PROGRAM
M. Tech.
Robotics and Automation

Faculty of Engineering

Revised in June 2016
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PROGRAM OUTCOMES

PO1: An ability to independently carry out research/investigation and development work to solve practical problems.
PO2: An ability to write and present a substantial technical report/document.
PO3: Students should be able to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor program.

PROGRAM SPECIFIC OUTCOMES

PSO1: To master the state of the art robotic and automation technologies.
PSO2: To identify the existence of the real-life engineering problems and carving the best solution using various technologies of robotics and automation.
PSO3: To secure a relevant job/research position in industries/research institutes having a core focus on robotics/automation technologies.
## CURRICULUM STRUCTURE

### Semester 1

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Type#</th>
<th>Course Title</th>
<th>Credits</th>
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<tbody>
<tr>
<td>16MA623</td>
<td>FC</td>
<td>Mathematics for Robotics and Automation</td>
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<tr>
<td>16RA601</td>
<td>FC</td>
<td>Embedded System Design</td>
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<tr>
<td>16CI622</td>
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<td>Digital Control Systems</td>
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<tr>
<td>19RA611</td>
<td>SC</td>
<td>Introduction to Robotics</td>
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<tr>
<td>E</td>
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<td>Elective - I</td>
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<tr>
<td>16HU601</td>
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Total Credits: 18

### Elective – 1 Courses

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<td>E</td>
<td>Computer Programming Including Python and Embedded C</td>
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<tr>
<td>16RA702</td>
<td>E</td>
<td>Modelling Mechanical and Electrical Systems</td>
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### Semester 2

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<td>Probability and Statistics</td>
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<td>16WN604</td>
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<td>Design and Analysis of Algorithms</td>
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<td>16RA613</td>
<td>SC</td>
<td>Mobile and Autonomous Robots</td>
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<td>16RA612</td>
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<td>16EN600</td>
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Total Credits: 19

### Elective – II Courses

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<tr>
<td>16RA704</td>
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<td>Machine Learning</td>
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<td>Elective – III</td>
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<td>E</td>
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<td>Elective – IV</td>
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<td>Course Code</td>
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<td>Stream 1: Career oriented</td>
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<td>16RA711</td>
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<td>Industrial Automation – II</td>
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<td>16CI624</td>
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<td>Process Control and Instrumentation</td>
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<tr>
<td>16RA712</td>
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<td>16RA713</td>
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<td>16RA714</td>
<td>E</td>
<td>Embedded Real Time Systems</td>
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<tr>
<td>16RA715</td>
<td>E</td>
<td>Robot Simulation and Offline Programming</td>
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<tr>
<td>16RA716</td>
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<td>Advanced Embedded System Design</td>
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<td>16RA721</td>
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<td>16RA722</td>
<td>E</td>
<td>Swarm Intelligence</td>
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<td>16RA723</td>
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<td>Behavioral Robotics</td>
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<td>16RA724</td>
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<td>Frontiers of Biomechanics</td>
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<td>Optimization Theory</td>
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<td>16RA725</td>
<td>E</td>
<td>Haptic Interfaces</td>
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<td>16RA726</td>
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<td>Innovating in Technology</td>
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<td>16RA727</td>
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<td>Measuring User Interface Quality</td>
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<td>16RA728</td>
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<td>Design for People: Principles and Practices of Human Centered Design</td>
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<td>Stream 2: Software Focus</td>
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<td>16RA731</td>
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<td>Advanced Perception for Robotics and HCI</td>
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<td>16CS701</td>
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<td>16RA732</td>
<td>E</td>
<td>Machine Vision</td>
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<td>16RA734</td>
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<td>Virtual Reality and Applications</td>
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<td>16RA735</td>
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<td>Non-Linear Control Theory</td>
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<tr>
<td>16RA736</td>
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<td>Experimental Haptics</td>
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Semester 4

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<td>16RA799</td>
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<td>Dissertation</td>
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</table>

TEXT BOOKS/REFERENCES:

[7] Howard Anton, "Elementary Linear Algebra with Applications".
[8] Bernard Kolman and David R. Hill, "Introductory Linear Algebra with Applications".
[10] Thomas and Finney, "Calculus".

