Department of Robotics and Mechatronics Engineering
University of Dhaka

Syllabus for M.Sc in Robotics and Mechatronics Engineering
Session : 2019-2020

a) Robotics		
Course Code	**Course Title**	**Credit Hour**
	Theory Courses	
RME 5101	Nano Robotics	3
RME 5102	Computer Vision	3
RME 5103	Neural Networks and Deep Learning	3
RME 5104	Advanced Artificial Intelligence	3
RME 5105	Multi Agent Systems	3
RME 5106	Pattern Recognition	3
RME 5107	Robotic System Simulation	3
RME 5108	Bio Robotics	3
RME 5109	Computational Human Robot Interaction	3
RME 5110	Aerial Robotics	3
RME 5111	Cloud Computing	3
RME 5112	Big Data Analysis	3
	Lab Courses	
RME 5122	Computer Vision Lab	1.5
RME 5123	Neural Networks and Deep Learning Lab	1.5
RME 5124	Advanced Artificial Intelligence Lab	1.5
RME 5125	Multi Agent Systems Lab	1.5
RME 5126	Pattern Recognition Lab	1.5
RME 5127	Robotic System Simulation Lab	1.5
RME 5129	Computational Human Robot Interaction Lab	1.5

b) Mechatronics		
Course Code	**Course Title**	**Credit Hour**
Theory Courses		
RME 5201	Industrial Automation	3
RME 5202	Multivariable Adaptive Control System	3
RME 5203	Hybrid Electric Vehicles	3
RME 5204	Advanced Power Electronics	3
RME 5205	Nanotechnology and Nanofabrication	3
RME 5206	Automotive Control and Simulation	3
RME 5207	Industrial Product Modeling and Visualization	3
Lab Courses		
RME 5211	Industrial Automation Lab	1.5
RME 5214	Advanced Power Electronics Lab	1.5
RME 5216	Automotive Control and Simulation Lab	1.5
RME 5217	Industrial Product Modeling and Visualization Lab	1.5

c) Common		
Course Code	**Course Title**	**Credit Hour**
Theory Courses		
RME 5301	Engineering Research Methodology	3
RME 5302	Advanced Algorithms: Design & Analysis	3
RME 5303	Internet of Things (IoT)	3
RME 5304	Mathematical Modeling & Optimization	3
RME 5305	Project Management	3
Lab Courses		
RME 5312	Advanced Algorithms: Design & Analysis Lab	1.5
RME 5313	Internet of Things (IoT) Lab	1.5

d) Thesis/Project		
Course Code	**Course Title**	**Credit Hour**
RME 5401	Thesis	18
RME 5402	Project	6
	Total Credits:	**18**

a) Robotics

RME 5101 : Nano Robotics - 3 Credit

Introduction:
Nano-Robotic system components, Nano-Robotic System examples around the world, wall climbing micro robot, Nano mechanical flying robot, Design, fabrication, Introduction to nano-manipulation, control and applications-Bottom up and Top down approach.

Nano Sensors:
Nano-scale sensor, Interferometric Sensors, AFM, Visual Force Sensing, Accelerometers, Gyroscopes, Chemical Sensors.

Nano Actuators:
Nano robot actuation, Piezoelectric Actuators, Piezotubes, Thin-Film Type, Surface Acoustic Waves, Electrostatic, Thermal, Ultrasonic, Magnetostrictive actuators, Shape memory alloy actuators, Polymer Actuators, Dielectric Elastomers, Carbon Nanotube (CNT) Actuators, Biomolecular Motors.

Nano Manipulator:
Nanogrippers, nanoassembly, Direct self-assembly, Optical Tweezers, Bio-Manipulation using Optical Tweezers, Carbon Nanotube Manipulation using Nanoprobes, High Density Data Storage Using Nanoprobes.

Nanorobotics: The Vision and Applications:
Nanorobotics: Past, Present, and Future, Nanomechanical Cantilever-Based Manipulation for Sensing and Imaging, Swarms of Self-Organized Nanorobots, Reservoir Nanoagents for In-Situ Sensing and Intervention, Miniaturization and Micro/Nanotechnology in Space Robotics, DiamondoidNanorobotics.

Nano-Manipulation and Industrial Nanorobotics:
Virtual Tooling for Nanoassembly and Nanomanipulations, Nanorobotic Mass Transport, Nanorobotic Manipulation of 1D Nanomaterials in Scanning Electron Microscopes.

Nano-Manipulation in Biomedical Applications:
Nanorobotic Manipulation and Sensing for Biomedical Applications, Nanohandling of Biomaterials, Apply Robot-Tweezers Manipulation to Cell Stretching for Biomechanical Characterization

Inside the Body Nanorobotic Applications:
Propulsion and Navigation Control of MRI-Guided Drug Delivery Nanorobots, Generating Magnetic Fields for Controlling Nanorobots in Medical Applications, Techniques for MRI-Based Nanorobotics, Therapeutic Bacterial Nanorobots for Targeted Drug Delivery Deep Inside

Tumors, Sensing Strategies for Early Diagnosis of Cancer by Swarm of Nanorobots: An Evidential Paradigm

Bio-Nano Actuators for Nanorobotics:
DNA Nanorobotics, DNA for Self-Assembly, Local Environmental Control Technique for Bacterial Flagellar Motor, Protein-Based Nanoscale Actuation.

References

1. Elwenspoek.M and Wiegerink.R., “Mechanical Microsensors”, Springer-Verlag Berlin, 2001.
2. Israelachvili.J, “Intermolecular & Surface Forces”, Academic Press Ltd., 2nd Edition, 1992.
3. Norio Taniguchi, “Nanotechnology”, Oxford university press, Cambridge, 1996.
4. Scherge.M and Gorb.S, “Biological Micro- and Nano-tribology": Nature’s Solutions”, Springer Verlag, Berlin Heidelberg, 2001.
5. Morris.V.J.,Kirby.R., Gunning.P., “Atomic Force Microscopy for Biologists”, London, Imperial College Press, 1999.
6. DrorSarid, “Scanning Probe Microscopy”, Oxford University Press, Revised Edition, 1994.
7. Fatikow.S. Rembold.U., “Microsystem Technology and Microrobotics”, Springer Verlag, 1997.
8. Güntherodt.H.J., Anselmetti.D.,Meyer.E., “Forces in Scanning Probe Methods”, NASA Science Series, 1995.
9. Bhushan.B., “Handbook of Micro/Nanotribology”, CRC Press, 2nd Ed., 1999.
10. Maugis.D, “Contact, Adhesion and Rupture of Elastic Solids”, Springer Verlag, Berlin, 2000.
11. Madou.M, “Fundamentals of Microfabrication”, CRC Press, 1997.
12. Kovacs.G.T., “Micromachined Transducers Sourcebook”, Mc-GrawHillComp.inc., 1998.
13. Tai-Ran Hsu, “MEMS and Microsystems Design and Manufacture”, McGraw-Hill inc., 2002.
14. Nanorobotics, Current Approaches and Techniques by ConstantinosMavroidis and Antoine Ferreira.

RME 5102 : Computer Vision - 3 Credit

Introduction:
Overview of computer vision, related areas, and applications.

Image formation and representation:
Imaging geometry, radiometry, digitization, cameras and projections, rigid and affine transformations.

