M. Tech

IN

INSTRUMENTATION AND CONTROL SYSTEMS

CURRICULUM AND SYLLABI

(Applicable from 2023 admission onwards)

Department of Electrical Engineering
NATIONAL INSTITUTE OF TECHNOLOGY CALICUT
Kozhikode - 673601, KERALA, INDIA

The Program Educational Objectives (PEOs) of M. Tech in Instrumentation and Control Systems

PEO1	Apply enhanced knowledge and skills in the areas of control systems and instrumentation so as to excel in various sectors in modern industry/utility and/ or teaching and/or higher education and / or research.
PEO2	Engage in design of novel products and strategic solutions to real life problems in the areas of control systems and instrumentation that are technically sound, economically feasible and socially acceptable.
PEO3	Exhibit professionalism, keep up ethics in profession and demonstrate communication skills, leadership qualities as well as willingness to work in groups.

Programme Outcomes (POs) of M. Tech in Instrumentation and Control Systems

PO1	Ability to independently carry out research /investigation and development work to solve practical problems
PO2	Ability to write and present a substantial technical report/document
PO3	Ability to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor program
PO4	Ability to utilize the acquired knowledge to take up administrative challenges including the management of projects in the field of control systems and instrumentation having multidisciplinary nature with a perspective to maintain lifelong learning process.
PO5	Willingness and ability to upkeep professional ethics and social values while carrying out the responsibilities as a control system/ instrumentation engineer/researcher in devising solutions to real life engineering problems in an independent manner

CURRICULUM

Total credits for completing the M. Tech programme in Instrumentation and Control Systems is 75.

COURSE CATEGORIES AND CREDIT REQUIREMENTS:

The structure of M. Tech programme shall have the following Course Categories:

Sl. No.	Course Category	Minimum Credits
1.	Program Core (PC)	26
2.	Program Electives (PE)	12
3.	Institute Elective (IE)	2
4.	Projects	35

The effort to be put in by the student is indicated in the tables below as follows:
L: Lecture (One unit is of 50-minute duration)
T: Tutorial (One unit is of 50-minute duration)
P: Practical (One unit is of one-hour duration)
O: Outside the class effort / self-study (One unit is of one-hour duration)

PROGRAMME STRUCTURE

Semester I

Sl. No.	Course Code	Course Title	L	T	P	O	Credits	Category
1.	MA6007E	Mathematical Methods in System Engineering	3	0	0	6	3	PC
2.	EE6101E	Systems Theory	3	0	0	6	3	PC
3.	EE6102E	Nonlinear Systems and Control	3	0	0	6	3	PC
4.	EE6103E	Principles of Measurement Systems	3	0	0	6	3	PC
5.		Programme Elective - 1	3	0	0	6	3	PE
6.		Programme Elective – 2 (from Instrumentation Basket)	3	0	0	6	3	PE
7.	EE6191E	Advanced Control Systems Lab	0	0	2	1	1	PC
8.		Institute Elective	2	0	0	4	2	IE
		Total	**20**	**0**	**2**	**41**	**21**	**--**

Semester II

Sl. No.	Course Code	Course Title	L	T	P	O	Credits	Category
1.	EE6111E	Digital Control: Theory and Design	3	0	0	6	3	PC
2.	EE6112E	Optimal and Robust Control	3	0	0	6	3	PC
3.	EE6113E	Stochastic Modelling and Identification of Dynamical Systems	3	0	0	6	3	PC
4.	EE6114E	Advanced Sensing Systems and Interfacing Circuits	3	0	0	6	3	PC
5.		Programme Elective - 3	3	0	0	6	3	PE
6.		Programme Elective - 4 (from Control Basket)	3	0	0	6	3	PE
7.	EE6192E	Instrumentation Systems Lab	0	0	2	1	1	PC
8.	EE6193E	Project Phase I	0	0	3	3	2	PC
		Total	**18**	**0**	**5**	**40**	**21**	**--**

Semester III

Sl. No.	Course Code	Course Title	L	T	P	O	Credits	Category
1.	EE7191E	Project Phase II *	0	0	6	3	3	PC
2.	EE7192E	Project Phase III	0	0	30	15	15	PC
		Total	**0**	**0**	**36**	**18**	**18**	**--**

** to be completed during Summer*

Semester IV

Sl. No.	Course Code	Course Title	L	T	P	O	Credits	Category
1.	EE7193E	Project Phase IV	0	0	30	15	15	PC
		Total	**0**	**0**	**30**	**15**	**15**	**--**

List of Electives**

Sl. No.	Course Code	Course Title	L	T	P	O	Credits
Programme Elective 1 and 3							
1.	EE6121E	Predictive Control: Theory and Applications	3	0	0	6	3
2.	EE6122E	Fractional Order and Time Delay Systems: Analysis and Control	3	0	0	6	3
3.	EE6123E	Robotics and Computer Vision	3	0	0	6	3
4.	EE6124E	Optimal Estimation and Filtering	3	0	0	6	3

5.	EE6125E	Large Scale Systems	3	0	0	6	3
6.	EE6126E	Multivariable Control Systems	3	0	0	6	3
7.	EE6127E	Flight Control Systems	3	0	0	6	3
8.	EE6128E	Guidance, Navigation & Control	3	0	0	6	3
9.	EE6129E	Flexible Structures	3	0	0	6	3
10.	EE6130E	Quantitative Feedback Theory	3	0	0	6	3
11.	EE6131E	Numerical Methods for Control System Design	3	0	0	6	3
12.	EE6132E	Networked Control and Multiagent Systems	3	0	0	6	3
13.	EE6133E	Instrumentation for Embedded Control Systems	3	0	0	6	3
14.	EE6134E	Analytical Instrumentation	3	0	0	6	3
15.	EE6135E	Multisensor Data Fusion	3	0	0	6	3
16.	EE6136E	Artificial Intelligence and Machine Learning for Biomedical Applications	3	0	0	6	3
17.	EE6137E	Biomedical Signal Processing and Applications	3	0	0	6	3
18.	EE6138E	Medical Imaging Systems	3	0	0	6	3
19.	EE6203E	Advanced Power System Operation and Control	3	0	0	6	3
20.	EE6211E	Power System Stability and Dynamics	3	0	0	6	3
21.	EE6303E	Modern Digital Signal Processors	3	0	0	6	3
22.	EE6325E	Linear and Digital Electronics	3	0	0	6	3
23.	EE6329E	Advanced Microprocessor based systems	3	0	0	6	3
24.	EE6401E	Industrial Internet of Things	3	0	0	6	3
25.	EE6412E	Industrial Instrumentation	3	0	0	6	3
26.	EE6422E	Process Control and Automation	3	0	0	6	3
27.	EE6423E	Computer Controlled Systems	3	0	0	6	3
28.	EE6424E	Engineering Optimization and Algorithms	3	0	0	6	3
29.	EE6425E	Industrial Communication	3	0	0	6	3
30.	EE6429E	SCADA Systems & Applications	3	0	0	6	3
31.	EE6430E	Wireless & Sensor Networks	3	0	0	6	3
32.	EE6431E	Network & Data Security	3	0	0	6	3
33.	EE6432E	Advanced Algorithms & Data Structure Analysis	3	0	0	6	3

34.	EE6433E	Industrial Load Modelling & Control	3	0	0	6	3
35.	EE6434E	Industrial Operation and Control	3	0	0	6	3
Programme Elective - 2 (Instrumentation Basket)							
36.	EE6139E	Data Acquisition and Telemetry	3	0	0	6	3
37.	EE6140E	Wireless Sensors, Networks and IOT	3	0	0	6	3
38.	EE6141E	Automotive Sensors and Instrumentation	3	0	0	6	3
39.	EE6142E	Biomedical Instrumentation	3	0	0	6	3
40.	EE6143E	Assistive Technology for Rehabilitation	3	0	0	6	3
Programme Elective - 4 (Control Basket)							
41.	EE6144E	Adaptive and Intelligent Control Techniques	3	0	0	6	3
42.	EE6145E	Sliding Mode Control and Applications	3	0	0	6	3
43.	EE6146E	Modelling and Control of Unmanned Aerial Vehicles	3	0	0	6	3
Institute Electives							
1.	ZZ6001E	Research Methodology	2	0	0	4	2
2.	MS6174E	Technical Communication and Writing	2	1	0	3	2
3.	IE6001E	Entrepreneurship Development	2	0	0	4	2

*** List of Electives offered in each semester will be announced by the Department. Any other PG level course approved by the Senate offered in the Institute can also be credited as Programme Elective – 1 or Programme Elective – 3 with the prior approval of the Programme Coordinator.*

MA6007E MATHEMATICAL METHODS IN SYSTEM ENGINEERING

Pre-requisites: **NIL**

Total Lecture Sessions: 39

L	T	P	O	C
3	0	0	6	3

Course Outcomes:

CO1: Analyze the existence and uniqueness of solutions of linear systems and use the properties of vector spaces and linear transformations.

CO2: Demonstrate the distribution and transformation of random variables and determine limiting distributions of finite state Markov Chains.

CO3: Determine existence and uniqueness of solution and stability of system of ODEs.

CO4: Evaluate extrema by techniques of the calculus of variations.

Linear Algebra

System of linear equations: Range space and null space of a matrix, rank of a matrix, existence and uniqueness of solution of the system of linear equations, dimension of the solution space associated with the system of linear equations.

Vector Spaces: Definition of vector space, sub spaces, dual spaces, kernel, null space, linear independence and dependence, linear span, basis, dimension, direct sum, linear transformations.

Matrix representations: Eigenvalues and Eigen vectors, similarity, rank and nullity, diagonalization, Jordan form.

Random Variables and Random Processes

Random Variables, Distributions and Density functions, Moments and Moment generating function, Multivariate distributions, Independent Random Variables, Marginal and Conditional distributions, Conditional Expectation, Transformation of Random Variables, Elements of stochastic processes, Classification of general stochastic processes.

Markov Chains: Definition, Examples, Transition Probabilities, Classification of states and chains, Basic limit theorem, Limiting distribution of Markov chains.

System of ODE and Calculus of Variations

System of ODE: Existence and uniqueness of solution through Lipchitz conditions, Solution and stability.

Calculus of Variations: Examples of variational problems, Basic calculus of variations problem, Weak and strong extrema, Variable end point problems, Hamiltonian.

References:

1. Serg Lang, *Linear Algebra*, 3rd Edition, Springer, 2004
2. Kenneth Holfman and Ray Kunze, *Linear Algebra*, 2nd edition, Pearson, 2015.
3. J. Medhi; "*Stochastic Processes*", New Age International, 4th Edn, 2019.
4. S. Ross, *A First Course in Probability*, 9th Edition, Pearson, 2014
5. William E Boyce and Richard C DiPrima, *Elementary Differential Equations and Boundary Value Problems*, 9th edition John Wiley & Sons, 2009.
6. George F Simmons, *Differential Equations with Applications and Historical Notes*, TMH edition, 1974.
7. Shepley L Ross, *Differential Equations*, 3rd edition, John Wiley and Sons, 2007.
8. I M Gelfand and S V Fomin, *Calculus of Variations*, Dover Publication, 2000.
9. Bernard Dacorogna, *Introduction to the Calculus of Variation*, 3rd edition, World Scientific, 2014.
10. Robert Weinstock, *Calculus of Variation with applications to Physics and Engineering*, Dover Publications, 2012.

EE6101E SYSTEMS THEORY

Pre-requisites: **NIL**

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Develop mathematical models of dynamical systems in state space form and solve the state equations

CO2: Apply various tools to analyze the controllability, observability and stability of LTI systems represented in state space form

CO3: Create minimal realizations for LTI systems using Markov parameters and Hankel matrices

CO4: Design state and output feedback controllers and state observers for LTI systems

State space models of linear systems

State space models of linear systems - Explicit solutions to linear differential equations, solution to LTI and LTV systems, solutions to homogeneous and non-homogeneous cases - Computation of matrix exponentials – Equivalent state space models: similarity transformations, canonical forms, zero state equivalence.

Controllability and Observability

Controllability and Observability of LTI systems - Controllable and reachable subspaces - Physical examples and system interconnections - Reachability and controllability Gramians - Controllabilty matrix, Eigen vector test for controllability, Lyapunov test for controllability - Controllable decomposition and block diagram interpretation - Stabilizable system: Eigen vector test for stabilizability, Popov-Belevitch_Hautus (PBH) Test for stabilizability, Lyapunov test for stabilizability. Feedback stabilization based on Lyapunov test - Unobservable and unconstructable subspaces: Physical examples, observability and Constructability Gramians, Gramian based reconstruction – Duality - Observable decompositions, Kalman decomposition theorem - Detectability, detectability tests

System Stability and System Realization

Stability - Internal or Lyapunov stability, Lyapunov stability theorem, Eigenvalue conditions for Lyapunov stability - Input-Output stability: BIBO stability, Time domain conditions for BIBO stability. Frequency domain conditions for BIBO stability - Minimal realizations and co-prime factorizations, Markov parameters, Hankel matrices.

Stabilization, Control and State estimation

Stabilization by output feedback – Eigenvalue assignment by output injection – State feedback for stabilization and control – Pole placement - Ackermann's formula - State estimation and observer design – Separation principle - Reduced order observer - Servo Design - State feedback with Integral Control

References:

1. Chi-Tsong Chen, '*Linear System Theory and Design*', Oxford University Press,1984
2. John S. Bay, '*Fundamentals of Linear State Space Systems'*, Mc-Graw Hill, 1999
3. Thomas Kailath, '*Linear Syst*em', Prentice Hall, 1990
4. Gillette, '*Computer Oriented Operation Research*', McGraw Hill Publications.
5. F.M. Callier and C.A. Desoer, '*Linear System The*ory', Springer Verlag, 1991
6. P. Halmos, '*Finite Dimensional Vector Spaces'*, Springer, 1984
7. M. Gopal, '*Digital Control and State Variable Methods*', 4th Ed, Tata McGraw Hill Publishing Company, 2017.
8. Katsuhiko Ogata, *Modern Control Engineering*, 5th edition, Pearson Prentice Hall, 2015.
9. M Gopal and Nagrath, *Control Systems Engineering*, 7th ed., Tata McGraw Hill, 2021
10. Karl J. Astrom and T. Hagglund, *PID Controllers: Theory, Design and Tuning,* 2nd edition, 1995
11. Hassan K Khalil, *Control Systems: An introduction,* Michigan State University, 2023

EE6102E NONLINEAR SYSTEMS AND CONTROL

Pre-requisites: **NIL**

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Analyse nonlinear systems using classical techniques

CO2: Analyse stability of non-linear systems using advanced techniques

CO3: Analyse nonlinear feedback systems using time and frequency domain techniques

CO4: Design controllers for nonlinear systems using advanced methods

Introduction and classical techniques

Characteristics of nonlinear systems – examples of systems exhibiting nonlinear phenomena- second order nonlinear autonomous systems- vector field representation- classification of equilibrium points – qualitative behavior near equilibrium points- limit cycles – existence of periodic orbits- Poincare-Bendixon criterion- Poincare index of equilibrium points- stability of periodic solutions- analysis of systems with piecewise constant inputs using phase plane analysis-Jump response.

Lyapunov Stability

Existence and uniqueness of solutions of nonlinear state equations- stability of nonlinear systems - Lyapunov stability - local linearization and stability in the small – Centre manifold theorem- Direct method of Lyapunov - generation of Lyapunov function for linear and nonlinear systems- Variable gradient method- La Salle's Invariance theorem – Input to state stability - L stability - L stability of state models-Small gain theorem- Passivity- Positive real transfer functions-L2 and Lyapunov stability -Passivity theorems- Loop transformation.

Time domain analysis of feedback systems

Absolute stability of feedback interconnections of a linear part and nonlinear part- Circle criterion- Popov criterion- Frequency theorem- Harmonic linearization- filter hypothesis- Describing function of standard nonlinearities- amplitude and frequency of limit cycle using SIDF.

