Preface

Mechatronics is an exciting interdisciplinary field of engineering, based on mechanical and electrical engineering, control engineering as well as signal and data processing. Mechatronics systems sense their environment through multiple sensors, process the sensor signals and act back on the world by actuators. They can be found in almost all technological fields. Examples are current automobiles, airplanes, locomotives and train sets, smart home devices as there are washing machines or automated industrial production lines or agricultural robotic applications like ecological weed management or even wind power plant maintenance devices from the green energy sector.

Very typical for mechatronic systems is a high degree of integration of the different system components. The strong linkage between mechanical and electrical parts requires a new integrated design philosophy. It is no longer possible to develop the mechanical and electrical subsystems independently. Mechatronic system design simultaneously considers the mechanical, electrical and all other physical domains involved.

If you are a creative engineer interested in learning about the latest technology in this multidisciplinary field, have a closer look at the Mechatronics Master’s degree programme offered by Amrita Center for Advanced Robotics, Amrita Vishwa Vidyapeetham, Amritapuri Campus.

Curriculum

<table>
<thead>
<tr>
<th>SEMESTER 1</th>
<th>Course Code</th>
<th>Course Title</th>
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<tr>
<td></td>
<td>22MT601</td>
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<tr>
<td></td>
<td>22MT602</td>
<td>Embedded Computing and Programming</td>
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<td></td>
<td>22MT603</td>
<td>Sensors and Actuators</td>
<td>3</td>
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<td>22MT604</td>
<td>Robot Design and Analysis</td>
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<td>22MT605</td>
<td>Theory and Design of Control Systems</td>
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<td>22MT681</td>
<td>Sensors and Actuators Lab</td>
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<td>22MT612</td>
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<td>22MT613</td>
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Total Credits for MTech Program: 71
## Electives List

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<tr>
<th>Title</th>
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<tr>
<td>22MT631 Industry 4.0 Technologies</td>
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<td>22MT632 Electronic System Level Design</td>
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<td>22MT633 Semiconductor device modelling</td>
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<td>22MT634 Emerging Architectures for Machine Learning</td>
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<tr>
<td>22MT635 Data Structures and Algorithms</td>
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<td>22MT636 Embedded Real Time Systems</td>
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<tr>
<td>22MT637 FPGA Based System Design</td>
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<tr>
<td>22MT638 Process Control and Instrumentation</td>
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<td>22MT639 Advanced Process Control</td>
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<td>22MT640 Digital Image Processing</td>
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<td>22MT641 Kinematics and Dynamics of Robots</td>
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<td>22MT642 Machine Learning and Algorithm Design</td>
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<tr>
<td>22MT643 Unmanned Aerial Vehicles</td>
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<td>22MT644 Advanced AI for Robotics</td>
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<td>22MT645 Computational Intelligence</td>
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<td>22MT646 Medical Robotics</td>
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<td>22MT647 Embedded Systems For Automotive Applications</td>
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<td>22MT648 Embedded Systems in Biomedical Applications</td>
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<td>22MT649 Design For IoT And Cloud Computing</td>
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<tr>
<td>22MT650 Micro Electro Mechanical Systems (MEMS)</td>
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</table>
22MT601 Advanced Mechatronics Engineering 4

Unit I
Similarity transformations, diagonal form and Jordan form, functions of a square matrix, Lyapunov equation, quadratic form and positive/negative definiteness; Singular value decomposition, norms of matrices, solution of LTI state equations; Input-output stability of LTI systems, internal stability, Lyapunov theorem; Controllability, observability, canonical decomposition, minimal realizations and coprime fractions, state feedback and state estimators.

Unit II
Qualitative behavior near equilibrium points, limit cycles, existence of periodic orbits, Lyapunov stability; Input output stability, $L$ stability, $L_2$ gain; Feedback system: The small gain theorem; Passivity, memoryless functions, state models, feedback systems: passivity theorem, absolute stability, circle criterion, Popov criterion; Feedback control: Stabilization via linearization, integral control, integral control via linearization.