Course outcome:

CO1: To get introduced to linear algebra, differential equations
CO2: To understand the role of Linear algebra and differential equation in robotics applications
CO3: To provide conceptual foundations for careers in research, teaching or industrial work in which advanced mathematics is used in an essential way
Microcontroller fundamentals: ARM ASM programming and basic of C; IO Interfacing: LED and Switch; Design and Development Process: Architecture, Microarchitecture, Design, Implementation, Verification and Validation; Development Tools: Block Diagrams, Flow Charts, Call Graphs, Dataflow Graphs, Finite State Machines; The Parallel Interface: GPIO; The Serial Interface: UART; PLL programming; Timer: SysTick; Fixed Point; Software: Structs, Stacks and Recursion; Device Driver: Interfacing with an Hitachi HD44780 display; IO Synchronization; Interrupts; DAC: Music Synthesis and Music Playback; ADC: Real world interfacing and Data Acquisition.

Labs include prototypes of actual embedded systems, e.g., Traffic Light Controller (FSM), LCD Device Driver (Hitachi HD44780), Digital Piano (DAC, Interrupts), Digital Vernier Caliper (ADC, Interrupts, LCD), Distributed Data Acquisition (Interrupts, ADC, LCD, UART) accomplished using Arduino based system. Basics of system booting and Boot Loaders. Concurrency, Timeouts, Inter Process Communication. Capstone Design Project, A popular video game, e.g., Space Invaders, Connect-4, Pipe Dream, etc.

TEXT BOOKS/REFERENCES:


Course outcome:

CO1: To study how an embedded system could be used to solve real-world problems especially related to Robotics and Automation technologies
CO2: To understand how to interface input and output devices to ARM board
CO3: To study ARM programming

Review of Z transforms. Pulse transfer function. Digital control system: sampling, quantization, data reconstruction and filtering of sampled signals. Z transform analysis of closed loop and open loop systems, multi rate Z transform. Stability analysis of closed loop systems in the z plane: root loci, frequency domain analysis, stability tests. Discrete equivalents. Digital controller design for SISO systems: design based on root locus method in the z plane, design based on frequency response method, design of the lag compensator, lead compensator, lag lead compensator, design of PID controller based on frequency response
method, direct design, method of Ragazzini. Controllability, observability, control law design,
decoupling by state variable feedback, effect of sampling period. Estimator/Observer design:
full order observers, reduced order observers, regulator design.

TEXT BOOKS/REFERENCES:


Course outcome:

CO1: To provide a thorough understanding of control systems
CO2: To understand control system design techniques, their limitations, and benefits
CO3: To provide knowledge on designing a control system for a particular application with necessary simulations
CO4: To provide knowledge on analyzing a control system

16RA611 INTRODUCTION TO ROBOTICS 2-1-1-4


TEXT BOOKS/REFERENCES:


Course outcome:

CO1: To understand about Industrial robot architecture
CO2: To gain knowledge on kinematic and dynamic modelling of serial chain manipulators
CO3: To understand the robot-control aspects
CO4: To study how to do programming and control ABB Industrial Manipulators

16RA701 COMPUTER PROGRAMMING INCLUDING PYTHON AND EMBEDDED C 2-0-2-4

Programming in C, Basic Computer Organization and Architecture, Build and Compilation process, Debugging concepts. Data Types and Variables, Input/Output implementation and usage. Control flow, Modular Programming with functions, Stack Frames and Activation Records. Arrays, Pointers, Strings, Structures and Implementation of Structures. Memory, Dynamic Memory Allocation, Stacks and Heap. Recursion. Program Runtime Analysis, Big-Oh Notation. Exception Handling, Watchdog and Fault Tolerance. Data structures such as maps, multi-maps, lists, etc. Assembly Language Programming. Programming in Embedded C. Significant labs, e.g., implementation of a Spell Checker with a real dictionary, implementation of a data structure such as a Vector/Set, development of a Customer Relationship Management system, etc. Capstone Design Project, Game of Life, Data Compression, etc.

