Department of Mechatronics

M.Tech in Industrial Automation and Robotics

Detailed Syllabus 2023

MAT 5133: MATHEMATICS FOR MODELLING AND SIMULATION [4 0 0 4]

Mathematical Modelling **[8]**

Principles, Definitions of Mathematical Modelling and Simulation, State and System Parameters, Case studies: Modelling of inverted pendulum on moving cart. Models in medicine, arms race, battles and international trade in terms of system of equations. Idea of Partial Differential Equations, Closed and Numerical Solution of PDE, Modelling of heat flow problems, traffic flow.

Numerical Methods **[7]**

Concept of Finite Difference method to heat, wave, Laplace and Poisson. Finite Element Method to Differential equations.

Optimization **[7]**

Convex set, nonlinear and constrained optimization: definition, basic concept, Lagrange Multipliers method, Kuhn-tucker theorem; Nonlinear unconstrained optimization: definition, basic concept, Steepest Descent method, Steepest Ascent method, Conjugate Gradient method, variable matrix method etc.

Graph Theoretic Algorithms **[12]**

Aspects of linear algebra: basis, orthogonality and least squares, projections, simple matrix decompositions. Matrix Representations of graphs, Matrix - tree theorem on number of spanning trees. Computer representation of graphs - Input and output, Spanning Tree, Fundamental Circuits, Directed Circuits and Shortest paths.

Probability and Statistics **[14]**

Basic theory, Permutation and combination, independence, One-Two dimensional random variable, Distribution, Parameter estimation, Hypothesis Testing, Random Process, correlation and covariance, Markov process, probabilistic roadmap (PRM). Stochastic optimal control methods, Bayesian networks, Inference with Bayesian networks.

Text Books:

1. Ross Sheldon M, *Introduction to Probability and Statistics for Engineers and Scientists*, Elseveir, 2010.
2. J. N. Kapur, *Mathematical Modelling*, Wiley Estern, 1998.
3. David C. Lay, Linear Algebra and its Applications, 5th Edn. (Pearson) 2016.
4. D B West, Introduction to Graph Theory, Pearson, 2000

MTE 5113: ROBOT KINEMATICS AND DYNAMICS [3 1 0 4]

Introduction **[6]**

Definition of robots; types of robots, robot application, degrees of freedom; degrees of movements, robot configuration, definition and factor affecting the control resolution, spatial resolution, accuracy and repeatability, specification of a robot, actuators and sensors, drives and transmission systems used in robotics.

Kinematic analysis & coordinate transformation **[12]**

Direct kinematic problem in robotics, geometry based direct kinematic analysis coordinate & vector transformation using matrices, the orientation matrix & translator vector, homogeneous transformation matrices, three dimensional homogeneous transformations, joint space, and cartesian space, Denavit Hartenberg convention-implementing the dh convention, obtaining the dh displacement matrices. Applications of DH method- three axis robot arms, three axis wrists, six axis robot manipulators, assigning the tool coordinate system. Inverse manipulator kinematics Solvability, algebraic solution by reduction to polynomial, examples of inverse manipulator kinematics, robot kinematics constraints, robot workspace-degree of freedom, holonomic robots, definition of Jacobian matrix, Jacobian matrix for positioning, the Jacobian matrix for positioning & orienting, Jacobian singularity, examples of manipulator singularity.

Trajectory generation **[8]**

Introduction, general considerations in path description and generation, joint-space schemes cartesian-space schemes, geometric problems with cartesian paths.

Manipulator dynamics **[10]**

Introduction, acceleration of a rigid body, mass distribution, Force, Inertia, and Energy, Newton's equation, Euler's equation iterative newton-euler dynamic formulation, iterative vs. closed form, formulating manipulator dynamics in cartesian space, examples for equation of motion of manipulator.

Mobile robot planning & navigation **[6]**

Introduction, competences for navigation-planning & reacting, path planning, obstacle avoidance. Navigation architectures-modularity for code reuse & sharing, control localization, techniques for decomposition, case studies-tiered robot architectures.

Case studies **[6]**

Software simulations: Inverse and forward kinematics of rigid manipulators, Singularity and workspace generation, form and force closure analysis of flexible manipulator.

Self-study: Case studies on different robot configurations.

References:

1. Lynch, Kevin M. *Modern Robotics-Mechanics, Planning, and Control*: Video supplements and software." (2017).
2. Murray, Richard M. *A mathematical introduction to robotic manipulation*. CRC press, 2017.
3. Craig, John J. I*ntroduction to robotics: mechanics and control*. Vol. 3. Upper Saddle River, NJ, USA: Pearson/Prentice Hall, 2005.
4. Niku, Saeed. *Introduction to robotics.* John Wiley & Sons, 2010**.**
5. Mittal, R. K., and I. J. Nagrath. *Robotics and control.* Tata McGraw-Hill, 2003.

MTE 5114: SENSORS AND DRIVES FOR INDUSTRIAL AUTOMATION [3 1 0 4]

Introduction to Sensor Technology **[8]**

Sensors and transducers, static and dynamic characteristics, selection criteria, working principle, operation, and applications of industrial sensors: temperature, humidity, pressure, flow, level, displacement, speed, acceleration, force, torque, tactile measurement sensors, tactile sensors, data acquisition, signals conditioning.

Fundamentals of Electric drives **[8]**

Components of electric drives, factors affecting choice of drives, fundamental torque equation, speed-torque conventions, steady state stability, multi-quadrant operation of electric drives, load torque components, load equalization, determination of motor power rating, motor duty cycles, electric braking, modes of operation, speed control and drive classification, closed loop control, current limit control, speed control, position control, torque control, PLL control, multimotor drive control, digital control. DC motor control, speed control, position control, proportional control, PID controllers.

Power Electronic Converters for Drives **[10]**

Power electronic devices: power MOSFET, power BJT, SCR, IGBT, turn on, turn off characteristics, triggering methods, PWM methods. Power converters-Rectifiers choppers, inverters, ac to ac controlled converters, cycloconverters.

DC Motor Drives **[8]**

classification, fundamental laws of operation, DC motor: Construction, working, applications, DC shunt and series motors, working, torque-speed characteristics, applications, speed control of DC motors, torque-speed characteristics, speed control of DC motor using rectifiers, four quadrant operation of DC motors using fully controlled rectifiers, speed control of DC motors using Buck and Boost converters, closed loop position and speed control of DC motors**.**

AC Motor Drives **[8]**

Construction, working and applications of induction motors, torque speed and torque slip characteristics, power flow, speed control of induction motor: voltage, frequency, V/f, voltage source inverter fed induction motor drives, open and closed loop speed control of VSI fed induction motor drives, Synchronous motors: construction, working, torque-speed characteristics, applications, Open loof v/f speed control of synchronous motors, Closed loop speed control of load commutated inverter fed synchronous motor for drive application, Closed loop speed control of VSI fed PMAC for drive application.

Special motor drives **[6]**

Switched reluctance motors: Construction, working, characteristics, applications, closed loop speed control of switched reluctance motors for drive application, BLDC motors: construction, working, applications, closed loop speed control of BLDC for drive application, stepper motor, servo motor, linear induction motor drives.

References:

1. G.K. Dubey, *Fundamentals of Electric drives, 2/e, Alpha Science International Ltd.*, 2010
2. P.S. Bimbra, *Power electronics, 3/e, KhannaPublishers*, 2018.
3. I.J. Nagrath and D.P. Kothari, *Electric machines, 3/e, Tata McGraw Hill*, 2001.
4. J.B.Gupta, *A course in electrical technology,* S.K.Kataria & sons, 2012.
5. A.K. Sawhney, *A course in electrical and electronic measurements and instrumentation,* Dhanpat Rai and Co. Publication, 2015
6. D.V.S. Murty, "T*ransducers and Instrumentation,* 2/e, PHI learning private Ltd., 2008

MTE 5115: FLUID POWER AUTOMATION [3 0 3 4]

Pneumatic control system **[5]**

Need for automation, structure of hydraulic & pneumatic system, comparison and selection their criteria. Pneumatic control elements and their - ISO symbols. Case studies on pneumatic controls.