Nonlinear system design tools

Control problems- stabilization via linearization - integral control via linearization- Gain scheduling. Feedback linearization-stabilization and tracking via state feedback control.
Sliding mode control Regulation via integral control- Lyapunov redesign- stabilization and nonlinear damping- Backstepping- Passivity based control- High gain observers.

References:

1. Hassan K Khalil, *Nonlinear Systems*, 3rd edition, Prentice Hall International (UK), 2002.
2. J J Slotine and W. Li, *'Applied Nonlinear Control'*, Prentice Hall, Engelwood New Jersey 1991
3. S. Strogatz, *Nonlinear Dynamics and Chaos*, 2nd Edition, CRC Press, 2018
4. A. Isidori, *'Nonlinear Control systems',* 3rd ed., Springer verlag, New york, 2013
5. S. Wiggins, *'Introduction to Applied Nonlinear Dynamical Systems and chaos'*, Springer Verlag New York, 1990
6. H. Nijmeijer and A.J. Van Der Shaft, *'Nonlinear Dynamic Control Systems'*, Springer Verlag, Berlin, 1990.
7. Arther E. Gelb and Vender Velde, *'Multiple input Describing function and Nonlinear System Design'*, MC Graw Hill, 1968
8. Z Vukic, L Kuljaca, *'Nonlinear Control Systems',* Marcel Dekker, Inc., New York, 2003.

EE6103E PRINCIPLES OF MEASUREMENT SYSTEMS

Pre-requisites: **NIL**

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Classify the various digital measurement systems and basic sensing elements based on working principles.

CO2: Design state-of-the-art signal conditioning and processing circuits for various measurement systems.

CO3: Select appropriate sensing elements and justify the selection with their characteristics for specific industrial applications.

CO4: Design and develop smart sensor systems for modern day applications.

Digital Measurement and Sensing Elements

Introduction to Digital measurement System: Digital frequency measurement, Digital voltage measurement.
Sensing Elements: Sensor Characteristics : Static and dynamic characteristics - Principles of sensing: Resistive: potentiometric displacement sensor, RTD, thermistor, strain gauge and semiconductor gas sensor – Capacitive: Displacement sensor, liquid level sensor, pressure sensor - Inductive: variable reluctance displacement sensor, LVDT - Electromagnetic sensing element - Hall effect sensor - Thermoelectric sensing element - Elastic sensing element - Piezoelectric sensing elements - Electrochemical sensing elements.

Signal conditioning and processing of sensor data

Overview of secondary sensing elements : Deflection bridges - Amplifiers: charge amplifiers, precision amplifiers, pingpong amplifiers, stabilized amplifiers, spinning current technique - AC carrier systems: current transmitters, intelligent and smart transmitters - Oscillators - Resonators - Frequency to Digital conversion - Coherent Detection - Resolver-to-Digital and Digital- to Resolver Converters - ADC and DAC Dynamic offset and compensation: Auto zeroing and chopping, Correlated double sampling, Dynamic element matching - Introduction to compressive sensing - Noise sources and filtering - Case study: Design of Signal conditioning circuit for capacitive sensors.

Specialized Measurement Systems

Construction and working principles of Torque and Speed measurement systems - Force and Pressure measurement systems - Flow measurement systems: volumetric and mass flow rate of liquid and gas - Level measurement system - Fluid thermal conductivity and composition measurements: Katharometer system - Optical measurement systems - Ultrasonic measurement systems - Vibration measurement systems - Fluid Viscosity and Density measurement systems.

Smart sensor and applications
Microcontrollers for sensor interface - sensor integration - communication systems for sensor data - automated/remote sensing - alternative views of remote sensing - smart loop - HVAC sensor chip - Microcontrollers unit with integrated pressure sensor
Smart wind sensor - Smart Hall sensor - Smart Temperature sensor - Smart thermal diffusivity sensor - Smart building sensor: smoke and occupancy - Remote health monitoring - Precision farming - Smart energy meter.

References:

1. E.O. Doebelin, D.N. Manik, Measurement systems, 6th ed. Tata McGraw Hill, New Delhi, 2017.
2. J.P. Bentley, Principles of Measurement systems, 4th ed. Pearson education Ltd, UK, 2005.
3. Alan S. Morris, R. Langari, Measurement and Instrumentation; Theory and Application, 3rd ed. Academic Press, USA, 2020.
4. Ramon Pallas-Areny, John G. Webster, Sensors and Signal Conditioning, 2nd ed. Wiley, 2000.
5. Rang Wu, Johan H. Huising, Kofi A.A. Makinwa, Precision Instrumentation Amplifiers and Read-Out Integrated Circuits: Analog Circuits and Signal Processing, 1st ed. Springer, 2013.
6. Randy Frank, Understanding Smart Sensors, 3rd ed. Artech House Publishers, 2013.
7. Gerard Meijer, Smart Sensor Systems, John Wiley and Sons, UK, 2008.

EE6191E ADVANCED CONTROL SYSTEMS LAB

Pre-requisites: **NIL**

L	T	P	O	C
0	0	2	1	1

Total Practical Sessions: 26

Course Outcomes:

CO1: Use laboratory techniques, tools, and practices of advanced control systems engineering

CO2: Design and implement control systems for linear time-invariant systems and nonlinear systems

CO3: Report concisely the results of the work in the laboratory accurately in appropriate detail.

CO4: Work in a team and communicate effectively to perform the design and implementation of control schemes for various processes

List of Experiments:

1. Modelling and implementation of controllers for twin rotor MIMO System
2. Stabilization control of Inverted Pendulum
3. Programmable logic controller: familiarization and real-time applications
4. System identification and multi loop control of quadruple tank system
5. Real-time control using dSPACE
6. PID tuning using different methods for FOPTD systems, implementation issues and enhancements
7. AC servo system: familiarization and AC position control
8. Design and implementation of controllers for rotary flexible link module
9. Advanced control system simulation using MATLAB and Simulink
10. Design and implementation of trajectory tracking controller for a robotic manipulator
11. Real-time implementation of controllers for buck converter
12. Design and implementation of controllers for aerospace systems using Quanser Aero

References:

1. Gene F Franklin, J David Powell, Abbas EmamiNaeini, *Feedback Control of Dynamic Systems*, Pearson Education, 8th Ed, 2018
2. Graham C Goodwin, Stefan F Graebe, Mario E Salgado, *Control System Design*, Pearson India, 2015.
3. John J D'Azzo, Constantine H Houpis, Stuart N. Sheldon, *Linear Control System Analysis &Design with MATLAB*, 6th Ed, CRC Press Inc, 2013
4. P. C. Sen, *Principles of Electrical Machines & Power Electronics,* 2nd Eds, John Wiley, 2007.
5. John E Gibson, Franz B. Tuteur, *Control System Components,* McGrawHill, 1958.
6. Ramesh S Gaonkar, *Microprocessor architecture Programming and application with 8085/8080A'2E,* 6th Eds, Penram International Publishing, 2013.
7. User's Manual for FEEDBACKR MS150 AC Modular Servo System
8. User's Manual for FEEDBACKR MS150 DC Modular Servo System
9. User's Manual for Bytronics

EE6111E DIGITAL CONTROL: THEORY AND DESIGN

Pre-requisites: **NIL**

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Develop mathematical models of Digital Control Systems

CO2: Design and analyse digital control systems using classical techniques

CO3: Design and analyse SISO and MIMO digital control systems in the state space domain

CO4: Apply various techniques for the stability analysis of nonlinear digital control systems

Introduction to digital control

Introduction -Discrete time system representation –Sample & Hold-Mathematical modeling of sampling process – Data reconstruction-Design of the hardware and software architecture – Software requirements- Selection of ADC and DAC- Choice of the sampling period –Prefilter/Antialiasing filters - Effects of quantization errors - Phase delay introduced by the ZOH-Sampling period switching- Dual rate control.

Modeling discrete-time systems by pulse transfer function -Revisiting Z-transform -Mapping of s-plane to z-plane - Pulse transfer function - Pulse transfer function of closed loop system - Sampled signal flow graph -Stability analysis of discrete time systems -Jury stability test - Stability analysis using bi-linear transformation

Design of sampled data control systems

Design of PID controller-Filtering the derivative action- Integrator windup- Bumpless transfer between manual and automatic mode - Incremental form-Root locus method - Controller design using root locus - Root locus based controller design using MATLAB - Nyquist stability criteria - Bode plot – Lead compensator design using Bode plot - Lag compensator design using Bode plot - Lag-lead compensator design in frequency domain-Deadbeat response design -Design of digital control systems with deadbeat response - Practical issues with deadbeat response design - Sampled data control systems with deadbeat response

Discrete state space model and state feedback design

Introduction to state variable model for SISO systems- Various canonical forms - Characteristic equation, state transition matrix - Solution to discrete state equation-Controllability, observability and stability of discrete state space models -Controllability and observability - Stability

Pole placement by state feedback - Set point tracking controller - Full order observer - Reduced order observer-Servo Design- State feedback with Integral Control-Deadbeat Control by state feedback and deadbeat observers -Output feedback design - Output feedback design: Theory - Output feedback design: Examples. Introduction to Multivariable & Multi-input Multi-output (MIMO) Digital Control Systems

Nonlinear Digital control systems

Discretization of nonlinear systems - Extended linearization by input redefinition - - input and state redefinition - output differentiation - Extended linearization using matching conditions – Nonlinear difference equations - Logarithmic transformation- Equilibrium of nonlinear discrete-time systems - Lyapunov stability theory- Lyapunov functions - Stability theorems -Rate of convergence – Lyapunov stability of linear systems - Lyapunov's linearization method- Instability theorems - Estimation of the domain of attraction - Stability of analog systems with digital control-Hybrid Systems - State plane analysis - Discrete-time nonlinear controller design- Controller design using extended linearization- Controller design based on Lyapunov stability theory - Input-output stability and the small gain theorem, Absolute stability

References:

1. B.C Kuo, 'Digital Control Systems', Oxford University Press, Inc., New York, 2nd Ed, 1995
2. G.F. Franklin, J.D. Powell, and M.L. Workman, 'Digital control of Dynamic Systems', Addison-Wesley Longman, Inc., Menlo Park, CA, 1998.
3. M. Gopal, '*Digital Control and State Variable Methods*', 4th Ed, Tata McGraw Hill Publishing Company, 2017.
4. John F. Walkerly, 'Microcomputer architecture and Programs', Tata McGraw Hill Publishing Company, ,John Wiley and Sons Inc., New York, 1981.
5. K. Ogata, 'Discrete Time Control Systems' , 2nd Ed, Prentice Hall India Learning Private Limited, 2005.
6. C. H. Houpis and G.B. Lamont, 'Digital Control Systems', McGraw Hill Book Company, 2nd Ed, 1992.
7. C.L. Philips and H.T Nagle, Jr., 'Digital Control System Analysis and Design', Prentice Hall, Inc., Englewood Cliffs, N. J., 1995
8. M. Sami Fadali Antonio Visioli, 'Digital Control Engineering Analysis and Design', 3rd Ed, Academic Press, 2019

EE6112E OPTIMAL AND ROBUST CONTROL

Pre-requisites: **NI**L

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Formulate optimal control problems and apply the concepts of calculus of variations to solve them.

CO2: Solve linear regulator and tracking problems and develop state estimators.

CO3: Model uncertain systems and formulate robust control problems

CO4: Design robust controllers using various techniques.

Variational approach to optimal control problems

[Review of Calculus of variations]

From Calculus of variations to optimal control: necessary conditions for strong extrema, calculus of variations versus optimal control, optimal control problem formulation and assumptions, fixed time and free end point problems.

Pontryagin's Minimum principle: Statement of minimum principle for basic fixed endpoint and variable end point control problems, poof of the minimum principle, properties of the Hamiltonian, minimum time and minimum energy problems.

Regulators, tracking controllers and state estimation

Linear Quadratic Regulator: Finite horizon LQR problem, Candidate optimal feedback law, Ricatti differential equations (RDE), Global existence of solution for the RDE, Infinite horizon LQR problem, Existence and properties of the limit, solution, closed loop stability using output feedback: Output feedback LQR design equations, Closed loop stability, Solution of design equations, Numerical solution of Riccatti Equations – Linear Quadratic tracking control: Tracking a reference input with compensators of known structure, tracking by regulator redesign, Command generator tracker, Explicit model following design - Linear Quadratic Gaussian controller (LQG) and Kalman-Bucy Filter: LQG control equations, estimator in feedback loop, steady state filter gain, constraints and minimizing control, state estimation using Kalman-Bucy Filter, constraints and optimal control.

Modelling of uncertain systems and control

Robust Control - Control system representations, System stabilities, Co-prime factorization and stabilizing controllers, Signals and system norms, Modelling of uncertain systems - Unstructured Uncertainties: Additive, multiplicative and other forms, Parametric uncertainty, Interval Systems - Structured uncertainties: Linear fractional transformation - Robust design specifications -Small gain theorem and robust stabilization - Performance considerations - Structured singular values - Mixed sensitivity optimization - 2-Degree of freedom design - Sub-optimal solutions:, $H_2\ /H_\infty$ control.

Design of Robust Controllers

Loop-shaping design procedures: Robust stabilization against Normalized co-prime factor perturbation, μ - Analysis and Synthesis - Consideration of robust performance - μ synthesis: D – K iteration method, Schur Compliment and Linear Matrix Inequalities - Some standard LMI problems – eigenvalue problems, generalized eigenvalue problems, Algorithms to solve LMI problems: Ellipsoid algorithm, interior point methods.

References:

1. D. E. Kirk, *Optimal Control Theory: An Introduction*, 10th ed, Prentice-Hall, 2007.
2. B. D. O. Anderson and J. B. Moore, *Optimal Control: Linear Quadratic Methods*, Prentice-Hall, 2007.
3. Naidu Desineni Subbaram, *Optimal Control Systems*, CRC Press, Boca Raton London New York Washington, D.C, 2002
4. Liberzon, Daniel. *Calculus of variations and optimal control theory: a concise introduction*. Princeton university press, 2011.
5. D. W.Gu, P. Hr.Petkov and M.M.Konstantinov, '*Robust Control Design with MATLAB'*, Springer, 2005.
6. Alok Sinha, *'Linear Systems-Optimal and Robust Controls',* CRC Press, 2007.
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11. Stephen Boyd, Laurent El Ghaoul, Eric Feron, '*Linear Matrix Inequalities in System and Control Theory',* SIAM, 1994.

EE6113E STOCHASTIC MODELLING AND IDENTIFICATION OF DYNAMICAL SYSTEMS

Pre-requisites: **NIL**

L	T	P	O	C
3	0	0	6	3

Total Lecture sessions: 39

Course Outcomes:

CO1: Apply the principles of stochastic modelling for engineering systems.

CO2: Develop models of dynamical systems using classical identification techniques

CO3: Apply estimation techniques for system identification

CO4: Design Kalman filter and related algorithms for linear and nonlinear systems

System models

[*Review of Probability and Statistics*] - Introduction to system identification : linear time invariant system models - distributed parameter models – model structures and identifiability – identifiability of some model structures – Models of time varying and nonlinear systems- linear time varying models- nonlinear state space models - nonlinear black box models – neural networks - Time series models: AR, MA, ARMA, ARMAX - Markov process - Non-parametric and parametric methods for modelling - modeling of uncertainty using Fuzzy logic and probability concepts.

Stochastic processes and development of system models

Elements of the theory of stochastic processes, Gauss Markov sequence model, Gauss Markov Process model- Discrete and Continuous-time Markov Chains (MCs): Transition probability matrix, Chapman-Kolmogorov equations; n-step transition and limiting probabilities, ergodicity, stationarity, correlation-random walk Brownian motion: Wiener process as a limit of random walk, White noise-optimal smoothing, filtering and prediction for continuous and discrete linear systems.

