IFAC
INTERNATIONAL FEDERATION OF AUTOMATIC CONTROL

8th IFAC Symposium on
Advances in Automotive Control - AAC 2016
June 20-23, 2016,
Kolmården Wildlife Resort, Sweden
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# Lithium ion Batteries for Electromobility: Performance, Life estimation and Life Extension

Announcing a two day tutorial that will be held 18-19 June 2016 at Linköping University, Sweden. This is a pre-symposium tutorial at the 8th IFAC Symposium on Advances in Automotive Control (AAC2016).

## Tutorial Outline

This tutorial is an introduction to the Lithium ion battery technology for energy storage in electrified vehicles, with focus on the state of the art and the critical issues that are inspiring today's R&D efforts. The tutorial explains the basic operation and electrochemical principles of Lithium ion batteries, physics-based and control-oriented modeling techniques for characterization of performance and aging, and finally introduces the problems of degradation, life estimation and prognostics. Emphasis will be given to the use of computation tools for solving system integration problems, including performance modeling and SOC/SOH estimation.

## Target Group

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## Instructors

**Marcello Canova, The Ohio State University**
Assistant Professor, Department of Mechanical and Aerospace Engineering
Associate Fellow, Center for Automotive Research
Marcello Canova is an Assistant Professor of Mechanical and Aerospace Engineering at the Ohio State University. Since 2006, he is affiliated with the Center for Automotive Research. He received his Diploma di Laurea Cum Laude in 2002 and his Ph.D. in 2006 in Mechanical Engineering, all from the University of Parma, Italy.

**Giorgio Rizzoni, The Ohio State University**
Professor, Department of Mechanical and Aerospace Engineering
Director, Center for Automotive Research
Giorgio Rizzoni, the Ford Motor Company Chair in ElectroMechanical Systems, is a Professor of Mechanical and Aerospace Engineering and of Electrical and Computer Engineering at The Ohio State University (OSU). He received his B.S. (ECE) in 1980, his M.S. (ECE) in 1982, his Ph.D. (ECE) in 1986, all from the University of Michigan. Since 1999 he has been the director of the Ohio State University Center for Automotive Research (CAR), an interdisciplinary university research center in the OSU College of Engineering. He is author or co-author in over 400 journal and conference papers, and three books. He is a Fellow of SAE (2005), a Fellow of IEEE (2004), a recipient of the 1991 National Science Foundation Presidential Young Investigator Award.

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## Day 1: Introduction to Lithium-ion Batteries, Modeling and SOC Estimation

**Module 1**
- Basic Concepts and Terminology
- Components and Operation of a Lithium-ion Battery Cell
- Charging/Discharging Performance Curves

**Module 2**
- Classification of Battery Models
- Overview of First-Principles Models (Electrochemical - Single Particle)
- From First-Principles to Control-Oriented Models: Model Order Reduction
- Thermal Modeling

**Module 3**
- Introduction and Problem Definition
- Overview of Conventional Methods
- Overview of Observer Design Methods: Extended Kalman Filter
- Application of State of Charge Estimation

**Laboratory Session 1**
- Identification and Analysis of Single-Particle Model of Lithium-ion cell
- Build and Compare Different State of Charge Estimation Methods

## Day 2: Degradation and Aging in Lithium-ion Batteries, Life Estimation and Prognosis

**Module 4**
- State of Health (SOH) life assessment and experimental characterization methods
- Physical phenomena leading to cell performance degradation
- Modeling electromechanical processes explaining performance degradation
- Overview of battery life prediction and estimation framework

**Module 5**
- Modeling aging in individual battery cells: cycle life and calendar life
- Aging propagation among cells - electrical thermal interdependencies
- Modeling aging in battery systems

**Module 6**
- Need for managing battery SOC and temperature
- Battery voltage equalization - passive and active methods
- Battery thermal management
- BMS functions and architectures

**Laboratory Session 2**
- Simulation of battery aging - effect of cycling and environment
- Develop a "soft" BMS using a battery pack simulation

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