Department of Mechatronics
M.Tech. in Industrial Automation and Robotics
Program Structure (Applicable to 2023 admission onwards)

YEAR	FIRST SEMESTER						SECOND SEMESTER					
	SUB CODE	**SUBJECT NAME**	**L**	**T**	**P**	**C**	**SUB CODE**	**SUBJECT NAME**	**L**	**T**	**P**	**C**
I	MAT 5133	MATHEMATICS FOR MODELLING AND SIMULATION	4	0	0	4	MTE 5214	EMBEDDED SYSTEMS FOR AUTOMATION	3	0	3	4
	MTE 5113	ROBOT KINEMATICS AND DYNAMICS	3	1	0	4	MTE 5215	MOTION CONTROL AND PATH PLANNING	3	1	0	4
	MTE 5114	SENSORS AND DRIVES FOR INDUSTRIAL AUTOMATION	3	1	0	4	MTE ****	PROGRAM ELECTIVE I	3	1	0	4
	MTE 5115	FLUID POWER AUTOMATION	3	0	3	4	MTE ****	PROGRAM ELECTIVE II	3	1	0	4
	MTE ****	PROGRAM ELECTIVE	3	1	0	4	MTE ****	PROGRAM ELECTIVE III	3	1	0	4
	HUM 5051	RESEARCH METHODOLOGY & TECHNICAL COMMUNICATION	1	0	3	-	*** ****	OPEN ELECTIVE	3	0	0	3
	MTE 5141	PLC AND MPS LAB	0	0	3	1	HUM 5051	RESEARCH METHODOLOGY & TECHNICAL COMMUNICATION*	1	0	3	2
	MTE 5142	INDUSTRIAL INTERNET OF THINGS LAB	0	0	3	1	MTE 5241	ROBOTICS LAB	0	0	6	2
	MTE 5143	DRIVES, CONTROL AND MODELLING LAB	0	0	3	1						
	Total					**23**						**27**
	THIRD AND FOURTH SEMESTER											
II	MTE 6091	PROJECT WORK & INDUSTRIAL TRAINING							**0**	**0**	**0**	**25**

*TAUGHT IN BOTH SEMESTERS AND EVALUATED AND CREDITED IN THE SECOND SEMESTER

**LAB COURSES 2 & 3 AND 4&5 MAY BE COMBINED INTO ONE BY EITHER ALLOTTING 6 Hrs/WEEK OR 3 Hrs/WEEK WITH A PROVISION FOR MINI PROJECT/ASSIGMENTS

PROGRAM ELECTIVES		OPEN ELECTIVES	
COURSE CODE	COURSE TITLE	COURSE CODE	COURSE TITLE
MTE 5401	Analog and Digital Electronics	MTE 5301	Autotronics and Vehicle Intelligence
MTE 5402	Artificial Intelligence and Expert Systems	MTE 5302	Product Design and development
MTE 5403	Automated Manufacturing Systems	MTE 5303	Electric Vehicle Technology (Not to be offered to M. Tech. in Electric Vehicle technology program of E&E Dept)
MTE 5404	Data Analytics for Automation	MTE 5304	Underwater Robotics
MTE 5405	Digital Manufacturing		
MTE 5406	Drone Technology		
MTE 5407	Edge Computing in Automation		
MTE 5408	Legged Robotics		
MTE 5409	Machine Vision and Image Processing		
MTE 5410	Machines and Mechanisms		
MTE 5411	Micro Manufacturing Systems		
MTE 5412	Soft Robotics		
MTE 5413	Virtual Reality		

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

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. Concept of Finite Difference method to heat, wave, Laplace and Poisson. Finite Element Method to differential equations. 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. 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. Tournament. Computer representation of graphs - Input and output, Algorithms for connectedness, Spanning Tree, Fundamental Circuits, Directed Circuits and Shortest paths. Basics of Permutation and combination, independence, One-Two dimensional random variable, Distribution, Parameter estimation, Hypothesis Testing, Random Process, Markov chain Monte Carlo method, probabilistic roadmap (PRM). Stochastic optimal control methods. Bayesian networks, Inference with Bayesian networks

References:

