Post Graduate Diploma in Industrial Robotics

Course Duration: 1 year (2 Semesters, Credits)

- **Course Description:**

Industrial automation is a discipline that comprises of knowledge and skills from various engineering fields, which include electronics, electrical, mechanical, computer, software and communication engineering. This Post Graduate Diploma in Industrial Robotics provides career options for students in the areas of industrial automation, robotics, and PLCs. The student will acquire the competent knowledge and skill sets to seek jobs in this sector. The course provides comprehensive knowledge in technical expertise and hands-on experience. Students will have an in-depth knowledge of designing, engineering and commissioning equipment that are used in automated manufacturing, assembly, and handling applications.

The study of industrial robots and associated systems enables students to assume key roles in a number of industries like robotics, aerospace, transportation, defense, automotive, building systems and manufacturing industries. This sector is growing rapidly in India, with investments provided for developing manufacturing sector.

The program provides in-depth knowledge in the areas of flexible automation covering its varied aspects such as system design, electro mechanics, sensors, instrumentation, artificial intelligence, robotic vision, project engineering. The curriculum is designed to impart fundamental knowledge of engineering studies with focus on robotic engineering concepts and theories.

- **Employment Opportunities**

  - Medium and Large Manufacturing Companies
  - Automotive and Component Suppliers
  - Diverse Fields Ranging from Aerospace, Marine, Industrial Systems, Healthcare, Electronics and Consumer Product Industries
  - Industrial Packaging Applications such as a Material Handling, Packaging
  - Food & Beverage, Pharma, and Consumer Goods

- **Course Objective:**

The course comprises of theory, practical and project work.

Theory

Theoretical studies on Pneumatics and Hydraulics, Robotics, CAD/ CAM, Sensors and Actuators, Electrical, Control Systems, Industrial Electronics, PLC, Mechatronics System Design, CNC Technology, Robotics and Motion Controls, Robot Applications.

Practical

Practical exposure to Robotic programming and Interfacing with PLCs, actuators & sensors.

Internship

Internship in the area of industrial electronics and mechatronics systems like hydraulics and pneumatics control systems, special purpose machines, industrial automation, vision control systems, robotic applications.

- **Course Duration: 1 Year**

Post Graduate Diploma in Industrial Robotics

Course Matrix

Ist Semester	Paper 1	Introduction to Robotics		
	Paper 2	Sensors, Drives and Actuators		
	Paper 3	Control Systems		
	Paper 4	Soft Skills		
	Lab 1	Simulation & Design Lab		

	Lab 2	Sensors, Actuators and PLC Lab		
TOTAL HOURS				
IInd Semester	Paper 5	Robot Applications in Industries		
	Paper 6	Machine Vision and Image Processing		
	Paper 7	Industrial Safety Standards and Quality Standards		
	Lab 3	Robot Programing Lab		
	Lab 4	Image Processing Lab		
	Lab 5	SCADA & HMI Lab		
		Internship		
TOTAL HOURS				

Syllabus - Semester I

Paper 1: Introduction to Robotics

1. Robot Definition: Definition of robots, Evolution of robots, Laws of robots, International Robotic Standards, Why Robots? Types of robots, Selection of robots.

2. Robot Classifications: degrees of freedom; degrees of movements, robot configuration; accuracy and repeatability, specification of a robot ,actuators and sensors, drives and

transmission systems used in robotics. Applications of robots

3. Coordinate Transformation: Direct kinematic problem in robotics, geometry based direct kinematic analysis coordinate & vector transformation using matrices, the orientation matrix & translator vector, homogeneous transformation matrices, three dimensional homogeneous transformations.

4. Trajectory interpolation: Introduction, the necessity of interpolators, the generation of motion commands, the trajectory planning, basic structure of interpolators. The solvability of the inverse, kinematics problem. particular solutions for the inverse kinematics problem - two – axis planar mechanisms, example of three-axis spherical mechanism, specific solutions for six-axis manipulators.

5. Autonomous mobile robots: Introduction, locomotion - key issues for locomotion, legged mobile robots, leg configurations & stability , examples of legged robot locomotion , wheeled mobile robots, wheeled locomotion-the design space, wheeled locomotion: case studies.

6. Mobile robot kinematics: introduction, kinematics models & constraints, representing robot position, forward kinematics models, wheel kinematics constraints, robot kinematics constraints, examples robot kinematics models & constraints. Mobile robot maneuverability- degree of mobility, degree of steerability, robot maneuverability. Mobile robot workspace-degree of freedom, holonomic robots, path & trajectory considerations. Motion control - open loop control, feedback control.

TEXT BOOKS

- Robotics & Control – R.K. Mittal & I.J. Nagrath – TMH Publications
- Robotics for engineers - Yoram Korean- McGrew Hill Co.
- Industrial Robotics Technology programming and Applications - M.P.Groover, M.Weiss, R.N.Nagel, N.G.Odrey.

