Catalog Information: Topics include state-space description of dynamic systems, analysis and design of linear systems, similarity transformation, state feedback, state observers, and matrix characterization of multivariable systems.

Course Objectives: To provide students with basic knowledge of design and analysis of linear dynamical systems. To lay the foundations of state space design, including stability, controllability, observability, minimality, and duality. To provide design and computer simulation techniques for design of control systems, observers, and regulators. To study system structure in terms of block diagram realizations and Jordan normal form.

Course outline:

I. SYSTEM ANALYSIS

- Review of matrix algebra
- State variable systems
  - nonlinear state equation
  - linear state equation
- Computer simulation of nonlinear dynamical systems
  - MATLAB review
- Review for continuous-time systems
  - Laplace transform review
  - Second-Order systems
- Continuous-time state variable analysis
  - frequency response and transfer function
  - time response
  - Relative degree and system zeros
- Stability I
  - Stability of input/output systems and Routh test
  - Stability of SV systems
- Lagrange’s equation and SV models of some representative systems
- Multivariable zeros and Minimality
  - Popov-Belevitch-Hautus (PBH) Tests
- System Input/Output Structure Analysis
  - Reachability
  - Observability
  - Duality

- Review for Discrete-time Systems
  - Z transform review

- Discrete-time state variable analysis
    - frequency response and transfer function
    - time response
- Expanded State Equation (ESE)
    - Iterative Solution of Discrete Time systems and DT ESE
    - ESE for Discrete-Time and Continuous-Time Systems
- Stability of Discrete-time systems
- Lyapunov stability analysis, open-loop

- Discretization of continuous-time systems
    - Sampling the state equation
    - Euler's approximation sampling
    - Effect of sampling on the poles
    - Sampling the transfer function
    - Effect of sampling on the zeros
- Realization and canonical forms
    - Reachable and Observable canonical forms
    - Parallel canonical form
    - Duality
    - Minimality
- State-Space Transformations and JNF
    - State-Space Transformations
    - SST and Reachability / Observability
    - Jordan Normal Form
    - Kalman Decomposition

II. SYSTEM DESIGN

- State-variable feedback
    - Reachability
    - Ackermann's formula
    - Multivariable system eigenstructure assignment
    - Linear quadratic regulator
- Digital Control
    - Control for Discrete-time systems
        - Deadbeat control
        - DT linear quadratic regulator

    - Discretization of continuous-time controllers
- Output Injection
    - Observability and Duality
    - State Observers
- Dynamic Regulator Design
    - Separation Principle
- Diophantine equation polynomial design
- Lyapunov stability analysis, closed-loop

- Output Feedback Control
    - Output Feedback Design
    - Output Feedback Design for Inverted Pendulum
    - Digital Output Feedback Design for Inverted Pendulum

Class hours: MW 4-520pm, NH 105 Nedderman Hall

Instructor: Hamidreza Modares, office: UTARI room 219, modares@uta.edu

Office hours: before or after class

Teaching Assistants:

Bahare Kiumarsi, kiumarsi@ uta.edu

Ioana corina Bogdan, ioanacorina.bogdan@mavs.uta.ed

Office hours: TBA at the IEEE Mentoring Office

Texts:

1) Chen, Linea system Theory and Design
2) Antsaklis and Michel, Linear Systems primer

Grading:

Homework--	25%	
Exam 1-- (1 sheet of notes both sides)	25%	Wed 9 Oct
Exam 2-- (2 sheets of notes both sides)	25%	Wed 20 Nov
Final Exam	25%	Week of 9 Dec

The instructor reserves the right to make appropriate changes to the grading policy.

Submission of Homeworks and Posting of Solutions:

Homeworks and exams should be submitted to the GTA through Blackboard online. Solutions will also be posted on Blackboard.

Student Learning Outcomes:

1. Acquire the mathematical tools needed to analyze feedback control systems by state space methods

   Assessment- homework design projects and examinations.

2. Learn the relation of state space systems to classical forms including transfer functions.

   Assessment- design and simulation projects in homeworks, exams.

3. Acquire the mathematical tools needed to study system stability, performance, controllability, observability.

   Assessment- homework design projects and examinations.

4. Ability to perform feedback control system design using state variable methods including pole placement and LQR.

   Assessment- design and simulation projects in homeworks, exams.

5. Ability to perform designs with various control tools using MATLAB computer simulation toolboxes.

   Assessment- computer design and simulation projects assigned in homeworks.

6. Ability to design dynamic feedback systems using state variable form including observers, output feedback and regulators.

   Assessment- design and simulation projects in homeworks, exams.

Relation to Program Objectives. This course is meant to provide basic training and familiarity with state space feedback control systems. Feedback systems are ubiquitous in daily life and appear in many other disciplines including communications, industrial process control, aerospace, vehicle **engine** systems, environmental efficiency, and elsewhere. State Variable methods for feedback have been introduced since the 1960s and are responsible for the high performance and stability of modern engineered systems including aerospace, robotic, and industry processes. This course shows the students the foundations of state space methods and prepares them for further courses in optimal control, nonlinear systems, and advanced topics such as adaptive control and collaborative control of networked systems.

Attendance is not mandatory. If you skip classes, you will find the homework and exams more difficult. Due to the pace of the lectures, copying someone else's notes may be an unreliable way of making up an absence. You are responsible for all material covered in class regardless of absences.

You will need to use MATLAB including Simulink and the Control Systems Toolbox. MATLAB is available in some of the OIT computer labs and you can also purchase the student edition of MATLAB for your personal computer.

Check the grading of the exams thoroughly. You will have one week after the exam to see me for regrading. After this period, the grade is final.