SEMESTER I

21UC01 MATHEMATICS OF SYSTEMS ENGINEERING

Vide Applied electronics 21EA01

21UC02 SMART SENSORS AND DATA NETWORKS

3 0 0 3

MICRO AND SMART SENSOR: Micro Sensors and Actuators: Principle, characteristics and application - Smart Sensor: Construction and characteristics - Integration of micromachining and microelectronics - Various sensing techniques: Capacitive sensing, Piezoelectric sensing, Hall effect - Digital output sensors: Incremental optical encoders, Digital techniques - Applications of smart sensors - Design of signal conditioning circuit: 4 to 20 mA transmitter. (12)

SMART FIELD DEVICES AND COMMUNICATION PROTOCOLS: Smart transmitters - Primary and secondary sensors - Compensation methods - Handheld communicator - Smart valve positioners - Communication protocols: CAN protocol, LIN protocol, FlexRay protocol - Protocols in Silicon: MCU with integrated CAN, Ethernet Controller - Industrial Ethernet - Introduction to IIoT. (11)

STANDARDS FOR SMART SENSING: Setting standards for smart sensors and systems - IEEE 1451 family of standards - Network-Capable Application Processor, Network communication models, Smart Transducer Interface Module, Transducer Electronic Data Sheet, Transducer-Independent Interface, Calibration/Correction Engine - Extending system to the network. (11)

WIRELESS SENSOR NETWORKS: Challenges in wireless sensor networks - Single node architecture - Hardware components - Energy consumption of sensor nodes - Network architecture - Sensor network scenarios: Types of sources and sinks, single hop versus multi-hop networks, multiple sinks and sources - Design principles and applications of WSNs - Bluetooth sensor networks - IEEE 802 sensor networks. (11)

Total L: 45

REFERENCES:

1. Holger Karl and Andreas Willig, “Protocols and Architectures for Wireless Sensor Networks”, John Wiley, 2014.
2. Randy Frank, “Understanding Smart Sensors”, Third Edition, Artech House, 2013.
3. Ananthasuresh G K, Vinoy K J, Gopalakrishnan S, Bhat K N and Aatre V K, “Micro and Smart Systems”, Wiley Publishers, 2011.
4. Gerard Meijer, Michiel Pertijs,Kofi Makinwa, “Smart Sensor Systems”, John Wiley and Sons, 2014.
5. Halit Eren, “Wireless Sensors and Instruments: Networks, Design and Applications”, CRC Press, 2018.

21UC03 DYNAMICAL SYSTEMS AND CONTROL

3 1 0 4

MATHEMATICAL DESCRIPTION OF SYSTEM: System properties: Causality – Lumpedness – Linearity. Linearization-Concept of state, state variables and state model – State space representation using physical, phase and canonical variables - Comparison of input-output description and state variable description – MIMO systems – Discretization of a continuous time model. (11+3)

SOLUTION OF STATE EQUATIONS: State transition matrix – Significance – Properties – Computation, impulse response matrix – Solution of continuous time state equation – Solution of discrete time state equation – Solution of linear time variant systems. Transfer function from state space model – Similarity transformation – Decomposition of transfer functions: direct, cascade and parallel decomposition techniques. (11+4)

CONCEPT OF CONTROLLABILITY AND OBSERVABILITY: Kalman`s and Gilbert`s test for controllability – Pole assignment by state feedback using Ackermann’s formula – Kalman canonical form – Controller design using output feedback – Controllability of discrete LTI systems – Controllability of linear time variant systems. Kalman`s and Gilbert`s test for observability – Design of full order observer using Ackermann’s formula – Observable canonical form – Duality – Observer based controller design – Reduced order observer design – Observability of discrete LTI Systems – Observability of linear time variant systems. (12+4)

STABILITY: Stability in the sense of Lyapunov, asymptotic stability of linear time invariant continuous and discrete systems – Solution of Lyapunov equation – Disturbance rejection, sensitivity and complementary sensitivity functions, internal stability, stability of linear time variant system.
SISO feedback control: Feedback structures. Nominal sensitivity functions. Stability and polynomial analysis. Nominal stability using frequency response – Relative stability: Stability margins and sensitivity peaks. Synthesis of SISO controllers: Polynomial approach. PI and PID synthesis revisited using pole assignment. Frequency domain design limitations: Bode's integral constraints on sensitivity. Integral constraints on complementary sensitivity. (11+4)

Total L: 45 +T:15 = 60

REFERENCES:

1. Chen CT, “Linear System Theory and Design”, Fourth Edition, Oxford University Press, 2014.
2. Katsuhiko Ogata, “Modern Control Engineering”, Fifth Edition, Pearson Education India, 2015.

3. Farid Golnaraghi and Benjamin C Kuo, “Automatic Control Systems”, Tenth Edition, McGraw-Hill Education, 2017.
4. William L Brogan, “Modern Control Theory”, Third Edition, Dorling Kindersley (India) Pvt. Ltd., 2011.
5. Graham C Goodwin, Stefan F Graebe and Mario E Salgado, “Control System Design”, First Edition, Pearson Education India, 2015.

21UC04 PROCESS CONTROL AND AUTOMATION

4 0 0 4

PROCESS DYNAMICS AND CONTROL ACTIONS: Process dynamics: Degrees of freedom , servo and regulator operation , self regulation – Mathematical model of processes – Linearization of nonlinear systems – Characteristic of ON-OFF, P, P+I, P+D and P+I+D control modes – Digital PID algorithm – Auto/manual transfer - Reset windup - Selection of control modes - Evaluation criteria: IAE, ISE, ITAE and ¼ decay ratio - Controller tuning – Auto tuning – Final Control element: Control valve types, Characteristics and selection criteria. (15)

ADVANCED CONTROL SYSTEMS: Control systems with multiple loops: Cascade control, Selective control systems, split range control, feed-forward control, ratio control, adaptive control, inferential control - Multivariable Control: Interaction of control loops, pairing of Inputs and outputs, Relative Gain Array (RGA), multi-loop PID Controller, decoupling of control loops - Model based Control: Smith predictor control scheme, internal model control and introduction to model predictive control.(15)

PROGRAMMABLE LOGIC CONTROLLER (PLC): Overview of PLC system – Input / Output modules - PLC programming languages - Basic relay logic functions - Timer/Counter functions - Arithmetic functions - Comparison functions - Skip and MCR functions - Data transfer functions - Matrix functions - Sequencer function - Analog PLC operation - PID function - Alternate programming languages - Design of interlocks and alarms using PLC - PLC applications- Safety PLC- Process safety management during start up and shut down. (15)

DISTRIBUTED CONTROL SYSTEM AND INDUSTRIAL COMMUNICATION STANDARDS: Introduction - Evolution of DCS-DCS architecture – Local control unit - Operator interface – Displays - Engineering interface - Redundancy concept - Factors to be considered in selecting DCS - Communication facilities: HART protocol, Foundation Field bus, Profibus, Industrial Ethernet, Profinet. (15)

Total: L: 60

REFERENCES:

1. Stephanopoulos G, “Chemical Process Control”, Pearson Education India, New Delhi, 2015.
2. Dale E. Seborg, Thomas F. Edgar, Duncan A Mellichamp and Francis J. Doyle. “Process Dynamics and Control”, John Wiley and sons, Fourth Edition, 2016
3. Frank D Petruzella, “Programmable Logic Controllers”, McGraw Hill, Fifth Edition, 2019.
4. Moustafa Elshafei, “Modern Distributed Control Systems: A comprehensive coverage of DCS technologies and standards”, Amazon Digital Services, 2016
5. Lawrence M. Thompson,, Tim Shaw, “Industrial Data Communications”, ISA, Fifth Edition, 2015.

