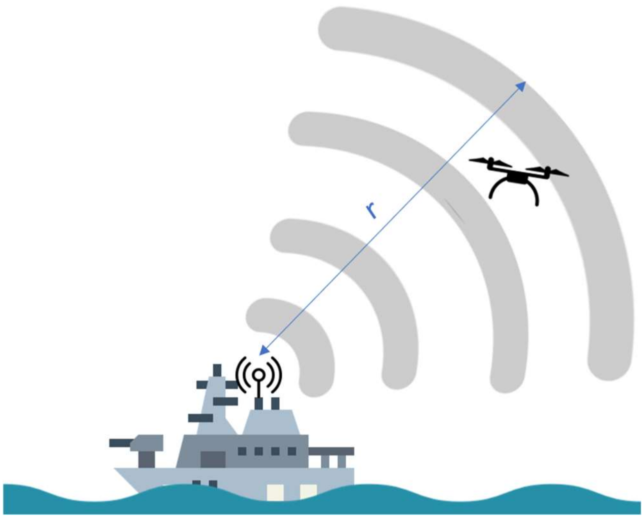
Master thesis proposal for the Department of Control Engineering and System Analysis (SAAS)

Academic year 2020-2021

Content

1. Path planning for cooperative teams of heterogeneous vehicles

Supervisors: Emanuele Garone (egarone@ulb.ac.be), Nicolás Bono Rosselló (nbonoros@ulb.ac.be),



Context of the work: Transportation and delivery problems have been widely studied by the scientific literature. How to combine a fleet of vehicles and to compute their optimal routes has been established as one of the well known combinatorial optimization problems**.** In this context, the use of groups of heterogeneous vehicles has been proved to provide levels of flexibility and capabilities unable to be found in homogeneous group.

In this master thesis, the student will work on the development of path planning strategies for combination of vehicles with different roles and capabilities. Namely, this MsC thesis will focus on the case of a multivehicle team composed by two kinds of vehicle: a large and slow vehicle, e.g. a ship, and a fast and small vehicle, e.g. a drone. The student will work on the development of path planning strategies for multivehicle system in the meaningful cases of drone's autonomy limitation or in maximum distance between the vehicles.

The project will address the following aspects of the path planning problem:

- Modelling of the system
- Development of optimal and suboptimal strategies

Requested skills: Basic knowledge in control theory, combinatorial optimization and programming skills in Matlab(optimization toolbox).

2. Battery pack real-time parameter estimation

Supervisors:

Luis D. Couto and Michel Kinnaert, lcoutome@ulb.ac.be and Michel.Kinnaert@ulb.ac.be , SAAS, ULB

Context of the work:

Renewable energies and electric transportation are the cornerstones for developing a sustainable future society. Energy storage is fundamental in this context, in order to store surplus of energy and use it when the wind does not blow, or to produce vehicles that do not pollute the environment. Among the possibilities, lithium-ion batteries are the technology of choice given their high energy capacity and efficiency. However and in contrast with other battery technologies, the benefits of lithium-ion batteries come at the price of careful monitoring requirements.

Among the different tasks of a monitoring system for lithium-ion batteries, the estimation of the state-of-charge (SOC) and state-of-health (SOH) is possibly the most important one. The SOC for a battery is equivalent to the level indicator for a fuel tank, i.e. it is the energy available with respect to the total energy. The SOH is related with the age of the battery, and it decreases continuously with battery usage. One way to compute the SOH is to resort to a mathematical model of the battery and associate specific parametric changes to given degradation mechanisms. By identifying the parameters of the system from input/output data, SOH indicators can be derived. One extra level of difficulty comes from the fact that lithium-ion battery cells need to be assembled in series/parallel arrangements, called packs (see Figure 1), in order to comply with voltage/energy requirements from a given application.

In this project, we pursue the real-time estimation of the SOH of each cell in the pack. This will allow spotting potentially dangerous cells in the battery pack. The first challenge is to achieve this goal with a limited number of current, voltage and temperature sensors deployed throughout the battery pack. The second challenge is to use an efficient estimator that is able to accurately identify the model parameters. As a starting point, a MATLAB battery pack simulator will be used.

