Department of Electronics and Communication Engineering Curriculum 2021

M.Tech Biomedical Engineering

Biomedical engineering is an exciting and emerging interdisciplinary field that combines engineering and life sciences. Due to the advanced developments in electronics and multicore processors, artificial intelligence plays a major role in medical sciences and its allied areas contributing to technological breakthrough. Machine learning based systems are on high demand in biomedical data processing and image analysis. Students pursuing the programme would be able to develop and implement algorithms for objective interpretation and analysis of biological data. The programme is intended to equip engineers with the skills, knowledge and jargon required to interact knowledgeably with medical practitioners so that both professions are benefitted.

The programme lays the foundation for career opportunities at reputed organizations including super-specialty hospitals, biomedical analytics and healthcare industries, research organizations, and top national and international institutions.

The salient features of the programme include

- Experienced domain-specific Faculty
- Excellent Infrastructure with fully Equipped Laboratories
- Machine Intelligence Research Laboratory
- Active mentoring by Amrita Institute of Medical Sciences, Kochi
- Student Publications
- Seminars / Expert Lectures / Webinars
- Integrated M.Tech + PhD Programmes
- International Program Opportunities
- Placements and Internships

The programme is equipped with facilities that provide a platform for students and research scholars to explore various equipment and software tools for the design and analysis of Biomedical systems. These include ECG and EEG trainer kits for real-time monitoring, Data Acquisition (DAQ) device that provides simultaneous analog inputs with digital I/O and counter measurements, and PCB design software package for analyzing, designing, and real time testing of Biomedical circuits and their PCB layouts.

The programme is supported by experienced faculty members with Doctoral degree from reputed institutions and solid industry/academic experience in various domains such as

- Biomedical Signal and Image Processing
- Machine Learning based Biomedical Analytics
- Biomedical Sensors and Transducers
- Biomedical Data Acquisition
- Multi-parameter Patient Monitoring
- Medical Robotics
- Artificial Intelligence for Healthcare

Department of Electronics and Communication Engineering
Curriculum 2021
M.Tech Biomedical Engineering

Program Educational Objectives (PEOs)

PO1	To create manpower in healthcare involving interdisciplinary domains of Electronics, Instrumentation and Computation
PO2	To enable state-of-the-art research potential in the emerging areas of Biomedical Signal Processing and Analytics
PO3	To exhibit professional competency and leadership qualities with harmonious blend of ethics leading to an integrated personality development

Program Outcomes (POs)

PO1	An ability to independently carry out research /investigation and development work to solve practical problems
PO2	An ability to write and present a substantial technical report/document
PO3	An ability to demonstrate a degree of mastery over the area as per the specialization of the program
PO4	An ability to use modern tools for engineering design problems, analyze the performance and optimize the systems-level approaches
PO5	An ability to engage in independent and life-long learning in the context of technological change and industrial demands

Semester -I

Type	Code	Course Name	Teaching Schemes			Credits
			L	T	P	
FC	21BM601	Embedded Computing and Programming	3	0	0	3
FC	21BM602	Machine Learning and Algorithm Design	3	0	0	3
FC	21BM603	Human Physiology	3	0	0	3
SC	21BM611	Biomedical Signal Processing	3	0	0	3
SC	21BM612	Biosensors and Instrumentation	3	0	0	3
SC	21BM681	Machine Learning and Embedded Programming Lab	0	0	4	2
SC	21BM682	Biomedical Signal Processing and Instrumentation Lab	0	0	4	2

HU	21HU601	Amrita Value Program				P/F
HU	21HU602	Career Competency- I				P/F
		Total	15	0	8	19

Semester -II

Type	Code	Course Name	Teaching Schemes			Credits
			L	T	P	
SC	21BM613	Medical Imaging Techniques and Processing	3	0	0	3
SC	21BM614	Medical Decision Support Systems	3	0	0	3
E		Elective-1	3	0	0	3
E		Elective-2	3	0	0	3
E		Elective-3	3	0	0	3
SC	21BM683	Medical Image Processing Lab	0	0	4	2
SC	21BM684	Bio-signal Analysis Lab	0	0	4	2
SC	21RM603	Research Methodology	2	0	0	2
HU	21HU603	Career Competency - II	0	0	2	1
		Total	17	0	10	22

Semester -III

Type	Code	Course Name	Teaching Schemes			Credits
			L	T	P	
E		Open Elective*	3	0	0	3
SC	21LIV607*	Open Lab / Live-in Lab	0	0	4	2
P	21BM798	Dissertation Phase -I	0	0	20	10
		Total	3	0	24	15

**21LIV607-Code for Live-in-Lab*

Department of Electronics and Communication Engineering Curriculum 2021

M.Tech Biomedical Engineering

**Open Elective can be either regular courses on campus or online portal based (NPTEL, Coursera, Udemy, Swayam, etc) with prior approval*

Semester -IV

Type	Code	Course Name	Teaching Schemes			Credits
			L	T	P	
P	21BM799	Dissertation Phase -II	0	0	28	14
		Total	0	0	28	14

Total Credits: 70

Program Specific Elective Courses

Domain Name: Biomedical Signal Processing

Sl.No	Code	Course Name	Teaching Schemes			Credits
			L	T	P	
1	21BM701	Biostatistics	3	0	0	3
2	21BM702	Multivariate Signal Processing	3	0	0	3
3	21BM703	Medical Image Analysis	3	0	0	3
4	21BM704	Video Processing and Analysis	3	0	0	3
5	21BM705	Speech and Audio Processing	3	0	0	3

Domain Name: Biomedical Instrumentation

Sl.No	Code	Course Name	Teaching Schemes			Credits
			L	T	P	
1	21BM711	Smart Materials and Sensors	3	0	0	3
2	21BM712	Microstructural Sensors	3	0	0	3
3	21BM713	Laser Instrumentation in Biomedical Applications	3	0	0	3
4	21BM714	Virtual Instrumentation for Medical Systems	3	0	0	3
5	21BM715	Biomedical Equipment and Safety	3	0	0	3

6	21BM716	BioMEMS	3	0	0	3

Domain Name: Artificial Intelligence

Sl.No	Code	Course Name	Teaching Schemes			Credits
			L	T	P	
1	21BM721	Computer Vision	3	0	0	3
2	21BM722	Pattern Recognition	3	0	0	3
3	21BM723	Bio-Inspired Computing	3	0	0	3
4	21BM724	Data Mining and Visualization Techniques	3	0	0	3
5	21BM725	Multisensor Data Fusion	3	0	0	3
6	21BM726	Medical Robotics	3	0	0	3

Domain Name: Healthcare systems

Sl.No	Code	Course Name	Teaching Schemes			Credits
			L	T	P	
1	21BM731	Wearable Biomedical Systems	3	0	0	3
2	21BM732	Computational Neuroscience	3	0	0	3
3	21BM733	Essentials of Telemedicine	3	0	0	3
4	21BM734	Brain Computer Interfacing	3	0	0	3
5	21BM735	IoT in Healthcare	3	0	0	3

Embedded Computing and Programming

21BM601 **3-0-0-3**

Learning Objectives

LO1 To introduce design concepts of embedded systems

LO2 To provide insights on embedded C programming for configuring microcontroller and peripherals

LO3 To enable development of embedded system models

Course Outcomes

CO1 Ability to identify the features of STM32F microcontroller

CO2 Ability to apply embedded C programming skills for configuring STM32F peripherals

CO3 Ability to analyze external peripheral interfacing with a microcontroller

CO4 Ability to design and develop embedded systems using STM32F microcontroller

CO-PO Mapping

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5

CO 1	-	-	-	-	-
CO 2	-	-	3	-	2
CO 3	-	-	3	-	2
CO 4	-	-	3	3	2

Skills acquired: Provide detailed insight on configuration and programming of various peripherals in STM32 Microcontroller

Course Contents

Unit 1: (15 hours)

STM32F Processor - Introduction to Embedded Systems - Introduction to ARM - Advanced RISC Features - Core Data path - Register Organization - System Architecture - Memory Organization - Low Power Modes - Power Control Registers - Backup Registers - Programming STM32F

Unit 2: (15 hours)

STM32F Peripherals - Introduction to Embedded C Programming - General Purpose Input Output - UART - ADC - DAC - Timers - Interrupts and Exceptions - PWM - SPI

Unit 3: (15 hours)

External Peripheral Interfacing - LCD - Keypad - Motor - Servo Motor - EEPROM - Seven Segment Interfacing - Sensor Interfacing

References

1. Muhammad Ali Mazidi, *STM32 Arm Programming for Embedded Systems*, 2019
2. Donald Norris, *Programming with STM32: Getting Started with the Nucleo Board and C/C++*, McGraw-Hill Education, 2018
3. *STM32F446xx advanced Arm®-based 32-bit MCUs, Reference Manual*, 2020

Evaluation Pattern:

Assessment	Internal	External
Periodical 1 (P1)	15	NA
Periodical 2 (P2)	15	NA
*Continuous Assessment (CA)	20	NA
End Semester	NA	50
Total	50	50

*CA - Can be Quizzes, Assignments, and Term Work with Report

Machine Learning and Algorithm Design

21BM602 **3-0-0-3**

Learning Objectives

LO1 To introduce the concepts and provide a mathematical foundation for developing machine learning models
LO2 To provide insights on the evaluation of machine learning models for various applications
LO3 To impart knowledge on algorithm design and its applications

Course Outcomes
CO1 Ability to understand concepts of machine learning and algorithm design
CO2 Ability to apply machine learning and algorithm design concepts for analysis of problems
CO3 Ability to analyze and process datasets using machine learning techniques for extracting useful information
CO4 Ability to design and implement machine learning models for the given task

CO-PO Mapping

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	-	-	2	-	-
CO 2	-	-	2	3	2
CO 3	-	-	2	3	2
CO 4	-	-	2	3	3

Skills Acquired: The design and programming ability in machine learning model development for a wide range of industrial applications

Course Contents
Unit 1: (15 hours)
Mathematical concepts review - Central tendency - Dispersion of data - Descriptive data summaries - k-nearest neighbor classifier - Bayes classifiers - Classifier performance measures

Unit 2: (15 hours)
Decision tree - Ensemble methods - Ordinary Least Squares - Artificial neurons - Perceptron - Multi Layer Perceptron and back propagation - Hyperparameter tuning - Cluster analysis - Partitioning methods - Hierarchical methods - Density-based methods - Cluster evaluation

Unit 3: (15 hours)
Graphs - Definitions and applications - Graph Connectivity - Graph Traversal - Testing Bipartiteness - Breadth - First Search - Directed graphs - Directed Acyclic Graphs Topological ordering - Interval scheduling - Optimal caching - Shortest paths - Minimum Spanning Tree - Clustering - Huffman Codes - Data Compression - Partitioning Problems - Graph Coloring

References

1. Jiawei Han, Micheline Kamber, Jian Pei, *Data Mining: Concepts and Techniques*, Third Edition, Morgan Kaufmann Publishers (Elsevier), 2011.
2. Aurélien Géron, *Hands-On Machine Learning with Scikit-Learn, Keras, and TensorFlow: Concepts, Tools, and Techniques to Build Intelligent Systems*, Second Edition, O'Reilly Media, 2019.
3. Earl Gose, Richard Johnson baugh, Steve Jost, *Pattern Recognition and Image Analysis*, Pearson EducationIndia, 2015
4. Jon Kleinberg, ÉvaTardos, *Algorithm Design*, Pearson, 2006

Evaluation Pattern:

Assessment	Internal	External
Periodical 1 (P1)	15	NA
Periodical 2 (P2)	15	NA
*Continuous Assessment (CA)	20	NA
End Semester	NA	50
Total	50	50

*CA - Can be Quizzes, Assignments, and Term Work with Report

Human Physiology

21BM603 **3-0-0-3**

Learning Objectives

LO1 To introduce the basic description of cells, tissues, organs and biological systems
LO2 To impart knowledge on the functioning of various organs and systems
LO3 To enable the biological concepts to biomedical signal analysis
LO4 To introduce the various aspects of ethical medical research

Course Outcomes

CO1 Ability to understand the importance of safeguarding medical data and patient/volunteer confidentiality
CO2 Ability to understand the anatomy, physiology, functions of various organs and disorders
CO3 Ability to apply the physiological concepts in modelling biomedical systems
CO4 Ability to analyze the functioning of various vital organs and systems