TEXT BOOKS/REFERENCES:

Course Outcomes:
CO1: To increase the programming skills on Python and Embedded C through hands-on coding sessions.
CO2: To provide insight on program debugging and bug fixing.

16RA702 MODELLING MECHANICAL AND ELECTRICAL SYSTEMS 3-0-1-4

TEXT BOOKS/REFERENCES:


Course Outcomes:

CO1: To give an overview of the importance in mathematically modelling systems/problems
CO2: To understand the necessary concepts to model real world mechanical and electrical systems

16MA622 PROBABILITY AND STATISTICS 3-0-0-3

Probability: Introduction to data analysis and statistics, Algebra of sets, Counting, Axioms of probability, Conditional probability, Law of Total Probability and Bayes' rule, Independence of events, Random variables; Types of data, Descriptive statistics (measures of central tendency and variation), Graphical representation of data, Distribution functions, Expectation, variance, and moments of discrete & continuous random variables, Functions of random variables, Discrete Uniform, Bernoulli, Binomial, Poisson, and Geometric distributions, Continuous Uniform, Normal, and Exponential random variables; Measurement errors - accuracy and precision; Framing hypothesis statements (practical statement vs. statistical statement), Concept of statistical hypothesis tests; Type I Error, Type II Error, and p-value, Point estimation vs. interval estimation, Test of single mean, Test of comparison of two means (independent and paired t-tests), Test of single variance, Test of comparison of two variances, Test of comparison of more than two means (ANOVA), Test of independence of two discrete random variables (Chi-square), Correlation and covariance, Concept of Linear Regression.

TEXT BOOKS/REFERENCES:


Course outcome:

CO1: To get a deep insight into probability and statistics
CO2: To know how to do hypothesis testing
CO3: To use probability and statistics in real-world robotics problems

TEXT BOOKS/REFERENCES:


Course Outcome:

CO1: To introduce to design principles and concepts for algorithm design
CO2: To have a mathematical foundation in the analysis of algorithms
CO3: To understand different algorithmic design strategies and to analyze the efficiency of algorithms

16RA613 MOBILE AND AUTONOMOUS ROBOTS 3-0-1-4

Simulation systems, Mechanisms for negotiating with staircases and unstructured environments. ROS

TEXT BOOKS/REFERENCES:


Course outcome:

CO1: To familiarize with the mobile robot classification
CO2: To gain knowledge on the kinematic modelling of wheeled robots
CO3: To gain knowledge on the architecture of a wheeled mobile robot
CO4: To have a deep insight into the robot perception and navigation
CO5: To study how to perform robot simulations in ROS

16RA612 DIGITAL IMAGE PROCESSING 3-0-0-3

TEXT BOOKS/REFERENCES:


Course Outcomes:

CO1: To understand the fundamentals of digital image processing
CO2: To analyze image using various transforms
CO3: To understand various image enhancement, restoration and reconstruction techniques

16EN600 TECHNICAL WRITING P/F


TEXTBOOKS/REFERENCES:


Course Outcomes:

CO1: To understand how to prepare technical reports, research proposals etc.
CO2: To understand the ethics to be followed during research and documentation
CO3: To get introduced to the documentation software LateX
Introduction to Automation, Introduction to Pneumatic System: Introduction to pneumatic systems: advantages and limitations, applications, structure and signal flow of pneumatic systems; pneumatic power pack: air generation and distribution, air reservoir, filter, lubricator, pressure regulator, actuators, direction control valves, check valves, flow control valves, pneumatic counter. Pneumatic Symbols. Pneumatic system design
Introduction to Hydraulic systems: advantages and limitations, physical principles of oil hydraulics, hydraulic power pack, hydraulic fluids, filters, types of hydraulic pumps, hydraulic actuators and accessories, accumulator, hydraulic valves: pressure control valves, flow control valves. Hydraulic symbols. Hydraulic system design
Programmable Logic Controllers (PLCs): Introduction, Architecture of PLC, PLC networking, programing and wiring, PLC installation, troubleshooting and maintenance, Design of HMI.

TEXT BOOKS/REFERENCES:

[8] Ries and Ries, "Programming Logic Controllers", PHI.