21UC05 APPLIED DIGITAL SIGNAL PROCESSING

4 0 0 4

SIGNAL REPRESENTATION: Fourier transform – Shortcoming of Fourier transform – Short-Time Fourier Transform (STFT) – Properties - Limitations of STFT – Continuous Wavelet Transform – Discrete Wavelet Transform – Multi resolution analysis - Introduction to sparse representation –Analysis of speech signal, biomedical signals using joint time-frequency and time scale analysis. (15)

MULTIRATE SIGNAL PROCESSING: Multirate operators in time and frequency domain – Noble identities – Polyphase decomposition – Multistage decimation and interpolation – Filter bank – Types of filter bank – Perfect reconstruction criteria in filter bank- Subband coding of speech and image signal. (15)

ADAPTIVE FILTERS: Motivation for adaptive filter – Wiener filter – Limitations of Wiener filter –Steepest descent algorithm – LMS algorithm – Variants of LMS algorithm – RLS algorithm – Applications of adaptive filter in system identification, Prediction, echo cancellation and channel equalization. (15)

POWER SPECTRAL DENSITY ESTIMATION: Signal modeling – LTI system with random input - Paley-Wiener criterion – Spectral factorization – AR, MA and ARMA models – Yule Walker equation – Non-parametric methods: Periodogram, Modified periodogram, Bartlett’s method, Welch method, Blackman-Tukey method – Parametric method of power spectral density estimation. (15)

Total L: 60

REFERENCES

1. StephaneMallat,”A Wavelet Tour of Signal Processing: The Sparse Way”, Academic Press, 2009.
2. Vaidyanathan P P, “Multirate Systems and Filter Banks”, Pearson Education, 2016.
3. Simon Haykin, “Adaptive Filter Theory”, Pearson Education, 2015.
4. Monson H. Hayes, “Statistical Digital Signal Processing and Modelling”, Wiley, 2018.
5. Dimitris G. Manolakis, Vinay K. Ingle, Stephen M. Kogon, “Statistical and Adaptive Signal Processing: Spectral Estimation, Signal Modeling, Adaptive Filtering, and Array Processing”, McGrawHill, 2016.

21UC61 RESEARCH METHODOLOGY AND IPR

vide Automotive Engineering 21AE06

21UC72 AUDIT COURSE I

vide Automotive Engineering 21AE72

21UC51 SYSTEMS AND CONTROL LABORATORY

0 0 4 2

Scope of the problems:

1. Analyzing the impact of poles and zeros of first and second order systems.
2. Simulation of system responses.
3. Stability analysis of systems in time and frequency domain.
4. Analyzing non-stationary signals using time-frequency analysis.
5. Signal decomposition using filterbank.
6. Power spectral density estimation using non-parametric and parametric methods.

Total: P: 60

REFERENCES:

1. Norman S. Nise,"Control Systems Engineering", John Wiley & Sons, 2019.
2. Department of Instrumentation and Control Systems Engineering, "Laboratory Manual",2021.

21UC52 PROCESS AUTOMATION LABORATORY

0 0 4 2

In this course, students will gain exposure on designing control schemes for industrial processes and developing ladder logic for sequential processes using Programmable Logic Controller. Students will also acquire knowledge on controlling a process plant in real time using a Distributed Control System.

Scope of the problems:

1. Tuning and performance analysis of various PID control modes for Level / Pressure / Temperature / Flow processes
2. Design and analysis of the performance of various multi loop control systems.
3. Control of sequential processes using Programmable Logic Controller.
4. On-line monitoring and control of a pilot plant using Distributed Control System.

Total: P: 60

REFERENCES:

1. Frank D Petruzella, “Programmable Logic Controllers”, McGraw Hill, Fifth Edition, 2019.
2. Department of Instrumentation and Control Systems Engineering , "Laboratory Manual",2021.

SEMESTER II

21UC06 SYSTEM IDENTIFICATION

3 0 0 3

INTRODUCTION TO IDENTIFICATION AND MODELS: System Identification Procedure- Identifiability- Signal-to-Noise ratio- Over fitting- Models: Definition of a model, Classification of models, Models for discrete time linear time-invariant Systems, Models for Linear Stationary Processes - Case Study (11)

ESTIMATION METHODS: Types of estimation problems- Goodness of Estimators: Fisher information, Bias, Variance, Efficiency, Sufficiency, Cramer-Rao’s inequality, Asymptotic bias, Mean square error, Consistency, Distribution of estimates – Estimation methods: Method of moments estimators- Least squares estimators- Non-linear least squares- Maximum likelihood estimators- Bayesian estimators. (11)

NON-PARAMETRIC AND PARAMETRIC MODELS FOR IDENTIFICATION: Non-parametric descriptions and parametric descriptions - Identification of parametric time series models: Estimation of AR models- Estimation of MA models- Estimation of ARMA models. Identification of non-parametric input-output models: Impulse response estimation- Step response estimation- Estimation of frequency response function- Identification of parametric input-output models: Prediction-error minimization methods - Properties of the PEM estimator. (12)

STATISTICAL ELEMENTS OF MODEL AND STATE SPACE MODEL IDENTIFICATION: Informative data- Input design for identification- Data pre-processing- Time-delay estimation- Model development- Identification of state-space models: Kalman filter- Foundations for subspace identification (11)

Total: L: 45

REFERENCES:
1. Lennart Ljung, “System Identification: Theory for the User”, Pearson Hall, 1999.
2. Arun K Tangirala, “Principles of System Identification: Theory and practice”, CRC Press, 2014.
3. Thomas Kailath, Ali H Sayed and Babak Hassibi, “Linear Estimation”, Prentice Hall, 2000.
4. Johan Schoukens, Rik Pintelon, Yves Rolain, “Mastering System Identification in 100 Exercises”, Wiley, 2012
5. Jer Nan Juang, “Applied System Identification”, Prentice Hall, 1994.

21UC07 EMBEDDED CONTROL SYSTEMS

3 1 0 4

EMBEDDED SYSTEM AND EMBEDDED PROCESSOR:
EMBEDDED SYSTEMS – Hardware and Software Components – Types of Embedded Systems -Challenges in Embedded Computing System Design- IoT enabled Embedded Systems- Miniaturization of the Devices- EMBEDDED PROCESSOR - RISC and CISC architectures - CPU - Memory organization- On chip peripherals: Timers - ADC – PWM - Interrupt Controller – DMA - Communication protocols – ARM Processor - Pipelined architecture - Instruction level parallelism. (12+4)

EMBEDDED APPLICATION SOFTWARE DEVELOPMENT: Cross compiler- Embedded Programming in Assembly and C- Peripheral programming- Debugging- Interfacing- Motor control: Position control of DC motor. (11+4)

DIGITAL REALIZATION OF CONTROLLERS: Digital control system- Components of Digital Control System - Discretization - Digital realization of controllers- Proportional-Integral-Derivative (PID) Controller-Hardware implementation considerations- Fixed and Floating point number representation-IEEE 754-Floating point emulation-Fixed point implementation of control algorithms. (11+4)

REAL TIME SYSTEMS: Real-time issues in controller implementation - Algorithmic and Code Optimization - Performance assessment of control algorithms- Constraints of the operating systems - Real-time operating systems – Task Management- Memory management - Context switching- Scheduling algorithms and their performance analysis-Inter task communication - Introduction to MicroC/OS-II. (11+3)

Total L: 45 +T:15 = 60

REFERENCES:
1. Raj Kamal, “Embedded Systems: Architecture, Programming and Design”, Tata-McGraw Hill, 2017.
2. David E Simon, “An Embedded Software Primer”, Prentice Hall, 2007.
3. Jonathan W Valvano, “Embedded Microcomputer Systems: Real Time Interfacing”, Cengage Learning, 2012.
4. Alexandru Forrai, “Embedded Control System Design: A Model Based Approach”, Springer, 2013.
5. Andrew N Sloss, Dominic Symes and Chris Wright, “ARM System Developer’s Guide: Designing and Optimizing System Software”, Margan Kaufmann Publishers, 2004.

21UC82 AUDIT COURSE II
vide Automotive Engineering 21AE82

21UC53 EMBEDDED CONTROL SYSTEMS LABORATORY

0 0 4 2

Scope of the problems:
1. To impart knowledge on Embedded C-programming.
2. To introduce the architectural features and associated peripherals of Microcontroller for building Embedded Systems..
3. To provide an insight over the practical aspects of interfacing field devices with Microcontroller.
4. To facilitate the students to realize the significant features of real time Embedded Systems.
5. To impart knowledge on the inherent features of IoT for Embedded Applications.
6. To implement multitasks on an RTOS enabled Embedded System.
7. To implement real-time control applications (Inverted pendulum or dc motor etc.) using RTOS.