1. Ross Sheldon M, *Introduction to Probability and Statistics for Engineers and Scientists*, Elseveir, 2010.
2. J. N. Kapur, *Mathematical Modelling*, Wiley Eastern, 1998.
3. David C. Lay, *Linear Algebra and its Applications, 5/e*, (Pearson) 2016.
4. D B West, Introduction to Graph Theory, Pearson, 2000
5. Nielsen, Thomas Dyhre, and Finn Verner Jensen. *Bayesian networks and decision graphs*. Springer Science & Business Media, 2009.
6. Katsuhiko Ogata, *Modern control engineering*, Prentice-Hall, 2002
7. Rao S.S., *Optimization: theory and Practice*, Wiley Eastern Limited, 2005.
8. Jain, Mahinder Kumar, *Numerical methods for scientific and engineering computation*, New Age International, 2003.
9. Miller, Freund and Johnson - *Probability and Statistics for Engineers, 8/e*, PHI, 2011.
10. Hogg and Craig, *Introduction to Mathematical Statistics, 6/e*, Pearson education, New Dehli, 2012.
11. Athanasious Papoulis and S.U. Pillai, *Probability Random Variables and Stochastic Processes*, McGraw Hill, 2002.

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

Introduction to robotics- types and specification of robots, DoF, configurations, control resolution, spatial resolution, accuracy and repeatability, actuators and sensors, drives, and transmission systems used in robotics. Kinematic analysis & coordinate transformation-Direct kinematic problem in robotics, homogeneous transformation matrices, joint space, and cartesian space, Denavit-Hartenberg method, Inverse manipulator kinematics solvability, robot kinematics constraints, robot workspace, holonomic robots, Jacobian matrix, Jacobian singularity. Trajectory generation- general considerations in the path description and generation, joint-space schemes, and cartesian-space schemes. Manipulator dynamics-Newton's equation, Euler's dynamic formulation, iterative vs. closed form. Mobile robot planning & navigation- Introduction, competencies for navigation-planning & reacting, obstacle avoidance. Navigation architectures-modularity for code reuse & sharing, control localization, techniques for decomposition. 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. *Introduction 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 Industry 4.0, sensors and transducers, static and dynamic characteristics, selection criteria, working principle, operation, and applications of industrial sensors. Components of electric drives, factors affecting choice of drives, speed-torque conventions, steady state stability, multi-quadrant operation of electric drives, closed loop control, current limit control, speed control, position control, torque control, PLL control, multi-motor drive control. 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: DC shunt and series motors, working, torque-speed characteristics, applications, speed control of DC motors. AC Motor Drives: Construction, working, applications, torque- speed convention, speed control of induction motors, Synchronous motors: construction, working, torque-speed characteristics, applications, speed control, special motor drives: switched reluctance motor drive, BLDC, 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, Khanna Publishers*, 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, *Transducers and Instrumentation*, 2/e, PHI learning private Ltd., 2008.

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

Structure of hydraulic & pneumatic system, compressors, hydraulic pumps and motor, actuators, mounting details, power packs, reservoir accumulators - standard circuit symbols, 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, 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 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. Industrial applications of pneumatic and hydraulic control system.

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.

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

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. Introduction to the Mechatronics and Modular Production Systems (MPS) 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.
5. Hackworth and Hackworth F.D, *Programmable logic controllers- Programming Method and applications*, Pearson, 2004.

MTE 5142: INDUSTRIAL INTERNET OF THINGS LAB [0 0 3 1]

Computer Networking fundamentals, communication protocols. 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. Self-study: Coursera course entitled: The Bits and Bytes of Computer Networking

References:

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

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

Modelling and simulation of first and second-order circuits using Analytical, Numerical, and circuit approaches. Model DC-DC converter drives for DC Motor. Analyse and design suitable control for closed-loop speed control of DC Motor drive. Develop a DC-AC inverter to control AC motors using 180deg conduction mode and SPWM techniques. Implement the real-time control of DC and AC drives. 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.

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.
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]

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

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 systems, *McGraw Hill, 2009*
4. Frank Vahid, Tony Givargis, *Embedded Systems architecture, Wiley India Edition, 2002.*

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

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). Configuration space, Degree of freedom 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. 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. Manipulation planning, Optimal motion planning, Feedback motion planning, Randomized Kino dynamic 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. Planning Algorithms, “Steven M. LaValle”, 1/e, Cambridge University Press, 2006.
3. Farbod Fahimi – “Autonomous Robots- Modeling, Path Planning, and Control”, 1/e Springer, 2009

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 5241: ROBOTICS LAB [0 0 6 2]

Introduction to ROS2, Installation, Create ROS2 Workspace: Python and C++ Package, Object-Oriented Programming, ROS2 Nodes, Publisher/Subscriber, Custom, Experiments with Turtle Sim Package, Topics, Services, Actions, Parameters, Debug Tools in ROS2, Introduction to URDF, 3 axis manipulator design, Control of manipulator, Mobile robot design, Gazebo and RViz, Sensor Integration, Introduction to Moveit2, Industrial Robots, Collaborative Robots, Working with TurtleBot and UR5 using ROS2, Robotic safety, Augmented and Virtual Reality Use cases in Robotic Applications.