CO-PO Mapping

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	-	-	-	-	2
CO 2	-	-	2	-	2
CO 3	-	-	2	-	2
CO 4	-	-	3	-	3

Skills Acquired: The understanding of human physiology, biomedical signals and abnormalities

Course Contents

Unit 1: (15 hours)

Cell Physiology - Introduction to cell organelles - Bioelectric potentials - Neuro muscular system - Bone types - Nervous system - Sensory nervous system - Motor nervous system - Brain structure and its functions - Blood and lymph - Functions of blood - Blood groups - Hemostasis

Unit 2: (15 hours)

Circulatory system - Functional anatomy of the heart - Conducting system of the heart - Arterial and venous blood pressure - Gastro intestinal system - Gastric secretion - Pancreatic secretion - Renal physiology - Structure of kidney - Glomerular filtrate - Respiratory system - Mechanism of breathing - Regulation of respiration - Transport of gases - Hypoxia - Endocrinology - Endocrine glands - Hormones and their functions

Unit 3: (15 hours)

Medical Ethics - moral - Legal - Social - Religious and cultural contexts - Information and consent - Truthfulness -Voluntariness - Patient data confidentiality - End-of-Life Ethics - Genetics and biotechnology - Children and pregnant women - Clinical trials - Case studies - Regulatory compliance

References

1. Marieb, Elaine N, Wilhelm, Patricia Brady, Mallatt, Jon B, *Human anatomy*,

Pearson India education, 2016

2. Garry's, *Atlas of human anatomy*, Scientific International, 2018
3. Anne Waugh and Allison Grant, *Anatomy and Physiology in Health and Wellness*, twelfth edition, Elsevier, 2014
4. Marieb, Elaine N, *Essentials of human anatomy and physiology*, Pearson Education, 2006
5. Shamoo A and Resnik D B, *Responsible Conduct of Research*, Third Edition, Oxford University Press, 2015

6. Gopalakrishnan B, Khaute M, Bhat B S, Bhat S, Sastry S R, Kaur K, Menon M, Kamath A, Saha M, Sadhya M, *Reflections on Medical Law and Ethics in India*, First Edition, Eastern Law House, 2016

Evaluation Pattern:

Assessment	Internal	External
Periodical 1 (P1)	15	NA
Periodical 2 (P2)	15	NA
*Continuous Assessment (CA)	20	NA
End Semester	NA	50
Total	50	50

*CA - Can be Quizzes, Assignments, and Term Work with Report

Biomedical Signal Processing

21BM611 **3-0-0-3**

Learning Objectives

LO1 To introduce characteristics of biomedical signals
LO2 To provide understanding of artifact removal in biomedical signals
LO3 To enhance knowledge in event detection and waveform analysis of biomedical signals
LO4 To provide insight on pattern classification in biomedical signals

Course Outcomes

CO1 Ability to understand concepts of signal processing
CO2 Ability to apply algorithms for signal processing
CO3 Ability to analyze biomedical signals and systems
CO4 Ability to evaluate biomedical signal processing systems

CO-PO Mapping

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	-	-	2	2	3
CO 2	-	-	3	3	3
CO 3	-	-	3	3	3
CO 4	-	-	3	3	3

Skills Acquired: Implementation of algorithms for processing and analyzing biomedical signals

Course Contents

Unit 1: (15 hours)

Introduction to biomedical signals - Electrocardiography (ECG) - Electroencephalography (EEG) - Electromyography (EMG) - Challenges in biomedical signal acquisition and analysis - Need for Computer Aided Diagnosis (CAD) - Types of noise - Random noise -

Structured noise - Physiological interference - Linear time-invariant filters - Time domain filters - Synchronized averaging - Moving average filters - Derivative based filters

Unit 2: (15 hours)

Transform domain analysis of signals and systems - Discrete Fourier Transform (DFT) and its properties - Pole-zero plot - Time-frequency analysis - Short-Time Fourier Transform (STFT) - Wavelet Transform - Frequency domain filters - Filter design - Butterworth filters - Notch and comb filters - Event detection - Analysis of waveshape and waveform complexity - Morphological analysis - Envelope extraction and analysis - Feature extraction

Unit 3: (15 hours)

Pattern classification and diagnostic decision - Supervised and Unsupervised Pattern Classification - Discriminant, distance and likelihood functions - Logistic regression - Neural networks - Measures of diagnostic accuracy and cost - Receiver operating characteristics - Case studies - Removal of artifacts - QRS Detection and classification of ectopic beats in ECG signals - Detection of epileptic seizures in EEG signals - Study of muscular contraction using parametric analysis of EMG signals

References

1. Rangayyan, Rangaraj M, *Biomedical signal analysis*, John Wiley & Sons, 2015
2. Subasi, Abdulhamit. *Biomedical signal analysis and its usage in healthcare in Biomedical Engineering and its Applications in Healthcare*, pp. 423-452. Springer, 2019
3. Devasahayam, S.R., *Signals and systems in biomedical engineering: signal processing and physiological systems modeling*. Springer Science & Business Media, 2012
4. Haykin, Simon, and Barry Van Veen, *Signals and systems*, John Wiley & Sons, 2007

Evaluation Pattern:

Assessment	Internal	External
Periodical 1 (P1)	15	NA
Periodical 2 (P2)	15	NA
*Continuous Assessment (CA)	20	NA
End Semester	NA	50
Total	50	50

*CA - Can be Quizzes, Assignments, and Term Work with Report

Biosensors and Instrumentation

21BM612 **3-0-0-3**

Learning Objectives

LO1 To introduce the operation of biosensors
LO2 To provide understanding on characterization techniques of biosensors
LO3 To impart knowledge on Lab-on-a-Chip concepts

LO4 To provide insight on different medical instrumentation devices

Course Outcomes

CO1 Ability to understand the working principles of biosensors
CO2 Ability to characterize optical and electrochemical sensors
CO3 Ability to analyze the response of biosensors
CO4 Ability to evaluate the medical instrumentation devices

CO-PO Mapping

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	-	-	3	-	-
CO 2	-	-	3	-	-
CO 3	-	-	3	-	2
CO4	-	-	3	-	2

Skills Acquired: Characterization of biosensors and assessment of instrumentation in biomedical applications

Course Contents

Unit 1: (15 hours)

Introduction to biosensor - Classification based on the signal transduction and biorecognition element - Enzymatic and non-enzymatic sensors - DNA and protein based sensors - Immunosensors - Principle - Fabrication and working of optical biosensors - Direct and indirect detectors - Surface plasmon - Electroluminescence

Unit 2: (15 hours)

Electrochemical biosensors - Construction and working of potentiometric - Amperometric and impedemetric sensors - Development and applications of piezoelectric sensors - Electrochemical sensors for glucose - Vitamins - Cholesterol - Dopamine - Biochips and electrochemical microarrays - Lab-on-a-chip - Biosensing using nanomaterials - Biocompatibility of sensors - PCR Principles

Unit 3: (15 hours)

Implantable cardiac pacemakers - Defibrillators - External defibrillators - Clinical defibrillators - Implantable defibrillators - Implantable stimulators for neuro muscular control - Mechanical ventilation - Electrosurgical devices - Blood glucose monitoring sensors - Telemedicine - Prerecorded telemedicine - Real time telemedicine - Case study - Product development - Pulse oximeter - Ventilators

References

1.Zhang X, Ju H and Wang J, *Electrochemical Sensors, Biosensors and Their Biomedical Applications*, Academic Press, 2008
2.Grundler P, *Chemical Sensors -An Introduction for Scientists and Engineers*, Springer Verlag, 2007
3.Rasooly A and Herold K E (Eds), *Biosensors and Biodetection: Methods and Protocols,*

Volume 503: Optical-Based Detectors, Springer-Verlag, 2009

4. Donald R. Peterson, Joseph D. Bronzino, *Medical Devices and Human Engineering* 2017

5. Richard Wootton, John Craig, Victor Patterson, *Introduction to Telemedicine*, Second Edition, 2017

6. Oruganti Venkata, S., Koenig, A. and Pidaparti, R., 2021. *Mechanical Ventilator Parameter Estimation for Lung Health through Machine Learning*, Bioengineering, 8(5), p.60.

7. C. Phillips, D. Liaqat, M. Gabel and E. de Lara, *WristO2: Reliable Peripheral Oxygen Saturation Readings from Wrist-Worn Pulse Oximeters*, 2021 IEEE International Conference on Pervasive Computing and Communications Workshops and other Affiliated Events (PerCom Workshops), 2021, pp. 623-629.

Evaluation Pattern:

Assessment	Internal	External
Periodical 1 (P1)	15	NA
Periodical 2 (P2)	15	NA
*Continuous Assessment (CA)	20	NA
End Semester	NA	50
Total	50	50

*CA - Can be Quizzes, Assignments, and Term Work with Report

Machine Learning and Embedded Programming Lab

21BM681 **0-0-4-2**

Learning Objectives

LO1 To provide design concepts on implementation of Embedded Systems
LO2 To provide insight on communication protocols used in embedded domain
LO3 To demonstrate peripheral configuration of a microcontroller platform
LO4 To provide insights into design and implementation of machine learning algorithms

Course Outcomes

CO1 Ability to interface external peripherals with a programmable platform
CO2 Ability to implement and analyze serial communication protocol
CO3 Ability to design and implement embedded system or machine learning based solutions for a specific application
CO4 Ability to analyze and optimize the performance of the given machine learning model

CO-PO Mapping

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	2	-	2	3	2
CO 2	2	-	2	3	2
CO 3	3	3	3	3	3
CO 4	3	3	2	3	3

Skills Acquired: Programming ability in embedded system design and machine learning model development for a wide range of applications.

Lab Course Contents

Ex.No.	Experiment details
1	General purpose input output configuration and programming
2	LCD and keypad interfacing
3	Universal asynchronous receiver and transmitter (UART) configuration and programming
4	Analog to digital conversion (ADC) peripheral configuration and programming
5	Timer configuration and programming
6	PWM generation and motor speed control
7	Design and implementation of a Bayes classifier for two-class and multi-class classification
8	Design and implementation of an MLP based Artificial Neural Network Model for classification or regression
9	Design and implementation of a deep learning classifier model using transfer learning
10	Design and implementation of a simple DAG Network for deep learning
11	Design and implementation of clustering algorithms
12	Determining the Bipartiteness of a graph using search algorithms

Recommended Tools

STM32CubeMX, Keil µVision, MATLAB, Python

References

1. Muhammad Ali Mazidi, *STM32 Arm Programming for Embedded Systems*, 2019
2. Donald Norris, *Programming with STM32: Getting Started with the Nucleo Board and C/C++*, McGraw-Hill Education, 2018
3. *STM32F446xx advanced Arm®-based 32-bit MCUs, Reference Manual*, 2020
4. Aurélien Géron, *Hands-On Machine Learning with Scikit-Learn, Keras, and TensorFlow: Concepts, Tools, and Techniques to Build Intelligent Systems*, 2nd Edition, O'Reilly Media, 2019

Evaluation Pattern:

Assessment	Internal	External
*Continuous Assessment (CA)	70	NA
End Semester	NA	30
Total	70	30

*CA - Based on Lab Experiments, and Term Work with Report

Biomedical Signal Processing and Instrumentation Lab

21BM682 **0-0-4-2**

Learning Objectives

LO1 To introduce practical aspects of data acquisition
LO2 To enable design of biomedical signal conditioning circuits
LO3 To provide hands-on experience in filtering of biomedical signals
LO4 To enhance practical knowledge in biomedical signal analysis

Course Outcomes

CO1 Ability to apply algorithms for signal processing
CO2 Ability to analyze biomedical signals and systems
CO3 Ability to design and implement biomedical signal conditioning circuits
CO4 Ability to evaluate biomedical signal acquisition and processing systems

CO-PO Mapping

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	2	2	2	3	3
CO 2	3	3	2	3	2
CO 3	3	3	3	3	3
CO 4	3	3	3	3	3

Skills Acquired: ○ Ability to design and implement signal conditioning circuits for biomedical signals ○ Programming ability towards implementation of algorithms for processing and analyzing biomedical signals

