Indian Institute of Space Science and Technology

Department of Space,

Thiruvananthapuram

Curriculum and Syllabus for

M.TECH CONTROL SYSTEM

Department of Avionics

[From Academic Period 2022-23] (Approved By Academic Council on 27-4-2022) Version 1 / 17-5-2022

Program Educational Objectives (PEO)

1. Strengthen analytical skills and the technical knowledge in the interdisciplinary area of control theory and applications
2. Enable the graduates to pursue research by adopting dynamic academic curriculum; implement innovative learning and research practices to harness curiosity and creativity; inspire and educate the students to analyze and solve complex problems.
3. Enhance the employability of the graduates in Industry/Academia/R&D organizations by inculcating strong theoretical and experimental knowledge in the domain with exposure to real-life and practical applications.
4. Instill deep sense of ethics, social values, professionalism and inter-personal skills among students.

Program Outcomes (PO)

Program Outcomes	Statements
PO1	An 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	Students should be able 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	Analytical skills for dynamical system modeling and control system design.
PO5	An ability to simulate and implement feedback control systems using advanced software and embedded tools.

COURSE STRUCTURE

Semester I

Code	Course Title	L	T	P	C
AVC611	Linear Systems Theory	3	0	0	3
AVC612	Nonlinear Dynamical Systems	3	0	0	3
AVC613	Control System Design	3	0	0	3
MA619	Advanced Mathematics	3	1	0	4
E01	Elective I	3	0	0	3
AVC851	Embedded System Design Lab	1	0	1	2
	Total	16	1	1	18

Semester II

Code	Course Title	L	T	P	C
E02	Elective 2	3	0	0	3
AVC621	Optimal Control Systems	3	0	0	3
AVC622	Nonlinear Control Systems	3	0	0	3
AVC852	Control System Design Project	0	0	0	3
E03	Elective 3	3	0	0	3
E04	Elective 4 (Swayam or Department Elective)	3	0	0	3
	Total	15	0	0	18

Semester III

Code	Course Title	L	T	P	C
AVC853	Project - Phase I	0	0	0	17
	Total	0	0	0	17

Semester IV

Code	Course Title	L	T	P	C
AVC854	Project - Phase II	0	0	0	17
	Total	0	0	0	17

Summary

Semester	**Credits**
I	18
II	18
III	17
IV	17
Total	**70**

DEPARTMENT ELECTIVE COURSES

Code	Course Title	L	T	P	C
From Control Systems					
AVC861	Modeling and Control of Robotic Systems	3	0	0	3
AVC862	Mobile Robotics and Visual Servoing	3	0	0	3
AVC863	Adaptive Control	3	0	0	3
AVC864	Geometric Approach to Mechanics and Control	3	0	0	3
AVC865	Modelling of Launch Vehicle Dynamics	3	0	0	3
AVC866	Robust Control Systems	3	0	0	3
AVC867	Spacecraft Dynamics and Control	3	0	0	3
AVC868	Advanced Sensors and Interface Electronics	3	0	0	3
AVC869	System Identification and Parameter Estimation	3	0	0	3
AVC870	Fractional Calculus and Control	3	0	0	3
From other M. Tech Specialization					
AVD864	Computer Vision	3	0	0	3
AVD867	Pattern Recognition and Machine learning	3	0	0	3
AVD870	Deep Learning for Computational data sciences	3	0	0	3

Code	Course Title	L	T	P	C
AVD871	Applied Markov Decision Processes and Reinforcement Learning	3	0	0	3
AVD887	Internet of Things	3	0	0	3
AVP 613	Control of AC Motor Drives	3	0	0	3
AVP 865	Power System Dynamics and Control	3	0	0	3
AVP 867	Electronics System Design	3	0	0	3
MA611	Optimization Techniques	3	0	0	3
MA613	Data Mining	3	0	0	3
MA624	Advanced Machine Learning	3	0	0	3
AE820	Multidisciplinary Design Optimization	3	0	0	3

- **Any other relevant approved elective from different branch can be taken after taking approval from PG coordinator**
- **In addition, any one relevant NPTEL/Swayam course can be taken as an elective**

Semester I

AVC611	Linear Systems Theory	(3 0 0) Credits

Introduction to Modern Control Theory: Introduction to state-space versus transform methods in linear systems; internal versus input/output formulation; discrete-time and continuous- time systems; Solution to LTI and LTV systems for homogeneous and non-homogeneous cases. Computation of matrix exponentials using Laplace transforms and Jordan Normal form. Applications of Eigen values and Eigen vectors.

Stability: Internal or Lyapunov stability, Lyapunov stability theorem, Eigen value conditions for Lyapunov stability, Input-Output stability: BIBO stability, Time domain and frequency domain conditions for BIBO stability. BIBO versus Lyapunov stability.

Controllability and Stabilizability: Controllable and reachable subspaces, Physical examples and system interconnections, Reachability and controllability Grammians, Open loop minimum energy control, Controllability matrix(LTI), 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.

Observability and Detectability: Unobservable and unconstructable subspaces, Physical examples, observability and Constructability Grammians, Grammian based reconstruction, Duality (LTI), Observable decompositions, Kalman decomposition theorem, State estimation, Eigen value assignment by output injection, Application - Modelling, controller design and analysis of the Physical system – Analysis of implementable controllers and observers

Text Books/References

1. Linear Systems Theory, Joao P. Hespanaha Princeton University Press, 2009.
2. Linear System Theory and Design, Chi-Tsong Chen 3rd ed., Oxford, 1999.
3. Linear Systems Theory, P. Antsaklis and A. Michel McGraw Hill, 1997.
4. Linear System Theory, Wilson J. Rugh, Prentice Hall, 1996
5. Linear System Theory and Design, Chi-Tsong Chen, Holt, Rinehart and Winston, 1970.
6. Linear Systems, T. Kailath, Prentice Hall, 1980.
7. Matrix Mathematics: Theory, Facts, and Formulas with Application to Linear Systems Theory, Dennis S. Bernstein, Princeton University Press, 2006.

Course Outcomes (COs):

Course Outcomes	Statements
CO1	Understanding basics of state-space modeling which includes representation and solution to state space
CO2	Ability to understand the physical significance of Eigenvalues and Eigenvectors
CO3	Develop skills to analyze the stability using Lyapunov stability
CO4	Can work independently to analyze the controllability and observability with applications

AVC612	Nonlinear Dynamical Systems	(3 0 0) 3 Credits

Introduction to Nonlinear systems: Non-linear elements in control systems, overview of analysis methods. Phase plane analysis: Concepts of phase plane analysis, Phase plane analysis of linear and nonlinear systems, Existence of limit cycles. Fundamentals of Lyapunov theory: Nonlinear systems and equilibrium points, Concepts of stability, Linearization and local stability, Liapunov's direct method, Invariant set theorems, Lyapunov analysis of LTI systems, Krasovskii's method, Variable gradient method, Physically motivated Lyapunov functions. Advanced stability theory: Concepts of stability for Non-autonomous systems, Lyapunov analysis of non- autonomous systems, instability theorems, Existence of Lyapunov functions, Barbalat's Lemma and stability analysis.

Text Books/References

1. Applied nonlinear Control, Jean- Jacques Slotine and Weiping Li, Prentice Hall, ISBN:0-13-040890, 1991.
2. Nonlinear Systems, H.K. Khalil, 3rd ed., Prentice hall, 2002.
3. Bilinear Systems, D. Elliott, Springer, 2009.
4. Nonlinear Systems; Analysis, Stability and Control, Shankar Sastry, Springer. 1999.
5. Stability by Liapunov's direct method: with applications, P. LaSalle, Solomon Lefschetz Joseph Academic Press, 1961.
6. Nonlinear systems analysis, Mathukumalli Vidyasagar, SIAM, 2002.