Filtering:
Convolution, smoothing, differencing, and scale space.

Feature detection:

Edge detection, corner detection, line and curve detection, active contours, SIFT and HOG descriptors, shape context descriptors.

Model fitting:
Hough transform, line fitting, ellipse and conic sections fitting, algebraic and Euclidean distance measures.

Camera calibration:
Camera models; intrinsic and extrinsic parameters; radial lens distortion; direct parameter calibration; camera parameters from projection matrices; orthographic, weak perspective, affine, and perspective camera models.

Epipolar geometry:
Introduction to projective geometry; epipolar constraints; the essential and fundamental matrices; estimation of the essential/fundamental matrix.

Model reconstruction:
Reconstruction by triangulation; Euclidean reconstruction; affine and projective reconstruction.

Motion analysis:
The motion field of rigid objects; motion parallax; optical flow, the image brightness constancy equation, affine flow; differential techniques; feature-based techniques; regularization and robust estimation; motion segmentation through EM.

Motion tracking:
Statistical filtering; iterated estimation; observability and linear systems; the Kalman filter; the extended Kalman filter

Object recognition and shape representation:
Alignment, appearance-based methods, invariants, image eigenspaces, data-based techniques.

Reference Book:

1. Computer Vision: Algorithms and Applications, by R. Szeliski, Springer-Verlag, 2011
2. Machine Vision, by R. Jain et. al, McGraw Hill, 1995
3. Introductory Techniques for 3-D Computer Vision, by E. Trucco, and A. Verri, Prentice Hall, 1998.
4. A Guided Tour of Computer Vision, by V. Nawla, Addison-Wesley, 1993

RME 5103 : Neural Networks and Deep Learning- 3 Credit

Introduction:
Perceptrons, Sigmoid neurons, The architecture of neural networks, Learning with gradient descent, Implementing a neural net to recognize handwritten digits.

Backpropagation:

A fast matrix-based approach to computing the output from a neural network, The two assumptions we need about the cost function, The four fundamental equations behind backpropagation, The backpropagation algorithm, Backpropagation: the big picture.

Improving the way neural networks learn:
The cross-entropy cost function, softmax, Overfitting and regularization, Weight initialization, How to choose a neural network's hyper-parameters? Other techniques, Variations on stochastic gradient descent .

Why are deep neural networks hard to train:
The vanishing gradient problem, What's causing the vanishing gradient problem? Unstable gradients in deep neural nets, Unstable gradients in more complex networks, Other obstacles to deep learning.

Deep Learning:
Convolutional networks, Recent progress in image recognition, Other approaches to deep neural nets, On the future of neural networks.

Reference Books:

1. Simon Haykin, 2nd edition, Neural Networks, A comprehensive foundation.
2. Ian Goodfellow, YoshuaBengio, Aaron Courville. Deep Learning.
3. Duda, R.O., Hart, P.E., and Stork, D.G. Pattern Classification. Wiley-Interscience. 2nd Edition. 2001.
4. Theodoridis, S. and Koutroumbas, K. Pattern Recognition. Edition 4. Academic Press, 2008.
5. Russell, S. and Norvig, N. Artificial Intelligence: A Modern Approach. Prentice Hall Series in Artificial Intelligence. 2003.
6. Bishop, C. M. Neural Networks for Pattern Recognition. Oxford University Press. 1995.
7. Hastie, T., Tibshirani, R. and Friedman, J. The Elements of Statistical Learning. Springer. 2001.
8. Koller, D. and Friedman, N. Probabilistic Graphical Models. MIT Press. 2009.
9. Place Coding in Analog VLSI: A Neuromorphic Approach to Computation, Oliver Landolt (auth.), 1998

RME 5104 : Advanced Artificial Intelligence- 3 Credit

Overview:
Foundations, scope, problems, and approaches of AI.

Quick Review Topics:
Problem solving by searching, Constraint Satisfaction Problems, Game Trees, Markov Decision Processes, Reinforcement learning.

Bayesian Networks:
Probabilistic inference, Bayes Nets: Representation, Inference, Sampling, D-Separation.

Hidden Markov Models:
Markov models, The Mini-Forward algorithm, Stationary distributions, Forward algorithm, Inference tasks, HMM filtering algorithm, Viterbi algorithm.

Particle Filtering:
Representation of particles, Particle filtering simulation, Robot localization, Particle filter localization (Sonar), Dynamic Bayes Nets, Dynamic particle filters.

Decision Networks:
Decisions as outcome trees, The value of perfect information (VPI), Properties of VPI, POMDPs, POMDPs as decision networks.

Deep Reinforcement Learning:
The policy gradient algorithm, Basic variance reduction: causality, Basic variance reduction: baselines, Policy gradient examples. Actor-Critic Algorithms, Value Function Methods, Deep RL with Q-functions.

Advanced Applications:
Natural language processing, Games and cars, Robotics and computer vision.

Reference Book:

1. Artificial Intelligence: A Modern Approach, 3rd ed. by Stuart Russell and Peter Norvig.

RME 5105 : Multi Agent Systems - 3 Credit

Introduction:
Introduction to Distributed Artificial Intelligence (DAI), Historical background,Different domains of DAI.

Distributed Problem Solving:
Distributed constraint reasoning, Utility functions, Probabilistic and deterministic graphical models,Constraint graphical representations: Constraint network, DFS-tree, Junction tree, Factor graph.

Inference:
Variable or Bucket Elimination Algorithm. Sampling-based Inference.

Monte-Carlo Tree Search. Consistency-Enforcing Strategies:
Arc-consistency, Path-consistency and higher levels of i-consistency, Constraintpropagation.

Constraint Reasoning Frameworks:
Distributed Constraint Satisfaction Problems (DCSPs), Distributed Constraint Optimization Problems (DCOPs) anddifferent families (i.e. optimal and approximate) of constraint reasoningalgorithms: search-based optimal algorithms: ABT, ADOPT and OptAPO. Inference-

based Optimal algorithms: DPOP, Action-GDL. Local search-based approximate algorithms: DSA, MGM and DBA. Inference-based approximate algorithms: Max-product,Max-Sum.

Multi-Agent Systems (MAS):
Formulation of MAS, Values in MAS (Privacy, Safety, Security, Transparency, etc.), Agent-based Modelling, Coordination strategies.

Multi-Agent planning:
Automated planning, Privacy-preserving planning, Distributed planning and Centralized planning.

Sequential Decision Making:
Markov Decision Process (MDP), Partially Observable Markov Decision Process (POMDP) and their variants.

Swarm Intelligence:
Ant Colony Optimization (ACO), Particle Swarm Optimization (PSO).

Game Theory:
Basics of Game Theory, Mechanism Design, Cooperative and Non Cooperative Games, Current trends and modern applications.

Crowdsourcing:
Basic of Crowdsourcing, Mechanism Design, Applications.