Total: P: 60

REFERENCES:
1. Jonathan W Valvano, “Embedded Microcomputer Systems: Real Time Interfacing”, Cengage Learning, 2012
2. Department of Instrumentation and Control Systems Engineering, "Laboratory Manual”,2021.

21UC54 ADVANCED CONTROL LABORATORY

0 0 4 2

Scope of the Problems:
1. Mathematical modeling of systems.
2. Implementation of state estimator.
3. Design and implementation of multivariable PID, adaptive controller, model predictive controller, state feedback controller and non linear controller.
4. Control of one degree of freedom and two degree of freedom systems

Total: P: 60

REFERENCES:

1. Katsuhiko Ogata, “Modern Control Engineering”, Fifth Edition, Pearson Education India, 2015.
2. Department of Instrumentation and Control Systems Engineering, "Laboratory Manual”,2021.

21UC55 INDUSTRIAL VISIT AND TECHNICAL SEMINAR

vide Automotive Engineering 21AE63

SEMESTER – III

21UC71 PROJECT WORK I

vide Automotive Engineering 21AE71

SEMESTER – IV

21UC81 PROJECT WORK II

Vide Automotive Engineering 21AE81

PROFESSIONAL ELECTIVE COURSES

21UC21 NONLINEAR CONTROL

3 0 0 3

NONLINEAR SYSTEMS AND DESCRIBING FUNCTION ANALYSIS: Need for nonlinear control- Nonlinear system behavior- Common nonlinearities in control systems- Autonomy. Describing function fundamentals -Describing functions of common nonlinearities – Describing function analysis of nonlinear systems: Existence and stability of limit cycles. (11)

PHASE PLANE AND STABILITY ANALYSIS: Singular points - Construction of phase plane using Isocline and delta methods - Existence of limit cycles: Poincare index and Bendixon theorems - Stability. Concepts of stability in the sense of Lyapunov- Linearization and local stability-Lyapunov’s direct method –Generation of Lyapunov functions: Krasovski’s, Lure’s and Variable Gradient Method- Popov’s stability criterion. LaSalle's invariance principle. (12)

FEEDBACK LINEARIZATION: Method of feedback linearization-Mathematical tools: Lie derivatives, lie brackets, involutive condition and Frobenius theorem. Input-state linearization of SISO systems- Input-output linearization of SISO systems- Internal dynamics and zero dynamics of nonlinear systems. (11)

NONLINEAR CONTROL DESIGN: Basic concepts of variable structure systems - Sliding surfaces- Filippov’s construction of equivalent dynamics. Conditions for existence of sliding regions. Design of sliding controllers- Backstepping control- Basic back stepping method- Design procedure- Case Study: Backstepping for pure and non-feedback nonlinear systems. (11)

Total: L: 45

REFERENCES:

1. Jean Jacques Slotine and Weiping Li, “Applied Nonlinear Control”, Prentice Hall Inc., 1991.
2. Harry G. Kwatny and Gilmer L. Blankenship, "Nonlinear Control and Analytical Mechanics: a Computational Approach", Springer, 2017
3. Gopal M “Digital Control and State Variable Methods”, Fourth Edition, Tata McGraw- Hill Ltd, New Delhi, 2017.
4. Strogatz, S. H , "Nonlinear Dynamics and Chaos, with Applications to Physics, Biology, Chemistry and Engineering", Second Edition, Westview Press, 2014.
5. Wilfrid Peruquetti and Jean Pierre Barabot, “Sliding Mode Control in Engineering”, Marcel Dekker Inc, 2002.

21UC22 OPTIMAL CONTROL

3 0 0 3

CALCULUS OF VARIATIONS AND OPEN LOOP OPTIMAL CONTROL: Introduction- State variable representation of systems- Performance measures for optimal control problems - Selection of performance measures – Calculus of variations – Definitions– The basic variational problem - Extrema of functions and functional with conditions – Variational approach to optimal control system- Discrete time optimal control system:- Variational calculus, Fixed final state and Free-final state open loop optimal control. (12)

LINEAR QUADRATIC OPTIMAL CONTROL SYSTEM: Problem formulation – Finite time Linear Quadratic regulator – Infinite time LQR system: Time Varying case- Time-invariant case – Stability issues of Time-invariant regulator – Linear Quadratic Tracking system: Fine time case and Infinite time case - Linear Quadratic Gaussian Control - Discrete time linear state regulator system. (12)

PONTRYAGIN MINIMUM PRINCIPLE: Pontryagin Minimum Principle – Dynamic Programming:- Principle of optimality, optimal control using Dynamic Programming – Optimal Control of Continuous time and Discrete-time systems – Hamilton-Jacobi-Bellman Equation – LQR system using H-J-B equation. (10)

CONSTRAINED OPTIMAL CONTROL SYSTEMS: Time optimal control systems – Fuel Optimal Control Systems – Energy optimal control systems – Optimal control systems with state constraints. (11)

Total: L: 45

REFERENCES:
1. Kirk D E, “Optimal Control Theory: An Introduction”, Prentice Hall, New Jersey, 2012.
2. Desineni Subbaram Naidu, “Optimal Control Systems”, CRC Press, 2018.
3. Jeffrey B Burl, “Linear Optimal Control”, Addison-Wesley, California, 1999.
4. Frank L. Lewis, Draguna Vrabie, Vassilis L. Syrmos, “Optimal Control”, John Wiley & Sons, New York, 2012.
5. Gopal M, “Modern Control System Theory”, Wiley Eastern, New Delhi, 1993.

21UC23 ADAPTIVE CONTROL

3 0 0 3

INTRODUCTION: Adaptive Schemes - The adaptive Control Problem - Applications - Parameter estimation in dynamical systems: - Least squares and regression methods. Gain scheduling: The principle - Design of gain scheduling controllers - Nonlinear transformations - Application of gain scheduling - Auto-tuning techniques- Methods based on Relay feedback. (12)
DETERMINISTIC SELF-TUNING REGULATORS : Pole Placement design - Indirect Self-tuning regulators – Continuous-time self tuners - direct self-tuning regulators – Disturbances with known characteristics (11)

STOCHASTIC AND PREDICTIVE SELF-TUNING REGULATORS: Design of minimum variance controller - Design of moving average controller - stochastic self-tuning regulators - Unification of direct self tuning regulators - Linear Quadratic STR - Adaptive Predictive Control. (11)

MODEL REFERENCE ADAPTIVE SYSTEM: Introduction – MIT rule – Determination of adaptation gain – Lyapunov theory – Design of MRAS using Lyapunov theory – Relation between MRAS and STR. (11)

Total: L: 45

REFERENCES:
1. Karl J Astrom and Bjorn Wittenmark, “Adaptive Control”, Pearson Education Inc., New Delhi, 2008.
2. Ioannou P A and Sun J, “Robust Adaptive Control”, Prentice Hall, 1996.
3. Krstic M, Kanellakopoulos I and Kokotovic P, “Nonlinear and Adaptive Control Design”, Wiley -Interscience, 1995.
4. Chalam V V, “Adaptive Control Systems – Techniques and Applications”, Marcel Dekkar Inc., NewJersey, 1987.
5. Shankar Sastry and Marc Bodson, “Adaptive Control – Stability, Convergence and Robustness”, Prentice Hall Englewood Cliffs, New Jersey, 1989.

