Service d’Automatique et d’Analyse des Systèmes (SAAS)

Master thesis proposals for the academic year 2015-2016

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1. Alarm filtering for wind farms

Contact persons

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Context of the work

Alarm systems aim at warning the operator of an industrial process about abnormal situations. Most often the design of the alarm systems is such that, upon occurrence of a malfunction, a series of alarms are triggered. It is then quite difficult to deduce the source of the malfunction from the set of alarms. Therefore, tools are needed to help the operator in the analysis of such events. The purpose of the master thesis is to develop an alarm filtering tool and to use it to analyse the alarms issued from an offshore wind farm located in the North Sea.

This work takes place in the framework of BRUWIND (Brussels Wind Energy Institute), which aims at fostering the development of expertise in wind energy in the Brussels Region by cooperation between teams from VUB, ULB and Erasmushogeschool Brussel. The objective of the research projects within BRUWIND is to reduce the operation and maintenance costs of offshore wind farms by increasing the availability and reliability of wind turbines, by optimizing the management of wind farms, and by improving technologies for the construction of offshore wind turbines.

Work to be done

- Gaining acquaintance with wind turbine operation
- Bibliographical study on alarm filtering tools
- Analysis of alarm data from the offshore wind farm
- Selection of the most promising methods and possible development of new methods for alarm analysis
- Development of a MATLAB code that implements the above methods
- Validation on the wind farm data

Requested skills

Data analysis and processing, physical understanding of wind turbine operation, programming in the MATLAB environment.
2. Wind farm condition monitoring

Contact person

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In cooperation with Maintenance Partners Wallonie

Context of the work

Within the POWER project (MecaTech pole of the Walloon region) a model-based approach has been developed for detecting and localizing faults in a wind turbine. The malfunctions that were considered include sensor and actuator faults and the method was validated using measurements recorded on actual wind turbines.

The purpose of this master thesis is to pursue this work by examining whether a malfunction in a wind turbine operation could be detected by comparing its behaviour with the behaviour of the neighbouring turbines in the wind farm. Fault indicators should thus be designed by analysing the correlation between the measured data recorded for the different turbines and examining how faults can affect such correlations. The fault indicators should be sensitive to the fault effects while being insensitive to the differences in wind profiles in front of the turbines. A detailed wind turbine simulator including various faulty scenarios will be used together with actual data recorded on wind farms in order to study both the healthy and the faulty behaviours.

Work to be done

- Gaining acquaintance with wind turbine operation
- Bibliographical study on fault detection and isolation for wind farms based on comparing turbine behaviours
- Selection of faulty scenarios according to available wind farm data
- Analysis of the operation under healthy and faulty conditions and design of fault indicators
- Validation of fault indicators on simulated data and on actual wind farm data

Requested skills

Data analysis and processing, physical understanding of wind turbine operation, programming in the MATLAB environment
3. Paintable battery modelling for the design of a battery management system

Contact person

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Context of the work

A battery-management system (BMS) is a supervising unit used in order to improve battery lifetime and performance. It is based on a mathematical model of the behavior of the battery. A BMS is able to estimate battery state-of-charge (SOC)\(^\text{1}\) and state-of-health (SOH)\(^\text{2}\), as well as to detect and localize any malfunction. Besides SOC balancing among the battery cells must be ensured and their safe operation must be guaranteed. The two main approaches to develop a battery model for a BMS are: equivalent circuit model (ECM) and electrochemical model (EChM).

The ECM uses electric circuits to predict the internal states of the battery. The simplest ECM is the internal resistance model (R\text{int}) which consists of an ideal voltage source and an ohmic resistance, that represent the open-circuit voltage (OCV) and the internal resistance of the battery, respectively (Figure 1). Both OCV and resistance are functions of SOC, SOH and temperature.

\[ \text{Figure 1. An electrochemical system being approximated by an equivalent circuit model.} \]

The ECM is easy to handle, but its parameters do not have physical meaning. However, its application range and accuracy could be improved by adding extra electric components to the model, such as RC pairs, and by fitting parameters. These additional components are different for each battery chemistry, therefore a suitable ECM would be related with a specific chemistry.