Reference Book:

1. Stuart J. Russell and Peter Norvig (2016). *Artificial intelligence: a modern approach*. Third Edition, Pearson Education Limited.
2. Gerhard Weiss (Eds.) (2013), *Multi-Agent Systems: A Modern Approach to Distributed Artificial Intelligence,* Second Edition, MIT Press.
3. Greg MP O'Hare and Nicholas R. Jennings (Eds.). (1996). *Foundations of Distributed Artificial Intelligence* (Vol. 9). John Wiley & Sons
4. RinaDechter(2013), *Processing Probabilistic and Deterministic Graphical Models.*
5. RinaDechter(2003),*Constraint Processing*, Morgan Kaufmann Publications.
6. Swarm Robotics: A Formal Approach, by HeikoHamann, Springer International Publishing, 2018.
7. Handbook of Research on Design, Control, and Modeling of Swarm Robotics, by Ying Tan, lGI Global, 2015.

RME 5106 : Pattern Recognition- 3 Credit

Introduction and General Pattern Recognition Concerns:

Pattern Recognition (PR), Classification and Description, feature extraction with examples, feature extraction from images, training and learning in PR system, pattern recognition approaches.

Bayesian Decision Theory:
Review of probability theory and some linear algebra, Bayesian Decision making; Bayesian networks, linear discriminants, separability, multi-class discrimination; quadratic classifiers, Bayesian estimation, Random vectors, expectation, correlation, covariance, linear transformations decision theory, Likelihood ratio test Linear and quadratic discriminants, Fisher discriminants, Sufficient statistics, coping with missing or noisy features.

Statistical Pattern Recognition:
Introduction to statistical pattern recognition, The Gaussian and Class Dependence, Discriminant Functions, Kalman filtering and smoothing, Classifier performance, risk and Errors.

Supervised Learning:
Parametric Estimation and Supervise Learning, maximum likelihood Estimation approach, Bayesian parameter estimation approach, Non-parametric approaches, Parzen windows, Non-parametric estimation, Nearest Neighbor Rule, Mixture modeling, optimization by Expectation-Maximization.

Un-supervised learning and Clustering:
Formulation of Unsupervised learning Problems, Clustering for unsupervised learning and classification, vector quantization, K-means Feature extraction for representation and classification.

Syntactic Pattern Recognition:
Syntactic Pattern Recognition overview, Quantifying structure in pattern description and recognition, Grammar-Based approach and Applications, Elements of formal Grammars, Example of string generations as pattern description, Syntactic recognition via parsing and other grammars, Graphical approaches to syntactic pattern recognition.

Classification:
Template-based recognition, Eigen vector analysis, PCA Sequence analysis, HMMs, Viterbi algorithm, Baum-Welch algorithm, Maximum likelihood and Bayesian parameter estimation, optimization by gradient descent, SVM, Neural nets, Perceptron learning, Multi-layer Perceptrons, Neural networks for pattern recognition, Decision trees.

Applications:
Object detection and recognition, Biological object recognition, Tracking, Gesture recognition

References:

1. Statistical Pattern Recognition, 2nd Edition, Andrew R. Webb QinetiQ Ltd., Malvern, UK
2. Pattern Recognition and Machine Learning, Cristopher M. Bishop
3. Pattern Recognition, 2nd edition, SergiosTheodoridisKonstantiNosKoutrou M Bas

RME 5107 : Robotic System Simulation- 3 Credit

Planning and navigation:
Definition of obstacle avoidance, Reactive Navigation: Braitenberg vehicle and bug algorithms, Map based planning, Distance transform and D*, Voronoi Roadmap Method, Visibility graph, Cell decomposition, Probabilistic Roadmaps methods, Rapidly-exploring random tree.

Localization systems:
Landmark-based navigation: Z shape, ceeling sheet, Globally unique localization: US, Signal strength, Positioning beacon systems, Route-based localization: magnetic paint path.

Probabilistic localization:
Parametric and non-parametric state estimation, Kalman filter (EKF, UKF, EIF), Particle filter, Propagation of uncertainty (first order models), Dead reckoning, Map-based localization, Kalman filter localization, Markov localization.

Simultaneous localization and mapping:
Mapping: feature based and occupancy grid mapping, Simultaneous localization and mapping: feature based SLAM and pose SLAM, Optimal navigation, Autonomous exploration.

ROS Basics and Foundation:
ROS Workspace and ROS Package (Setting up your ROS projects), Setup ROS Project, The ROS Master Node, ROS Topics, Nodes and Messages, ROS File system and Ecosystem, ROS Service, Create the Service File and Request/Response Messages, Write ROS Service (Client/Server) in Python.

Motion in ROS:
Moving in a Straight Line, Rotate Left and Right, Go to Goal Location.

ROS Tool and Utilities:
ROS Network Configuration, Launch Files: Running multiple nodes with roslaunch, including a launch file and define parameter.

Perception in ROS:
How robots see the environment using a camera, how the images are collected in ROS and how they are processed in OpenCV.

Connecting New Hardware with ROS:
Rosserial, Install rosserial libraries, rosserial applications.

References:

1. Planning Algorithms by Steve LaValle (Cambridge Univ. Press, New York, 2006).
2. Principles of Robot Motion: Theory, Algorithms, and Implementations By Howie Choset, Kevin Lynch, Seth Hutchinson, George Kantor, Wolfram Burgard, Lydia Kavraki, and Sebastian Thrun, Bradford Books, MIT Press, 2007.
3. Robot Motion Planning by J.C. Latombe, Kluwer Publishing.

4. Programming Robots with ROS by ByBrian Gerkey, William Smart, Morgan Quigley, O'Reilly Media

RME 5108 : Bio Robotics- 3 Credit

Introduction:

Introduction to medical robotics (applications and paradigms), Basic kinematics concepts (forward, inverse, remote center of motion), Basic control concepts (impedance, admittance), Surgery for engineers, Interventional radiology for engineers.

Minimally Invasive Surgery (MIS):

Human-machine interfaces, Tele-operation, Cooperative manipulation, Robot design concepts.

Guided Interventions:

Medical imaging modalities (e.g., MRI, X-ray, CT), Robot compatibility with medical imagers, Image segmentation and modeling, Tracking devices, Frames and transformations, Surgical navigation, Calibration, Rigid and non-rigid registration Radiosurgery.

Biomedical Robotics:

Biomechanical Modeling; Biomechanical Testing Techniques; Basic Bio-instrumentation System; Basic Circuit Elements and Concepts; Linear Network Analysis; The Origin of Bio-potential Signals; How Biosensors Record Signals in the Human Body; Imaging Techniques.

Artificial Hearts:

The heart, Energy transmission, Monitoring blood flow, Appropriate materials, Prosthetic device, Heart-lung machine, Mechanical hearts.

Active limb prostheses:

Common Types of Prosthetic Limbs, Adaptive Foot in Lower-Limb Prostheses, Active Upper-Limb Prostheses, Active lower limb prosthetics: a systematic review of design issues and solutions, Types of Prosthetic Legs, Arm Amputation and Prosthetics, Types of Prosthetic Arms.

Neuromodulation:

Neuromodulation, Neurophysiology, biomedical instrumentation, robotics surgery and human joint rehabilitation, Biomechatronics and Human Machine Interaction.

References:

John D. Enderle& Joseph D. Bronzino (2012) Introduction to Biomedical Engineering. ISBN: 978-012-374-979-6

RME 5109 : Computational Human Robot Interaction- 3 Credit

Overview of HRI:

Types of HRI Studies, HRI taxonomy, Cognitive Science and HRI, Sensors and perception for HRI.

