Western University
Faculty of Engineering
Mechatronic Systems Engineering Program

MSE 4401A—Robotic Manipulators
Course Outline 2019-20

Description: This course presents an overview of serial rigid-link robotic manipulators and the theory behind modelling, planning and control of such manipulators. It includes topics in robot kinematics and dynamics, differential kinematics, path and trajectory planning and control. The material will be presented in a combination of lectures, assignments and laboratory work.

Instructor: Dr. R.V. Patel, PhD, PEng
TEB379, 519-661-2111 ext. 84263 rvpatel@uwo.ca
Office hours: To be determined.

Academic Calendar Copy: Introduces the basic principles and techniques involved in modelling, simulating and controlling serial rigid-link manipulators, including such topics as forward and inverse kinematics, manipulator dynamics and control.

Contact Hours: 3 lecture hours, 3 laboratory hours, 0.5 course.

Prerequisites: MSE 3302A/B.

Pre or corequisite: MSE 3381A/B or MME 3381A/B.

Restricted to students enrolled in the Mechatronic Systems Engineering program.

Unless you have either the requisites for this course or written special permission from your Dean to enroll in it, you will be removed from this course and it will be deleted from your record. This decision may not be appealed. You will receive no adjustment to your fees in the event that you are dropped from a course for failing to have the necessary prerequisites.

CEAB Academic Units: Engineering Science 100%, Engineering Design 0%.


Required Software: MATLAB and Simulink

Recommended References: if applicable, other recommended readings will be made available through OWL.
General Learning Objectives (CEAB Graduate Attributes)

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Notation: x represents the content level code as defined by the CEAB. blank = not applicable; I = introduced (introductory); D = developed (intermediate) and A = applied (advanced).

Topics and Specific Learning Objectives

1. **Introduction to Robotics, Spatial Descriptions and Transformations**
   
   At the end of this section, students will be able to:
   
   a. Distinguish which mechatronic devices can be considered robots.
   b. Describe the characteristics, types and uses of various robotic manipulators.
   c. Mathematical tools for describing robotic manipulators.

2. **Forward and Inverse Kinematics**
   
   At the end of this section, students will be able to:
   
   a. Compute the forward kinematics of rigid-link serial manipulators.
   b. Compute the inverse kinematics of rigid-link serial manipulators using algebraic and geometric approaches.

3. **Jacobians: Velocities and Static Forces**
   
   At the end of this section, students will be able to:
   
   a. Calculate the Jacobian matrix of rigid-link serial manipulators and understand the relationship between joint and end-effector velocities and static forces.
   b. Identify the location of kinematic singularities and characterize manipulability.

4. **Manipulator Dynamics**
   
   At the end of this section, students will be able to:
   
   Develop techniques and computational algorithms for obtaining the dynamic behaviour of rigid-link robot manipulators.

5. **Trajectory Generation**
   
   At the end of this section, students will be able to:
   
   a. Understand the issues involved in planning robot motions.
   b. Implement algorithms for computing joint and end-effector trajectories.

6. **Control of Robot Manipulators**
   
   At the end of this section, students will be able to:
   
   a. Understand the concepts of position and force control of rigid-link manipulators.
   b. Implement algorithms for position and force control of robot manipulators.


**Evaluation**

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**Homework Assignments:** There will be 6 assignments spread out throughout the term. The grade for the 5 highest marks will be considered towards the final grade, only if all 6 assignments are completed and submitted by the due date. Due dates are non-negotiable. Assignments are to be handed in during class or online as specified and are due when indicated by the instructor on the due date.

**Laboratory:** All students will attend a 3-hour laboratory session each week. Absence from any session or a portion of a session without permission will result in a zero being assigned to the corresponding laboratory report. Three laboratory reports will be completed throughout the term. Lab reports are to be handed in during the assigned laboratory period or online as instructed, and are due at the start of the period on the due date or when otherwise instructed.

**Midterm Test:** The Midterm Test will be held on Thursday, October 24th during class. The test will cover the material discussed in class up to that point. The exam will be closed-book with a formula sheet allowed (one-sided formula sheet with no drawings or examples to be approved by the instructor). Standard calculators will be allowed. A total of 1 hour and 40 minutes will be allotted for the completion of the exam.

**Final Examination:** The final examination will take place during the regular examination period. The exam will cover all of the material covered in class and in the labs. This exam will be closed book with a formula sheet allowed (two-sided formula sheet with no drawings or examples to be approved by the instructor). Standard calculators will be allowed. A total of 3 hours will be allotted for the completion of the exam.