Lab Course Contents

Ex.No.	Experiment details
1	Design and implementation of amplification circuits
2	Filter design and hardware implementation
3	Analogue front end of biomedical system
4	Real time acquisition of bio-signals
5	Digital signal processing - Basic operations
6	Time domain filtering
7	Discrete Fourier Transform (DFT)
8	Frequency domain filtering
9	Artifact removal in bio-signals
10	Waveform analysis and feature extraction from bio-signals

11	Pattern classification in bio-signals

Recommended Tools MATLAB,
Python

References

1. Subasi, A., *Practical guide for biomedical signals analysis using machine learning techniques: A MATLAB based approach*. Academic Press, 2019
2. Blinowska, Katarzyn J., and Jaroslaw Zygierewicz. *Practical biomedical signal analysis using MATLAB®*. CRC Press, 2011
3. Subasi, Abdulhamit. "Biomedical signal analysis and its usage in healthcare." In *Biomedical Engineering and its Applications in Healthcare*, pp. 423-452. Springer, Singapore, 2019
4. Rangayyan, Rangaraj M, *Biomedical signal analysis*, John Wiley & Sons, 2015
5. Adel S. Sedra, Dean Emeritus Adel S Sedra, *Microelectronic Circuits*, 2011
6. John G. Webster, Amit J Nimunkar, *Medical Instrumentation Application and Design*, Wiley publications, 2020

Evaluation Pattern:

Assessment	Internal	External
*Continuous Assessment (CA)	70	NA
End Semester	NA	30
Total	70	30

*CA - Based on Lab Experiments, and Term Work with Report

Medical Imaging Techniques and Processing

21BM613 **3-0-0-3**

Learning Objectives

LO1 To provide understanding of medical imaging modalities
LO2 To impart the concepts of image processing and its applications
LO3 To enable the feature analysis in biomedical images
LO4 To comprehend the applications of biomedical image processing

Course Outcomes

CO1 Ability to understand the operation of various imaging techniques
CO2 Ability to apply different techniques employed for the enhancement of images
CO3 Ability to analyze the various features from biomedical images
CO4 Ability to evaluate the performances of image processing algorithms

CO-PO Mapping

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	-	-	3	-	3
CO 2	-	-	3	3	3
CO 3	-	-	3	3	3
CO 4	-	-	2	2	2

Skills Acquired: Implementing algorithms for processing and analyzing medical images

Course Contents

Unit 1: (15 hours)

Objectives of biomedical image analysis - Computer aided diagnosis - Nature of medical images: X-ray imaging - Tomography - Nuclear medicine imaging - SPECT imaging - Positron imaging tomography - Ultrasonography - Magnetic resonance imaging - Removal of artifacts - Image Enhancement - Gray level transforms - Histogram transformation

Unit 2: (15 hours)

Spatial domain filters - Frequency domain filters - Morphological image processing - Binary morphological operations and properties - Morphological algorithms - Thresholding - Region growing - Region splitting and merging - Edge detection

Unit 3: (15 hours)

Analysis of shape and texture - Representation of shapes and contours - Shape factors - Models for generation of texture - Statistical analysis of texture - Fractal analysis - Fourier domain analysis of texture - Applications - Contrast enhancement of mammograms - Detection of calcifications by region growing - Shape and texture analysis of tumors

References

1. Rangayyan R M, *Biomedical Image Analysis*, Fifth Edition, CRC Press, 2005
2. Gonzalez R C, Woods R E, *Digital Image Processing*, Third Edition, Prentice Hall, 2007
3. Meyer-Baese A, *Pattern Recognition and Signal Analysis in Medical Imaging*, Academic Press, Second Edition, 2014
4. Sinha G. R, Patel, B. C., *Medical Image Processing: Concepts and Applications*, Prentice Hall, 2014
5.Andreas Maier, Stefan Steidl, Vincent Christlein, Joachim Hornegger, *Medical Imaging Systems - An Introductory Guide*, Lecture Notes in Computer Science, Springer 2018

Evaluation Pattern:

Assessment	Internal	External
Periodical 1 (P1)	15	NA
Periodical 2 (P2)	15	NA
*Continuous Assessment (CA)	20	NA
End Semester	NA	50
Total	50	50

*CA - Can be Quizzes, Assignments, and Term Work with Report

Medical Decision Support Systems

21BM614 **3-0-0-3**

Learning Objectives

LO1 To introduce the concepts of medical decision support systems
LO2 To provide an insight on deep learning architectures
LO3 To impart knowledge on application of deep learning for biomedical problems

Course Outcomes

CO1 Ability to understand the concepts of medical decision support systems
CO2 Ability to apply deep learning techniques to process biomedical data
CO3 Ability to analyze biomedical problems using deep learning architectures CO4
Ability to implement deep learning models for medical diagnosis

Skills Acquired: Implementation of deep learning models for medical decision support

CO-PO Mapping

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	-	-	2	2	2
CO 2	-	-	2	3	2
CO 3	-	-	2	3	2
CO 4	-	-	2	3	3

Course Contents

Unit 1: (15 hours)

Artificial Intelligence and Decision support systems - Deep Learning architectures Convolutional Neural Networks (CNN) - Recurrent Neural Networks (RNN) - Autoencoders - Deep Neural Network (DNN) - Deep Belief Network (DBN) - Long Short-Term Memory (LSTM)

Unit 2: (15 hours)

Applications of deep learning concepts for medical diagnosis - Early diagnosis of heart diseases - ECG Heartbeat classifier - Heart sound analysis using PCG - EEG characterization - Diagnosing Parkinson’s and Alzheimer's diseases

Unit 3: (15 hours)

Simulation of biomedical signals and images - Diagnosing diabetic retinopathy - Gene expression prediction - Protein structure classification - Psychological personal support system - Deep Learning techniques for optimizing medical data

References

1. Kose, Utku, Omer Deperlioglu, JafarAlzubi, and Bogdan Patrut. *Deep learning for medical decision support systems*. Springer, 2020

2. Basant Agarwal, Valentina Emilia Balas, Lakshmi CJ Jain, Ramesh chandrapoonia, Manisha, *Deep Learning for biomedical and health informatics*, Academic press, Elsevier 2020
3. Ian Goodfellow, YoshuaBengio, Aaron Courville, *Deep Learning*, MIT Press, 2016 4. Christopher M. Bishop, *Pattern Recognition and Machine Learning*, Springer, 2006
5. Cao, Chensi, Feng Liu, Hai Tan, Deshou Song, Wenjie Shu, Weizhong Li, Yiming Zhou, Xiaochen Bo, and Zhi Xie., *Deep learning and its applications in biomedicine*, Genomics, proteomics & bioinformatics 16, no. 1, 17-32, 2018.

Evaluation Pattern:

Assessment	Internal	External
Periodical 1 (P1)	15	NA
Periodical 2 (P2)	15	NA
*Continuous Assessment (CA)	20	NA
End Semester	NA	50
Total	50	50

*CA - Can be Quizzes, Assignments, and Term Work with Report

Medical Image Processing Lab

21BM683 **0-0-4-2**

Learning Objectives

LO1 To provide exposure and knowledge on various medical images
LO2 To enable hands-on experience in the processing of biomedical images
LO3 To provide knowledge on feature extraction techniques for medical images
LO4 To develop the skill set for higher learning in image processing

Course Outcomes

CO1 Ability to apply algorithm for analyzing medical images
CO2 Ability to analyze the extracted features from different biomedical images CO3 Ability to evaluate the performance metrics in biomedical images

CO-PO Mapping

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	3	2	2	3	2
CO 2	3	3	3	3	3
CO 3	3	2	2	3	-

Skills Acquired: Programming ability in processing and analysis of medical images

Lab Course Contents

Ex.No.	Experiment details
1	Basic operations on images
2	Image enhancement using point operations

3	Image enhancement using spatial domain filters
4	Histogram processing of images
5	Image enhancement using frequency domain filters
6	Denoising of medical images
7	Medical image segmentation using edge and region-based methods
8	Extraction of shape and texture features from a medical image
9	Design of pattern classification system for biomedical images
10	Performance metrics in bioimages

Recommended Tools MATLAB,
Python

References

1. Chris Soloman, Toby Breckon, *Fundamentals of Digital Image Processing: A Practical Approach with examples in Matlab*, Wiley-Blackwell, 2010
2. Rafael C. Gonzalez, Richard Eugene Woods, Steven L. Eddins, *Digital Image Processing using Matlab*, Pearson Education India, 2004.
3. Sinha G. R, Patel, B. C., *Medical Image Processing: Concepts and Applications*, Prentice Hall, 2014
4. Chityala, Ravishankar; Pudipeddi, Sridevi, *Image Processing and Acquisition using Python*, CRC Press 2020

Evaluation Pattern:

Assessment	Internal	External
*Continuous Assessment (CA)	70	NA
End Semester	NA	30
Total	70	30

*CA - Based on Lab Experiments, and Term Work with Report

Bio-signal Analysis Lab

21BM684 **3-0-0-3**

Learning Objectives

LO1 To introduce practical aspects of deep learning
LO2 To provide an insight on implementation of deep learning architectures
LO3 To provide knowledge on application of deep learning for biomedical problems

Course Outcomes

CO1 Ability to apply deep learning architectures for univariate and multivariate data
CO2 Ability to analyze biomedical data using feature extraction techniques CO3 Ability to evaluate deep learning models for medical diagnosis

CO-PO Mapping

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	2	2	2	2	2
CO 2	3	2	2	3	3
CO 3	3	3	3	3	3

Skills Acquired: Implementation of deep learning models for medical diagnosis

Lab Course Contents

Ex.No.	Experiment details
1	Implementation of CNN
2	Implementation of LSTM
3	Implementation of stacked autoencoders
4	Feature extraction of biomedical signals
5	Image encoding of biomedical signals
6	Simulation of biomedical signals
7	Dimensionality reduction of Biomedical signals using autoencoders
8	ECG analysis using CNN
9	Time series forecasting of ECG signal using LSTM
10	EEG analysis using CNN
11	Diagnosing diabetic retinopathy using CNN

Recommended Tools
Python, Matlab

References

1. Jiawei Han, Micheline Kamber, Jian Pei, *Data Mining: Concepts and Techniques*, Third edition, Morgan Kaufmann Publishers (Elsevier), 2011.
2. AurélienGéron, *Hands-On Machine Learning with Scikit-Learn, Keras and TensorFlow: Concepts, Tools, and Techniques to Build Intelligent Systems*, Second eition, O'Reilly Media, 2019
3. Earl Gose, Richard Johnsonbaugh, Steve Jost, *Pattern Recognition and Image Analysis*, Pearson Education India, 2015.
4. Jon Kleinberg, ÉvaTardos, *Algorithm Design*, PearsonEducation, 2006

Evaluation Pattern:

Assessment	Internal	External
*Continuous Assessment (CA)	70	NA
End Semester	NA	30
Total	70	30

*CA - Based on Lab Experiments, and Term Work with Report

RESEARCH METHODOLOGY

21RM603 **2-0-0-2**

Learning Objectives

LO1 To enable defining and formulating research approaches towards obtaining solutions to practical problems
LO2 To facilitate development of scientific oral and written communication skills LO3 To comprehend the concepts behind adhering to scientific ethics and values

Course Outcomes
CO1 Ability to understand some basic concepts of research and its methodologies
CO2 Ability to define and apply appropriate parameters and research problems
CO3 Ability to develop skills to draft a research paper
CO4 Ability to analyse and comprehend the ethical practices in conducting research and dissemination of results in different forms

CO-PO Mapping

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	2	2	3	-	2
CO 2	2	2	2	-	2
CO 3	3	2	3	-	3
CO4	3	2	2	3	3

Skills Acquired: Design, analyse and conduct research and comprehend the results.

