FALL TERM

EMERGING BIOMEDICAL TECHNOLOGIES

Polytechnique has become a hub of biomedical engineering activity, supported by an internationally recognized translational institute, TransMedTech, established academic programs at the undergraduate and graduate levels, a research alliance with Montréal hospital networks, and a critical mass of researchers. This cluster targets students looking to learn about and take part in emerging-technology development in the field of biomedical engineering. This cluster is highly recommended for students enrolled in their final years of a biomedical, computer, electrical, mechanical or physics engineering program.

Students must take 12 to 15 credits among the following :

GBM6700E // 3D Reconstruction from Medical Images (3 cr.)

3D reconstruction systems from medical images. Passive vision systems: cameras and X-ray systems calibration, stereo-matching, geometric features, intensity-based features, Epipolar geometry, 3D reconstruction, multimodal medical image fusion. 3D reconstruction from image sequences: self-calibration, features tracking, 3D reconstruction from motion, shading and texture. Active vision systems: interferometry principle, active triangulation, 3D surface registration, rigid registraion, elastic registration, texture mapping. Application: 3D reconstruction of anatomical structures from medical images.

Prerequisites: Biomedical imaging, signal processing.

GBM8810E // Biomedical Nanotechnologies (3 cr.)

Physical concepts of nanotechnology. Fabrication and functionalization of nanomaterials. Bionanoplasmonics: concept of plasmons, Mie theory, nanophotothermy and therapeutic applications. Optical nanobiosensors: Theory and application of plasmonics. Biomedical nanophotonics: quantum dots, optical tweezers and laser nanosurgery. Biomedical nanomagnetism: properties of magnetic nanomaterials and applications in biosensing and therapy. Ethics and social issues of nanotechnologies in biomedical.

Prerequisites: Notions of optics, quantum mechanics, thermodynamics.

GBM6330E // Emerging Biomedical Technologies (3 cr.)

Selected topics in biomedical instrumentation. Study of emerging measurement, monitoring, diagnosis and intervention systems in medicine. Case studies of five emerging technologies that will transform biomedical practice in the short to medium term. Presentations by the professor and external experts. Assessment and critique of scientific articles by students. Writing a review articles.

Prerequisites: Background courses in biomedical engineering.

SL303E // Research Internship or Final Project (3 cr.)
SL306E // Research Internship or Final Project (6 cr.)

Exchange students can pursue a research internship in one of Polytechnique laboratories. These serve as introduction to research through the execution of a project in a research environment.

French Language Course (3 cr.)

Exchange students have access to the Université de Montréal credited French language course offer and will receive by email several weeks before the beginning of classes the detailed application procedure. For more information regarding the French as a second language course offer *click here*.

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For more information: *point@polymtl.ca* // 514 340-4975

POLYMTL.CA/INTERNATIONAL

The above courses offer may vary slightly from year to year.

POLYTECHNIQUE MONTRÉAL
TECHNOLOGICAL UNIVERSITY

CODE

GBM6700E

COURSE SYLLABUS

NAME	HOURS/WEEK (in class / practical work / individual work)	CREDITS
3D reconstruction from medical images	3 / 1,5 / 4,5	3
PREREQUISITES	**COREQUISITES**	**SEMESTER**
80 credits		☐ W ☐ S ☒ Fall

COURSE DESCRIPTION

3D reconstruction systems from multimodal medical images. Passive vision systems: camera calibration, X-rays systems calibration, stereo matching, epipolar geometry, geometry-based primitives, intensity-based primitives, primitives matching using classifiers. Medical image registration. 3D reconstruction from image sequences: self-calibration, primitive temporal tracking, 3D structure from motion, shading and texture. Active vision systems: interferometry approach, active triangulation, 3D surface registration, elastic registration, texture mapping. Applications on 3D reconstruction of anatomical structures from medical images.