**Course Policies:**

All work submitted must be of professional quality. Material that is handed in dirty, illegible, or disorganized will be returned to the student for resubmission and the late submission penalty will take effect. An additional penalty of 10% may be deducted for poor grammar, incoherence or lack of flow in the written reports.

**Take home assignments:** Take home assignments will be penalized by 10% of the available marks per day for late submission. Assignments more than 5 days late will not be accepted. Work submitted after the last day of classes will not be accepted and will receive a grade of zero.
Laboratory sessions: Attendance at all laboratory sessions is mandatory. Students who arrive 20 min after the scheduled lab time without a legitimate reason, leave the lab early without permission from the TA, or miss the lab without a legitimate reason will be receive a zero for the corresponding laboratory report. Students who miss a lab with academic consideration are required to contact the course instructor for further instructions. Failure to do so will result in a zero mark for that lab. A minimum mark of 50% in each laboratory exercise, with a minimum average of 60% across all laboratory exercises is required to pass the course.

Final examination: To obtain a passing grade in the course, a mark of 60% or more must be achieved on the final examination. A final examination mark < 60% will result in a final course grade of 48% or less.

If the above conditions are not met, your final grade cannot be greater than 48%. Students who have failed this course (i.e., final average < 50%) must repeat all components of the course.

Assignment Submission Locker: Locker 236 located on the second floor of TEB.

How to succeed in this course:
Class attendance is highly encouraged. Attention to the events happening in each lecture will ensure your understanding of the topics and will allow you to gain the most from the course.

While every student works at a different level, it is the effort placed in each requirement that ultimately leads to success. Your interest in the course, participation in class by asking relevant questions, and talking to the instructor during office hours will all contribute to your successful completion of the assignments, labs and examinations and are all highly encouraged.

It is your responsibility to determine what is required of you. If you miss a lecture, it is your responsibility to find out what was discussed and what instructions were given regarding assignments, laboratory sessions or exams.

Plan to arrive to class and to the lab a few minutes early. Lectures will start promptly, and immediate attention will be required from the start.

Use of English: In accordance with Senate and Faculty Policy, students may be penalized up to 10% of the marks on all assignments, tests, and examinations for improper use of English. Additionally, poorly written work with the exception of the final examination may be returned without grading. If resubmission of the work is permitted, it may be graded with marks deducted for poor English and/or late submission.

Attendance: All classes, laboratories, and tutorials are mandatory unless otherwise stated. Any
student who, in the opinion of the instructor, is absent too frequently from class, laboratory, or tutorial periods will be reported to the Dean (after due warning has been given). On the recommendation of the department, and with the permission of the Dean, the student will be debarred from taking the regular final examination in the course.

**Absence Due to Illness or Other Circumstances:** Students should immediately consult with the instructor or program director if they have any problems that could affect their performance in the course. Where appropriate, the problems should be documented (see the attached “Instructions for Students Unable to Write Tests or Examinations or Submit Assignments as Scheduled”). The student should seek advice from the instructor or program director regarding how best to deal with the problem. Failure to notify the instructor or program director immediately (or as soon as possible thereafter) will have a negative effect on any appeal.

For more information concerning medical accommodations, see the relevant section of the Academic Handbook:

http://www.uwo.ca/univsec/pdf/academic_policies/appeals/accommodation_medical.pdf

For more information concerning accommodations for religious holidays, see the relevant section of the Academic Handbook:

http://www.uwo.ca/univsec/pdf/academic_policies/appeals/accommodation_religious.pdf

**Missed Midterm Examinations:** If a student misses a midterm examination, the exam will not be rescheduled. The student must follow the Instructions for Students Unable to Write Tests and provide documentation to their program within 24 hours of the missed test. The program will decide whether to allow the reweighting of the test, where reweighting means the marks normally allotted for the midterm will be added to the final exam. If no reasonable justification for missing the test can be found, then the student will receive a mark of zero for the test.

If a student is going to miss the midterm examination for religious reasons, they must inform the instructor in writing within 48 hours of the announcement of the exam date or they will be required to write the exam.

