I. COURSE TITLE: LINEAR SYSTEMS

II. ACADEMIC TERM: First Semester (fall) of Academic Year

III. PROFESSOR: Prof: Gilead Tadmor (Northeastern University): tadmor@coe.neu.edu

IV. COURSE OBJECTIVES: An introduction to the fundamental concepts, mathematical structures and design and optimization tools, for linear input/output systems, using state space methods. A user-level understanding of related concepts in advanced algebra and applied functional analysis is an essential component of that objective, and indeed, is essential for R&D activities in the wide area spanning DSP and Imaging, Communication, Information Theory, Data Mining and Machine Learning, and Control Systems, to name a few examples.

V. COURSE DESCRIPTION: The course begins with a review of topics in advanced algebra and mathematical analysis, including algebraic, geometric and topological aspects of vector spaces and linear operators; inner products and projections, Fourier analysis basics, least mean squares (LMS) approximations and linear-quadratic (LQ) optimization; matrices, Jordan forms and singular value decomposition (SVD). Using these tools, it continues with an introduction to linear system, including the concept of a state, state variable theory of continuous and discrete linear systems, canonical representations, interconnected systems, solutions of state equations, stability, algebraic, geometric and analytic controllability and observability, controller and observer design and optimization.

VI. TOPICS TO BE COVERED IN THE COURSE:

1. Introduction: what linear systems are about.
2. Vector spaces: finite and infinite dimensional (signal) spaces, bases and coordinates.
3. Linear transformations: basic concepts, matrix representations, similarity transformations, spectral theory (Jordan forms).
4. Norms and inner products: convergence, orthogonality, projections, least squares approximations and Fourier expansions.
5. Operator and matrix norms: approximations, singular value decomposition (SVD) and simple estimation problems.
6. State space representations of continuous & discrete time systems: the concept of a state variable, state equations and their solutions.
7. Relationships between state variables and transfer function representations.
8. Stability: different definitions, connections to Jordan form analysis, operator theoretical formulation, Lyapunov stability.
9. Controllability and Observability: basic definitions, geometric and algebraic analysis, Grammians and optimization, canonical forms
10. Controller and observer design, relations to basic LMS optimization problem

VII. INSTRUCTIONAL STRATEGIES: Conferences, guest speakers, literature reviews, Group exercises and extra curricular activities deemed congruente and complementary to the objectives of this course. Substantial independent and Group study will be undertaken. **The course is taught at NEU with Web Streaming Capabilities to UPRM.**

VIII. COMPUTER SKILLS AND ACCESS: The use MATLAB is an absolute requirement

IX. TEXTBOOKS

1. **Required**
   - W. L. Brogan, Modern Control Theory (3rd Ed.), Prentice-Hall, 1991 (ISBN: 0-13-589763-7)
2. **Recommended Material:** Books in advanced linear algebra, applied functional analysis, operator theory, linear systems. Note: other books are very useful as supplementary resources to gain a broader and deeper understanding; looking frantically at books for understanding of material you have difficulties with is usually a very poor and ineffective policy. If you have questions regarding the material, please interrupt me and ask questions in class, or during office hours.

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