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

Academic year 2021-2022

Content

1. Identification of the absolute phase of a shaft by extracting its angular signature

Supervisors:

Patrick Hendrick (ATM), pahendrick@ulb.ac.be

Michel Kinnaert (SAAS), Michel.Kinnaert@ulb.ac.be

Bertrand Haut (LABORELEC)

Context: In the context of automatic monitoring of the rotating machines (alternators, pumps…) health status, it is sometimes needed to know the angular position of the shaft.

On critical equipment's, a physical reference (e.g. a notch in the shaft) is available and a dedicated sensor can monitor this angular position. On machines less important this reference is not always available.

Objective: The objective is to be able to construct a *virtual* reference for shafts without any physical reference.

To achieve this, we have at disposal multiple measurements coming from one or more inductive sensors. The fundamental assumption is that the shaft impurities will be visible in these signals. These impurities having by definition a one-turn periodicity, it should therefore be possible to identify when a complete turn has occurred. Otherwise stated, we want to extract from the provided signal a sub-signal with a 1-turn periodicity (the "shaft signature").

Approach: multiple approaches can be investigated in parallel: used of "classical" signal processing techniques (filtering, frequential analysis…) or a more "Machine Learning" approach (formulation as an optimization problem, approximation of the speed using a parametric model…)

Remark: given the size/complexity of the problem, it is reasonable to assume that a student will be able to follow only one type of approach.

2. Battery pack state and 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 SOC and 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 as well as data gathered on batteries arrangements in strings..

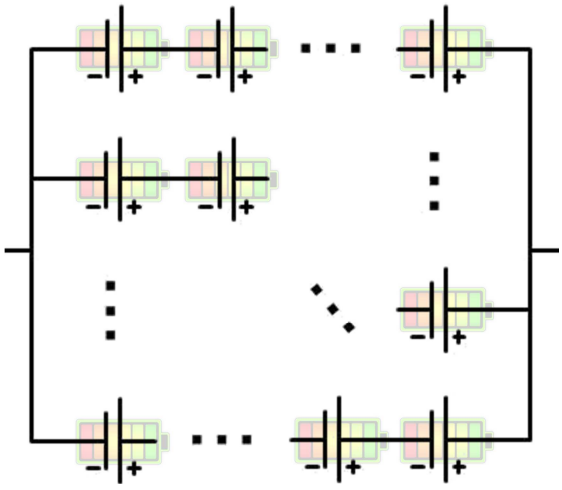

Figure 1. Battery pack.

Requested skills: Basic knowledge in programing and control theory.

3. Battery cell state and parameter estimation for battery chemistries characterized by flat open circuit voltage characteristics

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. Several approaches notably based on state observers have been developed for achieving this goal. However, for several chemistries the battery state is not observably in a significant part of the operating region of the battery. This is linked to the slope of the so-called open circuit voltage curve of the battery.

The objective of this thesis is to examine if this issue can be circumvented either by using thermal measurements or high frequency excitation current excitation. The work will rely on a detailed battery cell simulator as well as experimental measurements.

Requested skills: Basic knowledge in programing and control theory.

4. "Ball in the tube" device for teaching of control engineering

Supervising staff

Laurent Catoire (Laurent.Catoire@ulb.be) , SAAS, ULB
Michel Osée (Michel.Osee@ulb.be), BEAMS, ULB
Michel Kinnaert (Michel.Kinnaert@ulb.ac.be), SAAS, ULB
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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.

A first prototype comprising an experimental setup, based on the application "ball in the tube", as well as a Python-based software part has been designed. The objective of this project is to analyse the existing setup and to come up with a more modular and flexible solution both regarding the electronic part and the mechanical part of the device. In particular a reliable and simple solution must be found for ensuring real time operation and handling various sensors including encoders. With regard to the mechanical part, various options should be investigated to ensure that the setup can behave either like a type 0 or a type 1 (integrating) process.