**Cheating and Plagiarism:** Students must write their reports and assignments in their own words. Whenever students take an idea or a passage from another author, they must acknowledge their debt both by using quotation marks where appropriate and by proper referencing such as footnotes or citations. University policy states that cheating, including plagiarism, is a scholastic offence. The commission of a scholastic offence is attended by academic penalties, which might include expulsion from the program. If you are caught cheating, there will be no second warning.
All required papers may be subject to submission for textual similarity review to commercial plagiarism-detection software under license to the University for the detection of plagiarism. All papers submitted will be included as source documents on the reference database for the purpose of detecting plagiarism of papers subsequently submitted to the system. Use of the service is subject to the licensing agreement, currently between the University of Western Ontario and Turnitin.com (http://www.turnitin.com).

Scholastic offences are taken seriously and students are directed to read the appropriate policy, specifically, the definition of what constitutes a Scholastic Offence, in the relevant section of the Academic Handbook:

http://www.uwo.ca/univsec/pdf/academic_policies/appeals/scholastic_discipline_undergrad.pdf

Use of Electronic Devices: Turn off all sound for pagers and cell phones. Students may use laptops, tablet computers, or smart phones only to access the course OWL site or for taking in-class notes during lectures, labs and tutorials. Only the use of nonprogrammable calculators is permitted during examinations. No other electronic devices may be used at any time during lectures, tutorials, or examinations.

Policy on Repeating All Components of a Course: Students who are required to repeat an Engineering course must repeat all components of the course. No special permissions will be granted enabling a student to retain laboratory, assignment, or test marks from previous years. Previously completed assignments and laboratories cannot be resubmitted by the student for grading in subsequent years.

Internet and Electronic Mail: Students are responsible for regularly checking their Western e-mail and the course web site (https://owl.uwo.ca/portal/) and making themselves aware of any information that is posted about the course. If the student fails to act on information that has been posted on these sites and does so without a legitimate explanation (i.e., those covered under the illness/compassionate form), then there are NO grounds for an appeal.

Accessibility: Please contact the course instructor if you require material in an alternate format or if any other arrangements can make this course more accessible to you. You may also wish to contact Services for Students with Disabilities (SSD) at 519-661-2111 ext. 82147 for any specific question regarding an accommodation.

Support Services:
Office of the Registrar, http://www.registrar.uwo.ca/ Student
Development Centre, http://www.sdc.uwo.ca/
Students who are in emotional/mental distress should refer to Mental Health @ Western, http://www.health.uwo.ca/mental_health/, for a complete list of options about how to obtain
INSTRUCTIONS FOR STUDENTS UNABLE TO WRITE TESTS OR EXAMINATIONS OR SUBMIT ASSIGNMENTS AS SCHEDULED

If, on medical or compassionate grounds, you are unable to write term tests or final examinations or complete course work by the due date, you should follow the instructions listed below. You should understand that academic relief will not be granted automatically on request. You must demonstrate to your department (or the Undergraduate Services Office) that there are compelling medical or compassionate grounds that can be documented before academic relief will be considered. Different regulations apply to term tests, final examinations and late assignments. Please read the instructions carefully.

NEW: Requests for Academic Consideration using the Self-Reported Absence Form

If you experience an unexpected illness or injury or an extenuating circumstance (48 hours or less) that is sufficiently severe to temporarily render you unable to meet academic requirements (e.g., attending lectures or labs, writing tests or midterm exams, completing and submitting assignments, participating in presentations) you should self-declare using the online Self-Reported Absence portal. This option should be used in situations where you expect to resume academic responsibilities within 48 hours or less.

Each student will be allowed a maximum of two self-reported absences between September and April and one self-reported absence between May and August. Self-reporting may not be used for final exams or assessments (e.g. midterm exams, tests, reports, presentations, or essays) worth more than 30% of any given course.

For full instructions about the Self-Reporting System refer to the Academic Calendar: http://westerncalendar.uwo.ca/PolicyPages.cfm?PolicyCategoryID=1&Command=showCategory&Keywords=report&SubHeadingID=322&SelectedCalendar=Live&ArchiveID=#SubHeading_322

A. GENERAL REGULATIONS & PROCEDURES (other than self-reported absences)

1. All first year students will report to the Undergraduate Services Office, SEB 2097, for all instances.

2. If you are an upper year student and you are missing a test/assignment/lab or examination that is worth LESS THAN 10% of your mark, you should report to your department office to request relief. If your course work is worth MORE THAN 10% of your final grade, you will report to the Undergraduate Services Office, SEB 2097.