Course Outcomes:

CO1: Introduce the requirement of Automation in Industries
CO2: To design pneumatic actuation system
CO3: To design hydraulic actuation system
CO4: To design electric actuation system
CO5: To implement PLC control for a process

16RA704 MACHINE LEARNING 3-0-1-4


TEXT BOOKS/REFERENCES:


Course Outcomes:

CO1: To have an overview of the supervised, unsupervised and reinforcement techniques of machine learning
CO2: To understand the characteristics of machine learning, which enables them to apply for real-world problems
CO3: To understand the underlying principles of neural networks and artificial intelligence

16RA711 INDUSTRIAL AUTOMATION II 3-0-0-3

Overview of MES (Manufacturing Execution Systems) including computer integrated manufacturing (CIM) and computer integrated automation (CIA) and their integration into manufacturing execution systems. Overview of the applications of robotic systems in industrial automation. Recap of pneumatic and Hydraulic system design, Selection and control of motors for an application, motor drives - Variable Frequency Drives and Servo Drives. Supervisory Control and Data Acquisition: operation and use of SCADA commercial packages, application of SCADA in controlling and monitoring the control of both local and

TEXT BOOKS/REFERENCES:


Course Outcomes:

CO1: To introduce to computer integrated manufacturing system
CO2: To get a deep knowledge on PLC and DCS
CO3: To give an idea on how a robotic system can be configured for a particular automation task
CO4: To use SCADA for data acquisition and supervisory control of a process
CO5: To design automation solutions through case studies

16CI624 PROCESS CONTROL AND INSTRUMENTATION 3-0-0-3


TEXT BOOKS/REFERENCES:


Course Outcomes:

CO1: To get a deep insight into the process automation domain
CO2: To gain knowledge on process modelling
CO3: To study how to develop various control schemes for automating a process
CO4: To implement SCADA systems for control and data acquisition

16RA712 ADVANCED PROCESS CONTROL 3-0-0-3


TEXT BOOKS/REFERENCES:


Course Outcome:

CO1: To provide deep insight to the applications of process control through case studies
CO2: To review and apply various control schemes for process control depending on the requirement

TEXT BOOKS/REFERENCES:


Course Outcome:

CO1: To translate software applications to hardware logic for FPGA architecture
CO2: To design VHDL systems
CO3: To design architecture for high performance computing applications
CO4: To introduce to commercially available FPGA tools

16RA714 EMBEDDED REAL TIME SYSTEMS 3-0-0-3

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 real-time 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, High-Speed Interfacing, File system management, Interfacing Robotic Components, High-Speed Networks, Robotic Systems.

Course Outcomes:

CO1: To introduce to various components and methodologies for building embedded systems
CO2: To introduce to computer architecture
CO3: To understand the difference between generalized computing systems and embedded systems
CO4: To introduce to the software design optimization

TEXT BOOKS/REFERENCES:


16RA715 ROBOT SIMULATION AND OFFLINE PROGRAMMING 3-0-0-3

This course provides the student with a background in the programming and application of industrial robots and general purpose synchronized multi-axis motion control. The topics covered include safety rules and devices for working with or around industrial robots; advantages, functions, components, operation and applications of industrial robots and end effectors; the function, operation, storage and retrieval of robot programs and position points; the use, function and operation of on-line programming, off-line programming, teach pendants, operator stations, and digital inputs and outputs for industrial robots. Use a PC and robot programming software for various operations. Use the Cartesian coordinate system to command robot position and program with World Coordinates and Tool Coordinates. Connect, configure, program and operate a robot in conjunction with both servo-driven and non-servo-driven conveyors. Use robot simulation software to design a work-cell. Use PLC Open motion function blocks to implement a synchronized multi-axis motion application. Troubleshoot a multi-axis motion system. Robot Simulation using Gazebo and ROS.

