Indira Gandhi Delhi Technical University For Women

(Established by Govt. of Delhi vide Act 9 of 2012)

ISO 9001:2015 Certified University

Department of Mechanical and Automation Engineering

TWO YEAR POST GRADAUATE PROGRAMME

M. Tech [Robotics and AI]

Teaching Scheme and Syllabus

Course Structure for M Tech Programme

M. Tech. (Robotics and AI)

1st Semester					
S. No	**Subject Code**	**Subject Name**	**L-T-P**	**Credits**	**Category**
1	MRA 101	Robotics Engineering	3-0-2	4	DCC
2	MRA 103	Mechatronics and Micro Controllers	3-0-2	4	DCC
3	MRA 105	Artificial Intelligence	3-0-2	4	DCC
4	MRA 107	Automation in Manufacturing	3-0-2	4	DCC
5	MRA 1xx	Department Elective 1	3-0-2	4	DEC
6	GEC 101	Generic Open Elective	2-0-0/1-1-0/0-0-4	2	GEC
			Total	22	

2nd Semester					
S. No.	**Subject Code**	**Subject Name**	**L-T-P**	**Credits**	**Category**
1	MRA 102	Pattern Recognition and Vision	3-0-2	4	DCC
2	MRA 104	Advanced Robotics	3-0-2	4	DCC
3	MRA 1yy	Department Elective 2	3-0-2	4	DEC
4	MRA 1zz	Department Elective 3	3-0-2	4	DEC
5	MRA 1vv	Department Elective 4	3-0-2	4	DEC
6	ROC 902	Research Methodology and Publication Ethics	3-0-2	4	ROC
			Total	24	

3rd Semester					
S. No.	**Subject Code**	**Subject Name**	**L-T-P**	**Credits**	**Category**
1	MRA 2xx	Department Elective 5	3-0-2	4	DEC
2	MRA 2yy	Department Elective 6	3-0-2/3-1-0	4	DEC
3	GEC 102	Generic Open Elective II	3-0-2/3-1-0/0-0-4	2	GEC
4	MRA 251	Dissertation- 1/Project Work	-	6	ROC
5	MRA 253	Industrial Training/Project	-	1	ROC
			Total	23	

4th Semester					
S. No.	**Subject Code**	**Subject Name**	**L-T-P**	**Credits**	**Category**
1	MRA 252	Dissertation – II/Project Work		20	ROC
			Total	20	

Note: Industrial training/Internships will be done in the summer break of the previous academic session. Assessment will be done within the first two weeks of the opening of the academic session by the Department.

List of Departmental Elective Courses

Category	Course Code	Subject	Credits
Department Elective Course-1	MRA 109	Modern Control Theory	3-0-2
	MRA 111	MEMS and Micro system for Automation	3-0-2
	MRA 113	Modelling and Simulation for Dynamic systems	3-0-2
	MRA 115	Robot Sensing and Vision	3-0-2
	MRA 117	Statistical Fundamentals of Data Sciences	3-0-2
Department Elective Course-2	MRA 106	Sensors and Actuators	3-0-2
	MRA 108	Mathematical Techniques for Control and DSP	3-0-2
	MRA 110	Deep Learning	3-0-2
	MRA 112	Neural Network and Fuzzy Logic	3-0-2
Department Elective Course-3	MRA 114	Optimization for Engineering	3-0-2
	MRA 116	Intelligent Systems and Interfaces	3-0-2
	MRA 118	Industry 4.0	3-0-2
Department Elective Course-4	MRA 120	Cyber-Physical Systems	3-0-2
	MRA 122	Wireless Sensor Networks	3-0-2
	MRA 124	Aerial Robotics	3-0-2
Department Elective Course-5	MRA 201	Industrial Automation	3-0-2
	MRA 203	Design of Experiments	3-0-2
	MRA 205	Human-Computer Interaction	3-0-2
	MRA 207	Internet of Things	3-0-2
	MRA 209	AI and Sustainability	3-0-2
	MRA 211	Rapid Prototyping	3-0-2
Department Elective Course – 6	MRA 213	Intelligent Robots	3-0-2
	MRA 215	Embedded System Design for Automation	3-0-2
	MRA 217	Bio Sensors	3-0-2
	MRA 219	Multi-Body Dynamics	3-0-2
	MRA 221	Smart Manufacturing	3-0-2

Robotics Engineering	
Course Code: MRA-101	Credits: 4
Contact Hours: L-3 T-0 P-2	Semester: 1
Course Category: DEC	

Introduction: The study of robotics concerns itself with the desire to synthesize some aspects of human function by the use of mechanisms, sensors, actuators, and computers. This subject provides important background material to students involved in understanding the basic functionalities of robotics.

Course Objectives: The objectives of this course are:

- To provide an introduction to robotics including robot classifications, design and selection, analysis, sensing and control, and applications in industry.
- To introduce students to robot kinematics, and motion.
- To make students aware of various types of sensors and control that are used in Robotics.
- To impart knowledge of Robot Programming to students

Pre-Requisites: Basic knowledge of Engineering mechanics, Kinematics and Dynamics of Machines, and basic Mathematics.

Course Outcomes: After successful completion of the course, the students will be able to -

- Understand the introduction of fundamentals of Robotics and automation.
- To impart knowledge in Robot Kinematics, Dynamics, and its applications.
- Identify and use various types of end effectors, sensors, and control systems.
- Program robots for the required tasks.

Pedagogy: Classroom teaching is supported by White board, black board, chalks, markers,projector and screen. The hand written notes, PowerPoint slides and assignments will be provided to the students and also mailed to them. The students can also raise their issues related to the course in the class and mail.

Contents:

UNIT I	11Hours
Fundamentals of Robotics: Robot definition, automation for robotics, classification of robots, Robot anatomy, Work space volume, Drive systems. Control systems. Accuracy and repeatability. Robot design configuration, Components and robotic systems, Sensors in robotics. Robot configurations, Path control. Introduction to robot programming.	
UNIT II	11 Hours
Robot Kinematics: Mapping, Homogeneous transformations, Rotation matrix, Forward Kinematics Denavit - Hartenberg (DH) representation, inverse kinematics: solution of inverse problems. Robot Differential Motion: Linear and Angular velocity of rigid link, Velocity and angular velocity and acceleration along link, Maipulatorjacobian, Static force analysis with jacobian.End effectors: Types of grippers. Tools as end effectors. Robot and effectors interface. Gripper selection and design, current and emerging issues in Robotics.	
UNIT III	10 Hours
Robot drive, Sensors, Actuators and Control: Robot drive systems- Hydraulic. Pneumatic & Electric. Robot sensors- Contact and noncontact type sensors, Force and Torque sensor, Robotics vision system, Basic control systems concept and models, controllers, Control system analysis.	
UNIT IV	10 Hours
Robot Programming Language & Applications:	

Methods of Robot Programming, Lead through Programming Methods, Robot languages and classifications. Programming Exercise on ACL/ATS for Robots. Robots applications areas- Material transfer and machine loading/ Unloading, Processing operations, assembly and Inspection, Future manufacturing applications robots.

Text Books	
1	Mikell P Grover, Mitchell Weiss, “Industrial Robotics: Technology, Programming and Application”, Tata Mc-Graw & Hills, 2017.
2	Saeed B. Niku, “Introduction to Robotics Analysis, Systems & Applications”, Pearson Education Singapore P. Ltd., 2nd Edition, 2011.
3	S.K. Saha, “ Robotics”, Tata Mc Grow Hills Pvt. Ltd. 2nd Edition, 2009
Reference Books	
1	J.J. Craig, “Introduction to Robotics”. Addison Wesley N Delhi, Pearson, 4th edition, 2017.
2	K. S. Fu., “Robotics”, Mc Grow Hill International Editions, 2017.
3	www.nptel.ac.in
4	http://ocw.mit.edu

Mechatronics and Microcontrollers	
Course Code: MRA-103	Credits: 4
Contact Hours: L-3 T-0 P-2	Semester: 1
Course Category: DCC	

Introduction: Mechatronic systems are integrated mechanical, electrical, and computer systems, and are enabling for a number of important technologies including electric vehicles, disk drives, power and flight control systems, production machinery, and robotics.

Course Objectives: The objectives of this course are to

- Learn about mechatronic systems
- Understand the major conceptual pieces comprising a mechatronic system
- Provide a hands-on experience with electro-mechanical hardware. Develop intuition of how these systems function.
- Give an understanding about the concepts and basic architecture of 8051
- Help understand the importance of different peripheral devices & their interfacing to 8051
- Become familiar with core electrical and mechanical components

Pre-Requisites: Basic Electronics

Course Outcomes: After successful completion of the course, the students will be able to -

- Understand characteristics and the components of mechatronics systems
- Demonstrate an ability to identify, select, and integrate mechatronic components to meet product requirements

Pedagogy: Classroom teaching is supported by White board, black board, chalks, markers, projector and screen. The hand written notes, PowerPoint slides and assignments will be provided to the students and also mailed to them. The students can also raise their issues related to the course in the class and mail.

Contents:

UNIT I	11Hours
Pneumatic & Hydraulic Actuation Systems: Fluid power systems, hydraulic systems, Pneumatic systems, hydraulic pumps and Pressure Control Valves and regulation, Cylinders, Direction Control Valves, Rotary Actuators, Accumulators, Amplifiers, and Pneumatic Sequencing Problems. Electrical Actuation Systems: Switching Devices, Mechanical Switches – SPST, SPDT, DPDT, keypads; Relays, Solenoid Operated Hydraulic and Pneumatic Valves, Electro-Pneumatic Sequencing Problems.	
UNIT II	11 Hours
Digital Electronics and Systems: Gates and Integrated Circuits Like 7408, 7402, Karnaugh Maps, Application of Logic Gates as: Parity Generators, Digital Comparators, BCD to Decimal Decoders, Flip Flops and applications, sequential logic Sensors, Transducers and Application: Performance Terminology, Static and Dynamic Characteristics, Displacement, Position and Proximity Sensors, Potentiometer Sensors, Strain Gauge Element, LVDT, Optical Encoders, Pneumatic Sensors, Hall Effect Sensors, Tachogenerators, Strain Gauge Load Cell, Thermostats, Photo Darlington.	
UNIT III	10 Hours
Introduction to Signal Conditioning: Signal Conditioning Processes, Inverting Amplifiers, Non Inverting Amplifiers, Summing, Integrating, Differential, Logarithmic Amplifiers, Comparators, Amplifiers Error, Filtering, wheatstone Bridge.	

Programmable Logic Controllers: Programmable logic controllers (PLC) Structure, Input / Output Processing, principles of operation, PLC versus computer, Programming Languages, programming using Ladder Diagrams, Logic Functions, Latching, Sequencing, Timers, Internal Relays And Counters, Shift Registers, Master and Jump Controls.

UNIT IV	10 Hours
Micro controller –difference between micro controller and microprocessor, criteria for choosing a microcontroller, internal architecture of MCS51 microcontroller and its family. 8051 assembly language programming: instruction set-arithmetic, logical, data transfer branching and Flag manipulation Instructions, addressing modes, 8051 timer/counter, serial communication programming, interrupts structure, interrupt programming, usage of C programming to 8051 family.	

Text Books	
1	W. Bolton, "Mechatronics – Electronic Control Systems in Mechanical & Electrical Engineering", Pearson Education Ltd., 2010.
2	Nitaigour Premch and Mahalik, "Mechatronics Principles, Concepts & Application", Tata McGraw Hill Publishing Co. Ltd., 2017.
3	Mazidi, "The 8051 microcontroller and embedded system", Pearson Education, 2nd Edition, 2012.
Reference Books	
1	David g Alciatore, Michael B Histand, "Introduction to Mechatronics", McGraw Hill Education, 4th Edition, 2017.
2	A Smaili, F Mrad, "Mechatronics – Integrated Technologies for Intelligent Machines", Oxford Higher Education, 2017.
3	Clarence W. de Silva, Mechatronics: A Foundation Course, CRC Press, June 4, 2010.
4	www.nptel.ac.in
5	http://ocw.mit.edu

Artificial Intelligence	
Course Code: MRA-105 Contact Hours: L-3 T-0 P-2 Course Category: DCC	Credits: 4 Semester: 1

Introduction: Artificial Intelligence or AI, deals with building smart machines that are capable of performing complex tasks that normally require human interference and intelligence. It combines Data Science with real-life data to leverage machines and computers to imitate the decision-making and problem-solving capabilities that the human mind has.

Course Objectives: The objectives of this course are:

1. To impart knowledge about Artificial Intelligence.
2. To give an understanding of the main abstractions and reasoning for intelligent systems.
3. To enable the students to understand the basic principles of Artificial Intelligence in various applications.

Pre-Requisites: Basic knowledge of computers and mathematics

Course Outcomes: On completion of the course the student will be able to

1. Apply artificial intelligence techniques, including search heuristics, knowledge representation, planning and reasoning.
2. Describe the key components of the artificial intelligence (AI) field.
3. Explain and solve problems by applying a suitable search method.
4. Compare minimax search and alpha-beta pruning in game playing.
5. Describe and list the key aspects of planning in artificial intelligence

Pedagogy: Classroom teaching is supported by White board, black board, chalks, markers, projector and screen. The hand written notes, PowerPoint slides and assignments will be provided to the students and also mailed to them. The students can also raise their issues related to the course in the class and mail.

Contents:

UNIT I	11 Hours
Scope of AI: Robotics, Machine Learning, Intelligent Machines, Expert Systems, Gamestheorem proving, natural language processing, vision and speech processing, expert system, AI techniques-search knowledge, abstraction. Intelligent Agents: Autonomy, Properties, Environments, Taxonomy, MobileAgents, Architectures-Reactive, Hybrid& Mobile Architecture. Robotics: Taxonomy, Hard & Soft Robots, Natural Sensing Control, Perception with sensors, Actuation with Effectors, Movement Planning, Robot Programming Languages.	
UNIT II	11 Hours
Machine Learning: Machine Learning Algorithms, Supervised learning, unsupervised learning, Markov Model, Nearest Neighbor classification-kNN, Knowledge Representation: Predicate Logic: Unification, Modus Ponens, Modus Tolens, Resolution in Predicate Logic, ConflictResolution Forward Chaining, Backward chaining, Declarative and Procedural Representation, Rule based Systems.	
UNIT III	10 Hours

Rule Based Systems, Inference Systems, ProblemSolving (Blind): State Space search; production system, depth-first, breadth-first search. Heuristic search, Hill climbing, best-first search, branch and bound, Problem reduction, Constraint Satisfaction End		
UNIT IV		10 Hours
Expert System: Need and justification for expert System, Knowledge acquisition, Architecture of Expert Systems. Case Studies: Intelligent Air Condition, Sugar Mill Boiler, Salmon Cutting Machine.		
Text Books		
1.	Russel S. & Norvig P. "Artificial Intelligence –A Modern Approach", Second Edition 2013.	
2.	Schalkoff R., "Intelligent Systems -Principles, Paradigms & Pragmatics" Jones &Bartlet Learning, First Indian Edition 2011	
Reference Books		
1.	Jones M. T "Artificial Intelligence –A systems Approach", Firewall Media, Infinity Science Press, 2008.	
2.	Luger G.F. "Artificial Intelligence –Structures and Strategies for Complex Problem Solving", Pearson Education, 5thEdition, 2010.	

Automation in Manufacturing	
Course Code: MRA-107 Contact Hours: L-3 T-0 P-2 Course Category: DCC	Credits: 4 Semester: 1

Introduction: This is a basic introductory course on automation in Industry. A management course which concentrates on importance of automation, effect of automation of an organization, choosing the level of automation required and enlightens the students about costing involved and problems such as line balancing in an automated environment.

Course Objectives: The objectives of this course are:

1. To develop the understanding related to the need of automation in manufacturing systems.
2. To familiarize with the potential benefits obtained with the implementation of automation at various levels in industry.
3. Describe the basic concepts of automation in manufacturing systems.
4. Acquire the fundamental concepts of automated flow lines and their analysis.
5. Classify automated material handling, automated storage and retrieval systems.
6. The students are to be provided hands on practical exposure on topics covered in the course.

Pre-Requisites: Basic knowledge of manufacturing

Course Outcomes: On completion of this course students should be able to:

1. Identify the basic components required for manufacturing systems automation.
2. Intend an automated material handling and inspection systems.
3. Design and analyze an automated manufacturing system.
4. The practical sessions will improve visualization of the concepts taught in theory.

Pedagogy: Classroom teaching is supported by White board, black board, chalks, markers, projector and screen. The hand written notes, PowerPoint slides and assignments will be provided to the students and also mailed to them. The students can also raise their issues related to the course in the class and mail.
Class room teaching is consequently supported by practical sessions and assignments / projects given in labs during practical sessions.

Contents:

UNIT I	11 Hours
Definition of automation, Types of production, Functions of Manufacturing, Organization and Information Processing in Manufacturing, Production concepts and Mathematical Models, Automation Strategies. Fixed Automation: Automated Flow lines, Methods of Workpart Transport, Transfer Mechanism - Continuous transfer, intermittent transfer, Indexing mechanism, OperatorPaced Free Transfer Machine, Buffer Storage, Control Functions,	

Automation for Machining Operations, Design and Fabrication Considerations. Analysis of Automated Flow Lines: General Terminology and Analysis, Analysis of Transfer Lines without Storage, Partial Automation, Automated Flow Lines with Storage Buffers.	
UNIT II	11 Hours
Assembly Systems and Line Balancing: The Assembly Process, Assembly Systems, Manual Assembly Lines, The Line Balancing Problem, Methods of Line Balancing, Computerized Line Balancing Methods, Other ways to improve the Line Balancing, Flexible Manual Assembly Lines. Automated Assembly Systems: Design for Automated Assembly, Types of Automated Assembly Systems, Vibratory bowl feeder and Non-vibratory bowl feeder, Part Orienting Systems, Feed tracks, Escapements and part placing mechanism, Analysis of Multi-station Assembly Machines, Analysis of a Single Station Assembly Machine	
UNIT III	10 Hours
Automated Materials Handling: The material handling function, Types of Material Handling Equipment, Analysis for Material Handling Systems, Design of the System, Conveyor Systems, Automated Guided Vehicle Systems. Automated Storage Systems: Storage System Performance, Automated Storage/Retrieval Systems, Carousel Storage Systems, Work-in-process Storage, Interfacing Handling and Storage with Manufacturing.	
UNIT IV	10 Hours
Automated Inspection and Testing: Inspection and testing, Statistical Quality Control, Automated Inspection Principles and Methods, Sensor Technologies for Automated Inspection, Coordinate Measuring Machines, Other Contact Inspection Methods, Machine Vision, Other optical Inspection Methods. Modeling Automated Manufacturing Systems: Role of Performance Modeling, Performance Measures, Performance Modeling Tools: Simulation Models, Analytical Models. The Future Automated Factory: Trends in Manufacturing, The Future Automated Factory, Human Workers in the Future Automated Factory, The social impact.	

Text Books	
1.	Mikell P.Grover, "Automation, Production Systems and Computer Integrated Manufacturing", Pearson Education Asia, New Delhi, 2016.
2.	Asfahl,C.R., "Robots and manufacturing Automation", John Wiley and Sons New York, 2010.

Reference Books	
1.	Wolson Mike, "Implementation of Robot Systems: An introduction to robotics, automation, and successful systems integration in manufacturing", Butterworth-Heinemann, 1st edition, 2014.
2.	Chirag Singh, M. Charles Sahayaraj, "Innovation and Challenges in Industry Automation and Smart Manufacturing", InSc International Publisher, 2021.

Modern Control Theory	
Course Code: MRA-109 Contact Hours: L-3 T-0 P-2 Course Category: DEC	Credits: 4 Semester: 1

Introduction: This course provides the fundamentals in modern control theory - centred around the so-called state space methods - as a continuation of classical control theory taught in Linear Control Theory. Emphasis is placed on the treatment of such concepts as controllability and observability, pole allocation, the realization problem, observers, and linear quadratic optimal regulators.

Course Objectives: The objectives of this course are to:

- Provide a basic understanding of the concepts and techniques involved in designing control schemes for dynamic systems.
- Develop the ability to generate state-space models for dynamic systems described by:– time histories,–transfer functions, or–sets of differential or difference equations.
- Be able to determine solutions to these state equations by a variety of methods.
- Develop the ability to determine various properties of these systems including controllability, observability, and stability.
- Develop the ability to design feedback controllers for specified eigenvalues based on state space methods.
- Develop the ability to design state observers based on state-space methods and other methods.

Pre-Requisites: Basic knowledge of Control systems

Course Outcomes: At the end of this course, student will be able to

- Have an exposure to state space representation of dynamic systems and analysis.
- Analyse dynamic systems for their stability and performance.
- Design controllers (such as Proportional-Integral-Derivative) based on stability and performance requirements.

Pedagogy: Classroom teaching is supported by White board, black board, chalks, markers, projector and screen. The hand written notes, PowerPoint slides and assignments will be provided to the students and also mailed to them. The students can also raise their issues related to the course in the class and mail.
Class room teaching is consequently supported by practical sessions and assignments / projects given in labs during practical sessions.

Contents:

UNIT I	11 Hours
Introduction: Digital Control System configuration, Basic discrete time signals, time domain models for discrete time systems, transfer function models, stability on z	

plane, z domain description of continuous time systems, implementation of digital controllers, stepper motors, servo motors, position control systems, z transforms	
UNIT II	11 Hours
Linear Algebra: Vectors and matrices, state variable representation, conversion of state variable models to transfer function and vice versa, Eigen values and Eigen vectors, solution of state equations: forced and unforced systems, controllability and observe ability, multi variable systems, state variable analysis of digital control systems	
UNIT III	10 Hours
Linear Systems: State variable feedback structure, pole placement design using state feedback, state feedback with integral control, observer-based state feedback control, digital control using state feedback, optimal control systems, optimal digital control	
UNIT IV	10 Hours
Non-Linear Systems: Linear approximations, common nonlinearities in control systems, describing function method for stability analysis, concepts of phase plane analysis, lyapunov stability analysis, linear quadratic optimal control through lyapunov equation	
Text Books	
1.	M. Gopal, "Digital control and state variable methods", McGraw Hill Education; 4th edition, 2017.
2.	M. Gopal, "Control systems: Principles and design", McGraw Hill Education; 4th edition, 2012.
3.	K. Ogata, "Modern Control Engineering", Pearson, 5th Edition, 2015.
Reference Books	
1.	Ghosh Smarajit, "Control Systems: Theory and Applications", Pearson India, 2nd Edition, 2012.
2.	Kumar A. A., "Control Systems", Prantice Hall, 2nd Edition, 2014.

MEMS and Microsystems for Automation	
Course Code: MRA-111 Contact Hours: L-3 T-0 P-2 Course Category: DEC	Credits: 4 Semester: 1

Introduction: Micro-electro-mechanical systems, or MEMS, is an emerging area with applications to a variety of engineering fields such as mechanical, electrical, aerospace and bioengineering. This course is an introductory course and forms the first part of a 2-series MEMS course at SDSU. This introductory part concentrates in educating students the manufacturing techniques (micromachining), materials, mask layout, and multi-physics simulation of MEMS.

Course Objectives: The objectives of this course are to

- Provide basic knowledge on overview of MEMS (Micro electro Mechanical System) and various fabrication techniques.
- Enable students to design, analysis, fabrication and testing the MEMS based components.
- To introduce the fundamental concept of MEMS & Microsystem and their relevance to current industry/scientific needs

Pre-Requisites: Basic knowledge of microsystems

Course Outcomes: Having completed this course student will be able to:

- Understand MEMS-specific design issues and constraints
- Perform Dynamics and modelling of Microsystems
- Perform applications of micro-sensors and micro-actuators

Pedagogy:

Classroom teaching is supported by White board, black board, chalks, markers, projector and screen. The hand written notes, PowerPoint slides and assignments will be provided to the students and also mailed to them. The students can also raise their issues related to the course in the class and mail. Conduction of group discussions among students. Class room teaching is consequently supported by practical sessions and assignments / projects given in labs during practical sessions.

Contents:

UNIT I	11 Hours
Introduction to MEMS & Microsystems, Introduction to Micro sensors, Evaluation of MEMS, Micro sensors, Market survey, application of MEMS, MEMS Materials, MEMS	

materials properties, microelectronic technology for MEMS, micromachining technology for MEMS		
UNIT II		11 Hours
Micromachining process, Etch stop techniques and microstructure, surface and quartz Micromachining, Fabrication of micro machined microstructure, Micro stereolithography MEMS micro sensors, thermal micro machined micro sensors, Mechanical MEMS, Pressure and flow sensor, Micro machined flow sensors, MEMS inertial sensors.		
UNIT III		10 Hours
Micro machined micro accelerometers for MEMS, MEMS accelerometers for avionics, Temperature drift and damping analysis, Piezo-resistive accelerometer technology, MEMS capacitive accelerometer, MEMS capacitive accelerometer process		
UNIT IV		10 Hours
MEMS gyro sensor, MEMS for space application, Polymer MEMS & carbon nano tubes (CNT), Wafer bonding & packaging of MEMS, Interface electronics for MEMS, MEMS for biomedical applications (Bio-MEMS)		
Text Books		
1.	Tai-Ran Hsu, "MEMS and Microsystems: Design and Manufacture", McGraw-Hill, 2017.	
2.	Chang Liu, "Foundations of MEMS", Pearson Education, 2011.	
3.	Ghodssi, Reza; Lin, Pinyen (Eds.), "MEMS Materials and Processes Handbook", Springer, 2012.	
Reference Books		
1.	Mohamed Gad-el-Hak, "MEMS: Introduction and Fundamentals", Taylor and Francis, 2005.	
2.	Jan Korvink and Oliver Paul, "MEMS: A Practical Guide to Design, Analysis and Applications", 2005.	
3.	Nitai Gour Premchand Mahalik, "MEMS", McGraw Hill Education, 2007.	
4.	Stephen D Senturia, "Microsystem Design", Kluwer Academic Publishers, 2001.	
5.	Thomas M. Adams and Richard A. Layton, "Introductory MEMS: Fabrication and Applications", Springer, 2010.	

Modelling and Simulation for Dynamic Systems	
Course Code: MRA-113 Contact Hours: L-3 T-0 P-2 Course Category: DEC	Credits: 4 Semester: 1

Introduction: Modelling and Simulation is the use of models to develop data as a basis for making managerial or technical decisions.

Course Objectives: The objectives of this course are to

- Define the basics of simulation modelling and replicating the practical situations in organizations
- Generate random numbers and random variates using different techniques.
- Develop simulation model using heuristic methods.
- Analysis of Simulation models using input analyzer, and output analyser
- Explain Verification and Validation of simulation model.
- The students are to be provided hands on practical exposure on topics covered in the course.

Pre-Requisites: Engineering Mathematics

Course Outcomes: Having successfully completed this course, the student will be able to

- Understand Modelling & Simulation concepts
- Understand and apply the concepts of M&S to develop their own M&S applications
- The practical sessions will improve visualization of the concepts taught in theory.

Pedagogy: Classroom teaching is supported by White board, black board, chalks, markers, projector and screen. The hand written notes, PowerPoint slides and assignments will be provided to the students and also mailed to them. The students can also raise their issues related to the course in the class and mail.

Class room teaching is consequently supported by practical sessions and assignments / projects given in labs during practical sessions.

Contents:

	11 Hours
System Modeling: Concept of System and environment, Stochastic activities, Continuous and discrete systems, Types of Models, Principles of modeling, System studies and analysis, Advantages and disadvantages of simulation, Decision making with simulation, Numericals.	
UNIT II	11 Hours
System Simulation: Techniques of simulation, Monte Carl.o method, Experimental nature of simulation, Numerical computation techniques, Distributed lag models, Cobweb models Continuous system models, Analog and Hybrid simulation, Feedback systems, Computers	

in simulation studies, Simulation software packages. System Dynamics: Exponential Growth and Decay models, Logistic curves, System dynamics diagrams, Time delay representation, Examples.	
UNIT III	10 Hours
Probability Concepts in Simulation: Stochastic variables, discrete and continuous probability functions, Random numbers, Methods of generation of Random numbers, Queuing disciplines, Measures of queues, Mathematical solutions of queuing problems, server utilization and Grade of service. Simulation software: Comparison of simulation packages with programming languages, classification of simulation software, Description of a general-purpose simulation package- Design of scenario and modules, dialog box, database, animation, plots and output, interfacing with other software, summary of results. Examples with MATLAB/ AWESIM / ARENA.	
UNIT IV	10 Hours
Analysis of Simulation output: Importance of the variance of the sample mean, Procedure for estimating mean and variance, Subinterval method, Replication Method, Regenerative method; Variance reduction techniques, Start up policies, Stopping rules, Statistical inferences, Design of experiments. Simulation of Manufacturing Systems: Objective of Simulation in Manufacturing, Modeling system randomness, A simulation case study of manufacturing system.	

Text Books	
1.	Geoffrey Gordon, “System Simulation”, Prentice Hall India, 2015.
2	W. David Kelton et al, “Simulation with Arena”, 6th edition, McGraw-Hill, Boston, MA, 2014
3	Robert E. Shannon, “System Simulation: The Art and Science”, Prentice Hall India. 1975.
Reference Books	
1.	Charles M Close and Dean K. Frederick Houghton Mifflin, “Modelling and Analysis of Dynamic Systems”, TMH, 2001.
2.	Allan Carrie, “Simulation of manufacturing”, John Wiley & Sons, 1988.
3.	Sheldon M. Ross “Simulation”, Elsevier Academic Press, New York, 2012.

Robot Sensing and Vision	
Course Code: MRA-115 Contact Hours: L-3 T-0 P-2 Course Category: DEC	Credits: 4 Semester: 1

Introduction: The course will start with a brief introduction to robots and robotics. The motivation behind keeping robots in modern industries will be discussed. After providing a brief history of robotics, different components of a robotic system will be identified. The method of determining degrees of freedom of a robotic system will be discussed with some examples. After classifying the robots based on certain criteria, workspace analysis of manipulators will be carried out. Applications of robots in different areas like in manufacturing units, medical science, space, and others, will be discussed. Various methods of robot teaching will be explained with some suitable examples. Economic analysis will be conducted to decide whether we should purchase a robot. Both forward and inverse kinematics problems will be solved with the help of some suitable examples. To ensure smooth variation of joint angles of the robot, trajectory planning schemes will be explained.

Course Objectives: The objectives of this course are:

- To learn kinematics and dynamics
- To develop controllers for tracking a desired trajectory by a robot
- To learn computer vision for robot motion control

Pre-Requisites: Basic knowledge of dynamics and control

Course Outcomes:

- To learn about kinematics and dynamics
- To design controllers for tracking control of a robot
- To apply computer vision for motion control of robotic systems

Pedagogy: Classroom teaching is supported by White board, black board, chalks, markers, projector and screen. The hand written notes, PowerPoint slides and assignments will be provided to the students and also mailed to them. The students can also raise their issues related to the course in the class and mail.

Contents:

UNIT I	11 Hours
Automation and Robotics, Basic Structure of Robots, Robot Anatomy, Classification of Robots, Fundamentals about Robot Technology, Factors related to use Robot Performance, Basic Robot Configurations and their Relative Merits and Demerits, the Wrist & Gripper Subassemblies.	

UNIT II	11 Hours
Kinematics of Robot Manipulator: Direct Kinematics problem, Geometry Based Direct kinematics problem, Co-ordinate and vector transformation using matrices, Rotation matrix, Inverse Transformations, Problems, Composite Rotation matrix, Homogenous Transformations,, Robotic Manipulator Joint Co-Ordinate System, Euler Angle & Euler Transformations, RollPitch-Yaw(RPY) Transformation,. D-H Representation & Displacement Matrices for Standard Configurations, Jacobian Transformation in Robotic Manipulation	
UNIT III	10 Hours
Trajectory Planning: Trajectory Interpolators, Basic Structure of Trajectory, Interpolators, Cubic Joint Trajectories. General Design Consideration on Trajectories:- 4-3-4 & 3-5-3 Trajectories Dynamics of Robotic Manipulators: Introduction,. Preliminary Definitions, Generalized Robotic Coordinates, Jacobian for a Two link Manipulator, Euler Equations, The Lagrangian Equations of motion. Application of Lagrange–Euler Dynamic Modeling of Robotic Manipulators: - Velocity of Joints, Kinetic Energy of Arm, Potential Energy of Robotic Arm, The Lagrange , Two Link Robotic Dynamics with Distributed Mass	
UNIT IV	10 Hours
Control design for Robotic System: Control Loops of Robotic Systems, trajectory, velocity and force control, Computed Torque control, Linear and Nonlinear controller design of robot. Robot Sensing & Vision: Use of Sensors and Sensor Based System in Robotics, Machine Vision System, Description, Sensing, Digitizing, Image Processing and Analysis and Application of Machine Vision System, Robotic Assembly Sensors and Intelligent Sensors, visual servo-control. Application of Robotics: Applications of robotics in active perception, medical robotics, autonomous vehicles, and other areas.	

Text Books	
1.	John J. Craig, *Introduction to Robotics-*, Addison Wesley Publishing, 3rd edition, 2010
2.	Donald R. Franceschetti, Principles of Robotics & Artificial Intelligence, Grey House Publishing, 2018
3	Robotics: Fundamental Concepts and Analysis, Oxford University Press, Second reprint, May 2008.
Reference Books	
1.	Klafter, Chmielewski and Negin, *Robotic Engineering - An Integrated approach,*, PHI, 1st edition, 2009.
2.	Peter C., Robotics, Vision and Control: Fundamental Algorithms in MATLAB, Springer Tracts in Advanced Robotics, 2011.
3.	Lewis F.L., Dawson D.M. and Abdallah C.T., Robot Manipulator Control: Theory and Practice, Marcel Dekker Inc., NY, USA, 2004.

Statistical Fundamentals of Data Sciences	
Course Code: MRA-117 Contact Hours: L-3 T-0 P-2 Course Category: DCC	Credits: 4 Semester: 1

Introduction: Statistics is one of the popularly known disciplines that is mainly focused on data collection, data organization, data analysis, data interpretation, and data visualization. Earlier, statistics was practiced by statisticians, economists, business owners to calculate and represent relevant data in their field. Nowadays, statistics has taken a pivotal role in various fields like data science, machine learning, data analyst role, business intelligence analyst role, computer science role, and much more.

Course Objectives: The objectives of this course are:

- To give an overview of the statistical data and data handling
- To familiarize students with the importance and types of analysis
- To enable students how to use the software used for the hypothesis testing

Pre-Requisites: Basic knowledge of mathematics and statistics

Course Outcomes: After the completion of this course the student will be able to:

- Knowledge about the data and data handling
- Knowledge about the various analysis of the data for interpretation of
- Outcomes and hypothesis testing knowledge

Pedagogy: Classroom teaching is supported by Whiteboard, blackboard, chalks, markers, projector and screen. The handwritten notes, PowerPoint slides and assignments will be provided to the students and also mailed to them. The students can also raise their issues related to the course in the class and by mail.

Contents:

UNIT I	11 Hours
Fundamentals of Statistics – Introduction to Data, primary and secondary data, population, sample, distribution curves, variability,variance, standard deviation, skewness and kurtosis, probability, measures and descriptors of data.	
UNIT II	11 Hours
Unit 2 Statistical Factor Analysis for Data Sciences- Reliability test of data, Descriptive data analysis, Exploratory factor analysis, Confirmatory Factor Analysis, Statistical Analysis of Data Sciences using any popular software.	
UNIT III	10 Hours
Regression Analysis – Dependent and Independent variables of data set, Correlation among the factors, Analysis of correlation, equation of regression analysis for data sciences, ANOVA	
UNIT IV	10 Hours
Hypothesis Testing – Framing hypothesis, null hypothesis, alternative hypothesis, testing of hypothesis, model fit, statistical software for model formulation and results of data.	

Text Books	
1	Sanjeev J. Wagh, Manisha S. Bhende, Anuradha D. Thakare, Fundamentals of Data Science, 1st Edition, Chapman and Hall, 2021.
2	Jianqing Fan , Runze Li, Cun-Hui Zhang, Hui Zou, “Statistical Foundations of Data Science”, Chapman & Hall, 2020.
1	Avrim Blum, John Hopcroft, and Ravindran Kannan “Foundations of Data Science”, industan Book Agency, 2018
2	Göran Kauermann, Helmut Küchenhoff, Christian Heumann, “Statistical Foundations, Reasoning and Inference: For Science and Data Science (Springer Series in Statistics)”, Springer Nature Switzerland AG, 2021.

Pattern Recognition and Vision	
Course Code: MRA-102 Contact Hours: L-3 T-0 P-2 Course Category: DCC	Credits: 4 Semester: 2

Introduction:

Pattern recognition analyzes incoming data and tries to identify patterns. While explorative pattern recognition aims to identify data patterns in general, descriptive pattern recognition starts categorizing the detected patterns. Hence, pattern recognition deals with both of these scenarios, and different pattern recognition methods are applied depending on the use case and form of data. Consequently, pattern recognition is not *one* technique but rather a broad collection of often loosely related knowledge and techniques. Pattern recognition capability is often a prerequisite for intelligent systems.

Course Objectives: The objectives of this course are :

- To develop the mathematical tools required for the pattern recognition.
- To impart understanding of the neural networks
- To impart knowledge of vision fundamentals.

Pre-**Requisites:** Higher Engineering Mathematics.

Course Outcomes: On completion of this course students should be able to:

- Explain and compare a variety of pattern classification, structural pattern recognition, and pattern classifier combination techniques.
- Apply performance evaluation methods for pattern recognition
- Implement simple pattern classifiers, classifier combinations, and structural pattern recognizers.
- Explain and differentiate between computer vision and human vision
- Design Support Vector Machine for classification
- Implement various image processing methods

Pedagogy: Classroom teaching is supported by White board, black board, chalks, markers, projector and screen. The hand written notes, PowerPoint slides and assignments will be provided to the students and also mailed to them. The students can also raise their issues related to the course in the class and mail.

Consequently, classroom teaching is supported by practical sessions and assignments/projects given in labs during practical sessions.

Contents:

UNIT I	11 Hours
INTRODUCTION Pattern Recognition Systems, Example,The Design Cycle, Learning and Adaptation BAYESIAN DECISION THEORY Bayesian Decision Theory-Continuous Features, Minimum-Error-Rate Classification, Classifiers, Discriminant Functions, and Decision Surfaces,	

Discriminant Functions for the Normal Density, Error Probabilities and Integrals, Error Bounds for Normal Densities, Bayes Decision TheoryDiscrete Features, Missing and Noisy Features, Bayesian Belief Networks, Compound Bayesian Decision Theory and Context	
UNIT II	11 Hours
MAXIMUM-LIKELIHOOD AND BAYESIAN PARAMETER ESTIMATION Maximum-Likelihood Estimation, Bayesian Estimation, Sufficient Statistics, Problems of Dimensionality, Component Analysis and Discriminants, Expectation-Maximization (EM) LINEAR DISCRIMINANT FUNCTIONS Linear Discriminant Functions and Decision Surfaces, Generalized Linear Discriminant Functions, Minimizing the Perceptron Criterion Function, Relaxation Procedures, Nonseparable Behavior, Minimum Squared-Error Procedures, The Ho-Kashyap Procedures, Linear Programming Algorithms, Support Vector Machines,	
UNIT III Image formation Introduction to computer vision Human vision Image formation How machine sees and recognizes things , Applications,Light in Space, Light at Surfaces, geometric image features, analytical image features Filtering and smoothing operations, Morphological techniques, Feature Extraction, Lines and corners detection, Identification of basic geometrical structures, Colorandtexture analysis, Color models, kinds of texture, texture feature extraction, geometrical methods	10 Hours
UNIT IV	10 Hours
Image Segmentation and Image Classification :Unsupervised segmentation based on regions and edges, Supervised classification, theoretical decision methods, statistical methods, neural networks, Stereoscopic Vision. Camera calibration and camera systems, epipolar geometry, image rectification, search for correspondences, triangulation.	

Text Books	
1.	Trevor Hastie, Robert Tibshirani, Jerome H. Friedman, “The Elements of Statistical Learning”, Springer, 2017.
2.	Bishop, “Pattern Recognition and Machine Learning”, Springer, 2011.
3.	Computer vision : a modern approach - Forsyth, David A; Ponce, Jean, Pearson Education, cop. 2012. ISBN: 9780273764144
Reference Books	
1.	Richard O. Duda, Peter E. Hart, David G. Stork, “Pattern Classification”, 2nd Edition John Wiley & Sons, 2021.
2.	Robert J Schalkoff, “Pattern Recognition: Statistical, Structural and Neural Approaches” Wiley; 1st edition 2007.

Advanced Robotics	
Course Code: MRA-104 Contact Hours: L-3 T-0 P-2 Course Category: DCC	Credits: 4 Semester: 2

Introduction: Advanced Robotics is a combination of sophisticated programming and powerful hardware that make use of smart sensor technology to interact with the real world.

Course Objectives: The objectives of this course are:

1. Provide an understanding of the role of automation technology in industry.
2. Develop high level mathematical skills for analysis and synthesis of an articulated arm robot.
3. Develop skills in the selection and application of different robots for various tasks.

Pre-Requisites: Robotics Engineering

Course Outcomes: On completion of this course students should be able to:

1. Design multi-jointed serially linked manipulators.
2. Identify intermediate arm matrices describing individual links.
3. Determine the joint angle equations to attain a global position and attitude of the end effector.
4. Determine how to identify velocity profiles of individual joints to achieve a desired global spatial trajectory.
5. Relate driving currents and torques needed to control this trajectory for electrically-driven robots.

Pedagogy: Classroom teaching is supported by White board, black board, chalks, markers, projector and screen. The hand written notes, PowerPoint slides and assignments will be provided to the students and also mailed to them. The students can also raise their issues related to the course in the class and mail.
Class room teaching is consequently supported by practical sessions and assignments / projects given in labs during practical sessions.

Contents:

UNIT I	11 Hours
Review of serial, parallel robotic manipulators, sensors ans vision: Kinematic chain; Degrees of freedom; Forward and Inverse Kinematics; Dynamics, sensors, internal sensors, external sensors, vision Different types of wheeled mobile robots and walking machines: Number of wheels; Type of wheels (e.g., Omni directional, torus, etc.); legged robots (Biped, Quadruped, etc.).	
UNIT II	11 Hours

Algorithmic issues for inverse and forward kinematics of robotic systems: Efficiency (Computational Count); Accuracy in numerical calculations; Numerical stability (tolerances in numerical solutions of algebraic and differential equations). Kinematic design of serial and parallel robots based on singularity and workspace: Definition of workspace; How to calculate it? Meaning of singularity; How to calculate it?	
UNIT III	10 Hours
Manipulability and dexterity: Definitions; How to use them? Kinematics and Dynamics algorithms -Inverse, forward: Jacobian computation, Jacobian using DeNOC, Forward and inverse velocity analysis and acceleration analysis, Formulation of dynamic model (equations of motion); Newton-Euler algorithm; Use of computer-orientated approaches, e.g., Decoupled Natural Orthogonal Complement (DeNOC) based; Inverse dynamics; Forward dynamics; , Mechanical design (choice of material, cross-section, etc.)	
UNIT IV	10 Hours
Control of robotic systems: Basics of control; PD, PI and PID control; Transfer function and state-space representation, performance and stability of feedback control, PID control of a moving block, state feedback control, Joint control, Force control; Adaptive control Mechanical design of robot links and joints: Design from mechanical failure and stiffness criteria; Consideration of natural frequency in design.	
Text Books	
1.	Ghosal, A., “Robotics”, Oxford, New Delhi, 2016
2.	S.K.Saha, “Introduction to Robotics”, Tata McGraw Hill, 2017.
3.	Saeed B. Nikku, “Introduction to Robotics, Analysis, Control, Application” 2ndEdition, 2011
4.	Roland Siegwart, Illah R Nourbakhsh, Davide Scaramuzza, “Autonomous Mobile Robots”, PHI, 2011
Reference Books	
1.	Craig, J.J., “Introduction to Robotics: Mechanics and Control”, Pearson, Delhi, 3rd Edition, 2009
2.	Tsai, L, “Robot Analysis”, John Wiley & Sons, Singapore, 19995Saha, S.K., “Introduction to Robotics”, Tata McGraw Hill, 4th reprint, 2010

Sensors and Actuators	
Course Code: MRA-106	Credits: 4
Contact Hours: L-3 T-0 P-2	Semester: 2
Course Category: DEC	

Introduction: This course is designed with an aim of educating students in microtechnology and its use to fabricate sensors and systems. The students will have an exposure to sensors and its importance in the real world. The students will also able to understand how to fabricate some of those sensors. They will have an exposure towards how to fabricate the sensors and its application in real world and understand and also learn modern day microsensors and micro actuators, how to simulate some of those sensors and characterize before fabricating it.