3. Check the course outline to see if the instructor has a policy for missed tests, examinations, late assignments or attendance.

4. Documentation must be provided as soon as possible. If no one is available in your department office or the Undergraduate Services Office, leave a message clearly stating your name & student number and reason for your call. The department telephone numbers are given at the end of these instructions.

5. If you decide to write a test or an examination you should be prepared to accept the mark you earn. Rewriting tests or examinations or having the value of a test or examination reweighted on a retroactive basis is not permitted.

B. TERM/MIDTERM TESTS (other than self-reported absences)

1. If you are in first year and you are unable to write a midterm/term test, contact the Undergraduate Services Office, SEB 2097 PRIOR to the scheduled date of the test.

2. If you are an upper year student and you are unable to write a midterm/term test, inform your instructor PRIOR to the scheduled date of the test. If the instructor is not available, leave a message for him/her at the department office. If the test is worth LESS THAN 10% of your mark, you should report to your department office to request relief. If the test is worth MORE THAN 10% of your final grade you will report to the Undergraduate Services Office, SEB 2097 to request relief.

3. Be prepared to provide supporting documentation to the Department Chair and/or the Undergraduate Services Office (see next page for information on documentation).

4. Discuss with the instructor if and when the test can be rescheduled. N.B. The approval of the Chair or the Undergraduate Services Office is required when rescheduling midterm/term tests.
C. **FINAL EXAMINATIONS (cannot be self-reported)**

1. If you are unable to write a final examination, contact the Undergraduate Services Office PRIOR TO THE SCHEDULED EXAMINATION TIME to request permission to write a Special Final Examination. If no one is available in the Undergraduate Services Office, leave a message clearly stating your name & student number.

2. Be prepared to provide the Undergraduate Services Office with supporting documentation (see next page for information on documentation) the next day, or as soon as possible (in cases where students are hospitalized). The following circumstances are not considered grounds for missing a final examination or requesting special examinations: common cold, headache, sleeping in, misreading timetable and travel arrangements.

3. In order to receive permission to write a Special Examination, you must obtain the approval of the Chair of the Department and the Associate Dean and in order to apply you must sign a "Recommendation for a Special Examination Form" available in the Undergraduate Services Office. The Undergraduate Services Office will then notify the course instructor(s) and reschedule the examination on your behalf.

   **PLEASE NOTE:** It is the student's responsibility to check the date, time and location of the Special Examination.

D. **LATE ASSIGNMENTS**

1. Advise the instructor if you are having problems completing the assignment on time (prior to the due date of the assignment).

2. Be prepared to provide documentation if requested by the instructor (see reverse side for information on documentation).

3. If you are granted an extension, establish a due date. The approval of the Chair of your Department (or the Assistant Dean, First Year Studies, if you are in first year) is not required if assignments will be completed prior to the last day of classes.

4. i) Extensions beyond the end of classes must have the consent of the instructor, the department Chair and the Associate Dean, Undergraduate Studies. Documentation is mandatory.

   ii) A Recommendation of Incomplete Form must be filled out indicating the work to be completed and the date by which it is due. This form must be signed by the student, the instructor, the department Chair and the Associate Dean, Undergraduate Studies.

E. **SHORT ABSENCES**

If you miss a class due to a minor illness or other problem, check your course outlines for information regarding attendance requirements and make sure you are not missing a test, laboratory or assignment. Cover any readings and arrange to borrow notes from a classmate.

F. **EXTENDED ABSENCES**

If you are absent more than one week or if you get too far behind to catch up, you should consider reducing your workload by dropping one or more courses. (Note drop deadlines listed below). You are strongly encouraged to seek advice from your Academic Counsellor in the Undergraduate Services Office.

G. **DOCUMENTATION**

If you consulted an off-campus doctor or Student Health Services regarding your illness or personal problem, you must provide the doctor with a Student Medical Certificate to complete at the time of your visit and then bring it to the Department (or the Undergraduate Services Office). This note must contain the following information: severity of illness, effect on academic studies and duration of absence. Regular doctor’s notes will not be accepted; only the Student Medical Certificate will be accepted.

**In Case of Serious Illness of a Family Member:** Provide a Student Medical Certificate to your family member's physician to complete and bring it to the Department (or the Undergraduate Services Office if you are in first year).

**In Case of a Death:** Obtain a copy of the death certificate or the notice provided by the funeral director's office. You must include your relationship to the deceased and bring it to the Department (or the Undergraduate Services Office if you are in first year).