Bayesian estimation and System identification

Maximum likelihood estimation, linear mean square estimation- Parameter estimation for Time series models, AR, MA, ARMA, ARMAX - efficiency and bias of estimators - minimizing prediction errors- Instrumental variable method - consistency and identifiability - Recursive methods- Matrix inversion lemma-RLS Algorithm - Weighted RLS algorithm-Modelling with orthogonal functions and transforms feature extraction - system identification experiments: design of inputs for system identification, persistent excitation, open loop and closed loop system identification - Asymptotic Distribution of Parameter Estimates - Pseudo Random Binary Signals (PRBS) - Cramer-Rao Lower Bound and Best Unbiased Estimate.

State estimation using Kalman Filter

Wiener Filter - estimation problem - Wiener Hopf equation - realizability - stochastic state estimation problem - optimal filtering and prediction - derivation of Kalman filter - Extended Kalman Filter - Unscented Kalman Filter - Combined state and parameter estimation - System identification for control.

References:

1. Schoukens, Johan, Rik Pintelon, and Yves Rolain, *"Mastering System Identification in 100 Exercises"*, Wiley IEEE Press, 2012
2. Lingfeng Wang, Kay Chen Tan, *"Modern Industrial Automation Software Design"* , Wiley IEEE Press, 2012
3. Ravindra V. Jategaonkar, *"Flight Vehicle System Identification: A Time-Domain Methodology",* 2nd Edition, Aerospace Research Central, American Institute of Aeronautics & Astronautics, USA, 2015.
4. J S Meditch, *"Stochastic Optimal Linear Estimation and Control*", McGraw Hill Book Company, 1969
5. Charles K Chui, Guanrong Chen, "*Kalman Filtering with Real time Applications*", Springer, 2009
6. P R Kumar and Pravin Varaiya, *Stochastic Systems: Estimation, Identification, and Adaptive Control,* Society for Industrial and Applied Mathematics, 2016
7. Hayes, Monson H. *Statistical digital signal processing and modeling*. John Wiley & Sons, 1996.
8. Sinha N K and Kuztsa, System Identification and Modelling of Systems, 1983

EE6114E ADVANCED SENSING SYSTEMS AND INTERFACING CIRCUITS

Pre-requisites: **NIL**

Total Lecture Sessions: 39

L	T	P	O	C
3	0	0	6	3

Course Outcomes:

CO1: Analyze the fabrication techniques of MEMS and NEMS sensing devices.

CO2: Apply the knowledge of modern sensor systems for habitat monitoring.

CO3: Choose the appropriate sensor and justify the selection with their characteristics for robotic applications.

CO4: Relate the design of MEMS sensors in biochemical applications.

MEMS and NEMS Sensing Devices

Introduction to thick film sensors and thin film sensors - Micro and Nano Electro Mechanical Systems (MEMS AND NEMS) - Materials, Fabrication steps and procedures - Micromachining: Bulk Micromachining, Surface Micromachining, LIGA, DRIE, Packaging - Interfacing electronics - Design of MEMS based Vibratory gyroscope, MEMS Pressure sensors, Design of Micro actuators using shape memory alloys and piezoelectric materials, ZnO nanorods-based NEMS device for Gas sensing.

Modern Sensors for Habitat monitoring

Air quality monitoring: Semiconductor gas detectors, Ambient temperature and barometric pressure sensors, Planar interdigital sensors - Water quality monitoring: Ion-Selective electrodes, Conductometric sensors - Soil quality monitoring: pH sensor, Humidity sensors - Disaster monitoring: Tsunami warning system - Sensors for soot detection - Sensors for vertical farming - MEMS based habitat monitoring sensors: ocean sensors - Marine environment monitoring - geophones for locating oil and gas reserves - hydrophones for tertiary waves - Smart dust - E-nose systems.

Robotics Sensors

Introduction to sensors in robotics - Types of sensors: Light sensors: photoresistors and photovoltaic cells, CCDs, Phototubes, Phototransistors - Touch or Tactile sensors - Binary and Analog sensors - Proximity sensors: contact and noncontact proximity sensors - Tilt and Navigation sensors: GPS, Digital magnetic compass, Acceleration and Gyroscopic sensors, Inertial Measurement Units (IMU) - Vision sensors and Camera.

Biosensors

Basic components of lab-on-a-chip and its integration: molecular recognition, on-chip biochemical detection methods - Introduction to micro/nano fluidics - sensors and actuators for medical instrumentation - Fundamentals of bio-signal conditioning and processing - Applications of Biosensors: Enzyme sensors, Cell based biosensors using microelectrodes, Food Analysis. Case study: MEMS Cantilever based biosensor for food pathogen detection and its readout electronics.

References:

1. Chang Liu, *Foundations of MEMS*, 2nd ed. Pearson, 2011.
2. Julian W. Gardner, Vijay K. Varadan, Osama O. Awadelkarim, *Micro sensors, MEMS and Smart Devices*, Wiley India, 2001.
3. Charles P.Poole, Frank J.Owens, *Introduction to nanotechnology*, John Wiley & sons, 2003.
4. M. Campbell, *Sensors Systems for Environmental Monitoring*, Springer, 2011.
5. H. R. Everett, *Sensors for mobile robots: theory and application*, A K Peters, 1995.
6. S. R. Deb, Sankha Deb, *Robotics technology and Flexible automation,* 2nd ed. McGraw-Hill Education (India), 2010.
7. Dorf RC, *Sensors, Nanoscience, Biomedical engineering and instruments*, 3rd ed. CRC Press, 2006.
8. Sergey Yurish, *Sensors and Biosensors, MEMS Technologies and its Applications*, IFSA Publishing, 2014.

EE6192E INSTRUMENTATION SYSTEMS LAB

L	T	P	O	C
0	0	2	1	1

Pre-requisites: **NIL**

Total Practical Sessions: 26

Course Outcomes:

CO1: Use laboratory techniques, tools, and practices of instrumentation systems

CO2: Design and implement measurement and instrumentation systems for various applications

CO3: Report concisely the results of the work in the laboratory accurately in appropriate detail.

CO4: Work in a team and communicate effectively to perform the design and implementation of instrumentation systems

List of Experiments:

1. Experiments on sensors and transducers with feedback instrumentation kit- variable resistance transducer and strain gauge.
2. Experiments on sensors and transducers- variable capacitance transducer, variable inductance transducer and LVDT.
3. Implementation of logic gates using Pneumatic valves and hydraulic cylinders.
4. Pressure and temperature measurement and air stream and temperature control.
5. Implementation of real-time PID controller for quadruple tank system using virtual instrumentation.
6. Calibration of pressure gauge using dead weight tester.
7. (a) Data Acquisition using NI MYDAQ for calibrating an angle sensor.
   (b) Creating a virtual replica of the angle sensed by the calibrated angle sensor.
8. Experimental determination of step response characteristic of RTD and thermocouple and temperature compensation of RTD with three and four leads.
9. Real time measurement and analysis of physical parameters using Sensor Cassy.
10. Implementation of various control schemes on Heating, Ventilation & Air Conditioning (HVAC).
11. Experiments on flight dynamics and Vertical take-off and landing control (VTOL) using virtual instrumentation.
12. Hardware in the loop simulation using Microcontroller and PC based DAQ.

References:

1. Ernest O. Doebelin: ‘Measurement Systems: Application and Design’, McGraw Hill International Editions, 2017
2. Patranabis D, Principles of Industrial Instrumentation, 3rd Edition, Tata McGraw Hill, 2010.
3. Bela G. Liptak: ‘Process Control Instrument Engineer’s Handbook’, Butterworth-Heinemann, 2006.
4. Roy Needham: ‘Hydraulics, Tutor Notes & Workbook’, Mechatronics International Ltd, 2001.
5. Roy Needham: ‘Pneumatics, Tutor Notes & Workbook’, Mechatronics International Ltd, 2001.
6. Manual for Transducers Kit, M/S Feedback instruments UK.
7. Manual for Air and Temperature Control System, LD DIDACTIC GmbH, Germany

EE6193E PROJECT PHASE I

Pre-requisites: **NIL**

L	T	P	O	C
0	0	3	3	2

Course Outcomes:

CO1: Identify and review research papers for understanding emerging technologies in the field of control and/or instrumentation systems.

CO2: Identify a research problem in the areas of control and/or instrumentation systems and its feasible solutions by summarizing the reviewed papers.

CO3: Demonstrate the identified problem and its feasible solutions through basic simulations or experiments.

CO4: Document the identified problem and its feasible solutions through a detailed report and demonstrate through an oral presentation.

Each student has to choose a topic in the field of control and/or instrumentation systems, outside the M. Tech syllabus and identify relevant literature. Students have to identify a research problem in the field and study the feasible solutions available in the literature. Basic experiments and/or simulations may be used for this. Students have to submit a detailed report of the work and give an oral presentation before a panel of examiners.

EE7191E PROJECT PHASE II

Pre-requisites: **NIL**

L	T	P	O	C
0	0	6	3	3

Course Outcomes:

CO1: Review literature on any topic in the fields of control and/or instrumentation systems and formulate a research problem.

CO2: Apply relevant techniques and tools to arrive at feasible solutions for the problem formulated

CO3: Evaluate the solutions developed through simulations and/or experiments.

CO4: Document the problem formulation and its feasible solutions through a detailed report and demonstrate through an oral presentation.

Each student has to identify and formulate a research problem in the fields of control and/or instrumentation systems, develop solutions for it and validate the solutions through experiments and/or simulations. This project may/may not be a continuation of Project Phase I. Students have to submit a detailed report of the work and give an oral presentation before a panel of examiners.

EE7192E PROJECT PHASE III

Pre-requisites: **NIL**

L	T	P	O	C
0	0	30	15	15

Course Outcomes:

CO1: Identify a research topic in the area of control and/or instrumentation systems, conduct literature survey, formulate the problem, and state the objectives.

CO2: Design and implement control techniques and/or instrumentation systems for the selected process/problem.

CO3: Apply new tools and techniques for development of cost effective and environment friendly designs in the areas of control and/or instrumentation systems.

CO4: Document the work through a technical project report, communicate through oral presentations before a panel of examiners and publish in reputed conferences/journals and.

Project Phase III - Major Project Part I may or may not be the continuation of Project Phase I and/or Project Phase II. Faculty members propose projects/broad area of work and student will be asked to meet the faculty member who is offering the project of interest for guidance. Student can also select the topic after discussions with guide. Students are encouraged to take up interdisciplinary project too. Students can carry out their projects in R&D organizations/ industries which have facility in the proposed area with an officer from there as the external guide and a faculty from the department as internal guide. Students are required to undertake detailed technical work in the chosen area using one or more of the following: (i) Analytical models (ii) Computer simulations (iii) Hardware implementation. The complete project report is not expected at the end this semester. However, a 30-40 page typed report based on the work done will have to be submitted by the students to the assessing committee.

EE7193E PROJECT PHASE IV

Pre-requisites: **NIL**

L	T	P	O	C
0	0	30	15	15

Course Outcomes:

CO1: Develop comprehensive solutions to the issues identified in previous semester work and meet the requirements as stated in the objectives.

CO2: Demonstrate and validate the developed solutions through simulations and/or experiments.

CO3: Analyze the results critically, interpret the results and justify the achievement of the stated objectives.

CO4: Summarize the research and its results in the form a thesis, communicate effectively the research contribution through oral presentations and publish in reputed journals /conferences and/or apply for Patents.

EE7193E Project Phase IV may be continuation of EE7192E Project Phase III. Students should complete the work planned in the third semester, attaining all the objectives, and should prepare the project report of the complete work done in the two semesters. They are expected to communicate their research contributions in reputed conferences and/or journals.

EE6121E PREDICTIVE CONTROL: THEORY AND APPLICATIONS

Pre-requisites: **NIL**

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Formulate linear predictive control problems based on the given requirements

CO2: Apply the various methods for unconstrained and constrained model predictive control for engineering problems

CO3: Design nonlinear model predictive controllers for dynamical systems

CO4: Implement MPC for practical problems using simulation tools under various computational and resource constraints

Introduction and Elements of Predictive Control

Limitations of classical control - Optimization-based Control - Origins of MPC, Mathematical formulation of MPC: prediction models, objective functions, and constraints - Models for MPC: Finite impulse and step response models, Model prediction, Parameter estimation - Prediction using LTI models, transfer function models, Model analysis and Disturbance Modeling- Receding Horizon, Finite Horizon Approximation, Cost versus Horizon - Infinite Horizon Control.
Fundamentals of Convex Optimization: Review of linear programming, quadratic programming, and mixed-integer programming

Linear Model predictive control

Dynamic Matrix Control – MPC based on quadratic programming - constrained MPC - state-space based MPC - Discrete-time MPC Using Laguerre Functions - Generalized predictive control – Event triggered MPC.
Stability analysis of MPC: Lyapunov stability, terminal state constraints, and terminal cost function.
Design considerations for MPC: prediction and control horizon selection, weighting matrices, and handling constraints - Robustness analysis and mitigation techniques for MPC- computational considerations.

Nonlinear Model Predictive Control

Introduction to Nonlinear Model Predictive Control (NMPC): motivations and challenges - NMPC formulations: direct and indirect approaches, multiple shooting, and collocation methods - suboptimal MPC - Nonlinear system modeling and prediction for NMPC: AR and MA models, Neural Networks - nonlinear optimization: Gradient and Newton methods - Preconditioning and convergence - Stability analysis and Lyapunov-based control approach for NMPC - Computations: Algorithms and Explicit Control Laws.
Real-time implementation of MPC: online model updating, state estimation, and disturbance rejection.

Applications of MPC

Case studies and applications of MPC in systems, such as chemical processes, robotics, Power Electronics Applications, Building HVAC Systems, and aerospace systems - Implementing discrete-time controllers in numerical simulation software and toolboxes.

References:

1. Borrelli, F., Bemporad, A., and Morari, M. *Predictive Control for Linear and Hybrid Systems*. Cambridge: Cambridge University Press, 2017
2. J.B. Rawlings, D.Q. Mayne and M.M. Diehl, *Model Predictive Control: Theory, Computation, and Design,* Nobb Hill, 2nd edition, 2018
3. E.F. Camacho and C. Bordons, *Model Predictive Control,* 2nd edition, Springer.2013
4. Wang, Liuping, *Model predictive control system design and implementation using MATLAB.* Springer Science & Business Media, 2009.
5. Saša V. Raković, William S. Levine, *Handbook of Model Predictive Control*, Springer-Birkhauser, 2019.
6. Lars Grüne, Jürgen Pannek : *Nonlinear Model Predictive Control Theory and Algorithms*, Springer International Publishing, 2016

EE6122E FRACTIONAL ORDER AND TIME DELAY SYSTEMS: ANALYSIS AND CONTROL

Pre-requisites: **NIL**

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Develop mathematical models of fractional order systems

CO2: Design and analyze fractional order control systems using frequency and time domain techniques

CO3: Develop mathematical models of time-delay systems

CO4: Design and analyze time delay control systems using frequency and time domain techniques

Modelling of fractional order systems

Need for Fractional Order models, Fractional-order Operators: Definitions and Properties, Fractional-order Integrals, Fractional-order Derivatives, Fractional-order Differential Equations, Fractional-order Systems Models and Representations, Stability, Analysis of Time and Frequency Domain Responses, Solution of the State Equation of Continuous and discrete-time LTI Commensurate-order Systems-Inverse Laplace Transform, Jordan Matrix Decomposition and Cayley–Hamilton Methods, Controllability and Observability of Continuous and discrete time LTI Commensurate-order Systems.