21UC24 ROBUST CONTROL

3 0 0 3

INTRODUCTION: Concepts of model uncertainty, including both parametric and dynamic uncertainty - Fundamental concept of robustness and the relationship between physical systems and mathematical models - Mathematical background including norms for vectors, matrices, signals, and systems - Co prime Factorization and stabilizing controllers, singular value decomposition and its application to perturbation analysis. (11)

MODELLING OF UNCERTAIN SYSTEMS: Unstructured Uncertainties - Parametric Uncertainty - Linear fractional transformations and canonical forms - Structured Uncertainty - Robust stability and performance problems. (11)

ROBUST DESIGN SPECIFICATIONS: Small gain theorem and Robust Stabilization, Performance Consideration, Structured Singular Values. H – infinity design: Mixed Sensitivity H-infinity Optimization. H-infinity suboptimal solutions, Discrete time case H-infinity loop shaping design: Robust Stabilization against normalised Coprime Factor Perturbations, Loop Shaping Design, Mixed Optimization Design Method with LSDP. μ- Analysis and Synthesis: Consideration of Robust performance, μ-synthesis-D-K Iteration method, μ-K Iteration method. (12)

LOWER ORDER CONTROLLERS: Absolute-error Approximation Methods, Reduction via Fractional Factors, Relative-error Approximation Methods, Frequency Weighted Approximation Methods. (11)

Total L: 45

REFERENCES:
1. Ian Postlethwaite, Sigurd Skogestad "Multivariable Feedback Control: Analysis and Design", Wiley, 2015.
2. Mackenroth U "Robust Control Systems, Theory and Case Studies", Springer India Pvt. Ltd, New Delhi, 2010.
3. Gu D W, Petkov P and Konstantinov M M, "Robust Control Design with MATLAB", Springer, 2013.
4. Kemin Zhou and John Doyle, "Essentials of Robust Control", Prentice-Hall Inc., 1998.
5. Zhou K, Doyle J C and Glover K, "Robust and Optimal Control", Prentice-Hall Inc., 1996.

21UC25 INDUSTRIAL DRIVES AND CONTROL

3 0 0 3

DC MOTOR DRIVES: Introduction to Electrical drives, Fundamental torque equations, Speed torque conventions and multi quadrant operation, Components of load torques, Nature and classification of load torques, State space model of DC motor drive, Single-phase and Three-phase drives: Half converter, Semi converter, Full converter and Dual converter fed drives- Two quadrant and four quadrant chopper controlled drives – Closed loop control of dc drives (12)

INDUCTION MOTOR DRIVES: Performance characteristics, Stator Control: Stator voltage control, Rotor voltage control, Frequency control, Voltage and frequency control, Current control, Voltage, current and frequency control - Rotor resistance control: Conventional methods, Static rotor resistance control - Slip power recovery: Static Kramer drive, Static Scherbius drive. (11)

VECTOR CONTROL OF INDUCTION MOTOR DRIVES: Principle of vector control – Direct vector control - Flux vector estimation – Indirect vector control – Vector control of line-side PWM rectifier – Stator flux oriented vector control – Vector control of current fed inverter drive. (11)

SYNCHRONOUS AND SPECIAL DRIVES: Synchronous Motor Drives: Open loop volts/hertz control, Self control model Permanent magnet ac motor drives, Brushless dc motor drives, Sensorless control - Stepper motor and Switched reluctance motor drives. (11)

REFERENCES:
1. Gopal K Dubey, "Fundamentals of Electric Drives", Narosa Publishing House, New Delhi, 2018.
2. Bimal K Bose, "Power Electronics and Variable Frequency Drives - Technology and Application", Wiley, New Delhi, 2017.
3. Ion Boldea and Nasar S A, "Electric Drives", CRC Press LLC, New York, 2006.
4. Krishnan R, "Electric Motor Drives: Modelling, Analysis and Control", Prentice Hall of India, New Delhi, 2014.
5. Muhammad H Rashid, "Power Electronics Handbook", Academic Press, 2004.

21UC26 SLIDING MODE CONTROL

3 0 0 3

INTRODUCTION TO SLIDING MODE CONTROL: Properties of sliding motion, different controller designs, pseudo-sliding with a smooth control action, state space approach. Sliding mode control problem statement, existence of solution and equivalent control, properties of sliding motion. Reachability problem, single input and multivariable case. Unit vector approach, continuous approximations. (11)

DESIGN APPROACHES: Regular form based approach, robust eigen structure assignment, quadratic minimisation, direct eigen structure assignment. Incorporation of tracking requirement, model reference approach , integral action approach. (12)

CONTROLLER DESIGN USING OUTPUT INFORMATION: Problem formulation, special case square plants. General frame work, hyperplane design, control law synthesis. Dynamic compensation, model reference system using only outputs. (11)

HIGHER ORDER SLIDING MODES: Definitions, higher order sliding modes in control systems, sliding order and dynamic actuators, 2-sliding controllers, arbitrary order sliding controllers. Introduction to sliding mode observers. Sliding observers for output and output derivative injection form. (11)

Total L: 45

REFERENCES:
1. Christopher Edwards and Sarah K. Spurgeon, "Sliding Mode Control: Theory and Applications", Taylor and Francis Ltd., 1998.
2. Wilfrid Perruquetti and Jean Pierre Barbot, "Sliding Mode Control in Engineering", Marcel Dekker, Inc, 2002.
3. Zinober A. S. I.and Dorling C. M., "Deterministic Control of Uncertain Systems", Peter Peregrinus, 1990.
4. Utkin V. I., "Sliding Modes in Control Optimization", Springer – Verlag, 1992.
5. Yuri Shtessel,Christopher Edwards, Leonid Fridman,Birkhäuser; 2013 ,"Sliding Mode Control and Observation" ,Arie Levant

21UC27 FAULT DIAGNOSIS AND CONTROL

3 0 0 3

INTRODUCTION & ANALYTICAL REDUNDANCY CONCEPTS: Types of faults and different tasks of Fault Diagnosis and Implementation - Different approaches to FDD: Model free and Model based approaches- Mathematical representation of Faults and Disturbances: Additive and Multiplicative types – Residual Generation: Detection, Isolation, Computational and Stability properties – Design of Residual generator – Residual specification and implementation. (11)

FAULT DETECTION AND DIAGNOSIS USING PARITY EQUATIONS: Residual structure of single fault Isolation: Structural and Canonical structures- Residual structure of multiple fault Isolation: Diagonal and Full Row canonical concepts – Introduction to parity equation implementation and alternative representation - Directional Specifications: Directional specification with and without disturbances – Parity equation implementation. (11)

FAULT DIAGNOSIS USING STATE ESTIMATORS: State observer – State estimators – Norms based residual evaluation and threshold computation – Fault Detection and Diagnosis using Generalized Likelihood Ratio Approach and Marginalized Likelihood Ratio Approach. (11)

FAULT TOLERANT CONTROL: Passive Fault-tolerant control- Active Fault-tolerant control - Actuator and Sensor Fault tolerance Principles: Compensation for actuator – Sensor Fault-tolerant control design – Fault-tolerant control architecture - Fault-tolerant control design against major actuator failures - Case studies. (12)

Total L: 45

REFERENCES:

1. Mogens Blanke, Michel Kinnaert, Jan Lunze, Marcel Staroswiecki, “Diagnosis and Fault-Tolerant Control”, Springer, 2016.
2. Steven X. Ding, “Model based Fault Diagnosis Techniques: Schemes, Algorithms, and Tools”, Springer Publication, 2012.
3. Rolf Isermann, “Fault-Diagnosis Systems an Introduction from Fault Detection to Fault Tolerance”, Springer Verlag, 2006.
4. Hassan Noura, Didier Theilliol, Jean-Christophe Ponsart, Abbas Chamseddine, “Fault-Tolerant Control Systems: Design and Practical Applications”, Springer Publication, 2009.
5. Janos J. Gertler, “Fault Detection and Diagnosis in Engineering systems”, Second Edition, Marcel Dekker, 1998.

