BIO-491

New tools & research strategies in personalized health

Friedli Marc, Trono Didier

Cursus	Sem.	Type
Biomedical technologies minor	E	Opt.
Biotechnology minor	E	Opt.
Life Sciences Engineering	MA2, MA4	Opt.
Minor in life sciences engineering	E	Opt.

Language of teaching	English
Credits	4
Session	Summer
Semester	Spring
Exam	During the semester
Workload	120h
Weeks	14
Hours	**4 weekly**
Courses	2 weekly
Exercises	2 weekly
Number of positions	

Summary

We will define the concept of personalized health, describe the underlying technologies, the technological, legal and ethical challenges that the field faces today, and how they are being met.

Content

In line with the Health 2030 Initiative (https://health2030.ch/), this course aims to be multidisciplinary, to tackle different aspects of personalized health. Under supervision of a PI to coach you, you will study a specific problem, evaluating its basis and proposing solutions. The output will be a short report and an oral defense of your interdisciplinary project.

Learning Prerequisites

Required courses

None

Learning Outcomes

By the end of the course, the student must be able to:

- Distinguish the tenents of personalized health
- Discuss new technologies within the context of personalized health

Transversal skills

- Write a scientific or technical report.
- Make an oral presentation.
- Take feedback (critique) and respond in an appropriate manner.
- Assess progress against the plan, and adapt the plan as appropriate.
- Collect data.
- Use a work methodology appropriate to the task.
- Continue to work through difficulties or initial failure to find optimal solutions.
- Use both general and domain specific IT resources and tools

Teaching methods

Ex-cathedra lectures, discussions, coaching, preparation of a project, oral defense of the project.

Expected student activities

Attend all the lectures
Preparation of project
Oral defense of project
Active participation to discussions
Work in small groups

Assessment methods

Written: A **mid-term individual assessment** based on the lectures.
Oral: Presentation of a project: quality of slides, clarity and content of presentation, ability to answer questions.
Project: Relevance to personalized health, explanation of relevant background, explanation of research strategy. Multidisciplinary approach.

Supervision

Office hours	No
Assistants	Yes
Others	Coach and contact persons for project

Resources

Bibliography

No prerequisite

Notes/Handbook

When possible, copies of the slides will be provided

Websites

- https://health2030.ch/

Moodle Link

- https://go.epfl.ch/BIO-491

EE-512 **Applied biomedical signal processing**

Lemay Mathieu

Cursus	Sem.	Type
Biomedical technologies minor	H	Opt.
Computer science	MA1, MA3	Opt.
Cybersecurity	MA1, MA3	Opt.
Electrical and Electronical Engineering	MA1, MA3	Opt.
Life Sciences Engineering	MA1, MA3	Opt.
Microtechnics	MA1, MA3	Opt.
SC master EPFL	MA1, MA3	Opt.

Language of teaching	English
Credits	4
Session	Winter
Semester	Fall
Exam	Written
Workload	120h
Weeks	14
Hours	**4 weekly**
Courses	2 weekly
Project	2 weekly
Number of positions	

Summary

The goal of this course is twofold: (1) to introduce physiological basis, signal acquisition solutions (sensors) and state-of-the-art signal processing techniques, and (2) to propose concrete examples of applications for vital sign monitoring and diagnosis purposes.

Content

- Introduction on the basics in anatomy and physiology of autonomous nervous system, electrical cardiac system, hemodynamic basis, brain and respiratory activities as well as location.
- Digital signal processing basics including sampling, Fourier transform, filtering, stochastic signal correlation and power spectral density. Time-frequency analysis including short-term Fourier and wavelet transforms. Linear modelling including autoregressive models, linear prediction, parametric spectral estimation, and criteria for model selection. Adaptive filtering including adaptive prediction and estimations of transfer functions as well as adaptive interference cancellation.
- Digital signal processing miscellaneous techniques including polynomial models, singular value decomposition and principal component analysis, phase-rectified signal averaging, source separation, support vector regression, and neural network structures such as CNN and RNN.
- Applications and exercises related to cardiac arrythmia detection and classification, central blood pressure estimation, sleep phase classification, heart rate tracking robust against motion artefacts, epilepsy event detection, fall detection, apnoea detection, SpO2 estimation, and respiration tracking and volume estimation. These exercises will be based on biomedical signals such as bio-impedance, electrocardiogram, electroencephalogram, hypnogram, movement (accelerometer, gyroscope, and barometer), photoplethysmography, vocal/audio.