Course Outcomes (COs):

Course Outcomes	Statements
CO1	Explain the role of nonlinear elements in control systems and provide an overview of methods used for their analysis.
CO2	Describe the concepts of phase plane analysis and apply them to both linear and nonlinear systems.
CO3	Utilize Lyapunov's direct method and invariant set theorems to assess stability and instability of nonlinear systems.
CO4	Extend stability concepts to non-autonomous systems and apply Lyapunov analysis techniques.

AVC613	Control System Design	(3 0 0) 3 Credits

Basics of feedback control: History and motivation for feedback; terminologies, Frequency response, Stability concepts, Bandwidth, Transient response, closed loop design specifications w.r.t tracking and disturbance rejection, Sensitivity to parameter variations. Linear Control System Design Techniques: PD, PI and PID controllers, Lead and Lag compensators, Controller design with root locus technique, frequency response technique and state-space technique.

Introduction to Digital Controllers: Continuous versus digital control, Sampling theorem, ZOH, effect of sampling rate, Discretization of continuous transfer functions; Digital filters, digital controller design using transformation techniques.

Limitations of performance in SISO Feedback systems: Time domain design limitations- Integrators and overshoots, Open RHP poles and overshoots, Open RHP zeros and undershoots, Frequency domain design specifications, Algebraic design tradeoffs, Analytic design tradeoffs, The Bode gain-phase relation, The Bode sensitivity integral, The Poisson sensitivity integral, The Middleton Complementary sensitivity integral, The Poisson complementary sensitivity integral, Sensor noise vs. plant disturbance tradeoffs, uncertainty and other factors which impose fundamental limits on feedback performance.

Text Books/References:

1. Control Systems Engineering, Nise, Norman S. John Wiley & Sons, 2007.
2. Modern Control Engineering. Ogata, Katsuhiko, and Yanjuan Yang Vol. 4. Prentice-Hall, 2002.
3. Digital Control & State Variable Method. Gopal, Madan, Tata McGraw-Hill Education, 2012.
4. Feedback Systems: an introduction for scientists and engineers. Aström, Karl Johan, and Richard M. Murray Princeton university press, 2010.
5. A first graduate course in feedback control, J.S. Freudenberg with C. V. Hollot and D.P. Looze, ebook.
6. Computer-Controlled Systems: theory and design, Karl Johan Åström, Björn Wittenmark, Prentice Hall, 1996.
7. Digital Control of Dynamic Systems, Gene Franklin, Ellis-Kagle Press, J. David Powell, Pearson Education, 2005.

Course Outcomes (COs):

Course Outcomes	Statements
CO1	Comprehend fundamentals of feedback control
CO2	Apply control system design techniques
CO3	Evaluate performance limitations in SISO feedback systems
CO4	Synthesize optimal solutions for feedback systems

MA619 Advanced Mathematics (3 1 0) 4 Credits

Vectors: Representation and Dot products, Norms, Matrices: The Four Fundamental Spaces of a Matrix, The Matrix as a Linear Operator, The Geometry associated with matrix operations, Inverses and Generalized Inverses, Matrix factorization/Decompositions, rank of a matrix, Matrix Norms. Vector spaces: Column and row spaces, Null Space, Solving Ax=0 and Ax=b, Independence, basis, dimension, linear transformations, Orthogonality: Orthogonal vectors and subspaces, projection and least squares, Gram-Schmidt orthogonalization, Determinants: Determinant formula, cofactors, inverses and volume, Eigenvalues and Eigenvectors: characteristic polynomial, Eigen spaces, Diagonalization, Hermitian and Unitary matrices, Spectral theorem, Change of basis, Positive definite matrices and singular value decomposition, Linear transformations, Quadratic forms

Review of Probability: Basic set theory and set algebra, basic axioms of probability, Conditional Probability, Random variables - PDF/PMF/CDF - Properties, Bayes theorem/Law of total probability, random vectors - marginal/joint/conditional density functions, transformation of Random Variables, characteristic/moment generating functions, Random sums of Random variables, Law of Large numbers (strong and Weak), Limit theorems - convergence types, Inequalities - Chebyshev/Markov/Chernoff bounds.

Random processes: classification of random processes, wide sense stationary processes, autocorrelation function, and power spectral density and their properties. Examples of random process models - Gaussian/Markov Random process, Random processes through LTI systems.

Text Books/References:

1. Introduction to linear algebra - Gilbert Strang, SIAM, 2016.
2. Introduction to probability - Bertsekas and Tsitsiklis, Athena, 2008.
3. Probability and Random processes for Electrical Engineers, Leon Garcia Addison Wesley, 2nd edition, 1994.
4. Probability and Random Processes, Geoffrey Grimmett, David Stirzaker, 3rd Edition, Oxford University Press, 2001.
5. Probability and Stochastic Process, Roy D Yates, David J Goodman, 2nd edition Wiley, 2010.

E01 — Elective 1 — (3 0 0) 3 Credits

- Refer Elective List

AVC 851 — Embedded System Design Lab — (1 0 1) 2 Credits

Introduction to C: 'Hello World!' program, Fizz-buzz program, and Fizz-Buzz-Zazz program.

Micro controllers and DSP: Getting started with Code composer studio/ PSoC Creator: Architecture and review of Digital Signal Controllers/ microcontroller (PSoC), Architecture of PSoC-5 LP, PSoC Creator edit and debug modes, blinking of an LED with one second ON, half second OFF

Programing requirements for time critical control applications: Enabling of Hardware triggered interrupts, triggering Hardware interrupts with Timers and PWM, Program structure for time critical events, use of putty (Serial interface through USB) to turn on and off an LED, Modulation of LED brightness using PWM.

Fixed point operations: DAC initialization and updates, fixed point arithmetic basics and development of Macros for (a) addition 4.12 + 4.12, (b) multiplication 4.12 and 4.12 numbers, (c) number format casting - 4.12 to 8.24 and vice versa, integrators, signal generation of square wave with variable duty and frequency (fixed amplitude) upto 50 kHz, signal generator functions (sine, square, saw tooth, triangle generation with variable magnitude and variable frequency upto 500 Hz) frequency input to be given through UART interface.

Data Acquisition: ADC initialization, signal acquisition and setup, sensing signals using onboard ADC of PSoC5 - issues with sampling time and input frequency, find max, min, average, RMS of the input signal.

Filter implementation: Nth order IIR filter implementation, time constant relationship with sampling times, Nth order FIR filter implementation, memory requirements for filters, Sampling and quantization errors, outputs for different input signals.

Controllers (simulated plant): Implementation of a P controller, implementation of an I controller, implementation of a PI controller, implementation of a 2 DOF controller.

Controllers (physical plant): The plant is RC filter (physical) with a varying load resistance. RC filter is fed with PWM module. Implementation of a P controller, implementation of an I controller, implementation of a PI controller, implementation of a 2 DOF controller.

FPGAs: Hardware description language (HDL - VHDL), Program architecture (Functional and behavioral models), Simple combinational blocks and look-up tables, multiplexer, demultiplexer implementation, introduction to design of sequential logic circuits.