Design and implementation of fractional order controllers

Need for Fractional-order Control, design and tuning of Fractional-order PID Controller, tuning of Fractional-order Lead-lag Compensators. design of robust fractional order controllers- CRONE, design of nonlinear fractional order controller: design of fractional order sliding mode controller, fractional calculus-based model reference adaptive controller

Continuous-time Implementations of Fractional-order Operators- Continued Fraction Approximations, Oustaloup Recursive Approximations, Modified Oustaloup Filter

Discrete-time Implementation of Fractional-order Operators-FIR Filter Approximation, Discretization Using the Tustin method with prewarping

Modelling and analysis of time delay systems

Mathematical preliminaries, modelling of time-delay systems, frequency domain & modal analyses; state space and rational approximations, Stability analysis, stability notions; frequency sweeping; Lyapunov's method

Performance analysis of time- delay systems: exponential stability and input to state stability, passivity and positive realness, L_2 gain analysis

Design of controllers for time delay systems

Smith-predictor based control and its modifications, linear matrix inequality-based design for time varying delays, H control via descriptor discretized Lyapunov functional method, controller design for nonlinear systems with time-delay, controller design for sampled data systems with time-delay

References:

1. Concepción A. Monje, YangQuan Chen, Blas M. Vinagre, DingyüXue and Vicente Feliu, 'Fractional-order Systems and Controls-Fundamentals and Applications', Springer-Verlag London Limited , 2010.
2. Sabatier J., Lanusse P., Melchior P., Oustaloup, 'A Fractional Order Differentiation and Robust Control Design-CRONE, H-infinity and Motion Control', Springer, 2015.
3. Emilia Fridman, 'Introduction to Time-Delay Systems: Analysis and Control', Springer International Switzerland 2014.
4. J. E. Marshall, H. Gorecki, A. Korytowski, and K. Walton, 'Time-Delay Systems: Stability and Performance Criteria with Applications', London: Ellis Horwood, 1992.K. Gu, V. L. Kharitonov, and J. Chen, 'Stability of Time-Delay Systems', Boston: Birkhauser, 2003.
5. R. F. Curtain and H. Zwart, 'An Introduction to Infinite-Dimensional Linear Systems Theory',. New York: Springer-Verlag, 1995.
6. Qing –ChnagZhong, 'Robust Control of Time-delay System', Springer-Verlag London, 2006.

EE6123E ROBOTICS AND COMPUTER VISION

Pre-requisites: **NIL**

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Apply the mathematics of spatial descriptions and transformations

CO2: Develop kinematics, dynamics, and simple control for a given robotic manipulator

CO3: Analyze the different methods for image enhancement and segmentation

CO4: Apply CNN for the computer vision applications

Introduction to spatial descriptions and transformations

Introduction: Robotics, Robot manipulators, simple two/three degrees of freedom model. Homogeneous Transformation: Co-ordinate frames, translation and rotation, change of frames, homogeneous transformation, composite homogeneous transformations, general axis of rotation
Differential Relationships: Derivative of homogeneous transformation, velocity and acceleration of end-effector, manipulator Jacobian

Kinematics, Dynamics, and Control of Robotic Manipulator

Kinematics & Dynamics: Link co-ordinate frames, kinematics parameters, the D-H representation, Arm equation, Inverse Kinematics, Solution of inverse kinematics problem with examples - introduction to dynamic analysis: Lagrangian formulation - trajectory planning: joint space and cartesian space
Manipulator Control: Independent joint control- Feed-forward control-Inverse dynamics control-Robot controller architectures. Implementation problems.

Fundamentals of Image Processing

Digital Image Fundamentals: Human visual system and visual perception - Image sensing and acquisition Image file types - Pixel representation and spatial relationship - Image Enhancement and Restoration- Mean and median filtering; Concepts of least square and Wiener filtering - Edge detection and feature extraction.
Image Segmentation: Thresholding; Edge-based segmentation; Region growing - Image Compression - Motion Estimation: Optical flow estimation, Structure from motion, Visual odometry - Visual Servoing: Image-based visual servoing (IBVS), Position-based visual servoing (PBVS)

Deep Learning for Computer Vision

Deep Learning for Computer Vision - Review of Deep Learning, Multi-layer Perceptron, Backpropagation, Convolutional Neural Networks (CNN) for image classification - Recurrent Neural Networks - Object detection algorithms (e.g., YOLO, Faster R-CNN) - Image segmentation using deep learning - 3D vision and depth estimation-control strategies for robots based on visual feedback.

References:

1. John J. Craig, *Introduction to Robotics, Mechanics and Control,* 3rd ed., Addison – Wesley, 2018.
2. Saeed B. Niku, *Introduction to Robotics, Analysis, Systems and applications*, Prentice Hall India, 2002
3. Schilling, Robort J., *Fundamentals of Robotics: Analysis and Control,* Prentice Hall of India, 2007
4. Fu, K.S., R.C. Gonzalez, C.S.G. Lee, *Robotics: Control, Sensing, Vision & Intelligence*, McGrawHill, 1987.
5. Sciavicco, L., B. Siciliano, *Modelling & Control of Robot Manipulators*, 2nd Edition, Springer Verlag, 2000.
6. Mark W. Spong, and M. Vidyasagar, *Robot Dynamics and Control*, John Wiley & Sons, 2008
7. Rafael C. Gonzalez and Richard E. Woods, *Digital Image Processing*, 4th Ed, Pearson ,2017
8. Richard Szeliski, *Computer Vision: Algorithms and Applications*, Springer-Verlag London Ltd. 2011
9. Simon Prince, *Computer Vision: Models, Learning, and Inference*, 2012.
10. Ian Goodfellow, Yoshua Bengio, Aaron Courville, *Deep Learning*, The MIT Press, 2016
11. Michael Nielsen, *Neural Networks and Deep Learning*, San Francisco, CA, USA: Determination press; 2015

EE6124E OPTIMAL ESTIMATION AND FILTERING

Pre-requisites: **NIL**

Total Lecture sessions: **39**

L	T	P	O	C
3	0	0	6	3

Course Outcomes

CO1: Formulate optimal estimation problems

CO2: Design linear optimal filters and predictors

CO3: Implement smoothing algorithms by UD and square root methods

CO4: Develop nonlinear filters by incorporating practical aspects

Introduction to estimation problems

[*Review of random processes and probability*]
Principles of estimation - Error models - princiciples of estimation - shaping filters and state augmentation – mean and covariance propagation – relationship with model parameters – orthogonality principle

Linear Optimal Filters and Predictors

Kalman-Bucy Filter – Optimal linear predictors – Correlated noise sources – relation between Kalman-Bucy and Wiener filters - Quadratic loss function – Matrix Riccati differential equation: Continuous and discrete time – model equations for transformed variables – Application of Kalman filters, simulation practice

Optimal Smoothers and Implementation Methods

Fixed Interval, fixed lag and fixed-point smoother algorithms. Computer round off – effect of round off errors on Kalman filters - factorization methods for square root filtering – UD filters - comparison of implementation methods.

Nonlinear Filtering and Practical Considerations

Quasi-linear filtering —extended Kalman filers – iterated EKF - sampling methods for nonlinear filtering - Detecting and correcting anomalies – bad data and missing data – stability of Kalman filters – Suboptimal and reduced order filters – Memory throughput - Word length considerations - computational efforts – reduction – Error budgets and sensitivity analysis – optimizing measurement selection policies

References

1. J.S. Meditch, *Stochastic Optimal Linear Estimation and Control,* McGraw-Hill Inc.,US, 1969
2. Mohinder S Grewal and Angus P Andrews, *Kalman Filtering Theory and Practice Using MATLAB,* John Wiley and Sons, 4th ed., 2015
3. B D O Anderson, and John B Moore, *Optimal Filtering*, Dover Books on Electrical Engineering. 2005
4. Lewis, F.L., Xie, L. and Popa, D., *Optimal and robust estimation: with an introduction to stochastic control theory*. 2nd ed., CRC press, 2017.
5. DG Luenberger, *Optimization by Vector Space Methods*, John Wiley and Sons Inc., 1998
6. Andrew H Jazwinski, *Stochastic Processes and Filtering Theory*, Dover Books on Electrical Engineering, 2008
7. D. Bertsekas, '*Dynamic Programming and Optimal Control'*, 4th ed., Athena Scientific, 2005

EE6125E LARGE SCALE SYSTEMS

Pre-requisites: **NIL**

L	T	P	O	C
3	0	0	6	3

Total Lecture sessions: 39

Course Outcomes:

CO1: Model large scale systems consisting of many subsystems

CO2: Analyse the stability of large scale systems.

CO3: Apply modal analysis and aggregation methods for model reduction and control.

CO4: Apply frequency domain and norm based methods for model reduction of large scale systems.

Modelling of Large Scale Systems

Modelling Large Scale Systems- interacting subsystems exchanging matter, energy, or information with the environment-Lumped-distributed-time varying systems-Ordinary Differential Equation Modelling Differential Algebraic Equations- Linearization- determination of Jacobian- Difference Equations-Basics for analysis of systems-Singular Values- Order and Dimension-State Space-Parameter Space-Vector space-norms-2 norm-Hankel matrices-Sparsity-Modelling power systems-Microgrids-Thermal systems tall buildings-flexible structures-Fractional order & integer order modelling

Stability and Control

Stability and Control of Large-Scale Systems- Controllability-Observability- grammians-computation-vector Lyapunov function methods, vector dissipativity theory, and decentralized control architectures. Continuous-time, discrete-time, and hybrid large-scale systems. - finite-time stability and finite-time decentralized stabilization, thermodynamic modeling, maximum entropy control, and energy-based decentralized control.

Model Order Reduction and Control: Modal Analysis and Aggregation Methods

Modal Analysis: Reduced Order Model Using Davison, Chidambara and Marshall Techniques, Suboptimal Control Using Davison and Chidambara Models, Control Law Reduction Approach Using Davison Model and Chidambara Models, Choice of Reduced Model Order.

Aggregation Methods*:* Aggregation of Control Systems Determination and Properties of Aggregated System Matrix, Error in Aggregation, Modal Aggregation- Reduced Order Model Stability of Feedback System, Aggregation by Continued Fraction.

Model Order Reduction: Frequency Domain and Norm Based Methods

Frequency Domain Methods: Moment Matching, Pade' Approximation Methods, Routh Approximation Techniques, Continued Fraction Method.

Norm Based Methods: Norms of Vectors and Matrices, Singular Value Decomposition, Grammian Matrices and Hankel Singular Values , Matrix Inversion Formulae, Model Reduction by Balanced Truncation, Balanced Realization, Steady State Matching Reduction of Unstable Systems, Properties of Truncated Systems Frequency-Weighted Balanced Model Reduction Model Reduction by Impulse/Step Error Minimization, Optimal Model Order Reduction

Reference:

1. Mohammad Jamshidi, "*Large-scale systems: modelling control and fuzzy logic*", Prentice Hall, 1997.
2. Jan Lunze, "*Feedback control of large scale systems*", Prentice-Hall, 1992.
3. Jose B. Cruz, "*Advances in Large Scale Systems: Theory and Applications',* JAI Press, 1984
4. Richard Saeks (eds.),"*Large-scale Dynamical Systems*" Point Lobos Press, 1976
5. Andrew P. Sage, "*Methodology for large-scale systems*", McGraw-Hill, 1977
6. Javad Mohammadpour, and Karolos M (Eds.), *Efficient Modeling and Control of Large-Scale Systems*, Springer, 2010.
7. M. Jamshidi, *Large-Scale Systems - Modeling and Control*, Elsevier North- *Holland*, New York, NY, 2010.
8. L. Fortuna, G. Nunnari and A. Gallo, "*Model Order Reduction Techniques with Applications in Electrical Engineering*", Springer-Verlag London, 2011.
9. S. Janardhanan, "*Model Order Reduction and Controller Design Techniques*", IIT Bombay, 2005.

EE6126E MULTIVARIABLE CONTROL SYSTEMS

Pre-requisites: **NIL**

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Develop mathematical models of multivariable systems

CO2: Analyse stability of multivariable feedback control systems

CO3: Design controllers for multivariable systems

CO4: Develop realization and synthesis techniques for multivariable systems

Modeling of multivariable system

Dynamic models of typical multivariable systems- Linear models and deviation variables-Linearization of nonlinear models-interacting and non-interacting systems- examples-multivariable transfer functions- poles and zeros-Smith and Smith McMillan forms- Relations between poles, zeros and eigenvalues of system matrix- pole vectors and directions- zero directions- Faddeev Leverrier Algorithm-Review of vector spaces-Quadratic form-sign definiteness-Sylvester's criterion- Norms , induced and infinity norms.

Stability of multivariable feedback control systems

Closed loop stability- Well-posedness of feedback loop- internal stability- The Nyquist stability criterion- coprime factorization over stable transfer functions- stabilizing controllers- strong and simultaneous stabilization-controllability- observability- controllability and observability Gramians- Eigenvalue sensitivity-output controllability- stabilizability- detectability-parameterization of all stabilizing compensators- simultaneous stabilization

Multivariable control system design

Performance specification in multivariable systems and their limitations- state feedback design- sequential loop closing- Output feedback design-characteristic locus method- PI controller for MIMO systems- internal model control (IMC)- IMC based PID controller- Decoupling- Diagonal controller- Nyquist array method-Exact model matching-approximate model matching

Realization and synthesis of multivariable systems

S-S Realization of external descriptions-existence and minimality of realization- Realizations in controller/ observer form and using singular value decomposition- systems represented by polynomial matrix descriptions- Diophantine equation- Two degrees of freedom feedback controllers- controller implementation configurations.

References:

1. P.J. Antsaklis, A.N. Michel, *Linear Systems,* Birkhäuser, 1st Corr. 2nd printing, 2005
2. Thomas Kailath, *Linear Systems*, Prentice-Hall, 1980
3. M. Vidyasagar,*Control system synthesis: A factorization approach*, The MIT Press, 1985
4. S. Skogestad, Ian Postlethwaite, *Multivariable feedback control: Analysis and* design, 2nd edition, Wiley Publications, 2007
5. B.W. Bequette, *Process control Modeling, Design and simulation*, PHI Learning Pvt. Ltd, 2013
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8. J M Maciejowski, Multivariable feedback design, Addison Wesley publishing company, 1989
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11. W. A. Wolovich, *Linear Multivariable Systems,* Springer- Verlag New York ,1974

EE6127E FLIGHT CONTROL SYSTEMS

Pre-requisites: **NIL**

L	T	P	O	C
3	0	0	6	3

Total Lecture sessions: 39

Course Outcomes:

CO1: Develop mathematical models for Aerodynamical systems

CO2: Analyse aircraft dynamics

CO3: Analyse aerodynamics of helicopter flights

CO4: Integrate the various aspects of astrodynamics

Introduction to Aerodynamics and Rigid Body Motion

Aerodynamics-standard atmosphere-layers of atmosphere-Aerodynamic flows-Mach number-Reynolds number-Airfoils-airfoil nomenclature-generation of lift-lifting surfaces-wings-wing geometry-aspect ratio chord line –angle of attack-Aerodynamic coefficients-lift, drag and moment coefficients-variation with angle of attack-aerodynamic centre and centre of pressure-Wind tunnels-control surfaces-elevator aileron-rudder-canard-tail plane-loads on tail plane dihedral angle-dihedral effect-flaps-slots-spoilers. Earth, Body and Inertial Coordinates and basics of Reference frame transformations using 3D rotation matrices for rigid body. Degrees of freedom and mathematical methods for modelling the dynamics of motion of rigid bodies with six degrees of freedom.

Aerial Vehicles

Classification of aerospace vehicles-aircrafts-helicopters-launch vehicles-missiles-unmanned aerial vehicles and spacecraft- Equation of motion of aircraft-level, un-accelerated flight-take-off performance- landing performance. Aircraft Stability and Control - Longitudinal and lateral dynamics- stability -modes of motion-stability derivatives. Aircraft transfer functions-control surface actuator - autopilot - stability augmentation.

Modeling and Control of Rotorcraft

Introduction to helicopter flight-rotor aerodynamics-configuration-operation-vertical flight-disc loading and power loading- induced flow ratio Climb and Descent- Forward flight- Blade Element Analysis – Momentum theory-Type of rotors-flapping hinge-lead lag hinge- flapping angle. Helicopter performance- hovering and axial climb- forward flight performance-reverse flow.

Stability and control- longitudinal and lateral dynamics- flying qualities.

