2SC5293 – Advanced supervision of biogas production from waste

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Language of instruction: FRANCAIS
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 40
On-site hours (HPE): 27,00

Description

Anaerobic digestion is a natural process of degradation of organic substances by micro-organisms (bacteria and archaea) in the absence of oxygen (anaerobic conditions).
This process makes it possible to recover a fraction of the energy contained in the waste in the form of biogas, a mixture of methane and CO2.
The widespread use of these technologies would on the one hand considerably reduce the energy demand necessary to treat waste (10% of the energy used on the planet) but could in the long term constitute a source of energy.

However, the anaerobic digestion process is complex and involves several hundred species of microorganisms. Moreover, it is unstable, and intermediate compounds (volatile fatty acids) can, under certain conditions, accumulate and lead to the total shutdown of the reactor. To avoid this, very precise and costly monitoring is necessary.

The objective of the Challenge Week is to propose and develop monitoring and control strategies to reduce the risk of reactor acidification and to optimize energy production from waste.

Quarter number

ST5

Prerequisites (in terms of CS courses)

There are no specific prerequisites.

Syllabus

Students will first need to understand an anaerobic digestion model that will be provided and simulate it for different conditions.
In particular, they will need to simulate reactor acidification under conditions of overloading the reactor.

They must propose a simulator with a simplified model for this complex system, for the purpose of implementing control and estimation strategies.
In a second step, they will have to develop observers to evaluate certain intermediate compounds, and in particular volatile fatty acids. It is desirable that a self-calibration dynamic is introduced to take into account the slow drifts of certain model parameters.
Other groups will use the models to develop control strategies. Different approaches will be implemented (e.g. PID, feedback control).
In the end, a supervisor will be proposed by associating an observer(s) to a control law. The performances of the different supervisors will be compared for different reactor operating scenarios.

Class components (lecture, labs, etc.)
Students will be divided into groups. The project will be carried out by organizing the internal work of each group in order to address the different themes of the specifications.
Analytical and numerical tools will have to be developed by the students in order to address the problems raised.
The hypotheses and data considered must be questioned; these elements will lead the students to iterate on their design choices in order to obtain relevant solutions.

Grading
The evaluation will include a continuous assessent, a final report, and an oral presentation.

Course support, bibliography

- Anaerobic Digestion Model No. 1, PWA Publishing, 2002.
- Dynamical Model Development and Parameter identification for an anaerobic wastewater treatment process, O. Bernard et al., *Biotechnology and bioengineering*, *75*(4), 424-438, 2001.
- On-line Estimation and Adaptive Control of Bioreactors, G. Bastin, D. Dochain, Elsevier, 1990.
- Automatic Control of Bioprocesses, éditeur D. Dochain. Wiley-ISTE, 2008.

Resources

- Simulator of the bioprocess to be studied,
- State-of-the-art and a description of the studied bioprocess.
- Supervision: researchers from INRIA (Sophia-Antipolis), teacher-reseacrhers of CentraleSupélec, with regular contact with the industrial partner.

- Work in group.

Learning outcomes covered on the course

At the end of the Challenge Week, the students will be able to:

- Model a bioprocess for the culture of a microorganism for environmental application
- Design software sensors to reconstruct variables not available online
- Design control laws to maintain the system at desired operating conditions (pH, temperature, concentrations, etc.) to maximize the productivity of the bioprocess.
- Analyse the proposed solution (including economic analysis and ecological footprint) and be critical of the results obtained.

Description of the skills acquired at the end of the course

– C1.1, Analyze: study a system as a whole, the situation as a whole. Identify, formulate and analyze a system within a transdisciplinary approach with its scientific, economic, human dimensions, etc. Milestone 1

– C1.2, Modeling: using and developing the appropriate models, choosing the correct modeling scale and the relevant simplifying assumptions. Milestone 2

– C2.3, Identify and independently acquire new knowledge and skills. Milestone 2

– C4.2, Propose one or more solutions answering the question rephrased in terms of value creation and complemented by the impact on other stakeholders and by taking into account other dimensions. Quantify the value created by these solutions. Arbitrate between possible solutions. Milestone 1

– C7.1, Basically: Structure ideas and arguments, be synthetic (assumptions, objectives, expected results, approach, and value created). Milestone 2

– C7.2, On the relationship with others: Understand the needs and expectations of his interlocutors evolutionarily. Encourage interactions, be a teacher, and create a climate of trust. Milestone 2

ST5 – 53 – AUTONOMOUS AND CONNECTED VEHICLE

Dominante : SCOC (Communicating Systems and Connected Objects)
Langue d'enseignement : French
Campus où le cours est proposé : Paris-Saclay