Course projects (Any one in groups of 2 or 3):

1. Auto volume leveler with microcontroller and audio source
2. A PWM module implemented with FPGA (Xilinx Spartan-3 series)
3. Electronic speed controller for BLDC - 1 axis reaction wheel system - control of orientation
4. Magnetic levitation with hardware building (2 students)

Text Books/References:

1. Power Electronics: Essentials and Applications by L. Umanand, Wiley international.
2. Application notes for C2000 processors by Texas Instruments.
3. Application noted for Programmable Systems on Chip (PSoC) by Infineon.

Course Outcomes (COs):

Course Outcomes	Statements
CO1	Understanding the architectures of microcontrollers and DSP controllers
CO2	Programming hardware interrupts and generating various signals
CO3	Designing filters and controllers
CO4	Understanding HDL and designing logic circuits

SEMESTER II

AVC621	Optimal Control Systems	(3 0 0)	3 Credits

Basic mathematical concepts: Finite dimensional optimization, Infinite dimensional optimization, Conditions for optimality, Performance measures for optimal control problems.
Calculus of variations: Examples of variational problems, Basic calculus of variations problem, Weak and strong extrema, Variable end point problems, Hamiltonian formalism and mechanics: Hamilton's canonical equations.
From Calculus of variations to Optimal control: Necessary conditions for strong extrema, Calculus of variations versus optimal control, optimal control problem formulation and assumptions, variational approach to the fixed time, free end point problem.
The Pontryagin's Minimum principle: Statement of Minimum principle for basic fixed end point and variable end point control problems, Proof of the minimum principle, Properties of the Hamiltonian, Time optimal control problems.
The 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. Examples: Minimum energy control of a DC motor, Active suspension with optimal linear state feedback, Frequency shaped LQ Control.
LQR using output feedback: Output feedback LQR design equations, Closed loop stability, Solution of design equations, example.
Linear Quadratic tracking control: Tracking a reference input with compensators of known structure, tracking by regulator redesign, Command generator tracker, and Explicit model following design.

Text Books/References:

1. Optimal Control Theory- An Introduction, D.E.Kirk, Dover Publications, New York, 2004.
2. Linear Systems- Optimal and Robust Controls, Alok Sinha, CRC Press, 2007.
3. Calculus of variations and Optimal control theory, Daniel Liberzone, Princeton University Press, 2012.
4. Applied optimal control & Estimation- Digital design and implementation, Frank L. Lewis, Prentice Hall and Digital Signal Processing Series, Texas Instruments, 1992.
5. Primer on Optimal Control Theory, Jason L. Speyer, David H. Jacobson, SIAM, 2010.
6. Optimal Control Theory with Aerospace Applications, Ben-Asher, Joseph Z, American Institute of Aeronautics and Astronautics, 2010.
7. Optimal control: linear quadratic methods, Brian D. O. Anderson, John Barratt Moore, Dover, 2007.
8. Optimal filtering, Brian D. O. Anderson, John Barratt Moore, Dover, 2005.

Course Outcomes (COs):

Course Outcomes	Statements
CO1	Evaluate performance measures for optimal control problems, understanding their significance in practical applications.
CO2	Solve variational problems using basic calculus of variations principles.
CO3	Compare and contrast calculus of variations with optimal control methodologies, emphasizing problem formulation and underlying assumptions.

CO4	Solve the Optimal control problem using the parameterization approach and compare its formulation with the standard calculus of variations

AVC622 Nonlinear Control Systems (3 0 0) 3 Credits

Nonlinear Control: An introduction to vector fields, flows and integral curves of differential equations, Lie Brackets, Frobenious theorem, Orbits, accessibility and controllability, Control design based on Liapunov's method

Feedback Linearization: Feedback Linearization and the canonical form, Input-state Linearization of SISO systems, Input output Linearization of SISO systems

Sliding Mode Control: Sliding surfaces, Filippov's construction of the equivalent dynamics, direct implementations of switching control laws, Continuous approximations of switching control laws,

Text Books/References:

1. Nonlinear Systems, H. K. Khalil, Prentice Hall, 2002.
2. Applied nonlinear Control, Jean- Jacques Slotine and Weiping Li, Prentice Hall,1991.
3. Ordinary Differential Equations, V. Arnold, Springer, 1992.
4. Nonlinear Control Systems, A. Isidori, Springer, 1989.
5. Nonlinear Control Systems, H. Neijmier and A. Van der Schaft Springer,1992.

Course Outcomes (COs):

Course Outcomes	Statements
CO1	Apply Lie Brackets and the Frobenius theorem to analyze system dynamics and determine conditions for system integrability.
CO2	Implement Feedback Linearization techniques to transform nonlinear systems into a canonical form suitable for control design.
CO3	Define sliding surfaces and apply them to design robust control laws that ensure system trajectories remain on the sliding surface.
CO4	Integrate concepts from nonlinear control, feedback linearization, and sliding mode control to solve practical control problems.

AVC852 Control System Design Project (3 0 0) 3 Credits

- Modelling and simulation of a physical systems
- Control system design using time and frequency domain methods
- Experimental validation/demonstration

Note: Students are advised to do projects independently. Evaluation is based on midterm and final presentation of the work done.

Course Outcomes (COs):

Course Outcomes	Statements
CO1	Apply simulation software tools to simulate and analyze the behavior of modeled physical systems under different conditions.
CO2	Implement and analyze PID controllers and other classical control techniques to achieve desired system performance specifications
CO3	Plan and conduct experiments to validate control system designs and simulate physical system responses.
CO4	Integrate theoretical concepts of modelling, simulation, and control system design with practical applications and experimental validation.

E02 Elective 2 (3 0 0) 3 Credits

- **Refer Elective List**

E03 Elective 3 (3 0 0) 3 Credits

- **Refer Elective List**

E04 Elective 4 (Swayam or Department Elective) (3 0 0) 3 Credits

- **Refer Elective List**

Semester III

AVC853	**Project - Phase I**	**(0 0 0)**	**17 Credits**

- Midterm evaluation is based on interim report and presentation before a committee
- A final report in the prescribed format on the literature survey, theoretical analysis, design guidelines, simulation and experimental results etc. to be submitted to the committee during end semester evaluation
- Final evaluation is done based on the technical presentation before an expert committee, report submitted and supervisor's assessment

Semester IV

AVC854	**Project - Phase II**	**(0 0 0)**	**17 Credits**

- Midterm evaluation is based on interim report and presentation before a committee
- A final report in the prescribed format on the literature survey, theoretical analysis, design guidelines, simulation and experimental results etc. to be submitted to the committee during end semester evaluation
- Final evaluation is done based on the technical presentation before an expert committee, report submitted and supervisor's assessment

Elective Courses (From Control Systems)

AVC861	**Modeling and Control of Robotic Systems**	**(3 0 0)**	**3 Credits**

Introduction: Components and mechanisms of robotic systems, Robot Manipulators, Wheeled Robots, Legged robots, Autonomous Robots, Joint actuators and Sensors.

Robot Kinematics: Rotation Kinematics, Rotation matrix, Euler angles, Axis-angle representation, Rodrigues formula, Different types of Coordinate transformations, Kinematics of rigid motion, Homogeneous transformation, Modified DH Convention, Typical examples

Differential Kinematics and Statics: Joint configuration space and Task space of robots, Jacobian matrix and Differential motion, Kinematic singularities, Redundancy analysis, Closed loop Inverse Kinematics, Statics, Kineto-static duality, Velocity and force transformations, Spatial vector algebra, Unified representation for rigid motion, Rigid body transformation matrix

Dynamics: Joint space inertia matrix, Computation of kinetic and potential energies, Dynamical model of simple manipulator structures, Dynamics of Serial chain multibody systems, Euler-Lagrange and Newton-Euler formulations, Forward dynamics and inverse dynamics

Motion control: The control problem, Joint space control, Decentralized control, Computed torque feedforward control, Centralized control, PD Control with gravity compensation, Inverse dynamics control, Task space control, Control of redundant robotic manipulators.