SPECIFIC OBJECTIVES OF THE COURSE

- Understand the algorithmic aspects of 3D reconstruction systems;
- Identify the different components of 3D reconstruction systems from medical images;
- Analyze the performance of different 3D reconstruction systems

SPECIFIC OBJECTIVES OF THE PRACTICAL SESSIONS

- Implement calibration algorithms of X-ray acquisition systems;
- Evaluate the precision of 3D reconstruction algorithms for different configurations of the acquisition system;
- Analyze the impact of digitization errors on the 3D reconstruction results.

COURSE STRUCTURE (CONTENT AND HOURS)

Subjects	Hours
Presentation of the syllabus	1
Introduction to 3D reconstruction systems	2
Passive vision systems - Camera calibration - X-rays system calibration - Stereo-matching - Epipolar geometry - 3D Reconstruction - Medical image registration - Application: 3D reconstruction of bone structures from biplanar X-rays	12
3D reconstruction from image sequences - Self-calibration - Temporal tracking - Structure from motion - Structure from shading - Structure from texture - Application: Self-calibration of endoscopic images in minimal invasive surgeries	12
Active vision systems - Interferometry approach - Active triangulation - 3D surface registration - Texture mapping - Fusion of multimodal images - Physical modeling of anatomical structures - Application: Simulation of the postoperative shape of the human trunk	12
	Total: 39 h

REFERENCES

There is no required textbook. Lecture notes and other relevant material will be available on the course website: moodle.polymtl.ca/gbm6700E

Textbooks describing parts of the material that we will cover:

- Multiple View Geometry in computer vision, Richard Hartley and Andrew Zisserman, second edition, Cambridge University Press, 2003.
- Image Processing, Analysis, and Machine Vision, Milan Sonka, Vaclav Hlavac & Roger Boyle, third edition, Thomson 2008.
- Computer Vision: A Modern Approach, D. A. Forsyth & J. Ponce, Prentice Hall 2003.

ASSESSMENT METHODS

Nature	Individual	In a group	Number	Weight
Homework *2 pratical assignements* *1 Individual project (project description, oral presentation and a report)*	☒	☐	3	100 %
Period testing	☐	☐		
Oral presentations	☐	☐		
Final exam	☐	☐		
	Individual: 100 %	**In a group: 0 %**		**Total: 100 %**

POLYTECHNIQUE MONTRÉAL
TECHNOLOGICAL UNIVERSITY

CODE

GBM8810E

COURSE SYLLABUS

NAME	HOURS/WEEK (in class / practical work / individual work)	CREDITS
Biomedical Nanotechnologies	3 / 1 / 5	3
PREREQUISITES	**COREQUISITES**	**SEMESTER**
70 credits	None	☐ W ☐ S ☒ Fall

COURSE DESCRIPTION

Physical concepts nanotechnology and applications in the biomedical realm. Different approaches to nanotechnology: Fabrication and functionalization of metallic and semiconductor nanomaterials used in biomedical applications. Functionalization bioplasmonics: concept of plasmon, Mie theory, nanophotothermy and therapeutic applications. Optical nano-sensors: theory and application of plasmonics, biosensors based on surface plasmon resonance. Biomedical nanophotonics: quantum dots, laser nano-surgery. Biomedical nano-magnetism: properties of magnetic nanomaterials and applications in biodetection, imaging and therapy. Ethics and social impact of biomedical nanotechnologies.

COURSE AND LABORATORY OBJECTIVES

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

- discuss the specifics and the various approaches to nanotechnology, particularly those associated with the biomedical field;
- discuss the various techniques for manufacturing and functionalizing nanomaterials used in the biomedical field; know which one is most appropriate for a particular biomedical application;
- describe the optical and magnetic properties of nanomaterials and discuss the principles of their applications in biosensing/biodetection and therapy;
- know how to choose which type or set of optical and magnetic nanomaterials is most appropriate for a particular biomedical application;
- solve theoretical, analytical, and numeric/digital problems involving optical and magnetic nanomaterials in a particular biomedical application;
- describe the operating principles of various types of optical and electronic nanobiosensors;
- know which type of nanobiosensor is most appropriate for a particular biomedical application;
- solve theoretical, analytical, and numeric/digital problems involving biosensors;
- discuss the ethical and social challenges of biomedical nanotechnology.