Course Contents

Meaning of research - Types of research - Research process - Problem definition - Objectives of research - Research questions - Research design - Approaches to research - Quantitative vs. qualitative approach - Understanding theory - Building and validating theoretical models - Exploratory vs. confirmatory research - Experimental vs theoretical Research - Importance of reasoning in research

Problem formulation - Understanding modeling & simulation - Conducting literature review - Referencing - Information sources - Information retrieval - Role of libraries in information retrieval - Tools for identifying literatures - Indexing and abstracting services - Citation indexes

Experimental research - Cause effect relationship - Development of hypothesis - Measurement systems analysis - Error propagation - Validity of experiments - Statistical design of experiments - Field experiments - Data/Variable types & classification - Data collection - Numerical and graphical data analysis - Sampling - Observation - Surveys - Inferential statistics and interpretation of results

Preparation of dissertation and research papers - Tables and illustrations - Guidelines for writing the abstract, introduction, methodology, results and discussion, conclusion sections of a manuscript - References, citation and listing system of documents

Intellectual property rights (IPR) - Patents - Copyrights - Trademarks - Industrial design geographical indication - Ethics of research - Scientific misconduct - Forms of scientific misconduct - Plagiarism - Unscientific practices in thesis work - Ethics in science

References

1. Bordens, K. S. and Abbott, B. B., Research Design and Methods - A Process Approach, 8th Edition, McGraw-Hill, 2011.
2. C. R. Kothari, Research Methodology - Methods and Techniques, 2nd Edition, New Age International Publishers.
3. Davis, M., Davis K., and Dunagan M., Scientific Papers and Presentations, 3rd Edition, Elsevier Inc.
4. Michael P. Marder, Research Methods for Science, Cambridge University Press, 2011.
5. T. Ramappa, Intellectual Property Rights Under WTO, S. Chand, 2008.
6. Robert P. Merges, Peter S. Menell, Mark A. Lemley, Intellectual Property in New Technological Age. Aspen Law & Business; 6th Edition July 2012.
7. Tony Greenfield and Sue Greener., Research Methods for Postgraduates, 3rd Edition, John Wiley & Sons Ltd., 2016.

Evaluation Pattern:

Assessment	Internal	External
Periodical 1 (P1)	15	NA
Periodical 2 (P2)	15	NA
*Continuous Assessment (CA)	20	NA
End Semester	NA	50
Total	50	50

*CA - Can be Quizzes, Assignments, and Term Work with Report

21xxxxx/21LIV602 OPEN LAB / LIVE-IN LAB 0-0-4-2

Learning Objectives

LO1 To enable the students to acquire independent research aptitude.
LO2 To provide a platform to utilize the existing facilities / tools to address socially relevant problems.
LO3 To facilitate the design and development of a proof of concept system.

Course Outcomes

CO1 Ability to understand the research needs to address practical problems.
CO2 Ability to define and apply relevant concepts to the research problem.
CO3 Ability to develop a proof-of-concept system.
CO4 Ability to evaluate and analyse the results for further improvement.

CO-PO Mapping

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	2	-	3	-	3

CO 2	2	-	3	-	3
CO 3	2	3	3	3	-
CO4	2	3	3	3	-

Skills Acquired: ○ Ability to understand the research needs.
○ Develop a meaningful proof of concept system.

Course Contents

Design and development of a proof-of-concept system for the chosen problem

Evaluation Pattern:

Assessment	Internal	External
*Continuous Assessment (CA)	70	NA
End Semester	NA	30
Total	70	30

*CA - Based on Lab Experiments, and Term Work with Report

DISSERTATION PHASE I

21BM798 **0 0 20 10**

Learning Objectives

LO1 To impart knowledge of computational and electronic concepts in Biomedical Engineering

LO2 To provide a platform for innovations in Biomedical Engineering

LO3 To facilitate the identification of the state-of-the-art research challenges in Biomedical Engineering

Course Outcomes

CO1 Ability to define a research problem

CO2 Ability to apply mathematical concepts to the research problem

CO3 Ability to design and conduct independent research in the domain of interest CO4 Ability to evaluate and analyze the outcomes of the research

CO-PO Mapping

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	3	3	3	-	-
CO 2	3	3	3	3	3
CO 3	3	3	3	3	3

CO4	3	3	3	-	3

Skills Acquired:
- Design and perform independent research.
- Evaluate and analyze the outcomes of the research.

Course Contents

Problems and concepts may be defined based on extensive literature survey by standard research articles - Significance of proposed problem and the state-of the art to be explored - Industry relevant tools may be used for demonstrating the results with physical meaning and create necessary research components - Publications in reputed journals and conferences may be considered for authenticating the results

Evaluation Pattern:

Assessment	Internal	External
*Continuous Assessment (CA)	70	NA
End Semester	NA	30
Total	70	30

*CA - Can be Periodical Reviews, Demonstrations and Reports

DISSERTATION PHASE II

21BM799 **0 0 28 14**

Learning Objectives

LO1 To impart knowledge of computational and electronic concepts in Biomedical Engineering

LO2 To provide a platform for innovations in Biomedical Engineering

LO3 To facilitate the identification of the state-of-the-art research challenges in Biomedical Engineering

Course Outcomes

CO1 Ability to define a research problem

CO2 Ability to apply mathematical concepts to the research problem

CO3 Ability to design and conduct independent research in the domain of interest CO4 Ability to evaluate and analyze the outcomes of the research

CO-PO Mapping

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	3	3	3	-	-
CO 2	3	3	3	3	3
CO 3	3	3	3	3	3
CO 4	3	3	3	-	3

Skills Acquired:

- Design and perform independent research.
- Evaluate and analyze the outcomes of the research.

Course Contents

Problems and concepts may be defined based on extensive literature survey by standard research articles - Significance of proposed problem and the state-of the art to be explored - Industry relevant tools may be used for demonstrating the results with physical meaning and create necessary research components - Publications in reputed journals and conferences may be considered for authenticating the results

Evaluation Pattern:

Assessment	Internal	External
*Continuous Assessment (CA)	70	NA
End Semester	NA	30
Total	70	30

*CA - Can be Periodical Reviews, Demonstrations and Reports

Biostatistics

21BM701 **3-0-0-3**

Learning Objectives

LO1 To enable understanding of basic concepts of biostatistics
LO2 To provide insight on descriptive statistics
LO3 To provide understanding of interval estimation and hypothesis testing
LO4 To impart knowledge on statistical tools and inferential analysis of data

Course Outcomes

CO1 Ability to understand the concepts of biostatistics
CO2 Ability to apply probability and random variables for data analysis
CO3 Ability to analyze experimental and observational data for modelling correlations
CO4 Ability to evaluate assumptions of population parameters using hypothesis testing

CO-PO Mapping

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	-	-	3	2	-
CO 2	-	-	3	-	-
CO 3	-	-	3	3	-
CO 4	-	-	3	3	2

Skills Acquired: Statistical analysis and hypothesis testing provide the needed skills to critically analyze the results of observations and experiments conducted

Course Contents

Unit 1: (15 hours)

Observational data - Random sampling - Measures of central tendency - Measures of variability and dispersion - Population parameters and sample statistics - Sampling and statistical inference- Descriptive statistics - Data types - Frequency and cumulative frequency distributions - Box plots - Scatter plots

Unit 2: (15 hours)

Probabilities - Conditional probabilities - Bayes theorem - Probability distributions Poisson - Binomial - Normal - Random variables - Functions of random variables - Expectations Moments - Joint distribution functions - Mean - Variance - Covariance - Correlation and linear regression

Unit 3: (15 hours)

Hypothesis tests - Test on a single mean - Test of equality of two means - Test on a single variance - Test of equality of two variances - Test of a single proportion - Test of equality of two proportions - Analysis of Variance (ANOVA) - Case study - Biostatistics in seizure detection

References

1.Ramachandran, Kandethody M, and Chris P. Tsokos, *Mathematical statistics with applications in R*, Third Edition, Academic Press, 2020

2.Zar, Jerrold H, *Biostatistical analysis*, Fifth Edition, Prentice Hall, India, 2010

3. Glantz S.A, *Primer of Biostatistics*, Seventh Edition, McGraw-Hill Medical Pub, New York, 2011

4. Daniel W.W, *Biostatistics :Basic Concepts and Methodology for the Health Sciences*, Ninth Edition, Wiley India Pvt. Ltd, New Delhi, 2010

Evaluation Pattern:

Assessment	Internal	External
Periodical 1 (P1)	15	NA
Periodical 2 (P2)	15	NA
*Continuous Assessment (CA)	20	NA
End Semester	NA	50
Total	50	50

*CA - Can be Quizzes, Assignments, and Term Work with Report

Multivariate Signal Processing

21BM702 **3-0-0-3**

Learning Objectives

LO1 To provide basic concepts of multivariate signals

LO2 To impart knowledge on statistical analysis of multivariate time series data

LO3 To introduce time and spectral domain approaches for analyzing multivariate biomedical data

Course Outcomes

CO1 Ability to understand the basics of multivariate signal processing
CO2 Ability to apply statistical analysis for mutivariate time series data
CO3 Ability to analyze multi-domain features of Biomedical signals
CO4 Ability to evaluate performance of multivariate signal processing algorithms

CO-PO Mapping

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	-	-	2	2	2
CO 2	-	-	2	2	2
CO 3	-	-	3	2	3
CO 4	-	-	3	3	3

Skills Acquired: The application of multivariate signal processing aids in understanding of wide range of biomedical signal analysis

Course Contents

Unit 1: (15 hours)

Concept of random variables - Stochastic processes - Relations among random variables - correlation, multiple correlation and partial correlation - Univariate and multivariate Gaussian distributions - Univariate Time Series - Time domain approach - Frequency domain approach

Unit 2: (15 hours)

Time series models - AR Models, ARMA Models - Multivariate Time Series - Time domain approach and spectral domain approach - Assessing relations among time series in the spectral domain - Data based estimation versus model based estimation - Principal Component Analysis (PCA) - Signal decorrelation - Independent Component Analysis (ICA)

Unit 3: (15 hours)

Data compression of EEG and ECG signals - EMG Source signal separation techniques - EEG signal separation and Pattern Classification - Correlation of Biomedical signals - Evaluating causal relations in biomedical systems - Case studies - ICA based analysis on neurological disorders using EEG - Deep learning based arrhythmia classification using EEG

References:

1.William W. S. Wei, *Multivariate Time Series Analysis and Applications*, Wiley, 2019
2.Katarzyn Blinowska, Jaroslaw Zygierewicz, *Practical Biomedical Signal Analysis Using MATLAB -Multiple channels (multivariate) signal,* CRC press, 2011
3. Johnson, *Applied Multivariate Statistical Analysis*, PHI publisher, 2012
4. Jocelyn Chanussot, Jocelyn Chanussot, Kacem Chehdi, *Multivariate Image processing*, Wile Publication, 2009

Evaluation Pattern:

Assessment	Internal	External
Periodical 1 (P1)	15	NA
Periodical 2 (P2)	15	NA
*Continuous Assessment (CA)	20	NA
End Semester	NA	50
Total	50	50

*CA - Can be Quizzes, Assignments, and Term Work with Report

Medical Image Analysis

21BM703 **3-0-0-3**

Learning Objectives

LO1 To provide an overview on various image analysis for biomedical applications
LO2 To enable an understanding of various image restoration methods
LO3 To provide knowledge on various feature extraction methods and classification algorithms
LO2 To impart basic knowledge on image registration and image fusion

Course Outcomes

CO1 Able to understand the image registration techniques
CO2 Able to apply image restoration for medical imaging applications
CO3 Able to analyse the performance of classification models
CO4 Able to pursue research in image analysis and applications

CO-PO Mapping

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	-	-	3	2	2
CO 2	-	-	3	2	2
CO 3	-	-	3	3	3
CO 4	-	-	3	3	3

Skills Acquired: Programming ability towards implementation of various image processing techniques for a wide range of real life biomedical applications

Course Contents

Unit 1: (15 hours)

Medical Image Registration - Linear transformation - Non-linear transformation - Non-rigid transformation - Feature-based and voxel-based registration - Applications - Analysis of bilateral asymmetry in mammograms

Unit 2: (15 hours)
Image Restoration - Spatial filtering - Frequency domain filtering - Inverse filtering - Wiener Filtering - Constrained least squares filtering - Applications - Restoration of Nuclear Medicine and SPECT images

Unit 3: (15 hours)
Global Descriptors - Local Descriptors - SIFT - HOG - MSER - Machine learning for Medical Image Analysis - Support Vector Machine - Artificial Neural Networks - Deep learning - Case study - Mammogram tissue characterization and classification