Hydraulic control system **[5]**

Hydraulic pumps and motor gears, vane, piston pumps-motors-selection and specification-drive characteristics - linear actuator - types, mounting details, cushioning - power packs - construction. Reservoir capacity, heat dissipation, accumulators - standard circuit symbols, circuit (flow) analysis.

Control and regulation elements **[5]**

Direction flow and pressure control valves-methods of actuation, types, sizing of ports-pressure and temperature compensation, overlapped and under lapped spool valves-operating characteristics- electro-hydraulic system, electro-hydraulic servo valves-different types, characteristics and performance.

Advanced hydraulics **[5]**

Types of proportional control devices- pressure relief, flow control, direction control, hydraulic symbols, spool configurations, selection & sizing with reference to manufacturer's data, electrical operation, basic electrical circuits and operation, solenoid design, comparison between conventional and proportional valves.

Electrical control of fluid power **[7]**

Electrical control of hydraulic and pneumatic, use of relays, timers, counters, PLC ladder diagram for various circuits, motion controllers, use of field busses in circuits electronic circuits for various open loop control and close loop (servo) control of hydraulics and pneumatics.

Circuit design **[10]**

Typical industrial hydraulic circuits-design methodology – ladder diagram-cascade, method truth table-karnaugh map method-sequencing circuits-combinational and logic circuit.

Applications of proportional and servo valves **[11]**

Velocity control, position control and directional control applications example: paper industry, process industry, printing sawmill, woodworking, extrusion press, powder methodology press, continuous casting, food and packaging, injection moulding, solar energy and automobile.

References:

1. Antony Esposito, *Fluid Power with Applications*, 7th edition, Pearson Prentice Hall, 2013.
2. S. Ilango, V. Soundararajan, *Introduction to Hydraulics and Pneumatics,* 2nd edition, PHI Learning, 2011.
3. R. Srinivasan *Hydraulic and Pneumatic Control*, 3rd edition, published by Vijay Nicole Imprints Private Ltd. 2004
4. Shizurou Konami, Takao Nishiumi, *Hydraulic control systems: Theory and Practice*, World Scientific Publishing, 2017.

HUM 5051: RESEARCH METHODOLOGY & TECHNICAL COMMUNICATION [1 0 3 2]

Research Methodology: Basic concepts: Types of research, Significance of research, Research framework. Sources of data, Methods of data collection. Research formulation: Components, selection and formulation of a research problem, Objectives of formulation, and Criteria of a good research problem. Research hypothesis: Criterion for hypothesis construction, Nature of hypothesis, Characteristics and Types of hypothesis, Elements of research design, Introduction to various sampling methods Sources of data, Collection of data, Research reports, references styles, Effective Presentation techniques, Research Ethics.

References:

1. Sekaran, U., & Bougie, R. (2016). *Research methods for business: A skill building approach*. John Wiley & Sons.
2. Zikmund, W. G., Babin, B. J., Carr, J. C., & Griffin, M. (2013). *Business research methods*. Cengage Learning.
3. Creswell, J. W., & Creswell, J. D. (2017). *Research design: Qualitative, quantitative, and mixed methods approaches*. Sage Publications.
4. Donald R Cooper & Pamela S Schindler, *Business Research Methods*, McGraw Hill International, 2018.

MTE 5141: PLC AND MPS LAB [0 0 3 1]

PLC Lab **[21]**

Introduction of PLC, study of basic components, networking and different programming technique of PLC. Study of NO, NC and holding circuit programs, Implement of Simple Ladder program, to study basic functions of timers, counters, arithmetic, logical and program control instructions. Study different industrial applications using ladder logic. Study hardware and software used in particular vendor PLC.

MPS Lab **[15]**

Introduction to the Mechatronics and Modular Production Systems (MPS), Brief study and understanding of Distribution station, Handling station, Buffer station, Processing station, Handling station and Separating station along with demonstration and hands on experiment with PLC.

Industrial assembly line/manufacturing relevant case studies and mini-project.

References:

1. *Mechatronics training practice module*, FESTO manual Germany 2011.
2. *Drives and Control training system practice module*, BOSCH REXROTH manual Germany 2011
3. *PLC training practice module*, BOSCH REXROTH manual Germany 2011
4. John W. Webb and Ronald A. Reiss, *Programmable logic controllers-Principle and applications, (5e)*, PHI, 1994.
5. Hackworth and Hackworth F.D, *Programmable logic controllers- Programming Method and applications*, Pearson, 2004.

MTE 5142: IIOT LAB [0 0 3 1]

Computer Networking fundamentals. Simulation of network devices viz., hub, switch and router using Cisco packet Tracer. Simulation of IIoT environment using Cisco Packet tracer. Operation of MSP432 microcontroller from TI. Interfacing of communication booster packs for Wi-Fi and Radio communication. Sensor data logger using STM32 microcontroller. [36]

Self-study:

CourseEra course entitled: The Bits and Bytes of Computer Networking

References:

1. MSP432 Manual by Texas Instrumentation.
2. STM32 Manual by STMicroelectronics

MTE 5143: DRIVES AND CONTROL LAB [0 0 3 1]

Modelling and simulation of first and second order circuits using Analytical, Numerical and circuit approaches. **[3]**

Model DC-DC converters, Rectifiers, AC-AC Regulators, Closed Loop control of DC-DC Converters. **[6]**

Modelling of DC Motor, Analyse and design suitable control for closed loop speed control of DC Motor drive. **[6]**

Develop a DC-AC inverter to control AC motors using 180deg conduction mode and SPWM techniques. **[3]**

Implementation of chopper-based DC Motor drive and Inverter based Induction Motor Control using IGBT. **[6]**

Configuring masters and slaves, synchronizing master & slave, making drives PLC enabled, restructuring encoders, running motors in translation and rotation mode, position & velocity control, PLC programming – pick and place operation, tracing drive parameters. Automation motors and their drivers and controls. **[3]**

HMI Programming and its applications **[3]**

References:

1. Matlab Documentation, Mathworks
2. *Drives and Control training system practice module*, BOSCH REXROTH manual, Germany 2011.
3. *PLC training practice module*, BOSCH REXROTH manual Germany 2011.
4. John W. Webb and Ronald A. Reiss, *Programmable logic controllers-Principle and applications*, (5e), PHI, 1994.
5. Hackworth and Hackworth F.D, *Programmable logic controllers- Programming Method and applications*, Pearson, 2004.

MTE 5214: EMBEDDED SYSTEMS FOR AUTOMATION [3 0 3 4]

Introduction to Controller and Processor **[5]**

Basic controller and processor – architecture and philosophy, Introduction to datatypes and variables, RISC and CISC – instruction set, architecture.

ARM processor and instructions **[14]**

Introduction to arm, processor architecture and organization, RISC and arm design philosophy, embedded system hardware, embedded system software, arm processor fundamentals, arm processor fundamentals, exceptions, interrupts and vector table, developmental tools, core extensions, arm processor families, arm 3 and 5 stages pipelining, instruction set, data processing instruction, data transfer, branch and branch with link instruction execution, thumb instruction, Programming, and embedded arm application.

Introduction to FPGA **[11]**

FPGA & CPLD Architectures - FPGA Programming Technologies- FPGA Logic Cell Structures- FPGA Programmable Interconnect and I/O Ports - FPGA Implementation of Combinational Circuits - FPGA Sequential Circuits - Timing Issues in FPGA Synchronous Circuits. Real-time operating systems-based embedded system design, operating system basics, types of operating systems, multi-processing and multi-tasking, task scheduling-non pre-emptive and pre-emptive scheduling with examples.