Keywords

signal processing, biomedical engineering, signal modelling, spectral analysis, adaptive filtering, algorithm design

Learning Prerequisites

Recommended courses

Signal processing for telecommunications COM-303
Signal processing EE-350

Important concepts to start the course

basics of discrete-time signal analysis
basics in signal processing programming

Teaching methods

Ex cathedra lectures (approx.. 2h per module) and practical work using Matlab/Python (approx.. 2h per module). The student should provide a separate report for each of the practical work session for evaluation. Grades are based on the practicals and a final exam.

Expected student activities

- Attending lectures
- Processing and analysing human data
- Testing signal processing techniques

Assessment methods

1.75 points in total for the lab/exercise sessions reports during the semester (35% of the final total grade)
3.25 points for the final exam during the examination period (65% of the final total grade)

Supervision

Assistants	Yes

Resources

Moodle Link

- https://go.epfl.ch/EE-512

BIO-341

Dynamical systems in biology

Naef Felix, Shillcock Julian Charles

Cursus	Sem.	Type
Life Sciences Engineering	BA5	Obl.
Systems Engineering minor	H	Opt.

Language of teaching	English
Credits	4
Session	Winter
Semester	Fall
Exam	Written
Workload	120h
Weeks	14
Hours	**4 weekly**
Courses	2 weekly
Exercises	2 weekly
Number of positions	

Summary

Life is non-linear. This course introduces dynamical systems as a technique for modelling simple biological processes. The emphasis is on the qualitative and numerical analysis of non-linear dynamical models. Examples are taken from biology and population models.

Content

1. Dynamical systems in 1D
   1. Introduction to dynamical systems, ordinary first-order differential equations in 1D.
   2. Linear stability analysis in 1D. Population dynamics in 1D.
   3. Bifurcations in 1D.
   4. Bistable gene expression and hysteresis in 1D.
2. Dynamical systems in 2D
   1. Linear 2D systems, stability and classification of fixed points, phase portraits.
   2. Non-linear 2D systems, numerical analysis.
   3. Predator-Prey models
   4. Limit cycles and Poincaré-Bendixson theorem, oscillators.
   5. Forced and coupled oscillators, phase oscillators.
3. Discrete dynamical systems
   1. Iterative maps in 1D, Logistic map, numerical analysis.
   2. Period doubling and the route to chaos.

Keywords

Non-linear dynamical systems; ordinary differential equations; qualitative analysis; numerical analysis, simulations; population models; bistability and hysteresis; biological oscillators; iterative maps in 1D, chaos and fractals.

Learning Prerequisites

Required courses

Informatics 1, II, III
Analysis I, II
Linear Algebra
Numerical Analysis

Recommended courses

Physics I, II

Important concepts to start the course

Analysis and linear algebra
Basic chemical kinetics

Learning Outcomes

By the end of the course, the student must be able to:

- Explain simple dynamical models (terms and parameters)
- Analyze dynamical models in 1D
- Analyze models in 2D including phase portraits
- Characterize fixed points and their stability
- Implement simulations of models
- Identify bifurcations in 1D models
- Model biochemical reactions
- Construct simple models
- Critique simple models

Transversal skills

- Plan and carry out activities in a way which makes optimal use of available time and other resources.
- Write a scientific or technical report.
- Demonstrate the capacity for critical thinking

Teaching methods

Lectures
Exercises

Expected student activities

Learn the theoretical material in the lectures
Solve the exercises using pencil and paper, and implement numerical analysis of models

Assessment methods

Written examination and graded exercises.

Supervision

Office hours	No
Assistants	Yes
Forum	Yes

Resources

Bibliography

S. H. Strogatz Nonlinear dynamics and chaos (CRC Press)
J. D. Murray Mathematical BIology (Spring)

Ressources en bibliothèque

- Strogatz, Nonlinear dynamics and chaos (CRC Press)

- Murray, Mathematical Biology (Spring)

Notes/Handbook

Course notes in pdf format

Moodle Link

- https://go.epfl.ch/BIO-341

EPFL

MICRO-568

Seminar in physiology and instrumentation

Radenovic Aleksandra

Cursus	Sem.	Type
Génie électrique et électronique	MA1, MA3	Opt.
MNIS	MA3	Opt.
Mineur en Technologies biomédicales	H	Opt.