Key objectives:

- design of the signal conditioning / acquisition stages
- design of modified 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

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

Supervising staff

Laurent Catoire (Laurent.Catoire@ulb.ac.be) , SAAS, ULB
Michel Kinnaert (Michel.Kinnaert@ulb.ac.be), SAAS, ULB

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.

A set of didactic devices is under development including a rotary inverted pendulum, a self-balancing robot, slave UAVs, …. The aim of this project consists in modifying/designing new features involving mechanical, electrical, as well as software parts in order to end up with a fully functional device that can be used both for teaching labs and for demos.

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

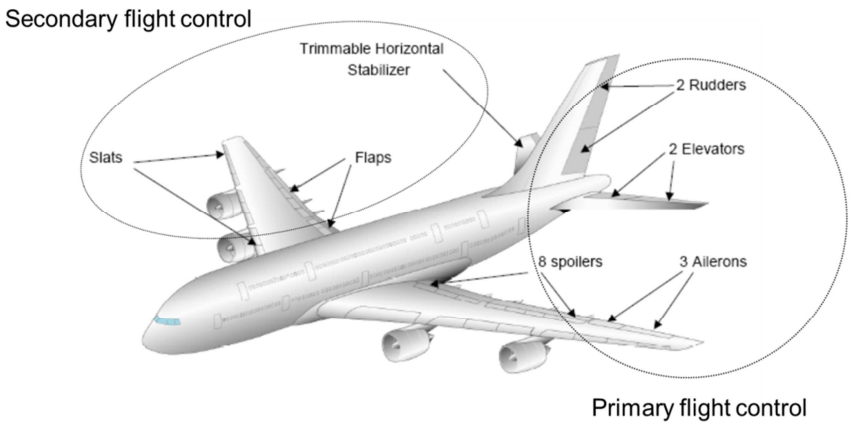
Supervisors:

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

Context of the work

This work takes place in the framework of the MONISA project performed in collaboration with SABCA. 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 health 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 and in the design of health monitoring systems based-on parameter varying models
3. Determination fault indicators on the basis of the taxi phase and/or the 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

7. Primary frequency control of a wind farm accounting for wake effects

Contact persons:

Michel Kinnaert, SAAS, ULB, Michel.Kinnaert@ulb.ac.be
Younes Oudich, SAAS, ULB, Younes.Oudich@ulb.be

Context

This project takes place in the framework of the PhairywinD project which gathers nine Belgian Universities and research institution and aims at training a group of researchers able to address the present challenges in the offshore wind energy sector.

With the increased share of wind farms in the production of electricity, it is important to ensure that wind turbines are able to provide ancillary services to the grid. They must notably be able to increase or decrease the produced active power in order to ensure grid balancing upon sudden production/load changes and hence keep the grid frequency close to 50 Hz.

Problem statement

Several approaches have been proposed to achieve primary control with a wind turbine. Much less research work has been performed at wind farm level. The aim of this work is to consider one of these approaches for primary control and to investigate different solutions to dispatch the power demand/ derating between the turbines in a wind farm in order to ensure adequate frequency control while limiting fatigue load on the turbines. The methods will be validated and compared by using the software FAST FARM and TURBSIM developed by the National Renewable Energy Lab (NREL) in the US.

Objective

The student will have to.

- Perform a bibliographic research on the topic
- Get familiar with the software FAST FARM and TURBSIM
- Select a frequency control scheme, design the corresponding controller, implement it on a single turbine and validate it
- Study and analyze different schemes for power dispatching in the wind farm
- Implement and compare different schemes from the previous point using FAST FARM