Dynamics and Control of Spacecraft

Introduction to astrodynamics- fundamental of orbital Mechanics- orbital parameters- N body problem – two body problem- Different types of orbits- orbital transfer and rendezvous – space flight - space vehicle trajectories Re- entry of space vehicles- re-entry dynamics. Attitude control of satellite- stabilization of satellites

References:

1. John D Anderson Jr, *'Introduction to Flight',* 6th ed., McGraw Hill International, 2005.
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EE6128E GUIDANCE, NAVIGATION AND CONTROL

L	T	P	O	C
3	0	0	6	3

Pre-requisites: **NIL**

Total Lecture Sessions: 39

Course Outcomes:

CO 1: Explain the various components of navigation systems

CO 2: Design guidance systems from various sensor systems

CO 3: Design guidance schemes for control of space vehicles and missiles

CO 4: Develop optimal control schemes for guidance of aerospace systems

Introduction to Navigation systems

Fundamentals of Navigation - geometric concepts of navigation- reference frames- Euler angles - direction cosine matrix- quaternion representation- coordinate transformations- comparison of transformation methods. Inertial navigation- inertial platforms- stabilized platforms – gimballed and strapdown INS – IMU Navigation equations- Schuler principle and mechanization

Guidance Systems

Inertial sensors-Inertial navigation-block diagram representation of essential components-Inertial sensors, Gyros: Principle of operation-TDF and SDF- gyro precession-Nutation-gimbal - lock-gimbal flip-gyro transfer function- rate gyro-integrating gyro - constructional details and operation of floated rate integrating gyro-Dynamically tuned gyro-Ring laser gyro-Fiber optic gyro -gyro performance parameters-Accelerometers-transfer function - Pendulous gyro integrating accelerometer Vibrating String accelerometer-Accelerometer performance parameters. .

Integrated navigation-externally aided navigation- introduction to radars- radar equations- operation – types of radar-Lidars.

Basics of satellite navigation- GPS and GNSS- principles of advanced navigation system.

Missile Guidance

Fundamentals of aerodynamics- airfoils -aerodynamic forces moments and coefficients- control surfaces.

Fundamentals of Guidance- Taxonomy of guidance laws- Command and Homing Guidance- Classical Guidance laws: Pursuit, LOS, CLOS, BR, Proportional Navigation and Its Variants such as PPN, BPN, APN, TPN, GPN and IPN - PPN with Non-Manoeuvring and Manoeuvring Targets – Qualitative analysis Modern guidance Laws- Guidance Laws derived from optimal control Theory and Lyapunov method - Missile autopilots - FCS.

Space Vehicle Guidance

Launch Vehicle Guidance- implicit and explicit guidance- open loop and closed loop guidance- FE guidance-E guidance – VG guidance – Q guidance - Delta guidance.

Design of optimal control for performance of aerospace guidance systems- Riccatti equation – performance measure-optimal mid-course guidance.

References:

1. Anthony Lawrence, *'Modern Inertial Technology'*, 2nd Edition. SpringerVerlag, New York, Inc., 2001.
2. David Titteron and John Weston, '*Strapdown Inertial Navigation Technology*', 2nd Edition, IEE Radar, Sonar, Navigation and Avionics Series, 2005.
3. Ching-Fang Lin, '*Modern Navigation, Guidance and Control Processing*', Prentice-Hall Inc., Engle Wood Cliffs, New Jersey, 1991
4. George M. Siouris, '*Missile Guidance and Control Systems*', Springer Verlag , New York Inc., 2004.
5. Paul Zarchan , '*Tactical and Strategic Missile Guidance*', 7th Edition, AIAA, Inc., 2019.
6. N.A. Shneydor, '*Missile Guidance and Pursuit: Kinematics, Dynamics and Control*', Ellis Horwood Publishers, 1998.
7. Robert C. Nelson, *'Flight Stability and Automatic Control'*, 2nd ed, WCB McGraw-Hill, 2017.
8. Roger R. Bate, '*Fundamentals of Astrodynamics*', Dover Publications Inc., New York, 1971.
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EE6129E FLEXIBLE STRUCTURES

Pre-requisites: **NIL**

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Develop basic mathematical models for flexible structures

CO2: Integrate different finite element methods for the modelling of flexible structures

CO3: Design of various controllers for flexible structures

CO4: Simulate the control strategies in various applications of flexible structures.

Introduction to flexible structures

Flexible structures -The Finite Element Method – The element characteristic matrix – Element assembly and solution for unknowns – Summary of finite element history - Basic equations of elasticity – Strain-displacement relations – Theory of stress and deformation – Stress-strain-temperature relations.

Modelling of flexible structures

Stationary Principles, Rayleigh-Ritz Method and Interpolation: - Principle of stationary potential energy – Problems having many d.o.f – Potential energy of an elastic body – The Rayleigh-Ritz method – Piecewise polynomial field – Finite element form of Rayleigh-Ritz method – Finite element formulations derived from a functional – Interpolation – Shape functions for C0 and C1 elements – Lagrangian and Hermitian interpolation functions for one dimensional elements – Lagrangian interpolation functions for two and three dimensional elements Introduction to Weighted Residual Method: -Some weighted residual methods – Galerkin finite element method – Integration by parts – Axially loaded bar – Beam – Plane elasticity

Analysis and control of flexible structures

Model order reduction for control design: Time Domain - modal cost analysis and component cost analysis-balancing method of model reduction. Frequency domain - Routh approximation method- Hankel norm model reduction Passive control and active control-Feedback and feed forward control-LQR control- decentralised/hierarchical control-model reference adaptive control – model free control.

Simulation studies of flexible structures

Applications of flexible structures- Flexible structures in robotics- Flexible aerospace structures- flexible solar panels - Flexible medical structure - Control of flexible links – Computer-based simulations

References:

1. Cook, Robert D., *Concepts and applications of finite element analysis*, 4th Eds, John Wiley & Sons, 2007.
2. Desai, Chandrakant S., *Elementary finite element method*, Civil Engineering and Engineering Mechanics Series', Englewood Cliffs': Prentice-Hall, 1979
3. Chandrupatla, Tirupathi R.. *Introduction to finite elements in engineering*, 4th edition, Pearson, 2011.
4. Krishnamoorthy, C. S. *Finite element analysis: theory and programming.* 2nd edition, Tata McGraw-Hill Education, 2017.
5. Zienkiewicz, Olgierd Cecil, The finite element method, Vol. 3. London: McGraw-hill, 1977.
6. Junkins, John L. *Introduction to dynamics and control of flexible structures*. American Institute of Aeronautics & Astronautics, 1993.
7. Cavallo, Alberto, *Active control of flexible structures–From modelling to implementation*, Springer, 2010.
8. Jinkun Liu, Wei He, *Distributed Parameter Modeling and Boundary Control of Flexible Manipulators*, Springer, 2018
9. Rush D. Robinett III, John Feddema, et.al, *Flexible Robot Dynamics and Controls*, Springer, 2012

EE6130E QUANTITATIVE FEEDBACK THEORY

Pre requisite: **NIL**

Total Lecture sessions: 39

L	T	P	O	C
3	0	0	6	3

Course Outcomes:

CO1: Explain the basics of QFT

CO2: Design QFT controller for SISO and MISO LTIV systems

CO3: Design QFT controller for MIMO LTIV systems

CO4: Apply discrete quantitative technique for MISO Systems

Introduction to QFT

Review of conventional control theory and introductory S-S theory- Need for QFT- QFT design objective- QFT basics- QFT design- Benefits of QFT- QFT applications

QFT design for SISO and MISO LTIV systems

Basics of SISO feedback controlled systems- Basic frequency domain characteristics- closed loop specifications- Performance limitations of NMP or unstable systems- Loop shaping- Synthesis of LTI controllers for MISO LTI Plants- one DoF system-Two DoF system

QFT design for MIMO LTIV systems

Specifications of desired closed loop performance measures- Representation of MIMO plants as SISO and MISO plants- One degree of freedom feedback system- Two DOF feedback system- Minimum phase diagonal elements- formulation using LFT notation- Sensitivity reduction and trade off nonminimum phase feedback systems.

Discrete quantitative feedback technique

Bilinear transformation- Discrete MISO module with plant uncertainty- QFT W domain digitization design- Basic design procedure for a MISO sample data control system- QFT technique pseudo continuous time system- Digital controller implementation

References:

1. C.H. Houpis, S.I. Raslussen,'*Quantitative Feedback Theory: Fundamentals and applications'*, 2nd Ed, Marcel Dekker, 2005.
2. O. Yanid, *'Quantitative Feedback Design of Linear and Nonlinear Control Systems'*, Kluwer Academic, Boston, 1999
3. I.M. Horowitz,*'Quantitative Feedback Theory'*, Vol 1, Colorado Press, Boulder, Colorado , 1993
4. M. Gopal, '*Digital Control and State Variable Methods*', 4th Ed, Tata McGraw Hill Publishing Company, 2017.
5. K.Ogata, *'Discrete-time Control Systems'*, 2nd Ed., Pearson Education Ltd., Singapore, 2002.

EE6131E NUMERICAL METHODS FOR CONTROL SYSTEM DESIGN

Pre-requisites: **NIL**

Total Lecture Sessions: 39

L	T	P	O	C
3	0	0	6	3

Course Outcomes:

CO1: Understand the advanced topics of matrices in linear algebra

CO2: Explain the numerical methods linear algebra for system analysis

CO3: Apply numerical methods for control system analysis

CO4: Develop simulations on computer for control system studies

Review of Linear Algebra

Review of Linear Algebra: Vector spaces, Orthogonality, Matrices, Vector and Matrix Norms, Kronecker Product - Moore Penrose Inverse, Matrix Inversion Lemma - Recursive Algorithm - Large scale Matrix computations, Rank-Condition Number- Singular Values - Similarity Transformations, rotations - Hermitian matrices, Toeplitz matrix - some selected software and computer based exercises.

Numerical Linear Algebra

Numerical Linear Algebra: Floating point numbers and errors in computations – Conditioning - Efficiency, Stability, and Accuracy - LU Factorization - Numerical solution of the Linear system Ax = b, QR factorization - Orthogonal projections - Least Squares problem - Singular Value Decomposition - Canonical forms obtained via orthogonal transformations - Heisenberg reduction of a matrix, sparse matrices, computations with sparse matrices, error analysis in various cases

Control Systems Analysis

Control Systems Analysis: Linear State-space models and solutions of the state equations - Continuous time systems, discrete time systems - frequency response calculations - Controllability, Observability, Numerical Methods for Controllability and Observability - Difficulties with Theoretical Criteria - Stability, Inertia, and Robust Stability - Numerical solutions and conditioning of Lyapunov and Sylvester equations.

Control Systems Design

Control Systems Design: Feedback stabilization - Eigenvalue assignment - Optimal Control - Quadratic optimization problems, Algebraic Riccati equations - Numerical Methods for State Feedback Stabilization, Eigenvalue Assignment (Pole-Placement) in both SISO and MIMO systems, Optimal Control via Riccati Equation- numerical solutions - H-infinity Control algorithms - Observer designs - State estimation and Kalman filter algorithms for discrete time state and parameter estimation problems - Computer based simulation of selected control systems.

References:

1. G. Strang, *Introduction to Linear Algebra*, 5th Edition, Wellesley-Cambridge Press, 2016
2. B.N. Datta, *Numerical Methods for Linear Control Systems*, Elsevier Academic Press, 2005.
3. G.H. Golub & C.F. Van Loan, *Matrix Computations*, 4th edition, John Hopkins University Press, 2013
4. J .H. Wilkinson, *The Eigenvalue Problem,* Oxford University Press, 1992.
5. G Meurant, *Computer Solution of Large Linear Systems*, Elsevier, North Holland, 2005
6. John Dorsey, *Continuous and Discrete Control Systems,* McGrawHill, 2002
7. Mariano Martin Martin, *Introduction to Software for Chemical Engineers*, CRC Press, 2015
8. Warren F Phillips, *Mechanics of Flight,* 2nd edition, John Wiley & Sons, 2010

EE6132E NETWORKED CONTROL AND MULTIAGENT SYSTEMS

Pre requisites: **NIL**

Total Lecture sessions: 39

L	T	P	O	C
3	0	0	6	3

Course Outcomes:

CO1: Model networked control problems using graph theory

CO2: Analyze the stability and performance of networked control systems

CO3: Develop distributed control strategies for multi-agent robotics

CO4: Develop strategies for implementing mobile sensor and communication networks

Basic Concepts in Networked Control

Review of Graph Theory - Connected Graph - Incidence Matrix - Tree - cutse t- loop/cycles - Minimum Spanning Tree - Network Models - graphs, random graphs, random geometric graphs, state-dependent graphs - Networked control systems - Proximity graphs - Algebraic and spectral graph theory - Connectivity: Cheeger's inequality - switching networks - From biological swarms to graph-based models - Rendezvous: A canonical problem

Decentralized Control

The agreement protocol: static case - Reaching decentralized agreements - Consensus equation: Static case - Leader networks and distributed estimation - Discrete time consensus.
The agreement protocol: dynamic case: Switched networks - Lyapunov-based stability - Consensus equation: Dynamic Case-Biological models: Flocking and swarming - Alignment and Kuramoto's coupled oscillators – Cucker-Smale model
Distributed estimation - Computational, communications, and controls resources in networked control systems - Distributed control - Convex Optimization - Optimization-based control design.

Multi Agent Robotics

Formations - Graph rigidity - Persistence - Formation control, sensor and actuation models-distance based formations, rigidity, position based formations, formation infeasibility - Consensus problem - static, dynamic, distributed estimation, leader-follower architectures for consensus-Reaching decentralized agreements through cooperative control - leader-follower networks-Network controllability - Network feedback - Averaging Systems - Positive Systems - nonholonomic, double integrator, rigid body dynamics - Collision avoidance: potential fields, navigation functions. Introduction to artificial intelligence and deep learning for multi-agent robotics.

Mobile Sensor and Communication Networks

Sensor networks: Coverage control - Coverage and detection problems-Gabriel and Voronoi graphs- Voronoi-based cooperation strategies - Random graphs - LANdroids: Communication networks Communication models - mobile communications networks - connectivity, connectivity maintenance, sampling, delays, packet losses, quantization, security - Swarming - sensor networks: sensing constraints, aggregation, dispersion, coverage control, deployment, flocking - Internet of things (IOT).

References:

1. Mehran Mesbahi and Magnus Egerstedt, '*Graph Theoretic Methods in Multiagent Networks*,' Princeton University Press, 2010.
2. F. Bullo, J. Cortes, and S. Martinez, '*Distributed Control of Robotic Networks'*, Princeton, 2009.
3. C. Godsil and G. Royle, '*Algebraic Graph Theory'*, Springer, 2001.
4. Wei Ren, Randal W. Beard, *'Distributed Consensus in Multi-vehicle Cooperative Control'*, Communications and Control Engineering Series, Springer-Verlag, London, 2008
5. Bullo, Francesco. *Lectures on network systems*. Vol. 1. Kindle Direct Publishing, 2020.
6. P. J. Antsaklis and P. Tabuada,, '*Networked Embedded Sensing and Control',* Springer 2006.
7. Strogatz S. *Sync: The emerging science of spontaneous order*., Hyperion Books, 2004

EE6133E INSTRUMENTATION FOR EMBEDDED CONTROL SYSTEMS

Pre-requisites: **NIL**

Total Lecture Sessions: 39

L	T	P	O	C
3	0	0	6	3

Course Outcomes:

CO1: Familiarize the main components and concepts of embedded control systems

CO2: Design proper instrumentation for controller implementation in embedded platform.

CO3: implement control applications on an embedded platform

CO4: Utilize modern software tools for analysis of embedded control systems.

Review of control system components

Control system components: Basic control system components and their roles - sensors and transducers - Types of actuators - Interface circuits for actuator control - Overview of sampling theory - discrete time PID controller - design issues with computer-based control - data types - quantization - overflow and resource issues - real-world issues in measuring frequency response.