Design and HRI:
Planning Human Subjects Studies, Research Ethics and the IRB, Anthropomorphism and Design, Human-robot interaction architectures, Design and Human Factors

Social Robotics:
Social, Service, and Assistive Robotics, Educational Robotics, Robots for Humanity, Emotion and Empathy, Human Robot Relation, Affects and Emotions in Social Robotics, Understanding Human Intentions, Social Robot Navigation.

Communication and Social Interactions:
Multi-modal human-robot communication, Non-verbal communication: Gaze and Gestures, Natural-language interactions with robots, Human-robot dialog.

Remote teleoperation:
Exploring Use Cases for Telepresence Robots, Bodies in Motion: Mobility, Presence, and Task Awareness in Telepresence.

Learning in HRI:
Social Learning, Human-Robot Collaborative Learning, Robot Influence on Human Actions.

Collaboration and Teamwork:
Human-robot collaboration, Collaborative manipulation, human-robot hand-overs.

Algorithmic HRI:
The What, Why, and How of Algorithmic HRI, Motion Planning, Trajectory Optimization, Optimal Motion Algorithms, Optimal Motion in HRI.

Measuring HRI:
HRI Metrics, Robot Evaluation, Social Interaction Evaluation, Task-Oriented Benchmarks, Assistive Evaluation.

Ethics in HRI:
Ethical Challenges in HRI, Principles for HRI Code of Ethics, Psychology and Human Factors in Robot Ethics, Ethics and Inscription in Social Robot Design.

HRI Case Studies

References:

1. “Where the Action Is, Foundations of embodied interaction”, Dourish.
2. “Human-Robot Interaction: A Survey,” Goodrich & Schulz
3. “Humans and Automation: system design and research issues”, Sheridan
4. “Robots and Privacy,” Calo
5. “Computational Human Robot Interaction”, Andrea Thomaz, Guy Hoffnan

6. "Human Robot Interaction in Social Robotics", Takayuki and Hiroshi Ishiguro

RME 5110 : Aerial Robotics- 3 Credit

Introduction to Aerial Robotics:
Unmanned aerial vehicles and quadrotors, Key Components of Autonomous Flight, State Estimation. Application, Basic Mechanics, Dynamics and 1-D Linear Control, Design Considerations, Agility and Maneuverability, Component Selection, Effects of Size, Problem solving using MATLAB.

Geometry and Mechanics:
Transformations, Rotations, Euler Angles, Axis/Angle Representations for Rotations, Angular Velocity, Formulation, Newton-Euler Equations, Principal Axes and Principal Moments of Inertia, Quadrotor Equations of Motion.

Planning and Control:
2-D Quadrotor Control, 3-D Quadrotor Control, Time, Motion, and Trajectories, Motion Planning for Quadrotors.

Advanced Topics:
Sensing and Estimation, Nonlinear Control, Control of Multiple Robots

References:

1. Nonami, K., Kendoul, F., Suzuki, S., Wang, W., &Nakazawa, D. Autonomous Flying Robots-Unmanned Aerial Vehicles and Micro Aerial Vehicles (2010).
2. Ollero, Aníbal, and IvánMaza, eds. Multiple heterogeneous unmanned aerial vehicles. Vol. 37. Springer, 2007.

RME 5111 : Cloud Computing

Introduction to Cloud Computing: Cloud Computing definition, history, characteristics-elasticity, multi-tenant, on-demand, ubiquitous access, usage metering, self-service, sla-monitoring, etc., technology overview, benefits, risks and the economic motivation.

Cloud Infrastructure: Historical overview of data centers, design considerations, Cloud service models/types-public, private, hybrid, and community clouds, Cloud reference architectures, Cloud standards (OSDIAPIs, etc.).

Cloud deployment models: IaaS, PaaS, SaaS and BPaas.

Cloud Resource Management: Virtualization, Different virtualization types, resource virtualization, different virtualization types, real use cases.

Cloud Storage: Overall organization of data and storage, problems of scale and management in big data, various storage abstractions, different types of file systems- Hadoop Distributed File System (HDFS), Ceph File System (CephFS).

Programming Models: Fundamental aspects of parallel and distributed programming models, different cloud programming models-MapReduce, Spark, GraphLab and Spark Streaming, execution flow, scheduling and fault tolerance concepts in the MapReduce programming model.

Cloud Security: Cloud security challenges, Cloud security approaches: encryption, tokenization/obfuscation, cloud security alliance standards, cloud security models and related patterns.

Text Books:

1. Cloud Computing Bible, by Barrie Sosinsky, Wiley, 1st edition
2. Cloud Computing, Mr. Ray Rafaels, CreateSpace Independent Publishing Platform, 2nd edition

RME 5112 : Big Data Analysis

Introduction to Big Data and Hadoop: Types of Digital Data, Introduction to Big Data, Big Data Analytics, History of Hadoop, Apache Hadoop, Analysing Data with Unix tools, Analysing Data with Hadoop, Hadoop Streaming, Hadoop Ecosystem, IBM Big Data Strategy, Introduction to Infosphere BigInsights and Big Sheets.

HDFS(Hadoop Distributed File System): The Design of HDFS, HDFS Concepts, Command Line Interface, Hadoop file system interfaces, Data flow, Data Ingest with Flume and Scoop and Hadoop archives, Hadoop I/O: Compression, Serialization, Avro and File-Based Data structures.
Map Reduce: Anatomy of a Map Reduce Job Run, Failures, Job Scheduling, Shuffle and Sort, Task Execution, Map Reduce Types and Formats, Map Reduce Features.

Hadoop EcoSystem: Pig-Introduction to PIG, Execution Modes of Pig, Comparison of Pig with Databases, Grunt, Pig Latin, User Defined Functions, Data Processing operators. Hive-Hive Shell, Hive Services, Hive Metastore, Comparison with Traditional Databases, HiveQL, Tables, Querying Data and User Defined Functions. Hbase-HBasics, Concepts, Clients, Example, Hbase Versus RDBMS. Big SQL-Introduction

Data Analytics with R Machine Learning : Introduction, Supervised Learning, Unsupervised Learning, Collaborative Filtering. Big Data Analytics with BigR.

Text Books:

1. Tom White " Hadoop: The Definitive Guide" Third Edit on, O'reily Media, 2012.
2. Seema Acharya, Subhasini Chellappan, "Big Data Analytics" Wiley 2015.

References:

1. Michael Berthold, David J. Hand, "Intelligent Data Analysis", Springer, 2007.
2. Jay Liebowitz, "Big Data and Business Analytics" Auerbach Publications, CRC press (2013)
3. Anand Rajaraman and Jef rey David Ulman, "Mining of Massive Datasets", Cambridge University Press, 2012.
4. Bill Franks, "Taming the Big Data Tidal Wave: Finding Opportunities in Huge Data Streams with Advanced Analytics", John Wiley & sons, 2012.
5. Glen J. Myat, "Making Sense of Data", John Wiley & Sons, 2007
6. Pete Warden, "Big Data Glossary", O'Reily, 2011.
7. Michael Mineli, Michele Chambers, Ambiga Dhiraj, "Big Data, Big Analytics: Emerging Business Intelligence and Analytic Trends for Today's Businesses", Wiley Publications, 2013.
8. ArvindSathi, "BigDataAnalytics: Disruptive Technologies for Changing the Game", MC Press, 2012
9. Paul Zikopoulos ,Dirk DeRoos , Krishnan Parasuraman , Thomas Deutsch , James Giles , David Corigan , "Harness the Power of Big Data The IBM Big Data Platform ", Tata McGraw Hill Publications, 2012.