Langue d'enseignement	français / anglais
Crédits	2
Session	Hiver
Semestre	Automne
Examen	Ecrit
Charge	60h
Semaines	14
Heures	**2 hebdo**
Cours	2 hebdo
Nombre de places	

Résumé

Acquérir la connaissance de l'état de l'art dans l'instrumentation bio-médicale. Comprendre la physiologie associée aux techniques de mesures.

Contenu

Introduction à la physiologie médicale.
Etudes de cas d'instruments

Mots-clés

physiology
biomedical technology

Compétences requises

Cours prérequis indicatifs

capteurs

Concepts importants à maîtriser

physique de base, électronique de base

Acquis de formation

A la fin de ce cours l'étudiant doit être capable de:

- Concevoir instrumentation médicale

Méthode d'enseignement

Série de leçons données par les instructeurs du cours ou des intervenants invités externes.
Exposé de chaque étudiant sur un instrument spécifique (liste des sujets donnée au début du cours) avec 10 min de présentation et 2 pages de résumé décrivant l'instrument (physiologie, principe de fonctionnement, spécifications).

Travail attendu

Discussion avec les intervenant du cours
Préparer un exposé pendant le semestre

Méthode d'évaluation

Exposé (50%)
Examen écrit, 2h (50%)

Encadrement

Office hours	Oui
Assistants	Non
Forum électronique	Non

Ressources

Bibliographie

- Textbook of medical physiology, A. Guyton, Elesvier (pdf extracts are available on the moodle for reading)
- Medical Instrumentation, Application and design, J. Webster, Wiley (pdf of selected chapters are available on the moodle for reading)
- Encyclopedia of Medical Devices and Instrumentation, J. Webster, Wiley (pdf of seleted chapters are available on the moodle for reading)

Ressources en bibliothèque

- Textbook of medical physiology / Guyton
- Medical Instrumentation, Application and design / Webster
- Encyclopedia of Medical Devices and Instrumentation / Webster

Polycopiés

Copie de présentations des invités
Coipe des présentations des étudiants

Liens Moodle

- https://go.epfl.ch/MICRO-568

EE-519

Bioelectronics and biomedical microelectronics

Schmid Alexandre

Cursus	Sem.	Type
Biomedical technologies minor	H	Opt.
Data and Internet of Things minor	H	Opt.
Electrical and Electronical Engineering	MA1, MA3	Opt.
Neuro-X minor	H	Opt.
Neuro-X	MA1, MA3	Opt.

Language of teaching	English
Credits	3
Session	Winter
Semester	Fall
Exam	Written
Workload	90h
Weeks	14
Hours	**3 weekly**
Courses	2 weekly
Exercises	1 weekly
Number of positions	

Summary

The course covers the fundaments of bioelectronics and integrated microelectronics for biomedical and implantable systems. Issues and trade-offs at the circuit and systems levels of invasive microelectronic systems as well as their eluding designs, methods and classical implementations are discussed

Content

Bioelectricity and bio-signals biopotentials, definition of selected bio-signals
Electrodes types of electrodes and integrated electrodes, characteristics and impact on the recording/driving circuits,neuron-semiconductor interface
Bio-signal recording low-noise amplifiers, architectures analysis, presentation of main design issues, low-powerlow-noise design techniques
Multichannel recording massively parallel recording techniques, examples of the cortical implants,compressed-sensing techniques
Electrical stimulation integrated circuits for electrical stimulation of tissues, specific issues related to operating voltage,charge balancing
In-vitro systems techniques for integrated recording in-vitro, stimulation
Neuromorphic integrated electronics usage of microelectronics to mimic neurons or higher-level functions,fundaments of microelectronic bio-inspired systems and applications in processing and vision
Application examples case studies of classical implanted systems, as well as prospective systems, including cochlearimplants, sight restoring retina implants, deep-brain stimulation systems, cortical recording systems (invasive), epilepsymanagement systems, bio-pills, multimodal systems

Keywords

Bio-electronics, bio-medical electronics, implantable microelectronic

Learning Prerequisites

Required courses

Electronics (fundaments, circuits and systems)

Learning Outcomes

By the end of the course, the student must be able to:

- Elaborate design strategies and method
- Elaborate specifications
- Analyze block level requirements
- Develop blocks, models

- Assess / Evaluate alternate existing method
- Elaborate design strategies and methods
- Elaborate specifications
- Analyze block level requirements
- Develop blocks, models
- Assess / Evaluate alternate existing method

Transversal skills

- Communicate effectively with professionals from other disciplines.
- Access and evaluate appropriate sources of information.
- Make an oral presentation.
- Write a literature review which assesses the state of the art.