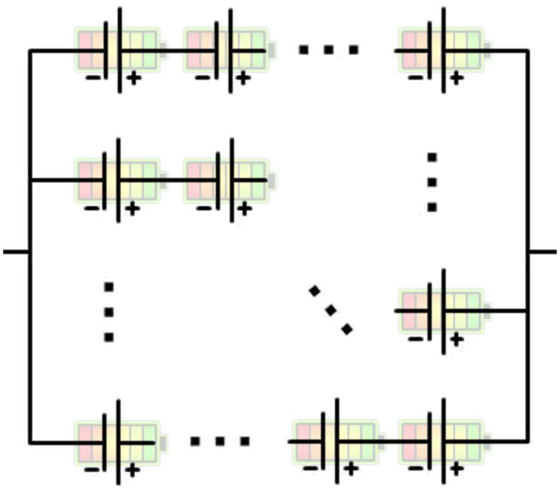


Figure 1. Battery pack.

Requested skills: Basic knowledge in programing and control theory.

3. Battery cell parameter estimation

Supervisors:

Luis D. Couto and Michel Kinnaert, lcoutome@ulb.ac.be and Michel.Kinnaert@ulb.ac.be , SAAS, ULB

Context of the work

Renewable energies and electric transportation are the cornerstones for developing a sustainable future society. Energy storage is fundamental in this context, in order to store surplus of energy and use it when the wind does not blow, or to produce vehicles that do not pollute the environment. Among the possibilities, lithium-ion batteries are the technology of choice given their high energy capacity and efficiency. However and in contrast with other battery technologies, the benefits of lithium-ion batteries come at the price of careful monitoring requirements.

One popular choice to monitor the evolution of the internal state of lithium-ion batteries is to use state observers. However, the performance of some of these observers heavily relies on the model parameters around which they are built on. Wrong parameters will considerably deteriorate the accuracy of the state estimates, which can have catastrophic consequences in the case of mishandled batteries. One of the ways to obtain more reliable models is through the optimal experiment design (OED). The basic idea of this approach is to design the input profile in such a way that some notion of "information" is maximized (see Fig 1). Once this input profile is available, then it is fed into the battery system to collect its voltage/temperature response. From the gathered data, the model parameters are inferred.

Our goal with this project is to estimate the parameters of a lithium-ion battery modelled from electrochemical principles. These models are often overparameterized, so a proper selection of the parameters to be estimated is the first challenge to be tackled. Secondly, this problem has been addressed either purely empirically or by designing a single input profile to estimate all the battery parameter in one shot. Here, we aim at designing a set of experiments in order to estimate a suitable set of parameters at a time.

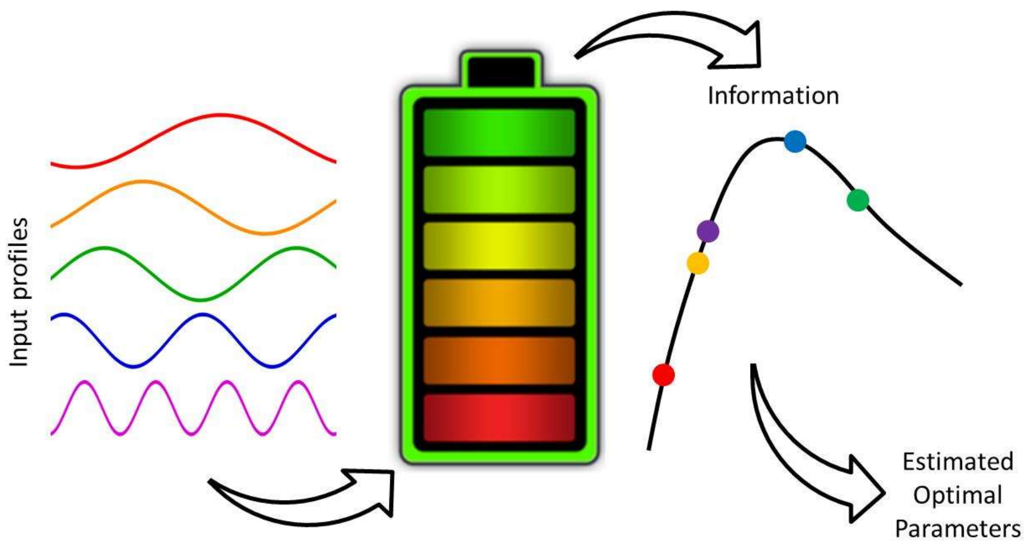


Figure 2. Simple diagram of OED for the parameter estimation of lithium-ion batteries.