References

1. Rangayyan R M, *Biomedical Image Analysis*, Fifth Edition, CRC Press, 2005
2. Gonzalez R C and Woods R E, *Digital Image Processing*, Third Edition, Prentice Hall, 201
3. Milan Sonka, Vaclav Hlavac and Roger Boyle, *Image Processing, Analysis and Machin Vision*, Third Edition, Cengage Learning, 2007
4. A. Ardheshir Goshtasby, *2-D and 3-D Image Registration for Medical, Remote Sensing, and Industrial Applications*, John Wiley and Sons, 2005

Evaluation Pattern:

Assessment	Internal	External
Periodical 1 (P1)	15	NA
Periodical 2 (P2)	15	NA
*Continuous Assessment (CA)	20	NA
End Semester	NA	50
Total	50	50

*CA - Can be Quizzes, Assignments, and Term Work with Report

Video Processing and Analysis

21BM704 **3-0-0-3**

Learning Objectives

LO1 To familiarize techniques for video filtering
LO2 To provide knowledge on motion estimation and segmentation
LO3 To introduce concepts of video indexing and retrieval
LO4 To provide insights on biomedical applications of video processing

Course Outcomes

CO1 Ability to understand fundamentals of video signal processing

CO2 Ability to apply video processing algorithms CO3
Ability to analyze biomedical video signals
CO4 Ability to evaluate video processing systems

CO-PO Mapping

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	-	-	2	2	2
CO 2	-	-	2	3	3
CO 3	-	-	3	3	3
CO 4	-	-	3	3	3

Skills Acquired: Programming ability towards implementation of video signal processing algorithms for analysis of medical videos

Course Contents

Unit 1: (15 hours)

Multi-dimensional signals and systems - Multi-dimensional transforms - Digital video - Spatial resolution and Frame rate - Video quality - Visual artifacts - Video filtering - Spatiotemporal filtering - Coding artifact reduction - Blotch detection and removal - Mutli-frame noise filtering

Unit 2: (15 hours)

Motion estimation - Image formation - Motion models - Optical flow estimation - Block matching - Phase correlation - Video segmentation - Scene change detection - Spatiotemporal change detection - Motion segmentation - Simultaneous motion estimation and segmentation - Motion tracking - Rigid object tracking - Articulated object tracking

Unit 3: (15 hours)

Video indexing and summarization - Storage and compression - Video compression standards - Video features - Statistical featured - Compressed-domain features - Contentbased features - Video Analysis - Shot boundary detection - Key-frame extraction - Video representation - Video Browsing - Video retrieval - Feature-based retrieval - Content-based retrieval - Case studies - Endoscopic video analysis for detection of abnormalities in gastrointestinal tract - Automatic kidney detection using real-time ultrasound videos - Carotid bulb detection in ultrasound videos

References

1. Tekalp, A. Murat, *Digital video processing,* Prentice Hall Press, 2015
2. Dey, Nilanjan, Amira Ashour, and Prasenjit Kr Patra, eds. *Feature detectors and motion detection in video processing*. IGI Global, 2016
3. Bovik, Alan C, *The essential guide to video processing,* Academic Press, 2009
4. Bovik, Alan C. *Handbook of image and video processing,* Academic press, 2010

Evaluation Pattern:

Assessment	Internal	External
Periodical 1 (P1)	15	NA
Periodical 2 (P2)	15	NA
*Continuous Assessment (CA)	20	NA
End Semester	NA	50
Total	50	50

*CA - Can be Quizzes, Assignments, and Term Work with Report

Speech and Audio Processing

21BM705 3-0-0-3

Learning Objectives

LO1 To introduce the concepts of signal processing with application to speech processing
LO2 To provide insights on feature extraction for speech coding, synthesis and recognition
LO3 To enable understanding of deep learning applications to speech processing and health care

Course Outcomes

CO1 Ability to understand concepts of Speech signal processing
CO2 Ability to apply the concepts of signal processing to feature extraction of speech/audio signals
CO3 Ability to analyze and process speech data for speech coding, synthesis and recognition
CO4 Ability to evaluate speech/audio processing techniques in healthcare applications

CO-PO Mapping

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	-	-	2	3	3
CO 2	-	-	-	3	2
CO 3	-	-	3	3	3
CO 4	-	-	3	2	3

Skills Acquired: Ability towards implementation of algorithms for analysis of speech and audio signals

Course Contents

Unit 1: (15 hours)

Introduction to signal processing - FIR and IIR filters - DFT - FFT - Speech analysis overview - Modelling of speech production - Speech perception and models - Feature extraction for speech processing - Auditory system as a filter bank - Linear predictive coding - Spectrum - Cepstrum - Mel-frequency cepstral coefficients

Unit 2: (15 hours)

Introduction to music synthesis - Music signal analysis - Source separation - Speech recognition - Synthesis and coding - Introduction to deep neural networks - Applications of deep learning techniques to speech processing - Applications of speech and audio processing in healthcare - Case studies - Dysarthria - Aphasia

Unit 3: (15 hours)

Analysis of speech/audio - Experiment with speech analysis and synthesis - Experiment with deep learning techniques for speech recognition - Analyze the speech signals of controls with dysarthria and aphasia

References

1. B. Gold, N. Morgan, D. Ellis, *Speech and Audio Signal Processing: Processing and Perception of Speech and Music*, Wiley, 2011
2. Xuedong Huang, Alex Acero, Hsiao-Wuen Hon, *Spoken Language Processing: A guide to theory, algorithm and system development*, Prentice Hall Inc., 2001
3. U Kamath, J Liu, J Whitaker, *Deep Learning for NLP and speech recognition*, Springer, 2019
4. Nancy Helm-Estabrooks, Martin L. Albert, & Marjorie Nicholas, *Manual of Aphasia and Aphasia Therapy*, Third Edition, Pro-Ed, 2013

Evaluation Pattern:

Assessment	Internal	External
Periodical 1 (P1)	15	NA
Periodical 2 (P2)	15	NA
*Continuous Assessment (CA)	20	NA
End Semester	NA	50
Total	50	50

*CA - Can be Quizzes, Assignments, and Term Work with Report

Smart Materials and Sensors

21BM711 **3-0-0-3**

Learning Objectives

LO1 To provide knowledge on smart materials
LO2 To provide insight on smart sensors
LO3 To comprehend real time applications of biosensors

Course Outcomes

CO1 Ability to understand smart materials and their function
CO2 Ability to identify suitable materials for biosensors
CO3 Ability to analyze the behavior of biosensors
CO4 Ability to evaluate the choice of sensors for biomedical applications

CO-PO Mapping

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	-	-	3	-	-
CO 2	-	-	3	-	-
CO 3	-	-	3	-	2
CO 4	-	-	3	-	2

Skills Acquired: Assessment of suitable smart sensors for different biomedical applications

Course Contents

Unit 1: (15 hours)

Introduction to smart materials - Review of piezoelectric materials - Piezoelectric materials as smart sensors - Electrostrictive materials and its review

Unit 2: (15 hours)

Review of magnetostrictive materials and giant magnetostrictive materials - Giant magnetoresistive materials - Magnetic gels as smart materials - Dielectric elastomers as smart materials

Unit 3: (15 hours)

Smart sensors for biomedical and health monitoring - Real time programmable closed loop stimulation/recording platforms for deep brain study - Implantable optical neural interface Functional nanofibers for flexible electronics - Biomimetic materials and structures for sensor applications

References

1. M. Shahinpoor, *Fundamentals of smart materials*, London: Royal Society of Chemistry, 2020
2. Schwartz, Mel M., *Smart Materials*, CRC Press, Taylor & Francis Group, 2009
3. Grundler P, *Chemical Sensors - An Introduction for Scientists and Engineers*, Springer Verlag, 2007
4. Lin, Youn-Long, *Smart sensors and systems*, Springer International PU, 2016

Evaluation Pattern:

Assessment	Internal	External
Periodical 1 (P1)	15	NA
Periodical 2 (P2)	15	NA
*Continuous Assessment (CA)	20	NA
End Semester	NA	50
Total	50	50

*CA - Can be Quizzes, Assignments, and Term Work with Report

Microstructural Sensors

21BM712 **3-0-0-3**

Learning Objectives

LO1 To introduce microelectrode based biosensors
LO2 To provide knowledge on microfluidics
LO3 To provide insight on microfluidics based synthesis
LO4 To impart knowledge on portable and point of care devices

Course Outcomes

CO1 Ability to understand microelectrode based biosensors
CO2 Ability to apply physics of microfluidic system in biomedical applications
CO3 Ability to analyze biomarkers using microfluidics
CO4 Ability to evaluate the performance of biosensors in point of care devices

CO-PO Mapping

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	-	-	-	2	2
CO 2	-	-	2	2	3
CO 3	-	-	2	-	2
CO 4	-	-	2	-	3

Skills Acquired: Technology ability to model and apply micro sensors in medical field

Course Contents

Unit 1: (15 hours)

Microelectrode designs - Microelectrode array fabrication and optimization - Mediators for microelectrode - Enzyme immobilization on microelectrode - Polymer-Enzyme composite biosensors - CNT based microelectrode - Label-free affinity biosensors based on electrochemical impedance spectroscopy - Aptamer-based electrochemical biosensorsElectrochemiluminescent biosensors - Molecularly imprinted polymers

Unit 2: (15 hours)

Introduction to microfluidics - Physics in microfluidics - Fabrication and modification of microfluidic - Chemical analysis - Disease diagnosis - Gene analysis - Drug delivery - Synthesis of organics - Multifunctional polymeric microparticles - Magnetic nanomaterials - Metallic nanomaterials - Synthesis of composites

Unit 3: (15 hours)

Portable optical detectors for point-of-care diagnostics - Paper-based diagnostic devices - Lateral flow technology for point-of-care and field-based applications - Electrochemical sensors for antibody detection - Cell-based biosensors - Applications: Food safety - Biowarfare detection and defence - Veterinary science

References

1. Stéphane Marinesco, Nicholas Dale, *Microelectrode Biosensors*, Humana press, 2013
2. Yujun Song, Daojian Cheng, and Liang Zhao, *Microfluidics Fundamentals, Devices and Applications*, Wiley-VCH, 2018
3. Spyridon E. Kintzios, *Portable Biosensors and Point-of-Care Systems*, The Institution of Engineering and Technology, 2017

Evaluation Pattern:

Assessment	Internal	External
Periodical 1 (P1)	15	NA
Periodical 2 (P2)	15	NA
*Continuous Assessment (CA)	20	NA
End Semester	NA	50
Total	50	50

*CA - Can be Quizzes, Assignments, and Term Work with Report

Laser Instrumentation in Biomedical Applications

21BM713 **3-0-0-3**

Learning Objectives

LO1 To introduce the fundamentals of laser and fiber
LO2 To enable understanding of biomedical application of laser technology
LO3 To provide knowledge of Laser instrumentation
LO4 To impart knowledge of laser-based diagnosis techniques

Course Outcomes

CO1 Ability to understand the laser and medium technology
CO2 Ability to apply the function of laser in bio-applications
CO3 Ability to analyze biological elements using the knowledge of laser instrumentation
CO4 Ability to evaluate the performance of laser technology in medical diagnosis

CO-PO Mapping

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	-	-	-	-	2
CO 2	-	-	2	-	2
CO 3	-	-	2	-	3
CO 4	-	-	3	-	3

Skills Acquired: Technology ability to apply the knowledge of laser in medical field

Course Contents

Unit 1: (15 hours)

Fundamentals of wave optics - Devices for fiber-Optic sensing - Principles of fiber-Optic sensing - Intensity-based sensors - Fiberbragg ratings - Distributed sensors - Fabryperotinterferometers - Standards for medical sensors - Lasers in medicine - Laser-tissue

interaction - Response of tissue to laser light - Types of laser used in medicine - Solid-state lasers - Gas lasers - Liquid and solid - State tunable organic dye lasers - Semiconductor lasers

Unit 2: (15 hours)
Applications of laser - Laser spectroscopy in medical diagnostics - Optical biopsy for cancer detection - Laser therapy in ophthalmology - Lasers in dermatology - Lasers in cardiology - Lasers in urology - Lasers in dentistry - Orthopaedic surgery - Introduction to short pulse laser imaging - Short pulse laser based thermal therapy - Use of nanoparticles

Unit 3: (15 hours)
Laser instrumentation - Doppler flowmetry - Laser flow cytometry - single cell separation - micro irradiation - Laser fluorescent micro irradiation - Laser eye instrumentation - Laser tissue transillumination and diaphanography - Speckle interferometry - Reflectance in tumour diagnostics - Holography

References

1. Daniele Tosi, Guido Perron, *Fiber-Optic Sensors for Biomedical Applications*, Artech House Publishers, 2018
2. Helena Jelínková, *Lasers for medical applications - Diagnostics, therapy and surgery*, Woodhead Publishing Limited, 2013
3. Kunal Mitra, Stephanie Miller, *Short Pulse Laser Systems for Biomedical Applications*, Springer Briefs in Applied Sciences and Technology, 2017
4. Leon Goldman, *The Biomedical Laser Technology and Clinical Applications*, Springer-Verlag, 1981.