Embedded control system and FPGA

Embedded control system: Block diagram - Commercially Available Embedded Processors: Microprocessors & microcontrollers - Digital signal processor - FPGA: Block diagram, Verilog, Finite state machine - Implementation Architecture of PID Controller - Integration of sensors and actuators with FPGA-based control systems - Parallel Implementation of Multiple Controllers.

Real-time operating system and communication protocol

Real-time Operating Systems (RTOS): Basic concepts of RTOS and its types, Concurrency, Reentrancy, Intertask communication - Implementation of RTOS with some case studies

Communication protocol: serial and parallel communication interfaces, such as UART, SPI, and I2C, and their utilization for sensor integration and data exchange - networking protocols: Ethernet, Modbus, Profibus, CAN, and wireless communication standards - Control Using Feedback over Wireless Ethernet and Bluetooth

Implementation of nonlinear control system

Implementation of nonlinear control system - Switched Nonlinear System - Embedded implementation of sliding mode control - case study on wheeled mobile robot.

Validation techniques for embedded control systems - Model Based Control System Design: discrete systems - notion of state - infinite State Machines - Extended State Machines - code generation - verification and validation - Hardware-in-the-Loop (HIL), Model-in-the-Loop (MIL), Software-in-the-Loop (SIL), Processor-in-the-Loop (PIL).

Introduction to different real time simulators - RTDS, OpalRT, SpeedGoat, Typhoon HIL, etc.

Performance assessment of control algorithms on the target implementation architectures - Case studies from automotive, aerospace, process control and other application domains

References:

1. Leena Vachhani, Pranjal Vyas, Arunkumar G. K., *Embedded Control for Mobile Robotic Applications*. John Wiley & Sons, 2022
2. Tim Wescott, *Applied Control Theory for embedded systems*, Newness publications, 2006
3. F. Vahid and T.D.Givargis, *Embedded System Design: A unified hardware/software introduction*, John Wiley & Sons, student eds, 2006
4. Dimitrios Hristu-Varsakelis, William S. Levine (Eds), *Handbook of Networked and Embedded Control Systems*, Birkhäuser Boston, MA, 2007
5. Jonathan Valvano, *Embedded Microcomputer Systems: Real Time Interfacing*, CENGAGE Learning Custom Publishing, 3rd Eds, 2011
6. Edward Ashford Lee, Sanjit Arunkumar Seshia, *Introduction to Embedded Systems, 2nd Edition: A Cyber-Physical Systems Approach*, MIT Press, 2016
7. Wayne Wolf, *Computers as Components: Principles of Embedded Computing System Design*, Morgan Kaufmann, 2nd Edition, 2008

EE6134E ANALYTICAL INSTRUMENTATION

Pre-requisites: **NIL**

Total Lecture Sessions: 39

L	T	P	O	C
3	0	0	6	3

Course Outcomes:

CO1: Classify the sampling methods and various analytical methods for gas concentration and composition measurement in pollution monitoring.

CO2: Analyze the various measurement techniques for humidity and moisture.

CO3: Choose appropriate analytical tools and justify the selection with their characteristics for chemical composition measurement.

CO4: Apply the concepts of various spectroscopic instruments for material characterization.

Introduction to Sampling techniques and Gas Analysis

Difference between analytical and other instruments - Sampling: sampling system for liquids and gasses, sampling components, automatic and faithful sampling - Gas Analysis: Gas Chromatography, principles & components, Thermal conductivity gas analyzers, Heat of reaction method, Estimation of Oxygen, Hydrogen, Methane, CO2, Carbon monoxide, paramagnetic oxygen analyzer, Electrochemical reaction method, Polarography, Density measurement.

Humidity and Moisture Measurements

Humidity measurement: Definitions: absolute, specific, relative humidity and dew point, Dry and wet bulb psychrometer, Hair hygrometer, Dew point meter, Moisture Measurement: definitions, electrical methods of measurement, NMR method, IR method.

Chemical Composition Measurements

Newtonian and Non Newtonian flow - Measurement of viscosity and consistency - Laboratory and online methods - Measurement of pH: definition and methods, redox potential - electrical conductivity: conductivity cell and applications - Density measurement: solids, liquids, gas.

Spectrochemical Analysis

Classification of techniques - Principles and components - Emission spectrometry: Flame emission, Atomic absorption type - Dispersive techniques - Scheme for UV, IR and near IR analysis, comparison of methods - X-ray analyzers - NMR spectrometry - ESR spectroscopy - Mass spectrometry -. Analytical Electron Microscope: An overview.

References:

1. Braun, Robert D., Introduction to Instrumental Analysis, Pharma Book Syndicate, Hyderabad, 2nd ed. 2012.
2. Ewing, Galen W., Instrumental Methods of Chemical Analysis, 5th ed. McGraw Hill, Singapore, 2013.
3. Khandpur R.S, Handbook of Analytical Instruments, 3rd ed. Tata McGraw Hill, 2015.
4. Sherman, R.E. and Rhodes L.J., Analytical Instrumentation, 1st ed. ISA Press, New York, 1996.
5. Jain, R.K., Mechanical and Industrial Measurements, 3rd ed. Khanna Publishers, Delhi, 2017.
6. Bela G. Liptak, Instrument Engineers' Handbook, Volume One: Process Measurement and analysis, 4th ed. CRC Press, 2003.

EE6135E MULTISENSOR DATA FUSION

Pre-requisites: **NIL**

Total Lecture Sessions: 39

L	T	P	O	C
3	0	0	6	3

Course Outcomes:

CO1: Apply the basic concepts of multi sensor data fusion for elementary applications.

CO2: Choose appropriate model and architecture of data fusion techniques for a given application.

CO3: Analyze the mathematical tools and fusion algorithms for data fusion applications.

CO4: Create fusion models for state estimation and localization for autonomous driving applications.

Introduction to Multi Sensor Data Fusion

Multi-sensor data fusion: Use of multiple sensors - Multi-sensor classification - Examples of Multi-sensor data acquisition: Elementary applications and techniques for data fusion in military and civilian systems, Interpretation of acquired multi-sensor data: Multi-sensor registration, Target-tracking.

Data Fusion Models and Architectures

Data fusion models: Joint Directors of Laboratories Model, Modified Waterfall Fusion Model, Intelligence Cycle-based Model, Boyd Model, Omnibus Model – Architectures: Centralized Fusion, Distributed Fusion, Hybrid Fusion - Benefits of data fusion - concepts and issues.

Mathematical Tools and Algorithms for Data Fusion

Mathematical tools: Coordinate transformations, Rigid body motion, Dependability and Markov chains, Meta-heuristics - Taxonomy of algorithms for multi-sensor data fusion - Data association - Identity declaration - Estimation: Kalman filtering, practical aspects of Kalman filtering, extended Kalman filters - Decision level identify fusion - Knowledge based approaches - Data information filter, extended information filter - Decentralized and scalable decentralized estimation - Sensor fusion and approximate agreement - Optimal sensor fusion using range trees recursively - Distributed dynamic sensor fusion.

Implementation methods of Data Fusion Systems

High performance data structures: Tessellated, trees, graphs and function - Representing ranges and uncertainty in data structures - Designing optimal sensor systems within dependability bounds - Implementing data fusion system: Automated Driving Systems: Mapping, Connectivity, Basics of LIDAR sensing - Use of multi sensor data fusion for autonomous driving.

References:

1. H. B. Mitchell, Multi Sensor Data Fusion, Springer Publisher, 2007.
2. David L. Hall, Sonya A H McMullen, Mathematical techniques in Multisensor data fusion, 2nd ed. Artech House, Boston, 2004
3. Arthur Gelb, Applied Optimal Estimation, M.I.T. Press, 1982.
4. James V. Candy, Signal Processing: The Model Based Approach, McGraw –Hill Book Company, 1987.
5. Martin Liggins II, David Hall, James Llinas, Handbook of Multisensor Data Fusion, 2nd ed. CRC Press, 2012.
6. R.R. Brooks and S.S. Iyengar, Multisensor Fusion: Fundamentals and Applications with Software, 1st ed. Prentice Hall Inc., New Jersey, 1998.
7. Jitendra R. Raol, Multi Sensor Data Fusion with MATLAB, CRC Press, 2009.
8. Lawrence A. Klein, Sensor and Data Fusion, 2nd ed. SPIE Press, 2012.

EE6136E ARTIFICIAL INTELLIGENCE AND MACHINE LEARNING FOR BIOMEDICAL APPLICATIONS

Pre-requisites: **NIL**

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Discuss the underlying concepts, methods, and the potential of intelligent systems in Biomedical applications

CO2: Apply the foundational methods in artificial intelligence (AI) and computational models with greater emphasis on machine learning and apply them to specific areas in biomedical signals.

CO3: Apply the deep learning models and justify their use as a computational tool in medicine and healthcare system.

CO4: Analyse the challenges and issues associated with the use of AI in healthcare system

Introduction to AI and its application to biomedical signals

Introduction to Human and Artificial Intelligence: terminologies, computational models of Intelligence - Review of relevant mathematical and statistical concepts: logarithmic loss, cross entropy optimizing cost functions - linear and logistic regression - Introductory concepts on modeling time series data and temporal features - Introduction to biomedical signals and data sets and application of these concepts to biomedical signal analysis.

Types of Machine Learning

Forms of Learning: supervised, semi-supervised, unsupervised and reinforcement learning - Supervised Learning: Decision trees, non-parametric methods for learning, support vector machines - Unsupervised Learning: basic and advanced clustering techniques, dimensionality reduction (Feature selection and feature extraction) - Bio-inspired Learning (from perceptron to deep learning): neural basis of computing - Application to biomedical signals such as EEG, ECG, EMG for decision making.

Deep Neural Network and its application to biomedical signals

Deep Neural Networks (DNN) - Convolutional Neural Network (CNN) - Recurrent Neural Network (RNN) : Long-Short- Term-Memory (LSTM) - Graph based Neural Network (GNN) - Preprocessing: Noise Removal using deep learning algorithms - Feature Extraction - Signal Analysis: Time Series Analysis - Model evaluation and performance metrics, cross-validation, model interpretability - case studies on disease detection using EEG signals, ERG and MRI in healthcare systems.

Ethics of AI

Introduction to Ensemble Methods for Signal Analysis - Emerging paradigms and concepts in artificial, social and emotional intelligence - Unique characteristics and challenges in medicine and healthcare - Tools and technologies for implementing AI methods - Ethics of AI: bias, fairness, accountability, and transparency in machine learning - Ethical, legal and social issues of AI in medicine and healthcare.

References:

1. Bishop C.M, *Pattern Recognition and Machine Learning*, Springer, 2006.
2. Goodfellow I, Bengio Y, Courville A, & Bengio Y, *Deep learning*, Cambridge: MIT Press, 2016.
3. Michael Nielsen, *Neural Networks and Deep Learning*, Goodreads (eBook), 2013.
4. Bengio Y, *Learning Deep Architectures for AI, Foundations and Trends in Machine Learning*, Now publishers, 2009.
5. Stuart Russell and Peter Norvig. *Artificial Intelligence: A Modern Approach* , 3rd ed.,. Prentice Hall Press, Upper Saddle River, NJ, USA,2009.
6. Jorge Garza Ulloa, Applied Biomedical Engineering Using Artificial Intelligence and Cognitive Models, Elsevier, 2021.
7. Donna L. Hudson, Maurice E. Cohen, Neural Networks and Artificial Intelligence for Biomedical Engineering, Wiley-IEEE Press,1999.
8. Jason Brownlee, Machine Learning mastery with Python, e-book, 2021.

EE6137E BIOMEDICAL SIGNAL PROCESSING AND APPLICATIONS

Pre-requisites: NIL

Total Lecture Sessions: 39

L	T	P	O	C
3	0	0	6	3

Course Outcomes:

CO1: Explain the principles of acquisition and pre-processing of biosignals

CO2: Design suitable algorithms for the analysis of ECG signals using the principles of electrocardiography

CO3: Apply methods to extract relevant information using the principles of electroencephalography and electromyography

CO4: Analyse respiratory and blood pressure signals for clinical interpretations and apply the principles of communication systems in biotelemetry

Introduction to biosignals and their recording, artifacts and processing

Introduction to biomedical signals – Action potential generation – Electrocardiogram, Electroencephalogram, Electromyogram, Electroneurogram, Electroretinogram. Basics of bio-signal acquisition – Electrode placement on acquisition sites – monopolar and bipolar electrodes – role of electrode gels. Preamplification of biosignals – Artifacts and their removal – 50 Hz powerline frequency – baseline wandering – movement artifact – interference from other physiological signals – use of filters. Sampling and quantization for biosignals – Fourier transform and Time-frequency analysis of biomedical signals - Z – transforms – Inverse Z – transforms – FIR and IIR Filters.

ECG Signal Processing

ECG processing – Generation of ECG – Vectorcardiogram – 12 Lead system for ECG aquisition - ECG signal from various lead configurations – frequency spectrum of ECG – QRS detection algorithms – use of moving average filter – Cardiac abnormalities and their interpretation from ECG – Feature extraction from ECG signals – time domain and frequency domain analysis – Long term ECG monitoring – Heart rate variability studies – Direct ECG data compression techniques – Transformation compression Techniques.

EEG and EMG Signal Processing

EEG processing – Generation of EEG – random nature of EEG signals – EEG aquisition system – frequency spectrum of EEG – identification of normal and abnormal brain states from EEG – feature extraction for various brain states – sleep, epilepsy, tumour, brain death. Features of evoked potentials.
EMG processing – Generation of EMG – Motor Unit Action Potential – Compound Muscle Action Potential – features of surface and intramuscular EMG – Introduction to neuromuscular control – myoelectronic control of prosthesis.

Processing of other physiological signals, Biotelemetry

Automated analysis of blood pressure and respiratory waveforms. Overview of multiparameter patient monitoring systems. Biotelemetry – cable transmission – radio transmission – implantable telemetry systems – signal processing for remote health monitoring.

References:

1. R M Rangayyan: Biomedical Signal Analysis, 2nd Edition, John Wiley, 2015.
2. W. J. Tompkins, Biomedical Digital Signal Processing, PHI, 2009.
3. D. C. Reddy, Biomedical Signal Processing: Principles and Techniques, TMH, 2005.
4. L. Sornmo and P Laguna, Bioelectrical Signal Processing in Cardiac and Neurological Applications, Elsevier Academic Press, 2005.
5. R. U. Acharya, J. S. Suri, J. A. E. Spaan, S. M. Krishnan, Advances in Cardiac Signal Processing, Springer, 2007
6. J G Proakis & D G Manolakis, Digital Signal Processing – Principles, Algorithms and Applications, 4th Edition, Pearson 2014.

EE6138E MEDICAL IMAGING SYSTEMS

Pre-requisites: NIL

Total Lecture Sessions: 39

L	T	P	O	C
3	0	0	6	3

Course Outcomes:

CO1: Explain the design concepts of X-ray machine and Ultrasound machines.

CO2: Demonstrate the construction of Computed Tomography systems, PET and SPECT.

CO3: Analyse the constructional features of MRI and Thermal Imaging systems.

CO4: Implement archiving of medical images for retrieval and apply advanced techniques in imaging.

X-rays and Ultrasound

X Rays – Introduction to physics of X rays – constructional features of X ray machine – detectors - X ray films and cassettes – Intensifying screen and its composition – Computed radiography – Flat panel detector based radiography. Performance metrics of X ray systems – contrast, noise, spatial resolution. X ray microscopy. Medical Ultrasound – Physics of US waves – Scan modes – Real time US imaging systems – Colour Doppler Flow Imaging – Design of US probes.