21UC28 MULTIVARIABLE CONTROL

3 0 0 3

MIMO SYSTEM REPRESENTATION: Introduction - Models and equivalence: State variable, matrix fraction descriptions, linear model, I/O representation, discretized model, and disturbance model - Properties of MIMO systems: Time response and frequency response properties - Limitations in MIMO control. (11)

MIMO SYSTEM ANALYSIS: Introduction - Linear system time response - Stability condition - Discretization - Gains and frequency response - System internal structure - Block system structure - Kalman form - I/O properties - Model reduction - Key issues in MIMO system analysis. (12)

DECENTRALIZED AND DECOUPLED CONTROL: Introduction - Multi-loop control pairing selection - Decoupling - SISO loops with MIMO cascade control - Other possibilities: Sequential and hierarchical design and tuning - Case study. (11)

CENTRALIZED CLOSED LOOP CONTROL: State feedback - Output feedback - Rejection of deterministic, unmeasurable disturbance - Augmented plant - Process and disturbance models - Multivariable model predictive control - Multivariable dynamic matrix control. (11)

Total: L: 45

REFERENCES:

1. P.Albertos, A.Sala, “Multivariable Control Systems – An Engineering Approach”, Springer International, 2008.
2. Sigurd Skogestad and Ian Postlethwaite, “Multivariable Feedback Control - Analysis and design” Wiley India, 2014.
3. Z. Bubnicki, “Multivariable Control”, Springer international, 2005.
4. Joseph J. Bongiorno Jr., Kiheon Park, “Design of Linear Multivariable Feedback Control Systems” Springer 2020
5. J. M. Maceijowski, Multi-Variable Feedback Design, Addision-Wesely Pub, 1989

21UC29 MODEL PREDICTIVE CONTROL

3 0 0 3

MODEL BASED CONTROL: Review of single input single output (SISO) control - Model based control - Multivariable control strategies - Model forms for model predictive control. (11)

PREDICTIVE CONTROL STRATEGY: Prediction model - Constraint handling prediction equations - Unconstrained optimization - Infinite horizon cost incorporating constraints - Quadratic programming. (11)

CLOSED LOOP PROPERTIES OF MODEL PREDICTIVE CONTROL: Incorporating constraints - Quadratic programming - Interior point QP algorithms - Coping with uncertainty - MPC with integral action - Robustness to constant disturbances - Robust constraint satisfaction (12)

MPC CONTROL SCHEMES AND ROBUSTNESS: Pre-stabilized predictions - Analysis of dynamic matrix control (DMC) and generalized predictive control (GPC) schemes - Controller tuning and robustness issues - Extensions to constrained and multivariable cases. (11)

Total: L: 45

REFERENCES:

1. James B. Rawlings, David Q. Mayne, and Moritz M. Diehl. Model Predictive Control: Theory, Computation, and Design. Nob Hill Publishing, LLC, 2019.
2. E. Camacho and C. Bordons, ”Model Predictive Control in the Process Industry”, 1995.
3. Francesco Borrelli, Alberto Bemporad, and Manfred Morari. Predictive Control for Linear and Hybrid Systems. Cambridge University Press, 2017.
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5. Rossiter, J.A., ”Predictive Control: a practical approach”, CRC Press, 2003

21UC30 ADVANCED PID CONTROLLERS

3 0 0 3

CLASSICAL PID CONTROLLER: Review of three term control – Implementation of cascade PID controller - PID implementation issues – Industrial PID control – State space analysis of classical PID structure – PID tuning: online model free methods and nonparametric approach (12)

ROBUST PID DESIGN: Kharitonov’s theorem and its generalization – Robust stabilisation using a constant gain- Robust stabilisation using PID controller – Design of robust and non-fragile PID settings – Robust controller design using YJBK parameterization. (11)

FRACTIONAL ORDER PID : Fractional order systems : fractional LTI systems, fractional nonlinear system - Analysis of superiority of FO control over the conventional IO control in terms of closed loop performance, robustness, stability - FO lead lag compensators, FO PID control, design of FO state feedback, Realization and implementation issues for FO controllers. (11)

OPTIMAL PID CONTROL: Introduction – unconstrained order optimal design - Optimal Synthesis for Continuous-Time Systems - Optimal Synthesis for Discrete-Time Systems. (11)

Total: L: 45

REFERENCES:

1. Michael A Johnson, .Mohammad HMoradi, “PID Control: New identification and design methods” Springer, 2005
2. R. Caponetto, G. Dongola, L. Fortuna, and I. Petras. Fractional Order Systems: Modeling and Control Applications. World Scientific, Singapore, 2010.
3. Aidan O’Dwyer , “Handbook of PI and PID Controller Tuning Rules” , Third Edition, Imperial College Press , 2009
4. Datta, Aniruddha, Ho, Ming-Tzu, Bhattacharyya, Shankar P., “Structure and Synthesis of PID Controllers” Springer , 2013
5. Iván D. Díaz-Rodríguez, Sangjin Han, Shankar P. Bhattacharyya · “ Analytical Design of PID Controllers”, Springer, 2019

21UC31 STATE ESTIMATION

3 0 0 3

INTRODUCTION TO STATE ESTIMATION AND KALMAN FILTER: Review of state observers for deterministic System- Least Square Estimation - Discrete Kalman filter- Kalman filter generalization – Correlated process and measurement noise- Limitations of Kalman filter – Case Studies. (11)

NONLINEAR KALMAN-BASED FILTERS: Linearized Kalman filter – Extended Kalman filter –Second order Extended Kalman filter – Constrained Extended Kalman filter- Unscented Kalman filter - Unscented transformation - Simplex unscented transformation – Spherical unscented transformation - Constrained Unscented Kalman filter – Case Studies .(12)

PARTICLE FILTER : Introduction - SIS filtering algorithm - Degeneracy phenomenon-SIR Particle filter - Implementation issues:- Sample Impoverishment – Selection of proposal density: Particle filter with EKF as proposal - Unscented Particle filter- Case Studies. (11)

DECENTRALIZED ESTIMATION FOR MULTISENSOR SYSTEMS: Introduction - Multisensor systems - Decentralized systems - Information Filter - Decentralized Estimators - Decentralized information filter - Decentralized Kalman filter - Limitations of fully connected Decentralization. (11)

Total: L:45

REFERENCES:

1. Dan Simon, “Optimal State Estimation Kalman, H-infinity and Non-linear Approaches”, John Wiley and Sons, 2006.
2. Branko Ristic, Sanjeev Arulampalam, Neil Gordon, “Beyond the Kalman Filter: Particle filters for Tracking Applications”

Artech House Publishers, Boston, London, 2004.
3. Bruce P. Gibbs, "Advanced Kalman Filtering, Least-Squares and Modeling: A Practical Handbook" John Wiley and Sons, 2011.
4. Arthur G O Mutambara, “Decentralized Estimation and Control for Multisensor Systems”, CRC Press, 2019.
5. Arthur Gelb, “Applied Optimal Estimation”, MIT Press, 1974.

21UC32 OPTIMIZATION TECHNIQUES

3 0 0 3

OPTIMIZATION & LINEAR PROGRAMMING: Statement of Optimization problems - Classical optimization techniques - Single variable and multi variable optimization - Method of direct substitution constraint variation - Lagrange multipliers multivariable optimization with equality constraints - Linear programming definition - Pivotal reduction of general system of equations - Simplex algorithms - Two phases of the simplex method - Revised simplex method . (12)

UNCONSTRAINED OPTIMIZATION: Optimality conditions-Direct search methods - Univariate method, Pattern search methods - Rosenbrock's method – The simplex method - Descent method - Conjugate gradient method - Quasi Newton methods-Least squares problem. (11)

CONSTRAINED OPTIMIZATION: Theory of constrained optimization – Direct methods - Complex method - Cutting plane method - Methods of feasible directions and determination of step length-Termination criteria, determination of step length- Penalty and Barrier methods, Interior point methods. (11)

DYNAMIC PROGRAMMING: Multistage decision process - Computational procedure - Final value problem to initial value problem -Continuous dynamic programming - Discrete dynamic programming. (11)

Total: L: 45

REFERENCES:

1. Singiresu S Rao, "Engineering Optimization Theory and Practice", John Wiley and Sons Pvt. Ltd, 2019.
2. Kalyanmoy Deb, “Optimization for Engineering Design, Algorithms and Examples", Prentice Hall, 2004.
3. Chong E K P and Zak S, “An Introduction to Optimization”, John Wiley and Sons Pvt. Ltd., Singapore, 2013.
4. David Luenberger and Yinyu Ye, "Linear and Nonlinear Programming", Springer, 2016.
5. Fletcher R, “Practical Methods of Optimization”, John Wiley, 2000.