Course Objectives: The objectives of this course are

- To learn the basic concepts of sensors and actuators.
- To learn designing and fabrication of sensors and actuators.

Pre-Requisites: Basic knowledge of sensors and actuators

Course Outcomes: After successful completion of the course, the students will be able to -

- To understand the basics of Sensors and actuators.
- To understand thin film deposition techniques.
- Gain knowledge about various gas sensors.
- Design and fabricate various microsensors.
- Simulate and optimize sensors and actuators.

Pedagogy: Classroom teaching is supported by Whiteboard, blackboard, chalks, markers, projector, and screen. The handwritten notes, PowerPoint slides, and assignments will be provided to the students and also mailed to them. The students can also raise their issues related to the course in the class and by mail.

Contents:

UNIT I	10Hours
Introduction: Basics of Energy Transformation: Transducers, Sensors, and Actuators, Understanding of thin-film physics: Application in MOSFET and its variants	
UNIT II	11 Hours
Thin Film Deposition Techniques: Chemical Vapor Deposition, Physical Vapor Deposition (Thermal Deposition, E-beam Evaporation, Sputtering, Pulsed Laser Deposition), Basic understanding of Photolithography for pattering layer. Detailed overview of Etching methods.	
UNIT III	10 Hours
Gas Sensors: Optical gas sensor, Metal oxide semiconductor gas sensor, Field effect transistor gas sensor, Piezoelectric gas sensor, Polymer gas sensor, Nano-structured based gas sensors	
UNIT IV	11 Hours
Design and fabrication process of Microsensors: Force Sensors, Pressure Sensors, Strain gauges, and practical applications, Explain working principles of Actuators. Piezoelectric and Piezoresistive actuators, micropumps and micro actuators with practical applications, Simulation, Optimization, and characterization of various sensors, Understanding of Sensor Interfacing with Microprocessor	

Text Books

1	Stefan Johann Rupitsch, “Piezoelectric Sensors and Actuators”, Fundamentals and Applications, Springer, 2018
2	Ernest O. Doebelin, “ Measurement systems Application and Design”, International Student Edition, VI Edition, Tata McGraw-Hill Book Company, 2011.
3	Ramón Pallás-Areny, John G. Webster, “Sensors and Signal Conditioning, Wiley- Blackwell, 2nd Edition, 2008
1	Clarence W. de Silva “Sensors and Actuators: Engineering System Instrumentation”, Second Edition, 2015.
2	J.D. Plummer, M.D. Deal, P.G. Griffin, “Silicon VLSI Technology: Fundamentals, Practice and Modeling”,Pearson, 1st edition, 2010.
3	Stephen D. Senturia, “Microsystem Design”, Kluwer Academic Publisher, 2001.
4	Marc J Madou, “Fundamentals of Microfabrication: The Science of Miniaturization, Second Edition”, CRC Press, 2002.
5	www.nptel.ac.in
6	https://ocw.mit.edu

Mathematical Techniques for Control and DSP	
Course Code: MRA-108 Contact Hours: L-3 T-0 P-2 Course Category: DEC	Credits: 4 Semester: 2

Introduction: The Mathematical Techniques for Control and DSP deep dives into topics like basic signals, systems & signal space, sampling theorems, signal representation, and wavelets. This way, the course will make student to theoretically adept in signal processing.

Course Objectives: The objectives of this course are

- To introduce the basic concepts and techniques for processing signals on a computer. By the end of the course, students will be familiar with the most important methods in DSP, including digital filter design, transform-domain processing and importance of Signal Processors.
- The course emphasizes intuitive understanding and practical implementations of the theoretical concepts.
- To produce graduates who understand how to analyse and manipulate digital signals and have the fundamental Mat lab programming knowledge to do so.

Pre-Requisites: Engineering Mathematics and numerical techniques.

Course Outcomes: Having completed this course student will be able to:

- Obtain different Continuous and Discrete time signals.
- Calculate Z-transforms for discrete time signals and system functions.
- Calculate discrete time domain and frequency domain of signals using discrete Fourier series and Fourier transform.
- Develop Fast Fourier Transform (FFT) algorithms for faster realization of signals and systems.
- Design different kinds of interpolator and decimator.

Pedagogy: Classroom teaching is supported by White board, black board, chalks, markers, projector and screen. The hand written notes, PowerPoint slides and assignments will be provided to the students and also mailed to them. The students can also raise their issues related to the course in the class and mail.

Contents:

UNIT I	11 Hours
Review of vector spaces, inner product spaces, orthogonal projections, state variable representation, Review of probability and random processes, Signal geometry and applications,	
UNIT II	11 Hours

Sampling theorems multirate signal processing decimation and expansion, Sampling rate conversion and efficient architectures, design of high decimation and interpolation filters, Multistage designs. Introduction to 2 channel QMF filter bank, M-channel filter banks, overcoming aliasing, amplitude and phase distortions.	
UNIT III	10 Hours
Sub band coding and Filter Designs: Applications to Signal Compression, Introduction to multiresolution analysis and wavelets, wavelet properties, Wavelet decomposition and reconstruction, applications to de noising.	
UNIT IV	10 Hours
Derivation of the KL Transform, properties and applications. Topics on matrix calculus and constrained optimization relevant to KL Transform derivations. Fourier expansion, properties, various notions of convergence and applications	

Text Books

1.	G. Strang, "Introduction to Linear Algebra", Springer, 2016.
2.	H. Stark & J. W. Woods, "Probability and Random Processes with Applications to Signal Processing", Pearson Education, 2014.

Reference Books

1.	A. Boggess & F. J. Narcowich, "A First Course in Wavelets with Fourier Analysis", Prentice Hall, 2009.
2.	Rainer Dahlhaus, Jürgen Kurths, "Mathematical Methods and Algorithms for Signal Processing", Springer, 2010.
3.	P. P. Vaidyanathan, "Multirate systems and filter banks", Prentice Hall, 2000.

Deep Learning	
Course Code: MRA-110	Credits: 4
Contact Hours: L-3 T-0 P-2	Semester: 2
Course Category: DEC	

Introduction: This course is an introduction to deep learning, a branch of machine learning concerned with the development and application of modern neural networks. Deep learning algorithms extract layered high-level representations of data in a way that maximizes performance on a given task. For example, asked to recognize faces, a deep neural network may learn to represent image pixels first with edges, followed by larger shapes, then parts of the face like eyes and ears, and, finally, individual face identities. Deep learning is behind many recent advances in AI, including Siri's speech recognition, Facebook's tag suggestions, and self-driving cars.

Course Objectives: The objectives of this course are

1. Introduce students to the optimization techniques.
2. Introduce students to various types of Neural Networks
3. To enable students to apply Neural Networks efficiently
4. Train students to develop deep learning algorithms.

Pre-Requisites: Introduction to Machine Learning

Course Outcomes: After successful completion of the course, the students will be able to –

1. Use the Deep learning Techniques and tools to design deep learning algorithms
2. Describe various types of neural networks.
3. Optimize the neural networks for efficient algorithms.

Pedagogy: Classroom teaching is supported by Whiteboard, blackboard, chalks, markers, projector, and screen. The handwritten notes, PowerPoint slides, and assignments will be provided to the students and also mailed to them. The students can also raise their issues related to the course in the class and by mail.

Contents:

UNIT I	10Hours
Introduction to Deep Learning, Bayesian Learning, Decision Surfaces, Linear Classifiers, Linear Machines with Hinge Loss, Optimization Techniques, Gradient Descent, Batch Optimization	
UNIT II	11 Hours
Introduction to Neural Network, Multilayer Perceptron, Back Propagation Learning, Unsupervised Learning with Deep Network, Autoencoders, Convolutional Neural Network, Building blocks of CNN, Transfer Learning	
UNIT III	10 Hours
Revisiting Gradient Descent, Momentum Optimizer, RMSProp, Adam, Effective training in Deep Net- early stopping, Dropout, Batch Normalization, Instance Normalization, Group Normalization, Fully Connected CNN etc.	
UNIT IV	11 Hours
Classical Supervised Tasks with Deep Learning, Image Denoising, Semantic Segmentation, Object Detection etc., LSTM Networks, Generative Modeling with DL, Variational Autoencoder.	

Text Books	
1	Ian Goodfellow, Yoshua Benjio, Aaron Courville, “Deep Learning”, The MIT Press, 2016.
2	Richard O. Duda, Peter E. Hart, David G. Stork, “Pattern Classification” John Wiley & Sons Inc, 2021.
3	Kelleher, John D., “Deep Learning”, The MIT Press 2019.
1	A. Ravindran, K. M. Ragsdell , and G. V. Reklaitis, “Engineering Optimization: Methods and Applications”, John Wiley & Sons, Inc. , 2016
2	Umberto Michelucci, “Advanced Applied Deep Learning: Convolutional Neural Networks and Object Detection”, Apress, 2019
3	www.nptel.ac.in
4	https://ocw.mit.edu

Neural Network and Fuzzy Logic	
Course Code: MRA-112 Contact Hours: L-3 T-0 P-2 Course Category: DEC	Credits: 4 Semester: 2

Introduction: This course introduces students to neural networks and fuzzy theory from an engineering perspective. This is a hands-on subject where students are given integrated exposure to professional practice. These areas include identification and control of dynamic systems, neural networks and fuzzy systems can be implemented as model-free estimators and/or controllers. As trainable dynamic systems, these intelligent control systems can learn from experience with numerical and linguistic sample data.

Course Objectives: The main objectives of this course are

- Introduce students to the various neural network and fuzzy systems models.
- Reveal different applications of these models to solve engineering and other problems.
- Introduce the theory and applications of artificial neural network and fuzzy systems to engineering applications with emphasis on image processing and control.
- Discuss neural networks and fuzzy systems, architectures, algorithms and applications, including Back-propagation, BAM, Hopfield network, Competitive Learning, ART, SOFM, Fuzzy inference methods and expert systems.

Pre-Requisites: NIL

Course Outcomes: Upon completion of the course, the student will be able to

- Comprehend the concepts of feed forward neural networks.
- Analyze the various feedback networks.
- Understand the concept of fuzziness involved in various systems and fuzzy set theory.
- Comprehend the fuzzy logic control and adaptive fuzzy logic and to design the fuzzy control using genetic algorithm.
- Analyze the application of fuzzy logic control to real time systems.

Pedagogy: Classroom teaching is supported by White board, black board, chalks, markers, projector and screen. The hand written notes, PowerPoint slides and assignments will be provided to the students and also mailed to them. The students can also raise their issues related to the course in the class and mail.

Class room teaching is consequently supported by practical sessions and assignments / projects given in labs during practical sessions.

Contents:

UNIT I	11 Hours
Network: History, Overview Of Biological Neuro-System, Mathematical Models Of Neurons, ANN architecture, Learning Rules, Learning Paradigms-Supervised, Unsupervised and Reinforcement Learning, ANN training Algorithms-perceptions, Training rules, , Back Propagation Algorithm, K Means clustering, Probabilistic Neural Network, Multilayer Perception Model, Hopfield Networks, Associative Memories, Applications of Artificial Neural Networks.	
UNIT II	11 Hours
FUZZY LOGIC: Introduction to fuzzy logic, Classical and fuzzy sets: Overview of Classical Sets, Membership Function and Fuzzy rule Generation. Operation on Fuzzy Sets: Compliment, Intersection, Unions, Combinations of Operations, Aggregation Operations Fuzzy Arithmetic: Fuzzy numbers, Linguistic variables, arithmetic operations on Intervals & Numbers, Lattice of Fuzzy Numbers, Fuzzy Equations.	
UNIT III	10 Hours
Fuzzy Logic: Classical Logic, Multivalued logics, Fuzzy Propositions, Fuzzy Qualifiers, Linguistic Hedges. Uncertainty based Information: Information& Uncertainty, Nonspecificity of Fuzzy & Crisp Sets, and Fuzziness of Fuzzy Sets.	
UNIT IV	10 Hours
Introduction of Neuro-Fuzzy Systems, Architecture of Neuro Fuzzy Networks. Application of Fuzzy Logic & Neural Networks in Intelligent Machine Design.	

Text Books	
1.	Ross T.J., “Fuzzy Logic with Engineering Applications”, Wiley India, 2011
2.	Lee H.H., “First Course on Fuzzy Theory & Application”, Springer Publications, 2004.
Reference Books	
1.	Yen J. & Langari R., “Fuzzy Logic—Intelligence Control & Information”, Pearson Education Asia, 1998.
2.	Haykins S., “Neural Networks and Learning Machines”, Pearson Education, 2009
3.	Kumar S., “Neural Networks”, Tata Mc GrawHill Publications, 2004.

Optimization for Engineering	
Course Code: MRA-114 Contact Hours: L-3 T-1 P-0 Course Category: DEC	Credits: 4 Semester: 2

Introduction: Optimization is the process of obtaining the best result under given circumstances. This course covers theory and applications for optimization in engineering.

Course Objectives: The aim of this course is to introduce the fundamental concepts of engineering optimization techniques.

- To understand the theory of optimization methods and algorithms developed for solving various types of optimization problems
- To develop and promote research interest in applying optimization techniques in problems of Engineering and Technology
- To apply the mathematical results and numerical techniques of optimization theory to concrete Engineering problems

Pre-Requisites: Basic knowledge of mathematics

Course Outcomes: Having successfully completed this course, the student will be able to

- Formulate optimization problems
- Understand and apply the concept of optimality criteria for various type of optimization problems
- Solve various constrained and unconstrained problems in single variable as well as multivariable

Pedagogy: Classroom teaching is supported by White board, black board, chalks, markers, projector and screen. The hand written notes, PowerPoint slides and assignments will be provided to the students and also mailed to them. The students can also raise their issues related to the course in the class and mail.

Contents:

UNIT I	11 Hours
Mathematical Background: Historical Development; Engineering applications of Optimization; Objective function; Constraints and Constraint surface; Formulation of design problems as mathematical programming problems; Classification of optimization problems based on nature of constraints, objective functions; Optimization techniques –classical and advanced techniques. Convex sets and Convex Cones-Introduction and preliminary definition -Convex sets and properties -Convex Hulls -Extreme point -Separation and support of convex sets -Convex Polytopes and Polyhedra -Convex cones -Convex and concave functions -Basic Properties-Differentiable convex functions -Generalization of convex functions Hessian matrix formulation; Eigen values; Kuhn-Tucker Conditions; Examples	
UNIT II	11 Hours

Dynamic Programming: Sequential optimization; Representation of multistage decision process; Types of multistage decision problems; Concept of sub optimization and the principle of optimality; Recursive equations –Forward and backward recursions; Computational procedurein dynamic programming (DP); Discrete versus continuous dynamic programming; Multiple state variables; curse of dimensionality in DP. Integer linear programming: Concept of cutting plane method; Mixed integer programming; Solution algorithms; Examples.

UNIT III	10 Hours
Nonlinear Programming: Minimization and maximization of convex functions -Local &Global optimum –Convergence -Speed ofconvergence unconstrained optimization: One dimensional minimization --Gradient methods -Steepest descent method Geometric Programming: Introduction, Unconstrained minimization problems, solution of unconstrained problem from arithmetic-geometric inequality point of view, Generalized polynomial optimization, Applications of geometric problems	
UNIT IV	10 Hours
Novel methods for Optimization: Introduction to simulated annealing, selection of simulatedannealing parameters, simulated annealing algorithm; Genetic Algorithm (GA), Design of GA, Key concepts of GA, Examples of simulated algorithm, genetic annealing and Neural Network method.	

Text Books	
1.	David G Luenberger, “Linear and Non-Linear Programming”, 2nd Ed, Addison-Wesley, 2016.
2.	S.S. Rao, “Engineering Optimization; Theory and Practice”; Revised 3rd Edition, New Age International Publishers, New Delhi, 2009.
Reference Books	
1.	S.M. Sinha, “Mathematical programming: Theory and Methods”, Elsevier, 2006.
2.	Hillier and Lieberman, “Introduction to Operations Research”, McGraw-Hill, 8th edition, 2014.
3.	Saul I Gass, “Linear programming”, McGraw-Hill, 5th edition, 2010.
4.	Bazarra M.S., Sherali H.D. & Shetty C.M., “Nonlinear Programming Theory and Algorithms”, John Wiley, New York, 2013.
5.	Kalyanmoy Deb, “Optimization for Engineering: Design-Algorithms and Examples”, PHI, 2012.

IIT Bombay Syllabus: (A FIRST COURSE IN OPTIMIZATION)

Motivation. mathematical review , matrix factorizations, sets and sequences, convex sets and functions, linear programming and simplex method, Weierstrass' theorem, Karush Kuhn Tucker optimality conditions, algorithms, convergence, unconstrained optimization, Line search methods, method of multidimensional search, steepest descent methods, Newton's method, modifications to Newton's method , trust region methods, conjugate gradient methods, quasi-Newton's methods. constrained optimization, penalty and barrier function methods, augmented Lagrangian methods, polynomial time algorithm for linear programming, successive linear programming, successive quadratic programming.

IIT Mandi

Convex sets and function, Introduction to optimization, Model formulation, Simplex based techniques, Concept of duality.

Quadratic Programming Problem, Geometric Programming, Separable Programming.

Direct and Gradient based search techniques for single and multi variable unconstrained optimization problems.

Penalty and barrier function based techniques for constrained optimization problems.

Evolutionary Optimization Techniques, Engineering application of Optimization techniques.

DTU Syllabus

Unit I

Introduction to Optimization - Introduction, Engineering Applications, Problem Statement, Classification of optimization problems.

Unit II

Classical Optimization techniques - Unconstrained Optimization: Optimizing Single- Variable Functions, conditions for Local Minimum and Maximum, Optimizing Multi- Variable Functions. Constrained Optimization: Optimizing Multivariable Functions with Equality Constraint: Lagrange Multipliers Method. Constrained Multivariable Optimization with inequality constrained: Kuhn-Tucker Necessary conditions, Kuhn –Tucker Sufficient Conditions.

Unit III

Non-Linear Programming- One-Dimensional Methods: Elimination Methods, Interpolation Methods, Direct Root Methods; Quasi-Newton Method, Secant Method. Docotomous search method, Fabonacci method, Golden section method, Unconstrained Optimization Techniques: Direct search methods, Descent Methods. Constrained Optimizations: Direct and Indirect methods.

Unit IV

Dynamic Programming: Concept of Dynamic Programming, Multi stage Decision Process, Calculus Method and Tabular Method.

Unit V

Integer Programming – Branch and bound Method, Cutting Plane Method.46Introduction to Advanced Optimization Techniques - Genetic Algorithms (GA), Simulated Annealing, Particle Swarm Optimization (PSO), Ant Colony Optimization (ACO), Neural Network, Separable Programming, Stochastic Programming, Monte Carlo Simulation.

Intelligent Systems and Interfaces	
Course Code: MRA-116 Contact Hours: L-3 T-0 P-2 Course Category: DEC	Credits: 4 Semester: 2

Introduction: Intelligent systems and interfaces have become more of a reality than being part of a sci-fi movie. Natural Language Processing (NLP) is one of the integral part of such interfaces. Statistics and Machine Learning (ML) have been used extensively to solve several problems in NLP. This course aims to introduce basic concepts in NLP, and to discuss statistical and ML models to solve NLP tasks. The course will focus on very specific NLP tasks and corresponding models.

Course Objectives:

1. To focus on building intelligent systems that involve a combination of computers and humans collaborating seamlessly over the Internet.
2. To gather and analyze data and communicate with other systems.
3. To enable computers to perform such intellectual tasks as decision making, problem solving, perception, understanding human communication.
4. The ability to design and develop systems that exploit artificial intelligence techniques such as machine learning, fuzzy logic, natural language processing, etc.

Pre-Requisites: As a prerequisite, subject require a sound knowledge of basic mathematics concepts to implement in software or systems. You must have a good catch on statistics, linear algebra, matrix, calculus, probability, programming languages and data modelling.

Course Outcomes: The outcomes of this subject are

1. Students will gain deep understanding of the basic artificial intelligence techniques.
2. Strategies and Actions used to produce the outcome.
3. Student shall learn about artificial intelligence techniques and intelligent systems.
4. Students shall learn about human and computer interaction.

Pedagogy: Classroom teaching is supported by White board, black board, chalks, markers, projector and screen. The hand written notes, PowerPoint slides and assignments will be provided to the students and also mailed to them. The students can also raise their issues related to the course in the class and mail.
Class room teaching is consequently supported by practical sessions and assignments / projects given in labs during practical sessions.

Contents:

UNIT I	11 Hours
Language Processing: Computational Phonology: Issues, Phonological rules, Mapping text to phones, Prosody in TTS, Probabilistic models of pronunciation and Spelling, N-Grams.	
UNIT II	11 Hours

<table>
<tr><td colspan="2">Syntax: Word classes and POS tagging, CFG for English, Lexicalized, and Probabilistic Parsing. Semantics: Semantic representation, Semantic and Lexical analysis, and Word sense disambiguation, IR.
Pragmatics: Discourse, Dialogue agents, Natural Language Generation and Machine translation.</td></tr>
<tr><td>UNIT III</td><td>10 Hours</td></tr>
<tr><td colspan="2">Machine Learning: Data Mining: Association rules, Clustering, Decision Trees. Text Mining. Synergetic techniques: Genetic algorithms and ANN techniques for machine learning. Applications to bioinformatics. Intelligent Interfaces: Incorporating Intelligence: Requirements, design issues.</td></tr>
<tr><td>UNIT IV</td><td>10 Hours</td></tr>
<tr><td colspan="2">Applications: Development of Intelligent interfaces for systems - Stand-alone systems like OS, Databases, Physical machines including robots. Web based applications like Tutoring systems, Web Mining, e-shopping.</td></tr>
</table>

<table>
<tr><td colspan="2">Text Books</td></tr>
<tr><td>1</td><td>Prentice Hal, Artificial Intelligence: A Modern Approach, by Stuart Russell and Peter Norvig , Third Edition, 2010.</td></tr>
<tr><td>2</td><td>DHS: Duda, Richard O., Peter E. Hart, and David G. Stork. Pattern Classification. John Wiley & Sons, 2012.</td></tr>
<tr><td>3</td><td>International Edition, Speech and Language Processing, by Dan Jurafsky and James Martin 3rd Edition, 2021</td></tr>
<tr><td colspan="2">Reference Books</td></tr>
<tr><td>1</td><td>Oviatt, Cohen: The Paradigm Shift to Multimodality in Contemporary Computer Interfaces, 2015</td></tr>
<tr><td>2</td><td>McGraw Hill Education, Machine Learning by Tom M. Mitchell</td></tr>
</table>

Industry 4.0	
Course Code: MRA-118 Contact Hours: L-3 T-0 P-2 Course Category: DEC	Credits: 4 Semester: 2

Introduction: The fourth era of change – Industry 4.0 – is driven by trends in connectivity, service orientation, advanced materials and processing technology, and collaborative advanced manufacturing networks; networks of advanced manufacturing devices controlled by computers combining them into a physical-digital environment. This change includes the entire value chain from raw materials to end-use to recovery, impacting business and support functions too

Course Objectives: The objectives of this course are:

*To give an introduction to the basics of Industry 4.0 and the fourth Industrial Revolution
*To familiarize the concepts of Industry 4.0 and related areas and technologies

Pre-Requisites: To have a basic knowledge of manufacturing in various domains of the industry.
To have a basic knowledge about automation and technologies for the manufacturing industries

Course Outcomes:

After successful completion of the course, the students will be able to-
* Knowledge of Industry 4.0 and its technologies
* Knowledge of cloud computing and data harnessing in Industry 4.0

Pedagogy: Classroom teaching is supported by Whiteboard, blackboard, chalks, markers, projector and screen. The handwritten notes, PowerPoint slides and assignments will be provided to the students and also mailed to them. The students can also raise their issues related to the course in the class and by mail.
Classroom teaching is consequently supported by practical sessions and assignments/projects given in labs during practical sessions.

Contents:

UNIT I	11 Hours
Introduction to Industry 4.0- The Various Industrial Revolutions, Digitalisation and the Networked Economy, Drivers, Enablers, Compelling Forces and Challenges for Industry 4.0, The Journey so far: Developments in USA, Europe, China and other countries , Comparison of Industry 4.0 Factory and Today's Factory	
UNIT II	11 Hours
IoT of Industry 4.0- Internet of Things (IoT), Introduction, Industrial Internet of Things (IIoT) & Internet of Services, Smart Manufacturing, Smart Devices and Products, Predictive Analytics	

UNIT III	10 Hours
Related technologies and Enablers of Industry 4.0- Cyberphysical Systems, Automation, Support System for Industry 4.0, Mobile Computing, Cyber Security, Related Disciplines	
UNIT IV	10 Hours
Resource based view of a firm, Data as a new resource for organisations- Harnessing and sharing knowledge in organisations, Cloud Computing Basics, Cloud Computing and Industry 4.0, Case Studies	
Text Books	
1. Industry 4.0, The Industrial Internet of Things, by Alasdair Gilchrist, 2016, Apress	
2. Industry 4.0, Managing the Digital Transformation, Alp Ustundag Emre Cevikcan, Springer	
Reference Books	
1. Industry 4.0: Concept & Development, by I.V.Tarasov, Business Strategies, Real Economy Publishing House.	

Cyber-Physical Systems	
Course Code: MRA-120 Contact Hours: L-3 T-0 P-2 Course Category: DEC	Credits: 4 Semester: 2

Introduction: This course introduces cyber physical system to the students which focused on different ubiquitous applications we interact in our day to day life ranging from simple system to mission critical applications. Such ubiquitous physical systems are controlled or integrated with the software to provide crucial functionality to various applications such as railway, avionics, automobile, healthcare, industrial, power or nuclear automation. Due to complicated interaction/integration with the real time systems and critical data processing makes cyber physical systems different from the embedded systems. This course aims to expose the student to cyber physical systems and provide a walk through the fundamentals, design and validation using real world examples.

Course Objectives: The objectives of this course are

- To provide an introduction to Microcontroller and Embedded Systems.
- To equip students with essential tools for Embedded systems.
- To foster understanding through real-world applications related to embedded systems.

Pre-Requisites: Basic knowledge of computers

Course Outcomes: At the end of the course students should be able to:

- Apply Embedded system concepts to solve real word problems.
- Present solution to automated systems to make life easier.
- Apply concepts of embedded systems and microcontroller to enhance existing systems.
- Ability to develop concepts, logics towards solving a unknown problem in research and industry.

Pedagogy: Classroom teaching is supported by White board, black board, chalks, markers, projector and screen. The hand written notes, PowerPoint slides and assignments will be provided to the students and also mailed to them. The students can also raise their issues related to the course in the class and mail.

Contents:

UNIT I	11 Hours
Introduction: Cyber-Physical System, Key Features of CPS, Application Domains of CPS, Basic principles of design and validation of CPS, Challenges in CPS.	
UNIT II	11 Hours
CPS Platform components: CPS HW platforms, Processors, Sensors and Actuators, CPS Network - Wireless, CAN, Automotive Ethernet, Scheduling Real Time CPS tasks, Synchronous Model and Asynchronous Model.	
UNIT III	10 Hours

Synchronous and Asynchronous Model: Reactive Components, Components Properties, Components Composing, Synchronous Designs and Circuits, Asynchronous Processes and operations, Design Primitives in Asynchronous Process, Coordination Protocols in Asynchronous Process, Leader Election, Reliable Transmission.		
UNIT IV		10 Hours
Security of Cyber-Physical Systems: Introduction to CPS Securities, Basic Techniques in CPS Securities, Cyber Security Requirements, Attack Model and Countermeasures, Ddvanced Techniques in CPS Securities. CPS Application: Health care and Medical Cyber-Physical Systems, Smart grid and Energy Cyber- Physical Systems, WSN based Cyber-Physical Systems, Smart Cities.		
Text Books		
1.	E. A. Lee and S. A. Seshia, "Introduction to Embedded Systems: A Cyber-Physical Systems Approach", 2011.	
2.	R. Alur, "Principles of Cyber-Physical Systems," MIT Press, 2015.	
3.	Raj Rajkumar, Dionisio de Niz and Mark Klein, "Cyber-Physical Systems", Addison-Wesley, 2017	
Reference Books		
1.	Rajeev Alur, "Principles of Cyber-Physical Systems", MIT Press, 2015	
2.	Fei Hu, "Cyber-Physical Systems", CRC Press 2013	

Wireless Sensor Networks	
Course Code: MRA-122 Contact Hours: L-3 T-0 P-2 Course Category: DEC	Credits: 4 Semester: 2

Introduction: The course covers testing of wireless sensor network using sensors & wireless sensor network test bed & testing of different wireless technology. To be honest, wireless sensor networks are an ideal candidate for a lab to give you a hands-on experience on distributed systems and communications. Sensor Networks (WSNs) research investigates the properties of networks.

Due to their processing and communication abilities wireless sensor networks are intelligent. Thus, the network can independently from human interaction deal with node failure, aggregate measurements from various nodes into meaningful data, reprogram selected nodes for new tasks.