Unit III
Real-time operating systems, requirements of real-time systems, deadlock, resource management, priority, pre-emption; Hard real-time scheduling algorithms: Rate monotonic and earliest deadline first, schedulability tests, real-time communication: introduction, necessity, hard and soft real-time, network topologies and main non-real-time protocols.

Text Book
1. Mechatronics: Electromechanics and Contromechanics (Denny K. Miu)

References:

22MT602 Embedded Computing and Programming 3

Unit I
STM32F Processor: Introduction to Embedded Systems - Introduction to ARM - Advanced RISC Features - Core Data path - Register Organization - System Architecture - Memory Organization - Low Power Modes - Power Control Registers – Backup Registers - Programming STM32F

Unit II
STM32F Peripherals: Introduction to Embedded C Programming – General Purpose Input Output - UART - ADC - DAC - Timers - Interrupts and Exceptions - PWM - SPI

Unit III
External Peripheral Interfacing: LCD - Keypad - Motor - Servo Motor - EEPROM - Seven Segment Interfacing - Sensor Interfacing
References
2. Donald Norris, Programming with STM32: Getting Started with the Nucleo Board and C/C++, McGraw-Hill Education, 2018
3. STM32F446xx advanced Arm®-based 32-bit MCUs, Reference Manual, 2020

22MT603 Sensors and Actuators 3
Unit I
Introduction: Sensors and Actuators, Definition, Classification, Principle of Operation, Selection Criteria, Calibration techniques, Time and Frequency Measurement, Time and Frequency Standards, Time and Frequency Transfer, Sensor and Actuator Characteristics. Thermocouples; Resistive sensors; Inductive sensors; Capacitive sensors; Piezoelectric sensors; Encoders and tachometers
Unit II
Unit III
Electromechanical Actuators, Electrical Machines, Piezoelectric Actuators, Hydraulic and Pneumatic Actuation Systems

Textbooks:

Reference

22MT604 Robot Design and Analysis 3
Unit I:
Introduction to product design and development; Design process and its Phases, Mechanical Design Review; Fundamentals of 3D modelling; Basic manufacturing processes; Various Robot Design
Unit II
Mechanical design review; Basic concepts of kinematics and dynamics; Modelling and analysis of robotics systems; Prototype basics – principles of prototyping – planning for prototypes.
Unit III
Material selection for Robot manufacturing - Economics - Cost Vs Performance - Weighted property Index - Value Analysis - Role of Processing and Design - Classification of
Manufacturing Process - Design for Manufacture - Design for Assembly - Design for castings, Forging, Metal Forming, Machining and Welding - Residual stresses - Fatigue, Fracture and Failure.

Textbooks:

References
2. Service Robots and Robotics: Design and Application, Marco Ceccarelli (University of Cassino, Italy). 2012

22MT605 Theory and Design of Control Systems 3

Unit I
Modeling: transfer function and state-space representations of differential governing equations; time and frequency-domain system response.

Unit II
Analysis: stability of linear and nonlinear systems; nominal sensitivity functions; Nyquist stability criterion; stability margins; sensitivity, robustness, and the robust stability theorem; design specifications and characterization of constraints; effect of open-loop integrators, poles and zeros; frequency-domain design limitations; eigenvalue and eigenvectors; Jordan canonical form; controllability and stabilizability; observability and detectability; canonical decomposition.

Unit III
Design: pole placement techniques in both the frequency domain and via state feedback; full state and reduced-order observer design; output feedback design; transfer function interpretations of output feedback design; introduction to the linear quadratic regulator.

Text Book

References:

22MT611 Mechatronics Systems Design 4

Unit I
Mechatronic systems – Integrated design issue in mechatronic – mechatronic key element, mechatronics approach – control program control – adaptive control and distributed system
Design process – Type of design – Integrated product design – Mechanism, load condition design and flexibility – structures – man machine interface, industrial design and ergonomics, information transfer, safety.

Unit II

Unit III
Real time interface – Introduction, Elements of a data acquisition and Control system, overview of I/O process, installation of I/O card and software – Installation of the application software – over framing.

