MECH 366

Modeling of Mechatronic Systems

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Connect site

https://connect.ubc.ca

Most course enquires can be made via the Connect site, although queries can also be made to the instructor directly at rohling@ece.ubc.ca.

The Connect site can be used only by students enrolled in the MECH366 course. Student accounts will be given access to the course that can be accessed both from UBC and home. Instructions are given on the main Connect page.

The Connect page contains on-line versions of the labs, exams, solutions, and mailing lists.

Class Schedule:

One hour lectures are given twice per week on Mondays and Fridays starting in the first week of classes.

Labs:

The labs are all performed in KAIS1160.

The labs are an integral part of the course and all labs must be completed to pass the course. Laboratories will be performed in teams. Two 2-hour lab sessions are scheduled for each lab (except Labs 1, 2 which only requires one session) and the TA will be available in the labs during the scheduled lab times. There is also a Lab 0 for introduction, team-building, and instructions on writing the lab reports.

Lab Marking

A short lab report must be handed in at the end of the lab session (due dates given in first lab). A lengthy report is not required. The report should include answers to any questions posed in the lab notes. Each lab will be marked out of 10.

If a lab is not demonstrated on time you will receive a maximum mark of 2/10:

However, remember that you must complete all labs, even if late, to pass the course. A few lab sessions will be scheduled near the end of the course to demonstrate late labs.

Since this is a group effort, only lab report needs to be submitted, clearly writing the names of all students on the report. Do not write names of students who were absent or did not participate.

Assignments

Assignments will be given out periodically and will be due approximately two weeks later. Your solutions should be handed in at the end of the lecture on the day they are due. *Late assignments will be given a mark of zero*.

Assignments are to be done individually. Students are encouraged to seek help from classmates but copying is not allowed. Possible penalties for plagiarism include a mark of zero for all assignments.

Schedule:

Assignment 1 due end of 5th week
Assignment 2 due end of 8th week
Assignment 3 due end of 12th week
Assignment 4 due end of 13th week

Midterm

The midterm is usually scheduled for the late October/ early November and will be 1 hour in duration.

Text

A textbook by UBC Professor C. de Silva will be used:

Mechatronics: An Integrated Approach. CRC Press. 2004.

We will be covering mainly chapters 2 and 5. Click on the links above to see the text at amazon.com or CRC Press. These chapters will be given as a Custom Course Notes package at the UBC bookstore, or you can purchase the entire textbook.

Other References:

Mechatronics,
D. Necsulescu
Upper Saddle River, N.J. : Prentice Hall, c2002
TJ163.12 .N43 2002
This is an introductory book covering a wide range of topics.

The art of electronics /2nd ed.
Horowitz, Paul, 1942- Hill, Winfield.
Cambridge [England] ; New York : Cambridge University Press, 1989.
TK7815.H67 1989
This a good practical reference book on most aspects of electronics although some of the material is dated.

Digital design /2nd ed.

Mano, M. Morris, 1927-
Englewood Cliffs, N.J., Prentice-Hall, c1991.
TK7888.3.M343 1991
This textbook goes into greater depth on digital design, much of which is not covered in this course, but it gives a good introduction to binary systems and state machines. (RNR)

Evaluation

There will be a one-hour midterm term examination and a 2.5 hour final exam in December. The final mark will be calculated as follows:
final exam 50%
midterm exam 20%
assignments 10%
labs 20%
Please note: *All labs must be completed to pass the course.*

Prerequisites

Student should have either (a) all of MECH 220, MECH 223, MECH 224, MECH 225 or (b) all of PHYS 253, EECE 251, MECH 260.

Objectives

The course outline is: "Modeling of mechanical, electrical, thermal, fluid elements and mixed mechatronic systems. Signal processing, signal conditioning. Sensors, data acquisition systems, actuators." The learning objectives will be taught in the lectures, and you will demonstrate your learning skills informally in the lectures during the brief 5-minute in-class questions. You will also demonstrate your skills with the 4 written assignments and the 5 reports from the laboraties.

