Course Code: MAT 483

Course Title: Mathematical Control Theory and Applications

Credit Weight: 3.0 Credits

Rationale of the Course:

Theory of dynamical systems and control methods are essential for engineers in a variety of disciplines. The applications are diverse and include among other things, chemical systems, air and land vehicles, electric machines, robotic and mechatronic systems. The purpose of this course is to provide students a solid understanding of a theoretical domain within system and control theory. The course covers what constitutes the common core of system and control theory: The theory of linear systems, analysis and design of control systems, modelling, stability analysis, system characteristics and performance analysis as well as ideas of model reduction.

The course is designed primarily to an audience consisting of mathematically mature advanced undergraduate or beginning graduate students. In addition, it can be used by engineering students interested in a modern applied mathematics-oriented course that goes beyond the classical applied math courses.

Prerequisite: Knowledge of multivariable calculus and ordinary differential equations is mandatory (MAT250, MAT350/MAT480 of NSU)

Course Objective:

1. To provide a basic concepts and results of mathematical control and system theory.
2. To give a sound fundamental understanding of the principles underlying the operation of control theory, like the transfer functions, bode diagram, system poles and zeros.
3. To analyze the behavior of continuous- and discrete-time linear control systems in time and frequency domains.
4. To demonstrate the stability of linear system and the importance of poles and zeros.
5. To develop the ability to apply the concept of control theory studies in developing realization algorithms of linear control systems.

Course Learning Outcomes (CLOs)/Course Outcomes (COs):

At the successful completion of this course, the student will have demonstrated the ability to:

(CLO1) Understand the mathematical foundation of control theory and the application in the continuous and discrete-time state-space systems.
(CLO2) Analyze fundamental principles of control systems underlying the operation of control theory.
(CLO3) Identify the different parameters and the basic strategies for design and implementation of controllers.
(CLO4) Solve linear matrix equations to illustrate the stability of linear control systems.
(CLO5) Apply the knowledge of control theory and relevant studies in developing model reduction algorithms of linear control systems

Course Contents:

The course includes the following topics:

- **Basics of Matrix Computations and Vector Analysis**
  -Definition of some special matrices, Matrix norms, LU factorization of matrices, Upper Hessenberg matrix.
  -QR factorization of matrix, SVD, Orthogonal projections, Numerical rank of a matrix.
- **Control Systems Analysis**
  -State-space representations of control systems, Linear time invariant (LTI) models, Modeling of state space models from different real-life problem statements.
  -Continuous-time systems and discrete-time systems.
  -Solutions of continuous-time and discrete-time systems, Transfer functions and frequency responses.
- **Controllability, Observability and Special Forms**
  - Controllability and Observability of continuous-time and discrete-time systems in their LTI forms.
  -Decompositions of uncontrollable and unobservable systems, Controller- and Observer-canonical forms,
  -Eigenvalue/Eigenvector test for controllability and Observability, Numerical tests.
- **Stability Analysis of LTI Control Systems**
  -Stability analysis of continuous-time and discrete-time systems, controllability and observability Gramians.
  -Lyapunov equation and stability theory, Robust stability, Distance to an unstable system.
- **Numerical Solutions of Lyapunov Equations**
  -Existence and uniqueness of solutions
  -Numerical methods for solutions of continuous-time and discrete-time Lyapunov equations.
  -Comparisons of different methods.
- **Model Reduction and Applications**
  -Introduction to model reduction
  - Minimal realization and Balanced realizations.
  -Balanced truncation model reduction method for linear systems
  -some selected software use: MATLAB Control System Toolbox, SLICOT

Reference Books:

(1) B. N. Datta: Numerical Methods for linear Control Systems, Elsevier Academic Press, 2004
(2) Norman S. Nise, Control System Engineering, 5th or Higher edition
(3) A. C. Antoulas, Approximation of Large Scale Dynamical Systems, SIAM Pub., 2004

Mapping Course Learning Outcomes (CLOs) with the PLOs

Table 1 Relationship between PLOs and PEOs

PLOs / CLOs	PLO(a): Mathematical Knowledge	PLO(b): Problem Analysis	PLO(c): Development/Design Solutions	PLO(d): Investigation and Make Decision	PLO(e): Usage of Modern Tools of Computation	PLO(f): Professionalism and sustainability	PLO(g): Ethics	PLO(h): Individual work and teamwork	PLO(i): Communication	PLO(j): Life-long Learning
CLO1	M	S	M	L						
CLO2	M	S	S	M						
CLO3	S	M	S	S	S		L		L	L
CLO4	S	S	M	M	S		L	L		
CLO5	M	M	S	M	M					L

Note: S: Strong correlation, M: Medium correlation, L: Low correlation

Mapping Course Learning Outcomes (CLOs) with the Teaching-Learning & Assessment Strategy

	Teaching Strategies						Assessment Strategies						
CLOs	Class Lecture	In -class Q/A	Group discussions	Assignments/ Homework	In-class problem solution	Computer Lab works	Continuous Assessments	Quizzes	Written exams (Midterm/Final)	Home Assignments	Oral Viva	Presentations	Lab Report
CLO1	√	√		√			√	√	√				
CLO2	√		√	√	√			√	√	√			
CLO3	√	√	√	√			√				√	√	
CLO4	√	√	√		√		√		√			√	
CLO5	√	√		√				√	√	√		√	

Course Assessment Policy:

Course Assessment System:	Attendance	10%
	Assignments (Minimum 4)	10%
	Quizzes (Best 3 of 5)	20%
	Mid-Term	20%
	Final Exam	40%
Grading Policy:	As per the NSU grading system.	
Attendance Policy:	As per NSU policy.	

Exams & Make-up Exam Policy

NO makeup for quizzes and NO Formative assessment will be retaken under any circumstances. If a student misses the Midterm and/or Final exams due to circumstances beyond their control (official valid documents are required) and is informed beforehand (if possible), a reasonable arrangement may be considered. Please note that the retake exam questions are generally a bit tricky and critical compared to the regular exam questions. **Students may get the opportunity to see/recheck their midterm and Final exam scripts. Cell phones are prohibited in exam sessions**.