RME 5122 : Computer Vision Lab- 1.5 Credit

Practical Classes based on the Topics Covered in**RME 5102.**

RME 5123 : Neural Networks and Deep Learning Lab- 1.5 Credit

Practical Classes based on the Topics Covered in**RME 5103.**

RME 5124 : Advanced Artificial Intelligence Lab- 1.5 Credit

Practical Classes based on the Topics Covered in**RME 5104.**

RME 5125 : Multi Agent Systems Lab- 1.5 Credit

Practical Classes based on the Topics Covered in**RME 5105.**

RME 5126 : Pattern Recognition Lab- 1.5 Credit
Practical Classes based on the Topics Covered in **RME 5106.**

RME 5127 : Robotic System Simulation Lab- 1.5 Credit
Practical Classes based on the Topics Covered in **RME 5107.**

RME 5129 : Computational Human Robot Interaction Lab- 1.5 Credit
Practical Classes based on the Topics Covered in **RME 5109.**

b) Mechatronics

RME 5201 : Industrial Automation- 3 Credit

Introduction:
Automation in Production System, Principles and Strategies of Automation, Basic Elements of an Automated System, Advanced Automation Functions, Levels of Automations. Flow lines & Transfer Mechanisms, Fundamentals of Transfer Lines.

Material handling and Identification Technologies:
Overview of Material Handling Systems, Principles and Design Consideration, Material Transport Systems, Storage Systems, Overview of Automatic Identification Methods.

Automated Manufacturing Systems:
Components, Classification and Overview of Manufacturing Systems, Manufacturing Cells, FMS and its Planning and Implementation.

Quality Control Systems:
Traditional and Modern Quality Control Methods, Inspection Principles and Practices, Inspection Technologies.

Control Technologies in Automation:
Industrial Control Systems, Process Industries Versus Discrete-Manufacturing Industries, Continuous Versus Discrete Control.

Computer Based Industrial Control:
Introduction & Automatic Process Control, Building Blocks of Automation Systems: LAN, Analog & Digital I/O Modules, SCADA Systems & RTU.

Distributed Control System:
Functional Requirements, Configurations & some popular Distributed Control Systems

Modeling and Simulation for Plant Automation:
Modern Tools & Future Perspective.

Industrial Control Applications:
Textile, Water Treatment, Steel Plants, etc.

Text Books:
1. Automation, Production Systems and Computer Integrated Manufacturing M.P.Groover, Pearson Education.5th edition, 2009.

References:
1. Computer Based Industrial Control- Krishna Kant, EEE-PHI, 2nd edition,2010
2. An Introduction to Automated Process Planning Systems- Tiess Chiu Chang & Richard A. Wysk
3. Performance Modeling of Automated Manufacturing Systems,-Viswanandham, PHI, 1st edition, 2009.

RME 5202 : Multivariable Adaptive Control System- 3 Credit

Examples of multivariable control systems:
Mathematical Modeling of Multivariable Systems, State space, polynomial and stable fraction models.

Realization theory of multivariable systems and algorithms:
Controllability, Observability and computations involved in their analysis.

Multivarible System Design:
Stability by Lyapunov's method, solution of Lyapunov equations. Pole placement, observer design and stabilization theory. Spectral factorizations of systems. Solution of the Ricatti equation. Balanced realizations and their computations. Mono-variable Control of Multivariable Systems: Single loop control (SLC) and choice of variables for SLC, decoupling

Multivariable Control:
Slow and fast state variables, discrete and continuous controllers, pole placement and feedback control, observer problem

Optimal Control:
Linear quadratic (LQ) criteria, discrete LQ control.

Observers:

Model based (Luenberger) observer, stochastic signals: white noise, Kalman filter, Kalman observer-adaptive control.

Multivariable Frequency Response

Adaptive Control:
Introduction , Recursive parameter estimation, Model reference adaptive control, State Feedback Design, Output Feedback Design, Adaptive pole placement control: Scalar Case, Polynomial Approach, State-Variable Approach, Robust adaptive control schemes, Averaging-based analysis, Adaptive control of nonlinear systems, Adaptive Control of Nonlinear Systems, Systems with Deadzone, Backlash or Hysteresis, Adaptive Control via Linearization, Adaptive Control via Backstepping, Repetitive Control

References:

1. Anderson and Moore, Optimal control-Linear quadratic methods, PHI 1995
2. BjörnWittenmark , Karl Johan Åström, Adaptive control, 2. ed. Addison-Wesley, 1995.
3. Petros A. Ioannou , Jing Sun, Robust adaptive control, Upper Saddle River, N.J. : Prentice HallInternational : 1996.

RME 5203 : Hybrid Electric Vehicles- 3 Credit

Introduction to Hybrid Electric Vehicles:
History of hybrid and electric vehicles, social and environmental importance of hybrid and electric vehicles, impact of modern drive-trains on energy supplies.

Conventional Vehicles:
Basics of vehicle performance, vehicle power source characterization, transmission characteristics, and mathematical models to describe vehicle performance.

Hybrid Electric Drive-trains:
Basic concept of hybrid traction, introduction to various hybrid drive-train topologies, power flow control in hybrid drive-train topologies, fuel efficiency analysis.

Electric Drive-trains:
Basic concept of electric traction, introduction to various electric drive-train topologies, power flow control in electric drive-train topologies, fuel efficiency analysis.

Electric Propulsion unit:
Introduction to electric components used in hybrid and electric vehicles, Configuration and control of DC Motor drives, Configuration and control of Induction Motor drives, configuration and control of Permanent Magnet Motor drives, Configuration and control of Switch Reluctance Motor drives, drive system efficiency.

Energy Storage:

Introduction to Energy Storage Requirements in Hybrid and Electric Vehicles, Battery based energy storage and its analysis, Fuel Cell based energy storage and its analysis, Super Capacitor based energy storage and its analysis, Flywheel based energy storage and its analysis, Hybridization of different energy storage devices.

Sizing the drive system:
Matching the electric machine and the internal combustion engine (ICE), Sizing the propulsion motor, sizing the power electronics, selecting the energy storage technology, Communications, supporting subsystems.

Energy Management Strategies:
Introduction to energy management strategies used in hybrid and electric vehicles, classification of different energy management strategies, comparison of different energy management strategies, implementation issues of energy management strategies.

Case Studies: Design of a Hybrid Electric Vehicle (HEV), Design of a Battery Electric Vehicle (BEV).

References:

1. Iqbal Hussein, Electric and Hybrid Vehicles: Design Fundamentals, CRCPress, 2003.
2. MehrdadEhsani, YimiGao, Sebastian E. Gay, Ali Emadi, Modern Electric,Hybrid Electric and Fuel Cell Vehicles: Fundamentals, Theory and Design,CRC Press, 2004.
3. James Larminie, John Lowry, Electric Vehicle Technology Explained,Wiley, 2003.