Complex models (such as EChM) could be expensive and sensitive to uncertainties, therefore a simple and accurate enough ECM might be preferred for BMS design.

\[^{1}\] The SOC for a battery is the equivalent of the fuel tank level indicator for a fuel tank: it is the energy available with respect to the total energy that was available when the battery was fully charged.

\[^{2}\] The SOH is related with internal battery parameters (such as capacity and power fade) that change with the battery usage.
Description of the work
The aim of this master thesis is to develop an ECM to be used within the BMS framework (on-line/real time applications). The focus will be on a specific lithium-ion battery chemistry (lithium titanium oxide and lithium iron phosphate). This chemistry is under research in order to develop a paintable battery\(^3\), in the framework of the BATWAL project (an excellence program of the Walloon Region).

The student is asked to develop and compare several ECMs, starting from the basic Rint model and progressively adding RC pairs and fitting parameters in order to improve it. Introducing temperature effects in a suitable way will be pursued. The circuit component values have to be found via parameter identification techniques. The ECM must be able to compute SOC and SOH. A comparative study between the performance of ECM and EChM will be performed for various operating modes, both in healthy and faulty situations.

Requested skills
Basic knowledge in control theory, electrical background, programming skills in MATLAB.

\(^3\) A battery in which each component is made of a thin layer of a specific paint.
4. Control of a force-feedback teleoperated palpation device for minimally invasive thoracic surgery

Contact persons

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Context of the work

Minimally invasive surgery (MIS) consists in operating through small incisions in which a camera and the surgical tools are inserted. This approach allows performing many interventions with reduced trauma for the patient. One of these is the ablation of peripheral pulmonary nodules. Nevertheless, the means for detecting nodules during MIS are limited. In fact, because of the lack of direct contact, the surgeon cannot palpate the lung to find invisible lesions, as he would do in classical open surgery. As a result, only clearly visible nodules can be treated by MIS presently.

One of the projects of the department consists in developing a teleoperated force-feedback palpation device in order to extend the possibilities of MIS in the thoracic field. This instrument, depicted on figure 1, is made of a master device, manipulated by the surgeon, and a miniaturized slave device which is in contact with the lung and reproduces the task imposed by the master. Adequate control laws between these two parts should allow restoring the operator’s haptic sensation. In other words, the device permits the surgeon to feel the lung, as if he was actually touching it.

Description of the work

The student is asked to design teleoperation control laws suitable for the palpation task. These control laws will be validated through a simulation and then implemented on the existing device. The palpation will be performed on a mock-up reproducing a human lung.

Performance criteria have to be defined and experiments have to be designed in order to compare several controllers. The performance of surgeons when using the device will then be evaluated. Finally, based on the surgeon’s feedback, the student will have to choose the most efficient controller.

Figure: CAD model of the palpation device

Requested skills: control engineering, medical background, programming in MATLAB/SIMULINK and LABVIEW environment, experimental skills.
5. Teteoperated control with force feedback and physiological movement cancellation for a 3 degree-of-freedom master slave device

Contact persons

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Context of the work

Minimally invasive surgery (MIS) consists in operating through small incisions in which a camera and the surgical tools are inserted. This approach allows performing many interventions with reduced trauma for the patient, but it makes operation for the surgeon less intuitive and comfortable. Teleoperated robotic devices have been developed to counteract these drawbacks and to increase dexterity within the patient body, notably. However, commercial master/slave devices do not include force feedback, which can be very helpful for precision gestures like suturing and needle insertion.

A 3 degree-of-freedom master slave device has been designed and built at SAAS in order to study force feedback in teleoperation. A first study has allowed one to ensure position control of the slave device through the master device including compensation of physiological movements in the absence of contact with the organ. The aim is now to complete the controller by studying the phase in which contact with the organ takes place. An appropriate force feedback scheme should be developed and implemented, while still guaranteeing compensation of the physiological movements. Next both the position and force control schemes should be combined to ensure a transparent teleoperated control.