Design considerations of embedded systems **[6]**

Design considerations, interfacing mixed-signal circuits and sensors, EMI/EMC considerations, PCB layout guidelines, characteristics and quality attributes of embedded systems, and examples of time-critical and safety-critical embedded systems. Case studies related to embedded systems.

Prerequisite: - Instruction set for ARM cortex M4., Embedded C Programming basics, the FPGA-based Sequential and combinational circuit implementation.

Self-Study: RTOS and its basics, applications in automation- automotive – aerospace – medical, and manufacturing.

References:

1. K.J. Ayala,Dhananjay V. Gadre, *The 8051 Microcontroller and Embedded systems*, CENGAGE Learning,*2010*
2. Muhammad Ali Mazidi, Janice Gillipse Mazidi, Rolin D. Mckinlay, *8051 Microcontroller and Embedded Systems Using Assembly and C*, Pearson Education, 2010.
3. Shibu K.V, *Introduction to Embedded sytems*, McGraw Hill, 2009.
4. Frank Vahid, Tony architecture Givargis, *Embedded Systems*, Wiley India Editi*on, 2002.*

(36HRS)

MTE 5215: MOTION CONTROL AND PATH PLANNING [3 1 0 4]

Introduction **[18]**

Classification of Robot (fixed, mobile), Fixed-Serial, Parallel, Hybrid. Mobile-Ground (wheeled (omnidirectional, holonomic), tracked, legged), under water (submarine, fishlike), Surface (Ship like) and Aerial (Fixed wing, flapping wing, rotor based).

Overview of Trajectory Planning **[4]**

Configuration space, Degree of freedom, Definition, Introduction to Trajectory planning, General consideration in path description and Generation of motion, Joint space motions, Cartesian space motions, Point to point: Straight line path, Trapezoidal motion profile and S curve motion, Polynomial via point Trajectories. Application: Two axis /three axis planar mechanism, Trajectory planning: Wheeled robots.

Over-view of Path Planning **[16]**

Algorithms – Analysis and complexity, running time, complexity, completeness. Visibility graph, Road Maps - Generalized Voronoi Graph (GVG) - definition, properties, Cell Decomposition – Trapezoidal decomposition, Morse cell decomposition – variable slice, sensor-based coverage, complexity coverage, Visibility based decomposition.

Control based planning **[10]**

Manipulation planning, Optimal motion planning, Feedback motion planning, Randomized Kinodynamic Planning, Legged robots- Introduction, locomotion - key issues for locomotion, legged mobile robots, leg configurations & stability, Gait analysis, examples of legged robot locomotion. Case studies.

Self-study: Case studies on different locomotion of robotics and implementing them in the mini projects

References:

1. H. Choset, K. M. Lynch, *Principles of Robot Motion: Theory, Algorithms, and Implementations*, 1/e, MIT Press, Boston, 2005.
2. Steven M. LaValle, *Planning Algorithms*, 1/e, Cambridge University Press, 2006.
3. Farbod Fahimi, *Autonomous Robots- Modeling, Path Planning, and Control*, 1/e Springer, 2009

MTE 5241: ROBOTICS LAB [0 0 6 2]

Introduction to Linux and ROS2 **[18]**

Introduction to Linux, common commands and operations, ROS2 Introduction, ROS2 basics: nodes, topics, messages, services, Installation, Create ROS2 Workspace: Python and C++ Package, Object-Oriented Programming, creation of ROS2 Nodes, understanding topics and messages, creation of Publisher and Subscriber nodes, Services, Actions, simulation of robot motion with turtlesim.

ROS based simulation [**15]**

Implementation of robot motion in Gazebo and Rviz environment, URDF based representation of robot model- 3 axis manipulator design and control, mobile robot design ROS based system for path planning, robot dynamic simulation, Gazebo and RViz, Introduction to Moveit2

Robot Vision **[9]**

Object detection with OpenCV and ROS2 using RGB and depth cameras, Integration of machine vision and robotics.

Robot Control **[15]**

Programming UR5 collaborative robot and ABB Industrial Robot for industrial applications, Sensor Integration with ROS2, Control of turtlebot.

Augmented and Virtual Reality **[15]**

Introduction to Unity, Use cases in Robotic Applications

Prerequisites: Knowledge of python coding

References:

1. Anis Koubâa, *Robot Operating System (ROS), the complete reference*, Vol.1, Springer International Publishing, 2016.
2. Anis Koubâa, *Robot Operating System (ROS), the complete reference,* Vol. 2, Springer International Publishing, 2017.
3. Lentin Joseph, *Robot Operating System for absolute beginners*, Apress Media LLC, 2018.
4. Wyatt Newman, *A systematic approach to learning robot programming with ROS*, Chapman and Hall, 2017.
5. Joseph Howse, Prateek Joshi, Michael Beyeler, *OpenCV_Computer Vision projects with Python*, Packt Publishing, 2016.
6. Alvaro Morena, *Artificial Vision and Language Processing for Robotics*, Packt Publishing, 2019.
7. https://wiki.ros.org/

MTE 5401: ANALOG AND DIGITAL ELECTRONICS [4 0 0 4]

Introduction to Mechatronics and Digital/ analog principles **[2]**

Mechatronics system, building blocks, domains, constituents, key elements, Advantages of digital technology, Digital and analog system design stages

Analog Circuits **[10]**

PN Diode, Diode types: Zener diode, LED, Photodiode, Varactor diode, Diode applications: rectifier, clipper, clamper. Transistor: BJT: VI characteristics, biasing, amplifiers, MOSFET-device characteristics, small signal model, spice model.

Self-learning: Zener voltage regulation, Voltage regulator IC’s 78XX & 79XX series

Op-amp and Applications **[10]**

Operational amplifiers and its properties. Linear applications: voltage follower, amplifier, adder, subtractor, integrator, differentiator, instrumentation amplifier. Non-linear applications: voltage comparator, zero crossing detector, Schmitt trigger, waveform generation.

Self-learning **[10]**

Window detector, precision rectifier, Analog filters: low pass, high pass, band pass, band stop, notch and comb filters, all-pass filters, Single-ended signalling vs. differential signalling, Differential op-amp based circuits

Analog Building Blocks **[4]**

Amplifier models: voltage amplifier, current amplifier, trans-conductance amplifier and trans-resistance amplifier, Current Mirror (CM): current sink, current source, Transconductor or G_m-cell, OTA, Current Conveyor (CC) and applications, Current mode operation.
Self-learning: G_m-C circuits, multiple output transconductors

Interface Hardware Blocks **[4]**

Data Converters **-** specifications, sample & hold circuit, DAC architectures: R-2R, Charge scaling. ADC architectures: Flash, Successive Approximation, I/O interface and signal conditioning, Data acquisition

Overview of number system and codes **[4]**

Binary, octal, hexadecimal and decimal number systems and their inter conversion, BCD numbers (8421-2421), Gray code, Excess–3 code, code conversion etc.

Combinational Logic Circuits **[4]**

Logic gates, adder, subtractor, Carry ripple adder, Multiplexer, De-multiplexer, Decoder, BCD to seven segment decoder, Encoder, Priority encoder, Magnitude comparator, Parity generator.
Self-learning: Logic minimization using Karnaugh Maps, Shannon's expansion theorem and its applications

Sequential Logic Circuits **[6]**

Latch, Flip-flop, types of triggering**,** S-R, D, J-K, T -flip-flops, Master slave flip-flop, Shift Registers, Types – SISO, SIPO, PISO, PIPO, Bidirectional shift register, Applications, Counters – Classification, comparisons, Synchronous/ Asynchronous counter, Up/ down counter, Johnson and Ring counter.

Case studies **[4]**

Design of regulated DC power supply, Simulation of G_m-C filters using behavioural models, Design of PID controller using analog blocks, Verilog modelling and simulation of logic circuits.