Evaluation Pattern:

Assessment	Internal	External
Periodical 1 (P1)	15	NA
Periodical 2 (P2)	15	NA
*Continuous Assessment (CA)	20	NA
End Semester	NA	50
Total	50	50

*CA - Can be Quizzes, Assignments, and Term Work with Report

Virtual Instrumentation for Medical Systems

21BM714 **3-0-0-3**

Learning Objectives

LO1 To provide knowledge of virtual instrumentation
LO2 To introduce the concepts of real time data acquisition
LO3 To enable understanding of virtual signal processing tools
LO4 To introduce biomedical applications of virtual instrumentation

Course Outcomes

CO1 Ability to understand programming concepts for virtual instrumentation

CO2 Ability to apply data acquisition techniques for biomedical applications
CO3 Ability to analyze bio-signal processing algorithms using virtual instrumentation CO4 Ability to develop virtual codes for biomedical applications

CO-PO Mapping

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	-	-	-	2	-
CO 2	-	-	2	2	2
CO 3	-	-	2	2	2
CO 4	-	-	2	-	3

Skills Acquired: Technology ability in processing and analysis of medical signals

Course Contents

Unit 1: (15 hours)

Introduction to virtual instrumentation - Loops and structures - Arrays and clusters - Graphs and charts - File and string handling - Basics of data acquisition - Common communication buses using DAQ assistant - Real world DAQ and issues - Network and distributed systems

Unit 2: (15 hours)

Data handling techniques - Signal acquisition and sampling theorem - Effect of undersampling - Convolution - Designing an FIR and IIR filters - FFT analysis of periodic and aperiodic signals - Designing of low pass filter - High pass filter - Bandpass filter - Band reject filter - Notch filter and Comb filter

Unit 3: (15 hours)

Processing of ECG, EMG and EOG signals - Adaptive signal processing - Data compression techniques - AZTEC - TP - CORTES and KL transform

References

1. Sanjay Gupta and Joseph John, *Virtual Instrumentation Using Labview*, Tata McGraw Hill Education Private Limited, 2010
2. Behzad Ehsani, *Data Acquisition using LabVIEW*, Packt Publishing, 2016
3. Kunal Mitra, Stephanie Miller, *Short Pulse Laser Systems for Biomedical Applications*, Springer Briefs in Applied Sciences and Technology, 2017
4. Leon Goldman, *The Biomedical Laser Technology and Clinical Applications*, SpringerVerlag, 1981

Evaluation Pattern:

Assessment	Internal	External
Periodical 1 (P1)	15	NA
Periodical 2 (P2)	15	NA
*Continuous Assessment (CA)	20	NA
End Semester	NA	50
Total	50	50

*CA - Can be Quizzes, Assignments, and Term Work with Report

Biomedical Equipment and Safety

21BM715 **3-0-0-3**

Learning Objectives

LO1 To introduce medical equipment and its life cycle
LO2 To impart knowledge on failure analysis of medical devices
LO3 To enable understanding of safety and reliability of health care systems
LO4 To familiarize the effect of environmental factors on performance of medical equipment

Course Outcomes

CO1 Ability to understand life cycle management of medical equipment
CO2 Ability to apply safety procedures and risk management
CO3 Ability to assess failures in medical equipment
CO4 Ability to evaluate impact of environmental factors on biomedical devices

CO-PO Mapping

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	-	-	3	-	-
CO 2	-	-	3	-	-
CO 3	-	-	3	-	2
CO 4	-	-	3	-	2

Skills Acquired: To practice safety measures in using medical equipment

Course Contents

Unit 1: (15 hours)

Medical equipment and its life cycle - Safety in health care - Reliability - Types of reliability - Concept of failure - Causes of failure - Types of failures in medical devices

Unit 2: (15 hours)

Safety testing - Failure assessment and documentation - Visual inspection: external and internal visual inspection - Measurement - Safety parameters - Safety and risk management - Manufacturer's and physician's responsibilities - Hardware and software design aspects - Standards - Testing - Quality management - Regulatory body and system for medical devices

Unit 3: (15 hours)

Safe medical devices - Operation - Medical application safety - Environmental safety - Interference with the environment - Ecological safety - Electrical safety - Limitation of voltages - Macroshock and microshock - Earth and protection - Leakage currents - Magnetic fields and compatibility

References

1. K. Willson, K. Ison, and S. Tabakov, *Medical equipment management*, Boca Raton: Taylor et Francis, 2014

2. Bertil Jacobson and Alan Murray, *Medical Devices use and Safety*, Elsevier Limited, 2007
3. Richard Fries, *Reliable Design of Medical Devices*, Second Edition, CRC Press, Taylor & Francis Group, 2006
4. Norbert Leitgeb, *Safety of Electro Medical Devices Law - Risks - Opportunities* Springer Verlog / Wein, 2010
5.
6. Gordon R Higson, *Medical Device Safety - The regulation of Medical Devices for Public Health and Safety*, IOP Publishing Limited, Bristol and Philadelphia, 2002

Evaluation Pattern:

Assessment	Internal	External
Periodical 1 (P1)	15	NA
Periodical 2 (P2)	15	NA
*Continuous Assessment (CA)	20	NA
End Semester	NA	50
Total	50	50

*CA - Can be Quizzes, Assignments, and Term Work with Report

BioMEMS

21BM716 **3-0-0-3**

Learning Objectives

LO1 To introduce the basics of MEMS
LO2 To provide understanding fabrication of BioMEMS
LO3 To impart knowledge on biomedical applications of MEMS
LO4 To enable understanding of modalities for biosensing

Course Outcomes

CO1 Ability to understand the working process of MEMS
CO2 Ability to apply BioMEMS techniques for medical applications
CO3 Ability to analyze the optic MEMS applications in bioengineering
CO4 Ability to evaluate the performance of MEMS in diagnostic applications

CO-PO Mapping

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	-	-	-	2	2
CO 2	-	-	2	-	2
CO 3	-	-	2	-	3
CO 4	-	-	3	-	2

Skills Acquired: Technology ability in modeling of MEMS devices in biomedical field

Course Contents

Unit 1: (15 hours)

Introduction to make small things - History of BioMEMS - Micropatterning of substrates and cells - Microfluidics - Molecular biology on a Chip - Cell-based chips for biotechnology - BioMEMS for cell biology - Tissue microengineering

Unit 2: (15 hours)
MEMS for biomedical sensing and diagnostic applications - MEMS for in vivo sensing - MEMS and Electrical Impedance Spectroscopy (EIS) for non-invasive measurement of cells - MEMS ultrasonic transducers for biomedical applications - BioMEMS for drug delivery applications - BioMEMS for drug delivery applications - Applications of MEMS technologies for minimally invasive medical procedures - Smart microgrippers for bioMEMS applications

Unit 3: (15 hours)
Optical bio-sensing applications - Colorimetric detection - Fluorescence detection - Luminescence detection - Bioluminescence detection - Chemiluminescence detection - Biochemiluminescence detection - Electrochemiluminescence detection

References
1. Albert Folch, *Introduction to BioMEMS*, CRC Press, 2013
2. Shekhar Bhansali and Abhay Vasudev, *MEMS for Biomedical Applications*, Woodhead Publishing Limited, 2012
3. Samira Hosseini, Michelle Alejandra Espinosa-Hernandez, Ricardo Garcia-Ramirez, Ana Sofia Cerda-Kipper, Sofia Reveles-Huizar, Luis Acosta-Soto, *BioMEMS - Biosensing Applications*, Springer, 2021

Evaluation Pattern:

Assessment	Internal	External
Periodical 1 (P1)	15	NA
Periodical 2 (P2)	15	NA
*Continuous Assessment (CA)	20	NA
End Semester	NA	50
Total	50	50

*CA - Can be Quizzes, Assignments, and Term Work with Report

Computer Vision

21BM721 **3-0-0-3**

Learning Objectives

LO1 To introduce the fundamentals of image formation
LO2 To provide understanding of segmentation techniques in vision-based applications
LO3 To impart knowledge on advanced concepts in image representation techniques
LO4 To provide insights on implementation of computer vision algorithms for biomedical applications

Course Outcomes

CO1 Ability to understand the fundamental concepts in computer vision
CO2 Ability to apply segmentation techniques and descriptors
CO3 Ability to analyze medical problems using computer vision techniques
CO4 Ability to evaluate performance of computer vision algorithms in biomedical applications

CO-PO Mapping

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	-	-	2	2	2
CO 2	-	-	3	3	3
CO 3	-	-	3	3	3
CO 4	-	-	3	3	3

Skills Acquired: Programming ability towards implementing vision based algorithms for practical applications

Course Contents

Unit 1: (15 hours)
Camera Models and Calibration - Camera Projection Models - Orthographic - Affine - Perspective - Projective models - Projective geometry - Transformation of 2-D and 3-D - Internal Parameters - Lens distortion models - Calibration methods - Linear, direct, indirect and multiplane methods - Epipolar geometry - Stereo and Multi-view reconstruction

Unit 2: (15 hours)
Image representation - Edge detection - Motion estimation - Regularization theory - Optical computation - Stereo vision - Structure from motion

Unit 3: (15 hours)
Shape representation and Segmentation - Deformable curves and surfaces - Snakes and active contours - Level set representations - Feature detectors and descriptors - Object Recognition - Hough transforms - Case study - Vision model for mammogram image analysis

References

1. Richard Szeliski, *Computer Vision: Algorithms and Applications*, Springer; 2011
2. D. Forsyth and J. Ponce, *Computer Vision - A modern approach*, Prentice Hall
3. Sonka M, Hlavac V, Boyle R, *Image processing, analysis, and machine vision*, Cengage Learning; 2014
4. Gonzalez R C and Woods R E, *Digital Image Processing*, Third Edition, Prentice Hall, 2010

Evaluation Pattern:

Assessment	Internal	External
Periodical 1 (P1)	15	NA
Periodical 2 (P2)	15	NA
*Continuous Assessment (CA)	20	NA

End Semester	NA	50
Total	50	50

*CA - Can be Quizzes, Assignments, and Term Work with Report

Pattern Recognition

21BM722 **3-0-0-3**

Learning Objectives

LO1 To introduce fundamental concepts of pattern recognition
LO2 To provide an overview on dimensionality reduction techniques
LO3 To provide insights on implementation of pattern recognition algorithms

Course Outcomes

CO1 Ability to understand the mathematical background of pattern recognition
CO2 Ability to apply pattern recognition techniques for decision making
CO3 Ability to analyze biomedical problems using pattern recognition
CO4 Ability to evaluate the performance of pattern recognition algorithms in biomedical applications

CO-PO Mapping

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	-	-	2	2	2
CO 2	-	-	3	3	3
CO 3	-	-	3	3	3
CO 4	-	-	3	3	3

Skills Acquired: Programming ability towards implementation of pattern recognition algorithms for a wide range of biomedical applications

Course Contents

Unit 1: (15 hours)

Introduction - Biomedical applications of pattern recognition - Design Cycle - Machine Perception - Probability distribution basics Bayesian decision making - Naïve bayes classifier - Decision boundaries - Linear discriminant/Perceptron learning - Unequal costs of error - Estimation of error rates. ROC Curves - Likelihood Ratio Test

Unit 2: (15 hours)