Requested skills: Programming with MATLAB/SIMULINK and control theory.

4. Lithium-ion battery packs balancing

Supervisors: Luis D. Couto, Emanuele Garone and Michel Kinnaert

Context of the work:

Renewable energies and electric transportation are the cornerstones for developing a sustainable future society. Energy storage is fundamental in this context, in order to store surplus of energy and use it when the wind does not blow, or to produce vehicles that do not pollute the environment. Among the possibilities, lithium-ion batteries are the technology of choice given their high energy capacity and efficiency. However and in contrast with other battery technologies, the benefits of lithium-ion batteries come at the price of careful management requirements.

From all the advantages of lithium-ion batteries, a single battery cell is not able to comply with standard voltage/energy requirements of a given large-scale application, such as renewable energy storage or electric vehicles. One way to solve this issue is to assemble battery cells in series/parallel arrangements called battery packs (see Figure 1). However, the performance of these entire packs is limited by the worst performant cells within the packs. In order to mitigate this problem and extract the full potential of all the cells in the pack, the cells need to be balanced based on a given metric (voltage, charge, energy, etc). This balancing can be seen as a synchronization of the different cells, which work together to achieve the given goal of powering up the desired device. Balancing methods can be divided into two main categories, namely passive balancing and active balancing. While passive balancing relies on burning excess of energy through resistors, it is cheap, the most widely used method and also very inefficient, active methods resort to moving charge from high charge cells to low charge cells within the pack, i.e. it is more efficient since there is no energy waste.

This project aims at developing a balancing scheme for a lithium-ion battery pack. This scheme should be able to balance the battery cells during charge and discharge stages while minimizing energy losses (active balancing). For battery charge, safe and fast charging protocols will be used, while the battery discharge will rely on realistic drive cycles coming from electric vehicle operations. As a starting point, a MATLAB battery pack simulator will be used.

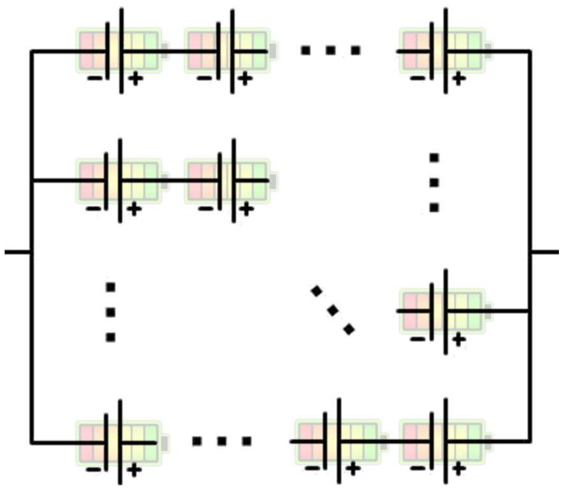


Figure 3. Battery pack.

Requested skills: Programming with MATLAB/SIMULINK and control theory.

5. Design of new didactic devices for teaching of control engineering

Supervising staff

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Context:

The framework of the project is the teaching of control system theory to future engineers. The goal consists in designing new modular, evolving, and open-source solutions to provide a better, more practical learning experience to the student.

Currently, the development of the first prototype comprising an experimental setup, based on the application "ball in the tube", as well as a Python-based software part is in progress. A portable pilot version called "take-home lab" is expected to be available at the end of the year. It will provide the student with a set of experiments that could be performed at home in parallel to the theoretical course. That version will be actively used during the teaching activities in the framework of the MATH-H-304 course.