Force Control: Manipulator interaction with environment, Compliance control, Impedance control, Force control, Constrained motion, Hybrid force/motion control

Text Books/References:

1. Robot Modelling and Control, M. W. Spong, S. Hutchinson and M. Vidyasagar, John Wiley & Sons Inc., 2006.
2. Course notes on Modelling and Control of Robotic Systems by Sam K Zachariah.
3. Robot and Multibody dynamics – Analysis and Algorithms, Abhinandan Jain, Springer, 2011
4. A Journey from Robot to Digital Human, Edward Y.L. Gu , Springer, 2013
5. Robotics- Modelling, Planning and Control, B. Siciliano, L. Sciavicco, L. Villani, G. Oriolo, Springer, 2009.
6. Springer Handbook of Robotics, B. Siciliano, O. Khatib (Eds) Springer, 2008.
7. Dynamics of Tree-Type Robotic Systems, S. V. Shah, S.K. Saha and J. K. Dutt, Springer, 2018.

AVC862	Mobile Robotics and Visual Servoing	(3 0 0)	3 Credits

Mobile Robotics: Introduction to mobile robots, Nonholonomic constraints, Kinematic models. Unicycle, Bicycle, Chained form, Dynamic model of mobile robots. Trajectory Planning: Path and Timing laws, Flat outputs, Path planning, Trajectory planning, Optimal trajectories. Motion Control: Trajectory tracking, Cartesian regulation, Posture regulation, Odometric localization. Obstacle avoidance and Motion planning: The canonical problem, Configuration space, Different types of obstacles, planning via retraction, planning via cell decomposition, Probabilistic planning, Planning via artificial potentials, Motion planning for manipulators. Visual Servoing: Vision for control, Different types of configuration, Image processing, Pose estimation, Interaction matrix, Stereo vision, Camera calibration Visual servoing problem: Position based visual servoing, Image based visual servoing, Hybrid visual servoing.

Text Books/References:

1. Robotics- Modelling, Planning and Control, B. Siciliano, L. Sciavicco, L. Villani, G. Oriolo, Springer, 2009.
2. Vision and Control, Peter Corke, Robotics, Springer, 2016.
3. Robot Modelling and Control, M.W.Spong, S.Hutchinson and M. Vidyasagar John Wiley & Sons Inc., 2006.

AVC863	Adaptive Control	(3 0 0)	3 Credits

Introduction: Parametric models of dynamical systems, Adaptive control problem Real time parameter estimation: Least squares and regression models, Estimating parameters in Dynamical Systems, Experimental conditions, Prior information, MLE, RLS, Instrument variable method. Deterministic Self tuning regulators (STR): Pole placement design, Indirect self tuning regulators, Continuous time self-tuners, Direct self-tuning regulators, disturbances with known characteristics. Stochastic and Predictive Self tuning regulators: Design of Minimum variance and Moving average controllers, Stochastic self-tuning regulators, Unification of direct self-tuning regulators. Linear quadratic STR, adaptive predictive control. Model reference adaptive control (MRAS): The MIT Rule, Determination of adaptation gain, Lyapunov theory, Design of MRAS using Lyapunov theory, BIBO stability, Output feedback, Relations between MRAS and STR.

Text Books/References:

1. Adaptive Control, 2nd ed., Pearson Education, 1995.
2. Adaptive Control Tutorial, Petros Ioannou and Baris Fidan, SIAM, 2006.
3. Robust Adaptive Control, P.A. Ioannou and J. Sun, Prentice Hall, 1995.
4. Adaptive Control- Stability, Sankar Sastry and Marc Bodson, Convergence and Robustness, Springer, 2011.
5. Nonlinear and Adaptive Control Design, M. Krstic, I. Kanellakopoulos and P. Kokotovic, Wiley- Interscience, 1995.
6. Nonlinear Systems, H.K. Khalil, Prentice Hall, 3rd ed., 2002.
7. Applied nonlinear Control, Jean- Jacques Slotine and Weiping Li, Prentice Hall,1991.
8. Instrumental variable estimation, Torsten Söderström, Springer, 1983.
9. Harold Wayne Sorenson, Parameter estimation: principles and problems, M Dekker, 1980.

AVC864 Geometric Approach to Mechanics and Control (3 0 0) 3 Credits

Prerequisites: Vector Spaces (Linear Algebra)

An introduction to differentiable manifolds, tangent ff vectors, vector fields, co vector fields, immersions and submersions, Lie groups, actions of groups, Lie algebras, adjoint co-adjoint maps, symmetries. Vector fields, integral curves, push-forward and pull-back, differential forms and Riemannian geometry.

Euler Poincare reduction for the rigid body and heavy top, satellite dynamics and control with coordinate free models, inverted pendulum on a cart.

Text Books/References:

1. Geometric Mechanics and Symmetry, D.D. Holm, T. Schmah and C. Stoica,Oxford University Press, 2009.
2. Introduction to Mechanics and Symmetry, J. Marsden and T. Ratiu, Springer-Verlag, 1994.
3. Control Theory from the Geometric Viewpoint, Agrachev and Y. Sachkov, Springer, 2004.
4. An Introduction to Manifolds, L. W. Tu, Springer 2008.
5. Ordinary Differential Equations, V. Arnold, Springer, 1992.
6. Elementary Topics in Differential Geometry, J. A. Thorpe, Springer 2004.
7. A Comprehensive Introduction to Differential Geometry, M. Spivak, Publish or Perish, 1999.

AVC865 Modelling of Launch Vehicle Dynamics (3 0 0) 3 Credits

Coordinate systems, Attitude dynamics and control, Rotational kinematics, Direction cosine matrix, Euler angles, Euler's Eigen axis rotation, Quaternions, Rigid body dynamics of launch vehicle, Angular momentum, Inertia matrix, Principal axes, Derivation of dynamic equations, Effect of aerodynamics, structural dynamics and flexibility, propellant sloshing, actuator dynamics, gimballed engine dynamics, External forces and moments, Linear model for Aero-structure-control-slosh interaction studies.

Text Books/References:

1. Automatic control of Aircraft and Missiles, J. H. Blakelock, Wiley India,1991.
2. Control Theory Vol. II- Analysis and Design of Space Vehicle Flight Control Systems, A. L. Greensite, Spartan Books, 1970.
3. Practical design of flight control systems for launch vehicles and Missiles, N V Kadam, Allied Publishers Pvt. Ltd., 2009.
4. Aircraft Control and Simulation, Brian L. Stevens, Frank L. Lewis, Wiley, 2003.
5. Space vehicle dynamics, K. J. Ball, G. F. Osborne, Clarendon P., 1967.
6. Analysis and Design of Space Vehicle Flight Control Systems – Short Period Dynamics, A. L. Greensite, Vol 1, NASA.
7. Analysis and Design of Space Vehicle Flight Control Systems, A. L. Greensite, - Trajectory Equations Vol 2, 1967, NASA.

AVC866 Robust Control Systems (3 0 0) 3 Credits

Vector and matrix Norms, Signal and System Norms, Singular Value Decomposition, Coprime factorization, LMIs, System representation, Sensitivity and Complementary sensitivity functions, pole and zero directions, performance imitations, well posedness, internal stability of feedback system, Nyquist plot, small gain theorem, Uncertainty representation (structured/parametric and unstructured), robust stability and robust performance, structured singular values, Kharitonov's theorem, linear fractional transformation, stabilizing controllers, H-infinity controllers, μ synthesis, applications of robust control in physical systems, Loop shaping design procedures.

Text Books/References:

1. Multivariable Feedback Control: Analysis and Design, Sigurd Skogestad, Ian Postlethwaite,Wiley, 2005.
2. Essentials of Robust Control, Kemin Zhou,John C Doyle, Pearson, 1998.
3. Linear Systems-Optimal and Robust Control, Alok Sinha, CRC Press, 2007.
4. Robust Control Design with MATLAB, Da-Wei Gu, Petko H. Petkov, Mihail M Konstantinov, 2013.

AVC867 Spacecraft Dynamics and Control (3 0 0) 3 Credits

Attitude Kinematics: Particle Kinematics and Vector Frames, Angular Velocities, Vector Differentiation and the Transport Theorem, Rigid Body Kinematics, Direct Cosine Matrix (DCM), Euler Angles, Quaternions, Differential Kinematic Equations, Attitude Determination using TRIAD Method and QUEST Methods.

Attitude Kinetics/Dynamics: Overview of Kinetics, Linear Momentum and Angular Momentum, Rigid Body Angular Momentum, Rigid Body Inertia Tensor, Rigid Body Kinetic Energy, Rigid Body Equations of Motion, Integrating Rigid Body Equations of Motion. Torque Free Motion with Axisymmetric Body, Torque Free Motion General Inertia, Overview of Momentum Exchange Devices.

Attitude Control: Nonlinear Rigid Body State and Rate Control, Global Stability of Nonlinear Attitude Control, Asymptotic Stability for Nonlinear Attitude Control.

Text Books/References:

1. Analytical mechanics of space systems. Schaub, Hanspeter, and John L. Junkins. AIAA, 2003.
2. Space vehicle dynamics and control, Wie, Bong, American Institute of Aeronautics and Astronautics, 2008.
3. Spacecraft dynamics and control: a practical engineering approach, Sidi, Marcel J. Vol. 7. Cambridge university press, 2000.
4. Spacecraft attitude determination and control, Wertz, James R., ed. Vol. 73., Springer Science & Business Media, 2012.
5. Spacecraft attitude dynamics, Hughes, Peter C. Courier Corporation, 2012.
6. Fundamentals of spacecraft attitude determination and control, Markley, F. Landis, and John L. Crassidis ,Vol.33. New York: Springer, 2014.
7. Spacecraft dynamics and control: an introduction, De Ruiter, Anton H., Christopher Damaren, and James R. Forbes, John Wiley & Sons, 2012.
8. Nonlinear dynamical control systems, Nijmeijer, Henk, and Arjan Van der Schaft, Vol. 175. New York: Springer- Verlag, 1990.

AVC868 Advanced Sensors and Interface Electronics (3 0 0) 3 Credits

Introduction and Background of state-of-art sensing and measurement techniques. Contactless potentiometer (resistance-capacitance scheme) – Methodology, Interface Circuits, Overview of Flight Instrumentation. Analog Electronic Blocks, CMRR Analysis (Non-ideal opamps) of an Instrumentation Amplifier, Linearization circuits for single-element wheatstone bridges (application to strain gauge), Direct Digital Converter for Strain gauges, Signal conditioning for Remote-connected sensor elements. Inductive sensors and electronic circuits, Eddy-current based sensors, Synchros and Resolvers, Magnetic shielding techniques. State-of-art Magnetic Sensors – Principle, Characteristics and Applications – Induction Magnetometer, Flux gate Magnetometer, Hall Effect Sensor, Magnetoresistance Sensors, GMR Sensors – Multi-layer and Spin Valve, Wiegand Effect, SQUID.

Case Study-1: GMR Based Angular Position Sensor, Sensing Arrangement, Linearization Electronics – Methodology, Circuit Design and Analysis.

Case study-2: Brake Wear Monitoring, Reluctance-Hall Effect Angle Transducer–Sensing Arrangement, Front-end Electronics. Overview of Basic Capacitive sensors. Various design considerations; guarding, stray fields, offset and stray capacitance, Ratio metric measurement – advantages and circuit implementations. RMS, Peak, Average Value Electronic Schemes for Capacitive Sensors, Synchronous Phase Detection – multiplier and switching type.

Case study-3: Liquid level detection – Concentric Cylindrical Plates, Plates on container walls – Dielectric and Conductive Liquids - Analysis.

Case study-4: Capacitive Angle Transducers and Front-end electronics.

Piezoelectric sensors, Seismic transducers. Introduction to MEMS, Piezoelectric, Electrodynamic and MEMS Capacitive Accelerometers, Principles of Ultrasonic sensors - Equivalent circuit and transfer function of a piezoelectric transmitter, crystal oscillator. NDT using ultrasonic and eddy-current.

Optical and Fibre Optic Sensors MEMS Pressure sensors, Vacuum-pressure estimation and important flow measurement (volume and mass flow rate) schemes, Flapper-nozzle systems. Sensing Schemes for Attitude, Position measurement and navigation Instrumentation Systems for Occupancy Detection – Ultrasound, Inductive and Capacitive schemes. Non-contact current and voltage measurement, Newhuman vital-sign sensing techniques.

Text Books/References:

1. Sensors and Signal Conditioning, Ramón Pallás-Areny, John G. Webster, 2nd Edition, Wiley, 2003.
2. Measurement systems: Application and Design, Doebelin, E.O., 5th ed., McGraw hill, 2003.
3. The Measurement, Instrumentation and Sensors Handbook, J. G. Webster, Vol 1 and 2, CRC Press, 1999.
4. Capacitive Sensors – Design and Applications, L. K. Baxter, IEEE Press Series on Electronic Technology, NJ, 1997.
5. Handbook of Modern Sensors – Physics, Designs and Applications, Jacob Fraden, Springer, 4th Edition, 2010.
6. Principle of Measurement Systems, John P. Bentley, Pearson Education; 3rd Edition, 2006.
7. Fundamentals of Industrial Instrumentation, A. Barua, Wiley, 2013.

AVC869 System Identification and Parameter Estimation (3 0 0) 3 Credits

Introduction, discrete systems, basic signal theory, Open-loop LTI SISO systems, time domain, frequency domain Least Squares Estimation, Covariance in Stationary, Ergodic Processes, White Noise, Detection of Periodicity and Transmission Delays, ARMA Processes.

Non-parametric identification: correlations and spectral analysis, Subspace identification, Identification with "Prediction Error" -methods: prediction, model structure, approximate models, order selection, validation, ARX and ARMAX Input Models, Output Error Model, Box-Jenkins Model. Non-linear model equations, Linearity in the parameters, Identifiability of parameters, Error propagation, MIMO-systems, Identification in the frequency domain, Identification of closed loop systems, Non-linear optimization

Text Books/References:

1. Lectures on system identification - Part 3, Department of Automatic Control, Karl Johan Åström, Lund Institute of Technology, 1975.
2. System Identification, T. Söderström and P. Stoica, Prentice Hall, 1989.
3. System identification – Theory for the user, L Ljung, Pearson Education, 1998.
4. Lessons in Digital Estimation Theory, Jerry M. Mendel, Prentice Hall, 1987.
5. Fundamentals of Statistical Signal Processing, Steven M. Kay, Prentice Hall, 2013.

