

## IECON 2022 Tutorial Proposal Form

- **Title of the Proposal:**

**Using IOPT-Tools for Petri nets driven controller development**

- **Presenter(s):**

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- **Brief description:**

The lack of tools ready to be integrated in engineering development frameworks are one major drawback when considering Petri nets usage within specific areas of application. This tutorial addresses usage of a model-driven development approach using Petri nets as the underlying modeling formalism. The tutorial is divided into two parts, being the first one more on Petri nets fundamentals and their usage for controller modeling and implementation, while the second one emphasizes on the development of controllers for embedded and/or cyber-physical systems. Both parts rely on the support from the IOPT-Tools framework, complemented by hands-on experimentation using IOPT-Tools for the development of controllers.

The IOPT-Tools web-based framework provides support for the complete development flow for cyber-physical systems and embedded systems, offering tools for engineers as well as for academics, including editor, simulator, remote debugger, and property verification tools. Rapid-prototyping is fully supported, allowing automatic code generation ready to be directly deployed in different types of platforms, ranging from FPGAs (where VHDL code is produced) to popular low-cost boards, such as Arduino and Raspberry Pi (where C code is produced), and also including PLCs (through Instruction List generation). The IOPT-Tools framework is publicly available at <http://gres.uninova.pt/IOPT-Tools/>.

Petri nets main characteristics and classes are presented, including firing semantics and common execution semantics (namely interleaving semantics used in most simulation environments, as well as maximal step semantics used in most control applications), net operations (namely addition and splitting), and properties verification techniques (namely formal techniques based on invariants and state space exploration). The tutorial will cover situations where a centralized execution is used, as well as others where distributed execution is the goal.

A few application examples will be used to illustrate the application of the referred tool framework in the development of different kinds of systems and implementation platforms (ranging from industrial PCs, RaspberryPi, Arduinos, and FPGAs).

Attendees are welcome to bring their own portable computers or smart phones to play with IOPT-Tools.

- **Duration:** 2 hours

- **Outline:**

Motivation to move towards model-driven controller development

Looking back

The productivity gap

The verification gap

The performance gap

- Open issues and challenges
- Moving to model-driven development
- Selection of modelling formalisms
- Petri nets
  - Introduction
  - Firing rules
  - Main modeling characteristics
  - Petri nets classes
    - Low-level vs high-level Petri nets
    - Autonomous vs non-autonomous Petri nets
  - Considerations on operational semantics
  - Application example
  - Algebraic representation
  - Property verification techniques
    - Behavioral vs structural properties
    - State space construction
    - Invariants
  - Petri nets for controller modelling
  - The Input-Output Place-Transition Petri nets class (IOPT-nets)
- IOPT-Tools - Petri nets tools for controller development
  - Development flow
  - Brief presentation of main tools
    - Model editor
    - Simulator
      - Token-player simulator
      - Timing diagrams
    - Remote debugger
    - State-space generator
    - Query editor and query results
    - Automatic code generation
      - C code
      - VHDL code
  - Implementation platforms
    - Software platforms (Arduino, Raspberry, ESP, Linux-based)
    - Hardware platforms (FPGAs)
  - Application example
- Demo and hands-on experimentation

- **Motivation and Focus:**

This tutorial is about to develop controllers for embedded and cyber-physical systems emphasizing the benefits from adoption of a model-driven approach. For that end, Petri nets modelling is proposed and a web-based development framework (the IOPT-Tools) is presented. Petri nets benefit from a strong theoretical body of knowledge as well as from tool support addressing all phases of developing of controllers. Whenever dependable or critical systems are needed, the capability to perform property verification, complementing simulation results, as well as to rely on tools for controller design

automation is of paramount importance. Petri nets modelling and IOPT-Tools can contribute to that answer.

During the tutorial the capabilities of IOPT-Tools will be presented, namely supporting simulation and verification of models, as well as to automatically generate implementation code, in C or VHDL, which can be directly deployable in common implementation platforms (and produce controller's execution code without writing a line of code).

Low-cost platforms, such as Arduino and Spartan FPGA boards, will be used for hands-on practice during the tutorial.

The IOPT-Tools framework is freely available at <http://gres.uninova.pt/IOPT-Tools/>.

#### Brief CV:



Luis Gomes received his Electrotech. Eng. Degree from Technical University of Lisbon, Portugal, in 1981, and a PhD degree in Digital Systems from Universidade Nova de Lisboa, Portugal, in 1997. He is a professor at the Electrical and Computer Engineering Department, Faculty of Sciences and Technology of NOVA University Lisbon, Portugal and a researcher at UNINOVA Institute, Portugal. From 1984 to 1987, he was with EID, a Portuguese medium enterprise, in the area of electronic system design, in the R&D engineering department. His main interests include the usage of Petri nets and other models of concurrency, applied to reconfigurable and embedded systems co-design and cyber-physical systems. He was made Honorary Professor of Transilvania University of Brasov, Brasov, Romania, in 2007, as well as Honorary Professor of Óbuda University, Budapest, Hungary, in 2014. He has received the IEEE Industrial Electronics Society Anthony J Hornfeck Service Award in 2016. Dr. Gomes is author/co-author of more than 200 papers and chapters published in journals, books and conference proceedings, as well as co-author of one book and co-editor for three books.

#### - **Relevant publications:** Maximally 5 publications including edited books

“Hardware Design and Petri Nets”; Alex. Yakovlev, Luís Gomes, Luciano Lavagno (Eds.); Kluwer Academic Publishers; 2000; ISBN 0-7923-7791-5; 331 pgs.

“Distributed Embedded Controller Development with Petri Nets - Application to Globally-Asynchronous Locally-Synchronous Systems”; Filipe Moutinho, Luís Gomes; SpringerBriefs in Electrical and Computer Engineering, Springer; 2016; ISBN 978-3-319-20821-3 ISBN 978-3-319-20822-0 (eBook) DOI 10.1007/978-3-319-20822-0  
([http://www.springer.com/gp/book/9783319208213?wt\\_mc=Internal.Event.1.SEM.BookAuthorCongrat](http://www.springer.com/gp/book/9783319208213?wt_mc=Internal.Event.1.SEM.BookAuthorCongrat))

“Asynchronous-channels within Petri net based GALS distributed embedded systems modeling”; Filipe Moutinho, Luís Gomes; IEEE Transactions on Industrial Informatics; Vol.10 Issue: 4; Nov. 2014; pp 2024-2033; ISSN: 1551-3203; DOI: 10.1109/TII.2014.2341933

“The IOPT-Flow modeling framework applied to Power Electronics controllers”; Fernando Pereira, Luis Gomes; IEEE Transactions on Industrial Electronics; Volume: 64, Issue: 3, March 2017, Page(s): 2363 – 2372; Date of Publication: 21 October 2016, DOI: 10.1109/TIE.2016.2620101

“IOPT-Tools – From executable models to automatic code generation for embedded controllers development”; Fernando Pereira, Filipe Moutinho, Anikó Costa, João-Paulo Barros, Rogério Campos-Rebello, Luis Gomes; PETRI NETS 2022 - 43rd International Conference on Application and Theory of Petri Nets and Concurrency; June 19 - 24, 2022, Bergen, Norway