CT, PET and SPECT

Computed Tomography – Basic principle – contrast scale. Components of a CT system – scanning, processing and viewing systems - gantry geometry. Software for viewing and analysing CT images. PET and SPECT – Fundamental principles, radioisotopes used – Image acquisition and interpretation

MRI and Thermal Imaging Systems

Magnetic Resonance Imaging – Fundamental principles – Bloch equation – T1 and T2 relaxation – spin echo – Image reconstruction techniques – Organization of the MRI imaging facility. Functional MRI – basic principle and applications (case study). NMR Imaging.
Thermal Imaging Systems – Instrumentation – IR camera, detectors – Image processing and analysis – microwave thermography. Applications of thermography in medicine – cancer detection, neuropathy, dermatological applications

Image Archival, Robotics in Imaging Systems

Archiving of Medical Images – DICOM standard – DICOM connectivity – Image compression for archiving and transfer – Server requirements – Content based approach for image retrieval – AI in Medical Imaging – Application in various diseases. Robotics in medical imaging – Application in treatment planning.

References:

1. Andreas Maier et al, *Medical Imaging Systems – An Introductory Guide,* Springer 2018
2. Dance et.al (Eds), Diagnostic Radiology Physics – A handbook for teachers and students, IAEA 2014
3. J L Prince and J M Links, *Medical Imaging Signals and Systems*, 2nd Edition, Pearson 2015
4. Thomas Jackson, Advances in Medical Imaging, Hayle Medical, 2015
5. D K Baghel, *A Textbook of Imaging Modalities and Recent Advances in Diagnostic Radiology for Medical Physicists, Residents & Technologists*, AITBS Publishers India, 2023
2. J G Webster, Medical Instrumentation, Application and Design, 4th Edition, John Wiley & Sons, 2015
3. R.S. Khandpur, Handbook of Biomedical Instrumentation, 3rd Edition, Tata McGraw-Hill, 2014.

EE6139E DATA ACQUISITION AND TELEMETRY

Pre-requisites: **NIL**

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Classify different forms of signal conditioning and conversion in data acquisition systems.

CO2: Identify an appropriate communication method for sensor data acquisition.

CO3: Analyze the different tools and techniques in Telemetry systems.

CO4: Implement telemetry and telecontrol methods for real-life problems.

Introduction to Data Acquisition System

Overview of Basic Analog/Digital conversion: Types of DAC and ADCs - Comparison of A/D conversion techniques- Sampling theorem – Sampling and digitizing – Aliasing – Sample and hold circuit - Data acquisition system (DAQ): Definition, functional block diagram, classification - Construction and salient features of the following data acquisition systems: Analog data acquisition system using time division multiplexing, Analog data acquisition system using frequency division multiplexing, Digital data acquisition system with different configurations and Data logger.

Communication Techniques in Data Acquisition Systems

Analog modulation of AC carrier: amplitude modulation and frequency spectrum of AM wave , frequency modulation and frequency spectrum of FM wave, Phase modulation and frequency spectrum of PM wave - Analog modulation of pulse carrier - basis of PAM, PFM - Digital Communication Techniques: Digital modulation of pulse carrier: basis of PCM, DCPM - Digital modulation of AC carrier: ASK, FSK, PSK - error detection and correction methods - error control techniques.

Introduction to Telemetry systems

Signal formation - Conversion and transmission - General block diagram of telemetry system - Types - Essential applications of telemetry system - Signal transmission media: Wires and cables, Power line carrier communication, terrestrial and satellite radio links, optical fiber communication - Multiplexing for Telemetry systems.

Classifications of Telemetry System and Telecontrol methods

Classification: Direct voltage and current telemetry system, AM and FM telemetry system, Multi-channel PAM and PWM telemetry system, Single and multi-channel digital telemetry system, Modem-based telemetry system, Short range radio telemetry and satellite telemetry system, Fiber optics telemetry system - Analog and Digital techniques in Telecontrol, Telecontrol apparatus –Remote adjustment, Guidance, and regulation –Telecontrol using information theory - Example of a Telecontrol System.

References:

1. John Park and Steve Mackay, Data Acquisition for Instrumentation and Control Systems, 2003.
2. Maurizio Di Paolo Emilio, Data Acquisition Systems: From Fundamentals to Applied Design, Springer New York, NY, 2013.
3. Tomasi W, Fundamentals of Electronic Communication Systems, 5th ed. Prentice Hall, 2008.
4. Ginzberg, Lekhtman and Malov, “Fundamentals of Automation and Remote Control,” Pergamon, 2013.
5. D Patranabis, *Telemetry Principle* 1st ed. McGraw-Hill, 2013.
6. Gruenberg EL, “Handbook of Telemetry and Remote Control,” McGraw-Hill, 1967.

EE6140E WIRELESS SENSORS, NETWORKS AND IOT

Pre-requisites: **NIL**

Total Lecture Sessions: 39

L	T	P	O	C
3	0	0	6	3

Course Outcomes:

CO1: Classify various elements and architectures of wireless sensor networks.

CO2: Apply appropriate communication protocols for wireless sensor networks.

CO3: Select suitable architecture and communication protocols for a given IoT based system.

CO4: Implement various architectures and design principles of wireless sensor networks with IoT for real-life problems.

Overview of Wireless Sensor Networks and Architectures

Challenges for Wireless Sensor Networks - Enabling Technologies for Wireless Sensor Networks - Single-Node Architecture - Hardware Components - Energy Consumption of Sensor Nodes - Operating Systems and Execution Environments - Network Architecture - Sensor Network Scenarios - Optimization Goals and Figures of Merit - Design principles for WSNs - Service interfaces of WSNs Gateway Concepts.

Communication Protocols

Physical Layer and Transceiver Design Considerations - MAC Protocols for Wireless Sensor Networks - Low Duty Cycle Protocols And Wake Up Concepts - S-MAC, The Mediation Device Protocol, Wake Up Radio Concepts, Contention based protocols: CSMA, PAMAS - Schedule based protocols: LEACH, SMACS, TRAMA - Address and Name Management in WSNs - Assignment of MAC Addresses - Routing Protocols - Energy - Efficient Routing, Geographic Routing - Hierarchical networks by clustering.

Overview of Internet of Things

IoT Conceptual Framework - IoT Architectural View - Technology Behind IoT - Sources of IoT - M2M communication - Examples of IoT - Modified OSI Model for the IoT/M2M Systems - data enrichment - data consolidation and device management at IoT/M2M Gateway - web communication protocols used by connected IoT/M2M devices - Message communication protocols for IoT/M2M devices : CoAP-SMS, CoAP-MQ, MQTT, XMPP.

Architecture and Design Principles for IOT

Internet connectivity - Internet based communication - IPv4, IPv6,6LoWPAN protocol - IP Addressing in the IoT - Application layer protocols: HTTP, HTTPS, FTP, TELNET and ports - Data Collection - Storage and Computing using a Cloud Platform: Introduction, Cloud computing paradigm for data collection, storage and computing, Cloud service models, IoT Cloud- based data collection, storage and computing services using Nimbits - Case study: Environmental pollution monitoring using WSN and IoT.

References:

1. Holger Karl, Andreas Willig, *Protocols and Architectures for Wireless Sensor Networks*, John Wiley & Sons, New Jersey, 2011.
2. Jun Zheng, Abbas Jamalipour, *Wireless Sensor Networks: A Networking Perspective*, Wiley-IEEE Press, USA, 2014,.
3. Waltenegus W. Dargie, Christian Poellabauer, Fundamentals of Wireless Sensor Networks:Theory and Practice, 1st ed., John Wiley & Sons, New Jersey, 2014,.
4. Ian F. Akyildiz, Mehmet Can Vuran, "Wireless Sensor Networks", John Wiley & Sons, New Jersey, 2011.
5. Zach Shelby, Carsten Bormann, "6LoWPAN: The Wireless Embedded Internet", John Wiley & Sons, New Jersey, 2009.
6. Raj Kamal, "Internet of Things-Architecture and design principles", McGraw Hill Education, 2017.

EE6141E AUTOMOTIVE SENSORS AND INSTRUMENTATION

Pre-requisites: **NIL**

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Categorize various automobile systems, sub systems and its components.

CO2: Apply suitable control techniques for automotive electronic engine and fuel, vehicle powertrain and motion systems.

CO3: Choose appropriate sensors and actuators and justify the selection with their characteristics in automotive systems.

CO4: Apply various devices and standard protocols involved in automobile safety systems.

Automobile Fundamentals

Introduction - Electronics in automotive and its evolution - Automotive physical configuration: Engine block, Cylinder head, Piston, Crankshaft, Camshaft, Connecting rod, Valve, 4-stroke cycle - Ignition system: Spark plug, High voltage circuit and distribution, Spark pulse generation, Ignition timing - Drivetrain: Transmission, Drive shaft, Differential, Suspension, Brakes, Steering system.

Automotive control systems

Overview of exhaust emission and Fuel economy - Electronic engine control: Performance parameters and variables: Torque, Power, BSFC, Fuel consumption, Efficiency, Calibration, Engine mapping, Effect of air-fuel ratio, Spark timing, EGR on engine performance - Electronic fuel control: Open and Close Loop - Exhaust gas oxygen (EGO) concentration, Intake manifold pressure, Speed density method, Electronic ignition - Vehicle powertrain and motion control: Electronic transmission control, Adaptive power Steering, Adaptive cruise control, Safety and comfort systems, Anti-lock braking, Traction control and electronic stability, Active suspension control.

Sensors and actuators

Automotive variable monitoring - Air flow rate sensor - Pressure measurement: Strain gauge MAP sensor - Optical crankshaft angular position sensor - Magnetic reluctance position sensor - Engine angular speed sensor - Timing sensor for ignition and fuel delivery - Throttle angle sensor - Temperature sensor - Coolant sensor, EGO sensor - Knock sensor - Angular rate sensor - LIDAR - Flex fuel sensor - Acceleration sensors - Fuel injection and Exhaust gas recirculation actuator - Variable valve timing - Electric motor actuator.

Automobile safety systems

Active and passive safety system: Body electronics including lighting control - Remote keyless entry - Immobilizers - Electronic instrument clusters and dashboard electronics - Aspects of hardware design for automotive including electro-magnetic interference suppression - Electromagnetic compatibility - Antilock Braking System (ABS) , Electronic Stability Program (ESP), Air bags - Automotive standards and protocols.

References:

1. William B. Ribbens, Understanding Automotive Electronics, 7th ed. Butterworth-Heinemann publications, 2018.
2. Walter E, Billiet and Leslie .F, Goings, Automotive Electric Systems, 3rd ed. American Technical Society, Chicago, 1971.
3. Young A.P., Griffiths L., Automotive Electrical Equipment, 6th ed. ELBS & New Press, 2010.
4. Tom Weather Jr., Cland C. Hunter, Automotive computers and control system, 1st ed. Prentice Hall Inc., New Jersey, 2009.
5. Crouse W.H., Automobile Electrical Equipment, 8th ed. McGraw Hill Co. Inc., New York, 2005.
6. Judge.A.W, Modern Electric Equipment for Automobiles, Chapman and Hall, London, 1975.
7. BOSCH, Automotive Hand Book, 9th ed. Bentley Publishers, Germany, 2014.

EE6142E BIOMEDICAL INSTRUMENTATION

Pre-requisites: NIL

Total Lecture Sessions: 39

L	T	P	O	C
3	0	0	6	3

Course Outcomes:

CO1: Explain the fundamental concepts in ECG, EEG and EMG.

CO2: Apply the various clinical measurement techniques for cardiovascular and pulmonary systems.

CO3: Illustrate the applications of physics and engineering principles related to diagnostic systems

CO4: Analyse the concepts of imaging and interfacing devices for the development of therapeutic health care systems.

Introduction to Biosignal Aquisition, ECG, EEG and EMG

Overview of physiological systems of human body – Origin of biosignals – Action potential generation – Overview of Biomedical Instrumentation System - Electrodes for biosignal acquisition – use of electrode gels – Electrode arrays. Electrocardiogram – Overview of 12 lead system – Einthoven's triangle – Heart rate variability – Cardiac pacemakers – Defibrillators – Electroencephalography – Electromyography – Testing of biomedical equipment for patient safety.

Cardiovascular System Measurements, Oximetry and Pulmonary System Measurements

Measurement of cardiac output – indicator dilution method – ultrasonic blood flow meter – electromagnetic blood flow meter. Blood pressure measurement – Korotkoff's sound method – ultrasonic doppler shift method. Oximetry – ear oximeter – pulse oximeter – skin reflectance oximeter. Instrumentation for pulmonary system – spirometry – pulmonary function analyzers –ventilators.

Lasers, X-rays, Ultrasound, Dialysis ans Electrosurgery

Lasers in medicine – Argon laser – Carbon dioxide laser – Excimer laser – Laser safety. X-ray machine – dental X-ray machine – portable and mobile X-ray units. Ultrasound in medicine – Biological effects of ultrasound – A, B and M-mode US scans. Hemodialysis – artificial kidney –dialyzers – membranes for hemodialysis. Principle of surgical diathermy – Electrosurgical Unit.

Electrotherapy, Drug Delivery Systems and MRI

Electrotherapy equipments – Bladder stimulators – Deep Brain stimulators – Pain relief therapy. Radiotherapy Equipment – Linear Accelerator machine. Automated drug delivery systems – Components of drug infusion pumps – implantable infusion systems. Overview of MRI.

References

1. John G Webster, Medical Instrumentation, Application and Design, 4th Edition, John Wiley &
1. Sons, 2015
2. L Cromwell, F J Weibell, E A Pfeiffer, Biomedical Instrumentation and Measurements, 2nd Edition, Pearson Education, 2015.
3. R.S.Khandpur, Handbook of Biomedical Instrumentation, 3rd Edition, Tata McGraw-Hill, 2014.
4. J D. Enderle and J D. Bronzino Introduction to Biomedical Engineering, 3rd Edition Elsevier, 2012
5. J D. Bronzino and D R. Peterson, The Biomedical Engineering Handbook, 4th Edition, CRC Press Taylor & Francis, 2015
6. Geddes & Baker, Principles of Applied Biomedical Instrumentation, 3rd Edition, John Wiley & Sons, 2008.

EE6143E ASSISTIVE TECHNOLOGY FOR REHABILITATION

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Describe the organization of human nervous and muscular systems and explain their working in health and neuromuscular disorders

CO2: Demonstrate the working of various types of stimulators and implement their design for rehabilitation.

CO3: Develop brain – computer interface systems for physical and cognitive rehabilitation

CO4: Design systems for neuromotor rehabilitation

Nervous System and Neuromuscular Physiology

Overview of human nervous system – Neuronal action potential generation and propagation – Neural tracts and pathways for perceiving touch, pain, heat, cold and vibration. Neuromuscular integration – control of motor activities – modeling of myoelectric activity – Physiological consequences of neuromuscular damage – spinal cord injury – concept of neuroplasticity.

Electrical stimulation for rehabilitation

Electrical stimulation – Neuromuscular electrical stimulation – Functional Electrical Stimulation. Design considerations of electrical stimulators – electrodes, sensors and their placement – stimulation intensity – frequency – clinical considerations. Recent advancements – Neuroprosthesis for walking, upper limb function, reaching and grasping. Bladder stimulator, Cerebellar stimulator, Transcranial Magnetic Stimulator.

Brain Computer Interfaces and Applications

Brain Computer Interfaces (BCI) – Basic Architecture – BCI types – Signal acquisition for BCI – Brain activation patterns – p300 – Event related potentials – Steady state evoked potentials (SSVEP, SSAEP, SSSEP), sensory motor rhythms, slow cortical rhythms – Feature extraction and classification of signals – Applications of BCIs – Case studies.

Deep Brain Stimulation, Devices for Neuromotor Rehabilitation

Deep Brain Stimulation - Design considerations, approaches and strategies. Sensory aids for visual impairment – Rehabilitation and visual prostheses. Sensory aids for auditory impairment – Rehabilitation and Auditory Prostheses. Robotic devices for neuromotor rehabilitation - Interactive control - exoskeleton for upper limb rehabilitation and adaptive control – Rehabilitation devices for cognitive impairment and dementia – case studies – Gait analysis.

