ELEC-7560/7566: Nonlinear Systems and Control

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- References

  1. Hassan Khalil, Nonlinear Systems, 3rd Ed., Prentice-Hall, 2002.
  2. Ronald R. Mohler, Nonlinear Systems, Vol. I: Dynamics and Control, Prentice-Hall, 1991.
  3. Jean-Jacque E. Slotine & Weiping Li, Applied Nonlinear Control, Prentice-Hall, 1991.
  4. M. Vidyasagar, Nonlinear Systems Analysis, 2nd Ed., Prentice-Hall, 1993.

  The first and fourth books are more difficult to read. The second book is very easy to read, but covers about half of the course content; it is a thin book that is becoming more difficult to find.

- Course grade is based on five (5) projects. Each project requires computer simulation and a brief report. Project reports may be submitted as the work is completed, or all together at the end of the semester (for example, a large report having five chapters). Please turn in all work no later than Aug. 2, which is the start of the summer final exam period.

- All lectures are available as Panopto recordings on Canvas. There are a total of 40 lessons. View at your own pace.

- I can be contacted by email, or by posting a discussion on Canvas. Posting a Canvas discussion benefits everyone in the class, especially those who are distance-learning. Responses may be delayed a few days because Canvas doesn't immediately notify the instructor about postings.

- Course Outline (Subject to change)

  1. Introduction
     (a) Review of LTI system characteristics
     (b) Common nonlinear system behaviors
  2. Phase plane analysis
     (a) Basic definitions
     (b) Classical construction methods (overview)
     (c) Second order analysis of linear systems

(d) Analysis of nonlinear systems (linearization)

3. Periodic solutions
   (a) Index theory, Poincaré's Theorem
   (b) Bendixson's Theorem
4. PROJECT #1: Phase plane analysis, periodic solutions
5. Stability
   (a) Isolated quilibrium points
   (b) Stability definitions
   (c) Lyapunov's first (indirect) method
   (d) Lyapunov's second (direct) method
   (e) Invariant set theorems
   (f) Lyapunov equation for linear systems
   (g) Finding Lyapunov functions
   (h) Other applications of Lyapunov theory
   (i) Lyapunov analysis of time varying systems
      i. uniformity
      ii. positive definiteness
      iii. decrescence
   (j) Lyapunov stability theorems for time varying systems
6. PROJECT #2: Controller design by Lyapunov's direct method.
7. Frequency domain analysis
   (a) Luré regulator problem
   (b) Circle criterion
   (c) Describing function analysis
8. PROJECT #3: Frequency domain analysis
9. Nonlinear control
   (a) Introduction to feedback linearization
      i. input-state linearization
      ii. input-output linearization
      iii. internal dynamics
      iv. normal form
   (b) Concepts from differential geometry
      i. Lie derivative, Lie bracket
      ii. accessibility, distinguishability
   (c) Feedback linearization for SISO systems
   (d) PROJECT #4: Feedback linearizing methods
   (e) Backstepping design
   (f) Variable structure systems
      i. equivalent control

ii. reaching law approach
iii. higher order sliding mode control (*time permitting*)
iv. PROJECT #5: Backstepping and variable structure control