Non-parametric Techniques - Density estimation - Histograms - K-nearest neighbor method - Parzen windows - Nearest neighborhood estimation - Linear discriminant functions and decision surfaces - Minimum squared error discriminant functions - Decision trees - Support Vector Machines - K-means clustering

Unit 3: (15 hours)

Dimensionality Reduction Techniques - Principal Component Analysis - Fisher Linear Discriminant - Singular Value Decomposition - Independent Component Analysis - Feature Selection - Feature Fusion - Classifier Ensembles - Case study - Computer aided tumor diagnosis

References

1. Earl Gose, Richard Johnsonbaugh and Steve Jost, *Pattern Recognition and Image Analysis*, Prentice Hall of India, 2002
2. Duda, R.O., Hart, P.E., and Stork, D.G,*Pattern Classification*, Second Edition, Wiley Interscience. 2003
3. Christopher M. Bishop, *Pattern Recognition and Machine Learning*, Springer, 2006
4. Meyer-Baese A, *Pattern Recognition and Signal Analysis in Medical Imaging*, Academi Press, Second Edition, 2014

Evaluation Pattern:

Assessment	Internal	External
Periodical 1 (P1)	15	NA
Periodical 2 (P2)	15	NA
*Continuous Assessment (CA)	20	NA
End Semester	NA	50
Total	50	50

*CA - Can be Quizzes, Assignments, and Term Work with Report

Bio-inspired Computing

21BM723 **3-0-0-3**

Learning Objectives

LO1 To introduce concepts of Bio-inspired Computing its applications
LO2 To provide insight on Artificial Neural Networks
LO3 To introduce Fuzzy logic and Fuzzy Systems
LO4 To provide knowledge on optimization algorithms

Course Outcomes

CO1 Ability to understand principles of bio-inspired algorithms
CO2 Ability to apply bio-inspired techniques for pattern recognition and optimization tasks
CO3 Ability to analyze problems in medical applications using bio-inspired approaches
CO4 Ability to evaluate performance of optimization algorithms

CO-PO Mapping

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	-	-	2	2	2
CO 2	-	-	2	3	3
CO 3	-	-	3	3	3

CO 4	-	-	3	3	3

Skills Acquired: Programming ability towards implementation of bio-inspired algorithms for analyzing and solving problems in biomedical domain

Course Contents

Unit 1: (15 hours)

Neural networks - Artificial neurons - Activation functions - Learning rules - Supervised and Unsupervised Learning - Single layer and multilayer perceptrons - Kohenen's selforganizing networks - Hopfiled networks

Unit 2: (15 hours)

Fuzzy systems - Fuzzy sets and relations - Membership functions - Rule base reduction methods - Decision making with fuzzy information - Fuzzy classification and pattern recognition - Neuro-fuzzy systems

Unit 3: (15 hours)

Introduction to genetic algorithms - Parent selection - Crossover - Mutation - Genetic Programming - Particle Swarm Optimization - Ant colony optimization - Artificial immune systems - Case Studies - Fuzzy region growing for segmentation of calcifications in mammograms - Classification of normal and ectopic beats using neural networks - Image registration using hybrid bio-inspired approaches

References

1. Fan, Xumei, William Sayers, Shujun Zhang, Zhiwu Han, Luquan Ren, and Hassan Chizari. *Review and classification of bio-inspired algorithms and their applications Journal of Bionic Engineering* 17, 611-631, 2020
2. Bernardino, Heder S., and Helio JC Barbosa. *Artificial immune systems for optimization* In *Nature-Inspired Algorithms for Optimisation*, pp. 389-411. Springer, Berlin, Heidelberg, 2009
3. Fausett, Laurene V. *Fundamentals of neural networks: architectures, algorithms and applications*, Pearson Education India, 2006
4. Ross, Timothy J. *Fuzzy logic with engineering applications*. Vol. 2. New York: Wiley, 2004
5. Goldberg, David E. *Genetic algorithms*, Pearson Education India, 2006

Evaluation Pattern:

Assessment	Internal	External
Periodical 1 (P1)	15	NA
Periodical 2 (P2)	15	NA
*Continuous Assessment (CA)	20	NA
End Semester	NA	50
Total	50	50

*CA - Can be Quizzes, Assignments, and Term Work with Report

Data Mining and Visualization Techniques

21BM724 **3-0-0-3**

Learning Objectives

LO1 To introduce the concepts of pattern processing

LO2 To provide insights on different techniques of pattern processing - supervised and unsupervised

LO3 To provide knowledge on techniques of data visualization techniques

Course Outcomes

CO1 Ability to understand the basic concepts of data mining

CO2 Ability to apply data mining, clustering, classification, and data visualization techniques

CO3 Ability to analyze data using mining, clustering and classification techniques

CO4 Ability to evaluate the effectiveness of various algorithms

CO-PO Mapping

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	-	-	3	3	-
CO 2	-	-	3	3	3
CO 3	-	-	3	3	3
CO 4	-	-	-	3	-

Skills Acquired: Ability towards implementation of algorithms for data mining and visualization

Course Contents

Unit 1: (15 hours)

Challenges in data mining - Data pre-processing - An overview of data cleaning methods - Data integration - Data reduction and data transformation - Dimensionality reduction - Linear regression - Regularisation

Unit 2: (15 hours)

Introduction to classification and clustering - Decision trees and random forests - Bayesian classifier - Support vector machines - Neural networks - Metrics for evaluating classifier performance - Model selection using statistical tests of significance - Comparing classifiers

based on cost-benefit and ROC curves - Techniques to improve classification accuracy Cluster analysis - Distance measures - k-means and k-Medoids - Agglomerative versus divisive hierarchical clustering - Detecting outliers

Unit 3: (15 hours)

Data visualisation - Bar plots - Histogram - Box plots - Violin plots - Pairplots - Distplot - Scatter plots - Pie charts - Bubble plots - Regression plots - Quantile plots - Heatmaps - Plotting covariance matrices - Waffle chart - Word cloud - PCA - LDA - Manifold learning for data visualisation - t-SNE - UMAP

References

1. Jiawei Han, Micheline Kamber, Jian Pei, *Data Mining: Concepts and Techniques*, Third Edition, Morgan Kaufmann Publishers (Elsevier), 2011
2. K.P Soman, Shyam Diwakar, V. Ajay, *Insight into Data Mining: Theory and Practice*, PHI Learning Private Ltd., New Delhi, 2006
3. J Vanderplas, *Python Data Science Handbook*, Nov. 2016, O'Reilly, Media Inc

Evaluation Pattern:

Assessment	Internal	External
Periodical 1 (P1)	15	NA
Periodical 2 (P2)	15	NA
*Continuous Assessment (CA)	20	NA
End Semester	NA	50
Total	50	50

*CA - Can be Quizzes, Assignments, and Term Work with Report

Multisensor Data Fusion

21BM725 **3-0-0-3**

Learning Objectives

LO1 To introduce the mathematical foundations of data fusion methods
LO2 To provide knowledge on intelligent fusion algorithms based on soft computing techniques
LO3 To enable understanding of data fusion models for biomedical applications

Course Outcomes

CO1 Ability to understand the basics of data fusion algorithms
CO2 Ability to apply appropriate data fusion techniques in biomedical applications
CO3 Ability to analyse biomedical problems using intelligent fusion algorithms CO4 Ability to create fusion models for biomedical applications

CO-PO Mapping

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	-	-	3	-	-
CO 2	-	-	3	2	2
CO 3	-	-	3	3	3
CO 4	-	-	3	3	2

Skills Acquired: The design and programming ability in data fusion models for biomedical applications

Course Contents

Unit 1: (15 hours)

Introduction to data fusion process - Data fusion models - Configurations and architectures. Probabilistic Data Fusion - Maximum Likelihood - Bayesian and Maximum entropy methods

- Recursive Bayesian methods for estimation and data fusion - Kalman filter theory - Kalman filter as a natural data-level fuser

Unit 2: (15 hours)
Data fusion by nonlinear Kalman filtering - Information filtering - H-infinity filtering - Multiple hypothesis filtering - Data fusion with missing measurements - Possibility theory and dempster - Shafer Method - Fuzzy Logic based Decision Fusion - Type 1 and type 2 fuzzy logic - Adaptive Neuro-Fuzzy Inference System (ANFIS) and generation of weights

Unit 3: (15 hours)
Decision Theory based Fusion - Bayesian decision theory - Decision making with multiple information sources - Fuzzy approach - Decision making based on voting - Performance evaluation of Data Fusion systems - Monte Carlo methods - Detection and diagnosis of diseases using the principles of multi-sensor fusion

References

1. Jitendra R Raol, *Data Fusion Mathematics: Theory and Practice*, CRC Press, 2016
2. David L. Hall, *Mathematical Techniques in Multisensor Data Fusion*, Artech House, Boston, 1992
3. R. Brooks and S.S. Iyengar, *Multisensor Fusion: Fundamentals and Applications with Software*, Prentice Hall Inc., New Jersey, 1998
4. James V. Candy, *Signal Processing: The Model Based Approach*, McGraw -Hill Book Company, 1987

Evaluation Pattern:

Assessment	Internal	External
Periodical 1 (P1)	15	NA
Periodical 2 (P2)	15	NA
*Continuous Assessment (CA)	20	NA
End Semester	NA	50
Total	50	50

*CA - Can be Quizzes, Assignments, and Term Work with Report

Medical Robotics

21BM726 **3-0-0-3**

Learning Objectives

LO1 To impart basic understanding of robotics
LO2 To enable understanding the design and control concepts of medical robots LO3 To comprehend on the application of robotics in the field of healthcare

Course Outcomes

CO1 Ability to understand different types of Robotic Systems

CO2 Ability to apply the concepts of robotics for surgery
CO3 Ability to analyze the positioning and orientation of medical robots
CO4 Ability to design the kinematics model for a specified robotic system

CO-PO Mapping

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	-	-	-	-	-
CO 2	-	-	-	-	2
CO 3	-	-	3	-	2
CO 4	-	-	3	-	2

Skills Acquired: The ability to analyze the kinematics model of a medical robot.

Course Contents

Unit 1: (15 hours)

Introduction to robots - Robots as mechanical devices - Classification of robotic manipulators - Robotic systems - Accuracy and repeatability - Wrists and end-effectors - Mathematical modeling of robots - Symbolic representation of robots - The configuration space - The state space - The workspace common kinematic arrangements of manipulators - Forward kinematics - Inverse kinematics - Velocity kinematics

Unit 2: (15 hours)

Medical robots - Robots for navigation - Movement replication - Robots for imaging - Rehabilitation and prosthetics - Describing spatial positioned orientation - Standardizing kinematic analysis - Computing joint angles - Quaternions - Robot kinematics -Three-joint robot - Six-joint robot

Unit 3: (15 hours)

Application of medical robots - The learning curve of robot - Assisted laparoscopic surgery - Haptic feedback in robotic heart surgery - Robotic applications in neurosurgery - Miniature robotic guidance for spine surgery

References

1. Achim Schweikard and Floris Ernst, *Medical Robotics*, Springer, 2015
2. VanjaBozovic, *Medical Robotics*, Springer, 2008
3. Mark W. Spong, Seth Hutchinson, and M. Vidyasagar, *Robot Modeling and Control*, John Wiley & Sons, 2005

Evaluation Pattern:

Assessment	Internal	External
Periodical 1 (P1)	15	NA
Periodical 2 (P2)	15	NA
*Continuous Assessment (CA)	20	NA
End Semester	NA	50
Total	50	50

*CA - Can be Quizzes, Assignments, and Term Work with Report

Wearable Biomedical Systems

21BM731 **3-0-0-3**

Learning Objectives

LO1 To introduce the fundamentals of wearable sensor technology
LO2 To impart knowledge on electronics in wearable system design
LO3 To enable knowledge development on principles of energy harvesting LO4
To provide insight to assistive technologies in wearable system

Course Outcomes

CO1 Ability to understand the basics of wearable sensor system design
CO2 Ability to apply the IC technologies for bio sensing
CO3 Ability to analyze the energy and power consumption requirements in system design
CO4 Ability to evaluate the multi parameter measurements from wearable sensors

Skills Acquired: To acquire and develop the skill to understand wearable technology for biomedical applications

CO-PO Mapping

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	-	-	2	-	3
CO 2	-	-	2	2	2
CO 3	-	-	3	-	2
CO 4	-	-	3	-	3