Teaching methods

Ex cathedra and practical exercises, seminars

Expected student activities

Attend class lectures, solve exercises, study professional litterature and prepare a short report and short seminar on a selected topic

Assessment methods

Mandatory continusous control: written midterm
Mandatory continuous control: seminar and report
Mandatory final written examination

Resources

Bibliography

Will be reported in class

Moodle Link

- https://go.epfl.ch/EE-519

Prerequisite for

Diploma projects

BIOENG-399

Immunoengineering

Tang Li

Cursus	Sem.	Type
Biotechnology minor	E	Opt.
Computational and Quantitative Biology		Opt.
Life Sciences Engineering	BA6, MA2, MA4	Opt.
Materials Science and Engineering	MA2, MA4	Opt.

Language of teaching	English
Credits	4
Session	Summer
Semester	Spring
Exam	Written
Workload	120h
Weeks	14
Hours	**4 weekly**
Courses	2 weekly
Exercises	2 weekly
Number of positions	

Summary

Immunoengineering is an emerging field where engineering principles are grounded in immunology. This course provides students a broad overview of how engineering approaches can be utilized to study immunology, model immune systems, modulate immune response, and develop novel immunotherapies.

Content

Part 1. Understanding immunology with engineering tools
Introduction of the course and expectation
Overview of the fundamentals of immunology
Definition and scope of immunoengineering
Engineering tools and new technologies to understand immunology

Part 2. Engineering novel immunotherapies for diseases
Cancer and cancer immunotherapies
Concept and overview of drug delivery
Materials engineering in the advancement of immunotherapies
Immune cell engineering and genetic engineering
Metabolic engineering and immune modulation
Overview of adaptive immunity and vaccines
Design of immunogenic vaccines
Other vaccines
Protein engineering in vaccine design

Part 3. Applications and practical issues
Considerations on immune drug discovery and development

Keywords

immunology, immunoengineering, vaccines, infectious diseases, autoimmunity, cancer, materials engineering, drug delivery, protein engineering, drug discovery and development

Learning Prerequisites

Required courses

This class requires a basic knowledge in biology, physics, chemistry, and materials science.
BIO-310 Immunology or an equivalent is required

Learning Outcomes

By the end of the course, the student must be able to:

- Describe the concept of immunoengineering
- Make examples of how engineering approaches has led to advancements in immunotherapy
- Take into consideration how to apply engineering principles to immunology research and applications
- Specify 1. Understand how to apply engineering principles to immunology research and applications
- 2. Show examples of how engineering approaches has led to advancements in immunotherapy and diagnosis
- 3. Describe the discovery or development of new immunotherapies from recent scientific literatures

Transversal skills

- Write a scientific or technical report.
- Communicate effectively, being understood, including across different languages and cultures.
- Write a scientific or technical report.
- Communicate effectively with professionals from other disciplines.

Assessment methods

Scientific ssay writing: 30%
Final written exam: 70%

Supervision

Office hours	Yes
Assistants	Yes
Forum	Yes
Others	*Library resources* ***How the immune system works: Lauren Sompayrac. all versions*** *Kuby Immunology: Owen, Pung, Stranford.* ***all versions*** *Cellular and Molecular Immunology: Abbas & Lichtman.* ***all versions*** ***Janeway's immunobiology: Kenneth Murphy ; Charles A. Janeway ; Allan Mowat . all versions*** *Slides/Notes* will be provided on Moodle webpageq

Resources

Bibliography

Library resources (good to read, but not required)
How the immune system works: Lauren Sompayrac. all versions
Kuby Immunology*: Owen, Pung, Stranford.* ***all versions***
Cellular and Molecular Immunology*: Abbas & Lichtman.* ***all versions***
Janeway's immunobiology: Kenneth Murphy ; Charles A. Janeway ; Allan Mowat . all versions

Ressources en bibliothèque

- How the immune system works / Sompayrac
- Kuby Immunology / Pung
- Cellular and Molecular Immunology / Abbas
- Janeway's immunobiology / Murphy

Notes/Handbook

Slides/Notes will be provided on Moodle webpageq

Moodle Link

- https://go.epfl.ch/BIOENG-399

ME-231(b) **Structural mechanics for SV**

Fantner Georg

Cursus	Sem.	Type
Life Sciences Engineering	BA5, MA1, MA3	Opt.