Course Outcomes:

CO1: To introduce to the offline programming of robots – manipulators and mobile platforms
CO2: To design and simulate a robot work cell in an offline programming software
CO3: To control the internal axis and external axis of a robotic work-cell
CO4: To implement the concept of manipulator multi-axis motion system through offline programming software

TEXT BOOKS/REFERENCES:


TEXT BOOKS/REFERENCES


Course Outcomes:

CO1: To introduce to computer architecture, operating system and software designing principles
CO2: To make advance level programming in Assembly language
CO3: To develop data acquisition systems with emphasis on wired and wireless communication for data transfer

The course aims at giving the students a basic understanding of the theory of humanoid robots, i.e. bipedal walking robots with an approximately humanlike shape, and a practical knowledge concerning humanoid robots, through a robot construction project. The contents of the course include Theory of humanoid robots, kinematics and dynamics. Methods for gait generation, including classical control theory, central pattern generators and linear genetic programming. Applications of humanoid robots. Humanoid robots in society - current and future applications, comparison with other types of robots. Hardware construction, including
the use of microcontrollers and servo motors in connection with humanoid robots. Simulation in ROS

**Course Outcomes:**

CO1: To understand the kinematic and dynamic model of a walking platform
CO2: To understand the methodology for capturing the GAIT pattern of a humanoid biped robot
CO3: To introduce to the design principles and control schemes used in controlling the dynamics of the humanoid robot

**TEXT BOOKS/REFERENCES:**

[3] Lorenzo Sciavicco and Bruno Siciliano, "Modelling and Control of Robot Manipulators".

**16RA722 SWARM INTELLIGENCE 3-0-0-3**

TEXT BOOKS/REFERENCES:


Course Outcomes:

CO1: To provide the concept of swarm robotics
CO2: To give an insight towards the various formation algorithms
CO3: To understand the methodology of task allocation between the robotic units in a formation

16RA723 BEHAVIORAL ROBOTICS 3-0-0-3

This course is designed to investigate and study methods and models in embodied cognitive science and artificial intelligence, with particular focus on behaviour-based techniques on robots. All models and architectures will be theoretically scrutinized and evaluated with respect to their conceptual clarity, support by empirical data, plausibility, etc. without neglecting issues of practicality such as feasibility of implementation, real-time/real-world issues, computational resources, etc. Topics include introduction to embodied cognitive science and behaviour-based robotics, reactive behaviour-based architectures, perception, deliberative systems, hybrid systems.

TEXT BOOKS/REFERENCES:


Course Outcomes:

CO1: To introduce to the cognitive science and AI with a strong focus on behavioural models
CO2: To give an insight to behaviour-based architecture for a robot
Topics consist of rehabilitation engineering, artificial tissue and organs, implantable neural prosthesis, orthopaedic implants and implanted devices, biology-machine interface, minimally invasive surgical instruments, surgical robot, introduces its basic principle, key technology and its development and application. They include introduction to Biomechatronic Systems, design and manufacturing of Biomechatronic products, musculoskeletal mechanics, review of multi-body dynamics, principles of motor control and sensorimotor integration, simulation of human movement, human locomotion and gait studies, motor control in patients with neurological disorders, artificial tissue and organ, orthopaedic implants, Biology-Machine Interface, implantable neural prosthesis, minimally invasive surgical instruments, surgical robot.

TEXT BOOKS/REFERENCES:


Course Outcomes:

CO1: To introduce to the underlying principles of wearable robotics for rehabilitation/human capability augmentation
CO2: To perform human motion simulation in state-of-the-art simulation platforms
CO3: To give a deep insight into human GAIT pattern and technique to measure it
CO4: To give an insight into various sensory devices to read biological signals


TEXT BOOKS/REFERENCES:


**Course Outcome:**

CO1: To understand the concept of optimization and classification of optimization
CO2: To get a deep insight to techniques like Linear Programming, nonlinear programming
CO3: To introduce to Dynamic programming

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**16RA725 HAPTIC INTERFACES 3-0-0-3**


**TEXT BOOKS/REFERENCES:**


**Course Outcomes:**

CO1: Introduces the domain of haptics technologies and its relevance
CO2: To give an understanding on the underlying principles for developing haptic devices
CO3: To give an introduction to haptic software development
CO4: To give an overview on haptic rendering algorithms

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**16RA726 INNOVATING IN TECHNOLOGY 3-0-0-3**

Management and organizational agility to support innovation. Developing an “Innovation Studio”.