References:

1. M D Singh, J G Joshi, *Mechatronics*, PHI Publication, 2006
2. A. Anand Kumar, *Fundamentals of Digital circuits*, 4th edition, PHI, 2016.
3. R. L. Boylestad, L. Nashelsky, *Electronic Devices and Circuit Theory*, 8th edition, PHI. 2003.
4. Ramakant, Gayakwad. *Op-amps and linear integrated circuits*. 4th edition, PHI, 2015.
5. C. Toumazou, *Analogue IC Design: The current-mode approach*, IET,1993.

MTE 5402: ARTIFICIAL INTELLIGENCE AND EXPERT SYSTEMS [3 1 0 4]

Artificial intelligence **[5]**

Overview and Historical Perspective, Principles of AI, Definitions and underlying assumptions, Applications in various domains.

Statistical and Probabilistic Reasoning **[5]**

Symbolic reasoning under uncertainly, probability and Bayes' theorem, certainty factors and rule based systems, Linear Discrimination, Bayesian networks and Decision Theory, Dempster–Shafer theory.

Machine learning **[8]**

Types of learnings, classification, regression and clustering. Types of Regression, Linear, Logistics, Multiple, and Polynomial with applications. K-means algorithm for Classification and Clustering. Hierarchical and Association Learning for Clustering. Support vector machines for classification problems. Naïve Bayes Learning method for Classification, Decision Trees and Random Forest Leaning method for classification and regression problems.

Optimization and Evolutionary Computation Techniques **[9]**

Introduction to optimization, Traditional optimization techniques with applications; *State Space Search***:** Depth First Search, Breadth First Search; *Heuristic Search:* Best First Search, Hill Climbing, Beam Search; *Finding Optimal Paths:* Branch and Bound, A*, IDA*, Divide and Conquer approaches, Beam Stack Search; *Randomized Search*: Simulated Annealing, Genetic Algorithms, Ant Colony Optimization

Fuzzy Logic Systems **[4]**

Crisp sets and relations, Fuzzy sets and relations. Fuzzy rule based systems, de-fuzzifications methods and applications.

Knowledge, Reasoning and Planning **[6]**

Logical Agents, Fundamental and Inference of First-Order Logic, Classical Planning, Knowledge Representation and Reinforcement Learning.

Artificial Neural Network **[7]**

Introduction, Fundamental Concepts, McCulloch-Pitts Neuron Model, Models of Artificial Neural Network, Learning and Adaption, Learning Rules Hebbian, Perceptron, Delta, Widrow-Hoff, Correlation, Winner-Take-All, Single Layer, Multilayer feedforward, Feedback Networks and Associative Memories.

Case Study and Application **[4]**

Autonomous Navigation of Mobile Robots, Robotic Manipulation, Learning-Based Control of Robotic Systems, Swarm Robotics with Artificial Intelligence etc.

Self-Study:

Bias and Fairness in AI, Privacy and Data Protection, Algorithmic Accountability, Safety and Reliability, Safety and Reliability.

References:

1. Khemani, Deepak, *A first course in artificial intelligence,* McGraw-Hill Education, 2013.
2. Rajasekaran, Sanguthevar, and GA Vijayalakshmi Pai, *Neural networks, fuzzy logic and genetic algorithm: synthesis and applications (with cd),* PHI Learning Pvt. Ltd., 2003.
3. Russell, Stuart J., and Peter Norvig, *Artificial intelligence: a modern approach. Malaysia*, Pearson Education Limited, 2016.

MTE 5403: AUTOMATED MANUFACTURING SYSTEMS [3 1 0 4]

Numerical control production systems **[12]**

Development in machine tools, introduction to NC technology, basic components of CNC system - part programming, machine control unit, machine tool. Design consideration of CNC machines, methods of improving machine accuracy and productivity, machine structure, guideways, spindle and feed drives, spindle bearings, interpolators, control loops of CNC systems – control loop of point to point systems, control loop of contouring systems. Machine control unit - data processing unit - elements and their functions - interpolators and sequential controllers.

Interpolators **[8]**

Types and stages of interpolation, principles of interpolation - techniques employed for interpolation scheme, requirements of interpolation algorithms, interpolation schemes - stairs approximation, digital differential analyzer, direct function calculation; DDA - hardware and software; software interpolators.

CNC programming **[8]**

Concepts of CAM - tool path generation and control methods. Co-ordinate systems, CNC programming for turning center and machining center by manual method (word address format only), CNC programming with interactive graphics, manual data input, distributed numerical control, adaptive control machining system, automated inspection and testing: principle and methods, coordinate measuring machines.

Material handling and identification technologies **[10]**

Introduction to material handling, material transport equipments, analysis of material transport systems. Storage system performance and location strategies, conventional storage methods and equipment, automated storage systems, engineering analysis of storage systems. Factory data collection - automatic identification and data capture, bar code technology, RFID in manufacturing.

Computer integrated manufacturing systems **[10]**

Part families – part classification and coding, production flow analysis, computer integrated manufacturing system, types of manufacturing system, machine tools and related equipment. Flexible manufacturing system, FMS work station, types of FMS layouts, computer control in CIM, human labor in CIM, benefits of CIM. Computer aided process planning, computer integrated planning systems. Material requirement planning, capacity planning, shop floor control.

References:

1. KorenYoram and Ben and Uri Joseph, *Numerical Control of Machine Tools*, Khanna Publishers, New Delhi, 2005.
2. GrooverMikell P., *Automation, Production Systems, and computer Integrated manufacturing,* Prenice Hall of India, New Delhi., 2003.
3. GrooverMikell P. and Zimmers Emory W., *Computer aided design and manufacturing*, Prentice Hall of India, New Delhi., 2003.
4. Radhakrishnan P., *Computer Numerical Control Machines,* New Central Book Agency (P) Ltd.,Kolkata., 2004.

MTE 5404: DATA ANALYTICS FOR AUTOMATION [3 1 0 4]

Data and Representation **[7]**

Introduction to Statistics and Analytics, Collection of data, classification and tabulation of data, Types of data: Primary data, Secondary data, Presentation of data Diagrammatic and Graphical Representation: Histogram, frequency curve, frequency polygon, Ogive curves, stem and leaf chart.

Diagnostic Analytics **[7]**

Bivariate normal distribution, types, importance, methods of measuring correlation-scatter diagram, Karl Pearson's Coefficient of Correlation and Spearman's rank Correlation. Regression lines, Difference between regression and correlation, uses of Regression

Data Warehousing, Mining, and Business Analysis **[12]**

Data warehousing Components –Building a Data warehouse –- Mapping the Data Warehouse to a Multiprocessor Architecture – DBMS Schemas for Decision Support – Data Extraction, Cleanup, and Transformation Tools –Metadata. Reporting and Query tools and Applications – Tool Categories –Online Analytical Processing (OLAP) – Need – Multidimensional Data Model – OLAP Guidelines – Multidimensional versus Multirelational OLAP Data Mining Functionalities – Interestingness of Patterns – Classification of Data Mining Systems – Data Mining Task Primitives – Integration of a Data Mining System with a Data Warehouse – Issues –Data Preprocessing, Cluster Analysis - Types of Data – Categorization of Major Clustering Methods – Kmeans – Partitioning Methods – Hierarchical Methods - Density-Based Methods –Grid Based Methods – Model-Based Clustering Methods – Clustering High Dimensional Data - Constraint – Based Cluster Analysis – Outlier Analysis – Data Mining Applications

Predictive Analytics **[11]**

Introduction to Analytics, Analytics in Decision Making, Predictive Analytics, Introduction to Regression, Model Development, Model Validation, Multiple Linear Regression, Estimation of Regression Parameters, Model Diagnostics, Dummy, Derived & Interaction Variables, Multi-collinearity, Forecasting, Time Series Analysis, Additive & Multiplicative models, Exponential smoothing techniques, Forecasting Accuracy, Auto-regressive and Moving average models, Introduction to Decision Trees, Chi-Square Automatic Interaction Detectors (CHAID) and Regression Tree (CART), Analysis of Unstructured data and Naive Bayes Classification.