REFERENCE BOOKS

- Robotics Control Sensing, Vision and Intelligence - K.S.Fu, R.C.Gonzalex, C.S.G.Lee- McGrew hill Book co.
- Kinematics and Synthesis of linkages - Hartenberg and Denavit - McGrew Hill Book Co
- Kinematics and Linkage Design - A.S. Hall - Prentice Hall
- Kinematics and Dynamics of Machinary - J.Hirchhorn - McGrew HillBook Company.

Paper 2: Sensors Drives and Actuators

1. Sensors: Principles and classification of transducers, guidelines for selection and application of transducers, basic requirements of transducers. Different types of transducers, displacement, strain gauge, LVDT, potentiometer, capacitive & inductive, Piezoelectric, temperature, optical, Hall effect transducers.

2. Measurement of parameter: Measurement of length, angle, area, temperature, pressure flow, speed force, torque, vibration, level, concentration (conductivity and ph.) measurement- sensors in robotics-tactile sensors-proximity and range sensors- miscellaneous sensors and sensor based systems-use of sensors in robotics.

3. Fundamentals of Electric drives - Components of electric drives, factors affecting choice of drives, fundamental torque equation, speed-torque conventions, steady state stability, multi-quadrant operation of electric drives, load torque components, nature and classification of load torque, equivalent moment of inertia, modes of operation.

4. Control Speed control and drive classification, closed loop control, current limit control, speed control, position control, torque control, PLL control, multi-motor drive control, digital control. DC motor control, speed control, position control, proportional control, PID controllers.

5. Pneumatic Drives: Merits of Fluid power & its utility for increasing productivity through Low Cost Automation, Transmission of Fluid Power through various types of Cylinders), Symbolic representation of Pneumatic elements (CETOP), Compressors and Air supply system including airline installations, signaling & control system. Pneumatic control elements (control valves & remote control system), Basic pneumatic circuits for controlling single & double acting cylinder, Basic pneumatic circuits, Advanced pneumatic circuits for controlling multi-cylinders (operable). Advanced pneumatic circuits for controlling multi-cylinders (inoperable circuits), Electro pneumatics with relay logic, and Pneumatics system with PID controls, Application of fluidics a non-moving part logic.

6. PLC : Evolution of PLC's - Sequential and programmable controllers - Architecture-Programming of PLC - Relay logic - Ladder logic - Gates, Flip flops and Timers.

Communication in PLC's: Requirement of communication networks of PLC - connecting PLC to computer -Interlocks and alarms - Case study of Tank level control system and Sequential switching of motors.

References:

- W. Shepherd, and L. N. Hully, “Power Electronics and Motor control”, (2e), Cambridge University, 1995.
- Gopal K. Dubbey,“Fundamentals of Electric Drives”, (2e), Narosa Publishers, 2001.

- R. Krishnan, “Electric Motor Drives Modeling, Analysis, and Control”, (2e), Prentice Hall, 2001

- Anthony Esposito, “Fluid power with applications”, Pearson Education, 2003.
- Sadhu Singh. "Computer Aided Design and Manufacturing", Khanna Publishers, New Delhi, 1998.

Paper 3 : CONTROL SYSTEMS

1. Control system modeling: System concept, differential equations and transfer functions. Modeling of electric systems, translational and rotational mechanical systems, and Simple electromechanical systems.

2. Block diagram representation of systems – Block diagram reduction methods – Closed loop transfer function, determination of signal flow graph. Mason’s gain formula – Examples.

3. Time domain analysis: Test signals- time response of first order and second order systems- time domain specifications-types and order of systems-generalized error co-efficient-steady state errors- concepts of stability-root locus.

4. Frequency domain analysis : Introduction – correlation between time and frequency response – stability analysis using Bode plots, Polar plots.

5. Compensators : Realization of basic compensators – cascade compensation in time domain and frequency domain and feedback compensation – design of lag, lead, lag-lead compensator using Bode plot and Root locus.

6. Practical controllers - Introduction to P, PI and PID controllers.

MATLAB & Simulink for PID.

REFERENCE:

- Applied Nonlinear Control, by Slotine and Li, Prentice-Hall, 1991, ISBN 0-13-040890-5.
- Ogata, K., Modern Control Engineering, Prentice-Hall, [2002]
- Gibson, J. E., Nonlinear AutomaticControl, McGraw-Hill, [1963]
- Khalil, Hasan K., Nonlinear Systems, Macmillan Publishing, [1992]

- Control System Engineering, L. Nagrath and Gopal, New Age International Publications
- Automatic Control System, B.C. Kuo, PHI
- Control Engineering – A Comprehensive Foundation, Ramakalyan, Vikas Publishing House Pvt. Ltd.

