



**Carleton**  
UNIVERSITY

Department of  
**Systems and**  
**Computer Engineering**

## **SYSC 4906** **Surgical Robotics**

### **Calendar description**

Surgical robotic system architecture, forward and inverse kinematics of articulated robot arms, force and position control, unilateral and bilateral teleoperation of surgical robots, haptics and force feedback, instrumentation, image-guided surgery, design and implementation of a robotic system for minimally invasive surgery. Includes laboratory activities with ultra-precise state-of-the-art arm robot arms and haptic devices.

<http://calendar.carleton.ca/undergrad/courses/SYSC/>

### **Prerequisites**

SYSC 3610 or SYSC 3600

### **Prior knowledge**

Students are expected to:

- Have strong analytical skills, including working with applied linear algebra and differential equations.
- Be able to program in Matlab and/or Simulink.
- Understand basic matrix operations and control system architectures.
- Be willing to work independently on an open-ended design project.

A biomedical engineering background is not required.

### **Course objectives**

This project-based course will introduce students to various aspects of robotic systems used in minimally invasive surgery. The course consists of lectures, interactive simulation of robotic systems in Matlab, hands-on laboratory exercises, and a design project. Students will acquire an understanding of surgical robotics, teleoperation, and other technologies that are relevant to research and clinical applications of surgery. The laboratory activities will enable student to experience the complexity of robotic-assisted minimally invasive surgery, implement and validate different teleoperation schemes, and work on an open-ended design project involving ultra-precise robotic arms and haptic devices.

### **List of topics**

- Introduction to medical robotics;
- Frame transformations;

- Euler angles;
- Forward kinematics of articulated robotic systems;
- Inverse kinematics of articulated robotic systems;
- The Denavit-Hartenberg convention;
- Differential motion and force;
- Trajectory generation;
- Jacobian and its use in robotics;
- Position and force control;
- Gradient decent and Newton-Raphson optimization;
- Differential inverse kinematics;
- Laparoscopic surgery;
- Teleoperation of surgical robots;
- Teleoperation transparency and stability;
- Haptics and force feedback;
- Collaborative human-robot operation;
- Force fields and impedance control;
- Instrumentation for robotic surgery;
- Image-guided surgery;
- Design project: Implementation of a teleoperated surgical robotic system as part of laboratory activities;
- Applications to surgical robotics throughout the course.
- Design project demonstration and presentation.

## **Learning outcomes**

By the end of this course, students should be able to:

- Demonstrate understanding of forward and inverse kinematics of robots.
- Demonstrate understanding of differential motion and trajectory generation.
- Simulate a robotic system in Matlab.
- Demonstrate a theoretical and practical understanding of differential motion, Jacobian, optimization algorithms, and force and position control of surgical robots.
- Conceptualize different teleoperation schemes used to control a robot arm with and without force feedback.
- Propose and execute an open-ended design project involving a robotic arm, force sensors, cameras, and haptic devices.

## **Graduate Attributes (GAs)**

The Canadian Engineering Accreditation Board requires graduates of engineering programs to possess 12 attributes at the time of graduation. There are no GA's related to this course. For more information, please visit: <https://engineerscanada.ca/>.

## **Special Information for Pandemic Measures**

Carleton has paused its mandatory mask mandate as of June 25, 2022. Even though masks will no longer be mandatory, **we continue to strongly recommend masking when indoors**, particularly if physical distancing cannot be maintained.

Please note that as health care facilities, **Health and Counselling Services and the Sports Medicine Clinic will continue to require masks** at this time.

As more public health measures are lifted, it is important to remember that COVID is still present in Ottawa. You can reduce your risk by:

- Stay home if sick and [report symptoms](#)
- Wash your hands or use hand sanitizer
- Keep up-to-date with vaccinations
- Wear a mask (recommended)
- Maintain physical distancing where possible

In addition, please continue to follow [Ottawa Public Health](#), [Public Health Ontario](#), the [Government of Ontario](#), and the [Public Health Agency of Canada](#) for the latest information about COVID-19 and recommendations for prevention.

View the [Carleton University COVID-19 Safety Plan \(PDF, 237 KB\)](#) and the [Carleton University Continuity of Education Plan \(PDF, 246 KB\)](#) as required by the Government of Ontario.

### **Instructor and TA contact**

Specific to course offering (tbd)

### **Textbook (or other resources)**

Specific to course offering (tbd)

### **Evaluation and grading scheme**

Specific to course offering (tbd)

### **Breakdown of course requirements**

Specific to course offering (tbd)

### **Tentative week-by-week breakdown**

Specific to course offering (tbd)

### **Important Information**

Specific to course offering (tbd) |

## **General regulations**

**Attendance:** Students are expected to attend all lectures and lab periods. The University requires students to have a conflict-free timetable. For more information, see the current *Undergraduate Calendar, Academic Regulations of the University, Section 2.1.3, Course Selection and Registration* and *Section 2.1.7, Deregistration*.