Course Objectives: The objectives of this course are:

- To understand the WSN node Architecture and Network Architecture
- To identify the Wireless Sensor Network Platforms
- To program WSN using embedded C
- To design and Develop wireless sensor node

Pre-Requisites: NIL

Course Outcomes:

- Analysis of various critical parameters in deploying a WSN
- Describe and explain standards and communication protocols adopted in wireless sensor networks
- Describe and explain the hardware, software and communication for wireless sensor network nodes
- Explain the architectures, features, and performance for wireless sensor network systems and platforms

Pedagogy: Classroom teaching is supported by White board, black board, chalks, markers, projector and screen. The hand written notes, PowerPoint slides and assignments will be provided to the students and also mailed to them. The students can also raise their issues related to the course in the class and mail.
Class room teaching is consequently supported by practical sessions and assignments / projects given in labs during practical sessions. Teacher's research-based teaching and Student's research-based studying together; in-class instructing and outside-class practicing together; textbook explaining and extensive reading together; teacher's guiding and student's self-studying together. It aims at the cultivation of student's engineering practical ability.

Contents:

UNIT I	11 Hours
Overview: Introduction, Challenges for Wireless Sensor Networks, Enabling Technologies for Wireless Sensor Networks. Architectures: Single-Node Architecture - Hardware Components, Energy Consumption of Sensor Nodes, Operating Systems and Execution Environments, Network Architecture, Sensor Network Scenarios, Optimization Goals and Figures of Merit, Gateway Concepts	
UNIT II	11 Hours
Networking: Physical Layer and Transceiver Design Considerations, MAC Protocols for Wireless Sensor Networks, Low Duty Cycle Protocols And Wakeup Concepts, S-MAC, The Mediation Device Protocol, Wakeup Radio Concepts, Address and Name Management, Assignment of MAC Addresses, Routing Protocols- Energy-Efficient Routing, Geographic Routing and Major Routing Protocols.	
UNIT III	10 Hours
Infrastructure Establishment: Topology Control, Clustering, Time Synchronization, Localization and Positioning, Sensor Tasking and Control.	
UNIT IV	10 Hours
Sensor Network Platforms And Tools: Sensor Node Hardware – Berkeley Motes, Deployment, Programming Challenges, Node-level software platforms, Embedded Operating System, Node level Simulators, State-centric programming.	

Text Books	
1.	F. Zhao and L. Guibas, "Wireless Sensor Network: Information Processing Approach" Elsevier, 2009
2.	E. H. Callaway, Jr. E. H. Callaway, "Wireless Sensor Networks Architecture and Protocols", CRC Press, 2009
Reference Books	
1.	Kazem Sohraby, Daniel Minoli, & Taieb Znati, "Wireless Sensor Networks-Technology, Protocols, And Applications", John Wiley, 2007.
2.	Anna Hac, "Wireless Sensor Network Designs", John Wiley, 2009.
3.	Robert Faludi, "Building Wireless Sensor Networks", O'reily Publications. John Pippenger & Tyler Hicks, "Industrial Hydraulics", 3rd edition Mc Graw Hill, 2010.
4.	Bhaskar Krishnamachari, Networking Wireless Sensors, Cambridge University Press, 2005

Aerial Robotics	
Course Code: MRA-124 Contact Hours: L-3 T-0 P-2 Course Category: DCC	Credits: 4 Semester: 2

Introduction: This course will teach an introduction to the mechanics of flight and the design of quadrotor flying robots and will be able to develop dynamic models, derive controllers, and synthesize planners for operating in three dimensional environments. You will be exposed to the challenges of using noisy sensors for localization and maneuvering in complex, three-dimensional environments. Finally, you will gain insights through seeing real world examples of the possible applications and challenges for the rapidly-growing drone industry.

Course Objectives: The objectives of this course are:

1. To provide an understanding of the mechanics of flight and the design of quadrotor flying robots .
2. To develop dynamic models, derive controllers, and synthesize planners for operating in three dimensional environments.
3. To exposed to the challenges of using noisy sensors for localization and maneuvering in complex, three-dimensional environments.

Pre-Requisites: Students taking this course are expected to have some familiarity with linear algebra, single variable calculus, and differential equations,and programming with MATLAB.

Course Outcomes: On completion of this course students should be able to:

1. Understand the mechanics of flight and the design of quadrotor flying robots
2. To develop dynamic models, derive controllers, and synthesize planners for operating in three dimensional environments
3. To expose to the challenges of using noisy sensors for localization and maneuvering in complex, three-dimensional environments
4. Gain insights through seeing real world examples of the possible applications and challenges for the rapidly-growing drone industry

Pedagogy: Classroom teaching is supported by White board, black board, chalks, markers, projector and screen. The hand written notes, PowerPoint slides and assignments will be provided to the students and also mailed to them. The students can also raise their issues related to the course in the class and mail.
Class room teaching is consequently supported by practical sessions and assignments / projects given in labs during practical sessions.

Contents:

UNIT I	11 Hours

Introduction to Aerial Robotics-Unmanned Aerial Robotics (UAVs) and quadrotors in particular, their basic mechanics and control strategies, component selection and design and their effects on vehicle's performance		
UNIT II		11 Hours
Geometry and Kinematics and Dynamics formulations- Frame Rotations and Representations, kinematics of quadrotors, derive the dynamic equations of motion for quadrotors, , Dynamics of a Multirotor Micro Aerial Vehicle		
UNIT III		10 Hours
Motion Planning and Control- PID control, LQR control, Linear controller for 1D quadrotor, controlling the quadrotor in two dimensions, Holonomic Vehicle Boundary Value Solver, Dubins Airplane model Boundary Value Solver, Collision-free Navigation, Structural Inspection Path Planning, motion planning for quadrotors.		
UNIT IV		10 Hours
Advanced Topics- Advanced technique to enable quadrotors to perform more agile maneuvers.		
Text Books		
1.	1 Yasmina Bestaoui Sebbane, "A First Course in Aerial Robots and Drones", Chapman and Hall/CRC, 2021.	
2.	Anibal Ollero and Bruno Siciliano, "Aerial Robotic Manipulation: Research, Development and Applications: 129 (Springer Tracts in Advanced Robotics)", Springer, 2019.	
3.	Saeed B. Nikku, Introduction to Robotics, Analysis, Control, Application 2ndEdition, 2011.	
Reference Books		
1.	Craig, J.J., "Introduction to Robotics: Mechanics and Control", Pearson, Delhi, 3rd Edition, 2009.	
2.	Tsai, L, "Robot Analysis", John Wiley & Sons, Singapore, 1995	
3.	Saha, S.K., "Introduction to Robotics", Tata McGraw Hill, 4th reprint, 2010.	

Industrial Automation	
Course Code: MRA-201 Contact Hours: L-3 T-0 P-2 Course Category: DEC	Credits: 4 Semester: 3

Introduction: Automation takes a step further mechanization that uses a particular machinery mechanism aided human operators for performing a task. Mechanization is the manual operation of a task using powered machinery that depends on human decision making.
On the other hand, automation replaces the human involvement with the use of logical programming commands and powerful machineries.

Course Objectives: The objectives of this course are to

1. Select & identify suitable automation hardware for the given application.
2. Describe & explain potential areas of automation, material handling, and Fluid power systems.
3. Analysis of Manufacturing systems & Mathematical models of production lines
4. To know Industrial Automated production lines and work part transfer mechanism and buffer storage analysis.
5. To understand Cellular Manufacturing, Flexible manufacturing Systems ,planning implementation issues and implementation quality programs in production systems.

Pre-Requisites: NIL

Course Outcomes: Having completed this course student will be able to:

1. Understand automation, material handling, and Fluid power systems.
2. Understand Industrial Automated production lines
3. Analyze manufacturing systems applications

Pedagogy: Classroom teaching is supported by White board, black board, chalks, markers, projector and screen. The hand written notes, PowerPoint slides and assignments will be provided to the students and also mailed to them. The students can also raise their issues related to the course in the class and mail.
Class room teaching is consequently supported by practical sessions and assignments / projects given in labs during practical sessions.

Contents:

UNIT I	11 Hours
Automation In Production System, Manual Labor in production systems ,Principles and Strategies of Automation, Basic Elements of An Automated System, Levels of Automation, production concepts and mathematical models. Material Handling: Introduction to Material Handling, Material Handling Equipment's, Principles and Design Consideration in material handling, Material Transport Equipment, Automated Storage systems, Lean Manufacturing	

UNIT II	11 Hours
Fluid Power and Pneumatic Systems: Introduction to Fluid power, Pascal’s Law, Hydraulic Circuit Design and Analysis-Introduction, Control of A Single-Acting Hydraulic Cylinder Circuit, Control of a Double Acting Hydraulic Cylinder Circuit, Regenerative Cylinder Circuit. Basic Pneumatic systems, Types of Cylinders-Single acting Cylinder- Double acting Cylinder, Direction Control Valves- Valve position, Shuttle Valve, Basic Pneumatic Circuits- Control of Single acting Cylinder Circuit- Control of Double acting circuit, Impulse operation- Pilot operation of single acting and Double acting cylinder. SLE: Solenoid Operated Valve	
UNIT III	10 Hours
Architecture of Industrial Automation Systems, Measurement Systems Characteristics, Data Acquisition Systems Introduction to Automatic Control, P-I-D Control, PID Control Tuning, Feedforward Control Ratio Control, Time Delay Systems and Inverse Response Systems, Special Control Structures, Process Control, Introduction to Sequence Control, PLC , RLL, Scan Cycle, Simple RLL Programs, RLL Elements, RLL Syntax A Structured Design Approach to Sequence Control PLC Hardware Environment	
UNIT IV	10 Hours
Introduction, Part Families, Manufacturing Cells, Cellular Manufacturing, Part classification and coding, Production Flow Analysis, Group Technology and its applications. Introduction to FMS, FMS Industrial Applications and its benefits, FMS components. Inspection and Quality control: Introduction, Inspection, Specifying limits of variability, dimensions and tolerances, selection of gauging equipments, gauge control, quality control and quality assurance, statistical quality control, total quality management, six sigma, quality standards, Simple numerical problems.	

Text Books	
1.	Automation, Production Systems and Computer Integrated Manufacturing- M. P. Groover, Pearson Education. Third edition/Fifth edition, 2009.
2.	William Bolton, “Mechatronics: Electronic Control Systems in Mechanical and Electrical Engineering”, Pearson, 2019.
1.	S. Mukhopadhyay, S. Sen and A. K. Deb, “Industrial Instrumentation, Control and Automation”, Jaico Publishing House, 2013.
2.	SR Majumdar, “Pneumatic Systems, Principles and Maintenance”, Mc Graw Hil, 2017.

Design of Experiments	
Course Code: MRA-203	Credits: 4
Contact Hours: L-3 T-0 P-2	Semester: 3
Course Category: DEC	

Introduction: Design of Experiments (DOE) is a methodology that can be effective for general problem solving, as well as for improving or optimizing product design and manufacturing processes. Specific applications of DOE include, but are not limited to, identifying root causes of quality or production problems, identifying optimized design and process settings, achieving robust designs, and generating predictive math models that describe physical system behavior.

Course Objectives: The objectives of this course are:

- To impart knowledge on various types of experimental designs conduct experiments and data analysis techniques.
- To introduce the basic principles and methods of statistical design of experiments.
- To make students aware of the significance of the effects of various factors on a given response are determined under uncertainty using statistical principles.

Pre-Requisites: Mathematical Statistics, Basic Calculus

Course Outcomes: After successful completion of the course, the students will be able to -

- Valuate the suitability of the models treated in the course, for different experimental situations
- Analyze experimental data
- Plan and conduct smaller experiments within given time frames
- Present the planning, implementation, and analysis of a conducted experiment

Pedagogy: Classroom teaching is supported by Whiteboard, blackboard, chalks, markers, projector, and screen. The handwritten notes, PowerPoint slides, and assignments will be provided to the students and also mailed to them. The students can also raise their issues related to the course in the class and by mail.

Contents:

UNIT I	11Hours
Strategy of experimentation, Some typical applications of experimental designs, basic principles, guidelines for designing experiments. Simple comparative experiments: Basic statistical concepts, sampling and sampling distributions, Experiments with a single factor: The Analysis of variance: Analysis of the fixed effects model, model adequacy checking, practical interpretation of results.	
UNIT II	11 Hours
Randomized Blocks, Latin Squares & Related designs: Randomized complete block designs, Latin Square design, the Graeco-Latin Square design, balanced incomplete block designs. Factorial design: Basic definitions and principles, the advantage of factorials, the two-factor factorial designs, statistical analysis of the fixed effects model, model adequacy checking, estimating the model parameters, the assumption of no – interaction in a two-factor model, one observation per cell.	
UNIT III	10 Hours
The general factorial design, 2k factorial designs: The 22 design, the 23 design, Yate's Algorithm, the General 2k factorial design, confounding the 2k factorial design in 2p blocks. Two level fractional factorial design: introduction; the one-half fraction of the 2k design; the one-quarter fraction of the 2k design; the Taguchi design: orthogonal array, signal-to-noise ratio, mean response table, analysis of variance, Examples of L8 and L9 Taguchi design	
UNIT IV	10 Hours
Fitting regression models: Introduction; multiple linear regression models; estimation of the parameters in linear regression models; Hypothesis testing in multiple regressions, test for significance of the regression.	

Text Books	
1	Douglas C. Montgomery, “Design and Analysis of Experiments”, John Wiley and sons, 2012.
2	Krishnaiah K, and Shahabudeen P, “Applied Design of Experiments and Taguchi Methods”, PHI, India, 2011.
3	Phillip J. Ross, “Taguchi Techniques for Quality Engineering”, Tata McGraw-Hill, India, 2005.
Reference Books	
1	Angela M. Dean and Daniel Voss, “Design and Analysis of Experiments”, Springer, NY, 2013.
2	Jiju Antony. “Design of Experiments for Engineers and Scientists”. 1st Ed. Butterworth-Heinemann, 2014
3	Hines and Montgomery, “Probability and Statistics for Engineers”, John Wiley and Sons, NY, 2019.
4	www.nptel.ac.in
5	http://ocw.mit.edu

Human-Computer Interaction	
Course Code: MRA-205	Credits: 4
Contact Hours: L-3 T-0 P-2	Semester: 3
Course Category: DEC	

Introduction: Students are introduced to the fundamental theories and concepts of human-computer interaction (HCI). HCI is an interdisciplinary field that integrates theories and methodologies across many domains including cognitive psychology, neurocognitive engineering, computer science, human factors, and engineering design. Students will gain theoretical knowledge of and practical experience in the fundamental aspects of human perception, cognition, and learning as relates to the design, implementation, and evaluation of interfaces

Course Objectives: The objective of this course is to

- Introduce students to HCI System
- Equip the students with tools to design efficient HCI
- Make students aware of the intricacies of the HCI Designs

Pre-Requisites: NIL

Course Outcomes: After successful completion of the course, the students will be able to –

- Appreciate the importance and applications of HCI
- Use toolkits to implement HCI
- Design Human-Computer Interactive System

Pedagogy: Classroom teaching is supported by White board, black board, chalks, markers, projector and screen. The hand written notes, PowerPoint slides and assignments will be provided to the students and also mailed to them. The students can also raise their issues related to the course in the class and mail.