Course Contents

Unit 1: (15 hours)

Introduction to Wearable sensors - Attributes of wearables - Meta-wearable - Challenges and opportunities - Future of wearables - Social interpretation of Aesthetics - Case study - Google glass - Wearable haptics - Need for wearable haptic devices - Categories of wearable haptic and tactile display - Wearable Sensors - Chemical and Biochemical sensors - System design - Challenges in chemical biochemical sensing - Applications

Unit 2: (15 hours)

Flexible Electronics and Energy Harvesting Systems - Thin-film transistors - Low-power Integrated Circuit design for biopotential sensing - Analog circuit design techniques - Low-power design for ADCs - Digital circuit design techniques - Architectural design for lowpower biopotential acquisition - Practical considerations - Energy harvesting from human body - Temperature gradient - Foot motion - Wireless energy transmission - Energy harvesting from light and RF energy - Energy and power consumption issues - Future considerations

Unit 3: (15 hours)

Monitoring Physical and Physiological Parameters - Wearable sensors for physiological signal measurement - Physical measurement - Cardiovascular diseases - Neurological

diseases - Gastrointestinal diseases - Wearable and non-invasive assistive technologies - Assistive devices for individuals with severe paralysis - Wearable tongue drive system - Dual-mode tongue drive system

References

1. Edward Sazonov, Michael R Neuman, *Wearable Sensors: Fundamentals, Implementation and Applications*, Academic Press, USA, 2014
2. Tom Bruno, *Wearable Technology: Smart Watches to Google Glass for Libraries*, Rowman & Littlefield Publishers, Lanham, Maryland, 2015
3. Raymond Tong, *Wearable Technology in Medicine and Health Care*, Academic Press, USA, 2018
4. Haider Raad, *The Wearable Technology Handbook*, United Scholars Publication, USA, 2017

Evaluation Pattern:

Assessment	Internal	External
Periodical 1 (P1)	15	NA
Periodical 2 (P2)	15	NA
*Continuous Assessment (CA)	20	NA
End Semester	NA	50
Total	50	50

*CA - Can be Quizzes, Assignments, and Term Work with Report

Computational Neuroscience

21BM732 **3-0-0-3**

Learning Objectives

LO1 To provide understanding of principal concepts behind the working of neurons
LO2 To enhance knowledge on neural encoding and decoding process
LO3 To enable modeling of neurons and neural networks
LO4 To provide insights on simulation tools to analyze neural systems

Course Outcomes

CO1 Ability to understand the basic principles of cognitive neuroscience
CO2 Ability to apply information theory for neural encoding and decoding
CO3 Ability to analyze neural activity using computational models
CO4 Ability to evaluate performance of learning methodologies of neurons

CO-PO Mapping

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	-	-	3	-	-
CO 2	-	-	3	-	-
CO 3	-	-	3	-	-

CO 4	-	-	3	-	2

Skills Acquired: Provides practical mathematical models for quantitatively analyzing neuronal behavior

Course Contents

Unit 1: (15 hours)

Review - Convolution - Linear systems - Vectors - Matrices - Basis vectors - Probability theory - Probability distribution - Bayes theorem - Dynamical systems - Electrical nature of neurons - Synapses - Brain areas - Brain functions - Neuron spikes - Entropy - Spike train information - Brain noise

Unit 2: (15 hours)

Coding principles - Neural encoding - Feature selection - Variability - Neural decoding and signal detection theory - Population coding - Bayesian estimation - Reconstructing stimulus - Neuron models - Mechanistic and interpretive models

Unit 3: (15 hours)

Spike train modelling - Hodgkin-Huxley model - Neural correlations - Synchrony - Synapses modelling - Firing rate models - Feed Forward Networks - Recurrent Networks - Synaptic plasticity - Statistical learning - Unsupervised learning - Sparse coding - Predictive coding Neurons as classifiers - Reinforcement Learning - Case study on modeling human brain function using Artificial Neural Networks

References

1. Dayan, P. and Abbott, L.F, *Theoretical neuroscience: computational and mathematical modeling of neural systems*, First Edition, MIT Press, 2001
2. Bielza, C. and Larrañaga, P,*Data-Driven Computational Neuroscience: Machine Learning and Statistical Models*. First Edition, Cambridge University Press, 2020
3. Arbib, M.A. and Bonaiuto, J.J, *From neuron to cognition via computational neuroscience*. First Edition, MIT Press, 2016
4. Miller P, *An introductory course in Computational Neuroscience*, First Edition, MIT Press, 2018

Evaluation Pattern:

Assessment	Internal	External
Periodical 1 (P1)	15	NA
Periodical 2 (P2)	15	NA
*Continuous Assessment (CA)	20	NA
End Semester	NA	50
Total	50	50

*CA - Can be Quizzes, Assignments, and Term Work with Report

Essentials of Telemedicine

21BM733 **3-0-0-3**

Learning Objectives

LO1 To enable understanding of the key principles in telemedicine and health
LO2 To equip with the concepts of technology of telemedicine
LO3 To provide the importance of data security in telemedicine LO4
To impart knowledge on medical ethics

Course Outcomes

CO1 Ability to understand the basic principles of telemedicine in healthcare
CO2 Ability to apply information technologies in telemedicine systems
CO3 Ability to analyze the security aspects in telemedicine data
CO4 Ability to evaluate the performance of data security techniques in telemedicine

CO-PO Mapping

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	-	-	2	-	3
CO 2	-	-	3	-	3
CO 3	-	-	3	-	2
CO 4	-	-	2	-	-

Skills Acquired: Technology ability in understanding the telemedicine in medical data

Course Contents

Unit 1: (15 hours)

Origins and development - Introduction - Definitions of telemedicine - Telehealth and telecare - Drivers of telemedicine and telecare – Scope - Benefits and limitations of telemedicine - Communication networks and services - Wireless technology in patient monitoring

Unit 2: (15 hours)

Technologies in medical information processing - Collecting data from patients - Bio-signal transmission and processing - Patient records and data mining applications - Wireless telemedicine - System deployment - Planning and deployment considerations - Scalability to support future growth - Integration with existing IT infrastructure - Evaluating IT service and solution provider

Unit 3: (15 hours)

Technologies for safeguarding medical data and privacy - Information security overview - Cryptography - Safeguarding patient medical history - Anonymous data collection and processing - Biometric security and identification - Ethical and legal aspects of telemedicine

References

1. Norris, Anthony Charles, and A. C. Norris. *Essentials of Telemedicine and Telecare*,

Chichester: Wiley, 2002
2. B.Fong, A.C.M Fong, A.C.M and C.K. Li., *Telemedicine Technologies: Information Technologies in medicine and Telehealth*, John Wiley & Sons, 2011
3. H. Eren and J. G. Webster, eds.,*Telemedicine and electronic medicine* , CRC Press, 2015
4. Wootton R. Craig, J., Patterson, V., *Introduction to Telemedicine*, Royal Society of Medicine Press Ltd, 2006

Evaluation Pattern:

Assessment	Internal	External
Periodical 1 (P1)	15	NA
Periodical 2 (P2)	15	NA
*Continuous Assessment (CA)	20	NA
End Semester	NA	50
Total	50	50

*CA - Can be Quizzes, Assignments, and Term Work with Report

Brain Computer Interfacing

21BM734 **3-0-0-3**

Learning Objectives

LO1 To introduce the concepts of Brain Computer Interfacing (BCI)
LO2 To impart knowledge about the data acquisition methods used in BCI
LO3 To enhance the understanding on BCI signal Processing and parameter extraction LO4 To enable the knowledge on classification of cognitive task from BCI parameters

Course Outcomes

CO1 Ability to understand the basic concepts of EEG and BCI
CO2 Ability to apply signal processing techniques in BCI
CO3 Ability to analyze human cognition using BCI parameters
CO4 Ability to evaluate machine learning methods in BCI applications

CO-PO Mapping

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	-	-	2	2	-
CO 2	-	-	2	2	2
CO 3	-	-	3	2	2
CO 4	-	-	3	2	3

Skills Acquired: The application of BCI in classification and automation of human cognition

Course Contents

Unit 1: (15 hours)
Brain activation patterns - Spikes - Oscillatory potential - Event-Related Potentials (ERP) - Mu rhythms - Stimulus related potentials - Visual evoked potentials and auditory evoked potentials - Potentials related to cognitive tasks - Brain computer interface types - Invasive - Non-invasive - Brain signal for BCI signal - EEG - MEG - fNIRS - fMRI

Unit 2: (15 hours)
BCI signal processing - Spatial - Temporal - Spatio-temporal filters - Spike sorting - Time and frequency domain analysis - Wavelet analysis - Principal Component Analysis (PCA) - Independent Component Analysis (ICA) - Artifacts reduction - Feature Extraction - Phase synchronization and coherence - ERP Analysis in BCI

Unit 3: (15 hours)
Interfacing Brain and Machine - BCI system monitoring hardware - Machine Learning for feature classification - BCI application - Neuro prosthetic devices - Cursor and robotic control using multi electrode array implant - Visual cognitive BCI - Emotion detection

References

1. Ella Hassianien, A &Azar.A.T, *Brain-Computer Interfaces Current Trends and Applications*, Springer, 2015
2. Rajesh.P, N.Rao, *Brain-Computer Interfacing: An Introduction*, Cambridge University Press, First edition, 2013
3. Jonathan Wolpaw, Elizabeth Winter Wolpaw, *Brain Computer Interfaces Principles and practice*, Oxford University Press, USA, Edition 1, January 2012
4. Bernhard Graimann, Brendan Allison, GertPfurtscheller, *Brain-Computer Interfaces: Revolutionizing Human-Computer Interaction*, Springer, 2010

Evaluation Pattern:

Assessment	Internal	External
Periodical 1 (P1)	15	NA
Periodical 2 (P2)	15	NA
*Continuous Assessment (CA)	20	NA
End Semester	NA	50
Total	50	50

*CA - Can be Quizzes, Assignments, and Term Work with Report

IoT in Healthcare

21BM735 **3-0-0-3**

Learning Objectives

LO1 To understand the concepts of Internet of Things
LO2 To provide exposure to the routing protocols used in medical IoT devices LO3 To comprehend on applications of IoT in the field of healthcare

Course Outcomes

CO1 Ability to understand the basic architecture of an IoT device
CO2 Ability to apply big data analytics in Medical IoT devices
CO3 Ability to analyze mobility in location based IoT systems
CO4 Ability to evaluate the performance of IoT applications in Healthcare

CO-PO Mapping

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	-	-	-	-	-
CO 2	-	-	-	-	2
CO 3	-	-	3	-	2
CO 4	-	-	3	-	2

Skills Acquired: The ability to analyze internet of things model for a specified healthcare application

Course Contents

Unit 1: (15 hours)

Introduction to IoT - Physical design of IoT - Logical design of IoT - IoT enabling technologies - IoT levels and deployment templates - Cloud computing - Deployment models - Service models - Service management - Cloud security - Communication protocols - CoAP - MQTT

Unit 2: (15 hours)

IoT in Healthcare - Challenges in current healthcare systems - IoT healthcare services - Big data in IoT - Architecture of apache flume and spark - Wireless Body Area Networks (WBAN) Routing Protocols - Medium access control - Issues of WBAN

Unit 3: (15 hours)

Case Studies - Wearable sensor network for remote health monitoring - IoT based location aware smart healthcare framework - Analysis of recovery of mobility through inertial navigation techniques and virtual reality - Control and remote monitoring of muscle activity and simulation in the rehabilitation process

References

1. Valentina Emilia Balas and Souvik Pal, *Healthcare Paradigms in the Internet of Things Ecosystem*, Academic Press, 2021
2. Arsheep Bahga and Vijay Madisetti, *Internet of Things: A Hands-on Approach*, Universities Press, 2015

3. Rajkumar Buyya and Amir Vahid Dastjerdi, *Internet of Things Principles and Paradigms*, Elsevier Inc, 2016

Evaluation Pattern:

Assessment	Internal	External
Periodical 1 (P1)	15	NA
Periodical 2 (P2)	15	NA
*Continuous Assessment (CA)	20	NA
End Semester	NA	50
Total	50	50

*CA - Can be Quizzes, Assignments, and Term Work with Report