Language of teaching	English
Credits	4
Session	Winter
Semester	Fall
Exam	Written
Workload	120h
Weeks	14
Hours	**4 weekly**
Courses	3 weekly
Exercises	1 weekly
Number of positions	

Summary

This course aims to provide a concise understanding of how materials and structures react to loads. It covers the basics of stress and strain in multi dimensions, deformation and failure criteria. The course is tailored to problems students from life science might encounter.

Content

- review of equilibrium ridged body mechanics
- strain & stress in one dimension
- strain & stress in higher dimensions
- stress concentrations
- torsion
- transformation of stress and strain
- stress and strain in beams (shear and bending moments)
- beam bending
- buckling

Learning Prerequisites

Important concepts to start the course

- Introduction to physics: mechanics (statics)
- vector and tensor math

Assessment methods

written exam

Resources

Moodle Link

- https://go.epfl.ch/ME-231_b

BIO-315

Structural biology

Dal Peraro Matteo

Cursus	Sem.	Type
Computational science and Engineering	MA2, MA4	Opt.
Computational science and engineering minor	E	Opt.
Life Sciences Engineering	MA2, MA4	Opt.
Minor in life sciences engineering	E	Opt.
Physics of living systems minor	E	Opt.

Language of teaching	English
Credits	4
Session	Summer
Semester	Spring
Exam	During the semester
Workload	120h
Weeks	14
Hours	**4 weekly**
Courses	2 weekly
Exercises	2 weekly
Number of positions	

Summary

The main focus of this course is on the molecular interactions defining the structure, dynamics and function of biological systems. The principal experimental and computational techniques used in structural biology, as well as molecular modeling and design will be introduced and practiced.

Content

The course will focus on the following topics:
1. Structure: intermolecular interactions, structure of biomolecules, experimental methods in structural biology (i.e., X-ray crystallography, NMR, cryo-electron microscopy), structural classification, protein structure prediction using genomic data and machine learning.
2. Dynamics: elements of statistical mechanics, molecular mechanics of biomolecules, molecular simulations, molecular binding and free energy calculations.
3. Selected topics: protein design and engineering; protein folding, molecular docking, integrative modeling; structure-based drug discovery, machine learning for structural biology.
Practicals and projects will run in parallel to lectures to have a first-hand experience on molecular visualization, major structural biology techniques, molecular modeling, protein design, biomolecular mechanics and dynamics, structure-based drug design, protein interaction networks, macromolecular assemblies, protein structure predictions using AlphaFold.

Keywords

Structural biology, X-ray crystallography, cryo-EM, NMR, AlphaFold, SAXS, integrative modeling, molecular modeling, molecular mechanics, molecular simulation, protein structure prediction, protein folding, protein design, drug discovery, machine learning.

Learning Prerequisites

Required courses

None in particular, but some are recommneded (see below)

Recommended courses

Basic bachelor courses on Maths, Physics, Molecular Biology and Biochemistry

Important concepts to start the course

Structural biology and biochemistry of biomoleculae. Classical mechanics, themodynamics, and electrostatics (Physics I, II, III), Organic Chemistry.

Learning Outcomes

By the end of the course, the student must be able to:

- Explore the structure of biomolecules (and their interactions)
- Predict the structure and dynamics of proteins
- Design the structure of proteins
- Visualize biomolecules
- Interpret structural data
- Choose the appropriate method to tackle a problem
- Design a project in structural biology
- Make a scientific report and presentation

Transversal skills

- Make an oral presentation.
- Write a scientific or technical report.
- Use a work methodology appropriate to the task.
- Demonstrate the capacity for critical thinking
- Use both general and domain specific IT resources and tools

Teaching methods

Half of the course is based on lectures, while in the other half practical experiences and projects (computational and experimental) are provided to the students.