Engineering problem

Today's vehicles are equipped with a multitude of sensors and electronic processing that provide driving assistance and even a certain level of autonomy in well-defined contexts. Today's vehicles are also connected to provide information on traffic conditions and navigation. According to roadmaps in the field, by 2030, the vehicle should be subject to complete connectivity via intelligent communication systems and adapted technologies to enable total autonomy, reducing the driver to a simple passenger who will only have to indicate his destination before departure. But before we get there, engineers will have to help answer many questions, of which we can give a taste. First of all, on a technical level, will technology be able to completely replace the driver? Or how can such systems be designed and validated while guaranteeing reliability and safety? From an ethical and regulatory point of view, how can personal data be protected, knowing that the vehicle will be connected to a network at all times and therefore likely to communicate information outside the cabin? From an economic point of view, upheavals are to be expected in the value chain of the automotive sector with the rise of the GAFAMs in this field and the future management of vehicle systems by operators. On the societal level, what new services could emerge? Finally, from an environmental point of view, how can we ensure that the autonomous and connected vehicle minimizes our ecological footprint?
During this thematic sequence, students will be trained in functional modeling methods, a preliminary step in any complex system design, and in control techniques. A specific course on the issue will provide an overview of technologies used in this context such as digital methods of modeling, simulation and validation vehicles, electronic architectures embedded, processing of multi-sensor data fusion, artificial intelligence for the vehicle, and communication protocols V2V and V2X. During the integration course, students will have to put into perspective all the knowledge acquired, starting from a specification and going up to the validation on a physical platform, constituted here by a system of rolling robots.

Adviced prerequisites

It is advisable to have taken the SPI Electronic Systems course and the SPI Networks and Security course.

Context and issue modules: This part is structured in conferences and round tables allowing to apprehend the problematic, the technologies and the stakes related to the autonomous and connected vehicle, namely the associated societal stakes such as safety, environment, traffic fluidity, the social-economic and industrial stakes.

Specific course (60 HEE) : *Architecture and technology of the autonomous vehicle*

Brief description:

The first part of the course focuses on the definition of an autonomous vehicle mobility system and in particular its functional architecture (perception, processing, communication, actuation, but also propulsion and energy conversion) as well as the development and validation methods of autonomous driving systems or driver assistance systems (AD/ADAS). The course then focuses on the electrical and electronic architecture of the vehicle (power supply network, computers, communication bus and embedded sensors). It is also a question of understanding the physical and environmental constraints to which the on-board electronics are subjected, to apprehend the problems of operating safety and real-time processing crucial in the automotive field. Some of these concepts are addressed and deepened through a workshop-type session in small groups around a case study of a level 4 autonomous vehicle. Also, a practical session allows to implement a real time embedded image processing with automatic code generation tools on electronic boards.

A second part addresses the processing and algorithms implemented for the autonomous vehicle. Control laws specific to the autonomous vehicle are addressed (Linear Quadratic Regulator, Kalman filtering, neural networks, fuzzy logic...) as well as artificial intelligence (AI) techniques relevant to the autonomous vehicle (supervised learning, connectionist AI). On this processing part, a practical session allows to study and test a control law for automatic parking, another one aims at studying the basic techniques of image processing and a third one studies deep learning algorithms in an automotive context.

A third part focuses on vehicular communication technologies with a comparison of existing communication means. The evaluation of the performance of a vehicular communication network will be addressed and this includes a study of the link budget for coverage as well as an analysis of the different channel access mechanisms (Aloha, Slotted-Aloha and CSMA/CA). A practical session allows the simulation and practical application of the concepts seen in this part.

Challenge week : *Design of a "last mile" urban delivery system using autonomous and connected vehicles*

Associated partner: Renault, Mathworks

- **Location:** Paris-Saclay campus

- **Short description :** The challenges of autonomous and connected vehicles do not only concern the automotive sector. The integration course proposed here will enable you to understand the design approach of a complex and critical system, and the plurality of issues of the autonomous and connected vehicle, through an industrial scenario in an appropriate context. The scenario chosen is that of a so-called "last mile" delivery, specified below.

The cost and delivery time of a parcel by carrier is strongly impacted by the last mile, especially in urban areas. Because of traffic jams and parking, delivery trucks could advantageously be replaced at the entrance to large cities by lighter means of transport adapted to the urban environment.

The use of bicycles is proving to be too costly; in the short term, transporters are considering a fully automated last-mile delivery. The solution consists of managing a fleet of autonomous and connected robots that carry out delivery routes based on arrivals, delivery addresses and the robots' characteristics.

Delivery trucks drop off the robots at the entrance of city centers. Each robot is in charge of one or more parcels and has a route to follow to deliver all the parcels as quickly and efficiently as possible. In addition to being able to move efficiently in an urban environment while avoiding obstacles, pedestrians and other vehicles, the robots must communicate with each other (V2V) and with the infrastructure (V2I) in order to avoid, for example, congestion points (demonstrations, work zones, etc.) and to have their route re-planned in real time.

You will work in a team in charge of designing such a delivery system. You will follow a model-driven system engineering approach to specify the system's functionalities. You will adopt a modeling methodology to develop the necessary algorithms (control/command, sensor fusion, data fusion, decision making and telecommunications) to meet the specifications. A small-scale test platform will allow you to evaluate the quality of the resulting delivery system and refine the algorithms.

During this work, you will have to take different points of view: system by establishing the control/command and communication strategy between vehicles; functions through the algorithms; components through your choices of implementation of these algorithms in order to take into account the specific constraints of the application (latency, limited resources, etc.)