21UC33 APPLIED MACHINE LEARNING FOR CONTROL

3 0 0 3

INTRODUCTION TO MACHINE LEARNING AND DATA PREPROCESSING: Introduction to Machine Learning: Human learning vs. Machine learning - Objectives of Machine Learning – Types of Machine Learning – Applications of Machine Learning - Machine Learning Process. Data preprocessing in Machine Learning: Data Cleaning, Data Integration, Data Reduction, Data Compression, Data Normalization, Data Discretization. (12)

SUPERVISED LEARNING: Linear Regression with one variable and multiple variables- Logistic Regression- Multi class classification- Regularization – Neural Network: Backpropagation Learning algorithm – Radial Basis Function Network – Support Vector Machines - Kernels – Risk and Loss Functions - Support Vector Machine algorithm – Multi Class classification – Support Vector Regression - Deep Learning - Case Studies. (11)

UNSUPERVISED LEARNING: Introduction – Clustering - Partitioning Methods: K-means algorithm - Hierarchical Clustering – Fuzzy Clustering – Clustering High-Dimensional Data: Problems – Challenges – Subspace Clustering – Biclustering – Anomaly Detection - Case studies. (10)

REINFORCEMENT LEARNING: Introduction - Markov Decision Process (MDP) - Bellman equations - Value iteration and policy iteration - Linear Quadratic Regulation - Linear Quadratic Gaussian - Q-learning value function approximation - Policy search – Reinforce – Case studies. (12)

Total: L: 45

REFERENCES:

1. Stephen Marsland, “Machine Learning: An Algorithmic Perspective”, 2nd Edition, CRC Press, 2015.
2. Ian H. Witten, Eibe Frank, Mark A. Hall, “Data Mining: Practical Machine Learning Tools and Techniques”, 4th Edition, Elsevier, 2016.
3. Masashi Sugiyama, “Statistical Reinforcement Learning: Modern Machine Learning Approaches”, CRC Press, 2015.
4. P. Harrington, “Machine learning in action”, Manning Publications, 2012.
5. T. M. Mitchell, “Machine Learning”, McGraw-Hill, 1997.

21UC34 MATHEMATICAL METHODS FOR PROCESS DATA ANALYTICS

3 0 0 3

REGRESSION: Introduction to process data analytics – Linear regression: Simple linear regression, multiple linear regression – K-nearest neighbours regression – Practical consideration in the regression model – Validation methods to assess model quality: The validation set approach, Leave-one-out cross validation, K-Fold cross validation Bias-variance trade off for K Fold cross validation. (11)

LINEAR MODEL SELECTION AND REGULARIZATION: Subset selection:- Best subset selection, Step-wise selection and choosing the optimal model – Shrinkage methods:-LASSO, Ridge regression, Elastic nets – Dimension reduction methods: Principal components regression, Partial least squares. (11)

SUPERVISED LEARNING WTH REGRESSION AND CLASSIFICATION TECHNIQUES: Logistic regression – Linear discriminant analysis – Quadratic discriminant analysis – Regression & classification trees – Support vector machines – Random forests, Bagging and Boosting – Neural Networks – Deep learning. (11)

APPLICATIONS: Process data analysis for system identification (under open loop) – Controller performance monitoring – Principal components analysis (PCA) for process monitoring and partial least squares (PS) for soft-sensor design – Data based causality analysis for identification of process topology. (12)

Total L: 45

REFERENCES:

1. Thomas A. Runkler, “Data Analytics: Models and Algorithms for Intelligent Data Analysis”, Springer Vieweg, Second Edition, 2016.
2. Arun K. Tangirala, “Principles of System Identification – Theory and Practice”, CRC Press, 2018.
3. Fan Yang, Pig Duan, Sirish L Shah, Tongwen Chen, “Capturing Connectivity and Causality in Complex Industrial Processes”, Springer, 2014.
4. Gareth James, Daniela Witten, Trevor Hastie, Robert Tibshirani, “An Introduction to Statistical Learning with Applications in R”, Springer Texts in Statistics, 2017.
5. EthemAlpaydin, “Introduction to Machine Learning”, Fourth Edition, MIT Press, 2020.

21UC35 AUTOMOTIVE CONTROL

3 0 0 3

OVERVIEW OF AUTOMOTIVE CONTROL, SAFETY AND SECURITY SYSTEMS: Motivation – Identifying the control requirements - Components of chassis management system – Role of various sensors and actuators pertaining to chassis system – Construction and working principle of speed, position, pressure, torque and level sensors - Safety and security systems: Airbags - Seat belt tightening system - Collision warning systems - Child Lock - Anti lock braking systems Road recognition system - Smart card system (12)

POWERTRAIN CONTROL SYSTEMS: Engine control loops - Control oriented engine modeling- Powertrain control – Air fuel ratio and spark - Idle speed control -Transmission Control (11)

COMFORT AND ACTIVE SUSPENSION CONTROL SYSTEMS: Active suspension systems: requirements, characteristics and types - Vehicle handling and ride characteristics of road vehicle - Thermal management system - Adaptive noise control - Optimal active suspension - Single degree of freedom model and two degree of freedom model active suspension with state estimation (11)

INTELLIGENT TRANSPORTATION SYSTEM: Traffic routing system - Automated highway systems - Lane warning system – Driver information system - Driver assistance systems - Data communication within the car - Driver conditioning warning - Route guidance and navigation systems – Vision enhancement system - In-Vehicle computing –Vehicle diagnostics system – Case studies (11)

TOTAL L: 45

REFERENCES:

1. Uwe Kiencke and Lars Nielsen, “Automotive Control Systems”, Springer-Verlag Berlin Heidelberg, 2000.
2. A Galip Ulsoy, Huei Peng and Melih Çakmakci, “Automotive Control Systems”, First Edition Cambridge Press, 2012.
3. Zongxuan Sun and Guoming G. Zhu, "Design and Control of Automotive Propulsion Systems", Taylor and Francis, 2015.
4. Ljubo Vlacic, Michel Parent and Fumio Hiroshima, “Intelligent Vehicle Technologies”, Butterworth-Heinemann publications, Oxford, 2001.
5. Crouse, W.H. and Anglin, D.L., “Automotive Mechanics”, Ninth edition, TMH, New Delhi, 2002.

21UC36 FLIGHT CONTROL

3 0 0 3

AIRCRAFT DYNAMICS: Standard atmosphere – Equation of motion of aircraft - Drag Polar- Drag polar of vehicles from low speed to hypersonic speed – Thrust required for level, un-accelerated flight – Thrust available and maximum velocity – Power required for level, un-accelerated flight – Power available and maximum velocity – Altitude effects on power required and available - Rate of climb - Gliding flight - Time to climb - Range and endurance – Take off performance- Landing performance - Turning flight and V-n diagram - Wing loading - Load factor - Absolute and service ceilings. (11)

AIRCRAFT STABILITY: Definition of Stability – Moments on the Airplane – Absolute angle of attack - Longitudinal and lateral dynamic stability – Criteria for longitudinal static stability - Equations of longitudinal static stability – Neutral point – Static margin - Calculation of Elevator angle to trim – Stick-Fixed versus stick-free static stability – Directional static stability –Lateral Static Stability (11)

CLOSED-LOOP CONTROL SYSTEMS: Control configurations and control architecture – Flight control modes – Sensors – Servo/Actuators – Flight control requirements: Longitudinal control requirements – Roll control Requirements – Directional control requirements – Control laws – PID controller – Optimal control – Linear Quadratic Regulator – Gain scheduling – Robust control – Digital control – Control System Design process (11)

ATTITUDE AND FLIGHT PATH CONTROL SYSTEMS: Cruising flight requirements – Pitch attitude hold – Altitude hold – Mach hold – Wing leveller – Turn coordinator – Heading angle hold – Vertical speed Hold – Landing operation procedures – Approach localizer tracking – approach glide slope tracking – automatic flare control – automatic landing system – VOR tracking – Automatic flight level change – automatic climb and descent – Terrain-following control system – Tracking a series of waypoints – detect and avoid system (12)

TOTAL L: 45

REFERENCES:

1. John D Andersonn, 'Introduction to Flight' McGraw Hill International, Eight Edition, 2016
2. John D. Anderson Jr, 'Fundamentals of Aerodynamics', McGraw Hill International, Fourth Edition 2007.
3. Mohammad Sadraey, 'Automatic Flight Control System', Morgan & Claypool Publishers, 2020.
4. Bernard Etkin, 'Dynamics of Flight Stability and Control', John Wiley and sons Inc., Third Edition, 1996.

