baniata

General introduction of the architecture and main components of the PriFoB solution. Its usage will be demonstrated for educational degree certificate management, where institutions can issue certificates to graduate students, and third parties can validate the certificates through Blockchain-based queries.

Lecture series 4: Understanding Mixed-Criticality Systems Models and Implementation

Instructor: Tullio Vardanega, University of Padova, IT

Author of laboratory materials: Mattia Bottaro, former MSc student at the University of Padova, IT

- Tullio Vardanega is at the University of Padua, Italy, since January 2002. He holds an MSc from the University of Pisa, IT (1986), and a PhD from the Technical University of Delft, NL (1998). After working as PI in a software consultancy firm, from 1987 until mid-1991, he was with the European Space Research and Technology Centre in the Netherlands until the end of 2001, investigating methods, tools and runtimes for the development and execution of on-board software. At the University of Padua, he lectures on high-integrity real-time systems, Cloud and Edge computing, software engineering methods, active learning methods, and computing education. He has run numerous collaborative projects in those research areas on funding from international and national bodies. He has been a member of IEEE and ACM for many years.

Outline

“Real-time computing” had been a niche ambit, separate from the rest of the computing world until recently, when it became apparent that, with software propelling so many dimensions of our personal, social and professional infrastructures, including health, transportation, and production, solid real-time fundaments should be a very desirable feature of such software. As real-time computing enters territories where mass production privileges average performance without bothering much about extreme cases, real-time systems theory must be updated for contemplate novel situations, where certain compromised have to be made, without renouncing safety. This is the case of mixed-criticality systems, which aim to accommodate applications with different integrity requirements on the same hardware resources, renouncing untenably costly physical segregation without jeopardizing high-criticality operation. In this lecture series we explore the origins of mixed-criticality systems, the techniques to analyse their real-time feasibility, and possible ways to implement them in practice.

The laboratory work in the lecture series will use tooling can be installed on any Ubuntu station.

Slot 1 (Lecture): Basics of real-time scheduling and response time analysis, Tullio Vardanega

The lecture will provide students with the basic understanding of real-time scheduling for single- and multi-core processors, and with the associated response time analysis, which is an exact (i.e., necessary and sufficient) method for ascertaining whether all the scheduling components of the program can meet their timing requirements under worst-case conditions.

Slot 2 (Laboratory): Hands-on response time analysis: how does it work, what does it tell, Tullio Vardanega

The activity in this session will have students familiarize with response-time analysis, understanding where to get trustworthy input data for it, how its mechanics work, and how its output should be interpreted.

Slot 3 (Lecture): A primer on Mixed-Criticality Systems: what is innovative in them, Tullio Vardanega

The lecture will introduce Mixed-Criticality Systems, for requirements, initial concept and the subsequent evolution. A particular model will be singled out for detail discussion of its innovative features, its practicality for implementation and its actual sustained performance in comparison with state-of-the-art solutions for isolation-based systems.

Slot 4 (Laboratory): What can learn from a concrete implementation with feather-weight instrumentation, Tullio Vardanega

The activity in this session will have students play hands-on with simulation-and-analysis pipelines that allow studying various load scenarios for particular Mixed-Criticality Systems approaches.