Expected student activities

Attending lectures, completing practical experiences, reading assignments, presenting a scientific paper, developing a project, writing a report, presenting the results of a project

Assessment methods

Assignments and projects assessment during the semester

Supervision

Office hours	Yes
Assistants	Yes
Forum	Yes

Resources

Moodle Link

- https://go.epfl.ch/BIO-315

EE-511 **Sensors in medical instrumentation**

Chételat Olivier Pierre, Ionescu Anisoara

Cursus	Sem.	Type
Biomedical technologies minor	E	Opt.
Electrical and Electronical Engineering	MA2, MA4	Opt.
Life Sciences Engineering	MA2, MA4	Opt.
Mechanical engineering	MA2, MA4	Opt.
Microtechnics	MA2, MA4	Opt.
Neuro-X minor	E	Opt.
Neuro-X	MA2, MA4	Opt.
Robotics, Control and Intelligent Systems		Opt.
Robotics	MA2, MA4	Opt.

Language of teaching	English
Credits	3
Session	Summer
Semester	Spring
Exam	Written
Workload	90h
Weeks	14
Hours	**3 weekly**
Courses	2 weekly
Exercises	1 weekly
Number of positions	

Summary

Fundamental principles and methods used for physiological signal conditioning. Electrode, optical, resistive, capacitive, inductive, and piezoelectric sensor techniques used to detect and convert physiological information to electrical signals. Medical devices for physiological signal monitoring.

Content

1. Electrode sensors

- **Action potentials**
  Nernst equation, Hodgkin-Huxley model, action potential, voltage clamp
- **Biopotentials**
  ECG (electrocardiogram), EEG (electroencephalogram), ExG (other electrogram), ECGi (ECG imaging)
- **Bioimpedances**
  Impedance model, impedance plethysmography, impedance spectroscopy, EIT (electrical impedance tomography), PAP (pulmonary artery pressure)
- **Basic safety of ME equipment**
  Regulations, 60601-1, MOP, applied part and patient connections, leakage and auxiliary currents, defibrillator-proof
- **Electrodes**
  Electrode model, motion artefacts, noise, dry electrodes, potential and current electrodes
- **Metrology of biopotentials**
  EM interferences, shielding, neutral electrode, common mode, defibrillation and ESD protections
- **Metrology of bioimpedances**
  Bipolar and tetrapolar methods, bi-electrodes, AM, IQ demodulation, leakage, shielding

2. Optical sensors

- **Photo-plethysmography**
  PPG, oHRM, ambient light, volume clamp blood pressure, optical blood pressure, SpO2
- **NIRS (near infrared spectroscopy)**
  Basic NIRS, differential NIRS

3. Resistive sensors
Thermistor and its biomedical applications; strain gage for the measurement of blood pressure; force and accelerations of the body
4. Inductive sensors
Simple and mutual inductance and its medical applications
5. Capacitive sensors
Respiratory flow measurement by the gradient of pressure
6. Piezoelectric sensors
Force platform, accelerometer, angular rate sensor for the measurement of tremors and body movements, ultrasound

transducer : measurement of pressure and flow rate

Keywords

Sensors, instrumentation, medical devices, physiological signals, electronic circuits, metrology, monitoring

Learning Prerequisites

Required courses

basic signal and control theory, basic electronics (Kirchhoff, OPA, INA)

Recommended courses

systems, sensors, electronics

Important concepts to start the course

basic electronics, basic physics

Learning Outcomes

By the end of the course, the student must be able to:

- Choose techniques detecting and convert physiological information's to electrical signals
- Exploit fundamental principles and methods used for physiological signal conditioning
- Design measuring devices
- Interpret error, noise in biomedical measuring systems
- Work out / Determine what sensors to choose and how to place them to measure a given physiologica signal.
- Work out / Determine what electronic circuits to use.
- Dimension the electronic circuit.
- Analyze the sources of noise.

Transversal skills

- Use a work methodology appropriate to the task.
- Communicate effectively with professionals from other disciplines.
- Take account of the social and human dimensions of the engineering profession.

Teaching methods

Ex cathedra (including examples) with textbook and exercises

Expected student activities

read textbook, exercises, quizzes and problems

Assessment methods

three quizzes/problems sessions during semester (each worth 5%)
final written exam (worth 85%)

Supervision

Office hours	Yes
Assistants	Yes
Forum	Yes

Resources

Virtual desktop infrastructure (VDI)
No

Bibliography
Medical Instrumentation, application and design, Webster, 4th edition

Ressources en bibliothèque
- Medical Instrumentation, application and design, Webster, 5th edition

Notes/Handbook
Sensors in medical instrumentation (textbook)
Slides

Moodle Link
- https://go.epfl.ch/EE-511

Prerequisite for
Semester project and Master project

MICRO-507 **Legged robots**

Ijspeert Auke

Cursus	Sem.	Type
Mechanical engineering	MA1, MA3	Opt.
Microtechnics	MA1, MA3	Opt.
Robotics	MA1, MA3	Opt.