**Health and Safety:** Every student should have a copy of our Health and Safety Manual. A PDF copy of this manual is available online: <http://sce.carleton.ca/courses/health-and-safety.pdf>

**Deferred Term Work:** Students who claim illness, injury or other extraordinary circumstances beyond their control as a reason for missed term work are held responsible for immediately informing the instructor concerned and for making alternate arrangements with the instructor and in all cases, this must occur no later than three (3.0) working days after the term work was due. The alternate arrangement must be made before the last day of classes in the term as published in the academic schedule.

Instructors may, at their discretion, require students to provide medical documentation to support requests for accommodation for missed course work including exams and assignments. As per the Provost's message of August 27, 2021, for the Fall 2021 term, students have been instructed to complete the Medical Self-Declaration form available on the Registrar's Office website rather than seeking to obtain a doctor's note or medical certificate. Instructions for the Winter 2022 term will be communicated by the Provost's office.

For more information, see the current *Undergraduate Calendar, Academic Regulations of the University, Section 4.4, Deferred Term Work*.

**Appeal of Grades:** The processes for dealing with questions or concerns regarding grades assigned during the term and final grades is described in the *Undergraduate Calendar, Academic Regulations of the University, Section 3.3.4, Informal Appeal of Grade* and *Section 3.3.5 Formal Appeal of Grade*.

**Academic Integrity:** Students should be aware of their obligations with regards to academic integrity. Please review the information about academic integrity at: <https://carleton.ca/registrar/academic-integrity/>. This site also contains a link to the complete Academic Integrity Policy that was approved by the University's Senate.

**Plagiarism:** The University Academic Integrity Policy defines plagiarism as “*presenting, whether intentionally or not, the ideas, expression of ideas or work of others as one’s own.*” This includes reproducing or paraphrasing portions of someone else’s published or unpublished material, regardless of the source, and presenting these as one’s own without proper citation or reference to the original source. Examples of sources from which the ideas, expressions of ideas or works of others may be drawn from include but are not limited to: books, articles, papers, literary compositions and phrases,

performance compositions, chemical compounds, artworks, laboratory reports, research results, calculations and the results of calculations, diagrams, constructions, computer reports, computer code/software, material on the internet and/or conversations.

Examples of plagiarism include, but are not limited to:

- any submission prepared in whole or in part, by someone else;
- using ideas or direct, verbatim quotations, paraphrased material, algorithms, formulae, scientific or mathematical concepts, or ideas without appropriate acknowledgment in any academic assignment;
- using another's data or research findings without appropriate acknowledgement;
- submitting a computer program developed in whole or in part by someone else, with or without modifications, as one's own; and
- failing to acknowledge sources through the use of proper citations when using another's work and/or failing to use quotations marks.

**Academic Accommodation:** You may need special arrangements to meet your academic obligations during the term. You can visit the Equity Services website to view the policies and to obtain more detailed information on academic accommodation at <http://www.carleton.ca/equity/> For an accommodation request, the processes are as follows:

- **Pregnancy or Religious obligation:** Please contact your instructor with any requests for academic accommodation during the first two weeks of class, or as soon as possible after the need for accommodation is known to exist. For more details see <https://carleton.ca/equity/wp-content/uploads/Student-Guide-to-Academic-Accommodation.pdf>  
For accommodation regarding a formally-scheduled final exam, you must complete the Pregnancy Accommodation Form.  
<https://carleton.ca/equity/contact/form-pregnancy-accommodation/>
- **Academic Accommodations for Students with Disabilities:** The Paul Menton Centre for Students with Disabilities (PMC) provides services to students with Learning Disabilities (LD), psychiatric/mental health disabilities, Attention Deficit Hyperactivity Disorder (ADHD), Autism Spectrum Disorders (ASD), chronic medical conditions, and impairments in mobility, hearing, and vision. If you have a disability requiring academic accommodations in this course, please contact PMC at 613-520-6608 or [pmc@carleton.ca](mailto:pmc@carleton.ca) for a formal evaluation. If you are already registered with the PMC, contact your PMC coordinator to send me your **Letter of Accommodation** at the beginning of the term, and no later than two weeks before the first in-class scheduled test or exam requiring accommodation (*if applicable*). **Requests made within two weeks will be reviewed on a case-by-case basis.** After requesting accommodation from PMC, meet with me to ensure accommodation arrangements are made. Please consult the PMC website ([www.carleton.ca/pmc](http://www.carleton.ca/pmc)) for the deadline to request accommodations for the formally-scheduled exam (*if applicable*).

- **Survivors of Sexual Violence:** As a community, Carleton University is committed to maintaining a positive learning, working and living environment where sexual violence will not be tolerated, and where survivors are supported through academic accommodations as per Carleton's Sexual Violence Policy. For more information about the services available at the university and to obtain information about sexual violence and/or support, visit: <https://carleton.ca/sexual-violence-support/>.
- **Accommodation for Student Activities:** Carleton University recognizes the substantial benefits, both to the individual student and for the university, that result from a student participating in activities beyond the classroom experience. Reasonable accommodation must be provided to students who compete or perform at the national or international level. Please contact your instructor with any requests for academic accommodation during the first two weeks of class, or as soon as possible after the need for accommodation is known to exist. For more details, see <https://carleton.ca/senate/wp-content/uploads/Accommodation-for-Student-Activities-1.pdf>

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