The master thesis proposal consists in upgrading the pilot version by creating/implementing new applications (inverted pendulum, rotary beam, ball and beam, slave UAVs …) or modifying/designing new features involving mechanical, electrical, as well as software parts. You will be integrated into a young and passionate team in charge of designing, developing and maintaining these teaching devices.

Key objectives:

- selection of the sensors/actuators
- design of the signal conditioning / acquisition stages
- design of the experimental setup (SolidWorks, 3D printer …)
- design of the power supply & cable management
- implementation of a control strategy (Python, Arduino/C programming)
- setup of some didactic experiments & their related teaching materials

Requested skills :

- quick & autonomous learner in a dynamic environment
- team player, creativity
- basic knowledge in control theory, digital signal processing, electronics

6. Force feedback and physiological motion compensation for a master-slave device with 3 degrees-of freedom

Supervisors:

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Context of the work

Minimally invasive surgery consists in operating through small incisions in which surgical tools as well as a camera are inserted. This approach results in interventions with less trauma for the patient, but they also make the operations of the surgeon less intuitive and comfortable. Robotized teleoperated surgery aim at alleviating these drawbacks and at increasing the dexterity of the surgeon inside the patient's body notably. However, the main commercial master/slave device, the Da Vinci robot, does not include force feedback, which can be interesting for gestures such as suturing or needle insertion at a precise location.

A 3 degree-of-freedom master-slave device has been designed and built at SAAS. Previous works have resulted in the position control of the master robot with physiological motion compensation and in a force feedback control when the slave robot is in contact with the environment. However, the physiological motion compensation is not realistic presently because it assumes a perfect knowledge of the distance between the organ and the tool.

Work to be done

1) Small state of the art regarding teleoperated robotics for surgical applications
2) Emulation of the movement of the organ (due to the patient respiration) by controlling a 1-degree-of-freedom positioning device.
3) Development of a system for measuring the distance between the tool and the organ (probably based on optical markers and image analysis)
4) Position control of the slave robot with motion compensation based on the measurements performed in the previous step.
5) If possible, introduction and, if necessary, adaptation of the previously developed force feedback scheme in the global control strategy.

Requested skills

Good understanding of control theory, taste for experimental work, programming skills in MATLAB/SIMULINK

7. Health monitoring of electromechanical actuators for the flight control surfaces of airplanes

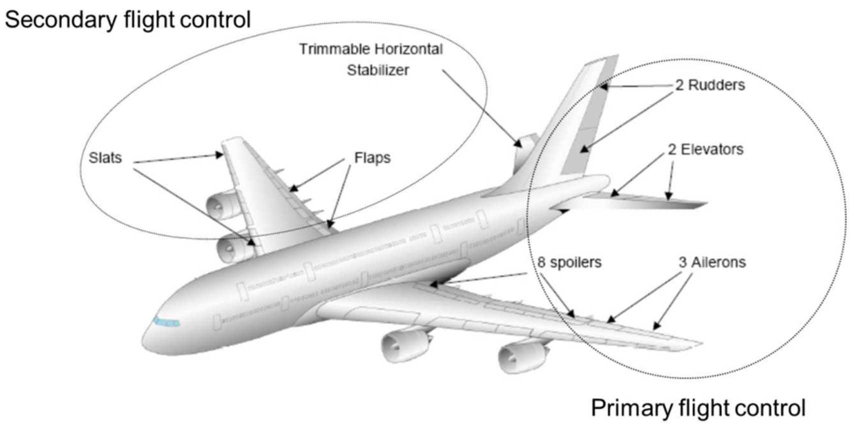
Supervisors:

Benjamin Wauthiion, SAAS, ULB (Benjamin.Wauthion@ulb.ac.be)
Michel Kinnaert , SAAS, ULB (Michel.Kinnaert@ulb.ac.be, 02 650.22.87)

Context of the work

In order to make aircraft lighter and hence reduce the kerosene consumption, the trend is to replace hydraulic actuators by electromechanical actuators (or EMAs). However, to keep the same level of availability and safety, EMAs must be equipped with a health monitoring (HM) system. The latter should be able to detect malfunctions at an early stage, and follow their evolution, in order to allow planning maintenance operations in due time. The monitoring system should have a small probability of false alarms in order not to affect the plane availability

The aim of this master thesis is to contribute to the development of such a monitoring system.