Contents:

UNIT I	11Hours
Introduction to Human-Computer Interaction and devices. Designing- Programming Interactive systems-Models of interaction, Frameworks, and HCI, Ergonomics, Interaction styles, Elements of the WIMP interface.	
UNIT II	11 Hours
Interaction design basics-The process of design, User focus, Scenarios, Navigation design, Screen design and layout, Iteration and prototyping, Design for non-Mouse interfaces, HCI in the software process, Iterative design and prototyping, Design rules, Principles to support usability.	
UNIT III	10 Hours
Implementation support - Elements of windowing systems, Programming the application, Using toolkits User interface management systems, Evaluation techniques, Universal design, User support Models and Theories - Cognitive models, Goal and task hierarchies, Linguistic models, The challenge of display-based systems.	
UNIT IV	10 Hours
Collaboration and communication - Face-to-face communication, Conversation, Text-based communication, Group working, Dialog design notations, Diagrammatic notations, Textual dialog notations, Dialog semantics, Dialog analysis and design Human factors and security - Groupware, Meeting and decision support systems, Shared applications and artifacts, Frameworks for groupware Implementing synchronous groupware, Mixed, Augmented and Virtual Reality.	

Text Books

1	Sharp and Rogers, “Interaction Design: Beyond Human-Computer Interaction”, Fourth Edition, Preece, 2015.
2	A Dix, Janet Finlay, G D Abowd, R Beale., “Human-Computer Interaction”, 3rd Edition, Pearson Publishers,2008
3	Shneiderman, Plaisant, Cohen and Jacobs, “Designing the User Interface: Strategies for Effective Human Computer Interaction”, 5th Edition, Pearson Publishers, 2010.
1	Cooper, Reimann, Cronin, & Noessel, “About Face: The Essentials of Interaction Design”, Fourth Edition, 2014.
2	Wickens, Lee, Liu, and Gordon-Becker, “Introduction to Human Factors Engineering”, Pearson, 2nd Edition, 2004.
4	www.nptel.ac.in
5	http://ocw.mit.edu

Internet of Things	
Course Code: MRA- 207 Contact Hours: L-3 T-0 P-2 Course Category: DEC	Credits: 4 Semester: 3

Introduction:The Internet is evolving to connect people to physical things and also physical things to other physical things all in real time. It is becoming the Internet of Things (IoT). The course enables student to understand the basics of Internet of things and protocols. Itintroduces some of the application areas where Internet of Things can be applied. Students will learn about the middleware for Internet of Things. To understand the concepts of Web of Things.

Course Objectives:The objectives of this course are

- Assess the genesis and impact of IoT applications, architectures in real world.
- Illustrate diverse methods of deploying smart objects and connect them to network.
- Compare different Application protocols for IoT.
- Infer the role of Data Analytics and Security in IoT.
- Identifysensor technologies for sensing real world entities and understand the role of IoT in various domains of Industry.

Pre-Requisites: Fundamentals of computer network, Network Security, internet technology.

Course Outcomes: After studying this course, students will be able to:

- Interpret the impact and challenges posed by IoT networks leading to new architectural models.
- Compare and contrast the deployment of smart objects and the technologies to connect them to network.
- Appraise the role of IoT protocols for efficient network communication.
- Elaborate the need for Data Analytics and Security in IoT.
- Illustrate different sensor technologies for sensing real world entities and identify the applications of IoT in Industry.

Pedagogy: Classroom teaching is supported by White board, black board, chalks, markers, projector and screen. The hand written notes, PowerPoint slides and assignments will be provided to the students and also mailed to them. The students can also raise their issues related to the course in the class and mail.

Contents:

UNIT I	11 Hours

Overview And Architectures: What is IoT, Genesis of IoT, IoT and Digitization, IoT Impact, Convergence of IT and IoT, IoT Challenges, IoT Network Architecture and Design, Drivers Behind New Network Architectures, Comparing IoT Architectures, A Simplified IoT Architecture, The Core IoT Functional Stack, IoT Data Management and Compute Stack	
UNIT II	11 Hours
Smart Objects: The "Things" in IoT, Sensors, Actuators, and Smart Objects, Sensor Networks, Connecting Smart Objects, Communications Criteria, IoT Access Technologies. IP as the IoT Network Layer: The Business Case for IP, The need for Optimization, Optimizing IP for IoT, Profiles and Compliances, Application Protocols for IoT, The Transport Layer, IoT Application Transport Methods.	
UNIT III	10 Hours
Data and Analytics for IoT:An Introduction to Data Analytics for IoT, Machine Learning, Big Data Analytics Tools and Technology, Edge Streaming Analytics, Network Analytics, Securing IoT, A Brief History of OT Security, Common Challenges in OT Security, How IT and OT Security Practices and Systems Vary, Formal Risk Analysis Structures: OCTAVE and FAIR, The Phased Application of Security in an Operational Environment	
UNIT IV	10 Hours
IoT Physical Devices and Endpoints - Arduino UNO: Introduction to Arduino, Arduino UNO, Installing the Software, Fundamentals of Arduino Programming. IoT Physical Devices and Endpoints - RaspberryPi: Introduction to RaspberryPi, About the RaspberryPi Board: Hardware Layout, Operating Systems on RaspberryPi, Configuring RaspberryPi, Programming RaspberryPi with Python, Wireless Temperature Monitoring System Using Pi, DS18B20 Temperature Sensor, Connecting Raspberry Pi via SSH, Accessing Temperature from DS18B20 sensors, Remote access to RaspberryPi, Smart and Connected Cities, An IoT Strategy for Smarter Cities, Smart City IoT Architecture, 10 Hours Smart City Security Architecture, Smart City Use-Case Examples.	

Text Books	
1.	David Hanes, Gonzalo Salgueiro, Patrick Grossetete, Robert Barton, Jerome Henry,"IoT Fundamentals: Networking Technologies, Protocols, and Use Cases for the Internet of Things", 1st Edition, Pearson Education, 2017.
2.	Srinivasa K G, "Internet of Things", CENGAGE Leaning India, 2017
Reference Books	
1.	Vijay Madisetti and ArshdeepBahga, "Internet of Things (A Hands-on-Approach)", 1stEdition, VPT, 2014.
2.	Raj Kamal, "Internet of Things: Architecture and Design Principles", 1st Edition, McGraw Hill Education, 2017.

3.	Alessandro Bassi, Martin Bauer, Martin Fiedler, Thorsten Kramp, Rob van Kranenburg, Sebastian Lange, Stefan Meissner, “Enabling things to talk – Designing IoT solutions with the IoT Architecture Reference Model”, Springer Open, 2016
4.	Jan Holler, VlasiosTsiatsis, Catherine Mulligan, Stamatis Karnouskos, Stefan Avesand, David Boyle, “From Machine to Machine to Internet of Things”, Elsevier Publications, 2014.
5.	Olivier Hersent, David Boswarthick, Omar Elloumi, “The Internet of Things – Key applicationsand Protocols”, Wiley, 2012.

Artificial Intelligence and Sustainability	
Course Code: MRA-209 Contact Hours: L-3 T-0 P-2 Course Category: DCC	Credits: 4 Semester: 3

Introduction: The emergence of artificial intelligence (AI) is shaping an increasing range of sectors. For instance, AI is expected to affect global productivity, equality and inclusion, environmental outcomes, and several other areas, both in the short and long term. Reported potential impacts of AI indicate both positive and negative impacts on sustainable development.

Course Objectives: The objectives of this course are:

- To familiarize the various goals of Sustainable Development
- To give knowledge of the AI and economic performance
- To give knowledge of the AI and environmental performance
- To give knowledge of the AI and societal performance

Pre-Requisites: To have a basic knowledge of sustainability
To have some basic idea about various performances and triple bottom line approach.

Course Outcomes: After the completion of this course the students will be able to:

- Students will have complete knowledge about the various SDG gaols
- Knowledge about the different performances like economic, environmental, and societal.
- Examines how this new approach will impact on the three arenas of society, environment and economics, ushering in a new age of reintegration.

Pedagogy: Classroom teaching is supported by White board, black board, chalks, markers, projector and screen. The hand written notes, PowerPoint slides and assignments will be provided to the students and also mailed to them. The students can also raise their issues related to the course in the class and mail.
Class room teaching is consequently supported by practical sessions and assignments / projects given in labs during practical sessions.

Contents:

UNIT I	11 Hours
AI and Sustainable development Goals	

Relation between AI and SDG, Need of Sustainability, Positive Effects of AI on Sustainability, Negative Effective of AI on Sustainability, Calculation of Negative effects, Carbon footprint	
UNIT II	11 Hours
AI and Economic Performance Economic Performance, Enablers and barriers of Implementation, Relation among AI and Economic Performance, Analysis of the relation, Hypothesis Testing, Model Fit, Case Studies using Software	
UNIT III	10 Hours
AI and Environmental Performance Environmental Performance, Enablers and barriers of Implementation, Relation among AI and Environmental Performance, Analysis of the relation, Hypothesis Testing, Model Fit, Case Studies using Software	
UNIT IV	10 Hours
AI and SocietalPerformance Societal Performance, Enablers and barriers of Implementation, Relation among AI and Societal Performance, Analysis of the relation, Hypothesis Testing, Model Fit, Case Studies using software.	

Text Books

1.	Henrik Skaug Sætra, "AI for the Sustainable Development Goals", 1st Edition, CRC Press, 2022.
2.	Keith Ronald Skene, "Artificial Intelligence and the Environmental Crisis Can Technology Really Save the World?", Routledge, 1st Edition, 2020

Reference Books

1.	Cindy Mason, "Artificial Intelligence and The Environment: AI Blueprints for 16 Environmental Projects Pioneering Sustainability (Paperback)", AI Education Resources ,2020
2.	Aboul Ella Hassanien, Roheet Bhatnagar, Ashraf Darwis, "Artificial Intelligence for Sustainable Development: Theory, Practice and Future Applications", Springer, 2021.

Rapid prototyping and reverse Engineering	
Course Code: MRA-211	Credits: 4
Contact Hours: L-3 T-0 P-2	Semester: 3
Course Category: DEC	

Introduction:

This course teaches the general concepts of Rapid Prototyping and Reverse Engineering. Through lecture and lab assignments, the student will learn basic skills necessary to convert CAD models into STL files and print them three-dimensionally. Students will also be exposed to basic fundamentals of Reverse Engineering, which consists of three-dimensional scanning using a probe and laser, and an articulating arm. Various types of rapid Prototyping methods and the effect of different processing parameter on the part will be elaborated .

Course Objectives: The objectives of this course are

- To provide knowledge on different types of Rapid Prototyping systems
- Role of Rapid prototyping in different components development.
- Causes of defects in RP components
- To provide knowledge on knowledge of reverse engineering
-

Pre-Requisites: MANUFACTURING TECHNOLOGY

Course Outcomes: After successful completion of the course, the students will be able to -

- Generating a good understanding of RP history, its development and applications.
- Expose the students to different types of Rapid prototyping processes, materials used in RP systems and reverse engineering.
- Students will be exposed to different types of Rapid prototyping processes, materials used in RP systems and reverse engineering.
- Students will product development using RP
- Students learn the concepts of rapid tool processing
- Application of RE in different applications

Pedagogy: Classroom teaching is supported by White board, black board, chalks, markers, projector and screen. The hand written notes, PowerPoint slides and assignments will be provided to the students and also mailed to them. The students can also raise their issues related to the course in the class and mail.

Contents:

UNIT I	11Hours
Review of solid modeling techniques with comparative advantages and disadvantages. Basic principle of RP processes, classification of RP processes, various Industrial RP systems like Stereolithography, Fused Deposition Modeling, Selective Laser Sintering, Laminated object Manufacturing, 3 D Printing.	
UNIT II	11 Hours
Role of Rapid Prototyping and Rapid Tooling in product development and simultaneous engineering. Process planning for rapid prototyping, STL file generation, defects in STL files, slicing procedure, Accuracy issues in Rapid Prototyping, Strength of RP parts, Surface roughness problem in RP.	
UNIT III	10 Hours
Part deposition orientation and issues like accuracy, surface finish, build time, support structure, cost etc. Rapid tooling techniques such as laminated metallic tooling, direct metal laser sintering, vacuum casting	
UNIT IV	10 Hours

Introduction to reverse engineering. Selecting and optimally employing 3-D digitization strategies and systems. Efficiently using 3-D scanning, CAD model development for complex components and tools. Various CAD commands in modelling. Tools and equipment's available for scanning and their comparison, 3D White light scanning.

Text Books	
1	Kai, Chua Chee, Fai Leong, "Rapid Prototyping: Principle & Application in Manufacturing", John Willey, London, 2010.
2	Rafiq Noorani, "Rapid Prototyping: Principles and Application", John Wiley, Hoboken, 2006.
3	Kevin Otto and Kristin Wood, "Product Design: Technology in Reverse Engineering and New Product Development", Pearson, New Delhi, 2004.
Reference Books	
1	Ian Gibson, "Advanced Manufacturing Technology for Medical Applications: Reverse Engineering", Software Conversion and Rapid Prototyping, Willey, London, 2006.
2	Ali K. Kamrani, Emad Abouel Nasr, "Rapid Prototyping: Theory and Practice", Volume 6 of Manufacturing Systems Engineering Series, Springer Science & Business Media, 2006.
3	G Bennett, Rapid Prototyping Casebook, Mechanical Engineering Publications, London, 1997.
4	http://ocw.mit.edu
5	www.nptel.ac.in
6	

Intelligent Robotics	
Course Code: MRA-213 Contact Hours: L-3 T-0 P-2 Course Category: DEC	Credits: 4 Semester: 3

Introduction: Robotics is an important topic in Artificial Intelligence (AI), focusing on the physical aspect of intelligence. A machine that can interact successfully with our physical world is an important demonstration of AI. The objective of this course is to learn some basic algorithms and techniques for robotic research and robot programming. This course will cover the following topics: motion control (PID control), state estimation and tracking (Kalman filters), localization (particle filters, SLAM), computer vision (color segmentation, deep learning, object detection), motion/path planning (PRM, RRT), action and sensor modeling (task planning), reinforcement learning (MDPs, Q-learning, inverse reinforcement learning), and human-robot interaction (socially intelligent robots), behavior architectures (subsumption architecture), applications (autonomous vehicles), and social implications (Isaac Asimov's "Three laws of Robotics”). Students will learn to program a robot in Robot Operating System (ROS).

Course Objectives: The objectives of this course are:

1. Provide an understanding of the role of automation technology in industry.
2. Develop high level mathematical skills for analysis and synthesis of a robot.
3. Develop skills in the selection and application of different robots for various tasks.

Pre-Requisites: The prerequisites of this course are Introduction to Robotics and Mathematics. Some knowledge of fundamental AI techniques is highly recommended but not required. Students are expected to have C++ and Python programming skills before taking this course.