Data Visualization **[11]**

Connecting to Data Metrics vs dimensions Data types and defaults Aliases and names Data Visualization Concepts, Exploratory Visualization Data Joins o Best Practices Creating visualizations with Tableau Sorting, Filtering Maps, Optimal visualization types, Binning values, Calculated fields, Table calculations, Level of Detail calculations. Dynamic charts - Dynamic maps - Animation types - 2D, 3D, Motion Animation - Animation Principles - Altair Package - Statistical Visualizations. Visual Perception and Cognition - Gestalt's Principles - Tufte's Principles - Applications of Principles of Information Visualization - Dashboard Design

Self-study:

Topics related to "Advanced Issues in Predictive Modeling" from *Galit Shmueli, Peter C. Bruce, Inbal Yahav, Nitin R. Patel, Kenneth C. Lichtendahl. Data Mining for Business Analytics: Concepts, Techniques and Applications.*

Reference

1. Mood, A. M., Graybill, F. A. And Boes, D.C., *Introduction to the Theory of Statistics*, McGraw Hill.
2. Biswas and Srivastava, *Mathematical Statistics: A Textbook*, Ist Edition, Narosa Publishing House, New Delhi, 2011.
3. Gupta, S.C. and V. K. Kapoor, *Fundamentals of Mathemathical Statistics*, Sultan Chand and sons, 2014.
4. Hogg,R.V. and Craig, A.T, *Introduction to Mathematical Statistic*s, McMillan.
5. S. C. Gupta, Fundamentals of Statistics, Himalaya Publishing House, 2018.

MTE 5405: DIGITAL MANUFACTURING [3 1 0 4]

Introduction to Digital manufacturing **[4]**

Types of production systems. Needs of digital manufacturing, effective & efficient use of digital manufacturing (DM) tools. Scope of digital manufacturing in future. Computers in manufacturing industries, Key challenges, techniques, requirements, product life cycle, Integration of CAD/CAM systems, Advantages of CAD/CAM systems.

Concurrent engineering **[6]**

Definition & philosophy of concurrent engineering; teamwork; interfacing of manufacturing and design - design for manufacturability; project management; life cycle based on concurrent engineering; design for assembly. Examples – MEMS and 3D printing

Industrial control systems **[4]**

Process interfacing, collecting manufacturing process data, system interpretation of process data, interfacing hardware devices, and digital input/output processing, hierarchical computer structure and networking

Computer networks in industries **[6]**

Network technologies, LAN/MAN/WAN networks, Communications: Communication Methods, Direct numerical control, communication standards, communication protocols, design activity in a networked environment.

CIM and DBMS in manufacturing **[8]**

CIM database, database requirements in CIM environment, database models – Hierarchical, network, RDBMS. Database architecture, SQL and coding.

Industrial ethics, technology and Engineering **[12]**

Introduction, the responsibility of engineers, Codes of conduct, normative ethics, the ethical cycle, Ethical questions in the design of technology, Designing morality, Ethical aspects of technological risks.

Digital twin and Blockchain technology in manufacturing **[8]**

Digital twin for condition monitoring of 3D printer nozzle, block chain technology in food processing industries, development of digital thread to track the products.

References:

1. M.P.Groover, E.W.Zimmers Jr., *CAD/CAM: Computer aided design and manufacturing*, Prentice-Hall of India Pvt. Ltd. 2001
2. P.N.Rao, *CAD/CAM: Principles and Application*, Tata McGraw Hill 2005.
3. Tai Ran Hsu, *MEMS and Microsystems- Design and manufacturing*, Tata McGraw Hill, 2001
4. Marc J. Madou, *Fundamentals of microfabrication,2002*
5. https://www.coursera.org/learn/ethics-technology-engineering/.

MTE 5406: DRONE TECHNOLOGY [3 1 0 4]

Introduction to Drone **[5]**

Definition of drones, Anatomy of Drone, Importance of Drone Technology, History of Drone, Types of Drone as per structure, Need of Drone Technology.

Components of Drone: **[7]**

Introduction, Antenna, Propellers, Motor, Camera and its accessories, Ground Station, chassis, Propellers, Battery and charger, Types of Battery, battery function in drone, Flight controller and its peripherals, GNSS & RTK Module, Flight Controller, ESC (Electronic speed Controller), Power Module, Radio Transmitter/Receiver.

Working principles of Drone: **[8]**

Introduction, Working Principle of drone, Definition of Propulsion, Propeller and vertical motion of Drone, Concept of drone flight, Take-off, and landing, Flight Modes and Maneuvering, Dynamics of an aerial system, Principal axes and rotation of aerial systems, on board flight control, Types of Platform and Propulsion system required for drone operation.

Stability and Control of Drone: **[8]**

Introduction to stability and Control of Drone, Definition of Stability, Definition of Control, Types of Stability required in Drone, Types of Control required in Drone

Sensors used in drones: **[9]**

Introduction of Sensor, Definition of Sensor, Working Principle of Sensor, Types of sensors, Accelerometer, Barometer, Gyro Sensor, Magnetometer, Time of Flight Sensors, Thermal Sensors, Chemical Sensors, Distance Sensors, Light - Pulse Distance Sensor, Radio Detection and Ranging and Sonar -Pulse Distance Sensing, Sensors such as Hyperspectral, Multispectral, Thermal and RGB and other payloads.

Regulation and Maintenance of Drone: **[7]**

Introduction, Basic Air. Regulations, DGCA regulation, foreign regulatory, FCC compliance, UAS registration and Federal Aircraft Regulations (FARs). Maintenance of Drones includes flight control box, ground station, Maintenance of ground equipment, batteries and Payloads, Scheduled servicing, Repair

Case studies: **[4]**

Application of Drones in the agriculture domain, mineral exploration, surveillance etc.

Self-Study topics:

Flight mode navigation, QGIS drone mapping, 3D mapping and real time applications.

Reference:

1. Tal, D., Altschuld, J., *Drone Technology in Architecture, Engineering and Construction: A Strategic Guide to Unmanned Aerial Vehicle Operation and Implementation*. United States: Wiley, 2021.
2. Boyle, M. J., *The Drone Age: How Drone Technology Will Change War and Peace.* United Kingdom: Oxford University Press, 2020.
3. *The Future of Drone Use: Opportunities and Threats from Ethical and Legal Perspectives.* Germany: T.M.C. Asser Press, 2016.
4. Tripathi, S. L., Rana, A. K., Sharma, S., Goyal, N., *Internet of Things: Robotic and Drone Technology*. United Kingdom: CRC Press, Taylor & Francis Group, 2022.
5. DeFrangesco, S., DeFrangesco, R., *The Big Book of Drones*. United States: CRC Press, 2022
6. Altschuld, J., Tal, D., *Drone Technology in Architecture, Engineering and Construction: A Strategic Guide to Unmanned Aerial Vehicle Operation and Implementation*. United States: Wiley, 2021
7. Stalley, P., *The Drone Technology: The Main Features and Utilization of the Unmanned Aircraft System*. (n.p.): Independently Published, 2019.

MTE 5407: EDGE COMPUTING IN AUTOMATION [3 1 0 4]

Internet of Things and New Computing Paradigm: [06]

Hierarchy of Fog and Edge Computing. Business models. Opportunities and Challenges. Fog and Edge Computing Completing the Cloud.

Hierarchy of Fog and Cloud Computing: [06]

Business Models, Opportunities and Challenges. Addressing the Challenges in Edge Computing: Network Challenge, Management Challenge.

Integrating IoT, Fog and Cloud Infrastructures: [06]

Methodology, Integrating C2F2T Literature by Use-Case Scenarios, Integrating C2F2T Literature by Use-Case Scenarios by metrics.