Requested skills

- Basis in control engineering; programming

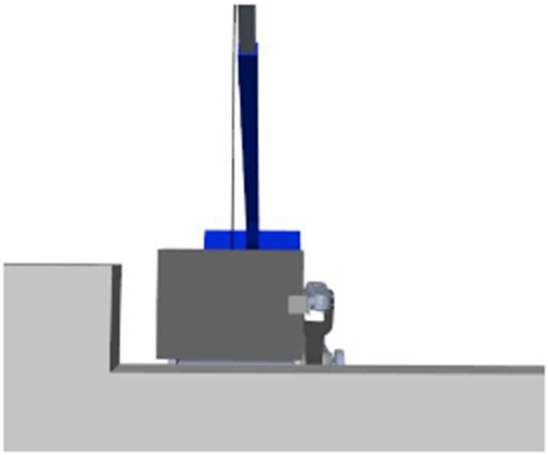
8. Visul Servoing with RGB-D

Contact persons:

Emanuele Garone, SAAS, ULB, Emanuele.Garone@ulb.be
Michele Ambrosino, SAAS, ULB, Michele.Ambrosino@ulb.be
Mehddad Teratani, LISA, ULB, mehrdad.teratani@ulb.ac.be

Context

This project takes place in the framework of the project Brickiebot aiming at developing a robotic solution for the bricklaying of walls with large sand-lime blocks consisting of a crane and a rigid robot.



Problem statement

The main problem we will focus on is the navigation of the robot using RGB-D camera (i.e. being able to reconstruct the position of the existing wall and of the block with respect to the robot) and being able to operate the “grabbing” action of the block by the robot.

Objective

The student will be requested to:

- Devise the best possible position of the RGB-D in the robotic system
- Make use of the RGB-D camera to reconstruct the environment and recognize the block
- Using RGB-D information study and Implement on a real robot (Kuka Iiwa) the “grabbing” of a suspended block.

The thesis will be carried out in cooperation with prof. Teratani, who is a specialist in computer vision.

9. Design, Realization and Control of an Autonomous Car (in collaboration with the youtubber J. Bruton)

Contact persons:

Emanuele Garone, SAAS, ULB, Emanuele.Garone@ulb.be
Laurent Catoire, SAAS, ULB, Laurent.Catoire@ulb.be

Objectives

The goal of this thesis is to design, build, and operate an in-scale self-driven electric car that can be produced within a limited budget. The car will be large enough to accommodate one person. The car is intended to be used as a budget platform for research and competitions on self-driven vehicles.

To keep the costs limited most of the chassis will consists of cardboard tubes interconnected with 3D printed interfaces, similarly to what presented in https://youtu.be/6v1DN7gZGzk. In the first part of the thesis the student will concentrate on the design of the mechanical and electronic components of the car. After this preliminary work the car will be produced, tested and assembled. The last part of the thesis will focus on the dynamic modelling and simulation of the car and on the development of a first self-driving policy using AI (see e.g. https://developer.nvidia.com/embedded/diy-ai-race).

Context

This thesis will be carried out with the co-supervision of the professional youtubber and maker James Bruton (https://www.youtube.com/jamesbruton) and the process of its making it is meant to be object of one or more youtube video (to this end particular attention will have to be put to the visual appearance of the car)

The Candidates

It is required that the student has a very high level of commitment and enthusiasm (the calendar will have a high pace starting from November, or if you don't have other commitments from this summer) and good capabilities in terms of mechanical design and manufacturing, electronics, and programming.

This master thesis can be carried out by one single student or by a team of two students.

To candidate yourself for this master thesis please write me possibly before the 15th of may at the email egarone@ulb.ac.be with your complete CV (included the marks you obtained so far)."

