Geophysical Signal Processing

1.1. Course Number: GE 321

1.2. Contact Hours: 2-0-2 Credits: 8

1.3. Semester Offered: 3rd Year-Odd

1.4. Prerequisite: An overview to mathematics and physics would be useful.

1.5. Syllabus Committee Members: Dr. Satish Sinha and Dr. Piyush Sarkar

2. **Objective:** The student will be exposed to fundamental and advanced aspects of time series analysis techniques for geo-record analysis and processing.

3. **Course Content:** Unit-wise distribution of content and number of lectures

Unit	Topics	Sub-topics	Lectures
1	Signals and Systems	Basic theory and introduction to signal and system, Historical development of time series, types of signals; Classification of signals, continuous and discrete signals. Classification of data, digitization, sampling interval and aliasing, wavelets, Z-transform, linear system, Dirac delta function and impulse response of a linear system, impulse response function, minimum delay, maximum delay and mixed delay wavelets. Types of noises; Energy and phase spectra, properties of time signal (time invariance, causality, linearity).	8
2	Convolution and Correlation Techniques	Convolution theorem, methods for convolution, properties of convolution, autocorrelation, cross-correlation, and their applications, time domain and frequency domain concepts.	3
3	Data Analysis	Fourier series and Fourier transform, Hilbert transform, Walsh transform, orthogonal function and Dirichlet conditions, complex form of Fourier Series and Fourier transform, physical significance and interpretation of Fourier transform, properties of Fourier transform, Fourier transform of a symmetrical rectangular pulse, reciprocity, Fast Fourier Transform (FFT), two dimensional Fourier transform and its applications.	6
4	Digital Filtering and Weighting Functions (Windows)	Low, high and band pass filters, truncation of unit impulse response function, illustration of Gibb's phenomenon. Butterworth filters, Chebysev filter, recursive filters. Hanning window, Hamming window and their comparison,	4

		triangular window, Bortlett window, Parren window, Denieil window, practical applications of windows.	
5	Techniques for Spectral Estimation and Deconvolution	Power spectrum, method for calculation of power spectrum, three basic data models, Moving Average (MA) method, Maximum Entropy Method (MEM), Maximum Likelihood Method (MLM), Autoregressive process (AR), comparison of MA, MEM, MLM and AR techniques. Introduction to Deconvolution, white spectrum, Wiener inverse filtering and its mathematical details, homomorphic applications of deconvolution filtering.	6
6	Application of Time Series in Geophysics	Seismic method, Signal enhancement for gravity and magnetic methods, resistivity and well-logging methods, use of spectral techniques in meteorology, oceanography and groundwater hydrology.	3
		Total	**30**

List of experiments:

- To digitize analogue signal by graphical method choosing different sampling intervals, plotting the digitized record and examining the aliasing phenomenon.
- To convolve the two signals (wavelets), plot and examine the results.
- To compute the autocorrelation and cross-correlation functions for a given data set, plot and examine the results.
- To perform digital filtering after designing a low, high and band pass filters and to examine the effects of truncation.
- To apply Hanning and Hamming windows on a given set of data points.
- To compute the amplitude, phase and power spectra of a given time series.
- To apply Wiener inverse filtering to seismic data, comment on wavelet extraction problems.
- To perform the spectral analysis of gravity, magnetic and meteorological data.

4. Readings:

4.1. Textbook:

- Bath, M., Spectral Analysis in Geophysics. Elsevier, Amsterdam, Netherlands.
- Gubbins D., Time series analysis and inverse theory for geophysicists, Cambridge University Press.

4.2. Reference Books:

- Baskakov, S., Signals and Circuits, Mir Publishers

- Beauchamp, K.G., Walsh Functions and their Applications. Academic Press, New York, NY.
- Blakeiy, Richard J., Potential Theory in Gravity and Magnetic Applications, Cambridge University Press.
- Kanasewich, E. R., Time Sequence Analysis in Geophysics, The University of Alberta Press
- Naidu, P. S., and Mathur, M. P., Analysis of Geophysical Potential Field: A Digital Signal Processing Approach: Elsevier
- Robinson, E. A., 'Time Series Analysis and Application
- Yilmaz, O., Seismic data processing, Society of Exploration Geophysicists

5. Outcome of the course:

- Theoretical knowledge on geophysical/geological time/space series data analysis.
- Basic understanding on periodicity, how to design a filter, algorithm for signal enhancement and noise removal.
- Application of signal processing techniques for exploration of geoscience.