Description of the work

- Gaining acquaintance with robot modeling and control, as well as basic teleoperation control schemes
- Implementation and calibration of new sensors on the robot (force sensor and proximity sensor) on the slave robot
- Design and implementation of teleoperation control scheme with force feedback
- Inclusion of physiological movement cancellation in the above scheme
- Combination of the control scheme for movement in contact with the organ and the control scheme in the absence of contact

Requested skills: control engineering, medical background, programming in MATLAB/SIMULINK and LABVIEW environment, experimental skills.
6. Digital control of a self-erecting double inverted pendulum

Contact persons

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Description

The double inverted pendulum of our laboratory is composed of a screw driven cart on which the pendulum is connected. The cart position is controlled by a direct current motor. A simplified scheme of the process is the following:

![Diagram of double inverted pendulum](attachment:double_pendulum_diagram.png)

Different sensors are available to measure: the position of the cart and the angles of the two pendulum poles.

The control objective is to take the pendulum from its stable position to the upright position by moving the cart.

Phases of the project

- Study of the process, familiarization with the existing simulator, validation of its parameters.
- Bibliographical study on inverted pendulum control
- Pendulum sizing (length of the poles)
- Design of different control laws
- Validation and comparison of the control laws in simulation
- Validation on the real process.
7. UAV interacting in force: Force interaction with the environment
Promoter: Prof. Emanuele Garone (egarone@ulb.ac.be)
Other Contacts: Marco Nicotra (mnicotra@ulb.ac.be)

In this Master Thesis the goal will be to study the interaction of a quadrotor with the environment. In particular this thesis will focus on the control of operations such as interaction in force with a wall or with a cable will be explored, for possible applications in the inspection and maintenance field. The thesis will include experimental activity in the SAAS flying lab.

8. UAV interacting in force: manipulation of objects
Promoter: Prof. Emanuele Garone (egarone@ulb.ac.be)
Other Contacts: Marco Nicotra (mnicotra@ulb.ac.be), Tam Nguyen (tanguyen@ulb.ac.be)

Goal of this Master Thesis is to study and control the interaction of one or more quadrotors which is manipulating an object to achieve specific goals: e.g. construction and pose of objects. The thesis will include experimental activity in the SAAS flying lab.

9. Swarm robotics: Robots with polyhedral spatial occupation
(In collaboration with University of Roma 3)
Promoter: Prof. Emanuele Garone (egarone@ulb.ac.be)
Co-promoter: Prof. Andrea Gasparri (Università di Roma 3)

The goal of this thesis is to study robot formation and interaction rules for mobile robots having a generic polyhedral spatial occupation. The idea is to extend existing results on swarming to the case of robots characterized by position and orientation and where their distance is characterized as distance between objects rather than between points. Internships are available at the university of Roma 3 on a related subject.
10. Modélisation du sommeil profond chez les sujets normatifs et pathologiques dans le cadre de l’étude de la maladie d’Alzheimer

Personnes de contact

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Contexte du travail

Une des fonctions principales du sommeil profond, caractérisé par la production d’ondes Delta (de fréquences de 0,5 à 3-4 Hz d’amplitudes de 100 à 200 microvolts), semble être l’élimination, par les canaux lymphatiques, des toxines accumulées par le cerveau lors de son activité diurne. Une piste concernant les origines de la maladie d'Alzheimer pourrait être le dysfonctionnement de ce procédé d’élimination se traduisant par l'auto-empoisonnement de l'encéphale.

But du travail

- définir une architecture de modèles du sommeil profond;
- déterminer les paramètres les plus vraisemblables de ces modèles et les intervalles d’erreurs y attachés;
- différencier les résultats obtenus pour les échantillons normatifs et les pathologiques;
- établir des corrélations entre les paramètres des modèles et d'autres marqueurs physiologiques.

Bibliographie


Automatique avancée 1 : techniques d'identification et d’estimation, Raymond Hanus, Hermès Science : 978-2-7462-1701-0
Internships
Possibilities for internship with:

- Vattenfal (Denmark) – Wind Energy
- Plastic Omnium (Brussels) – Automotive applications
- AW Europe (Briane l’Alleud) – Automotive applications