References:

1. Anis Koubaa, *Robot Operating System (ROS), the complete reference*, Vol.1, Springer International Publishing, 2016.
2. Anis Koubaa, *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 [3 1 0 4]

Introduction to Mechatronics and digital/ analog principles, Overview of number system, codes and code conversion, Combinational and sequential logic circuits, Analog circuits: PN Diode, Diode types, Diode applications, BJT, MOSFET, spice model, Op-amp and its properties, Linear and non-linear applications, Analog building blocks: voltage and current amplifier, trans-conductance amplifier and trans-resistance amplifier, current mirror, Transconductor,

OTA, Current conveyor and applications, Current mode operation. Interface hardware blocks: Data converters, sample and hold circuit, DAC and ADC architectures, signal conditioning, Data acquisition, Case study examples: Gm-C filters, 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.
6. Adel S. Sedra, Kenneth C. Smith, Arun N. Chandorkar, *Microelectronic Circuits: Theory and Applications*, 7th edition, Oxford University Press, 2017.

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

Overview and Historical Perspective of artificial Intelligence, Principles of AI, Definitions and underlying assumptions, Applications in various domains. Symbolic reasoning under uncertainly, probability and Bayes' theorem, certainty factors and rule-based systems, Linear Discrimination, Bayesian networks and Decision Theory, Dempster–Shafer theory. 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. Introduction to optimization, Traditional optimization techniques with plications; 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 approach, Beam Stack Search; *Randomized Search*: Simulated Annealing, Genetic Algorithms, Ant Colony Optimization. Fuzzy Crisp sets and relations, Fuzzy sets and relations. Fuzzy rule-based systems, de-fuzzification methods, and applications. Logical Agents, Fundamental and Inference of First-Order Logic, Classical Planning, Knowledge Representation and Reinforcement Learning. 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 Studies.

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]

NC technology, components of CNC system, 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, Interpolators and interpolation scheme, requirements of interpolation algorithms, interpolation schemes - stairs approximation, digital differential analyzer, direct function calculation; DDA - hardware and software; software interpolators. CNC programming for turning center and machining center by manual and automated methods, distributed numerical control, adaptive control machining,

automated inspection and testing, material handling and transport equipment. Storage system and strategies, Factory data collection, Concept of computer-integrated manufacturing systems, part classification and coding, production flow analysis, computer-integrated manufacturing system, types of manufacturing system, machine tools and related equipment. Flexible manufacturing system, FMS workstation, types of FMS layouts, computer control in CIM, human labour in CIM, benefits of CIM. Computer-aided process planning, computer-integrated planning systems. Material requirement planning, capacity planning, shop floor control.

References:

1. Koren Yoram and Ben and Uri Joseph, *Numerical Control of Machine Tools*, Khanna Publishers, New Delhi, 2005.
2. Groover Mikell P., *Automation, Production Systems, and computer Integrated manufacturing* Prenice Hall of India, New Delhi., 2003.
3. Groover Mikell 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]

Predictive Analytics, identify anomalies in the process, which help in preventive maintenance. Estimate the demand for product, raw material etc. based on historical data and current scenario. Forecast possible outcomes based on data obtained from the process. Prescriptive Analytics, implementing prescriptive analytics for predictive maintenance in industrial automation, using prescriptive analytics to optimize production scheduling and resource allocation in industrial automation, Prescriptive analytics for quality control and defect prevention in industrial automation, leveraging prescriptive analytics to improve energy efficiency in industrial automation. Diagnostic Analytics using data mining, data discover, correlation, and down and drill through methods are used in diagnostic analytics. Descriptive Analytics, the core purpose of descriptive analytics is to describe the problem by diagnosing the symptoms and Data Visualization.