TEXT BOOKS/REFERENCES:


Course Outcomes:

CO1: To introduce to the basic practices of innovation
CO2: To break down the myths around innovation, and learning various concepts and techniques for innovation
CO3: To understand the relevance of project management and organizational agility to support innovation

16RA727 MEASURING USER INTERFACE QUALITY 3-0-0-3

How to conduct a usability study. What to measure: Identifying top tasks, Common metrics, Task completion metrics, Performance metrics, Qualitative and quantitative metrics, Biometrics. When to measure: Before development, During development, Pre launch, Post Launch, Common problems and solutions to effective timing. How to measure: overview of approaches, usability labs, automated measurement, remote testing, field testing. With Who to measure: understanding user samples, identifying valid participants, techniques for finding participants. Taking Action: communicating findings, presenting usability issues, strategies for resolution.

TEXT BOOKS/REFERENCES


Course Outcomes:

CO1: To understand how to perform usability test
CO2: To understand the methodologies for testing user interface quality
16RA728 DESIGN FOR PEOPLE: PRINCIPLES AND PRACTICES OF HUMAN CENTERED DESIGN  
3-0-0-3


TEXT BOOKS/REFERENCES:


Course Outcomes:

CO1: To give an introduction to usability
CO2: To give an overview of the methods and concepts for understanding end users
CO3: To teach the essential practices of observing and interviewing users

16RA731 ADVANCED PERCEPTION FOR ROBOTICS AND HCI 3-0-0-3

This course is an advanced survey of the state of the art in machine vision, focused primarily on robotics applications and human-computer interfaces. Topics covered will be related to 3D reconstruction of objects and scenes from video, camera motion estimation from video, object detection and recognition, and tracking, cloud robotics as it relates to robot vision. They include optical flow estimation: motion field and optical flow, calculating optical flow, flow-based motion analysis, robust incremental optical flow. Object detection and recognition: Global methods, transformation search-based methods, geometric correspondence-based approaches, flexible shape matching, interest point detection and region descriptors, three-dimensional object recognition. Tracking and video analysis: Point tracking, deterministic methods, statistical methods, kernel tracking, template and density-based appearance models multi view appearance models, silhouette tracking, contour evolution, shape matching.

TEXT BOOKS/REFERENCES:


Course Outcomes:

CO1: To give an understanding on the relevance of machine vision technology for robot perception
CO2: To review various techniques in machine vision for data capturing and processing

16CS701 COMPUTATIONAL INTELLIGENCE 3-0-0-3


TEXTBOOKS/REFERENCES:


Course Outcome:

CO1: To introduce to the concept of Computational intelligence
CO2: To introduce to neural networks
CO3: To introduce to fuzzy and hybrid systems

16RA732 MACHINE VISION 3-0-0-3


TEXTBOOKS/REFERENCES:


Course Outcomes:

CO1: To give an overview of the various image processing techniques used in machine vison
CO2: To give knowledge on motion tracking and its techniques
CO3: To introduce vison system to assist in Simultaneous Localization and Mapping for mobile robots

16RA733 ADVANCED AI FOR ROBOTICS 3-0-0-3


TEXT BOOKS/REFERENCES:

Courses outcome:

CO1: To understand the application of artificial intelligence in robotics through use cases
CO2: To give a deep insight into artificial neural networks and fuzzy logic systems in robotics

16RA734 VIRTUAL REALITY AND APPLICATIONS 3-0-0-3


TEXT BOOKS/REFERENCES:


Courses outcome:

CO1: To master the VR design principles
CO2: To get introduced to various hardware and software to set up a VR system
CO3: To understand various modelling required to define an object in the VR environment
CO4: To understand the application of VR in various domains

16RA735 NON-LINEAR CONTROL THEORY 3-0-0-3


**TEXT BOOKS/REFERENCES:**


**Course Outcome:**

CO1: To gain a thorough knowledge of theory involved in modelling non-linear systems  
CO2: To introduce to the controllability of nonlinear systems  
CO3: To get introduced to Adaptive control theory

**19RA736 EXPERIMENTAL HAPTICS 3-0-0-3**

The goal of this course is to develop virtual reality simulations and applications that incorporate haptic interaction. Theoretical topics include haptic rendering in 3-D virtual environments, simulation of haptic interaction with rigid and deformable objects, haptic interfaces, psychophysics of touch. Applied topics include an introduction to the CHAI 3D/Unity 3D haptics library, implementation of algorithms for haptic rendering, collision detection, and deformable body simulation.