Specific objectives of practical work:

During hands-on sessions led by the professor or teaching assistant, problems brought forth by students will enable them to achieve the objectives described in the previous section.

COURSE STRUCTURE (CONTENT AND HOURS) – 1st SECTION

Subjects	Hours
Introduction to nanotechnology	3
Class plan Historical aspects of the development of nanotechnology. Orders of magnitude (mass). Convergence of fields (chemistry, physics, and biology). New phenomena at the nanoscale. Various fields of nanotechnology for biomedical use: nanomaterials, nanobiosensors/detectors, nanophotonics, and nanomagnetism	
Manufacturing of nanomaterials for biomedical uses	5
Various types of nanomaterials and an overview of applications for biomedical use. Development and growth of nanoparticles. Chemical (chemical reduction, sonochemistry, electrochemistry, photoreduction) and physical (laser ablation) synthesis methods of metallic and semiconductor nanomaterials. Functionalization of nanomaterials, cytotoxicity of nanomaterials	
Biomedical Nanoplasmonics	9
Reminder of the permittivity and optical properties of metals; the concept of plasmon; dipolar approximation of nanospheres; Mie theory, localized plasmons in plasmonic nanostructures (nanospheres, nanobatons, etc.). Biomedical applications: nanophotothermia; cancer treatment, molecular probes, imaging, SERS (Surface Enhanced Raman Spectroscopy).	
Nanobiosensors	6
Theory and applications of surface plasmons, local amplification of surface plasmons, nanoplasmonics; coupling and excitation; surface plasmon propagation; phase detection; optical design of SPR (Surface plasmon Resonance) biosensors	
Test	2
Nanophotonics in biomedical usage	4
Optical properties of quantum dots and applications in imaging; near-field microscopy; optical tweezers of biological elements; laser nanosurgery, PDT.	
Biomedical Nanomagnetism	4
Review of magnetism in the materials, and the magnetic properties of nanomaterials; applications of magnetic nanoparticles in the biomedical field: hyperthermia, imaging, magnetic separation.	
Ethics and social challenges of biomedical nanotechnology use	2
Student Presentations	4
Note: There will be approximately 2-3 visiting researchers during the semester who will give one-to-two-hour presentations on one of the hot topics in the field of biomedical nanotechnology	
Total	**39 h**

STRUCTURE OF PRACTICAL WORK (CONTENT AND HOURS) – 2nd SECTION

Subjects	Hours
Introduction to nanotechnology	1
Manufacturing of nanomaterials for biomedical uses	1
Biomedical Nanoplasmonics	3
Nanobiosensors	2
Biomedical Nanophotonics	2
Biomedical Nanomagnetism	1
Ethics and social challenges of biomedical nanotechnology use	1
Student Presentations	2
Total	**13 h**

ASSESSMENT METHODS

Nature	Individual	In a group	Number	Weight
Homework	☒	☐	10	25 %
Period testing	☒	☐	1	20 %
Oral presentations *Oral presentations will be made in a team of two students, and will cover a topic related to the course and approved by the professor*	☐	☒	1	20 %
Final exam	☒	☐	1	35 %
	Individual: 80 %	**In a group: 20 %**		**Total: 100 %**

POLYTECHNIQUE MONTRÉAL

TECHNOLOGICAL UNIVERSITY

CODE

GBM6330E

COURSE SYLLABUS

NAME	HOURS/WEEK (in class / practical work / individual work)	CREDITS
Emerging biomedical technologies	3 / 0 / 6	3
PREREQUISITES	**COREQUISITES**	**SEMESTER**
None	None	☐ W ☐ S ☒ Fall

COURSE DESCRIPTION

Students learn about emerging biomedical technologies through reading research articles and talking to the people behind them. Every two weeks a different topic is covered that has the potential to transform biomedical research and advance human health. Lectures are given by the professor and external experts in the fields of imaging, genetics, prosthetics, big data and artificial intelligence. Students are expected to produce written and multi-media summaries of research articles. The final project consists of an interview with a biomedical researcher that will be published on the course website (https://gbm6330.edublogs.org/).