Unit IV:

Text Books

Reference Books

**Text Book**

**22MT613 Advanced Topics in Intelligent Systems.**

**Unit I**
Introduction to Artificial Intelligence: definition of AI; Turing test; brief history of AI. Problem solving and search: problem formulation; search space; states vs. nodes; tree search: breadth-first, uniform cost, depth-first, depth-limited, iterative deepening; graph search. Informed search: greedy search; A* search; heuristic function; admissibility and consistency; deriving heuristics via problem relaxation. Local search: hill-climbing; simulated annealing; genetic algorithms; local search in continuous spaces. Dealing with geometry of physical agents: basic issues in robotics; degrees of freedom; Dijkstra’s shortest path algorithm;

**Unit II**

**Unit III**
Introduction to fuzzy set theory; Fuzzy set vs Crisp set; Problems on fuzzy set and crisp sets; Properties of fuzzy sets; Fuzzy Logic: Classical logic, multi valued logic; Fuzzy propositions; Fuzzy quantifiers; Fuzzy systems: fuzzy controllers;

**Text Books**

**Reference Books**

22MT631 Industry 4.0 Technologies 3

Unit I
Human-machine interaction - Augmented-reality systems - Transferring digital instructions to the physical world - Advanced robotics and 3-D printing - Autonomous activities - Lean Manufacturing - Human-machine interaction - Touch interfaces, virtual reality and augmented-reality systems

Unit II
Advanced robotics - 3-D printing - Cloud Computing and Concept of “Equipment-As-a-Service,” EAAS - Connectivity Solutions: Bluetooth, BLE, Bluetooth 5.0, ZigBee, ZigBee 3.0, Z-Wave, 6LowPAN, RFID, WiFi, Mobile/Cellular, SATCOM, PLC, PLC Programming (Ladder Logic Programming) - Proactive/Predictive Maintenance and Continuous Monitoring

Unit III
Cyber-physical systems (CPS) in the Industry 4.0 vision - Cyber-physical systems key characteristics - Industry 4.0 building blocks - The (Industrial) Internet of Things - Industry 4.0 principles: horizontal and vertical integration; Principles of Big Data, Data Mining, Data Organization and Data Warehousing - Data security in Industry 4.0

Text Book
1. Industry 4.0: The Industrial Internet of Things, Alasdair Gilchrist, Apress, 2017

References
1. The Fourth Industrial Revolution by Klaus Schwab
2. Sustainability in Manufacturing Enterprises: Concepts, Analyses and Assessments for Industry 4.0 by Ibrahim Garbie

22MT632 Electronic System Level Design 3

Unit I
Introduction to Electronic System Level Design— Hybrid Design – ESLD Flows and Methodologies – Architecture Exploration—Hardware-software Partitioning.

Unit II
Models for ESL Design— Open-Source Languages—SpecC–ArchC and SystemC for ESLD—Transaction Level Modelling Building Platform Models in SystemC.

Unit III

References
22MT633  Semiconductor Device Modeling  3

Unit I

Unit II

Unit III
Radiation Effects in Single gate and Multi gate FETs – Single event effects - Multigate MOSFET Circuit Design - Digital, Analog circuit design - Double gate MOSFET- Drain current model - Scale length - Fabrication Requirements – Challenges – SoC Design- Technology Aspects

References
3. J. P. Collinge, FinFETs and Other Multi-Gate Transistors, Springer, 2008

22MT634  Emerging Architectures for Machine Learning  3

Unit I

Unit II

Unit III

References
22MT635 Data Structures and Algorithms 3

Unit I

Unit II

Unit III

References

22MT636 Embedded Real Time Systems 3

This course looks at components, interfaces and methodologies for building systems. Specific topics include microcontrollers, design, verification, hardware/software synchronization, interfacing devices to the computer, timing diagrams, real-time operating systems, data collection and processing, motor control, analog filters, digital filters, and realtime signal processing. Topics include Computer Architecture review, Design of I/O Interfaces, Software Design, Real Time Operating Systems, Multitasking (preemptive scheduling, resource sharing and priority determination), Digital Signal Processing, HighSpeed Interfacing, File system management, Interfacing Robotic Components, High-Speed Networks, Robotic Systems.