Management and Orchestration of Network Slices in 5 G: [06]

Network Slicing in 5 G. Network Slicing in Software Designed Clouds. Network Slicing in Edge and Fog.

Optimization problems in Fog and Edge Computing: [06]

Formal Modelling Framework for Fog Computing. Resource Usage. Energy Consumption.

Data management and predictive analysis in Fog and Edge Computing: [18]

Using Machine Learning for Protecting the Security and Privacy of Internet of Things (IoT) Systems. Fog Computing for Big Data Analytics. Case studies: Edge computing for Health monitoring, Smart Transportation System and IoT applications.

Self-study:

Coursera course entitled: Computing anywhere: IoT and Edge for AI

References:

1. Buyya, R., Srirama, S. N., *Fog and Edge Computing: Principles and Paradigms*, Wiley, 2019.
2. Dharani, D., Sadasivam, D. S., *Edge Computing: Fundamentals, Advances and Applications*. CRC Press, 2021.
3. Bahga, Arshdeep, and Vijay Madisetti. *Internet of Things: A hands-on approach*, (1e), University Press, 2014
4. Simone Cirani, Gianluigi Ferrari, Marco Picone, Luca Veltri. *Internet of Things: Architectures, Protocols and Standards*, (1e), Wiley Publications, 2019

MTE 5408: LEGGED ROBOTICS [3 1 0 4]

Pre-requisite: Basics of Reinforcement learning

Introduction of Legged Robotics: **[8]**

History of legged robotics, four, and multi-legged robots. background concepts of legs, robots, and animals' motion.

Design of Legged Robots: **[10]**

Review of mechanical structures of legged robots, passive and dynamic walkers. dynamic versus static stability, different stability criteria, energy consumption, cost of transport (COT), state estimation. Properties of sensors, motors and muscles.

Models of Locomotion: **[8]**

Rimless wheel, inverted pendulums, linear inverted pendulum (LIP), spring-loaded inverted pendulum (SLIP), template versus anchor models.

Control of Legged Robots: **[10]**

Trajectory-based methods, virtual leg control, virtual model control, hybrid-zero dynamics, optimal control, planning approaches, approaches based on reinforcement learning, and bioinspired approaches.

Legged Robot Evaluation: **[8]**

Effectiveness of motion: speed, versatility, appearance. Energy of motion: VO2, COT. Stability of motion: eigenvalues, basin of attraction, disturbance rejection. Analysis approaches: no control (passive dynamics), perfect control (optimization).

Case Study and Application: **[4]**

Energy Efficient Legged robots. Teaching a Legged Robot How to Walk. Force control for Robust Quadruped Locomotion.

Self-Study:

On Safety Testing, Validation, and Characterization with Scenario-Sampling for Legged Robots. Random Processes, Multi-variable and nonlinear control.

References:

1. Mahapatra, Abhijit, Shibendu Shekhar Roy, and Dilip Kumar Pratihar. *Multi-body Dynamic Modeling of Multi-legged Robots*. Springer Nature, 2020.
2. Todd, David J. *Walking machines: an introduction to legged robots*. Springer Science & Business Media, 2013.

3. Kajita, Shuuji, and Bernard Espiau. "Legged robot." *Springer handbook of robotics*. Springer, 361-389, 2008.
4. De Santos, Pablo Gonzalez, Elena Garcia, and Joaquin Estremera. *Quadrupedal locomotion: an introduction to the control of four-legged robots*. Vol. 1. London: springer, 2006.
5. Raibert, Marc H. *Legged robots that balance*. MIT press, 1986.

MTE 5409: MACHINE VISION AND IMAGE PROCESSING [3 1 0 4]

Image Acquisition and Pre-processing **[12]**

Vision and image sensors, vision system components, 2D image formation, image digitization, image formats, image representation. color image processing, Data structures for image analysis. Pixel brightness transformations, image enhancement, image de-nosing, image restoration and reconstruction, morphological operations, visual image quality indexes.

Image Segmentation and Feature Extraction **[12]**

Edge detection**,** manual threshold and optimal thresholding, edge-based segmentation, region-based segmentation, splitting and merging, segmentation quality indexes. Feature extraction of images, Feature extraction: boundary and region feature descriptors, Harris corners, SIFT, SURF, HOG.

Motion Estimation and Object Recognition **[6]**

Background subtraction**,** Optical flow estimation, object tracking with Kalman filtering, Object detection: template matching, feature-based methods.

3D Vision **[10]**

3D vision formation, pinhole camera model, Parallel and Perspective projection geometry, lens distortion, 2D and 3D geometrical transformations, intrinsic and extrinsic camera parameters, calibration methods, stereovision, epipolar geometry, triangulation, fundamental matrix, stereo correspondence algorithms – feature based and correlation based, 3D reconstruction.

Case studies/application **[8]**

Automated object detection, human detection and face recognition, vehicle tracking, multispectral imaging in industrial application, industrial robot guidance, demonstration of applications using Computer vision software tools.

Self-study: Ethical Issues in Computer Vision and Strategies for Success. Computer Vision Applications and their Ethical Risks.

References:

1. Rafael C. Gonzalez, Richard E. Woods, *Digital Image Processing*, (4e), Pearson Education, 2018.
2. Sonka, Milan, Vaclav Hlavac, and Roger Boyle. *Image processing, analysis, and machine vision*. Cengage Learning, 2014.
3. Cyganek, Boguslaw, and J. Paul Siebert. *An introduction to 3D computer vision techniques and algorithms*. John Wiley & Sons, 2011.
4. Davies, E. Roy. *Machine vision: theory, algorithms, practicalities*. Elsevier, 2004.
5. Jain, Ramesh, Rangachar Kasturi, and Brian G. Schunck. *Machine vision*. Vol. 5. New York: McGraw-Hill, 1995.
6. Corke, Peter I., and Oussama Khatib. *Robotics, vision and control: fundamental algorithms in MATLAB*. Berlin: Springer, 2011.
7. Szeliski, *Computer Vision: Algorithms and Applications*, Springer, 2012

MTE 5410: MACHINES AND MECHANISMS [3 1 0 4]

Introduction to mechanism **[6]**

Types of motions, kinematic chain, links, joints (pairs), inversions, grashof's law:-four bar linkages and higher order linkages, Degree of freedom:- spatial and planar mechanisms, redundancy in robot manipulators, Kinematic constraints and diagrams.

Analysis **[14]**

Kinematic analysis of mechanisms: Position, velocity and acceleration analysis of four bar slider crank linkage and four bar inverted slider crank -Analytical approach. Kinametic study of any point on a linkage. Coriolis acceleration, Transmission angle. Straight line mechanisms in automation. Dynamic analysis of mechanisms: Force analysis of three bar crank-slide linkage and four bar linkage. Shaking forces and shaking torque. Case Studies.

Balancing and Vibration **[10]**

Unbalance, causes; Types of unbalance-static unbalance; quasi-static unbalance; couple unbalance; dynamic unbalance, unbalance due to eccentricity in mounting shaft and non-uniform mass distribution of rotor; Free vibration, equation of motion, natural frequency, damped vibration, bending critical speed of simple shaft, Torsional vibration, Forced vibration and isolation, Case Studies.

Synthesis **[8]**

Dimensional synthesis of mechanism; motion, path and function generation, precision point approach. Two position and Three position synthesis by graphical method: (Inversion method, Pole and Relative pole method), Advanced synthesis solutions, Coupler curves, Analytical method.

Force Analysis **[5]**

Applied and constrained forces free body diagrams, static equilibrium conditions, Two, Three and four members, static force analysis in simple members. Dynamics force analysis: interia forces and interia torque, D'Alembert's principle, Superposition principle, dynamic force analysis in simple members.

Gears **[5]**

Torque and power transmission, applications of helical, bevel & worm gears. Gear trains- simple, compound, reverted; Epicyclic/ planetary- speeds of element of gear train, tabulation and formula methods, differential gear box. Case Studies.