RME 5204 : Advanced Power Electronics- 3 Credit

Advanced solid state devices:
MOSFETs, IGBT, GTO, IGCT etc.Power modules, intelligent power modules, gating circuits, Thermal design, protection, Digital signal processors used in their control.

Non-isolated dc-dc converters:
Buck, boost, buck-boost, Cuk, SEPIC, Zeta in DCM and CCM.

Isolated dc-dc converters:
Flyback, forward, Cuk, SEPIC, Zeta, half bridge, push-pull and bridge in DCM and CCM, Single-phase, single-stage converters (SSSSC), power factor correction at ac mains in these converters. Their application in SMPS, UPS, welding and lighting systems.

Single-phase improved power quality ac-dc converters:
Buck, boost, buck-boost, PWM VSC (Voltage source converters), multilevel VSCs, PWM CSC (Current voltage source converters).

Three-phase improved power quality ac-dc converters:

VSC, multilevel VSCs, multipulse VSCs, PWM CSC (Current voltage source converters), Multipulse ac-dc converters: Diode and thyristor based converters.

Power quality mitigation devices:
Passive filters, active filters, hybrid filters, DTSTCOM (Distribution static compensator), DVR (Dynamic voltage restorer) and UPQC (Universal power quality conditioner).

FACTS devices:
TCR (thyristor controlled reactor), TSC (thyristor switched capacitors), STATCOM (Static synchronous compensator), SSSC (Static series synchronous compensator), UPFC (Unified power flow controller), IPFC (Interline power flow controller), HVDC (High voltage direct current) system: 12-pulseconverter based HVDC systems, HVDC light, HVDC PLUS (Power universal link), Multipulse and multilevel VSC based flexible HVDC systems.

Solid state controllers for motor drives:
Vector control and direct torque control of induction,synchronous, permanent magnet sine fed, synchronous reluctance motors, Permanent magnet brushless dc (PMLDC) and switched reluctance motors, LCI (load commutated inverter) fed large rating synchronous motor drives, Energy conservation and power quality improvements in these drives.

References:

1. R. S. Ramshaw, "Power Electronics Semiconductor Switches", Champman& Hall, 1993.
2. N. Mohan, T. M. Undeland and W. P. Robbins, "Power Electronics, Converter, Application and Design", Third Edition, John Willey & Sons, 2004.
3. M. H. Rashid, "Power Electronics, circuits, Devices and Applications", Pearson, 2002, India.
4. K. Billings, "Switch Mode Power Supply Handbook", McGraw-Hill, 1999, Boston.
5. A. I. Pressman, "Switch Mode Power Supply Design", McGraw-Hill, 1999, New York.
6. B. K. Bose, "Power Electronics and Variable Frequency Drive", Standard Publishers Distributors, 2000
7. Bin Wu, "High-Power Converters and AC Drives", IEEEPress,A John Wiley & Sons, Inc Publication, New York,2006.
8. G. T. Heydt, "Electric Power Quality", Stars in a CirclePublications, second edition, 1994, Avarua, Rarotonga,Cook Islands.
9. R. C. Duagan, M. F. Mcgranaghan and H. W. Beaty,"Electric Power System Quality", McGraw-Hill, 2001, 1221Avenue of the Americas, New York.
10. Vijay K. Sood, "HVDC and FACTS Controllers -Applications of Static Converters in Power Systems",Kluwer Academic Publishers, Masachusetts, 2004.
11. J. Arrillaga, Y. H. Liu and N. R. Waston, "Flexible PowerTransmission-The HVDC Options", John Wiley &Sons,Ltd, Chichester, UK, 2007.

RME 5205 : Nanotechnology and Nanofabrication- 3 Credit

Nanolithography:

Fundamentals of Electron Beam Exposure and Development, Simulation of Electron Beam Exposure and Resist Processing for Nano-Patterning, Helium Ion Lithography, Nanoimprint Technologies

Deposition at the Nanoscale:
Atomic Layer Deposition for Nanotechnology, Surface Functionalization in the Nanoscale Domain, Nanostructures Based on Self-Assembly of Block Copolymers, Epitaxial Growth of Metals on Semiconductors ViaElectrodeposition

Nanoscale Etching and Patterning:
Chemical Mechanical Polish for Nanotechnology, Deposition, Milling, and Etching with a Focused Helium Ion Beam, Laser Nanopatterning, Templating and Pattern Transfer Using Anodized Nanoporous Alumina/Titania

Research and Review Studies:
Atom, Molecule, and Nanocluster Manipulations for Nanostructure Fabrication Using Scanning Probe Microscopy, Atomic Force Microscope Lithography, Scanning Probe Arrays for Nanoscale Imaging, Sensing, and Modification, Nanofabrication Based on Self-Assembled Alumina Templates, Nanowire Assembly and Integration, Taper-Drawing Fabrication of Glass Nanowires, Nanotechnologies for Cancer Diagnostics and Treatment, Nano/Microstructuring of Ceramic Surfaces by Unconventional Lithographic Methods, Alternative Nanofabrication Approaches for Non-CMOS Applications, Nanofabrication of Nanoelectromechanical Systems (NEMS): Emerging Techniques.

References:

1. Nanofabrication: Techniques and Principles, Maria Stepanoval and Steven Dew
2. Nanofabrication: Fundamentals and Applications by Ampere A Tseng
3. Nanotechnology: Nanofabrication, Patterning and Self Assembly By Charles J. Dixon And Ollin W. Curtines

RME 5206 : Automotive Control and Simulation- 3 Credit

Creating computer models in MATLAB and Simulink:
Introduction to MATLAB programming, Introduction to modelling and simulation in Simulink, Linear system analysis in MATLAB, Finding operating points and linear models using MATLAB and Simulink.

Classical control concepts:
Key feedback concepts: stability, tracking performance, noise/disturbance rejection.

Classical control design:
Frequency-domain loop-shaping, Introduction to pre-filter design and ‘feed-forward’, Actuator saturation, noise and integrator wind-up.

Suspension Brakes and Safety:
Air suspension-Closed loop suspension-antiskid braking system, Retarders, Regenerative braking safety cage air bags.

Passenger comfort and Pollution Control:
Reduction of noise – Internal & external pollution control through alternate fuels/ power plants-Catalytic converters and filters for particular emission.

Vehicle Operation and Control:
Computer Control for pollution and noise control and for fuel economy-Transducers and operation of the vehicle like optimum speed and direction.

References:

1. Beranek. L.L. Noise Reduction, McGraw-Hill Book Co., Inc, Newyork, 1993
2. Bosch Hand Book, 3rd Edition, SAE,1993

RME 5207 : Industrial Product Modeling and Visualization- 3 Credit

Introduction:
An introduction to basic modeling, visualization and evaluation techniques creating models, parts and Assembles.

Linear Production Models and Discontinuous Factor Substitution:
Limitational Inputs and Fixed Coefficients of Production, Discontinuous Substitution: The Linear Production Model, Discontinuities in General.

Production Functions with Continuous Factor Substitution:
Factor Substitution and the Isoquant Map, Production Curves and Diminishing Returns, Cost Minimization, The Expansion Path and the Cost Function, The Expansion Path and the Cost Function.

Product Quality and the Production Function:
Product Quality in the Theory of Production, Quality Parameters in the Production Function, Quality Constraints.

