GUJARAT TECHNOLOGICAL UNIVERSITY

Program Name: Master of Engineering
Level: PG
Branch: Applied Instrumentation
Subject Code : ME02067051
Subject Name : Biomedical Signal Processing

WEF Academic Year:	2024-25
Semester:	2
Category of the Course:	Professional Elective Course

Prerequisite:	Fundamentals of signal and Image processing, Physics of Medical Imaging
Rationale:	The course aims at providing the students with the knowledge and methodology for extracting useful information, implement the advanced signal processing and pattern classification techniques on different biomedical signals like ECG, EEG, and EMG and from that interpret the results and validate the descriptors obtained in the light of knowledge of the biological system involved. Also, providing the fundamentals and various techniques of biomedical image processing to develop the algorithms for image analysis and diagnosis in medical imaging.

Course Outcome:

After Completion of the Course, Student will able to :

No	Course Outcomes	RBT Level*
01	Identify and Analyze Biomedical Signals	**RM**
02	Apply Filtering Techniques for Artifact Removal	**UN**
03	Detect and Interpret Key Signal Events	**AN**
04	Perform Waveform and Frequency-Domain Analyses	**EL**
05	Model Biomedical Systems and Process Signal Data	**CR**

*RM: Remember, UN: Understand, AP: Apply, AN: Analyze, EL: Evaluate, CR: Create

Course Scheme:

Teaching Scheme			Total Credits	Assessment Pattern and Marks				Total Marks
				Theory		Practical		
L	T	PR	C	ESE (E)	PA(M)	ESE (V)	PA (I)	
3	0	2	4	70	30	30	20	150

Course Content :

Sr. No.	Course Content	No. of Hours	% of Weightage
1	Preliminaries, Biomedical signal origin & dynamics (ECG), Biomedical signal origin & dynamics (EEG, EMG etc.)	3	7
2	Filtering for Removal of artifacts: Statistical Preliminaries, Time domain filtering (Synchronized Averaging, Moving Average), Time domain filtering (Moving Average Filter to Integration, Derivative-based operator), Frequency Domain Filtering (Notch Filter), Optimal Filtering: The Weiner Filter.	4	9
3	Filtering for Removal of artifacts contd.: Optimal Filtering: The Weiner Filter, Adaptive Filtering Selecting Appropriate Filter	4	9
4	Event Detection: Example events (viz. P, QRS and T wave in ECG), Derivative based Approaches for QRS Detection Pan Tompkins Algorithm for QRS Detection, Dicrotic Notch Detection Correlation Analysis of EEG Signal	4	9
5	Waveform Analysis: Illustrations of problem with case studies, Morphological Analysis of ECG, Correlation coefficient, The Minimum phase correspondent.	4	9
6	Waveform Analysis contd.: Signal length, Envelop Extraction, Amplitude demodulation, The Envelogram, Analysis of activity, Root Mean Square value, Zero-crossing rate, Turns Count, Form factor.	4	9
7	Frequency-domain Analysis: Periodogram, Averaged Periodogram, Blackman-Tukey Spectral Estimator, Daniell's Spectral Estimator, Measures derived from PSD.	4	9
8	Modelling of Biomedical Systems: Motor unit firing pattern, Cardiac rhythm, Formants and pitch of speech, Point process, Parametric system modelling, Autoregressive model, Autocorrelation method, Application to random signals, Computation of model parameters, Levinson-Durbin algorithm, Computation of gain factor, Covariance method, Spectral matching and parameterization, Model order selection, Relation between AR and Cepstral coefficients.	4	9
9	Modeling of Biomedical Systems & Tutorials: ARMA model, Sequential estimation of poles and zeros, Tutorial 1.1: Notch filter design, Tutorial 1.2: Synchronized averaging, Tutorial 1.3: Design Butterworth low pass filter.	4	9

10	Tutorials: Tutorial 2.1: Design derivative-based filter, Tutorial 2.2: Design Butterworth high pass filter, Tutorial 2.3: Design Wiener filter, Tutorial 3.1: Implement the Pan-Tompkins method for QRS detection.	**4**	**9**
11	Tutorials: Tutorial 3.2: Use cross-correlation to detect alpha rhythm, Tutorial 3.3: Design a matched filter, Tutorial 3.4: Pan-Tompkins method for QRS detection and the Lehner and Rangayyan method to detect dicrotic notch, Tutorial 4.1: Half wave and full wave rectification, Tutorial 4.2: RMS value calculation, Tutorial 4.3: Turns count calculation, Tutorial 4.4: RMS, Turns count and Zero-crossing rate calculations	**3**	**6**
12	Tutorials: Tutorial 4.5: Derive the Envelogram, Tutorial 4.6: RR interval and Form Factor calculations, Tutorial 5.1: Power spectrum calculations using different windows, Tutorial 5.2: Mean frequency and variance of PSD, Tutorial 5.3: Compute PSDs of Voiced, Unvoiced and Silent portion of sound signal, Tutorial 5.4: Compute mean frequency of PSDs and ratio of energies, Tutorial 5.5: Study the changes in the PSDs by varying window width, number of segments averaged, and type of the window used.	**3**	**6**
	Total	**45**	**100**

Reference Book:

1. "Biomedical Signal Processing: Principles and Techniques" by D.C. Reddy
2. "Biomedical Signal Analysis: A Case-Study Approach" by Rangaraj M. Rangayyan
3. "Bioelectrical Signal Processing in Cardiac and Neurological Applications" by Leif Sörnmo and Pablo Laguna

Suggested Course Practical List :

1. Acquisition and Basic Analysis of ECG, EEG, and EMG Signals
2. Artifact Removal with Time-Domain Filters
3. Frequency Domain Filtering and Notch Filter Design
4. Optimal Filtering with the Wiener Filter
5. Adaptive Filtering for Dynamic Noise Removal
6. QRS Complex Detection Using Pan-Tompkins Algorithm
7. Morphological and Correlation Analysis of ECG Signals
8. Envelope Extraction and Amplitude Demodulation
9. Frequency-Domain Analysis Using Periodogram and Spectral Estimation
10. Parametric Modeling and ARMA Model Application

List of Laboratory/Learning Resources Required:

1. NPTEL
2. Virtual Laboratory (vlab.co.in)

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