COURSE AND LABORATORY OBJECTIVES

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

- identify issues related to the implementation of emerging biomedical technologies;
- explain the functioning of six emerging biotechnologies introduced in class, and describe the benefits and transformational aspects of their implementation in hospital environments;
- assess new biomedical instrumentation technology in an independent and critical fashion;
- write a review-style journal article in the field of biomedical instrumentation.

GENERAL COURSE OBJECTIVES

This course will provide cutting-edge training in biomedical instrumentation, emphasizing emerging technologies. The main objective is to help train students who will lead careers in biomedical engineering or technological development for biomedical applications. The process of innovation, innovative instrument approval, barriers to entry, and evaluation of patient benefit will be reviewed through 6 case studies. Topics chosen will be drawn from current promising scientific developments, and will vary over the years, keeping content closely associated to emerging innovations. The course begins with a 3-hour session dedicated to the evaluation, transfer, and implementation of new biomedical technologies.

A secondary course objective is to develop graduate students' ability to read scientific literature and question the underlying assumptions of the work, assess the potential and limitations of a new technology, and understand the impact of a discovery on the evolution of biomedical practice. To achieve this objective, a mixed approach is recommended: for each of the subjects covered, a lecture based on 2-3 articles addressing the technology will be given during the first portion of the class. In subsequent portions, an additional specific article will be evaluated in detail in the form of a case study. During this time period, each student will produce a one-page summary of the article studied. In addition, a sub-group of students will be appointed in each class to act as community readers for the class, and they will give an oral presentation of their evaluations, criticisms, and perspectives of the work(s) studied. Where possible, case studies will be supported by an expert in the field. Lastly, each student must complete a written work in the form of a review-style journal article on a subject other than those covered in class.

This approach will enable students to:

- develop a habit of scientific reading and of the synthesis of critical work (writing of abstracts);
- develop the ability to summarize and orally describe complex work in all its details by reading the work and its precursors (community readers);
- independently study of a new technology in detail and write a written scientific description of its evaluation based on a literature review.

COURSE STRUCTURE (CONTENT AND HOURS) – 1st SECTION

Subjects	Hours
From innovation to implementation: phases of development, regulatory organizations, barriers to entry, safety standards, evaluation of new technologies	4
Microfluidics and high flow sensors: principles and applications	3
Personalized assessment of cancer therapies in tissue biopsies using microfluids and high-flow sensors	3
DNA sequencing: techniques and instrumentation	3
Medical applications and perspectives in DA sequencing	3
Ultra-fast ultrasound imaging: characterization of healthy and diseased tissue using elastography	3
Functional imaging of the brain and contractile activity of the heart using ultrafast 3h ultrasound imaging	3
Diffusion tensor imaging: principles and applications	3
The connectome and techniques to elucidate the functional links of the brain using diffusion tensor imaging	3
Contrast agents and therapeutic particles: from imaging to therapy	3
Photodynamic therapy with contrast agents and therapeutic particles	3
Telemedicine: introduction, needs and prospects, aging of the population, costs, prevention; challenges in terms of at-home patient monitoring and telemedicine; integration into patient files	3
Remote measurements and telemetry at home: ECG, temperature, falls, breathing, stresses, systems microelectromechanics	3
Total :	**39 h**

ASSESSMENT METHODS

Nature	Individual	In a group	Number	Weight
Homework *One-page article summaries - case studies (individual)*	☒	☐	6	30 %
Oral presentations *Oral presentation (critique) during a case study session (individual)*	☒	☐	1	30 %
Project(s) *Article review (individual)*	☒	☐	1	40 %

**Brief project(s) description:*

All works are to be completed individually. Review-style journal must be about a subject that has not been discussed in class. Subject selected by students at the beginning of the session, with the professor's approval. Student assessment during the oral presentation of the article (case studies portion) will be based on: clarity of the abstract; objective criticism of the reading; demonstrated comprehension of the subject via answering peers' and professor's, and guest's questions. Article summaries for each subject will be evaluated according to the same criteria.

Individual: 100 % **In a group: 0 %** **Total: 100 %**