ICEM 2024, Torino, September 1-4 2024

Tutorial Proposal

TUTORIAL TITLE:

Embedded Rapid Control Prototyping (RCP) for electric motors:

Open Source experimental approach for the user

TUTORIAL PRESENTERS (Full Names, affiliation and e-mail addresses):

- Romain DELPOUX, Associate professor at Ampère Lab, INSA Lyon, romain.delpoux@insa-lyon.fr, 25 avenue Jean Capelle - Bât St Exupéry, 69621 Villeurbanne Cedex – France
- Lubin KERHUEL, PhD Microchip Technology Inc., lubin.kerhuel@microchip.com, 19 rue Adrien Barthe, 64100 Bayonne, France
- Hiba HOUMSI, Phd Student at Ampère Lab, INSA Lyon, hiba.houmsi@insa-lyon.fr, 25 avenue Jean Capelle - Bât St Exupéry, 69621 Villeurbanne Cedex – France

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BIOS OF THE PRESENTERS (150 words each):

Romain Delpoux received the M.S. degree in control system and mechatronics form the Chalmers University of Technology, Gothenburg, Sweden, in 2009 and the Ph.D. degree in control theory, data and signal processing from the Ecole Centrale de Lille, Villeneuve-d'Ascq, France, in 2012. In September 2014, he joined INSA Lyon, Villeurbanne, France and the Ampere Laboratory, where he is currently an Associate Professor. His research concerns advanced control design for synchronous machines, with a view to developing optimal solutions for real-time implementation on a low-cost microcontroller target. In order to efficiently validate the proposed control laws, one aspect of this work has been to develop software solutions for rapid prototyping control of electric machines, based on Matlab/Simulink, making them easier to implement. His research work combines theory and methodology at the interface between control theory, electrical engineering and real-time implementation, with a systematic approach to experimental validation.

Lubin Kerhuel graduated in System-on-Chip from ESIEE Paris. He received the M.S. degree in signal processing and numerical communication from the University of Nice Sophia Antipolis, France, and the Ph.D. degree in control engineering and microelectronics from the Montpellier II University, France. His Ph.D research on visuo-inertial reflex, visual sensor and control laws for micro UAV were done within the Biorobotics Laboratory, Institute of Movement Sciences, National Center for Scientific Research/University of the Mediterranean, Marseille, France. He worked for two years on miniature low power movement analysis and attitude reconstruction based on MEMS at MOVEA, Grenoble, France. Expert on Rapid Control Prototyping tools, he develops the MPLAB® blockset for Simulink at Microchip Technology Inc (Bayonne, France) targeting dsPIC® and SAM® Micro-controllers. He creates Model Based Design motor control algorithms. He gives hands-on practice on rapid prototyping tools to 5th years students at INSA Lyon.

Hiba Houmsi completed a M.S. degree in electrical engineering in 2022 at the Institut National des Sciences Appliquées de Lyon (INSA de Lyon), located in Villeurbanne, France. Presently, she is pursuing her Ph.D. in control Engineering at the Ampère Laboratory within INSA de Lyon. Her research focuses on control strategies of synchronous machines, with particular emphasis on embedded controller optimization utilizing linear matrix inequalities. Her work encompasses uncertainty modelling, robust control synthesis techniques and real-time implementation. The proposed solutions aim to reduce the gap between control theory and its use in industrial practice. Additionally, she is also interested on field-weakening strategies for surface-mounted permanent magnets synchronous motors and interior-magnets synchronous motors.

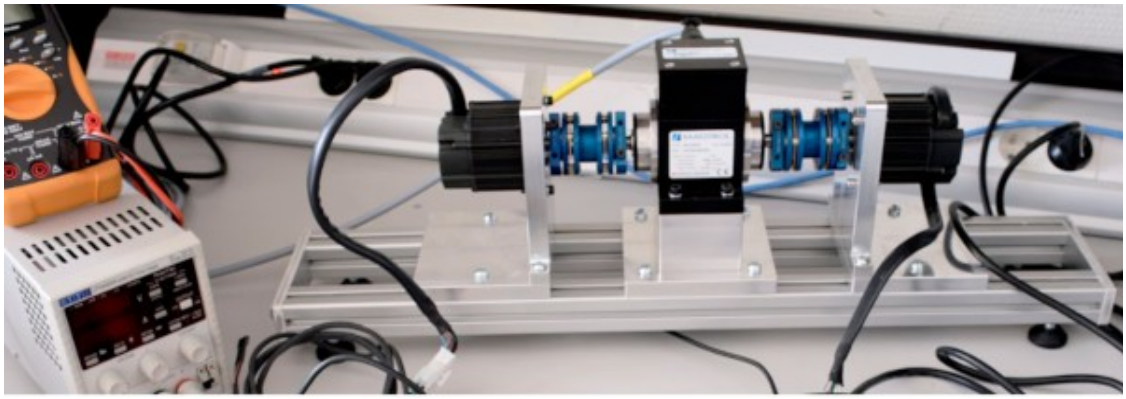
ABSTRACT (200 - 300 words):

Digital Signal controllers (DSC) are increasingly present in industry. Manufacturers seek ways to reduce global costs while maintaining safety and performance. In the context of electrical machines, cost constraints leads to reduced actuators and sensor quantity and quality, compensated by an increased algorithm complexity. Developing embedded controllers requires a solid grasp of control engineering (Matlab/Simulink, dSPACE...) and an expertise in embedded systems (C, assembly...). The typical resume of a control system engineer often lacks the combination of both.

