Robotics, the branch of technology that deals with the design, construction, operation, and application of robots, has become a highly relevant and upcoming discipline. It is being increasingly applied to almost every field of activity including improving the standard of living of humans, handling dangerous and hazardous situations, relieving mankind of repetitive and tiring activities, exploring outer space and performing complex medical procedures. Many industries also use robots in their manufacturing facilities and research. For instance, robots are used in areas like high heat welding and continuous handling of heavy loads. They can function tirelessly even in the most inhospitable working conditions. Owing to this, robots are taking over from man most of the manipulative, hazardous and tedious jobs in factories, mines, atomic plants, spaceships, deep-sea vessels, etc. The automation of work through robotics has led to substantial increase in productivity in these areas.

Given its diverse applications, the robotics field today demands in-depth knowledge of a broad range of disciplines such as electronics, computers, instrumentation and mechanics. A graduate entering the workforce in the area of robotics must be thoroughly familiar with intelligent systems and proficient in computer vision, control systems, and machine learning, as well as the design and programming of robotic systems. Specialization in automation also requires the student to apply a wide range of engineering principles in order to understand, modify or control the manufacture, delivery and maintenance of technology components in a broad range of industries. Graduates must know how to develop and maintain systems that cost-effectively optimize productivity and quality control.

The Amrita Vishwa Vidyapeetham Robotics and Automation M.Tech program is unique in that it provides an academic curriculum that pulls from mechanical engineering, electronics and instrumentation engineering and computer science disciplines, exposing the students to the breadth of and interdependence among the engineering disciplines and offering the students exactly what is required to master the technical knowledge required.

This M.Tech program will provide a comprehensive educational environment and enable students to gain expertise in next generation robotics and automation systems. By exposing our students to do course work from multiple disciplines and preparing them to think about robotics from a holistic approach, our program will prepare a skilled industry workforce as well as expert researchers who will be able to provide leadership in a world that is increasingly dependent on technology.
## CURRICULUM

### Semester 1

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Type</th>
<th>Course Title</th>
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<td>19RA601</td>
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<td>Embedded System Design</td>
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<td>Kinematic and Dynamic Modeling of Manipulators</td>
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*Non-credit course

**Total Credits: 18**

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**Total Credits: 66**
## ELECTIVES

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<td>19RA702</td>
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<td>19RA734</td>
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</table>
19MA611 MATHEMATICS FOR ROBOTICS AND AUTOMATION 3-0-0-3


TEXT BOOKS/REFERENCES:

2. Ronald L. Rardin, "Optimization in Operations Research".
4. Stephen D. Fisher, "Complex Variables".
5. Emil G. Milewski, "The Complex Variables Problem Solver".
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".

19RA601 EMBEDDED SYSTEMS DESIGN 3-0-1-4

Microcontroller fundamentals: ARM ASM programming and basic of C; IO Interfacing: LED and Switch; Design and Development Process: Architecture, Micro architecture, 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:


19RA602 DIGITAL CONTROL SYSTEMS 2-0-1-3


TEXT BOOKS/REFERENCES:


19RA611 KINEMATIC AND DYNAMIC MODELLING OF MANIPULATORS 2-1-1-4

19RA603    ROBOT OPERATING SYSTEM (ROS)    1-1-2-4

Introduction to ROS - ROS Basic Concepts: Nodes, topics, parameters, services - Simple ROS programs to publish and subscribe messages. Simulation of typical robot system in ROS: Manipulators, wheeled robots in scenarios such as in a maze etc., legged robots and UAVs in various environments.

19RA604    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. Estimation Theory, Bayes and Kalman filter. Introduction to SPSS/Minitab/Matlab for data Analysis.

TEXT BOOKS/REFERENCES:

1. K.M. Ramachandran and Chris P. Tsokos, "Mathematical Statistics with Applications"
Algorithm Analysis: Methodologies for Analyzing Algorithms, Asymptotic Notation, Recurrence Relations. Data Structures: Linear Data Structures (Stacks, Queues, Linked-Lists, Vectors), Trees (Binary Search Trees, AVL trees, Red-Black trees, B-trees), Hash-Tables (Dictionaries, Associative Arrays, Database Indexing, Caches, Sets) and Union-Find Structures. Searching and Sorting (Insertion and Selection Sort, Quicksort, Mergesort, Heapsort, Bucket Sort and Radix Sort), Comparison of sorting algorithms and lower bounds on sorting.


TEXT BOOKS/REFERENCES:


19RA612 AUTONOMOUS ROBOTS 3-0-1-4


TEXT BOOKS/REFERENCES:

19RA613 DIGITAL IMAGE PROCESSING 3-0-1-4


TEXT BOOKS/REFERENCES:


19RM600 RESEARCH METHODOLOGY 2-0-0-2

Unit I:
Unit II:
Problem Formulation, Understanding Modeling & Simulation, Conducting Literature Review, Referencing, Information Sources, Information Retrieval, Role of libraries in Information Retrieval, Tools for identifying literatures, Indexing and abstracting services, Citation indexes

Unit III:
Experimental Research: Cause effect relationship, Development of Hypothesis, Measurement Systems Analysis, Error Propagation, Validity of experiments, Statistical Design of Experiments, Field Experiments, Data/Variable Types & Classification, Data collection, Numerical and Graphical Data Analysis: Sampling, Observation, Surveys, Inferential Statistics, and Interpretation of Results

Unit IV:
Preparation of Dissertation and Research Papers, Tables and illustrations, Guidelines for writing the abstract, introduction, methodology, results and discussion, conclusion sections of a manuscript. References, Citation and listing system of documents

Unit V:

TEXT BOOKS/ REFERENCES:

19RA701 INDUSTRIAL AUTOMATION I 2-0-2-4

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, programming and wiring, PLC installation, troubleshooting and maintenance, Design of HMI.
TEXT BOOKS/REFERENCES:
[6.] Siemens "PLC Handbook".
[8.] Ries and Ries, "Programming Logic Controllers", PHI.
[9.] Werner Deppert and Kurt Stoll, “Pneumatic Control”, VOGEL Buchverlag Wurzburg, Germany.
[11.] Peter Croser and Frank Ebel, "Pneumatics Basic Level TP 101" Festo Didactic GMBH & Co, Germany.

19RA702 MACHINE LEARNING 3-0-1-4


TEXT BOOKS/REFERENCES:
[3.] http://www.stanford.edu/class/cs221/handouts.html
19RA711 INDUSTRIAL AUTOMATION II 2-0-1-3

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 remote processes using standard communication protocols. Distributed Control Systems in Automation: The theory and operation of DCS in large, medium and small automation applications, current development. Robot programming- RAPID language, Robot software- Pick Master, Robot studio. Project - Design and control of a process using PLC, HMI, SCADA including sensors and actuators.

TEXT BOOKS/REFERENCES:


19RA712 PROCESS CONTROL AND INSTRUMENTATION 3-0-0-3


TEXT BOOKS/ REFERENCES:


19RA713 ADVANCED PROCESS CONTROL 3-0-0-3


TEXT BOOKS/REFERENCES:
[3.] Statistical Process Control –ISA.
[4.] B.G. Liptak, "Handbook of Instrumentation - Process Control".

19RA714 FPGA BASED SYSTEM DESIGN 3-0-0-3

19RA715 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, RealTime 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.

TEXT BOOKS/REFERENCES:


19RA716 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 workcell. 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.

TEXT BOOKS/REFERENCES:
19RA717 ADVANCED EMBEDDED SYSTEM DESIGN 3-0-0-3


TEXT BOOKS/REFERENCES:


19RA718 HUMANOID ROBOTICS 3-0-0-3

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.

TEXT BOOKS/REFERENCES:

[3.] Lorenzo Sciavicco and Bruno Siciliano, "Modelling and Control of Robot Manipulators".
[4.] Jean-Claude Latombe, "Robot Motion Planning".

19RA719  SWARM INTELLIGENCE 3-0-0-3


TEXT BOOKS/REFERENCES:


19RA720  BEHAVIORAL BASED 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.
TEXTBOOKS/REFERENCES:


19RA721     FRONTIERS OF BIOMECHATRONICS 3-0-0-3

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 Bio-mechatronic Systems, design and manufacturing of Bio-mechatronic 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:


19RA722     OPTIMIZATION THEORY 3-0-0-3


TEXT BOOKS/REFERENCES:


19RA723 HAPTIC INTERFACES 2-0-1-3


TEXTBOOKS/REFERENCES:


19RA724 INNOVATING IN TECHNOLOGY 3-0-0-3


TEXT BOOKS/REFERENCES:


19RA725 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, 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


19RA726 DESIGN FOR PEOPLE: PRINCIPLES AND PRACTISES OF HUMAN CENTERED DESIGN


TEXT BOOKS/REFERENCES:


19RA727 ADVANCED PERCEPTION FOR ROBOTICS AND HCI

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 optimal 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:
19RA728 COMPUTER INTELLIGENCE 3-0-0-3


TEXTBOOKS/REFERENCES:


19RA729 MACHINE VISION 3-0-0-3


TEXTBOOKS/REFERENCES:


19RA730 ADVANCED AI FOR ROBOTICS 3-0-0-3


TEXT BOOKS/REFERENCES:


19RA731 VIRTUAL REALITY AND APPLICATIONS 3-0-0-3


TEXT BOOKS/REFERENCES:

19RA732 NON-LINEAR CONTROL THEORY 3-0-0-3


TEXT BOOKS/REFERENCES:


19RA733 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:


19RA734 UNMANNED AERIAL VEHICLES 1-0-2-3

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

TEXT BOOKS/REFERENCES: