1SC2193 – Modeling of a minimally-invasive surgical robot

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Department: DOMINANTE - GRANDS SYSTÈMES EN INTERACTION
Language of instruction: FRANCAIS
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 40
On-site hours (HPE): 27,00

Description

Surgical robots can improve the surgeon's precision of movement and reduce the effect of tremors, among other things. They also provide more freedom of movement and visibility thanks to the on-board vision system.
Minimally-invasive surgery aims to reduce the impact of an operation on the patient in terms of trauma and recovery time. The surgeon operates directly inside the patient's body using a camera and tools inserted through holes called trocars. The assistance of the surgeon by means of a robotic system makes it possible to overcome a certain number of constraints encountered by the surgeon in this type of operation (restricted work space, partial visibility, constraining posture...).
The design of such robotic systems therefore requires new constraints to be taken into account in terms of geometry (fixed point at the trocar), instrumentation (sensors, effectors, etc.) and safety (collisions in the patient's body or in the workspace of medical staff).
In this project, we are interested in modelling a robot with four degrees of freedom in order to evaluate its working space and estimate external forces in the event of a collision.

Quarter number

ST2

Prerequisites (in terms of CS courses)

None

Syllabus

Possible projects:

1. Study of interaction forces with the patient or surgeon
2. Study of virtual sensors for the reconstruction of interaction forces
3. Development of a simulator for a dynamic robot model
4. Study of joint friction based on experimental data

5. Study of the design of the actuators and sensors of the robot
6. Study of robot movements for control

Grading

involvement in the team work during the challenge week + deliverables at the end of the week + final defense

Resources

- large room for 30 students, with projector, organized in blocks by group
- 3 teachers per room
- Matlab/Simulink (network access for license) on individual students' PCs

Learning outcomes covered on the course

At the end of this challenge week, students will be able to:

1. Describe the current context of medical robotics through the main technical, application and economic challenges associated with it.
2. Identify current topics in medical robotics, and describe their technical specificities.
3. Describe the main hardware and software components of an industrial and medical robotic system.
4. Develop and simulate models of polyarticulated or mobile robots.
5. Designing, modeling and simulating a motorization chain.
6. Analyze a system in interaction with the external environment.

Description of the skills acquired at the end of the course

- C1 - Analyze, design, and build complex systems with scientific, technological, human, and economic components
- C4 - Have a sense of value creation for one's company and one' customers
- C7 - Know how to convince
- C8 - Lead a project, a team

ST2 – 22 – BIOINGENEERING : PRODUCE, PROTECT, REPAIR

Dominante : VSE (Vivant-Santé Environnement)
Langue d'enseignement : French
Campus où le cours est proposé : Paris-Saclay

Engineering issues

Bioengineering transfers and applies the engineering concepts, methods, and tools to living systems to produce more sustainably, protect a threatened natural environment or repair an organ.

Living systems are complex. Many scales are involved: cell, organ, organism, population, or ecosystem. The phenomena at play are multiple, requiring a multidisciplinary approach.

Modeling is currently one of the major challenges in bioengineering, to understand, describe and predict the behavior of living systems and participate in their control.

In the present Engineering Challenge Term, the students will learn about life sciences and carry out a modeling approach to address one issue in the field of health, sustainable production, or environment: (i) how the use of living systems may improve the healthcare, (ii) how to mitigate microbial communities (biofilms) which grow in cooling systems and may affect the production of power plants, (iii) how to use living organisms to produce high added value molecules in a sustainable way (iv) how to deliver a drug at a targeted body site at the right time and in the right amount .

4 Challenge weeks are proposed, offering the opportunity to:

- address the basics of (living) tissue engineering and regenerative medicine (bone reconstruction),
- analyze the industrial and economic problems raised by the microbial development in cooling systems,
- produce high-value molecules, in a sustainable way, using an innovative biofilm process,
- design new controlled-release drug delivery systems to increase efficacy, facilitate patient use and reduce dosage-related side effects.

Prerequisites: None

Engineering Challenge Introduction: The context and the challenges of bioengineering will be presented at conferences and round tables. The students will discover the contribution of modelling to meet the challenges of the living world and the environment. Aspects of the dynamics of ecological systems will be addressed. Mathematical models for the study and control of viral propagation in a human population will be presented. Economic perspectives in the biomedical and industrial biotechnology fields will be discussed by experts. Finally, the Integration Teachings will be presented by the ST partners: INSERM, EDF, INALVE and GALIEN INSTITUTE.

Specific Course (40 HEE): Life sciences

- **Short description:** The general principles that define life will be presented. The numerous scales that can be considered and the level of complexity that increases with the change of scale will be progressively covered from one course to another (macromolecule / cell / population of cells in suspension and in the form of a biofilm / organ). The first part of the course is a cell biology course that presents the macromolecular and cellular scale, and that finally proposes a review of the aspects of living organisms that it is now possible to model for an engineer. It will be followed by a course on bioprocesses, the aspects of bioproduction and bioremediation will be addressed, and finally a course on a living material (bone tissue). The course will be completed by practical exercises illustrating these fields. At the end of this course, it is possible to understand how to use living organisms to treat wastes (environmental challenge), produce sustainably from renewable resources (industrial challenge) and repair living systems (health challenge).

Challenge week n°1: Biomaterials for bone tissue engineering

- **Partner:** INSERM
- **Location:** Paris-Saclay campus
- **Short description:** The excellent natural healing capacity of bones is sufficient to repair most fractures. However, in some clinical cases (such as severe traumatic injuries with bone loss or extensive resections of bone tumor), a bone graft is mandatory. For extensive or multiple bone reconstructions, the available volume of bone material for autologous graft may be insufficient. In this context, INSERM is developing an alternative therapy for which a synthetic microporous biomaterial replaces bone flaps.
  The Challenge week focuses on the modeling of cell proliferation within the biomaterial. Different aspects of the multiphysics modeling will be addressed: (i) the characterization and the geometric representation of the microporous biomaterial, (ii) the hydrodynamics within the pores, (iii) the transport of the chemical species (oxygen and glucose), (iv) the cell proliferation and (v) the coupling between the biomaterial morphology, the hydrodynamics, the solute transport, and the cell proliferation.

Challenge week n°2: Biofilm: a hindrance to electricity production coupled with environmental and health risks

- **Partner:** EDF
- **Location:** Paris-Saclay campus
  - **Short description**: In this challenge week, the objective is to evaluate the negative impact of the growth of a biofilm in a heat exchanger cooled by sea water in an energy production plant. After establishing a model on a reference case, an industrial case will be considered. The students will develop scenarios that allow a level and safety of energy production in accordance with the customer's demand, based on computational results. They will take into account the environmental and sanitary constraints of water discharge into the natural environment. They will establish the amount of the investment in equipment and the associated operating costs according to the characteristics of the production site (Europe and Asia). Key Performance Indicators (KPIs) will be used to rank these scenarios and quantify the value created for the client.

Challenge week n°3: Microalgae production using a biofilm-based photobioreactor

- **Partners:** INALVE and INRIA
- **Location:** Paris-Saclay campus
- **Short description:** Microalgae are sun-light driven cell factories that convert carbon dioxide into food, feed and high-valuable molecules with a broad of industrial applications (chemical, pharmaceutical, cosmetics, …). They are cultivated in reactors, generally located outdoors and therefore subject to significant daily and seasonally variations in light and temperature. The objective of this Challenge week is to improve an innovative microalgae/protein production system through a modelling approach. The students will develop a model of the bioprocess integrating thermal and mass transfers that will allow to predict the productivity of the production system subject to variations in light and temperature. Finally, they will propose recommendations for the design and operation of the bioprocess by analyzing the results of the model.

Challenge week n°4: Controlled release systems for pharmaceutical agents

- **Partner:** GALIEN INSTITUTE Paris Saclay (School of Pharmacy)
- **Location:** Paris-Saclay campus
- **Short description:** The design of a pharmaceutical solution requires to consider the kinetics of release of its active agent into the bloodstream or tissue, and to maintain the adequate drug concentration over a specific period. To achieve this, the active agent is usually formulated in specific forms to control their release. However, in order to predict the kinetics in

the body, the physiological parameters of the patients must also be taken into account.

The objective of the Challenge week is to model the drug release kinetics of specific pharmaceutical systems in order to reduce the number of tests in a clinical trial. The models will be developed in an incremental manner: first a PBPK (Physology Based Pharmaco Kinetics) model will be implemented and validated against experimental data. This model will then be extended in order to account for the specificities of the client problematic, that is to say the drug delivery system, the inoculation mode, and the population characteristics.