Reference

1. Norton, Robert L. *Design of machinery: an introduction to the synthesis and analysis of mechanisms and machines*. 5/ed, McGraw-Hill, 2011.
2. Uicker, John Joseph, Gordon R. Pennock, and Joseph Edward Shigley. Theory of machines and mechanisms. Vol. 1. New York, NY: Oxford University Press, 2011.
3. Myszka, David H. Machines and mechanisms.Applied Kinematic Analysis. 4/e, Pearson Higher education, 2012.
4. Rattan, S.S Theory of machines, Tata McGraw-Hill Education. 5th edition,2019
5. Rao, J.S and Dukkipati R.V. Mechanism and Machine Theory. New Age International Pvt. Ltd, 2006
6. Sandor GN, Erdman AG. Advance mechanism design vol. 1 & 2: Analysis and synthesis. Prentice-Hall, 1984.
7. Rao SS, Yap FF. Mechanical vibrations. New York: Addison-Wesley,1995

MTE 5411: MICRO-MANUFACTURING SYSTEMS [3 1 0 4]

Introduction **[4]**

Micro-manufacturing: an overview, classifications of micro-manufacturing processes, challenges in meso, micro, and nano-manufacturing, industrial applications and future scope of micro-manufacturing processes.

Introduction to traditional and advanced micromachining **[11]**

Principles, working construction with applications of microturning, micromilling, microgrinding, biomachining, micro- and nano-manufacturing by focused ion beam, electric discharge micromachining, electrochemical micromachining, abrasive water jet micromachining.

Microcasting and micromolding **[10]**

Microcasting, micromolding – a soft lithography technique, fabrication of microelectronic devices.

Microforming **[8]**

Introduction to microforming, micro- and nanostructured surface development by nano plastic forming and roller imprinting, microextrusion, microbending with laser.

Microjoining **[7]**

Introduction to microjoining, laser microwelding, electron beams for macro- and microwelding working principle and construction with applications.

Nanofinishing **[8]**

Magnetorheological and allied finishing processes and their theoretical analysis, theoretical analysis of abrasive flow finishing (AFF) for micromanufacturing, an integrated wafer surface evolution model for chemical mechanical planarization (CMP).

References:

1. Jain V. K., *Introduction to micromachining*,Narosa Publishing house Pvt. Ltd., 2010
2. Jain V. K., *Micromanufacturing*, CRC Press, 2012
3. Jain V. K., *Advanced machining processes*, Allied Publishers Pvt. Ltd., 2014
4. Mahalik N. P., *Micromanufacturing& Nanotechnology*, Springer Berlin Heidelberg, 2006
5. Jackson J. M., *Microfabrication & Nanomanufacturing*, CRC Press, 2005.

MTE 5412: SOFT ROBOTICS [3 1 0 4]

Introduction to Soft Robotics- Motivation **[13]**

Bio robotics, biomimetics, nature-inspired designs, materials for soft robot, biological analogy, Soft Actuators (dielectrics, pneumatics, fluidics), Soft Sensors (fluidic, solid, composites, textiles), Electroactive Polymer, Ionic Polymer Metal Composites, Shape Memory Alloy, Artificial Muscles based on Electric/Pneumatics, Thermal/Chemical Actuation.

Fabrication of Pneumatics-Based Actuators **[13]**

Introduction to 3D Printing, 3D printing of Soft Materials, Hyper-elasticity, Finite Element Analysis, Stretchable Electronics, Soft Electrical Materials, Soft Mechanical Composite Materials, Gradient of Material Stiffness, Mechanical Soft Materials, Pneumatic Artificial Muscles. Materials, design, Introduction to 3D Printing, 3D printing of Soft Materials

Fabrication Of Piezo Based Actuators **[04]**

Materials, design, Introduction to 3D Printing, 3D printing of Soft Materials

Mechanics of Soft (Numerical, Computational, Analytical) **[13]**

Mathematical Modelling of Flexible Manipulator, Introduction to Euler Cautchy Elasticity Problem Hyper-redundant kinematic structures, Resolution of inverse kinematics, Mathematical formulation for animating flexible structure, Bio-mimetics (modelling of snake/earthworm, caterpillar etc), Continuum Mechanics, Eigenvalues and Eigenvectors, Geometric interpretation of eigenvectors, Cayley-Hamilton theorem, Principal Component Analysis, Singular Value Decomposition, ISO-Map Dimensional Reduction technique, Hyper-elasticity, Finite Element Analysis, Stretchable Electronics, Soft Electrical Materials, Soft Mechanical Composite Materials, Gradient of Material Stiffness, Mechanics of Soft Materials

Applications **[5]**

Case Studies on wearable Robotics, Space Robotics, Deep-Sea Robotics, Healthcare Systems, Under- actuated Robots

References:

1. Matthew Borgatti, Kari Love, Christopher G. Atkeson, *MAKE: Soft Robotics – A DIY Introduction to Squishy, Stretchy, and Flexible Robots,* 2018.
2. Jog, C.S., Foundations and applications of mechan*ics: Volume I: Continuum mechanics*, Narosa Publishing House, 2007.
3. Alexander Verl, Alin Albu-Schaffer, Oliver Brock, Annika Raatz, *Soft Robotics Transferring Theory to Application*, Springer, 2015.

4. Jaeyoun (Jay) Kim, *Microscale Soft Robotics: Motivations, Progress, and Outlook*, Springer International Publishing, 2017.
5. Cecilia Laschi, Jonathan Rossiter, Fumiya Iida, Matteo Cianchetti, Laura Margheri, *Soft Robotics: Trends, Applications and Challenges*, Springer International Publishing, 2016.

MTE 54013: VIRTUAL REALITY [3 1 0 4]

Introduction to AR/VR **[12]**

Augmented Reality, Virtual reality, Mixed Reality, Extended reality, history, Market Analysis, Hardware, and Software Integrated Development Environment IDE, VR and AR device classification, Non-Fungible Token, Internet of Things, AI/ML, Perception, Temporal resolution, spatial resolution, motion perception, depth perception, color perception, auditory, perception, haptics perception, locomotion interfaces

Unity3D **[12]**

Editor, Game objects and Components, materials, texturing, Basics lighting, skybox, Package import and export, modeling, scripting. Probuilder modeling, terrain creation, introduction to asset store, Avatar creation, Animator, Particle Systems, C# scritping.

AR-VR use cases **[10]**

Industry 4.0, Blockchain, medical robotics, military and defense, automobile industry, Architecture Engineering, and Construction, Education, Manufacturing industry, Health care Industry.

Extended Reality

XR tool kit setup, Assembly smart factory, locomotion move turn, conveyor system animation, teleoperation, UI interaction, XR challenges: XR Best methods and process, HMD Oculus, UX design, quality testing of XR systems. **[12]**

References

1. Ralf Doerner , Wolfgang Broll , Paul Grimm, Bernhard Jung, *Virtual and Augmented Reality (VR/AR): Foundations and Methods of Extended Realities (XR)*, Springer, 2022
2. Steve Aukstakalnis, *Practical Augmented Reality A Guide to the Technologies, Applications, and Human Factors for AR and VR*, Addison Wesley, 2016
3. Kipper, Gregory, and Joseph Rampolla, *Augmented reality: An emerging technologies guide to AR.*, Elsevier, 2012

MTE 5301: AUTOTRONICS AND VEHICLE INTELLIGENCE [3 0 0 3]

Fundamentals of Automotive Electric Systems **[5]**

Batteries, alternator, starter motor, ignition systems, headlamp, wiper motor, etc.

Sensors & Actuators **[5]**

Hall Effect, hot wire, thermistor, piezo electric, piezoresistive, based sensors. Introduction, basic sensor arrangement, types of sensors, oxygen concentration sensor, lambda sensor, crankshaft angular position sensor, cam position sensor, Mass air flow (MAF) rate, Manifold absolute pressure (MAP), Throttle plate angular position, engine oil pressure sensor, vehicle speed sensor, stepper motors, relays, detonation sensor, emission sensors.