References:

1. V Dietz & N Ward (Eds.), Oxford Textbook of Neurorehabilitation, Oxford University Press, 2015
2. W J Marks and J L Ostrem (Eds.) Deep Brain Stimulation Management, 3rd Edition, Cambridge University Press, 2022
3. V Bajaj and G R Sinha (Eds.), Analysis of Medical Modalities for Improved Diagnosis in Modern Healthcare, CRC Press, 2021
4. A Mihailidis and R Smith (Eds.), Rehabilitation Engineering, Principles and Practice, CRC Press, 2023
5. R A Cooper et. al (Eds.), An Introduction to Rehabilitation Engineering, CRC Press, 2006

EE6144E ADAPTIVE AND INTELLIGENT CONTROL TECHNIQUES

Pre-requisites: **NIL**

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:
CO1: Formulate adaptive and intelligent control problems for dynamical systems
CO2: Develop models for dynamical system using intelligent techniques.
CO3: Apply intelligent techniques to design adaptive controllers for complex and nonlinear systems.
CO4: Implement hybrid adaptive control techniques for practical systems using simulation tools.

Adaptive Control Techniques
[Review of Lyapunov Stability Theory]
Introduction to adaptive control - Direct and indirect adaptive control - Pole placement adaptive control - Model reference adaptive control: Control design using MIT Rules and Lyapunov Theory -. Singularity regions, Lyapunov redesign - Passivity-based adaptive control - Adaptive Backstepping - Adaptive Output Feedback Control - Gain Schedule control.

Modeling using Neural Networks
Introduction to Intelligent System: Need for intelligent modeling - Architecture for intelligent control - Concept of Artificial Neural Networks and its basic mathematical model - Feed forward Multilayer Perceptron - Learning and Training the neural network - RBF networks - Recurrent networks.
Modeling using Neural Networks: System identification using Neural networks -NNNARX, NNARMAX, NNOE models - selection of lag space -. Stability analysis of Neural-Network interconnection systems - Case studies: Identification of linear and nonlinear dynamic systems using simulation tools

Modeling and Control using Fuzzy logic
Introduction to crisp sets and fuzzy sets - basic fuzzy set operation and approximate reasoning - Fuzzification, inferencing and defuzzification - Fuzzy knowledge and rule bases.
Fuzzy Modeling and Control: Fuzzy modeling for nonlinear system - Modeling with Mamdani and Takagi-Sugeno - Type-2 fuzzy model - Fuzzy PD, PI, and PID controllers - Fuzzy state feedback controller (Fixed gain and Variable gain) - Self organizing fuzzy logic control - Fuzzy logic control for nonlinear time-delay system - Stability analysis of fuzzy control systems - Implementation of fuzzy logic controller using simulation toolbox.

Hybrid adaptive control of dynamical systems
Control using NNs: Inverse Control, Direct and indirect adaptive control, feedback linearization control: continuous and discrete affine system, model predictive control - Reinforcement Learning in Control: Markov decision processes (MDPs) and Q-learning, Policy learning and value function approximation – case study
Control using Hybrid System: Neuro fuzzy systems, ANFIS, hybrid learning algorithm - Neuro-fuzzy control: Inverse learning, specialized learning - derivative free optimization methods - Solution of typical control problems with derivative free optimization.
Practical examples: Intelligent Control design for Inverted pendulum and 2 link manipulator, Reinforcement learning based PI control for single tank system, simulation examples.

References

1. SR Jang, CT Sun, E Mizutani, *Neuro-fuzzy and soft computing: a computational approach to learning and machine intelligence*, Prentice-Hall of India, 1997
2. M. Norgaard, O. Ravn, N.K. Poulsen, L.K. Hansen, *Neural Networks for Modelling and Control of Dynamic Systems, A Practitioner's Handbook*, Springer; 2nd ed., 2012
3. Laxmidhar Behera, Indrani Kar, *Intelligent Systems and Control*, 5th edition, Oxford University Press, 2009
4. Christopher M. Bishop, *Neural Networks for Pattern Recognition*, Oxford University Press, New York, 1996
5. Driankov, Dimiter, Hans Hellendoorn, and Michael Reinfrank. *An introduction to fuzzy control,* Springer Berlin, Heidelberg, 2013.
6. Timothy J. Ross., *Fuzzy Logic with Engineering Applications*, 3rd edition, John Wiley and Sons, 2010
7. K.J. Astrom and B. Wittenmark, *Adaptive Control*, Dover, 2nd edition, 2008.
8. I.D. Landau, R. Lozano, M. M'Saad, *Adaptive Control*, Springer Verlag, London, 1998.
9. P.A. Ioannou , J. Sun, *Robust Adaptive Control* , Prentice Hall, Upper Saddle River, NJ, 1996
10. Shankar Sastry, Marc Bodson,*Adaptive Control: Stability, Convergence and Robustness*,Dover Publications Inc, 2011

EE6145E SLIDING MODE CONTROL AND APPLICATIONS

Pre-requisite: **NIL**

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: **39**

Course Outcomes

CO1: Design and implement stable systems from unstable structures and sliding mode controllers

CO2: Design stable sliding surface and implement sliding mode control laws for various systems using simulation tools

CO3: Apply various techniques chattering reduction and performance improvement of sliding mode controllers.

CO4: Design and implement sliding mode observers for various applications

Variable structure systems (VSS) and sliding mode control (SMC)

Introduction to VSS - synthesis of stable systems from unstable structures - VSS for improving speed of response - VSS for stability - variable structure systems with sliding mode - sliding mode motion - existence condition – design of SMC for simple systems – implementation using simulation tools/software

Sliding surface and SMC law design

Various methods for stable sliding surface design: equivalent control method, controllable canonical form method, pole placement method and regular form – computation of SMC law: equivalent and switching laws, various reaching laws - control input chattering - Invariance conditions – SMC design for discrete-time systems: reaching laws for discrete-time sliding mode - design and implementation of SMC laws for practical systems: inverted pendulum, dc motor etc. using simulations.

SMC design for chattering reduction and performance improvement

Chattering reduction techniques - higher order sliding mode control: twisting and super twisting algorithms – SMC schemes for systems with matched and unmatched uncertainties – integral and terminal SMC schemes – output feedback SMC - application to practical systems – implementation using simulations.

Sliding mode observers

Design of various sliding mode observers: Utkin observer, Walcott-Zak observer – discontinuous sliding mode observer: canonical form, existence condition – sliding mode observers for fault detection – detection of fault at output – implementation using simulation tools for practical systems: inverted pendulum, maglev system

References:

1. C. Edwards and S. Spurgeon, *Sliding Mode Control: Theory and Applications*, Taylor & Francis, 1998.
2. V Utkin, Jürgen Gulder, Jingxin Shi, *Sliding Mode Control in Electromechanical Systems*, CRC Press INC, 2009
3. Vadim I. Utkin, *Sliding Modes in Control and Optimization*, Springer Link, 1992.
4. Shtessel, Yuri, Christopher Edwards, Leonid Fridman, and Arie Levant. *Sliding mode control and observation*. Vol. 10, Springer New York, 2014.
5. B. Bandyopadhyay, Deepak Fulwani and K. S. Kim, *Sliding Mode Control using Novel Sliding Surfaces,* Vol.392, Lecture Notes in Control and Information Science, Springer-Verlag, 2009.

EE6146E MODELLING AND CONTROL OF UNMANNED AERIAL VEHICLES

Pre-requisites: **NIL**

L	T	P	O	C
3	0	0	6	3

Total Lecture sessions: 39

Course Outcomes:

CO1: Model unmanned aerial vehicle as a dynamical system

CO2: Apply estimation algorithms for UAV navigation

CO3: Design linear and nonlinear trajectory controllers for aerial vehicles

CO4: Develop motion planning and obstacle avoidance algorithms for UAVs.

Modelling of UAVs

Introduction to UAVs: subsystems, main characteristics - Aerodynamics of a thin aerofoil - propeller dynamics - Modeling of rigid bodies - Kinematics of rotation - rigid body dynamics - Frame Rotations and Representations - Euler angles – Yaw, pitch, and roll - direction cosine matrix- quaternion representation- coordinate transformations- comparison of transformation methods.
[*Review of State space techniques*] Dynamics of Fixed wing and Multirotor Aerial Vehicle – simulation practice.

Estimation Algorithms

Typical sensors: inertial measurement units, Gyroscopes, Accelerometers, Magnetometers, GPS - Errors in sensors - Position and attitude estimation - Dead recknoning - Estimation algorithms - predictor-corrector observer - Kalman Filter - Complementary filter.

Control and stabilization of UAVs

Equilibrium points - Linearization - classification of equilibrium points - stability of equilibrium points – linear system stability - nested control loops - PID Control design.
Notions of stability - Lyapunov stability - local stability - local linearization and stability in the small- Direct method of Lyapunov - generation of Lyapunov function for linear and nonlinear systems – variable gradient method - region of attraction - Invariance theorems - Lyapunov based nonlinear control design – Controller design for UAVs - simulation practice.

Motion planning for UAVs and Applications

Motion Planning - Trajectory generation - Path planning using RRT – Polynomial trajectory generation - Bezier Curves - obstacle avoidance – Potential function method - Simultaneous Localization and Mapping – Motion planning for fixed wing and multi-rotor vehicles.
Applications of UAVs – Photogrammetry – Precision agriculture

References

1. K. Valavanis, and P. Vachtsevanos, *'Handbook of Unmanned Aerial Vehicles*', Springer, 2015
2. R. Beard, and T. W. McLain, '*Small Unmanned Aircraft: Theory and Practice*', *Princeton University Press, 2012*
3. Stevens, B., and F. Lewis. '*Aircraft Control and Simulation*'. 2nd ed. New York: Wiley-Interscience, 2003.
4. Ching-Fang Lin, 'Modern Navigation, Guidance and Control Processing', Prentice-Hall Inc., Engle Wood Cliffs, New Jersey, 1991
5. Choset, Howie, et al., *Principles of robot motion: theory, algorithms, and implementations*. MIT press, 2005.
6. Siegwart, Roland, Illah Reza Nourbakhsh, and Davide Scaramuzza. *Introduction to autonomous mobile robots*, 2nd edition, MIT press, 2011.
7. LaValle, Steven M. *Planning algorithms*. Cambridge university press, 2006.
8. Sebastian Thrun, Wolfram Burgard , and Dieter Fox, Probabilistic Robotics, MIT Press, 2005

ZZ6001E RESEARCH METHODOLOGY

Pre-requisites: NIL

L	T	P	O	C
2	0	0	4	2

Total Lecture sessions: 26

Course Outcomes:

CO1: Explain the basic concepts and types of research

CO2: Develop research design and techniques of data analysis

CO3: Develop critical thinking skills and enhanced writing skills

CO4: Apply qualitative and quantitative methods for data analysis and presentation

CO5: Implement healthy research practice, research ethics, and responsible scientific conduct

Exploring Research Inquisitiveness
Philosophy of Scientific Research, Role of Research Guide, Planning the Research Project, Research Process, Research Problem Identification and Formulation, Variables, Framework development, Research Design, Types of Research, Sampling, Measurement, Validity and Reliability, Survey, Designing Experiments, Research Proposal, Research Communication, Research Publication, Structuring a research paper, structuring thesis/ dissertation,

Research Plan and Path
Developing a Research Plan: Reviewing the literature- Referencing – Information sources – Information retrieval – Role of libraries in information retrieval – Tools for identifying literatures – Reading and understanding a research article – Critical thinking and logical reasoning; Framing the research hypotheses, Converting research Question into a Model; Data collection- Types of data-Dataset creation- Primary and Secondary data- Scales of measurement- Sources and collection of data- Processing and analysis of data-Understanding Data-statistical analysis, displaying of data-Data visualization-Data interpretation; Research design- Qualitative and Quantitative Research- Designing of experiments- Validation of experiments- Inferential statistics and result interpretation

Scientific Conduct and Ethical Practice
Plagiarism– Ethics of Research- Scientific Misconduct- Forms of Scientific Misconduct. Plagiarism, Unscientific practices in thesis work-Conduct in the workplace and interaction with peers – Intellectual property: IPR and patent registration, copyrights; Current trends – Usage and ethics of AI tools in scientific research.

References:

1. Leedy, P D, *Practical Research: Planning and Design,* USA: Pearson, Twelfth ed., 2018.
2. Krishnaswamy, K. N., Sivakumar, A. I., and Mathirajan, M., *Management Research Methodology*, Pearson Education, 2006.
3. Tony Greenfield and Sue Greener., *Research Methods for Postgraduates*, USA: John Wiley & Sons Ltd., Third ed., 2016.
4. John W. Creswell and J. David Creswell, *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches*, USA: Sage Publications, Sixth ed., 2022.

MS6174E TECHNICAL COMMUNICATION AND WRITING

Pre-requisites: **NIL**

L	T	P	O	C
2	1	0	3	2

Total Lecture Sessions: 26

Course Outcomes:

CO1: Apply effective communication strategies for different professional and industry needs.

CO2: Collaborate on various writing projects for academic and technical purposes.

CO3: Combine attributes of critical thinking for improving technical documentation.

CO4: Adapt technical writing styles to different platforms.

Technical Communication
Process(es) and Types of Speaking and Writing for Professional Purposes - Technical Writing: Introduction, Definition, Scope and Characteristics - Audience Analysis - Conciseness and Coherences - Critical Thinking - Accuracy and Reliability - Ethical Consideration in Writing - Presentation Skills - Professional Grooming - Poster Presentations

Grammar, Punctuation and Stylistics
Constituent Structure of Sentences - Functional Roles of Elements in a Sentence - Thematic Structures and Interpretations - Clarity - Verb Tense and Mood - Active and Passive Structures - Reporting Verbs and Reported Tense - Formatting of Technical Documents - Incorporating Visuals Elements - Proofreading

Technical Documentation
Types of Technical Documents: Reports, Proposals, Cover Letters - Manuals and Instructions - Online Documentation - Product Documentation - Collaborative Writing: Tools and Software - Version Control Document Management - Self Editing, Peer Review and Feedback Processes

References:

1. Foley, M., & Hall, D., *Longman advanced learner's grammar, a self-study reference & practice book with answers*. Pearson Education Limited, 2018.
2. Gerson, S. J., & Gerson, S. M., *Technical writing: Process and product*, Pearson, 2009.
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IE6001E ENTREPRENEURSHIP DEVELOPMENT

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Pre-requisites: **NIL**

Total Lecture Sessions: 26

Course Outcomes:

CO1: Describe the various strategies and techniques used in business planning and scaling ventures.

CO2: Apply critical thinking and analytical skills to assess the feasibility and viability of business ideas.

CO3: Evaluate and select appropriate business models, financial strategies, marketing approaches, and operational plans for startup ventures.

CO4: Assess the performance and effectiveness of entrepreneurial strategies and actions through the use of relevant metrics and indicators.

Entrepreneurial Mindset and Opportunity Identification

Introduction to Entrepreneurship Development - Evolution of entrepreneurship, Entrepreneurial mindset, Economic development, Opportunity Recognition and Evaluation - Market gaps - Market potential, Feasibility analysis - Innovation and Creativity in Entrepreneurship - Innovation and entrepreneurship, Creativity techniques, Intellectual property management.

Business Planning and Execution

Business Model Development and Validation - Effective business models, Value proposition testing, Lean startup methodologies - Financial Management and Funding Strategies - Marketing and Sales Strategies - Market analysis, Marketing strategies, Sales techniques - Operations and Resource Management - Operational planning and management, Supply chain and logistics, Stream wise Case studies.

Growth and Scaling Strategies

Growth Strategies and Expansion - Sustainable growth strategies, Market expansion, Franchising and partnerships - Managing Entrepreneurial Risks and Challenges - Risk identification and mitigation, Crisis management, Ethical considerations - Leadership and Team Development - Stream wise Case studies.

References:

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3. Barringer, B. R., *Entrepreneurship: Successfully launching new ventures*, Pearson Education India, 2015.
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