Plant and Process Production Models:
Process Interdependencies and Optimization, Vertical Integration of Processes.

Multi-Product Models:
Alternative Processes and Joint Production, Alternative Processes, Multi-Product Processes. The representations that underpin modern CAED systems (wireframe surface, CSG and BRep), basic computer graphics (homogeneous transformations), Data exchange, information integration, product data management.

Economics of CAD/CAM systems:
Cost breakdown, potential benefits, improving cost/benefit ratio, Basic systems selection and justification and organizational impact and system management.

Reference:

1. Industrial Production Models, A Theoretical StudyBy Sven Dan**,** Professor of Managerial Economics, University Of Copenhagen.

RME 5211 : Industrial Automation Lab
Practical Classes based on the Topics Covered in**RME 5201.**

RME 5214 : Advanced Power Electronics Lab
Practical Classes based on the Topics Covered in**RME 5204.**

RME 5216 : Automotive Control and Simulation Lab
Practical Classes based on the Topics Covered in**RME 5206.**

RME 5217 : Industrial Product Modeling and Visualization Lab
Practical Classes based on the Topics Covered in**RME 5207.**

c) Common

RME 5301 : Engineering Research Methodology- 3 Credit

Foundations of Research:
Objectives and Motivation of Research, Types of Research, Research Approaches, Significance of Research, Research Methods versus Methodology, Research and Scientific Method, Important of Research Methodology, Research Process, Criteria of Good Research.

Defining the Research Problem:
Definition of Research Problem, Problem Formulation, Necessity of Defining the Problem, Technique involved in Defining a Problem, Constructing Hypotheses.

Literature Review:
Importance of Literature Review, Guidelines for Review, Sources of Information, Assessment of Quality of Journals and Articles.

Research Design:
Meaning of Research Design, Need of Research Design, Feature of a Good Design, Important Concepts Related to Research Design, Different Research Designs, Basic Principles of Experimental Design, Developing a Research Plan, Design of Experimental Set-up, Use of Standards and Codes.
Quantitative Methodology:

Collection of primary data, Secondary data, Data organization, Methods of data grouping, Diagrammatic representation of data, Graphical representation of data, Sample Design, Need for sampling, Principle of sampling, Different sampling techniques, Non-random sampling design, Sampling in qualitative research, Estimation of population, Role of Statistics for Data Analysis, Parametric V/s Non Parametric methods, Descriptive Statistics, Measures of central tendency and Dispersion, Hypothesis testing, Use of Statistical software.

Data Analysis:
Deterministic and random data, Uncertainty analysis, Tests for significance: Chisquare, student's t-test, Regression modeling, Direct and Interaction effects, ANOVA, F-test, Time Series analysis, Autocorrelation and Autoregressive modeling.

Research Proposal Preparation:

1. Writing a Research Proposal and Research Report, Writing Research Grant Proposal.

RME 5302 : Advanced Algorithms: Design and Analysis- 3 Credit

Complexity and Efficiency Analysis:
Asymptotic Analysis-Review of Asymptotic Analysis and Growth of Functions, Recurrence-Analyze the efficiency of algorithms using recurrences, Amortized Analysis-Analyze the efficiency of algorithms using amortized analysis, Binomial Heap, Fibonacci Heap, Splay Tree.

String matching:
KMP (Knuth Moris Pratt) string matching, Boyer Moore string matching, Suffix Tree.

Dynamic Programming:
Basics of dynamic programming, Top down vs. bottom up approach, Memoization, Sum of Subset, 0/1 Knapsack, Sequence Alignment, Edit Distance.

Network Flow:
The Maximum Flow Problem, Applications of Maximum Flow, MaxflowMincut Theorem, Mincost Flow.

Matching:
Maximum Bipartite Matching, Weighted Bipartite Matching (Hungarian Method). Sorting - Lower bound for comparison based sorting,

Non-comparison based sorting:
Count sort, bucket sort, radix sort.

NP and Computational Intractability:
NP-Completeness Fundamentals, NP-Complete problems, P versus NP, co-NP, NP Hardness, A Class of problems beyond NP.

Approximation Algorithm:
Randomized Algorithm-Contention Resolution, Finding the Global Minimum Cut, A Randomized Approximation Algorithm for MAX 3-SAT, Randomized Divide & Conquer.
Graphs:

Graphs, Sub graphs, Isomorphism, Walks, Paths, Circuits, Connectedness, Components, Euler graphs, Hamiltonian paths and circuits.

Trees, Connectivity and Planarity:
Trees, Properties of trees, Distance and centers in tree, Rooted and binary trees, Spanning trees, Forests, Fundamental circuits, Spanning trees in a weighted graph, cut sets, Properties of cut set, All cut sets, Fundamental circuits and cut sets, Connectivity and separability, Network flows, 1-Isomorphism, 2-Isomorphism, Combinational and geometric graphs, Planer graphs, Different representation of a planer graph.

Matrices, Colouring and Directed Graph:
Chromatic number, Chromatic partitioning, Chromatic polynomial, Matching, Covering, Vertex coloring, Edge coloring, Five color theorem, Four color problem, Critical graph, Directed graphs, Types of directed graphs, Digraphs and binary relations, Directed paths and connectedness, Euler graphs.

Homomorphism Digraph:
Different connectedness, Oriented graphs, Tournaments, Network flows and related algorithms, Groups, polynomials and graph enumeration, Matching and factorization, Perfect graphs, Ramsey number and Ramsey theorem, Forbidden graph theory, Miscellaneous applications.

Reference Books:

- Introduction to Algorithms, 3rd Edition, by Thomas H. Cormen, Charles E. Leiserson, Ronald L. Rivest, and Clifford Stein, The MIT Press, 2011.

RME 5303 : Internet of Things (IoT) - 3 Credit

Network and Internet Basics:
Internet in general and Internet of Things: layers, protocols, packets, services, performance parameters of a packet network as well as applications such as web, Peer-to-peer, sensor networks, and multimedia, Transport services: TCP, UDP, socket programming. Network layer: forwarding & routing algorithms (Link, DV), IP-addresses, DNS, NAT, and routers, Local Area Networks, MAC level, link protocols such as: point-to-point protocols, Ethernet, WiFi 802.11, cellular Internet access, and Machine-to-machine. Mobile Networking: roaming and handoffs, mobile IP, and ad hoc and infrastructure less networks. Real-time networking: soft and real time, quality of service/information, resource reservation and scheduling, and performance measurements.

Introduction to IoT:
Overview, Applications, Potential & Challenges, Architecture, Components of IOT solutions, Open Source and Commercial Examples, Standards for IOT.

IoT Sensors and Devices:
IoT devices and sensor types, Sensors and Data Collecting Points, Sensing, Actuation, how they work and connect.

IoT Network and Protocols:

Basics of Networking, Connectivity Technologies, Communication Protocols, Sensor Networks, Machine-to-Machine Communications, UAV Networks, Connected Vehicles, SDN for IoT.

IoT Programming:
Interoperability of IOR, Integration of Sensors and Actuators with Arduino, Implementation of IOT with Raspberry Pi.

IoT and Cloud:
Cloud Computing Fundamental, Cloud Computing Service Models, Cloud Computing Service Model and Security, Sensor-Cloud, IoT and Cloud Integration, Fog Computing.