**TEXT BOOKS/REFERENCES:**


**Course Outcomes:**

CO1: To understand how to combine VR with haptics technology  
CO2: To introduce to various algorithms for haptic rendering  
CO3: To introduce to various haptic rendering software like CHAI 3D/ Unity 3D etc
EVALUATION SCHEME AND GRADING SYSTEM

1 – credit course:

* The instructor can choose one of the following options for course assessment

* Continuous assessment has to be properly decided at the starting of the semester and should be approved by the Chairperson.

<table>
<thead>
<tr>
<th>Grading Options</th>
<th>Internal assessment</th>
<th>External assessment</th>
</tr>
</thead>
</table>
| A (Theory course) | 50% (Mid-sem exam, assignments, quizzes, Lab experiments, mini-project)  
Mid Sem – 15%  
Continuous Evaluation – 35% | 50% (2 hr exam) |
| B (Lab Based Course) | 70% - Lab based assessment (minimum of 4 experiments with an end semester lab exam(mini-project) evaluated by an external examiner)  
Lab experiments – 40%  
Mini Project/End Sem (20%) + Viva (10%) – 30% | 30% (1 hr exam) |
| C (Project Based Course) | 70% - Project based (one final review with a review panel comprised of at least one external examiner, student should submit a project report duly signed by the chairperson and external examiner)  
Project Implementation – 40%  
Final Review (20%) + Report (10%) – 30% | 30% (1 hr exam) |
| D (Analytical Courses) | 70% - Assignment and quiz based (Mathematical courses)  
Assignments (min 2) – 30%  
Quizzes (min 2) - 40% | 30% (1 hr exam) |

2 – credit course:

* The instructor can choose one of the following options for course assessment

* Continuous assessment has to be properly decided at the starting of the semester and should be approved by the Chairperson.

<table>
<thead>
<tr>
<th>Grading Options</th>
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<th>External assessment</th>
</tr>
</thead>
</table>
| A(Theory course) | 50% (Mid-sem exam, assignments, quizzes, Lab experiments, mini-project)  
Periodical 1 – 15%  
Periodical 2 – 15%  
Continuous Evaluation – 20% | 50% (2 hr exam) |
<table>
<thead>
<tr>
<th>Course Type</th>
<th>Grading Details</th>
<th>Assessment Breakdown</th>
</tr>
</thead>
<tbody>
<tr>
<td>B (Lab Based Course)</td>
<td>70% - Lab based assessment (minimum of 6 experiments with an end semester lab exam (mini-project) evaluated by an external examiner) Lab experiments – 40% Mini Project/End Sem (20%) + Viva (10%) – 30%</td>
<td>30% (1 hr exam)</td>
</tr>
<tr>
<td>C (Project Based Course)</td>
<td>70% - Project based (one final review with a review panel comprised of at least one external examiner, student should submit a project report duly signed by the chairperson and external examiner) Project Implementation – 40% Final Review (20%) + Report (10%) – 30%</td>
<td>30% (1 hr exam)</td>
</tr>
<tr>
<td>D (Analytical Courses)</td>
<td>70% - Assignment and quiz based Assignments (min 4) – 30% Quizzes (min 2) – 40%</td>
<td>30% (1 hr exam)</td>
</tr>
</tbody>
</table>

3 – Credit course:

* The instructor can choose one of the following options for course assessment

*Continuous assessment has to be properly decided at the starting of the semester and should be approved by the Chairperson.