Language of teaching	English
Credits	4
Session	Winter
Semester	Fall
Exam	During the semester
Workload	120h
Weeks	14
Hours	**4 weekly**
Courses	2 weekly
Exercises	1 weekly
TP	1 weekly
Number of positions	

Summary

The course presents the design, control, and applications of legged robots. It gives a review of different types of legged robots (including two-, four- and multi-legged robots), and an analysis of different control methods for legged locomotion.

Content

The course presents the design, control, and applications of legged robots. It gives a review of different types of legged robots (including two-, four- and multi-legged robots), and analysis of different control methods for legged locomotion. It also trains students in making critical analysis of key articles in the field, and in designing their own models and locomotion controllers for legged robots in simulation.

CONTENT

- History of legged robotics, including two-, four-, and multi-legged robots
- Review of mechanical structures of legged robots, passive and dynamic walkers
- Background concepts: dynamic versus static stability, different stability criteria (e.g. Zero-Moment Point ZMP, capturability, ...), energy consumption, cost of transport (COT), state estimation.
- Simple models of locomotion: rimless wheel, inverted pendulums, linear inverted pendulum (LIP), spring-loaded inverted pendulum (SLIP), template versus anchor models
- Analysis of different control approaches: trajectory-based methods, virtual leg control, virtual model control, hybrid-zero dynamics, optimal control, planning approaches, approaches based on reinforcement learning, and bioinspired approaches.
- Critical literature review and presentation: Students will read several important articles in the field, and present them to the class.
- Numerical exercises: The course will also involve numerical exercises in which students will develop their own controllers for simulated legged robots (with weekly sessions with assistants and the professor).

Keywords

Legged robots, control of locomotion

Learning Prerequisites

Required courses

Recommended courses

- Mobile robots
- Model predictive control

Learning Outcomes

By the end of the course, the student must be able to:

- Identify a suitable type of legged robot for a given application
- Argue about the validity of existing controllers from the literature
- Design their own controllers
- Test the controllers in simulation
- Assess / Evaluate the controllers performance and limits

Transversal skills

- Plan and carry out activities in a way which makes optimal use of available time and other resources.
- Access and evaluate appropriate sources of information.

Teaching methods

Lectures, reading articles, presentations, and numerical exercises

Expected student activities

- Attending weekly lectures
- Read and present scientific articles
- Develop locomotion controllers for simulated legged robots
- Present and analyse results in a report or a presentation

Assessment methods

Presentation of scientific articles (20%), report for the numerical exercises (50%), written exam (30%). Work for the presentations and the numerical exercises will be done by groups of 3 students. The written exam is taken individually.

Supervision

Office hours	No
Assistants	Yes
Forum	Yes

Resources

Bibliography

- Articles selected from the recent literature and presented / analysed in the class

Moodle Link

- https://go.epfl.ch/MICRO-507

EPFL

CS-432

Computational motor control

Ijspeert Auke

Cursus	Sem.	Type
Computational and Quantitative Biology		Obl.
Computational biology minor	E	Opt.
Life Sciences Engineering	MA2, MA4	Opt.
Mechanical engineering	MA2, MA4	Opt.
Microtechnics	MA2, MA4	Opt.
Neuro-X minor	E	Opt.
Neuro-X	MA2, MA4	Opt.
Robotics, Control and Intelligent Systems		Opt.
Robotics	MA2, MA4	Opt.

Language of teaching	English
Credits	4
Session	Summer
Semester	Spring
Exam	Written
Workload	120h
Weeks	14
Hours	**4 weekly**
Courses	2 weekly
Exercises	2 weekly
Number of positions	

Summary

The course gives (1) a review of different types of numerical models of control of locomotion and movement in animals, from fish to humans, (2) a presentation of different techniques for designing models, and (3) an analysis of the use and testing of those models in robotics and neuroprosthetics.

Content

• General concepts: Importance of numerical models in a scientific approach, introduction to nonlinear dynamical systems and neural network models.

• Numerical models of motor systems : Neural network models of control of locomotion, rhythm generation in central pattern generators, reflexes, force fields, sensory-motor coordination, and balance control.