**For Other Extenuating Circumstances:** If you are not sure what documentation to provide, ask the Departmental Office (or the Undergraduate Services Office if you are in first year) for direction.

**Note:** Forged notes and certificates will be dealt with severely. To submit a forged document is a scholastic offence (see below).
H. ACADEMIC CONCERNS

1. You need to know if your instructors have a policy on late penalties, missed tests, etc. This information may be included on the course outlines. If not, ask your instructor(s).

2. You should also be aware of attendance requirements in some courses. You can be debarred from writing the final examination if your attendance is not satisfactory.

3. If you are in academic difficulty, check out the minimum requirements for progression in the calendar. If in doubt, see your Academic Counsellor.

Calendar References: Check these regulations in your 2019 Western Academic Calendar available at www.westerncalendar.uwo.ca.

Self-Reporting Absences:
http://westerncalendar.uwo.ca/PolicyPages.cfm?PolicyCategoryID=1&Command=showCategory&Keywords=report&SubHeadingID=322&SelectedCalendar=Live&ArchiveID=#SubHeading_322

Absences Due to Illness:
http://www.westerncalendar.uwo.ca/PolicyPages.cfm?Command=showCategory&PolicyCategoryID=1&SelectedCalendar=Live&ArchiveID=#Page_12

Academic Accommodations for Students with Disabilities:
http://www.westerncalendar.uwo.ca/PolicyPages.cfm?Command=showCategory&PolicyCategoryID=1&SelectedCalendar=Live&ArchiveID=#Page_10

Academic Accommodations for Religious or Holy Days:
http://www.westerncalendar.uwo.ca/PolicyPages.cfm?Command=showCategory&PolicyCategoryID=1&SelectedCalendar=Live&ArchiveID=#Page_16

Course Withdrawals:
http://www.westerncalendar.uwo.ca/PolicyPages.cfm?Command=showCategory&PolicyCategoryID=6&SelectedCalendar=Live&ArchiveID=#Page_75

Examinations:
http://www.westerncalendar.uwo.ca/PolicyPages.cfm?PolicyCategoryID=5&Command=showCategory&SelectedCalendar=Live&ArchiveID=

Scheduling of Term Assignments:
http://www.westerncalendar.uwo.ca/PolicyPages.cfm?Command=showCategory&PolicyCategoryID=5&SelectedCalendar=Live&ArchiveID=#SubHeading_78

Scholastic Offences:
http://www.westerncalendar.uwo.ca/PolicyPages.cfm?Command=showCategory&PolicyCategoryID=1&SelectedCalendar=Live&ArchiveID=#Page_20

Student Medical Certificate:
https://www.eng.uwo.ca/files/undergraduate/forms/smc.pdf

Engineering Academic Regulations:
http://www.westerncalendar.uwo.ca/PolicyPages.cfm?Command=showCategory&PolicyCategoryID=4&SelectedCalendar=Live&ArchiveID=#Page_86

Note: These instructions apply to all students registered in the Faculty of Engineering regardless of whether the courses are offered by the Faculty of Engineering or other faculties in the University.

Add Deadlines:
First term half course (i.e. “A” or “F”) September 13, 2019
Full courses and full-year half course (i.e. “E”, “Y” or no suffix) September 13, 2019
Second term half course (i.e. “B” or “G”) January 14, 2020

Drop Deadlines:
First term half course (i.e. “A” or “F”) November 12, 2019
Full courses and full-year half courses (i.e. “E”, “Y” or no suffix) November 30, 2019
Second term half or second term full course (i.e. “B” or “G”) March 7, 2020

Contact Information:
Undergraduate Services Office: SEB 2097 Phone: 519-661-2130 E-mail: engugrad@uwo.ca
Chemical & Green Process Engineering: TEB 477 Phone: 519-661-2131 E-mail: cbeugrad@uwo.ca
Civil Engineering: SEB 3005 Phone: 519-661-2139 E-mail: civil@uwo.ca
Computer, Electrical, Mechatronic Systems & Software Engineering TEB 279 Phone: 519-661-3758 E-mail: eceugrad@uwo.ca
Integrated Engineering ACEB 2410 Phone: 519-661-6725 E-mail: engceli@uwo.ca
Mechanical Engineering: SEB 3002 Phone: 519-661-4122 E-mail: mmueundergraduate@uwo.ca

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