<table>
<thead>
<tr>
<th>Grading Options</th>
<th>Internal assessment</th>
<th>External assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td>A (Theory Course)</td>
<td>50 % Periodical 1 – 15% Periodical 2 – 15% Continuous Evaluation – 20%</td>
<td>50% (3 hr exam)</td>
</tr>
<tr>
<td>B</td>
<td>70 % Periodical 1 – 15% Periodical 2 – 15% Continuous Evaluation – 40%</td>
<td>30% (2 hr exam)</td>
</tr>
<tr>
<td>C (For Courses Complete d in 6 weeks)</td>
<td>50% Periodical 1 – 15% Assignments + Quizzes / lab-based experiments / mini-project – 35%</td>
<td>50% (3 hr exam)</td>
</tr>
<tr>
<td>D (Lab Based Course)</td>
<td>70% One Periodical Exam – 15% 50% - Lab based assessment (minimum of 5 experiments With one end semester exam(mini-project) which should be evaluated by an external examiner) Lab experiments - 25%</td>
<td>30% (2 hr exam)</td>
</tr>
</tbody>
</table>
Mini Project/End Sem Lab (20%) + Viva (10%) – 30%

<table>
<thead>
<tr>
<th>Course</th>
<th>E (Project Based Course)</th>
<th>F (Analytical Courses)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>70% - Project based (one mid-sem review and one final review with a review panel comprised of at least one external examiner, student should submit a project report duly signed by the chairperson and external examiner)</td>
<td>70% - One Periodical - 15%</td>
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<tr>
<td></td>
<td>Project Implementation – 40% (this can have a mid-sem review)</td>
<td>Assignments (min 6) – 20%</td>
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<tr>
<td></td>
<td>Final Review (20%) + Report (10%) – 30%</td>
<td>Quizzes (min 4) - 35%</td>
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<td></td>
<td></td>
<td>30% (2 hr exam)</td>
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</tbody>
</table>

4 – credit course:

*The instructor can choose one of the following options for course assessment*

*Continuous assessment has to be properly decided at the starting of the semester and should be approved by the Chairperson.*

<table>
<thead>
<tr>
<th>Grading Options</th>
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<th>External assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td>A (Theory Course)</td>
<td>50%</td>
<td>50% (3 hr exam)</td>
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<tr>
<td></td>
<td>Periodical 1 – 15%</td>
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<td>Periodical 2 – 15%</td>
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<tr>
<td></td>
<td>Continuous Evaluation – 20%</td>
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<tr>
<td>B</td>
<td>70%</td>
<td>30% (2 hr exam)</td>
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<tr>
<td></td>
<td>Periodical 1 – 15%</td>
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<tr>
<td></td>
<td>Periodical 2 – 15%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Continuous Evaluation – 40%</td>
<td></td>
</tr>
<tr>
<td>C (For Courses Completed in 6 weeks)</td>
<td>50%</td>
<td>50% (3 hr exam)</td>
</tr>
<tr>
<td></td>
<td>Periodical 1 – 15%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Assignments + Quizzes / lab-based experiments / mini-project – 35%</td>
<td></td>
</tr>
<tr>
<td>D (Lab Based Course)</td>
<td>70%</td>
<td>30% (2 hr exam)</td>
</tr>
<tr>
<td></td>
<td>One Periodical Exam – 15%</td>
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<tr>
<td></td>
<td>50% - Lab based assessment (minimum of 7 experiments with one end semester exam(mini-project) which should be evaluated by an external examiner)</td>
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<tr>
<td></td>
<td>Lab experiments – 25%</td>
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<tr>
<td>Mini Project/End Sem Lab (20%) + Viva (10%) – 30%</td>
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<tr>
<td><strong>E (Project Based Course)</strong> 70% - Project based (one mid-sem review and one final review with a review panel comprised of at least one external examiner, student should submit a project report duly signed by the chairperson and external examiner) Project Implementation – 40% (this can have a mid-sem review) Final Review (20%) + Report (10%) – 30%</td>
<td>30% (2 hr exam)</td>
<td></td>
</tr>
<tr>
<td><strong>F (Analytical Courses)</strong> 70% - One Periodical - 15% Assignments (min 8) – 20% Quizzes (min 6) - 35%</td>
<td>30% (2 hr exam)</td>
<td></td>
</tr>
</tbody>
</table>