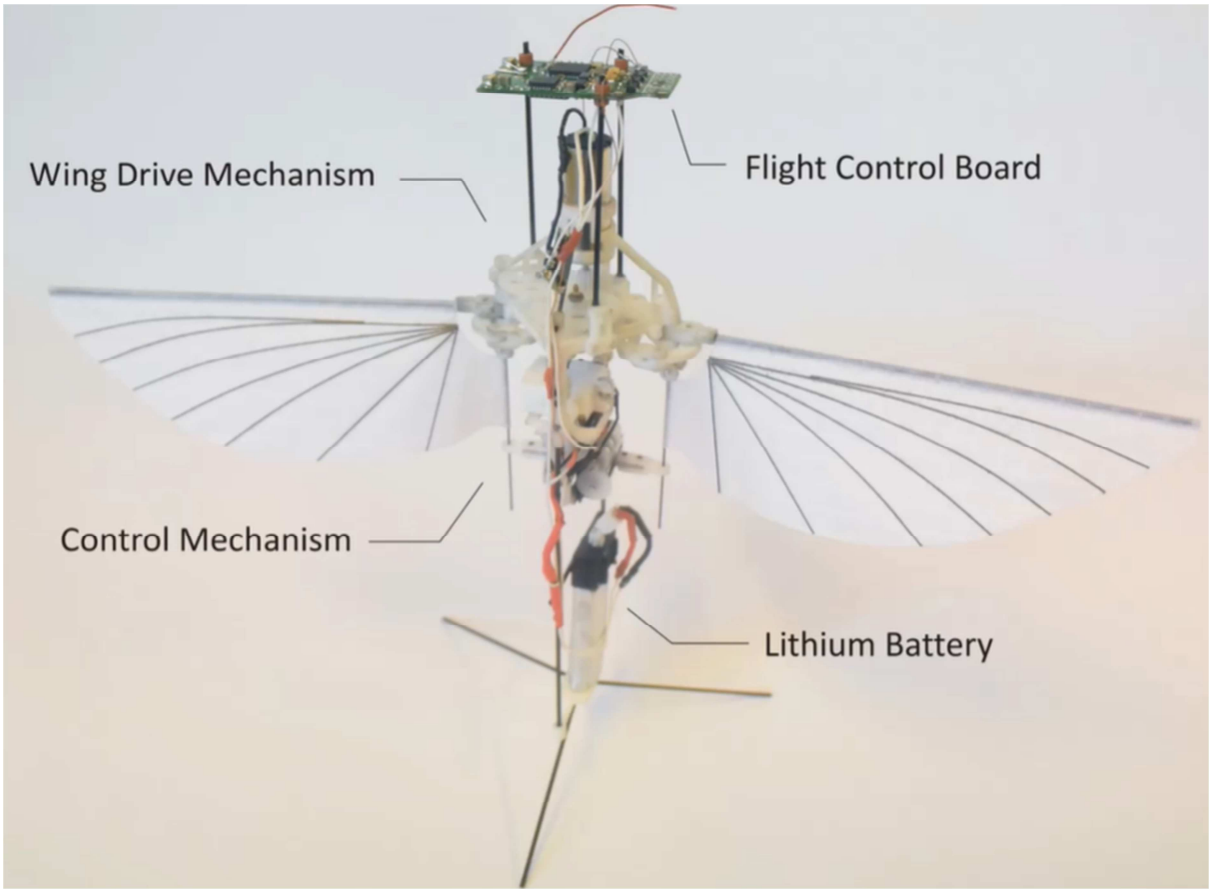
10. Colibri Project: embedded electronics and control

Contact persons:

Emanuele Garone, SAAS, ULB, Emanuele.Garone@ulb.be
Andre' Preumont, SAAS, ULB, Andre.Preumont@ulb.ac.be

Context:

The SAAS department is developing a Robotic Hummingbird (for a video: https://www.youtube.com/watch?v=-5-o9tvbziE) . Several thesis are possible in this context. The specific thesis subjects have to be discussed on a one-to-one basis with the student on the basis of competences, personal interest, and stage of advancement in the project.



11. Possible Internships + Thesis with Toyota Motor

Contact persons:

Emanuele Garone, SAAS, ULB, Emanuele.Garone@ulb.be

Context:

Internships + Thesis options are available with the Toyota research center located in Belgium. Specific internships and thesis subjects might be identified on a one to one basis.