21UC37 CONTROL OF UNMANNED AERIAL VEHICLE

3 0 0 3

INTRODUCTION TO UAV: History of UAVs – Classification – Contemporary applications – Societal impact and future outlook Operational Considerations - Concepts of flight control. (11)

UAV MODELLING: UAV System Components - Autonomous UAV description –Reference Frames and Coordinate Frames- UAV dynamics – Kinematic Models –Multi-Model Approach- Dynamic models – Sensors and Sensing Strategies. (11)

UAV FLIGHT CONTROL LOOP: Linear Control methods for UAV - Nonlinear Control methods for UAV – Fuzzy UAV control – Robust and Adaptive Control methods For UAV. (14)

UAV NAVIGATION SYSTEM: UAV navigation: Accelerometers, Gyros, GPS - Navigation loop – Inertial navigation – Path planning algorithms: Dubin's curves, way-points, Voronoi partitions. (9)

Total L: 45

REFERENCES:

1. Paul Gerin Fahlstrom and Thomas James Gleason, "Introduction to UAV Systems", Fourth Edition, John Wiley & Sons, 2012.
2. Yasmina Bestaoui Sebbane, "Smart Autonomous Aircraft: Flight Control and Planning for UAV", CRC Press, USA, 2016.
3. Kimon P. Valavanis and George J. Vachtsevanos, "Handbook of Unmanned Aerial Vehicles", Springer Publishing Company, 2015.
4. Reg Austin, "Unmanned Aircraft systems-UAVs Design, Development and Deployment", WILEY Publication, 2010.
5. Robert C. Nelson, "Flight Stability and Automatic Control", McGraw-Hill, 1998.

21UC38 ELECTRIC VEHICLE CONTROL

3 0 0 3

ARCHITECTURE AND MODELING: Classification of electric vehicles- benefits and challenges- general architecture- power flow- Basic components: Prime mover, Motors with converters, Energy storage systems, Transmission systems- Modeling of IC engine, motor, transmission system and vehicle body. PID based driver model (11)

ENERGY STORAGE SYSTEM MODELING AND CONTROL: Methods of determining the State of Charge (SoC)- Extended Kalman filter based SoC determination method- Estimation of battery power availability- Battery life prediction- Storage and cycling conditions- Cell balancing - Estimation of cell core temperature- Battery system efficiency- Utilization of solar power.(12)

ELECTRIC VEHICLE CONTROL LOOPS: Engine torque fluctuation dumping control- High-voltage bus spike control- Thermal control- Traction torque control- Anti-rollback control- Active suspension control- Tuning strategy of the SoC lower bound- Nominal SoC setpoint online tuning- Noise and vibration control (11)

DESIGN CONSIDERATIONS: Design Criteria of motor drives: DC drives, Induction motor drives, Permanent magnet drives, Switched Reluctance motor drives- Aerodynamic considerations- Consideration of vehicle mass- Alternate energy resources- Charging systems- Vehicle to Grid and Grid to Vehicle management of electric vehicles (11)

Total L: 45

REFERENCES:

1. Liu Wei, “Hybrid electric vehicle system modeling and control”, Wiley&Sons, Second Edition, 2017.
2. Emanuele Crisostomi, Robert Shorten, Sonja Stüdli and Fabian Wirth, “”Electric and Plug-in Hybrid Vehicle Networks, Optimization and Control” Taylor & Francis, First Edition, 2017
3. K.T. Chau, “Electric Vehicle Machines and Drives: Design, Analysis and Application”, Wiley-IEEE press, 2015
4. James Larminie and John Lowry, “Electric Vehicle Technology Explained”, Wiley–Blackwell, 2003.
5. C.C. Chan and K.T.Chau,” Modern Electric Vehicle Technology”, First Edition Oxford University Press, 2001.

21UC39 ROBOTIC SYSTEMS

3 0 0 3

INTRODUCTION TO ROBOTICS AND KINEMATICS: Robots Classifications –Elements of Robotics: Joints, Actuators and Sensors –End effectors – Applications – Kinematics: Matrix representation – Homogeneous transformation – DH representation of standard robots – Inverse kinematics. (11)

ROBOT DYNAMICS: Velocity kinematics – Jacobian and inverse Jacobian – Lagrangian formulation – Eulers Lagrangian formulation – Robot equation of motion-Trajectory planning. (11)

ROBOTIC VISION: Introduction to robotic vision-Image formation -Image processing and analysis- Vision applications: Detection, Recognition and Tracking- Camera geometry and calibration- Simulation using OpenCV. (11)

JOINT CONTROL: Linear control of robot manipulation – Second-order systems –Modeling and control of single joint – Performance of feedback control system-Implementation issues- Architecture of industrial robotic controllers – Robot Programming- Simulation and experimental case studies of robot manipulators. (12)

Total L: 45

REFERENCES:

1. Saeed B Niku, “Introduction to Robotics Analysis, Systems, Applications", Prentice Hall of India, 2010
2. Craig, “Introduction to Robotics Mechanics and Control”, Pearson Education, Asia, 2004.
3. Mikell P. Groover, Mitchell Weiss, Roger N Nagel and Nicholas G Odrey, “Industrial Robotics: Technology, Programming and Applications”, Mc-Graw Hill Publisher, 2011.
4. Ashitava Ghosal, “Robotics: Fundamental Concepts and Analysis”, Oxford University Press, 2006.
5. Davis E R, “Machine Vision: Theory, Algorithms and Practicalities”, Morgan Kaufmann Publishers, 2005.

21UC40 MACHINE VISION

3 0 0 3

IMAGE FORMATION AND TRANSFORM: Digital image – image sensor- image model – perspective geometry - image file formats - neighbours of a pixel - Fourier transform- Discrete Cosine Transform- KL transform- Singular Value Decomposition- Hough transform-Affine transform-scale invariant feature transform. (12)

IMAGE ENHANCEMENT AND RESTORATION: Spatial domain enhancement: gray level transformations - histogram processing-edge detection - Frequency domain enhancement: filtering in frequency domain- smoothing frequency domain filters-sharpening frequency domain filters- homomorphic filtering- Noise models- Restoration by order statistics filter - Inverse filtering - Wiener filtering. (11)

IMAGE REPRESENTATION AND SEGMENTATION: Chain code – Fourier descriptor- Bspline representation- Convex hull- Detection of discontinuities: point, line and edge detection-Edge linking and boundary detection-Thresholding: global thresholding- optimal thresholding- local thresholding- thresholds based on several variables- Region based segmentation: basic formulation- region growing- region splitting and merging. (11)

PATTERN RECOGNITION AND CLASSIFICATION: Feature –Feature vector – Feature extraction – Principal Component Analysis – Linear Discriminant Analysis – transform based feature extraction - Statically pattern recognition – Bayes classifier- k-nearest Neighbor classifier - Syntactic Pattern Recognition– Support Vector Machine. (11)

Total: L: 45

REFERENCES:

1. Sonka, Hlavac and Boyle, “Image Processing, Analysis, and Machine Vision”, Thomson Learning, 2012.
2. Forsyth and Ponce, “Computer Vision: A Modern Approach”, Prentice Hall, 2010.
3. Rafael C Gonzalez and Richard E Woods, "Digital Image Processing", Pearson Education, New Delhi, 2009.
4. Anil K Jain, "Fundamentals of Digital Image Processing" Prentice Hall of India, New Delhi, 2010.
5. Duda R, Hart P and Stork D, “Pattern Classification”, Wiley, 2010.