Textbooks/References:
22MT637 FPGA Based System Design 3

Unit I
Programmable logic devices - PROM- PAL – PLA- CPLD - Gate arrays -MPGA - FPGA-

Unit II
FPGA Design flow and abstraction levels – Verilog design for synthesis-one hot encoding-
Memory blocks- Block memory generator (BRAM/BROM)- single port memory- dual port memory- FIFO-distributed RAM-synthesis pitfalls-latch inference-static timing analysis-speed performance-timing constraints-clock management -clock buffers-clock tree routing

Unit III
Introduction to SoC design –Hard macros – multipliers –DSP block-hard core processors-
interface circuits— configuration chain – JTAG interface - Zynq7000

References

22MT638 Process Control and Instrumentation 3


Textbooks/ References:

Textbooks/References:
4. B.G. Liptak, "Handbook of Instrumentation - Process Control".

22MT640 Digital Image Processing 3

Textbooks/References:

22MT641 Kinematics And Dynamics Of Robots


Textbooks/References:

22MT642 Machine Learning and Algorithm Design

Unit I
Mathematical concepts review - Central tendency - Dispersion of data - Descriptive data summaries - k-nearest neighbor classifier - Bayes classifiers - Classifier performance measures

Unit II

Unit III
Graphs - Definitions and applications - Graph Connectivity - Graph Traversal - Testing Bipartiteness - Breadth-First Search - Directed graphs - Directed Acyclic Graphs - Topological
ordering - Interval scheduling - Optimal caching - Shortest paths - Minimum Spanning Tree - Clustering - Huffman Codes - Data Compression - Partitioning Problems - Graph Coloring

References
1. Jiawei Han, Micheline Kamber, Jian Pei, Data Mining: Concepts and Techniques, Third Edition, Morgan Kaufmann Publishers (Elsevier), 2011.

22MT643  Unmanned Aerial Vehicles  3

Introduction to UAV - Types of UAV - Geometry and Mechanics of UAVs including transformations, angular velocity, principal moment of inertia, equations of motions, ROS based Control, Trajectories and Motion Planning, Sensing and Probabilistic State Estimation, Visual Motion Estimation, Visual SLAM, Architectures, UAV and AGV interoperable frameworks.

Textbooks/References:

22MT644  Advanced AI For Robotics  3


Textbooks/References:

**22MT645  Computational Intelligence  3**


**Textbooks/References:**

**22MT646  Medical Robotics.  3**

Introduction to Medical Robotics; Medical Robot (MR) History, MR Automation and Navigation Challenges; Robotically Assisted Minimally Invasive Surgery (MIS); MR Visual Servoing; MR-MIS Navigation and Deformation Tracking; Haptic Feedback in MIS; Learning and Perceptual Docking in MIS; Surgical Robotics (Laparoscopic and Endoscopic Manipulators); Oncology Robotics

**Reading**
3. [http://medrobotics.ri.cmu.edu/node/128439](http://medrobotics.ri.cmu.edu/node/128439) (Medical Robotics at CMU)
4. [http://robotics.eecs.berkeley.edu/medical/](http://robotics.eecs.berkeley.edu/medical/) (Medical Robotics at UC Berkeley)
5. [http://www.imperial.ac.uk/study/pg/courses/global-health-innovation/medical-robotics/](http://www.imperial.ac.uk/study/pg/courses/global-health-innovation/medical-robotics/) (MRes Curriculum at Imperial College)

**22MT647  Embedded Systems For Automotive Applications  3**


Textbooks/References:

22MT648 Embedded Systems In Biomedical Applications


Textbooks/References:

22MT649 DESIGN FOR IoT AND CLOUD COMPUTING

Embedded Systems: Rise of embedded systems and their transition to intelligent systems and to Internet of Things -RFIDs, NFC, Web of Things - Embedded Systems Design: power and energy consumption; hardware design elements, software platforms –OS and

Textbooks / References:

22MT650 Micro Electro Mechanical Systems (MEMS) 3

Unit I

Unit II

Unit III

Text Book

References: