Master of Technology in
Automation and Robotics

***Brief Description*:** M.Tech. in Automation and Robotics is an interdisciplinary Masters Programme offered by School of Robotics, DIAT, which is open for students of various branches of Engineering such as Mechanical Engineering, Electrical / Electronics /Tele Communication Engineering, Computer science / Information Technology Engineering, Industrial Engineering and Instrumentation Engineering. The course aims to uplift the students on knowledge, technology and applied methodologies in the field of Automation and Robotics for Industrial, medical, domestic as well as Defence sector applications.

The program is designed for eligible candidates interested in designing, developing and controlling smart/ advanced systems in the field of Robotics and Automation.

Vision:-

To be a globally recognized center of excellence in Automation and Robotics education, renowned for innovative robotic product development, advanced industrial system training, and impactful research.

Mission:-

To empower students to excel in the fields of Automation and Robotics.

Program Objectives:-

PO1- Deliver comprehensive and up-to-date curricula that cover fundamental and advanced topics in automation and robotics, supported by state-of-the-art laboratory facilities.

PO2- Promote a robust research culture that encourages the development of innovative solutions and technologies in automation and robotics, addressing real-world industrial challenges.

PO3- Equip students with the skills and knowledge to contribute meaningfully to the global automation and robotics community, driving innovation and progress in industrial technologies.

PO4- To facilitate students with hands on experience on problem solving for modern trends in real life applications.

Program Educational Outcomes-

At the end of this course student may be able to-

PEO1- Get in-depth knowledge about Robotics and Automation related technologies, systems design and product development through exposure to course work from multiple disciplines.

PEO2-Demonstrate the ability to analyze, design, and implement industrial automation systems using programmable logic controllers (PLCs), SCADA, DCS, and other relevant technologies, optimizing for efficiency and reliability in industry 4.0

PEO3- Apply fundamental and advanced principles of robotics and deploy robotic systems for a variety of industrial and societal applications.

PEO4- Conduct research and solve problems related to Automation and Robotics in the real world scenario.

Eligibility:

1. This programme is open under sponsorship category, for officers of Indian Armed forces (Army, Navy & Air force), Coast Guard, DRDO Scientists, Indian Ordnance Factories, various Defence PSU's (HAL, BEL, BDL, etc.) This programme is also open to foreign nationals from the countries approved by GOI and self sponsored eligible candidates.

2. This programme is open under scholarship category for civilian students of any relevant graduation discipline with qualified GATE score in Mechanical Engg., Computer Science and Information Technology, Electronics and Communication Engg., Electrical Engg., Aerospace Engg., Instrumentation Engg., Production and Industrial Engg., Bio-medical Engg, or relevant discipline to Automation and Robotics

Organization: M. Tech in Automation and Robotics is a four-semester master’s programme. There are six compulsory courses in the first semester and two compulsory and Four elective subjects in the second semester. In each semester, three internal assessment exams as a part of continuous evaluation and an end semester examination will be conducted for each course. M. Tech dissertation first phase evaluation will be conducted at the end of third semester and at the end of the final semester, students submit their thesis and present their project work, which is evaluated by the Internal and External examiners.

M. Tech Automation and Robotics

Semester I

S. No.	Course Code	Course	Contact Hours/week		Credits
			L	T/P	
1	SR 601	Industrial Automation and Industry 4.0	3	1	4
2	SR 602	Introduction to Robotics	3	1	4
3	SR603	Sensors, Actuators and Drives	3	1	4
4	SR 610	Introduction to Automatic Control system	3	1	4
5	SR 605# Or SR 606##	Introduction to Mechanisms (SR 605) Or Introduction to Electronics Systems (SR 606)	3	1	4
6	AM 607	Mathematics for Engineers	3	1	4
7	PGC 601	PGC Course	2	-	2
		Total	**20**	**06**	**26**

Note: #SR 605 for (Non – Mechanical students) & ##SR 606 for (Non- Electronics students) compulsory subject.

Semester II

S. No.	Course Code	Course	Contact hours/week		Credits
			L	T/P	
1	SR 607	Robot Dynamics and control	3	1	4
2	SR 613	AI and ML for Robotics	3	1	4
3		Departmental Elective-1	3	1	4
4		Departmental Elective-2	3	1	4
5		Elective-1	3	1	4
6		Elective-2	3	1	4
7	PGC 602	PGC Course	2	-	2
		Total	**20**	**06**	**26**

Semester- III

S. No.	Course Code	Course	Credits		Total Credits
			L	T/P	
1	SR 651	M.Tech. Dissertation Phase I	28**		14
		Total	**28**		**14**

Semester-IV

S. No.	Course Code	Course	Credits		Total Credits
			L	T/P	
1	SR 652	M.Tech. Dissertation Phase II	28**		14
		Total	**28**		**14**

****Contact Hours / week:-**

- 1 credit in Theory/Tutorial implies one contact hour and 1 credit in Practice/ Thesis implies two contact hours.

List of Elective subjects

Sl. No.	Course Code	Course Name
1	SR 604	Programming languages for Robots
2	SR 608	Machine vision & Image Processing for Robots
3	SR 611	Advanced control system
4	SR 612	Design aspects of Automation
5	SR 614	Swarm robotics
6	SR 615	Introduction to Humanoid Robotics
7	SR 616	Field and service Robots
8	SR 617	Aerial Robotics
9	SR 618	Robotic Path planning and control
10	--	Open elective from other department

Detailed Contents

Semester-I

Course Name-Industrial Automation and Industry 4.0

Course Code-SR 601

Course Code	Course Name	L – T – P	**Credits**
SR 601	**Industrial Automation and Industry 4.0**	3-1-0	**4**

Course Objectives:

- To impart knowledge about industrial automation PLC, SCADA, HMI and DCS system.
- To introduce the fundamental concepts in latest industrial advancements of Industry 4.0.
- Learn about product lifecycle management and various automated material handling systems and identification methods.
- To enable the students to understand and implement concepts of industry 4.0 in traditional industrial plants.

Unit I: Introduction: Automation overview, Requirement of automation systems, Architecture of Industrial Automation system. Introduction to Networking, Sensing & actuation & communication protocols- Profibus, Field bus, HART protocols, LEAN Production Systems.

Unit II: Product Lifecycle Management. Overview of material handling systems, Types of material handling equipment, Conveyor system, Automated guided vehicle system, Automated storage and retrieval systems, Overview of Automatic Identification Methods.

Unit III. Programmable logic controllers, Analog digital input and output modules, PLC programming, Ladder diagram, Sequential flow chart, PLC selection, PLC Installation, Advantage of using PLC for Industrial automation, Application of PLC to process control industries.

Unit IV: SCADA Supervisory control and data acquisition system, segments and functions of SCADA, software and hardware working, HMI-Human Machine Interface , HMI design and programming for complex technological machines, high performance HMI for I 4.0

Unit V: Distributed Control System: Overview of DCS, , DCS communication, , DCS integration with PLC and Computers, Features of DCS, Advantages of DCS, Industrial Internet Systems. Industrial IoT Layers: Sensing, Processing, Communication. Communication, Networking

Unit VI: Role of computers in measurement and control, Cyber security in Industry 4.0, Big Data Analytics and Software Defined Networks. Machine Learning and Data Science

Course Outcomes

After completing this course, the students will be able to:
CO1: Understand various software and hardware infrastructure of industrial automation and their applications in the real world.
CO2: Learn the stages of product lifecycle management and understand process operation flow.
CO3: Design the automation line for industrial process using PLC to convert traditional manufacturing system into automation industry.
CO4: Apply various techniques of computer based control to upgrade industrial automation system to industry 4.0 standard.

Text Books

1. M.P.Groover, “Automation, Production Systems and Computer Integrated Manufacturing”, 5th Edition, Pearson Education, 2009.
2. John W. Webb and Ronald A. Reis, “Programmable Logic Controllers: Principles and Applications”, 5th Edition, Prentice Hall Inc., New Jersey, 2003.
3. Krishna Kant, “Computer - Based Industrial Control”, 2nd Edition, Prentice Hall, New Delhi, 2011.
4. Alasdair Gilchrist ,“Industry 4.0: The Industrial Internet of Things”, by Apress Berkeley, CA

Reference Books

1. Curtis D. Johnson, “Process Control Instrumentation Technology”, 8th Edition, Pearson New International, 2013.
2. Lukas M.P, “ Distributed Control Systems”, Van Nostrand Reinhold Co., New York, 1986.
3. N. Viswanandham, Y. Narahari, “Performance Modeling of Automated Manufacturing Systems”, 1st Edition, 2009.

4. Stuart A. Boyer, "Introduction to SCADA Systems", ISA; 4th edition, October 2009.
5. A.K. Gupta and S.K. Arora ,"Industrial Automation and Robotics: An Introduction", Mercury Learning & Information; Har/Cdr edition, February 2013.
6. Frank D. Petruzella, “Programmable Logic Controllers”, 5th Edition, McGraw- Hill, New York, 2016.
7. Sabina Jeschke, Christian Brecher, Houbing Song, Danda B. Rawat, “Industrial Internet of Things: Cyber manufacturing Systems” by Springer.

Course Name- Introduction to Robotics

Course Code-SR 602

Course Code	Course Name	L – T – P	**Credits**
SR 602	**Introduction to Robotics**	3-1-0	**4**

Course Objectives:

- Understand various types and components of robots and their applications.
- Learn about robot work cells, kinematic systems, and spatial descriptions using transformations and matrices.
- Explore various types of robot end effectors and grippers, their mechanisms, and design considerations.
- Study inverse kinematics, robot dynamics, and the relationship between velocity, acceleration, and force in robots.
- Understand trajectory planning, motion profiles, and path generation for robotic mechanisms.

Unit I: Robot classification, Types and components of Robot Anatomy, Robot terminology- Links, joints, DOF, Specification of a robot ,work volume, work space, work object , Robot geometrical configuration (PPP, RPP, RRP, RRR, etc) & Selection of Robots, Control Resolution & Spatial Resolution, Applications in industry.

Unit II : Robot work cell, Kinematic systems, spatial descriptions: Position, orientation and frames, Coordinate frames, Mapping between frames (D-H method and DH free notations), translations, rotations and transformations matrices and Homogeneous Transformation Matrix, serial and parallel manipulators.

Unit III : Robot end effectors-classification Grippers, Types of Grippers-Mechanical, finger grippers, Magnetic-vacuum/suction, Hooks, scoops and other devices, selection of grippers, gripping mechanisms, Gripper force analysis and design of Drive system for gripper, tools Characteristics and elements of End-of-Arm-Tooling.

Unit IV: Inverse Kinematics of Serial and parallel manipulators-geometric method, Analytical method, velocity, velocity propagation, Jacobian, acceleration, Jacobian-force relationship, Robot Dynamics, Inertia properties.

Unit V:. Trajectory Planning Definition, Introduction to Trajectory planning, General consideration in path description and Generation of motion. Point to point: Straight line path, Trapezoidal motion profile and S curve motion. Polynomial via point Trajectories. Application: Two axis planar mechanism Trajectory planning.

Unit VI: Robot capabilities and applications- wheeled, tracked, legged, aerial, underwater robots, surgical robots, rehabilitation robots, humanoid robots, Nano Robots, Robotic Accidents and safety, Robot maintenance, Introduction to Robot Programming, on-line and off-line Programming, Robot Programming Languages.

Course Outcomes

After completing this course, the students will be able to:
CO1: Classify different types of robots and explain their components and specifications.
CO2: Describe kinematic systems and apply transformation matrices in robotic systems..
CO3: Identify and design appropriate end effectors and grippers for specific applications
CO4: Solve inverse kinematics problems and analyze the dynamics of serial and parallel manipulators.
CO5: Plan and implement trajectory paths for robots using various motion profiles and programming techniques

Text Books

1. S.R. Deb, *Robotics Technology and flexible automation*, Tata Mc Graw Hill publishing company Ltd.
2. John J Craig, *Introduction to Robotics-Mechanics and control*, Pearson publication,2008
3. S K Saha, *Introduction to Robotics*, McGraw Hill Education(India) Private Ltd, 2014.
4. R K Mittal, I J Nagrath, *Robotics and Control*, McGraw Hill Education(India) Private Ltd, 2003.

Reference Books

1. Francis N. Nagy, Andras Siegler, *Engineering foundation of Robotics*, Prentice Hall Inc., 1980.
2. M.P. Groover, Mitchel Weiss, *"Industrial Robotics: Technology, Programming and Applications"(2e),* McGraw Hill , 2012
3. Richard D. Klafter, Thomas. A, ChriElewski, Michael Negin, "*Robotics Engineering an Integrated Approach"*, Prentice Hall of India Pvt. Ltd., 1989
4. Carl D. Crane and Joseph Duffy, "*Kinematic Analysis of Robot manipulation"*, Cambridge University press, 1998.
5. Yoram Koren, "*Robotics",* McGraw Hill, 1992.
6. K. C. Jain and Agarwal L. N. *"Robotics Principles and Practice",* Khanna Publishers, 1997.

7. Yu Kozihev, *"Industrial Robots Handbook"*, MIR Publications, 1997.
8. D K Pratihar, Fundamentals of Robotics, Narosa Book publisher, 2017

Course Name- Sensors, Actuators and Drives

Course Code- SR 603

Course Code	Course Name	L – T – P	**Credits**
SR 603	**Sensors, Actuators and Drives**	3-0-1	**4**

Course Objectives:

- Understand the principles, classification, and operation of various sensors and their applications.
- Learn about sensors used in robotics, including proximity, ultrasonic, magnetic, and other advanced sensing technologies.
- Explore the principles and types of actuators, including hydraulic, pneumatic, and electric actuators, and their applications in industry.
- Study the working principles, characteristics, and control methods of AC machines like induction motors and synchronous motors.
- Understand the principles, construction, and applications of special machines and electric drives, including their control and operational methods.

Unit I: Introduction to sensors & transducers - common conversion methods, Principle of operation of sensors, static characteristics, selection criteria of sensor, Encoders and its types, potentiometers, LVDT, velocity sensors Hall effect sensor signals conditioning, calibration and testing of sensor. Principle of operation of industrial sensors.

Unit II: Sensors for Robots- Proximity sensors, Ultrasonic, magnetic, light sensors, speed measurement, GPS, LIDAR, IMU motion sensor, radar, gyroscope, FT sensor, Force sensor, shape memory alloy materials, smart sensing, applications.

Unit III: Principle of operation of actuators-Hydraulic, Pneumatic, electric, other-fundamental laws, classification, Electrical actuators: working and types of DC motor, back emf, significance and applications, Speed-torque characteristics of DC motors, control methods for industrial applications.

Unit VI: AC Machines: Working principle of Induction motors, types of 1phase and 3 phase Induction Motor, slip, speed-torque characteristics, speed control calculations for industrial applications, Working principle of synchronous motors, types, concept of RMF, Speed control methods and applications.

Unit V: Special machines: Working principle, construction, speed-torque characteristics, applications, merits and demerits- Servo motors, Switched reluctance motors, BLDC motors, Stepper motor.

Unit VI: Components of electric drives, factors affecting choice of drives, fundamental torque equation, speed-torque conventions, steady state stability, multi-quadrant operation of electric drives, load torque components, load equalization, determination of motor power rating, motor duty cycles, electric braking, modes of operation, closed loop control, DC motor control, speed control, position control.
Course Outcomes
After completing this course, the students will be able to: **CO1:** Classify and explain the operation and characteristics of various sensors and transducers used in industrial applications. **CO2:** Describe and select appropriate sensors for robotic applications. **CO3:** Explain the principles and operation of different types of actuators, including hydraulic, pneumatic, and electric, and their industrial uses. **CO4:** Analyze the working principles and control methods of AC machines, including induction motors and synchronous motors, for industrial applications. **CO5:** Understand the construction, operation, and control methods of special machines and electric drives, and evaluate their applications and performance in various industrial settings.
Text Books
1. Gopal K. Dubbey, *"Fundamentals of Electric Drives", (2e)*, Narosa Publishers, 2001. 2. M. H. Rashid, "Power electronics, circuits, devices and applications",Pearson publishers,2014. 3. J. B. Gupta, "Theory & performance of Electric Machines", S K Kataria & Sons,2013.
Reference Books
1. A.K.Sawhney ,"*A course in Electrical and Electronic measurements and instrumentation*" Dhanpat Rai & Co.Publication. 2. W. Shepherd, and L. N. Hully, *"Power Electronics and Motor control", (2e)*, Cambridge University, 1995. 3. R. Krishnan, *"Electric Motor Drives Modeling, Analysis, and Control", (2e)*, Prentice Hall, 2001

Course Name-Introduction to Automatic control system-

Course Code- SR 610

Course Code	Course Name	L – T – P	**Credits**
SR 610	***Automatic control system***	3-1-0	**4**
Course Objectives: • Understand automatic control systems: types, performance specs, design process, block diagrams, Laplace transform, transient analysis, closed-loop/open-loop systems. • Model mechanical, electrical, hydraulic systems with block diagrams, analyze motor transfer functions, use block diagram reduction techniques, signal flow graphs. • Analyze time response: standard test signals, transient response for first/second-order systems, time domain specs, stability, steady-state error with Routh-Hurwitz criterion. • Study frequency response: domain specs, polar plots, Nyquist criteria, stability analysis with Nyquist plots, gain margin, phase margin, root locus technique for stability.			

- Explore control actions: discrete, proportional, integral, differential control actions, characteristics, limitations of comparators, actuators, amplifiers, servo motors, control valves.
- Implement control systems: pneumatic, hydraulic, electrical, microprocessor-based systems, PLCs, microcontrollers, network-based distributed control systems.

Unit I: Automatic Control System: definition and types, performance specifications, Design process, Block diagrams, Laplace transform and transient analysis, closed and open loop systems. Feedback and Feed forward control system, MIMO systems, state space analysis.

Unit II: Modeling of systems Mechanical, Electrical, hydraulic system block diagram representations, Transfer functions of motors. Block diagram reduction techniques, signal flow graphs.

Unit III: Time response analysis, Standard test signals, Static and Dynamic Characteristics of Control Systems- Transient Response for First and second order systems. Time domain specifications, Stability and Steady State Error, Routh Hurvitz criterion.

Unit III: Frequency response analysis, Frequency domain specifications, Polar Plots, Nyquist Criteria systems, stability analysis using Nyquest plots, Gain margin, Phase margin. Experimental determination of transfer function. Stability Analysis. Root Locus Technique

Unit IV: Control Actions and Control System Components- Discrete action, Proportional, Integral and Differential Control Action, Composite action. Characteristics, working and limitations of different types of Comparators and actuators, amplifiers, Servo motors and Control valves.

Unit V: Control System Implementations- Pneumatic Systems, Hydraulic Systems, Electrical Systems, Microprocessor Based Systems, Programmable Logic Controllers, Micro Controllers and Network Based Distributed Control Systems.

Unit VI: Case Studies.

Course Outcomes

After completing this course, the students will be able to:

- **CO1:** Define and categorize automatic control systems, analyze performance specifications, and design systems using block diagrams.
- **CO2:** Model mechanical, electrical, and hydraulic systems with block diagrams, derive transfer functions of motors, and perform block diagram reduction techniques.
- **CO3:** Analyze time response characteristics, including transient response and time domain specifications, and evaluate stability using Routh-Hurwitz criterion.
- **CO4:** Conduct frequency response analysis, including polar plots and Nyquist criteria, assess stability using gain margin, phase margin, and Nyquist plots, and determine transfer function experimentally.
- **CO5:** Implement control actions such as discrete, proportional, integral, and differential control, understand the characteristics and limitations of comparators, actuators, amplifiers, servo motors, and control valves.

Text /Reference Books
1. Nise, N.S., Control Systems Engineering, 5th Ed., Willey, 2008. 2. Ogata, K., " Modern Control Engineering", 5th Ed., Prentice Hall of India, 2013. 3. Kuo, B.C., "Automatic Control System", 5th Ed., Prentice Hall of India, 1995. 4. Raven, F.H., "Automatic Control Theory", 5th Ed., McGraw Hill, 1995
Reference Books
1. Rafael C. Gonzalez, Richard E. Woods, *Digital Image Processing, (2/e)*, Pearson education, 2003. 2. Boguslaw Cyganek& J. Paul Siebert, *An Introduction to 3D Computer Vision Techniques and Algorithms*, Wiley, 2009.

Course Name- Introduction to Mechanisms (Non Mechanical)

Course Code- SR 605

Course Code	Course Name	L – T – P	**Credits**
SR 605	***Introduction to Mechanisms (Non Mechanical)***	3-1-0	**4**

Course Objectives:

- Understand the basics of mechanics and apply to simple machines such as inclined planes, screw jacks, gears, belts, pulleys to analyze them.
- Understand the basic of kinematics for constrained rigid bodies and apply to planar and spatial mechanisms.
- Apply kinematics analysis to planar mechanisms.
- Understand planar linkages, gear drives, and basic mechanisms such as straight-line mechanisms and ratchet mechanisms.

Unit I Physical Principles: Force and Torque, Motion, Newton's Law of Motion, Momentum and Conservation of Momentum, Work, Power and Energy, material properties and selection, torque calculations and gearbox transmission mathematics for application.

Unit II Simple Machines: The Inclined Plane, Screw Jack, Gears, Belts and Pulleys, Lever, Wedge, Efficiency of Machines .

Unit III Machines and Mechanisms: Planar and Spatial Mechanisms, Kinematics and Dynamics of Mechanisms, Links, Frames and Kinematic Chains, Skeleton Outline, Pairs, Higher Pairs, Lower Pairs and Linkages, Kinematic Analysis and Synthesis.

Unit IV Kinematics: Basic Kinematics of Constrained Rigid Bodies, Degrees of Freedom of a Rigid Body, Kinematic Constraints, Constrained Rigid Bodies, Degrees of Freedom of Planar Mechanisms

Unit V Planar Linkages: Introduction, Four Link Mechanisms, Cams, Gears: Gear Classification, Gear-Tooth Action, Involute Curve, Terminology for Spur Gears, Condition for Correct Meshing, Ordinary Gear Trains, Planetary gear trains.

Unit VI Basic Mechanisms: Straight line mechanisms, Ratchet Mechanism, Overrunning Clutch, Intermittent Gearing, Geneva Wheel mechanism, Universal Joint.

Unit V: Motion estimation and tracking: Optical flow estimation, the concept of sensor fusion - Kalman filter, Localization and Mapping techniques, object tracking with Kalman filtering, feature extraction & object recognition **Unit VI:** Case studies/application: Industrial application of vision controlled Robotics systems, industrial robot guidance, demonstration of applications using computer vision toolbox and image processing toolbox.
Course Outcomes
After completing this course, the students will be able to: • **CO1:** Apply physical principles of force, torque, and motion to solve problems involving energy, material properties, and torque calculations. • **CO2:** Describe and analyze the operation and efficiency of simple machines, including inclined planes, gears, and pulleys. • **CO3:** Understand and perform kinematic analysis of mechanisms, including kinematic chains and linkages. • **CO4:** Analyze the degrees of freedom and kinematic constraints of constrained rigid bodies and planar mechanisms. • **CO5:** Design and analyze planar linkages, gear trains, and various basic mechanisms, understanding their applications and functionality.
Text Books
1. Irving H. Shames& GK Mohana Rao, *Engineering Mechanics: Statics and Dynamics*, PEARSON Education, 2006 2. Shingley.J.E. *Theory of Machines and Mechanisms*, 2nd Edition, McGraw Hills Inc, 1995. 3. J.E. Shigley, *Mechanical Engineering Design*, McGraw Hill International,2001.
Reference Books
1. P. Beer& Johnson, *Vector Mechanics for Engineers: Statics and Dynamics*, Tata McGraw Hill, New Delhi,2001. 2. Thomas Bevan, *Theory of machines*

Course Name- Introduction to Electronics Systems (Non Electronics)

Course Code- SR606

Course Code	Course Name	L – T – P	**Credits**
SR 606	***Introduction to Electronics Systems (Non Electronics)***	3-1-0	**4**
Course Objectives: • Understand the operation and characteristics of various semiconductor devices and rectifier circuits, and their application in regulated power supplies. • Learn about different types of amplifiers, operational amplifiers, and oscillators, and their applications in electronic circuits. • Explore the basics of computing, including number systems, logic gates, combinational and sequential circuit design, and programmable logic devices. • Understand the principles and applications of various measurement instruments, sensors, and data converters.			

- Study various electronic systems, including analog and digital communication systems, embedded systems, and electric drives.

Unit-I: REVIEW SEMICONDUCTOR DEVICES

Two terminal devices, three terminal devices: BJT, JFET, MOSFET, four terminal devices: SCR, DIAC, TRIAC, photo devices: photo diode, LED, LCD. Half wave and full wave rectifiers, filter circuits, regulated power supplies: introduction, characteristics, stabilization.

Unit-II: AMPLIFIERS AND OSCILLATORS

Transistor as an amplifier, single stage amplifier, multistage amplifier, Class A, B, and C amplifiers. Introduction to operational amplifier, specification and characteristics, application: constant gain, voltage summing, voltage buffer, instrumentation circuits, active filters. Oscillators.

Unit-III: INTRODUCTION TO COMPUTING

Number system and code conversion, logic gates, Boolean algebra, combinational circuit design, sequential circuit, flip flops, counters, shift registers, decoder, encoder, MUX, DEMUX, memories, I/O, programmable logic devices, microprocessors and microcontrollers.

Unit-IV: MEASUREMENTS AND INSTRUMENTS

Introduction, Analog to Digital converters and Digital to Analog converters, digital multimeter, frequency counters. Electronic circuits for sensors: temperature sensor, force and pressure sensor, magnetic field sensor, optical sensor, microwave sensor, acoustic sensor, and image sensor, etc.

Unit-V: COMMUNICATION AND SIGNAL PROCESSING

Analog communication system, digital communication system, wireless communication system, embedded system, real time system, VLSI, RF, Signal processing, signal conditioning.

Unit-VI: ELECTRIC DRIVES

Electric power converters: Rectifiers, choppers, inverters, cycloconverters, Power flow control switching, power electronic devices, SCR, V- I, turn on, turn off characteristics, Switching devices triggering methods, PWM methods. Power converters static Kramer drive, static Scherbius drive, stepper motor drives, BLDC drivers, PMAC drivers, switched reluctance motors drives.

Course Outcomes

After completing this course, the students will be able to:

- **CO1:** Explain the principles, operation, and characteristics of semiconductor devices, rectifier circuits, and regulated power supplies.
- **CO2:** Analyze and design different types of amplifiers, operational amplifiers, and oscillators for various applications.
- **CO3:** Understand and design basic computing circuits, including logic gates, flip-flops, counters, and memory devices.
- **CO4:** Utilize measurement instruments and sensors, and understand the conversion processes between analog and digital signals.
- **CO5:** Describe and analyze various electronic systems, including communication systems, embedded systems, and electric drives.

Text Books

1. Thomas L. Floyd, Electronic Devices, Pearson Education, 9th Edition, 2012.
2. Gopal K. Dubbey*, "Fundamentals of Electric Drives", (2e)*, Narosa Publishers, 2001

Reference Books

1. Thomas L. Floyd, Digital Fundamentals, Pearson Education, 11th Edition, 2015.
2. Jacob Fraden, Handbook of Modern Sensors, Springer, 4th Edition, 2010.
3. Robert L Boylestad, Electronic Devices & Circuit Theory, Pearson Education, 11th Edition, 2013.

Course Name-Mathematics for Engineer

Course Code-AM 607

Course Code	Course Name	L – T – P	**Credits**
AM 607	**Machine vision and Image processing**	4-0-0	**4**

Unit-I Elements of Probability and Statistics: Basic concepts of Probability, Discrete Probability Distributions (Binomial, Poisson etc.), Continuous Probability Distributions (Normal, Exponential, etc.,).

Unit-II Components of Operations Research:

Introduction to Operations Research, Linear programming (Simplex Method, Revised Simplex Method, Dual simplex, Duality theory), Transportation Models.

Unit-III Linear Algebra:

General (real) vector spaces, Subspaces, Linear Independence of Vectors, Basis and Dimension, Linear Transformations, Span, Norms, Orthogonal basis and Gram-Schmidt Orthogonalization.

Unit-IV Ordinary Differential Equations :

Review of solution methods for first order as well as second order equations, Power Series methods. Higher Order Linear Equations, Boundary Value Problems for Second Order Equations.

Unit-V Transform Techniques :

Overview of Laplace transforms, Fourier Transforms, Z transform.

Unit-VI Numerical Methods for ODE and P.D.E.:

Taylor series method – Euler and Modified Euler methods – Runge-Kutta method.
Parabolic, Hyperbolic and Elliptic Equations using finite difference method

Text Books

1. Advanced Engineering Mathematics, 11th Ed, 2010, Erwin Kreyszig, Wiley Eastern.
2. Linear Algebra and its Applications, 4th Ed., 2008, Gilbert Strang, Academic Press.
3. Numerical Methods for Scientists and Engineers, Joe D. Hoffman, Marcel Dekker Inc.

Reference Books

1. Numerical Methods for Engineers, Sixth Edition, Steven Chapra and Raymond Canale, McGraw-Hill Education
2. Elements of Numerical Analysis, 2nd Edition, Radhey S. Gupta**,** Cambridge University Press
3. Numerical Solutions of Partial Differential Equations: An Introduction, 2nd Ed., 2005, K. W. Morton, D. F. Mayers, Cambridge University Press.
4. Operations Research: An Introduction, 9th Ed., 2010, Taha, H.A., Prentice Hall of India.
5. Optimization Theory and Applications, 2nd Ed., 1984, S.S. Rao, Wieley Eastern Ltd.
6. Introduction to probability and statistics for engineers and scientists, 4th Ed., 2009, Ross S M, Acdemic Press.
7. An Introduction to Probability Theory and its Application, 3rd Ed., 2012, William Feller, John Wiley India Pvt. Ltd.
8. Differential Equations and Dynamical Systems, Texts in Applied Mathematics, L. Perko, 3rd Ed., Vol. 7, 2006, Springer Verlag, New York.
9. S. Gupta. Calculus of Variation, Prentice Hall of India Pvt. Ltd.

Semester II

Course Name- Robot Dynamics and control
Course Code- SR 607

Course Code	Course Name	L – T – P	**Credits**
SR 607	***Robot Dynamics and control***	3-1-0	**4**

Course Objectives:

- Understand robot kinematics: transformations, forward/inverse kinematics, Jacobians, trajectory generation for serial/parallel mechanisms.
- Learn robot dynamics: Lagrange-Euler, Newton's equations, state-variable representations, dynamics with actuators.
- Explore robot control: regulator, tracking problems, controllers for set point tracking, actuator saturation, anti-windup compensation, optimal control.
- Study nonlinear dynamics/control: Lyapunov stability, robust control, feedback linearization, variable-structure controllers.
- Understand inverse dynamics, force control, stiffness/impedance control, hybrid position/force control, under-actuated systems.

Unit I: Review of Robot Kinematics- Transformations: Joint/Task space, Forward Kinematics, Inverse Kinematics, Jacobians, Trajectory Generation, Serial and Parallel Kinematics.

Unit II: Robot Dynamics- Lagrange-Euler Dynamics, Force, Inertia, and Energy, Lagrange's Equations of Motion, Newton's equations of motion, Formulation of robot dynamics, State-Variable Representations, Dynamics of robots with actuators.

Unit III: Robot control problems – Regulator problem, tracking problem, controllers. Set point Tracking, Actuator Saturation, Integrator Anti-windup Compensation, Quadratic Optimal control problem.

Unit IV: Nonlinear dynamics and control - Lyapunov stability theorem, Robust control, Feedback Linearization Controllers, Lyapunov Designs, Variable-Structure Controllers, Saturation-Type Controllers.

Unit V: Inverse dynamics controllers, Force control, Stiffness control, Impedance control, Hybrid Position/Force Control, Reduced state modeling and control, Impedance Control, Stiffness and Compliance, Under-actuated System.

Unit VI: Case Studies.

Course Outcomes

After completing this course, the students will be able to:

1. **CO1:** Apply kinematic transformations, solve forward/inverse kinematics, generate trajectories for serial/parallel robots.
2. **CO2:** Formulate and solve robot dynamics using Lagrange-Euler, Newton's equations, state-variable representations.
3. **CO3:** Analyze and design controllers for set point tracking, actuator saturation, anti-windup compensation.
4. **CO4:** Implement nonlinear control: Lyapunov stability, robust control, feedback linearization.
5. **CO5:** Design inverse dynamics controllers, force/stiffness control, impedance control for under-actuated systems.

Text Books

1. Francis N-Nagy Andras Siegler, Engineering foundation of Robotics, Prentice HallInc., 1987
2. John J. Craig, Introduction to Robotics Mechanics and Control, Second Edition, Addison Wesly Longman Inc. International Student edition,1999
3. M.P. Groover , Mitchel Weiss, "Industrial Robotics: Technology, Programming and Applications"(2e), McGraw Hill ,2012

Reference Books

1. Robert J. Schilling, Fundamentals of Robotics Analysis and Control, Prentice Hall of India Pvt. Ltd.,2000
2. Richard D. Klafter, Thomas. A, Chmielewski, Michael Negin, Robotics Engineering an Integrated Approach, Prentice Hall of India Pvt. Ltd.,1989.
3. M. W. Spong and M. Vidyasagar, Robot Dynamics and Control, John Wiley & Sons, NY, USA, 2004 11
4. P.A. Janaki Raman, Robotics and Image Processing an Introduction, Tata Mc Graw Hill Publishing company Ltd.,1995
5. Bernard Hodges, Industrial Robotics, Jaico Publishing house, 2nd Edition,1993.
6. Tsuneo Yohikwa, Foundations of Robotics Analysis and Control, Prentice Hall of India Pvt. Ltd.,2001.
7. Bijay K.Ghosh, NingXi,T.J.Tarn, Control in Robtics and Automation Sensor-Based integration, Academic Press,1999

Course Name: AI & Machine Learning in Robotics
Course Code: SR 613

Course Code	Course Name	L – T – P	**Credits**
SR 613	***AI & Machine Learning in Robotics***	3-1-0	**4**

Course Objectives:

- Understand knowledge-based intelligent systems, rule-based expert systems, search methods, and effectively manage uncertainty in expert systems.
- Introduce uncertainty, basic probability theory, Bayesian reasoning, and certainty factors as applied to rule-based expert systems.
- Explore foundational concepts of machine learning, its applications, and understand the structure of artificial neural networks, including activation functions.

- Study various machine learning approaches: unsupervised, supervised, semi-supervised, reinforcement learning, and their practical applications.

- Introduce deep neural networks, specifically convolutional neural networks (CNNs), including operations like convolution, pooling, flattening, and CNN architecture design.

Unit I: Introduction to AI: Knowledge-based intelligent systems, rule based expert systems-search methods-uncertainty management in rule-based expert systems, Introduction to uncertainty, basic probability theory, Bayesian reasoning, certainty factor.

Unit II: Foundation of machine learning, applications of machine learning, model of neuron in artificial neural networks, activation function, back propagation to train neural network.

Unit III: Overview of machine learning approaches: unsupervised, supervised, semi-supervised, reinforcement LEARNING, Linear regression and classification: gradient descent, support vector machine, k nearest neighbor, and other classifiers.

Unit IV: Introduction of deep neural network, convolution neural network (CNN): convolution operations, pooling, flattening, building a CNN.

Unit V: Clustering: k-mean, self-organizing maps, other clustering algorithms, nature inspired algorithms, fuzzy logic.

Unit VI: Reinforcement learning, case studies in the area of robotics.

Course Outcomes

After completing this course, the students will be able to:

- **CO1:** Implement and evaluate knowledge-based and rule-based expert systems with proficient search methods and uncertainty management techniques.
- **CO2:** Apply probability theory, Bayesian reasoning, and certainty factors to enhance rule-based expert systems and decision-making processes.
- **CO3:** Utilize foundational machine learning models and neural networks, implementing backpropagation for network training.
- **CO4:** Implement and assess various supervised and unsupervised learning algorithms such as linear regression, SVMs, and k-nearest neighbors for classification tasks.
- **CO5:** Design and optimize CNN architectures for image recognition and other complex pattern recognition tasks.

Text Books

1. Artificial Intelligence: a modern approach, Stuart Russell & Peter Norvig, Prentice Hall, 3rd Edition, 2009.
2. Artificial Intelligence, E. Rich and K. Knight, 2nd ed., McGraw-Hill, New York, 1991.

Reference Books

1. An Introduction to Neural Network, J. A. Anderson, MIT Press, 1995.
2. Self-Organizing Maps, T. Kohonen, Springer.
3. Introduction to AI Robotics, Robin R. Murphy, MIT Press, 2000.

4. Artificial intelligence: a modern approach, Stuart Russell and Peter Norvig, 2002.
5. Soft Computing :Fundamentals and applications, D K Pratihar Narosa Publishing House 2015

Elective Subjects

Course Name- Programming languages for Robots
Course Code-SR 604

Course Code	Course Name	L – T – P	**Credits**
SR 604	***Programming languages for Robots***	3-1-0	**4**

Course Objectives:

- Understand programming fundamentals: languages (machine-level, assembly, high-level), data types, variables, operators, expressions, conditional statements, and program structures.
- Explore Robot software functions: coordinate systems, position control, control functions, subroutines, online/offline programming, and lead-through methods.
- Introduce Robot Operating System (ROS): packages, launch files, key concepts (services, actions, nodes), publisher-subscriber model, debugging, and environment setup.
- Learn basics of MATLAB/Python and Introduction to Arduino: interfacing, parallel/serial/USB concepts, and basics of robot control with Arduino.
- Explore real-time applications in mobile robotics.

Unit I: Introduction to fundamentals of programming language, machine-level, assembly, high level languages, data types- declarations, constants, variables, operators and expressions, conditional expressions, programming structures, Input and Output functions, mechanics of running, testing and debugging.

Unit II: Robot software functions - coordinate systems, position control, control functions, subroutines, Online programming, off-line programming, advantages of off-line programming, lead through methods - powered lead through, manual lead through, teach pendant, Robot program as a path in space, defining position in space, motion interpolation, applications.

Unit III: Introduction to Robot operating system (ROS)- packages, launch files, understanding key concepts-services, actions and nodes, publisher, subscriber & messages, client, server, debugging of nodes, building robot environment, practice examples, sensor interfacing.

Unit IV: Basics of MATLAB/python programming, Introduction to Arduino, Interfacing of Arduino with MATLAB, parallel, serial, USB interfacing concepts, robot detection and movement control.

Unit V: Introduction to image processing, MATLAB programming - Image segmentation, Image enhancement, image arithmetic and logical operations, feature extraction, disparity map using stereo camera, optical flow based object tracking, collision avoidance using mobile robot, object recognition, pose estimation.

Unit VI: Real time applications using Mobile robotics.

Course Outcomes

After completing this course, the students will be able to:

- **CO1:** Demonstrate proficiency in programming fundamentals across multiple languages and understand data handling and control structures.

- **CO2:** Apply Robot software functions including coordinate systems, position control, and motion interpolation techniques in programming tasks.

- **CO3:** Utilize Robot Operating System (ROS) effectively by creating and debugging nodes, managing packages, and understanding service-oriented architecture.

- **CO4:** Implement basic programming tasks using MATLAB/Python and Arduino, and interface Arduino with MATLAB for sensor interfacing and control applications.

- **CO5:** Apply image processing techniques in MATLAB for tasks such as segmentation, enhancement, feature extraction, object tracking, and recognition in robotic applications.

Text /Reference Books

1. Mikell P. Groover, Mitchell Weiss, Roger N. Nagel and Nicholas G. Odrey, '*Industrial Robotics Technology, Programming and Applications*', McGraw Hill Book company, 1986.
2. Bernard Hodges, '*Industrial Robotics*', Second Edition, Jaico Publishing House, 1993.

Reference Books

1. A.K.Gupta, S K Arora,'*Industrial Automation and Robotics*', University science press,2012.
2. R. C. Gonzalez, R. E. Woods and S. L. Eddins, *'Digital Image Processing Using MATLAB',*Gatesmark Publishing , 2020.

Course Name-Machine Vision and Image Processing

Course Code-SR 608

Course Code	Course Name	L – T – P	**Credits**
SR 609	**Machine vision and Image processing**	3-0-1	**4**

Course Objectives:

- Understand the architecture and components of robotic vision systems, including image acquisition and processing techniques.
- Learn the principles of image acquisition, analysis, and the components involved in vision systems, such as basic optics and radiometry.
- Explore various image enhancement and analysis techniques, including noise removal, segmentation, and feature extraction.
- Study 3D vision concepts, including perspective projection geometry, camera calibration, and 3D reconstruction methods.
- Understand motion estimation, tracking techniques, and sensor fusion methods, and their applications in robotic vision systems.

Unit I: Architecture of Robotic vision system, Image acquisition, representation, processing Data Acquisition, Conversion, Transmission and Processing: Inertial sensors, Laser Scanners 2D and 3D, Robot Vision, 3D cameras, filters for removal of noise and, INS, gyroscopes,2D,3D Scanner platforms.

Unit II: Image acquisition and analysis, Vision and image sensors, digitization, preprocessing, vision system components, basic optics, basic radiometry, image formats, image noise, image representation, color space, conversion of color spaces.

Unit III: Image enhancement, operations on images, noise removal, segmentation, thresholding, edge detection algorithms, morphological operations, image analysis coding and representation of regions, dimensional analysis, feature extraction Fourier transformations, spatial domain techniques, discrete cosine transform to images, image scaling, standard video formats.

Unit IV: 3D vision: Perspective projection geometry, pinhole camera model, lens distortion, affine and metric geometry, 2d and 3d geometrical transformations, intrinsic and extrinsic camera parameters, calibration methods, stereovision, epipolar geometry, triangulation, rotational matrix, fundamental matrix, stereo correspondence algorithms – feature based and correlation based, 3d reconstruction.

Unit V: Motion estimation and tracking: Optical flow estimation, the concept of sensor fusion - Kalman filter, Localization and Mapping techniques, object tracking with Kalman filtering, feature extraction & object recognition

Unit VI: Case studies/application: Industrial application of vision controlled Robotics systems, industrial robot guidance, demonstration of applications using computer vision toolbox and image processing toolbox.

Course Outcomes

After completing this course, the students will be able to:

- **CO1:** Describe the architecture of robotic vision systems and explain the processes of image acquisition, data conversion, and processing.
- **CO2:** Understand and apply the principles of image acquisition, analysis, and preprocessing, including basic optics and image representation.

- **CO3:** Perform image enhancement and analysis using techniques such as segmentation, edge detection, and feature extraction.
- **CO4:** Apply 3D vision concepts, including camera calibration, stereovision, and 3D reconstruction, to robotic vision systems.
- **CO5:** Implement motion estimation and tracking techniques, including sensor fusion and object recognition, in robotic vision applications.

Text Books

1. Milan Sonka, Vaclav Hlavac, Roger Boyle, *Image Processing, Analysis and Machine Vision", (2/e)*, 1998.
2. E.R. Davies, Royal Holloway, *Machine Vision: Theory, Algorithms and Practicalities, (3/e)*, University of London, December 2004.
3. R. Jain, R. Kasturi, B. G. Schunck, *Machine Vision*, McGraw-Hill, New York, 1995.
4. P.A. Janaki Raman, Robotics and Image Processing an Introduction, Tata Mc Graw Hill Publishing company Ltd., 1995.

Reference Books

1. Rafael C. Gonzalez, Richard E. Woods, *Digital Image Processing, (2/e)*, Pearson education, 2003.
2. Boguslaw Cyganek& J. Paul Siebert, *An Introduction to 3D Computer Vision Techniques and Algorithms*, Wiley, 2009.

Course Name: Advanced Control system

Course code: SR 611

Course Code	Course Name	L – T – P	**Credits**
SR 611	***Advanced Control system***	3-1-0	**4**

Course Objectives:

- Understand model-based controller design principles, including control structures, performance measures, PID controller limitations, and effects of noise and load.
- Explore frequency domain-based identification techniques using relay control systems, and conduct off-line and on-line dynamic model identification.
- Learn time domain-based state space identification methods, focusing on FOPDT, SOPDT models, and the identification of under-damped systems.
- Study steady-state gain determination, SOPDT model identification with pole multiplicity, limit cycles in unstable systems, and techniques for identifying TITO (Two Input Two Output) systems.
- Review and apply time and frequency domain-based identification methods, including on-line identification and advanced techniques such as Fourier series and wavelet transform for improved model parameter accuracy.

Unit I: Model Based Controller Design, Control structures and performance measures, Time and frequency domain performance measures, Design of controller, Design of controller for SISO system, Controller design for TITO processes, Limitations of PID controllers, PI-PD controller for SISO system, PID-P controller for Two Input Two Output system, Effects of measurement noise and load

Unit II: Frequency Domain Based Identification: Identification of dynamic models of plants, Relay control system for identification, Off-line identification of process dynamics, On-line identification of plant dynamics.

Unit III: Time Domain Based Identification: State space based identification, State space analysis of systems, State space based identification of systems -1, State space based identification of systems -2, Identification of simple systems, Identification of FOPDT model, Identification of second order plus dead time model, Identification of SOPDT model,

Unit IV: Steady state gain from asymmetrical relay test, Identification of SOPDT model with pole multiplicity, Existence of limit cycle for unstable system, Identification procedures, Identification of under damped systems, Off-line identification of TITO systems, On-line identification of TITO systems,

Unit V: Review of time domain based identification, DF based analytical expressions for on-line identification, Model parameter accuracy and sensitivity, Improved identification using Fourier series and wavelet transform, Reviews of DF based identification,

Unit VI: Design of Controllers: Advanced Smith predictor controller, Design of controllers for the advanced Smith predictor, Model-free controller design, Model based PID controller design, Model based PI-PD controller design, Tuning of reconfigurable PID controllers

Course Outcomes

After completing this course, the students will be able to:

- **CO1:** Apply principles of model-based controller design to analyze control structures, evaluate performance measures, and design controllers for both SISO (Single Input Single Output) and TITO systems.
- **CO2:** Implement frequency domain-based identification techniques to estimate dynamic models, performing both off-line and on-line identification of process dynamics.
- **CO3:** Utilize state space analysis for time domain-based identification, effectively modeling systems and identifying various models including FOPDT, SOPDT, and under-damped systems.
- **CO4:** Determine steady-state gains, identify SOPDT models considering pole multiplicity, analyze and mitigate limit cycles in unstable systems, and apply identification procedures tailored for TITO systems.

• **CO5:** Evaluate the strengths and limitations of time and frequency domain-based identification methods, implement on-line identification strategies, and enhance accuracy using advanced techniques such as Fourier series and wavelet transform in practical applications.
Text Books
1. S. Majhi, Advanced Control Theory-Relay Feedback Approach, Cengage Asia/IndiaPvt.Ltd, 2009.2. 2. A. Johnson and H. Moradi, New Identifications and Design Methods, Springer -Verlag, 2005.3.
Reference Books
1. Norman S. Nise, Control Systems Engineering, John Wiley & Sons, 2008

Course Name: Design aspect of Automation

Course code: SR 612

Course Code	Course Name	L – T – P	**Credits**
SR 611	***Advanced Control system***	4-0-0	**4**
Course Objectives: • Understand mechatronics fundamentals and design automated systems with proper component selection and fabrication. • Learn electromechanical system performance terms, use CAD for component design, and apply various fabrication methods. • Explore measurement systems using potentiometers, displacement, position, and proximity sensors for precise environmental measurements. • Study signal conditioning, microprocessor technology, including amplification, filtering, pulse modulation, and basic programming. • Investigate electrical drives, motor types (DC, AC, stepper, servo), industrial mechanisms, and ball screw-driven motion in automation.			
Unit I: Introduction, Basic concepts, Mechatronics, Design of automated systems, Mechatronics based systems, Automated systems and equipment used in manufacturing, selection and fabrication, selection of electrical and electronics components for Mechatronics based systems, **Unit II**: terms related to performance of electro mechanical systems, computer aided design of components, fabrication processes, Measurement system and potentiometer sensors,			

Displacement position and proximity sensor, fluid flow pressure and temperature measurement.

Unit III: Signal conditioning and microprocessor technology, signal conditioning, amplification, filtering, pulse modulation, protection devices and wheastone bridge, signal conversion, microprocessor technology, introduction to microprocessor programming,

Unit IV: Electrical drives, application of electric drives in automation, DC and AC motors, stepper motor and servo motor, Mechanisms: types of industrial automation mechanisms, Ball screw based linear motion drives,

Unit V: Application of camsin automation, Application of indexing mechanisms in automation, Application of tool magazine in automation, material handling systems, Hydraulic systems, fundamental concepts, hydraulic pumps, Control valves and graphical representation, direction control valves, flow control and pressure relief valves, graphical representation of hydraulic system elements,

Unit VI: Pneumatic systems, basic concepts and air compressors, air treatment and pressure regulation, graphical representation and pneumatic circuits, computer aided manufacturing and process planning, CNC machine and interpolation.

Course Outcomes

After completing this course, the students will be able to:

- **CO1:** Design and fabricate automated systems using mechatronics principles and appropriate components.
- **CO2:** Analyze electromechanical system performance, use CAD for component design, and apply diverse fabrication techniques.
- **CO3:** Implement measurement systems with precise sensors for positional and environmental data.
- **CO4:** Design signal conditioning circuits, utilize microprocessors for control, and program them for basic automation.
- **CO5:** Apply electrical drives, understand various motor types, and implement ball screw-driven motion effectively in automation.

Text Books

1. Bishop, R. H. (Ed.). (2017). "*Mechatronics: an introduction*", CRC Press.
2. Ogata, K. (2004). *System dynamics* (Vol. 13). Upper Saddle River, NJ: Pearson/Prentice Hall.

Reference Books

1. Bernard Hodges, "*Industrial Robotics*", Jaico Publishing house, 2nd Edition,1993.
2. Richard D. Klafter, Thomas. A, Chmielewski, Michael Negin, "*Robotics Engineering an Integrated Approach*", Prentice Hall of India Pvt. Ltd.,1989.

Course name- Swarm Robotics
Course code-SR 614

Course Code	Course Name	L – T – P	**Credits**
SR 614	***Swarm Robotics***	4-0-0	**4**

Course Objectives:

- Understand and apply ant colony optimization (AS, ACS, Max-Min AS) and Particle Swarm Optimization (PSO) for solving complex optimization problems.
- Explore neural networks including perceptrons, multilayer perceptrons, recurrent networks, and their training methods.
- Investigate self-organization in physical systems and its application in swarm intelligence for robotics and material science.
- Design algorithms for embodied swarm intelligence, considering topology, specification, and PSO tuning.
- Study synchronization challenges in computational systems with communication delays through case studies.

Unit I: Swarm Intelligence - from computational to physical intelligence, Introduction, Definition, Ant Colony Optimization, Biological Inspiration Computationally Hard Path Planning problems, The Ant Colony Optimization Meta-heuristic, Ant System (AS), Ant Colony System (ACS) and Max-Min Ant System.

Unit II: Particle Swarm Optimization, Biological inspiration, Convergence Evolutionary Algorithms, Genetic representation of a problem.

Unit III: Neural network: Biological background, A single layer perception, Multilayer perception, Recurrent neural network, Training of neural networks. Self-organization in physical system, Swarm intelligence in robotics systems, Robotic material

Unit IV: Designing algorithm for embodied swarm intelligence, topology and algorithm specification, PSO tuning,

Unit V: Task allocation, Optimal task allocation, Response threshold task allocation, Market based algorithms

Unit VI: Synchronization of computational systems with communication delays, case studies

Course Outcomes

After completing this course, the students will be able to:

- **CO1:** Apply AS, ACS, Max-Min AS, and PSO to solve computationally hard path planning and optimization problems effectively.

- **CO2:** Implement neural networks like perceptrons and multilayer networks for pattern recognition and prediction tasks.
- **CO3:** Apply self-organization principles to design effective swarm intelligence algorithms for robotics and material science applications.
- **CO4:** Develop optimized algorithms for task allocation using swarm intelligence principles.
- **CO5:** Analyze and mitigate synchronization issues in computational systems with communication delays using practical case studies.

Text Books

1. Swarm Intelligence: From natural to artificial systems. E. Bonabeau, G. Theraulaz, and M. Dorigo, 1999.
2. Self-Organization in Biological Systems, Camazine, Deneubourg, Franks, Sneyd, Theraulaz, Bonabeau, 2003.

Reference Books

1. Floreano, Dario, and Claudio Mattiussi. Bio-inspired artificial intelligence: theories, methods, and technologies. MIT press, 2008.
2. Decentralized Spatial Computing, M. Duckham, Springer, 2013

Course Name- Introduction to Humanoid Robotics

Course Code- SR 615

Course Code	Course Name	L – T – P	**Credits**
SR 615	***Introduction to Humanoid Robotics***	4-0-0	**4**

Course Objectives:

- Gain understanding of humanoid robotics: properties, kinematic equations, and rotational motion characteristics.
- Learn biped locomotion fundamentals: legged robot configurations, gait patterns, stability criteria, ZMP dynamics.
- Master two-dimensional walking pattern generation and control principles for humanoid robots on varied terrain.
- Explore hardware components, robot vision, behavior-based robotics, and human-robot interaction in social contexts.
- Analyze humanoid robot applications in healthcare, education, defense, space, and agriculture.

Unit I: Introduction to Humanoid Robotics, Understanding of specific properties of humanoid robots, and state-of-the-art, Kinamatic equation for basic robot systems-Coordinate transforms, Homogeneous transforms Characteristics of Rotational Motion.

Velocity in Three Dimensional Space. Robot Data Structure and Programming, Kinematics of a Humanoid Robot. **Unit II:** Biped locomotion fundamentals- Configuration of legged Robots, Terminologies of locomotion-Single support phase, double support phase, support polygon, Gait pattern, Gait stability criteria, Static and dynamic stability of humanoid robot systems, ZMP and Ground Reaction Forces, Measurement of ZMP Dynamics of Humanoid Robots Humanoid Robot Motion. Angular Momentum and Inertia Tensor of Rigid Body. **Unit III:** Two Dimensional Walking Pattern Generation, Two Dimensional Inverted Pendulum, Planning a Simple Biped Gait, Extension to a Walk on Uneven Terrain, ZMP Based Walking Pattern Generation, Stabilizer-Principles of Stabilizing Control, reconfiguration of legged robots. **Unit IV:** Hardware for humanoid Robots, Robot vision, behavior based robotics, Human robot interaction and social Robotics, learning for intelligent robotic manipulator, cognitive intelligence for Human-robot teaming **Unit V:** Humanoid applications in healthcare, teaching, military, space, agriculture. **Unit VI:** Real life Case studies.
Course Outcomes
After completing this course, the students will be able to: CO1: Apply kinematic equations and transforms to model humanoid robot motion and programming. CO2: Evaluate stability and dynamics of bipedal locomotion systems using ZMP and gait analysis. CO3: Design walking patterns and control strategies for bipedal robots on different terrains. CO4: Integrate hardware components, vision systems, and behavioral algorithms in humanoid robotics. CO5: Assess applications of humanoid robots in diverse fields through real-life case studies.
Text Books
1. Shuuji Kajita·Hirohisa Hirukawa Kensuke Harada·Kazuhito Yokoi, "*Introduction to Humanoid Robotics*", springer,2014.
Reference Books
1. Ambarish Goswami Prahlad Vadakkepat, "*Humaniod Robotics*",Springer reference,2019

Course Name- Field and service Robots
Course Code-SR 616

Course Code	Course Name	L – T – P	**Credits**

SR 616	***Field and service Robots***	4-0-0	**4**

Course Objectives:

- Explore field and service robots' history, trends, and future, focusing on non-conventional industries. Study mobile robots' kinematics, perception, and control.
- Investigate field robots for agriculture, mining, exploration, underwater tasks, and industrial applications like cleaning and painting.
- Study underwater robots, including kinematics, dynamics, navigation, and marine data collection.
- Explore aerial robots, covering sensors, actuators, modeling, control, and navigation for small UAVs.
- Analyze autonomous flight control systems for aerial robots in defense and other applications.

Unit I: Introduction to Humanoid Robotics, Understanding of specific properties of humanoid robots, and state-of-the-art, Kinamatic equation for basic robot systems-Coordinate transforms, Homogeneous transforms Characteristics of Rotational Motion. Velocity in Three Dimensional Space. Robot Data Structure and Programming, Kinematics of a Humanoid Robot.

Unit II: Biped locomotion fundamentals- Configuration of legged Robots, Terminologies of locomotion-Single support phase, double support phase, support polygon, Gait pattern, Gait stability criteria, Static and dynamic stability of humanoid robot systems, ZMP and Ground Reaction Forces, Measurement of ZMP Dynamics of Humanoid Robots Humanoid Robot Motion. Angular Momentum and Inertia Tensor of Rigid Body.

Unit III: Two Dimensional Walking Pattern Generation, Two Dimensional Inverted Pendulum, Planning a Simple Biped Gait, Extension to a Walk on Uneven Terrain, ZMP Based Walking Pattern Generation, Stabilizer-Principles of Stabilizing Control, reconfiguration of legged robots.

Unit IV: Hardware for humanoid Robots, Robot vision, behavior based robotics, Human robot interaction and social Robotics, learning for intelligent robotic manipulator, cognitive intelligence for Human-robot teaming

Unit V: Humanoid applications in healthcare, teaching, military, space, agriculture.

Unit VI: Real life Case studies.

Course Outcomes

After completing this course, the students will be able to:

CO1: Analyze the historical evolution and current status of service robotics, predicting future trends and innovations.

CO2: Apply principles of kinematics, perception, and motion planning to design autonomous mobile robots capable of intelligent decision-making.

CO3: Evaluate the design considerations and operational challenges of field robots across diverse applications, ensuring performance, safety, and robustness.

CO4: Demonstrate proficiency in designing and implementing navigation and control systems for underwater robots, integrating environmental data collection capabilities.

CO5: Design and develop guidance and control systems for aerial robots, ensuring effective navigation and operation in various environments, including autonomous indoor flight.

Text Books

1. Roland Siegwart, Illah Reza Nourbakhsh, Davide Scaramuzza, Introductionto Autonomous Mobile Robots, Bradford Company Scituate, USA, 2004
2. Riadh Siaer, The future of Humanoid Robots- Research and applications, Intech Publications,20

Reference Books

1. Richard D Klafter, Thomas A Chmielewski, Michael Negin, "*Robotics Engineering AnIntegrated Approach*", Eastern Economy Edition, Prentice Hall of India PLtd. ,2006.
2. Kelly, Alonzo; Iagnemma, Karl; Howard, Andrew, *Field and Service Robotics*, Springer,2011.

Course Name- Aerial Robotics
Course Code- SR 617

Course Code	Course Name	L – T – P	**Credits**
SR 617	***Aerial Robotics***	3-1-0	**4**

Course Objectives:

- Understand the fundamental concepts and configurations of multi-rotor UAVs.
- Master reference frames, rotational matrices, and UAV kinematics for accurate motion analysis.
- Analyze UAV dynamics, including forces, moments, and six-degree-of-freedom equations.
- Explore sensors, actuators, and autopilot systems for longitudinal and lateral control.
- Develop skills in modeling LTI systems, analyzing time and frequency responses, and implementing vision-based navigation for waypoint following in UAV operations.

Unit I: Introduction of unmanned aerial robotics, different type of multi-rotor UAV configurations.

Unit II: Reference frames, Rotational matrices, UAV-kinematics.

Unit III :UAV-forces and moments, UAV dynamics, Six-degree-of-freedom equations of motion, stability derivatives, trim conditions, linearization, longitudinal dynamics, lateral dynamics.

Unit IV: UAV sensors and actuators, longitudinal autopilot (pitch-rate damping, pitch hold, altitude hold, velocity hold), lateral autopilot (yaw-rate damping, roll hold, heading hold, coordinated turn, turn compensation)

Unit V: State-space model of LTI system, eigen value-eigenvectors, modalde composition, transfer function models, first and second-order systems, time response, frequency response, root locus, bode plot

Unit VI : Vision-based navigation, waypoint following.

Course Outcomes

After completing this course, the students will be able to:
CO1: Demonstrate proficiency in configuring and operating multi-rotor UAVs, understanding their dynamics, and applying kinematic principles.

CO2: Analyse and design longitudinal and lateral autopilot systems, including pitch-rate damping, altitude hold, and coordinated turns.

CO3: Model and analyse LTI systems using state-space and transfer function representations, evaluating time and frequency domain characteristics.

CO4: Apply root locus and Bode plot techniques to assess stability and performance of UAV control systems.

CO5: Implement vision-based navigation algorithms for accurate waypoint following in UAV missions, integrating sensor data for real-time decision making.

Text Books

1. Small Unmanned Aircraft: Theory and Practice, R. W. Beard and T. M. Mclain, first edition.
2. Automatic control of aircraft and missiles, John H. Blakelock, second edition.
3. Linear control systems: Analysis and Design, J. J. D'Azzo, C. H. Houpis and S.N. Sheldon, fifth edition.

Reference Books

1. Modern Control Engineering, K. Ogata, fifth edition.

Course Name- Robotic Path Planning and Control

Course Code- SR618

Course Code	Course Name	L – T – P	**Credits**
SR 618	***Robotic Path Planning and Control***	3-1-0	**4**

Course Objectives:

- Understand and apply ant colony optimization (AS, ACS, Max-Min AS) and Particle • Learn path planning techniques: Bug algorithms, C-space planning, Potential Fields, A* and D* algorithms, and Rapidly Exploring Random Trees.
- Understand trajectory generation: Cubic polynomials, linear functions, and Cartesian space schemes.
- Study linear robot control: Joint control, trajectory following, PID control.
- Explore nonlinear manipulator control: Coulomb friction, feedforward control, stability analysis.
- Investigate force control: Hybrid position/force control, compliance mechanisms.

Unit I: Swarm Intelligence - from computational to physical intelligence, Introduction, Definition, Ant Colony Optimization, Biological Inspiration Computationally Hard Path Planning problems, The Ant Colony Optimization Meta-heuristic, Ant System (AS), Ant Colony System (ACS) and Max-Min Ant System.

Unit II: Particle Swarm Optimization, Biological inspiration, Convergence Evolutionary Algorithms, Genetic representation of a problem.

Unit III: Neural network: Biological background, A single layer perception, Multilayer perception, Recurrent neural network, Training of neural networks. Self-organization in physical system, Swarm intelligence in robotics systems, Robotic material

Unit IV: Designing algorithm for embodied swarm intelligence, topology and algorithm specification, PSO tuning,

Unit V: Task allocation, Optimal task allocation, Response threshold task allocation, Market based algorithms

Unit VI: Synchronization of computational systems with communication delays, case studies

Course Outcomes

After completing this course, the students will be able to:

- **CO1:** Apply Bug algorithms, Potential Field methods, and visibility-based planning techniques to solve path planning problems in robotics.
- **CO2:** Implement trajectory generation methods such as cubic polynomials and Cartesian space schemes to generate smooth robot trajectories with specified constraints.
- **CO3:** Design and implement linear control strategies for robots, including trajectory following, PID control, and disturbance rejection.
- **CO4:** Develop nonlinear control strategies for manipulators to handle complexities like Coulomb friction, multi-input dynamics, and adaptive control in industrial settings.
- **CO5:** Implement force control techniques including hybrid position/force control and compliance mechanisms for tasks requiring precise force application and interaction with the environment.

Text Books
1. John J. Craig, *Introduction to Robotics Mechanics and Control*, 3rd Edition, Pearson, 2008. 2. Latombe, Jean-Claude. *Robot motion planning*. Vol. 124. Springer Science & Business Media, 2012. 3. K. Ogata, *Modern Control Engineering*, 5th Edition, Prentice Hall, 2010
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1. B. Friedland, *Control System Design-An Introduction to State Space Methods*, McGraw- Hill, Singapore, 1987 2. J.J.E Slotine and W. Li, *Aplied Nonlinear Control*, Prentice-Hall, NJ, 1991 3. M. W. Spong and M. Vidyasagar, *Robot Dynamics and Control*, John Wiley & Sons, NY, USA, 2004 4. Howie M Choset, Seth Hutchinson, Kevin M Lynch, George Kantor, Wolfram Burgard, Lydia E Kavraki, Sebastian Thrun *Principles of Robot Motion: Theory, Algorithms, and Implementation*, 2005