AVC87 0 **Fractional Calculus and Control** **(3 0 0) 3 Credits**

Fractional Calculus: Review of basic definitions of integer-order (IO) derivatives and integrals and their geometric and physical interpretations, Definition of Riemann-Liouville (RL) integration, Definitions of RL, Caputo and Grunwald-Letnikov (GL) fractional derivatives (FDs), Various geometrical and physical interpretations of these FDs, Computation of these FDs for some basic functions like constant, ramp, exponential, sine, cosine, etc., Laplace and Fourier transforms of FDs.
Fractional-order Differential Equations: Study of basic functions like Gamma function, Mittag-Leffler function, Dawson's function, Hypergeometric function, etc, Analysis of linear fractional order differential equations (FDEs): formulation, Solution with different FDs, Initial conditions, Problem of initialization and the remedies.
Fractional-order Modeling: Concepts of 'memory' and 'non-locality' in real-world and engineering systems, non- exponential relaxation , 'Mittag-Leffler' type decay and rise, Detailed analysis of fractional-order (FO) modeling of: electrical circuit elements like inductor, capacitor, electrical machines like transformer, induction motor and transmission lines, FO modeling of viscoelastic materials, concept of fractional damping, Models of basic circuits and mechanical systems using FO elements, Concept of anomalous diffusion, non- Gaussian probability density function and the development of corresponding FO model, FO models of heat transfer, A brief overview of FO models of biological systems.

Linear Fractional-order Systems: Review of basic concepts of complex analysis, Concepts of multivalued functions, branch points, branch cuts, Riemann surface and sheets, Fractional-order transfer function (FOTF) representation, Concepts like commensurate and non-commensurate TFs, stability, impulse, step and ramp response, Frequency response, non-minimum phase systems, Root locus, FO pseudo state-space (PSS) representation and the associated concepts like solution of PSS model, controllability, observability, etc.
Fractional-order Control: Detailed discussion and analysis of superiority of FO control over the conventional IO control in terms of closed-loop performance, robustness, stability, etc., FO lead lag compensators, FO PID control, design of FO state- feedback, Realization and implementation issues for FO controllers, survey of various realization methods and the comparative study.

Text Books/References:

1. The Fractional Calculus. K. B. Oldham and J. Spanier. Dover Publications, USA, 2006.
2. Theory and Applications of Fractional Differential Equations, Kilbas, H. M. Srivastava, and J. J. Trujillo. Elsevier, Netherlands, 2006.
3. Fractional Differential Equations, Podlubny, Academic Press, USA, 1999.
4. Fractional-order Systems and Control: Fundamentals and Applications , C. A. Monje, Y. Q. Chen, B. M. Vinagre, D. Xue, and V. Feliu. Springer-Verlag London Limited, UK, 2010.
5. Fractional Calculus in Bioengineering, R. L. Magin. Begell House Publishers, USA, 2006.
6. Fractional Order Systems: Modeling and Control Applications, R. Caponetto, G. Dongola, L. Fortuna, and I. Petras. World Scientific, Singapore, 2010.
7. An Introduction to the Fractional Calculus and Fractional Differential Equations.,K. S. Miller and B. Ross. John Wiley & Sons, USA, 1993.
8. Functional Fractional Calculus for System Identification and Controls, S. Das. Springer, Germany, 2011.
9. Fractional Calculus for Scientists and Engineers, M. D. Ortigueira. Springer, Germany, 2011.
10. Fractional-Order Nonlinear Systems: Modeling, Analysis and Simulation, Petras. Springer, USA, 2011.

Electives From other M. Tech Specialization

AVD864 **Computer Vision** **(3 0 0) 3 Credits**
4

The course is an introductory level computer vision course, suitable for graduate students. It will cover the basic topics of computer vision, and introduce some fundamental approaches for computer vision research: Image Filtering, Edge Detection, Interest Point Detectors, Motion and Optical Flow, Object Detection and Tracking, Region/Boundary Segmentation, Shape Analysis, and Statistical Shape Models, Deep Learning for Computer Vision, Imaging Geometry, Camera Modeling, and Calibration. Recent Advances in Computer vision.

Prerequisites: Basic Probability/Statistics, a good working knowledge of any programming language (Python, Matlab, C/C++, or Java), Linear algebra, and vector calculus.
Grading: Assignments and the term project should include explanatory/clear comments as well as a short report describing the approach, detailed analysis, and discussion/conclusion.
Course evaluation: 4 Programming assignments 20% (5% each), Term project 20%, Exam 20%, End Semester 40 %.

Text Books/References:

1. Computer Vision: Models, Learning, and Interface, Simon Prince, Cambridge University Press
2. Fundamentals of Computer Vision, Mubarak Shah,
3. Computer Vision: Algorithms and Applications, Richard Szeliski, Springer, 2010
4. Computer Vision: A Modern Approach, Forsyth and Ponce, Prentice-Hall, 2002
5. Vision Science, Palmer, MIT Press, 1999,
6. Pattern Classification 2nd Edition, Duda, Hart and Stork, Wiley, 2000,
7. Probabilistic Graphical Models: Principles and Techniques, Koller and Friedman, MIT Press, 2009,
8. Linear Algebra and Its Applications 2/e, Strang, Gilbert. Academic Press, 1980.

Programming: Python will be the main programming environment for the assignments. The following book (Python programming samples for computer vision tasks) is freely available. Python for Computer Vision. For mini-projects, a Processing programming language can be used too (strongly encouraged for android application development)

AVD867 **Pattern Recognition and Machine Learning** **(3 0 0) 3 Credits**

PR overview - Feature extraction - Statistical Pattern Recognition - Supervised Learning - Parametric methods - Non-parametric methods; ML estimation - Bayes estimation - k NN approaches. Dimensionality reduction, data normalization. Regression, and time series analysis. Linear discriminant functions. Fisher's linear discriminant and linear perceptron. Kernel methods and Support vector machine. Decision trees for classification. Unsupervised learning and clustering. K - means and hierarchical clustering. Decision Trees for classification. Ensemble/ AdaBoost classifier, Soft computing paradigms for classification and clustering. Applications to document analysis and recognition

Text Books/References:

1. Pattern classification, Duda and Hart, John Wiley and sons,2001.
2. Machine learning, T M Mitchel, McGraw Hills 1997 Pattern Recognition and Machine Learning, Christopher M. Bishop, Springer, 2006.

AVD870 Deep Learning for Computational Data Science (3 0 0) 3 Credits

Prerequisite: Linear algebra, Probability, and interest in programming
Description: Deep learning methods are now prevalent in the area of machine learning, and are now used invariably in many research areas. In recent years it received significant media attention as well. The influx of research articles in this area demonstrates that these methods are remarkably successful at a diverse range of tasks. Namely self-driving cars, new kinds of video games, AI, Automation, object detection and recognition, surveillance tracking etc. The proposed course aims at introducing the foundations of Deep learning to various professionals who are working in the area of automation, machine learning, artificial intelligence, mathematics, statistics, and neurosciences (both theory and applications). This is a proposed course to introduce Neural networks and Deep learning approaches (mainly Convolutional Neural networks) and give a few typical applications, where and how they are applied. The following topics will be explored in the proposed course. We will cover a range of topics from basic neural networks, convolutional and recurrent network structures, deep unsupervised and reinforcement learning, and applications to problem domains like speech recognition and computer vision.
Prerequisites: a strong mathematical background in calculus, linear algebra, and probability & statistics, as well as programming in Python and C/C++. There will be assignments and a final project.

1. Introduction to Visual Computing and Neural Networks
2. Basics of Multilayer Perceptron to Deep Neural Networks with Autoencoders
3. Unsupervised deep learning
4. Autoencoders for Representation Learning and MLP Initialization
5. Stacked, Sparse, Denoising Autoencoders and Ladder Training
6. Cost functions, Learning Rate Dynamics and Optimization
7. Introduction to Convolutional Neural Networks (CNN) and LeNet
8. Convolutional Autoencoders and Deep CNN (AlexNet, VGGNet)
9. Very Deep CNN architecture for Classification (GoogLeNet, ResNet, DenseNet)
10. Computational Complexity and Transfer Learning of a Network
11. Object Localization (RCNN) and Semantic Segmentation
12. Generative Models with Adversarial Learning
13. Recurrent Neural Networks (RNN) for Video Classification
14. Deep reinforcement learning
15. NLP/Vision Application

Text Books/References:

1. Deep Learning, Ian Goodfellow, Yoshua Bengio, Aaron Courville
2. Pattern Classification, Duda, R.O., Hart, P.E., and Stork, D.G, Wiley-Interscience. 2nd Edition. 2001.
3. Pattern Recognition,Edition 4. Theodoridis, S. and Koutroumbas, K, Academic Press, 2008.

4. Artificial Intelligence: A Modern Approach, Russell, S. and Norvig, N. Prentice-Hall Series in Artificial Intelligence. 2003.
5. Neural Networks for Pattern Recognition. Bishop, C. M. Oxford University Press. 1995.
6. The Elements of Statistical Learning. Hastie, T., Tibshirani, R. and Friedman, J. Springer. 2001.
7. Probabilistic Graphical Models. Koller, D. and Friedman, N, MIT Press. 2009.

AVD871 **Applied Markov Decision Processes and Reinforcement Learning** **(3 0 0) 3 Credits**

Review of basic probability and stochastic processes. Introduction to Markov chains. Markov models for discrete time dynamic systems, Reward, Policies, Policy evaluation, Markov decision processes, Optimality criteria, Bellman's optimality principle, Dynamic programming, Optimality equations, Policy search, Policy iteration, Value iteration. Generalized Policy Iteration, Approximate dynamic programming. Exploration versus Exploitation in Reinforcement learning, Multi-armed and Contextual Bandits, Reinforcement learning setup and Model free learning, Monte Carlo learning, Q-learning & SARSA, Temporal difference learning, Function approximation, Policy gradient methods, Actor-critic methods, Stochastic approximation and its applications to reinforcement learning, Neural networks in reinforcement learning, Deep reinforcement learning.
Applications and case studies of Markov decision processes and Reinforcement Learning in Machine Learning, Control, Communication, Robotics, and Optimization.

Text Books/References:

1. Reinforcement learning: An introduction, Richard S. Sutton and Andrew G. Barto, MIT press, 2018.
2. Dynamic programming and optimal control, Dimitri P. Bertsekas, Vols. I and II, Athena scientific, 2005.
3. Applied probability models with optimization applications, Sheldon M. Ross. Courier Corporation, 2013.
4. Introduction to stochastic dynamic programming, Sheldon M. Ross. Academic press, 2014.

Course Outcomes (COs):

Course Outcomes	Statements
CO1	Understand probability, stochastic processes (especially Markov chains) and their use in modelling of discrete time stochastic systems
CO2	Understand the theory of Markov decision processes and the problem of controlling discrete time dynamical systems and their formulation as Markov decision problems
CO3	Apply various methods (such as value iteration and policy iteration) for solving Markov decision processes
CO4	Understand the reinforcement learning framework and the fundamental problems of exploration-exploitation dilemma and credit assignment.
CO5	Understand, design, and implement reinforcement learning agents and apply them to real world problems.

AVD887	Internet of Things	(3 0 0) 3 Credits

Evolution of the Internet and Big Data. Introduction to the Internet of Things (IoT). The Internet protocol stack. IPv4 and IPv6. TCP and UDP. DNS and the IoT Protocol stack, Layers in the Internet of Things. Sensing and Actuator Layer, Network Layer, and Application Layer. Wireless Sensor Networks. Communication Technologies for the Internet of Things. CoAP, MQTT, and HTTP Protocols for IoT. Data aggregation and fusion. Operating Systems for IoT. Contiki OS, Tiny OS, and other IoT OSs. Databases for the Internet of things. Data mining for the Internet of Things. Blockchain design for the Internet of Things. Approaches of Big data analytics for IoT. Security issues and solutions in IoT. Applications of the Internet of Things. IoT for assisted living. Case studies of IoT. Internet of Medical Things. Introduction to the Digital Twins.

Text Books/References:

1. Building blocks for IoT analytics internet-of-things analytics, Soldatos, John Editor, River publishers, 2017.
2. Internet of Things for Architects: Architecting IoT solutions by implementing, Perry Lea, Packt Publishing Limited, 2018.
3. Internet of Things, Raj Kamal, McGraw Hill Education, 2017.
4. Ad hoc Wireless Networks: Architectures and Protocols, C. Siva Ram Murthy and B. S. Manoj, Prentice Hall PTR, New Jersey, May 2004.
5. Internet of Things, B. S. Manoj, bsmp, Trivandrum, 2022.
6. Relevant research publications.

AVP613	Control of AC Motor Drives	(3 0 0)	3 Credits

DC-AC Converters for control of AC Drives: Voltage Source Inverters, square wave operation, harmonic analysis, pulse width modulation (PWM) techniques, Space Vector PWM, Multilevel Inverters, Current Source Inverters.

Induction Motor Drives: Modelling of Induction Motors, Reference frame theory, speed-torque characteristics, Scalar control of Induction Motors, closed-loop operation, Vector control and field orientation, sensor- less control, flux observers, Direct torque and flux control.

Control of Synchronous Motors, Permanent Magnet Synchronous Motors, Vector control of Synchronous motor.

Applications: Electric vehicles, Drives for space systems.

Text Books/References:

1. Analysis of Electric Machinery and Drive System, Paul C Krause, Oleg Wasynczuk, Scott D

Sudhoff, Wiley Inter-science.
2. Control of Electrical Drives, Leonhard W., Springer-Verlag, 1985.
3. Power Electronics: Converters, Application and Design, Mohan, Undeland and Robbins, John Wiley and Sons, 1989.
4. Electric Motor drives: Modelling, Analysis and Control, Krishnan. R., Prentice Hall, March 2001.
5. Power Electronics and AC Drives, B. K. Bose, Prentice Hall.
6. High Power Converters and AC Drives, Bin Wu, IEEE Press.

AVP865 Power System Dynamics and Control (3 0 0) 3 Credits

Basic Concepts of dynamical systems and stability. Modelling of power system components for stability studies: generators, transmission lines, excitation and prime mover controllers, flexible AC transmission (FACTS) controllers.; Analysis of single machine and multi-machine systems. Small signal angle instability (low frequency oscillations): damping and synchronizing torque analysis, eigenvalue analysis.; Mitigation using power system stabilizers and supplementary modulation control of FACTS devices. Small signal angle instability (sub-synchronous frequency oscillations): analysis and counter-measures. Transient Instability: Analysis using digital simulation and energy function method. Transient stability controllers. Introduction to voltage Instability. Analysis of voltage Instability.

Text Books/References:

1. Power System Stability and Control, P. Kundur, McGraw Hill Inc, New York, 1995.
2. Power System Dynamics & Stability, P. Sauer & M. A. Pai, Prentice Hall, 1997.
3. Power System Dynamics, Stability & Control, K. R. Padiyar, Interline Publishers, Bangalore, 1996.