Powertrain and SI Engine Management **[5]**

Layout, Components of SI FI systems, types of FI systems: Throttle body, MPFI, GDI. Group and sequential injection techniques.

Electronic ignition systems **[5]**

Advantages of electronic ignition systems. Types of solid-state ignition systems and their principle of operation, Contactless electronic ignition system, electronic spark timing control.

CI Engine Management **[5]**

Fuel injection system, parameters affecting combustion, noise and emissions in CI engines. Pilot, main, advanced, post injection and retarded post injection. Electronically controlled Unit Injection - system. Layout of the common rail fuel injection system. Working of components like fuel injector, fuel pump, rail pressure limiter, flow limiter, EGR valve control in electronically controlled systems.

On-board Diagnostics **[6]**

OBD-I, OBD-II, EOBD, Indian Scenario Transmission Systems: AMT, OCT, AT, Chassis Control Systems, ABS, ESP, RSC, ASBRS, EPS, Active suspension systems.

Hybrid vehicles and Intelligent Vehicle Systems **[5]**

Unmanned ground vehicles, Vehicle Platooning.

References:

1. P.L. Kohli, *Automotive Electrical Equipment*, TMH, 1983
2. C.P. Nakra, *Basic automotive electrical systems*, Dhanpat Rai Pub, 2023
3. William H. Grouse, *Automotive mechanics*, TMH, 1983
4. A.W.Judge Modern Electrical Equipments, Springer Science & Business Media, 2012.

5. R K Jurgen, *Electric and Hybrid-electric vehicles*, SAE International, 2011
6. Mano, *Digital Logic and Computer Design*, Prentice Hall India, 2017
7. T Denton, *Automobile electrical and electronic systems*, Butterworth-Heinemann, 2004
8. Uwe Kiencke and Nielsen, *Automotive Control Systems: For Engine, Driveline, and Vehicle*, Second Edition, Springer 2005.

MTE 5302: PRODUCT DESIGN AND DEVELOPMENT [3 0 0 3]

Discrete electronic components manufacturing **[8]**
Materials terminology, devices and circuits for displays, sensors, MEMS, and flexible electronics.

Introduction to IC manufacturing **[6]**
Manufacturing and realization of passive components in ICs and VLSI; Electromagnetic interference, Yield and reliability, thermal budget and Current trends.

Basic packaging and supporting process **[10]**
Design and noise issues in electronic packaging, Packaging of power devices; Printed wiring boards, interconnects, hybrids, surface-mount technology, Physical integration of circuits, packages, boards, and full electronic systems.

Package modelling and simulations **[6]**
SPICE simulations of signals and noise. Semiconductor device packaging and improved Cable & Harness.

Case studies **[6]**

Software simulations: Inverse and forward kinematics of rigid manipulators, Singularity and workspace generation, form and force closure analysis of flexible manipulator.

References:

1. Moorthy, Srinivasa. S.A *Introduction to Electronic Packaging Unconventional Guide to Product Design*, Notion press, 2016
2. Lau J. H., Wong C. P., Prince J. L., Nakayama Wataru, *Electronic Packaging: Design, Materials, Process and Reliability*, Tata McGraw Hill, 1998.
3. Ghosh A., Basavaraj V. H. and Shigekazu S., *Manufacturing of electronic materials and components*, American Ceramic Society, 1998.
4. Shina Sammy G., *Six sigma electronics design and manufacturing*, Tata McGraw Hill, 2002.

MTE 5303: ELECTRIC VEHICLE TECHNOLOGY [3 0 0 3]

Introduction to EV **[5]**

History of Hybrid and Electric Vehicles technology, Economics and Environmental aspects of vehicle technologies, Need for Electric Mobility. Well to wheel analysis & comparison. EV Architectures, Case studies: Tesla Model S, Nissan Leaf, Ather 450, KPIT electric bus.

EV Configuration and Architecture **[4]**

Components of Electric vehicles: Power train, energy source and auxiliary subsystems. EV Configurations. Performance of EV: Traction motor characteristics, Tractive effort, and transmission requirement.

Power Train: **[10]**

Power Train: Configuration and control of dc and induction motor drives for EV. PMSM, BLDC, SRM and SyncRel Motor drives for EV. Sizing of EV Motor, Peak Torque and Power, sizing of power Electronics devices and topologies.

Energy and Auxiliary Components of EV: **[4]**

Energy and energy management strategies, Regenerative braking-fundamentals. Auxiliary components technology in electric: steering unit, braking unit, HVAC unit, Auxiliary battery charging.

EV Controls: **[7]**

Control of Electric vehicles: Function of Control in EV and HEV, Elementary of Control theory, Electronic Control unit, Control Area Network, Control variables. Electric vehicle safety engineering, limitations of EV, Infrastructure, Overview of Testing.

Fundamentals of Hybrid: **[6]**

Fundamental concept of hybrid traction, hybrid drive train architecture – series, parallel torque, and speed coupling. Hybridness, Hybrid design philosophy, Mild, Micro, PHEV, Range extension vehicles.

References:

1. Mehrdad Ehsani, *Modern Electric, Hybrid Electric and Fuel Cell Vehicles-Fundamentals, Theory and Design*, (3e), CRC Press, 2018.
2. Iqbal Hussein, *Electric and Hybrid Vehicles-Design Fundamentals,* (2e), CRC Press, 2010.

3. Gianfranco Pistoia, *Electric and Hybrid Vehicles - Power Sources, Models, Sustainability*, *infrastructure and the market*. Elsevier, 2010.

MTE 5304: UNDERWATER ROBOTICS [3 0 0 3]

Fundamentals of Underwater Robot **[4]**

An introduction to the types, applications and practical considerations of deploying and operating Maritime Robotic Systems including AUVs, ASVs, ROVs, underwater gliders and Argo floats.

Design of Underwater Robots **[6]**

Design of underwater robotic systems and calculation of vehicle parameters and performance metrics including pressure, buoyancy, power, speed, range.

Kinematics of Underwater Robot **[7]**

Equations for moving frame - rigid motion in a plane -representation of a rotated frame, modelling with respect to global coordinates.

Navigation **[5]**

Sensors and navigational strategies for underwater robotic systems including localisation using dead-reckoning, SLAM and uncertainty/probabilistic approaches.

Guidance **[6]**

Path planning algorithms and path following strategies including artificial potential field methods, Dijkstra’s, A* star algorithms and line of sight (LOS) guidance strategies.

Control **[5]**

Modelling and control of underwater robotic systems including PID controllers, system architectures, actuator and vehicle dynamics, design and analysis of thrusters.

Miscellaneous **[3]**

Remote sensing and environmental monitoring with underwater robots, underwater vehicle-manipulator systems, bio-mimetic underwater robotics, and bio-inspired robotic systems. Case studies from India, Singapore, Republic of Korea, Japan and USA.

References:

1. Alexander Schlaelfer and Ole Blaurock, *Robotic sailing*, Proceedings of the 4th International sailing conference, Springer, 2011

2. Sabiha A. Wadoo, Pushkin Kachroo, *Autonomous underwater vehicles, modelling, control design and Simulation*, CRC press, 2011
3. Robert D. Christ,Robert L. Wernli, Sr, *The ROV Manual A User Guide for Remotely Operated Vehicles*, Elsevier, second edition, 2014
4. Thor I Fossen, *Guidance and control of ocean vehicles*, John wiley and Sons, 1999
5. Yu Junzhi, *Visual Perception and Control of Underwater Robots*, 1st Edition, CRC Press, 2018
6. Mae L. Seto, *Marine Robot Autonomy*, Springer, 2013
7. Richard A Geyer, S*ubmersibles and their use in oceanography and ocean engineering*, Elsevier, 1997
8. Gianluca Antonelli, *Underwater robotics*, Springer, 2014