Cyber security and Privacy in IoT:
The security and privacy implications of the IoT.

IOT Application and Case Study:
Smart Cities and Smart Homes, Smart Grid, Industrial IoT, Agriculture, Healthcare, Activity Monitoring, Automotive, Energy/Utilities, Financial.

Reference Books:

1. IoT Fundamentals: Networking Technologies, Protocols and Use Cases for the Internet of Things by Pearson, 1st Edition, by Hanes David, Pearson Education, 2017.
2. Internet of Things, 1st Edition by Raj Kamal, McGraw Hill Education, 2017.
3. Internet of Things, 1st Edition, by Jeeva Jose, Khanna Publishing, 2018.
4. Getting Started With The Internet Of Things: Connecting Sensors and Microcontrollers to the Cloud, by CunoPfisto, by Shroff, 2011.
5. Big Data and The Internet of Things, 1st Edition, by Robert Stackowlak, Springer Nature, 2015.

RME 5304 : Mathematical Modeling & Optimization- 3 Credit

Linear Programming (LP) as a tool of Operational Research (OP):
The history of LP and the contribution of G. Dantzig. Modelling a problem as an LP problem by defining the objective function, the set of linear constraints that determines its feasible solutions. Forms of an LP problem, Unique optimal solution and infinite many optimal solutions. Incompatible constraints, unbounded feasible solution set and unbounded variables

Mathematical Modeling:
Linear, nonlinear, and integer programming models; Convex Analysis: Convex sets, polyhedral sets and polyhedral cones, Extreme points and extreme directions, Representation of polyhedral sets, Basic feasible solution and its relation with extreme points. Degenerated basic feasible solutions. The Extreme Point Theorem. Finding the optimal solution by the use of Linear Algebra

Linear Programming:

Motivation of the simplex method and the revised simplex method, Farkas' lemma and the Karush-Kuhn-Tucker optimality conditions, Duality and sensitivity analysis, Interior point methods; The big M method and its application on various problems. The two phase method and its application on various problems. LP Problems with Unbounded variables. The Dual LP problem. Economic Interpretation of the Dual LP problem. Duality theorem. Dual Simplex method and its application on various problems.

Computational Complexity Theory:
Complexity issues, polynomial-time algorithms, Decision problems and classes NP and P

Network Optimization: Network simplex method, Matching and assignment problems, Min-cost, max-flow problems.

Reference Books:

1. Linear Programming and Network Flows, 3rd Edition, by Mokhtar S. Bazaraa, John J. Jarvis, Hanif D, Wiley, 2011.

RME 5305 : Industrial Project Management- 3 Credit

Introduction: Motivation for Process Measurement, Process Sensors, The Physics of Measurement.

The Industrial Company - Its Purpose, History: Purpose, structure, typology, New challenges imposed by globalization and sustainable development.

The Two Modes of Operation of the Company – Operational and Entrepreneurial: Operational mode, Entrepreneurial mode, project management – the operational/entrepreneurial conflict.

The Strategic Management of the Company- Industrial Aspects: Systemic view of the industrial company, Strategy and strategic analysis of the company, Technological choices and vocations.

Foundations of Process Industrialization: Introduction, The various stages of process development: from research to the foundations of industrialization, Development stage of the process.

The Industrialization Process- Preliminary Projects: Steps of industrialization, Bases of industrialization or process development, Typical organization of an industrialization project, Selection of production sites, Identifying process improvements for energy efficiency, pinch analysis and process heat integration, energy management key performance indicators (enpis) and energy dashboards.

Lifecycle Analysis and Eco Design- Innovation Tools for Sustainable Industrial Chemistry: The chemical industry mobilized against upheavals, The lifecycle analysis, an eco-design, The lifecycle analysis, an eco-design.

Methods for Design and Evaluation of Sustainable Processes and Industrial Systems: Introduction, AIChE and IChemE metrics, Potential environmental impact index, SPI (Sustainable Process Index), Exergy as a thermodynamic base for a sustainable development metrics, Indicators resulting from a lifecycle assessment, Process design methods and sustainable systems.

Process Imaging: Direct Imaging, Tomographic Imaging.

Meet Alarm Management: Key Concepts, Alarm Performance Problems, Reasons for Alarm Improvement, A Brief History of Alarm Management, The "Management" in Alarm Management, Importance of Alarm Management, Importance of Alarm Management, Design for Human Limitations, Alarm Management and Six Sigma, Continuous versus Discrete and Batch, Application Effect on Alarm Design, Alarm Improvement Projects, Lessons for Successful Alarm Management, Important Design and Safety Notice.

Abnormal Situations: Introducing Abnormal Situations, General Lessons from Incidents, Critical Contributors to Incidents, Message of Abnormal Situations.

Strategy for Alarm Improvement: Strategy for Alarm Improvement, Strategy for Alarm Improvement,The Geography of Alarm Management, Alarm Improvement Projects.

Intelligent Maintenance Systems:
Architecture of Intelligent Maintenance Systems, Predictive maintenance, Spare Parts Demand Forecasting and Supply Chain Planning, IMS Simulator Development, Concept for Using the Results in SPSC Planning Methods**. Data Acquisition and Analysis, Industrial Case Studies, Distributed Instrumentation, Industrial Process Systems, Measurement Systems, Measurement Theory and Devices,** Machine intelligence, Design and operations of sustainable systems, Advanced materials and materials selection, Computer-aided Selection, Stages of materials selection: Translation, Materials screening, Material indices, Supporting information and final selection, Preventive maintenance, reactive maintenance, predictive maintenance, Renewable energy technology, Energy conversion, Advanced control systems, multi-domain computer modelling, in-vehicle communication networks, electromechanical and embedded systems, hardware-in the-loop validation and systems integration.

Entrepreneurship and Technological Innovation Management:

Entrepreneurship:

Identifying and exploiting opportunities, creating and launching new ventures, introducing new products and new services to new markets, implementing innovations within existing organizations and creating new opportunities, entrepreneurial thinking and methods of executing their ideas.

Business resources:

Recognizing and evaluating opportunities, forming new venture teams, preparing business and technology commercialization plans, obtaining resources, identifying execution action scenarios, and developing exit strategies.

Innovation:

Successful innovations, developing and introducing new products and processes.

Innovation Model:

Practical model of the dynamics of industrial innovation, designing profitable business models.

Case studies:

Cases and examples will be discussed for products in which cost and product performance are commanding factors, producing a solid business plan, raising capital, addressing legal considerations and developing a winning team.

Interface:

The important interface among R&D/manufacturing/marketing, International technology transfer and joint venture.

References:

1. Intelligent maintenance system: A Successful Design Process Paperback – January 13, 2018, by GerardusBlokdyk
2. Maintenance Systems and Documentation by Anthony Kelly, 1st edition
3. Process Engineering and Industrial Management, Gean Pierre Dal Pont
4. Energy Management and Efficiency for the Process Industries, Alan P. Rossiter Beth P. Jones
5. Alarm Management for Process Control, 2nd edition, Douglas H. Rothenberg

RME 5312 : Advanced Algorithms: Design & Analysis Lab

Practical Classes based on the Topics Covered in**RME 5302.**

RME 5313 : Internet of Things (IoT) Lab

Practical Classes based on the Topics Covered in**RME 5303.**