Reference

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

MTE 5405: DIGITAL MANUFACTURING [3 1 0 4]

Types of production systems. Needs of digital manufacturing, effective & efficient use of digital manufacturing (DM) tools. Integration of CAD/CAM systems, Advantages of CAD/CAM systems. Concurrent engineering: design for manufacturability; project management; design for assembly. Examples – MEMS and 3D printing, Industrial control systems: Process interfacing, collecting manufacturing process data, system interpretation of process data, Computer networks in industries: Direct numerical control, communication standards, communication protocols, design activity in a networked environment. CIM and DBMS in manufacturing: CIM database, database requirements in CIM environment, database models – Hierarchical, network, RDBMS. Database architecture, SQL and coding. Industrial ethics, technology and Engineering: 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. SDL - Digital twin and Blockchain technology in manufacturing: 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]

Definition of drones, Anatomy of Drone, Importance of Drone Technology, History of Drone, Types of drones as per structure, Need of Drone Technology. Components of Drone: 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 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 Platforms and Propulsion system required for drone operation. Stability and Control of Drone, Definition of Stability, Definition of Control, Types of Stability required in Drone, Types of Control required in Drone. Sensor used in Drones, 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. Basic Air Regulations, DGCA regulation, foreign regulatory, FCC compliance, sUAS 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

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.

8. Stalley, P. (2019). The Drone Technology: The Main Features and Utilization of the Unmanned Aircraft System. (n.p.): Independently Published.

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

Internet of Things and New Computing Paradigm: Fog and Edge Computing Completing the Cloud, Hierarchy of Fog and Cloud Computing, Business Models, Opportunities and Challenges. Addressing the Challenges in Edge Computing: Network Challenge, Management Challenge. Integrating IoT, Fog and Cloud Infrastructures. Management and Orchestration of Network Slices in 5 G, Fog, Edge and Clouds: Background, Network slicing in 5 G, Network slicing in software designed clouds. Optimization problems in Fog and Edge Computing. Middleware for Fog and Edge Computing devices. Data management and predictive analysis in Fog and Edge Computing. 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., (2019). *Fog and Edge Computing: Principles and Paradigms*, Wiley.
2. Dharani, D., Sadasivam, D., S., (2021). *Edge Computing: Fundamentals, Advances and Applications*. CRC Press.
3. Bahga, Arshdeep, and Vijay Madisetti. (2014). *Internet of Things: A hands-on approach*, (1e), University Press.
4. Simone Cirani, Gianluigi Ferrari, Marco Picone, Luca Veltri. (2019). *Internet of Things: Architectures, Protocols and Standards*, (1e), Wiley Publications.

MTE 5408: LEGGED ROBOTICS [3 1 0 4]

Introduction of Legged Robotics, History, four, and multi-legged robots. Design of Legged Robots, passive and dynamic walkers. dynamic versus static stability, different stability criteria, energy consumption, cost of transport (COT). Models of Locomotion, Rimless wheel, inverted pendulums, linear inverted pendulum (LIP), spring-loaded inverted pendulum (SLIP), template versus anchor models. Control of Legged Robots, Trajectory-based methods, virtual leg control, optimal control, approaches based on reinforcement learning, and bioinspired approaches. Legged Robot Evaluation, Effectiveness of motion. Stability of motion. Analysis approaches. Case Study and Application.

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, 2008. 361-389.
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, 2D image formation, color image processing, Data structures for image analysis, image enhancement, morphological operations, and visual image quality indexes. Edge detection, edge-based segmentation, region-based segmentation, feature

extraction: boundary and region feature descriptors. Background subtraction, optical flow estimation, object tracking with Kalman filtering. 3D vision formation, pinhole camera model, intrinsic and extrinsic camera parameters, calibration methods, stereovision, epipolar geometry, and 3D reconstruction. Case studies and applications.

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]

Kinematic pairs, Kinematic diagram and inversions. Mobility and range of movements. Displacement, velocity and acceleration analysis of planar linkages, analytical methods. Dimensional synthesis for motion, function and path generation. Two position and Three position synthesis, Advanced synthesis solutions, Coupler curves, Static Force analysis, Applied and constrained forces free body diagrams, static equilibrium conditions. D'Alembert's principle, Superposition principle, dynamic force analysis Inertia forces and their balancing for rotating machines. Free vibration, equation of motion, Torsional vibration, Forced vibration and isolation, Analytical method. Gyro-dynamics and effects on machines. Conveyors- types and applications, Bearings-types and applications. Gear types, selection and application, gear trains including compound epicyclic gears.

References:

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. *Advanced mechanism design* vol. 1 & 2: Analysis and synthesis. Prentice-Hall; 1984.
7. Rao SS, Yap FF. *Mechanical vibrations*. New York: Addison-Wesley; 1995 Mar.