Original controller development requires balanced work between control theory and implementation. Simulation speeds up development of new algorithms. Programming tools facilitate data collection, enabling refinement of the simulation, validation of the algorithm on real system, accounting for unmodeled aspects (missing dynamics, noises, non-linearity…). Additionally, implementation guarantees that the algorithm is suitable for an industrial embedded system, in terms of real-time and memory constraints. Iterations between simulation and hardware validation are prone to stimulate creativity. Thanks to this process, real experiments are reused for simulations.

It is crucial to conduct both simulation and implementation to benefit from the results of the two-sided approach. The proposed strategy, based on RCP, with MATLAB/Simulink and MBD, facilitates both simulation and execution on low-cost microcontrollers. We demonstrate implementation efficiency using the Microchip Technology “MPLAB device blocks for Simulink”. The tool’s objective is not to “hide” the generated code but to make it available to tackle any implementation issues. An experimental platform embedding a dsPIC DSC has been developed. Data visualization and real time constraints analysis will be presented. This work with open-source example is described on the website www.ctrl-elec.fr, including github repository and youTube channel.

This tutorial is aimed for engineers and researchers looking to quickly validate new control, observation, or identification laws. The tutorial will be illustrated live experimentally on the low-power bench shown below.



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List of contents:

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  - Introduction to MBD
  - Mplab Device Block for Simulink
- Embedded control strategies for synchronous motors
  - Field Oriented Control (FOC)
  - Optimal Field Weakening control
  - Embedded controller optimization
- Evaluation of real time performances
  - Implementation issues
  - Multi-tasking scheduler
  - Analysis of the CPU load of the different control tasks

Online resources:

To be more easily reproduced, the experimental solutions proposed during the tutorial are available online under open-source license :

1. ctrl-elec website: www.ctrl-elec.fr
2. Motor Control University (MCU) pages: www.ctrl-elec.fr/motor_control_university.html
3. GitHub repository : github.com/rdelpoux/ctrl-elec
4. YouTube channel: www.youtube.com/@ctrl_elec

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Selected personal articles in the field :

(Houmsi2023a) *H. Houmsi, F. B. Argomedo, P. Massioni and* ***R. Delpoux****, "A Karush-Kuhn-Tucker approach to field-weakening for Surface-Mounted Permanent Magnets Synchronous Motors," 2023 International Conference on Control, Automation and Diagnosis (ICCAD), Rome, Italy, 2023*

(Houmsi2023b) *H. Houmsi, P. Massioni, F. Bribiesca Argomedo,* ***R. Delpoux****, Embedded controller optimization for efficient electric motor drive, Proceedings of the 2023 Vehicular Power and Propulsion Conference (VPPC), October 2023, Milano, Italy.*

(Schullet2022) *L. Schuller, J. -Y. Gauthier,* ***R. Delpoux*** *and X. Brun, "Dynamical Model of Residual Magnetism for Synchronous Reluctance Machine Control," in IEEE Transactions on Industrial Electronics, vol. 69, no. 11, pp. 10926-10934, Nov. 2022, doi: 10.1109/TIE.2021.3127050.*

Morales(2021) *D. B. Morales,* ***R. Delpoux****, V. Léchappé and J. D. L. Morales, "Single-Gain Super-Twisting Algorithm Application to PMSM," in IEEE Journal of Emerging and Selected Topics in Industrial Electronics, vol. 2, no. 3, pp. 237-246, July 2021*

(Delpoux2021) Delpoux, R*.,* ***Kerhuel, L****., & Léchappé, V. (2021). On Chip Rapid Control Prototyping for DC Motor. J3eA, Journal Sur l'enseignement Des Sciences et Technologies de l'information et Des Systèmes.*

(Kreiss2018) *J. Kreiss, J. -F. Tregouet,* ***R. Delpoux****, J. -Y. Gauthier and X. Lin-Shi, "Flux Weakening of PMSM for Enhancing Torque Tracking," 2018 European Control Conference (ECC), Limassol, Cyprus, 2018*

(Delpoux2014) R. Delpoux *& T. Floquet High-order sliding mode control for sensorless trajectory tracking of a PMSM, International Journal of Control*

(Delpoux2014) R. Delpoux*, M. Bodson, T. Floquet, Parameter estimation of permanent magnet stepper motors without mechanical sensors, Control Engineering Practice, Volume 26, 2014, Pages 178-187.*