The overall objectives are to learn:

1. **Mathematical modeling of physical systems**. You will be expected to analyze a complex system and select the appropriate models for individual components. You will then be expected to analyze the system to measure the response to an input. You will be expected to analyze the system in time, frequency and Laplace domains. You will be expected to know which domain is most appropriate for a given system, and how to go between different domains.
2. **Building common differential equations for electrical and mechanical systems**. You will be expected to apply time-domain, frequency-domain and Laplace-domain equations to model a physical system. You will be expected to apply the same mathematical equations to mechanical, electrical, thermal, and fluid systems. You will be expected to investigate, compare and combine these different systems into a single mathematical framework.
3. **Engineering analysis of performance of integrated mechatronics systems in time and frequency domain**. You will be expected to select and apply standard performance specifications to measure the performance of a system. You will be expected to compare performance specifications and understand their limitations. You will be expected to present these performance specifications numerically and graphically. You will be expected to appreciate the

benefits and limitations of standardized performance metrics.

4. **Application of integrated modeling and instrumentation techniques to design and analysis of an industrial, mechatronics system**. You will be expected to create models of real physical systems by first graphically representing the system as a set of interconnected components. You will be expected to analyze the graphical representation to derive an analytical model using equations. Given an input to the system, you will be expected to solve for the outputs of the system using the equations. You will also be expected to select and use appropriate simplified linear time-invariant models and learn when these models are appropriate. You will be expected to identify when systems are not linear and produce models for restricted domain where linearity can be approximated. You will be expected to select and use appropriate instruments to measure the inputs, states and outputs of a physical system. You will also be expected to use those tools to derive linear analytic models of the components of the system and demonstrate the error in the modeling assumptions. You will be expected to apply a real input to the system, measure the output, and compare the output results to the predicted results of your model. You will be expected to produce clear sketches, plots and written summaries of the systems.

Detailed Course Objectives

1. Demonstrate one or more ways to create an equivalent lumped model of a system, each element described by a constant parameter
2. Explain the analogies with mechanical, electrical, fluid and thermal systems
3. Explain the most common elements of the systems (model building blocks) in 2.
    a. Select and use a suitable model element for a given component
    b. Appreciate the limitations of the model
4. For any of the systems in 2
    a. Choose and write the appropriate differential equations of dynamics by observation (simple systems)
    b. Apply the concept of state variables to write the equations of dynamics
    c. Use linear graphs to help write the equations of dynamics (more complicated systems)
5. Given a set of linear equations of dynamics, express the system in standard state space form (using matrices A,B,C,D).
6. Given the equations of dynamics, express as input/output differential equations
7. Explain how to deal with non-linear systems, and apply simplified modeling tools
    a. Write the steady state equations of dynamics
    b. Derive linear equations of dynamics for small deviations from the steady state
8. Given the equations of dynamics
    a. Write the input/output transfer function G(s) using Laplace transforms
    b. Given G(s) express as a block diagram (and vice versa)
    c. Given G(s) and an input u(t), find output y(t) (review of Laplace transforms)
9. Explain the concepts of mobility and impedance
    a. Select and use the concepts of mobility and impedance to help write G(s) easily
    b. Explain and be able to write force transmissibility and motion transmissibility
10. Given G(s), find the frequency domain representation in terms of magnitude and phase
    a. Given a sinusoid input, calculate the magnitude and phase of output

11. Explain how to convert amoung the Time domain, Laplace domain and Frequency domain, and be able to write the conversions mathematically:
    a. Time domain:
        i. Find y(t) using the particular and homogeneous solutions
        ii. Relate rise time, overshoot etc. to system parameters
    b. Laplace domain:
        i. Using G(s) and u(t), find y(t) using expansion and standard Laplace tables
        ii. Calculate system poles and relate to system parameters and performance
    c. Frequency domain:
        i. Perform system identification (draw Bode plots)
        ii. Draw Bode plots from G(s)
        iii. Relate resonance, gain etc. to system parameters and performance
12. Explain 1st and 2nd order systems in detail
    a. Describe them in Time, Laplace and Frequency domains
    b. Explain the concepts of underdamped, critically damped and overdamped 2nd order systems
13. Relate the theory in item 11 to state the performance of actual devices like sensors and actuators
14. Define and explain the causes of typical non-linearities
15. Define the meaning of manufacturer's specifications of instrument ratings and appreciate the utility and limitations of standard specifications.
16. Optimize a design using frequency domain specifications
    a. Explain the concept of bandwidth and calculate it in order to optimize performance
17. Explain the difference between continuous and discretely sampled systems
18. Identify and solve problems with sampling and aliasing.
19. Explain and calculate impedance matching.
20. Explain and create simple filters

Not covered in course:
Section 2.10 Bond Graphs
Sections 4.10-4.13 Bridge Circuits, Liberalizing Devices, Miscellaneous Circuits, Signal Analyzers
Section 5.10 Statistical Process Control