MTE 5411: MICRO-MANUFACTURING SYSTEMS [4 0 0 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: 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: Microcasting, micromolding – a soft lithography technique, fabrication of microelectronic devices. Microforming: micro- and nanostructured surface development by nano plastic forming and roller imprinting, microextrusion, microbending with laser. Microjoining: Introduction to microjoining, laser microwelding, electron beams for macro- and microwelding working principle and construction with applications. Nanofinishing: Magnetorheological and allied finishing processes and their theoretical analysis,

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., *Microfacbrication & Nanomanufacturing*, CRC Press, 2005.

MTE 5412: SOFT ROBOTICS [3 1 0 4]

Bio robotics, biomimetics, nature-inspired designs, materials for soft robot, biological analogy, Soft Actuators, Soft Sensors, Electroactive Polymer, Ionic Polymer Metal Composites, Shape Memory Alloy, Artificial Muscles based on Electric/Pneumatics, Thermal/Chemical Actuation, Piezo based soft robots, Working principles, Materials, Fabrication techniques and controls, 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, 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), Eigenvalues and Eigenvectors, Geometric interpretation of eigenvectors, Cayley-Hamilton theorem, Principal Component Analysis, Singular Value Decomposition, ISO-Map Dimensional Reduction technique, 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 5413: VIRTUAL REALITY [3 1 0 4]

Augmented Reality, Virtual reality, Mixed Reality, Extended reality, history, market analysis, hardware, and Software Integrated Development Environment, VR and AR device classification, Perception, Temporal resolution, spatial resolution, motion perception, depth perception, colour perception, auditory, perception, haptics perception, locomotion interfaces Unity3D – 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. AR-VR use cases- Industry 4.0,

Blockchain, medical robotics, military and defense, automobile industry, Architecture Engineering, and Construction, Education, Manufacturing industry, Health care Industry, XR tool kit setup, UI interaction, XR challenges: XR Best methods and process, HMD Oculus, UX design, quality testing of XR systems.

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, Batteries, alternators, starter motors, ignition systems, headlamps, wiper motors, etc. Sensors & Actuators, Introduction, basic sensor arrangement, types of sensors. Powertrain, SI Engine Management, Layout, Components of SI FI systems, types of FI systems, Group and sequential injection techniques. Electronic ignition systems and their advantages, Types of lid-state ignition systems and their principle of operation, Contactless electronic ignition system, electronic spark timing control. CI Engine Management, 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, Indian Scenario Transmission Systems: AMT, OCT, AT, Chassis Control Systems, ABS, ESP, RSC, ASBRS, EPS, Active suspension systems. Hybrid vehicles and Intelligent Vehicle Systems – 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; materials terminology, devices and circuits for displays, sensors, MEMS, and flexible electronics. Introduction to IC manufacturing and realization of passive components in ICs and VLSI; Electromagnetic interference, Yield and reliability, thermal budget and Current trends. 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: SPICE simulations of signals and noise. Semiconductor device packaging and improved Cable & Harness.

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]

History of Hybrid and Electric Vehicles technology, Economics and Environmental aspects of vehicle technologies. Electric propulsion unit: different motors, configuration and control of dc and induction motor drives, introduction to power modulators, control, advanced motor drives for EV: PMSM, BLDC, SRM and SyncRel Motor drives. Energy storage, regenerative breaking, classification of different energy management strategies, fundamentals of regenerative braking. Sizing the drive system- propulsion motor, sizing the power electronics, selecting the energy storage technology, communications, supporting subsystems. Hybridness, PHEV, Range extension vehicles, Control of Hybrid and Electric vehicles: ECU, CAN-bus, Vehicle Dynamics Control. Charging stations. Design of series hybrid drive train.

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]

Introduction to underwater robotics- types and specification of robots, applications and practical considerations of deploying and operating Maritime Robotic Systems including AUVs, ASVs, ROVs, underwater gliders and Argo floats. Design of underwater robotic systems and calculation of vehicle parameters and performance metrics including pressure, buoyancy, power, speed, range. Equations for moving frame - rigid motion in a plane - representation of a rotated frame, modelling with respect to global coordinates. Sensors and navigational strategies for underwater robotic systems including localisation using dead-reckoning, SLAM and uncertainty/probabilistic approaches. Path planning algorithms and path following strategies including artificial potential field methods, Dijkstra's, A* star algorithms and line of sight guidance strategies. Modelling and control of underwater robotic systems including PID controllers, system architectures, actuator and vehicle dynamics, design and analysis of thrusters. 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