AVP867 Electronics System Design (3 0 0) 3 Credits

Module 1: Role of Interface Electronics, Analog Electronic Blocks, OPAMP – internal structure, Open-loop gain, Input R, Output R, DC noise sources and their drifts, CMRR, PSRR, Bandwidth and stability, Slew rate, Noise – general introduction, OPAMP Circuits and Analysis - Difference and Instrumentation Amplifiers (3-opamp and 2-opamp), Effect of cable capacitance and wire-resistance on CMRR, IA with guards, Biomedical application, Current-mode IA (Howland), Current-input IA, filters, Filters with underdamped response, state-variable filters, All-pass filters, Current Sources (floating and grounded loads), PGA, V-to-f converters, Negative Resistance Generator, Gyrator, GIC and applications, Quadrature oscillator, Introduction to switched capacitor circuits and applications, OTA and applications.
Module 2: Frequency and Time Measurement, Sample Hold Circuits, ADCs and their properties, Different ADC Architectures – Single Slope, Dual Slope (with emphasis on DMM), SAR, Flash, Sigma-Delta. Voltage references and regulators,
Module 3: Basic electronic design concepts - potential divider, component packages, burden/loading effects, Error budgeting – Zener drift, resistance drift, voltage offsets and bias current errors, Transistor as amplifier –

Basic circuit, loading effects; transistor as a switch – Darlington pairs, drivers, high-side drives, transistor latch.
Module 4: Analog controllers – temperature controller, error amplifier, integral controller, PI controller, PID controller, system TC Vs sensing TC.
Module 5: Transistor (linear) voltage regulator – over current protection, fold-back protection, voltage regulator with bypass, heat-sink design, regulator design with LDOs, current sources – high side loads, grounded loads with reference wrt. Ground, current sources with 3 pin regulator ICs, 4-20mA current transmitters, loop powered circuits.
Module 6: Special topics: PLL, isolation amplifiers, gate drivers, oscilloscope probes (gain selection circuits), techniques for power management.

Text Books/References:

1. Sensors and Signal Conditioning, Ramón Pallás-Areny, John G. Webster, 2nd Edition, Wiley, 2003.
2. Design with Operational Amplifiers and Analog Integrated Circuits, Sergio Franco, 3rd Edition, McGraw hill, 2002.
3. Analog Signal Processing, Ramón Pallás-Areny, John G. Webster, 1st Edition, Wiley, 2011.
4. Operational Amplifiers, George Clayton, Steve Winder, 5th Edition, Elsevier Newnes, 2003.
5. Opamps and Linear Integrated Circuits, Ramakant A. Gayakwad, PHI India, 4th Edition
6. Capacitive Sensors – Design and Applications, L. K. Baxter, IEEE Press Series on Electronic Technology, NJ, 1997.
7. Principle of Measurement Systems, John P. Bentley, Pearson Education; 3rd Edition, 2006.
8. The art of electronics, Horowitz, P., & Hill, W. 3rd ed. Cambridge University Press, 2015.

MA611	**Optimization Techniques**	**(3 0 0)**	**3 Credits**

Optimization: Need for unconstrained methods in solving constrained problems, necessary conditions of unconstrained optimization, structure methods, quadratic models, methods of line search, steepest descent method; quasi-Newton methods: DFP, BFGS, conjugate-direction methods: methods for sums of squares and nonlinear equations; linear programming: sim- plex methods, duality in linear programming, transportation problem; nonlinear programming:

Text Books/References:

1. An Introduction to Optimization, Chong, E. K. and Zak, S. H., 2nd Ed., Wiley India, 2001.
2. Linear and Nonlinear Programming, Luenberger, D. G. and Ye, Y., 3rd Ed., Springer 2008.
3. Mathematical Programming Techniques, Kambo, N. S., East-West Press ,1997.

MA613 Data Mining (3 0 0) 3 Credits

Introduction to data mining concepts; linear methods for regression; classification methods: k- nearest neighbor classifiers, decision tree, logistic regression, naive Bayes, Gaussian discriminant analysis; model evaluation & selection; unsupervised learning: association rules; apriority algorithm, FP tree, cluster analysis, self-organizing maps, google page ranking; dimensionality reduction methods: supervised feature selection, principal component analysis; ensemble learning: bagging, boosting, Ada Boost; outlier mining; imbalance problem; multi class classification; evolutionary computation; introduction to semi supervised learning, transfer learning, active learning, data warehousing.

Text Books / References

1. Pattern Recognition and Machine Learning, Bishop, C. M., Springer, 2006.
2. The Elements of Statistical Learning: Data Mining, Inference, and Prediction, Hastie, T., Tibshirani, R., and Friedman, J., Springer, 2002.
3. Data Mining: Concepts and Techniques, Han, J., Kamber, M., and Pei, J., 3rd ed., Morgan Kaufmann, 2012.
4. Machine Learning, Mitchell, T. M., McGraw-Hill,1997.

MA624 Advanced Machine Learning (3 0 0) 3 Credits

Kernel Methods: Reproducing kernel Hilbert space concepts, kernel algorithms, multiple kernels, graph kernels; multitasking, deep learning architectures; spectral clustering; model based clustering, independent component analysis; sequential data: Hidden Markov models; factor analysis; graphical models; reinforcement learning; Gaussian processes; motif discovery; graph based semi supervised learning; natural language processing algorithms.

Text Books / References

1. Pattern Recognition and Machine Learning, Bishop, C. M., Springer, 2006.
2. The Elements of Statistical Learning: Data Mining, Inference, and Prediction, Hastie, T., Tibshirani, R., and Friedman, J., Springer, 2002.
3. An Introduction to Support Vector Machines and other kernel- based methods, Cristianini, N. and Shawe-Taylor, J., Cambridge Univ. Press, 2000.
4. Learning with Kernels: Support Vector Machines, Regularization, Optimization, and Beyond, Scholkopf, B. and Smola, A. J., The MIT Press, 2001.
5. Reinforcement Learning: An Introduction, Sutton R. S. and Barto, A. G., The MIT Press ,2017.
6. Deep Learning, Goodfellow, I., Bengio, Y., and Courville, A., The MIT Press, 2016.
7. Probabilistic Graphical Models: Principles and Techniques, Koller D. and Friedman, N., The MIT Press, 2009.

AE820 Multidisciplinary Design Optimization (3 0 0) 3 Credits

Multidisciplinary Design Optimization (MDO): Need and importance – Coupled systems – Analyser vs. evaluator – Single vs. bi-level optimisation – Nested vs. simultaneous analysis/design– MDO architectures – Concurrent subspace, collaborative optimisation and BLISS – Sensitivity analysis – AD (forward and reverse mode) – Complex variable and hyperdual numbers – Gradient and Hessian – Uncertainty quantification – Moment methods – PDF and CDF – Uncertainty propagation – Monte Carlo methods – Surrogate modelling – Design of experiments – Robust, reliability based and multi-point optimization formulations

Text Books / References

1. Computational Approaches for Aerospace Design: Keane, A. J. and Nair, P. B., The Pursuit of Excellence, Wiley ,2005.
2. Response Surfaces: Design and Analyses, Khuri, A. I. and Cornell, J. A., 2nd ed., Marcel Dekker ,1996.
3. Design and Analysis of Experiments, Montgomery, D. C.,8th ed., John Wiley, 2012
4. Evaluating Derivatives: Principles and Techniques of Algorithmic Differentiation, Griewank, A. and Walther, A., 2nd ed., SIAM, 2008.
5. A Engineering Design via Surrogate Modelling: A Practical Guide, Forrester, A., Sobester, A., and Keane, Wiley, 2008.