• Numerical models of the musculo-skeletal system: muscle models, biomechanical models of locomotion, gait classification, applications to bio-inspired robots.

• Numerical models of arm movements: invariants of human arm movements, different hypotheses about human motor control: inverse models and equilibrium point hypothesis. Muscle synergies.

• Numerical models of sensory systems : Proprioception and vestibular system. Visual processing in the retina, salamander and primate visual systems, applications to machine vision.

• Neuroprosthetics: short overview of current developments, analysis of how modeling can be used to improve interfaces between machines and the central nervous system

• Numerical exercises: The course will also involve numerical exercises in which students will develop their own numerical simulations of sensory-motor systems in Python and in a dynamical robot simulator (with weekly sessions with assistants and the professor).

Keywords

Numerical models of animal motor control, locomotion, biomechanics, neural control of movement, numerical models

Learning Prerequisites

Required courses

None

Recommended courses

None

Important concepts to start the course

Programming in Python, good mathematical background (dynamical systems)

Learning Outcomes

By the end of the course, the student must be able to:

- Argue about the validity of models
- Formulate models of motor control
- Hypothesize mechanisms of motor control
- Design models of motor control
- Test the models

Transversal skills

- Write a scientific or technical report.
- Access and evaluate appropriate sources of information.

Teaching methods

Lectures and numerical exercises on a computer using Python and FARMS, a dynamic simulator of animals and robots (with weekly sessions with assistants and the professor)

Expected student activities

- Attending lectures
- Read scientific articles
- Develop numerical models of the locomotor control circuits of a simulated animal in Python and FARMS
- Writting short scientific reports describing the models and analyzing the results of the simulations

Assessment methods

60% of the grade comes from the modeling projects (by groups of 3 students), and 40% comes from a written exam during the semester.

Resources

Moodle Link

- https://go.epfl.ch/CS-432

EPFL

BIO-503 **Lab immersion III**

Profs divers *

Cursus	Sem.	Type
Life Sciences Engineering	MA1, MA2, MA3, MA4	Opt.

Language of teaching	English
Credits	12
Withdrawal	Unauthorized
Session	Winter, Summer
Semester	Fall
Exam	During the semester
Workload	360h
Weeks	14
Hours	**12 weekly**
Project	12 weekly
Number of positions	

Il n'est pas autorisé de se retirer de cette matière après le délai d'inscription.

Summary

Engaging in a hands-on wetlab and/ or computational project in life sciences engineering, students develop skills in experimentation and data analysis.

Content

The research project is carried out in an EPFL laboratory in the School of Life Sciences (SV) or, with section approval, in another school.
Projects are available on the website of SV labs or discussed with the supervising professor/ head of laboratory:

- Brain Mind Institute (BMI)
- Global Health Institute (GHI)
- Institute of Bioengineering (IBI)
- Neuro-X Institute
- Swiss Institute for Experimental Cancer Research (ISREC)
- Research Core Facilities
- MAKE Interdisciplinary Projects

The project can be carried out part-time during the semester (approximately 24h/ week during 14 weeks) or full time between two semesters (approximately 42h/ week during 8 weeks).

Learning Outcomes

By the end of the course, the student must be able to:

- Conduct experiments relevant to the specific problem
- Implement appropriate technologies to address the scientific problem
- Optimize Optimize experimental protocols
- Develop expertise in a specific research area
- Analyze and interpret data from wetlab and computational experiments
- Plan experiments to test hypotheses based on results
- Manage an individual research project

Transversal skills

- Use a work methodology appropriate to the task.
- Plan and carry out activities in a way which makes optimal use of available time and other resources.
- Assess progress against the plan, and adapt the plan as appropriate.
- Continue to work through difficulties or initial failure to find optimal solutions.
- Demonstrate the capacity for critical thinking
- Keep appropriate documentation for group meetings.
- Make an oral presentation.
- Write a scientific or technical report.

Assessment methods

Written report and/ or oral presentation

The assessment method(s), and if applicable weighting of the different parts, must be defined with the supervising professor/ head of laboratory in advance.

Assessment deadline

- Autumn semester: Friday of the second week after the end of classes
- Spring semester: Friday of the first week after the end of classes
- Exceptions must be agreed upon by the student and the supervising professor

Resources

Websites

- https://www.epfl.ch/schools/sv/education/master-in-life-sciences-engineering/lab-immersion/