Course Outcomes: On completion of this course students should be able to:

1. Understand motion control (PID control),
2. learn state estimation and tracking (Kalman filters), localization (particle filters, SLAM),
3. Learn computer vision (color segmentation, deep learning, object detection),
4. Understand Motion/path planning (PRM, RRT), action and sensor modeling (task planning),
5. Learn Reinforcement learning (MDPs, Q-learning, inverse reinforcement learning), and human-robot interaction (socially intelligent robots), behavior architectures (subsumption architecture), applications (autonomous vehicles), and social implications (Isaac Asimov's "Three laws of Robotics”).
6. Program a robot in Robot Operating System (ROS).

Pedagogy: Classroom teaching is supported by White board, black board, chalks, markers, projector and screen. The hand written notes, PowerPoint slides and assignments will be provided to the students and also mailed to them. The students can also raise their issues related to the course in the class and mail.

Class room teaching is consequently supported by practical sessions and assignments / projects given in labs during practical sessions.

Contents:

UNIT I		11 Hours
Introduction to Robotics, Motion control, Probability/ sensing, Kalman filter, Localization		
UNIT II		11 Hours
Computer Vision for Robotics, Action, and sensor modeling.		
UNIT III		10 Hours
Behaviour Architecture, Planning with Markov Decision Processes (MDPs), Partially Observable Markov Decision Processes (POMDPs), Motion Planning, Sample method in motion planning, Path planning for Robots		
UNIT IV		10 Hours
Reinforcement learning, Applications, and Social Implications		
Text Books		
1.	Sebastian Thrun, Wolfram Burgard, and Dieter Fox, “Probabilistic Robotics”, MIT Press, 2005.	
2.	YoonSeok Pyo, HanCheol Cho, RyuWoon Jung, and TaeHoon Lim, “ROS Robot Programming”, ROBOTIS Co., Ltd, 2017.	
3.	Stuart Russell and Peter Norvig, Artificial Intelligence: A Modern Approach, 4th Edition, Prentice-Hall, 2020.	
Reference Books		
1.	Craig, J.J., “Introduction to Robotics: Mechanics and Control”, Pearson, Delhi, 3rd Edition, 2009	
2.	S.K.Saha, “Introduction to Robotics”, Tata McGraw Hill, 2008	
3.	Saeed B. Nikku, Introduction to Robotics, Analysis, Control, Application 2ndEdition, 2011	

Embedded System Design for Automation	
Course Code: MRA-215 Contact Hours: L-3 T-0 P-2 Course Category: DEC	Credits: 4 Semester: 3

Introduction: Embedded system design needs knowledge of hardware as well as software concepts. This course will pay attention to introduce some of the basic concepts of hardware and software designing of embedded systems with a well motivated perspective. The course will cover embedded hardware architecture, design process and approaches, interfacing techniques and real time operating systems

Course Objectives: The course will enable the students to understand the basics of an embedded system and program an embedded system. The student will also learn the method of designing an Embedded System for any type of applications and understand operating systems concepts, types and RTOS.

Pre-Requisites: Microprocessors & Microcontrollers

Course Outcomes: On successful completion of the course, the students will be able to

- To design, implement and test an embedded system.
- The student will be able to understand and design embedded systems.
- The student will learn basic of OS and RTOS,
- understand types of communications and interacting to external world

Pedagogy: Classroom teaching is supported by White board, black board, chalks, markers, projector and screen. The hand written notes, PowerPoint slides and assignments will be provided to the students and also mailed to them. The students can also raise their issues related to the course in the class and mail.
Class room teaching is consequently supported by practical sessions and assignments / projects given in labs during practical sessions.

Contents:

UNIT I	11 Hours
Fundamental design aspects: Embedded design life cycle-Product Specification- Hardware Software Partitioning-Design and Integration-Selection Process-Performance Selections and Evaluation of development Tools-Benchmarking- RTOS, Hardware Software co design, PreDesign and - Memory organization, interfacing.	
UNIT II	11 Hours
Embedded controllers: Processor Selection for embedded systems and its issues. Overview of 8051 architecture, Atmel AVR controllers, Atom architecture in terms of architecture, programming, interfacing and applications.	

UNIT III	10 Hours
Introduction to ARM Architectures and Its Programming: Interrupt Service RoutinesWatchdog timers-Flash memory-Basic toolset-Host based debugging-Remote debugging-ROM emulators-Logic Analyzer-Caches-Computer Optimization- Statistical profiling-In circuit emulators-Buffer control-Real-Time trace-Hardware break points-Overlay memory-Timing Constraints-Usage Issues-Triggers. Comparison between ARM and Atom processors.	
UNIT IV	10 Hours
Interfacing and Application Development: Cortex M4/A0/Atom (E6xx) Architecture and Programming by using Atmel SAM4 L Starter Kit/ NXP LPC11U24 (mbed)/, Tools, remote compilation, debugging and testing. Interfacing of displays, keyboard, and sensors.	

Text Books	
1.	Andrew Sloss, Dominic Symes, Chris Wright, “ARM System Developer's Guide: Designing and Optimizing System Software”, The Morgan Kaufmann Series an imprint of Elsevier, 2009.
2.	William Hohl, “ARM Assembly Language: Fundamentals and Techniques”, CRC Press, 2012
Reference Books	
1.	Arnold S. Berger “Embedded System Design” CMP Books USA 2002
2.	David.E.Simon “An Embedded Software Primer”Pearson Education 2001
3.	Frank Vahid and Tony Gwargie “Embedded System Design “John Wiley & Sons 2002
4.	Steve Heath “Embedded System Design” Elserian Second Edition 2004 Petter Barry
5.	Peter Barry, Patrick Crowley “Modern Embedded Computing”2012.

Bio Sensors	
Course Code: MRA-217 Contact Hours: L-3 T-0 P-2 Course Category: DEC	Credits: 4 Semester: 3

Introduction:

The purpose of the course is to provide a broad introduction to biosensor technology including: Working principle of the biosensors, Biosensors classification, Use of biological macromolecules as sensing elements, Presenting how engineering and biology can be used to perform diagnosis.

Course Objectives: The course will highlight

- Introduction to Biosensors
- Fundamentals and Applications.
- Understanding of Biosensing Technology
- Application of biosensor applications

Pre-Requisites: Basic knowledge of Sensors

Course Outcomes:

- Describe how biospecific interaction is used for various applications
- describe the most common sensor principles used today, such as electric, optical, and mechanic registration.
- compare different techniques with emphasis on sensitivity and selectivity
- describe and critically evaluate a selected application of a biosensor

Pedagogy: Classroom teaching is supported by White board, black board, chalks, markers, projector and screen. The hand written notes, PowerPoint slides and assignments will be provided to the students and also mailed to them. The students can also raise their issues related to the course in the class and mail.
Consequently, classroom teaching is supported by practical sessions and assignments/projects given in labs during practical sessions.

Contents:

UNIT I	11 Hours
Introduction to biosensors. Definitions, biological inspiration, types of sensors, biochemical components used in biosensor application: enzymes, antibodies, whole cell sensing, immobilization techniques	
UNIT II	11 Hours
Biosensor signal transducers : Basics of detection methods: Fluorescence Spectroscopy, UV-Vis Absorption and Emission, Surface Plasmon Resonance, Magnetic labeling, Electrochemical Detection	

Types of Transducer, electrochemical , Optical; Fiber Optic, Surface Plasmon Resonance, FET, Impedance, Piezoelectric; quartz , calorimetric biosensors		
UNIT III		10 Hours
Applications of Biosensors biosensors for food and water safety , for mycotoxin detection, clinical detections: Biosensors and diabetes management, DNa Chips, Point-of-care sensing: microfluidics and paper-based diagnostics		
UNIT IV		10 Hours
Applications of Nanomaterials in Biosensors Nano Materials in biosensors; Carbon-based Nano Material, Metal oxide and nano particle,		
Text Books		
1.	Introduction to Biosensors by Jeong-Yeol Yoon; Publisher: Springer-Verlag New York Ed.1	
2.	Biosensors: Essentials by Gennady Evtugyn, springer	
Reference Books		
1.	Biosensors: Fundamentals and Applications: Bansi Dhar Malhotra and Chandra Mouli Pandey, smithers Rapra 1 st edition	
2.		

Multi Body Dynamics	
Course Code: MRA-219 Contact Hours: L-3 T-0 P-2 Course Category: DEC	Credits: 4 Semester: 3

Introduction:

A multibody dynamic (MBD) system is one that consists of solid bodies, or links, that are connected to each other by joints that restrict their relative motion. The study of MBD is the analysis of how mechanical systems move under the influence of forces,. The students will be exposed to the fundamentals of the MBD systems and different approaches like Lagrange's to simulate and solve the real-world problems

Course Objectives:

The objective of this course is to present the theoretical knowledge of the foundation of the multibody dynamics with application to machine design and structural dynamics

Pre-Requisites: Engineering mathematics

Course Outcomes:

After successful completion of the course, the students will be able to -

- formulate a model and free body diagram of multibody systems
- incorporate holonomic and nonholonomic constraints into a multibody system
- derive the nonlinear and linear equations of motion of a multibody system
- analyze the motion of a multibody system
- interpret and analyze the results of the simulation

Pedagogy: Classroom teaching is supported by White board, black board, chalks, markers, projector and screen. The hand written notes, PowerPoint slides and assignments will be provided to the students and also mailed to them. The students can also raise their issues related to the course in the class and mail.
Class room teaching is consequently supported by practical sessions and assignments / projects given in labs during practical sessions.

Contents:

UNIT I	11 Hours
Overview of kinematic loops, constraints, degrees of freedom: Links and joints; Open and Closed-kinematic chains; Kinematic constraints (Holonomic and non-holonomic); Independent coordinates; Degrees of freedom. Review of dynamics for open and closed-loop chains: Generalized coordinates;	

EulerLagrange equations of motion; Newton's 2nd law; Euler's equations for rotational motion	
UNIT II	11 Hours
Computer-based approaches: Kane's equations of motion; Partial velocities; Orthogonal complement based approached like using Decoupled Natural Orthogonal Complement matrices. Dynamic algorithms: Inverse dynamics; Forward dynamics; Recursive algorithms; Use of software like ADAMS, RecurDyn, MATLAB- Sim Mechanics, ReDySim.	
UNIT III	10 Hours
Dynamics of closed-loop systems: Free-body diagrams; Tree-type systems; Cut-loop systems; Lagrange multipliers to represent cut-open joints; Dynamic algorithms for closed-loop systems. ODE and DAE formulations: Ordinary Differential Equations (ODE); Differential Algebraic Equations; Numerical instability; Stiff and non-stiff systems; Numerical algorithms to solve ODE and DAE equations.	
UNIT IV	10 Hours
Kinematic constraints of rigid and flexible systems: Discretization of deformation; Lagrange equations of motion; Inclusion of kinematic constraints due to joints. Dynamics of flexible multi body systems, dynamic analysis using classical approximation, FEM: Forward dynamics simulation of flexible body systems; Use of Finite Elements to represent deformations; Equations of motion; Use of software, e.g., ADAMS, RecurDyn.	

Text Books	
1.	Shabana, A., "Dynamics of Multi body Systems", Cambridge University Press, 2005
2.	Robert E. Roberson, Richard Schwertassek "Dynamics of Multibody Systems", springer verlag, berlin 1988
3.	J. Angeles, A. Kecskeméthy "Kinematics and Dynamics of Multi-Body Systems" springer verlag, berlin
Reference Books	
1.	Chaudhary, H., Saha , S. K., "Dynamics and Balancing of Multi body Systems", Springer, 2009
2.	Saha, S.K., "Introduction to Robotics", TMH, 2008

Smart Manufacturing	
Course Code: MRA-221 Contact Hours: L-3 T-0 P-2 Course Category: DEC	Credits: 4 Semester: 3

Introduction: Smart manufacturing is a broad category of manufacturing with the goal of optimizing concept generation, production, and product transaction. While manufacturing can be defined as the multi-phase process of creating a product out of raw materials, smart manufacturing is a subset that employs computer control and high levels of adaptability. Smart manufacturing aims to take advantage of advanced information and manufacturing technologies to enable flexibility in physical processes to address a dynamic and global market.

Course Objectives: The objectives of this course are

- Introduce students to the fundamentals of smart manufacturing
- To present a problem oriented in depth knowledge of Smart Manufacturing.
- To address the underlying concepts and methods behind Smart Manufacturing.

Pre-Requisites: NIL

Course Outcomes:

- The student can identify different areas of Smart Manufacturing.
- Can find the applications of all the areas in day to day life.
- Appreciate concepts and basic framework necessary for smart manufacturing
- Develop understanding about harnessing smartness into manufacturing processes from the data

Pedagogy: Classroom teaching is supported by White board, black board, chalks, markers, projector and screen. The hand written notes, PowerPoint slides and assignments will be provided to the students and also mailed to them. The students can also raise their issues related to the course in the class and mail.

Contents:

UNIT I	11 Hours
Introduction to Smart Manufacturing: What is “smart manufacturing” really and how does it differ from conventional/legacy manufacturing-Smart Manufacturing Processes-Three Dimensions: (1) Demand Driven and Integrated Supply Chains;(2) Dynamically Optimized Manufacturing Enterprises (plant + enterprise operations);(3) Real Time, Sustainable Resource Management (intelligent energy demand management, production energy optimization and reduction of GHG)	
UNIT II	11 Hours

Smart Design/Fabrication: Smart Design/Fabrication - Digital Tools, Product Representation and Exchange Technologies and Standards, Agile (Additive) Manufacturing Systems and Standards. Mass Customization, Smart Machine Tools, Robotics and Automation (perception, manipulation, mobility, autonomy), Smart Perception – Sensor networks and Devices.	
UNIT III	10 Hours
Smart Applications: Online Predictive Modelling, Monitoring and Intelligent Control of Machining/Manufacturing and Logistics/Supply Chain Processes; Smart Energy Management of manufacturing processes and facilities.	
UNIT IV	10 Hours
Smart and Empowered Workers: Eliminating Errors and Omissions, Deskilling Operations, Improving Speed/Agility, Improving Information Capture/Traceability, Improving Intelligent Decision Making under uncertainty Assisted/Augmented Production, Assisted/Augmented Assembly, Assisted/Augmented Quality, Assisted/Augmented Maintenance, Assisted/Augmented Warehouse Operations and Assisted Training.	

Text Books	
1.	M. Kuniavsky, "Smart Things: Ubiquitous Computing User Experience Design", 1st edition, Morgan Kaufmann, 2010.
2.	Tao F., Zhang M., and Nee A. Y. C., "Digital Twin Driven Smart Manufacturing", Academic Press, 2019.
Reference Books	
1.	Jeschke S., Brecher C., Song H., and Rawat D. B., "Industrial Internet of Things – Cyber manufacturing Systems", Springer, 2017.
2.	William Bolton, "Mechatronics: Electronic Control Systems in Mechanical and Electrical Engineering", Pearson, 2019.