21UC41 INDUSTRIAL CYBER PHYSICAL SYSTEMS

3 0 0 3

INDUSTRY 4.0: Industry 4.0 Roadmap - Introduction to Industrial Internet - IIOT Reference Architecture - Designing Industrial Internet Systems - Software design concepts - Securing the Industrial Internet - Smart Factories - Role of cyber physical systems in Industry 4.0. (11)

INTRODUCTION TO CPS: CPS based Disruptive Technology - Comparison among Physical vs Cyber vs CPS space - Key features of cyber physical systems - Components of cyber physical systems - Synchronous and Asynchronous models - Safety requirements - Real Time Scheduling - Hybrid Systems. Sensor classification - Sensors in CPS - Imaging vs location sensors - Deep Learning - Concepts of spatial information. (12)

CONTROL OF DYNAMICAL SYSTEMS AND SECURITY IN CPS: Continuous-Time system modelling - Stability criteria for dynamical systems - Controller design requirements - Software and platform issues in feedback control systems. Information security terminologies for CPS - Privacy and security definitions - Typical security threats in CPS - Description of different approaches to secure CPS. (12)

APPLICATION CASE STUDIES: System description and operational scenarios - Key design drivers and quality attributes - Designers challenges in different applications: Medical Cyber-Physical Systems, Energy Cyber-Physical Systems, Cyber-Physical Systems built on Wireless Sensor Networks. (10)

Total L: 45

REFERENCES:

1. Alasdair Gilchrist, “Industry 4.0: The Industrial Internet of Things”, Apress Media, LLC, 2016.
2. Rajeev Alur, “Principles of Cyber-Physical Systems”, The MIT Press, 2015.
3. Raj Rajkumar, Dionisio de Niz, Mark Klein, “Cyber-Physical Systems”, Addison Wesley, 2017.
4. Jung-Sup Um, “Drones as Cyber-Physical Systems: Concepts and Applications for the Fourth Industrial Revolution”, Springer, 2019.
5. Houbing Song et. al. (Eds.),” Cyber-Physical Systems, Foundations, Principles and Applications”, Elsevier, 2017.

21UC42 INDUSTRIAL CYBER SECURITY

3 0 0 3

ARCHITECTURE AND COMMUNICATION IN AN INDUSTRIAL CONTROL SYSTEM : Introduction - Components of an Industrial Control System-Programming and parameter setting stations- Industrial Internet of Things- Network equipment- Data processing platform- Lifecycle of an ICS. Network architecture- Different types of communication networks: Transport networks, Internet protocols, Industrial protocols, IoT protocols. IT/OT convergence. (10)

SECURITY ESSENTIALS AND VULNERABILITIES OF ICS : Overview of security principles- Threats-Attacks- vulnerabilities- Classical cryptosystem–Symmetric key and Asymmetric key cryptosystem– AES and RSA - Data Integrity- Hashing- Digital signatures- Certificates- SSH-IPsec-Authentication and access control - Types of authentication- -Sources of threats on ICS - Attack vectors- Main categories of malware- Attacks on equipment and applications- Attacks specific to ICS equipment- Attacks on IIoT systems- Network attacks- Physical attacks- Attacks using the human factor- Generic approach to vulnerability research- Attack surface- Vulnerabilities of SCADA industrial systems- Vulnerabilities of IoT industrial systems- Systematic analysis of vulnerabilities- Practical tools to analyze technical vulnerability. (15)

ICS RISK MANAGEMENT AND ASSESSMENT TOOLS: General principle of a risk analysis- Risk identification- Estimation of the level of risk- EBIOS method- Attack trees- Cyber PHA and cyber HAZOP- Bowtie cyber diagram- Risk analysis of IIoT systems. Identification of assets- Security management of industrial systems -Risk management process- Special considerations for doing a ICS risk assessment. (8)

ICS SECURITY ARCHITECTURE: Network segmentation and segregation- Firewall- Data diode- Intrusion detection system- Security incident and event monitoring- Secure element – Network segregation types- General firewall policies for ICS– Recommended firewall rules for specific services- NAT- Redundancy and fault tolerance – Incident detection, response and system recovery- ICS security controls: Executing the risk management framework for Industrial control system- Application of security controls to ICS. (12)

Total L: 45

REFERENCES:

1. Jean-Marie Flaus, “Cybersecurity of Industrial Systems”, John Wiley & Sons, 2019.
2. Ronald L and Krutz, Industrial Automation and Control System Security Principles, ISA, 2016.
3. Guide to Industrial Control Systems (ICS) Security, NIST Special Publication 800-82 ,Revision 2, 2015
4. Edward J.M. Colbert and Alexander Kott, Cyber-security of SCADA and other industrial control systems, Springer, 2016.
5. Lane Thames and Dirk Schaefer (Eds.), “Cyber-security for Industry 4.0: Analysis for Design and Manufacturing”, Springer, 2017.

OPEN ELECTIVE COURSES

21UC91 ENERGY MANAGEMENT SYSTEMS

3 0 0 3

INTRODUCTION TO ENERGY MANAGEMENT SYSTEMS: Working of Energy Management System - operation states- Network analysis functions- State estimation- Power system security- Economic Dispatch and optimal power flow. (11)

BUILDING AND SITE ENERGY AUDIT AND ANALYSIS: General methodology- site audits- building audits- varying levels of audits- measures of efficiency- factors contributing to inefficiency- Economic Analysis and estimation of savings – Electric Load Analysis (11)

MANAGEMENT OF PROCESS ENERGY: General principles for process energy management- process heat- transformers and electrical distribution systems- pumps and fans- refrigeration and process cooling- electrolytic systems- compressed air and manufacturing process (11)

INTEGRATED BUILDING SYSTEMS: General principles of energy management in building systems- environmental conformation- building function- occupancy and use- passive design considerations- building envelope design considerations- integration of building systems- peak demand control- sustainable design and green buildings (12)

Total L:45

REFERENCES:

1. Criag B.Smith and Kelly E.Parmenter, “Energy Management Principles”, Second Edition, Elsevier, 2015.
2. Tanuj Kumar Bisht, “SCADA and Energy Management System”, S.K. Kataria & Sons, 2014.
3. Hossam A. Gabbar, “Energy Conservation in Residential, Commercial, and Industrial Facilities” Wiley, 2018.
4. Richard Panke, “Energy Management Systems & Direct Digital Control” River publishers, 2020.
5. Anil Kumar, Om Prakash, Prashant Singh Chauhan and Samsher Gautam, “Energy Management: Conservation and Audits”, CRC Press, 2020.

21UC92 MATHEMATICS FOR SIGNAL ANALYSIS

3 0 0 3

TOOLS FOR SIGNAL ANALYSIS: Fourier transform – Limitation - Short-Time Fourier transform – Cepstrum analysis - Wavelet transform- Multi-resolution analysis (MRA) - Signal decomposition:Empirical mode decomposition – Variational mode decomposition (11)

VIBRATIONAL SIGNAL ANALYSIS: Concept of vibration – Types of vibration –Modelling of vibration – Degrees of freedom – Single degree of freedom undamped vibration: Deterministic modelling - Undamped free vibration – Harmonically forced vibration - Single degree of freedom damped vibration: Damping models – Free vibration with damping – Forced Harmonic vibration – Forced Periodic Vibration - Condition monitoring - Signal classification: Signals generated by rotating machines – Signals generated by reciprocating machines - (12)

POWERLINE SIGNAL ANALYSIS: Taxonomy of power quality events: DC offset, sag, spike, swell, momentary interruption, harmonics in power line signal. Detection and classification of power quality disturbances: feature extraction, feature selection and classification. (11)

BIOMEDICAL SIGNAL ANALYSIS: Genesis and significance of bioelectric potentials: Electrocardiogram (ECG), Electroencephalogram (EEG) and Electromyogram (EMG). ECG: Preprocessing, QRS detection, baseline wander removal, removal of powerline interference, classification and compression. EEG: characteristics of brain waves, sleep stage classification using EEG, Epilepsy detection, seizure detection and classification. EMG: Characteristics of EMG signal, muscle fatigue detection (11)

Total L :45

REFERENCES:

1. HaymBenaroya, Mark Nagurka and Seon Han, “Mechanical Vibration Analysis, Uncertainiteis and Control”, Fourth Edition, CRC Press, 2017.
2. WaldemarRebizant, JanuszSzafran and Andrzej Wiszniewski, “Digital Signal Processing in Power System Protection and Control”, Springer-Verlag, London, 2011.
3. Richard O. Duda, Peter E. Hart and David G. Stork, “Pattern Classification”, Wiley-Interscience, 2000.
4. Robert Bond Randall, “Vibration-based Condition Monitoring: Industrial, Aerospace and Automotive Applications”, Wiley, 2011.
5. Rangaraj M. Rangayyan, “Biomedical Signal Analysis”, Wiley, 2018