EE 503 Signal Analysis and Processing

Short Description:

The course aims to unify the knowledge of linear system theory, digital signal processing basics and stochastic processes into the framework of statistical signal processing. The course goal is to establish a firm foundation for estimation theory (parameter estimation, signal modeling), Wiener Filtering (approached from the direction of linear MSE estimation) and linear prediction. Some more advanced topics such as AR, MA, ARMA, Harmonic processes, linear decorrelating transform, series expansion of random processes, spectral factorization, causal – non causal IIR Wiener filters are also introduced along the path.

Outline of Topics:

1. Review of Some Linear Algebra Concepts:
    a. Matrices as Transformations
        i. Linear Space, Linear Operators in Linear Space
        ii. Equivalent representations with finite/infinite matrices
        iii. Isomorphism between finite energy functions and finite power sequences ($L_2 \Leftrightarrow l_2$ spaces)
        iv. Representation of points in alternative coordinate systems, representation of operators in alternative coordinate systems
        v. Diagonalization of operators (Eigenfunctions ⇔ Eigenvectors)
        vi. Hermitian Operators ⇔ Hermitian Matrices, Orthogonal Bases

        Ref: Strang, Wolf, Lancaster
    b. Matrices as Linear Combiners
        i. Range and Null space of the combination process
        ii. Linear independence of vectors (points in linear space)
        iii. Projection to Range/Null Space, Direct Sums

        Ref: Scharf
    c. Matrices as Equation Systems
        i. Linear constraints (equations), intersection of constraints
        ii. Under-Over determined systems, Unique-None-Infinite solution systems
        iii. LS solution for inconsistent equation systems (overdetermined)
            1. Projection to range space,
            2. Pseudo Inverse, SVD
        iv. Minimum norm solutions for systems with infinite solutions
        v. SVD and its properties.

        Ref: Scharf
2. Review of some DSP Concepts
    a. Basic Idea: Discrete time processing of continuous time signals
        i. Sampling Theorem (going to discrete time without any loss of information)
        ii. Bandlimited Interpolation (going back to continous time after processing)
    b. Discrete Time Operations:
        i. Z-Transform, discrete time LTI systems, convolution, convolution matrices, diagonalization of convolution matrices
3. Review of some Random Processes Concepts:

   a. Random variables, random vectors (or a sequence of random variables), random processes
   b. Moment descriptors (especially 2nd order moment description of R.P's, mean, variance, correlation, auto-correlation, power spectrum density etc.)
   c. Stationarity, Wide Sense Stationarity
   d. PSD and its properties, spectral factorization
   e. Linear Time Invariant Processing of WSS R.P's
   f. Ergodicity

   Ref: Hayes, Papoulis, Ross

4. Signal Modeling
   a. LS methods, Pade, Prony (Deterministic methods)
   b. AR, MA, ARMA Processes (Stochastic approach), Yule-Walker Equations, Non-linear set of equations for MA system fit,
      i. All-pole modeling
         1. Covariance Method
         2. Auto-correlation Method
   c. Harmonic Processes, Wold decomposition
   d. Decorrelating transforms such as Fourier Transforms for Harmonic Processes and KL transform in general.
   e. Applications: Signal Compression, Signal Prediction, System Identification, Spectrum Estimation.

   Ref: Hayes, Papoulis

5. Some Topics in Estimation Theory
   a. Cost Functions: Mean Square, Mean absolute, max error
   b. MSE, ML, absolute error estimators
   c. Min MSE estimators
      i. Regression line, orthogonality
   d. Linear min MSE estimators
   e. Linear unbiased min MSE estimators
   f. Bias, consistency, efficiency, bias-error variance trade-off.
   g. Discussion of LS estimator for Ax=b + n systems.
   h. Wiener Filters as optimal estimators
      i. Linear predictors defined from Wiener filters
      ii. Levinson-Durbin recursion for efficient solution of Wiener-Hopf equations.
      iii. Lattice Structures for efficient implementation of Wiener filters
   i. IIR Wiener Filters
      i. Non-causal, Causal

   Ref: Hayes, Scharf

References:

[Hayes] : M. H. Hayes, Statistical Signal Processing and Modeling, Wiley, New York, NY, 1996 (Available in bookstore; level: moderate)

[Scharf] : Louis L. Scharf, Statistical Signal Processing, Addison-Wesley Publishing Company, Inc., Reading, MA, 1991.(level : advanced)

[Papoulis] : A. Papoulis, *Probability, Random Variables, and Stochastic Processes*, 3rd edition, McGraw Hill, 1991. (level: reference book, mostly advanced)

[Ross]: S. M. Ross, Introduction to probability models, 7th ed. Harcourt Academic Press, 2000. (level : introductory but complete)

[Wolf] : Kurt Bernardo Wolf , Integral Transforms in Science and Engineering Plenum Pub Corp, January 1979 (level: advanced)

[Lancaster]: P. Lancaster and M. Tismenetsky. The Theory of Matrices. Academic Press, Boston, 2nd edition, 1985. (level: complete text, very valuable as a linear algebra reference)

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This set of Biomedical Instrumentation Multiple Choice Questions & Answers (MCQs) focuses on â€œBiomedical Signal Analysis and Processing Techniquesâ€. 1. Which of the following statement is true for an instrumentational amplifier? a) the input resistance of both the inputs is very high and does not change as the gain is varied b) the input resistance of both the inputs is very low and does not change as the gain is varied c) the input resistance of both the inputs is very high. and does change as the gain is varied d) the input resistance of both the inputs is very low and does change as the