Work to be done

1. Getting acquaintance with the problem setting and the existing simulator of EMA
2. State of the art in data-based fault detection/isolation methods for EMAs
3. Determination of data-based fault indicators on the basis of the taxi phase and in-flight phases
4. Analysis and design of classifiers for the processing of the fault indicators
5. Validation of the HM system resulting from step 3 and 4 using data generated from the simulator and possibly from test-benches at SABCA.

Requested skills

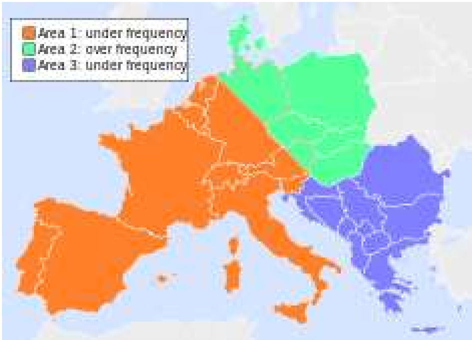
Good understanding of control theory, programming skills in MATLAB/SIMULINK

8. Detection of transmission system splits based on complex networks theory

Contact persons:

Pierre Henneaux, BEAMS, ULB, pierre.henneaux@ulb.ac.be
Michel Kinnaert, SAAS, ULB, Michel.Kinnaert@ulb.ac.be
Fortunato Villella, ELIA

Context

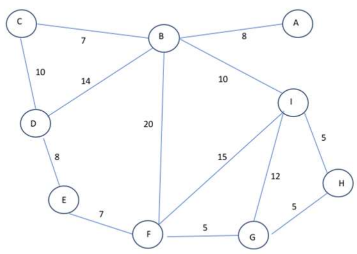


Figuur 1 : 2006 European System Split

The most recent incidents at European Scale (2006) has put more than 15 Million of people[1] in blackout, the incident has caused a system split due to cascading. In the recent years more and more international exchanges of power have appeared and will continue to increase.

This is also due to the additional variability coming from renewable sources. The analysis of possible system splits is very challenging considering the combinatorial nature and the pan-European size of the problem.

The connectivity of the power system can be represented in also as a set of nodes and branches, collection of classical graph algorithms for analysis and visualization are readily available as free packages (e.g. Networkx[2]).



Figuur 2 : Graph representation of the connectivity of a power system.

Elia is looking for alternative way to approach the problem using advanced analytics methodologies, such as complex network analysis and graph theory.

[1] https://www.entsoe.eu/fileadmin/user_upload/_library/publications/ce/otherreports/Final-Report-20070130.pdf
[2] https://networkx.github.io/

Objective

The student will have to.

- Perform a bibliographic research on the topic
- Synthetize the main findings of this research
- Propose possible existing algorithms to help analyzing the problem of system split
- Implement and test the algorithms using test cases or real system representations

Requested skills

- Data analysis and processing, power systems, graph theory, programming (e.g. Python)

9. Data-based modelling and performance monitoring of the power grid

Contact persons:

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Pierre Henneaux, BEAMS, ULB, pierre.henneaux@ulb.ac.be
Fortunato Villella, ELIA

Context

Elia has installed, since almost one year, online high definition measurement systems, namely two mobile Phasor Measurement Units (PMUs), GPS-synchronized and with 20 ms resolution. The measurement campaigns were performed notably on some generators and power lines. The primary aim of the installation was to perform specific installations performance monitoring. Nevertheless as by-product a large amount of data is now available for analysis.

Objective

The large amount of data should be analyzed in order to:

- Identify patterns in the data (oscillations...)
- Determine cross interaction among the PMUs measured variables
- Perform model identification starting from available black-box model
- Perform model definition and identification of nonlinear behavior of combination of load and distributed generation

Requested skills

Data analysis and processing, power systems, modelling and identification, MATLAB programming