Paper 4: Soft Skills

1. Self-Analysis:SWOT Analysis, Who am I, Attributes, Importance of Self Confidence, Self Esteem.
Attitude: Factors influencing Attitude, Challenges and lessons from Attitude.

2. Change Management: Exploring Challenges, Risking Comfort Zone, Managing Change

3. Motivation : Factors of motivation, Self-talk, Intrinsic & Extrinsic Motivators.

4. Goal Setting : Wish List, SMART Goals, Blue print for success, Short Term, Long Term, Life,Time Goals.

5. Time Management: Value of time, Diagnosing Time Management, Weekly Planner ,To do list,Prioritizing work.

6. Creativity : Out of box thinking, Lateral Thinking.

Lab 1: Simulation and Design

Simulation Basics– Introduction to robotics, step up and license key generation, setup , Concept of robot programing, Programing tools ,targets and the path ,Workobject , Frame, utilizing 7^{th} axis and Rail
Import Files-Libraries and Cad files import, Building station, Jogging mechanism, Pack and Go File creation. , Understanding Control and modelling tab, Conveyer setup .

Simulation– Overview, detecting collision, creating I/O signals, Measuring cycle time

Working online– connecting PC to the service port , building and modifying a system software ,download a system to controller , Creating a backup file and restoring back up .

CAD/CAM: The influence of computers on manufacturing environment, Introduction of CAD/CAM, the product cycle & CAD/CAM, automation and CAD/CAM, the common

database as linkage to various computerized applications. Project Engineering, Product engineering, Benefits of CAD/CAM, Concurrent engineering-CAD Software-SOLIDWORKS, AutoCAD.

REFERENCES

- Petrezeulla, “Programmable Controllers”, McGraw Hill , 1989.
- Hughes .T, “Programmable Logic Controllers”, ISA Press, 1989.
- Clayton.G.B, “Data Converters” , The Mac Millian Press Ltd., 1982.
- CAD/CAM Principles & Applications – P.N. Rao – TMH Publication
- CAD/CAM Computer Aided Design & Manufacturing – Mikell P. Groover, Emory W. Zimmer – Pearson Education

Lab 2: Sensors and Actuators Lab Basic

Optical sensors : Photodiodes, phototransistors and photo resistors based sensors, light-to-light detectors, Infrared sensors (thermal, PIR, AFIR, thermopiles).

Magnetic and Electromagnetic Sensors and Actuators : Motors as actuators (linear, rotational, stepping motors), magnetic valves, inductive sensors (eddy current, LVDT, RVDT, Proximity, switches), Hall Effect sensors, Magneto resistive sensors.

Mechanical Sensors : Accelerometers, Force sensors (strain gauges, tactile sensors), Pressure sensors (semiconductor, piezoresistive, capacitive, VRP).

Industrial Networks & Fieldbus: Advantages of fieldbus – wiring, reliability, and infrastructure. Types of bus – DN, PB, ProfiNet, Eth/IP

Interfacing to Controller : Connecting sensors to controller directly or through fieldbus. Configuration of digital, group, and analog IO. Use of instructions and logic. Strobing and handshaking with PLC as master, Encoder and Resolvers

PLC : Various hardware types of PLC (CPU and I/O modules).Centralized configuration of PLC.On-line with PLC (using serial port).Various languages and its over-view. Sample program down-load,Task configuration.Configuration of IP address & sample program download.Decentralized configuration of PLC (Profibus protocol).Configuration I/O modules on Profibus protocol. Modbus configuration (Master & Slave configuration).Modbus RTU (Remote Telemetry Unit) and Modbus TCP/IP communication with PC based software .

Syllabus - Semester II

Paper 5: Robot Application

Basics of Arc welding :Welding Guns, Welding Electrodes, Welding Power Sources, shielding gases, Robot interfacing , Types of Joints, Welding Parameters, Application software , Robot Programming with Arc ware, Seam Tracking, Touch sensor , Quality parameters, tooling.

Basics of Spot welding :Spot welding Gun , Spot welding Timer , Utilities , Robot selection , Integrating with Robots , Application software(Spot ware),Spot welding Parameters, programming Robot with spot welding application. Spot welding instructions, Quality parameters, tooling.

Paper 6 : Machine Vision and Image Processing

1. Image acquisition : Vision and image sensors, digitization, preprocessing, vision system components, basic optics, basic radiometry, image formats, image noise, image representation, color space, conversion of color spaces.
2. Image analysis : image enhancement, operations on images, noise removal, segmentation, thresholding, edge detection algorithms, morphological operations, image analysis coding and representation of regions, dimensional analysis, feature extraction Fourier transformations, spatial domain techniques, discrete cosine transform to images, image scaling, standard video formats.

3. 3D vision : Perspective projection geometry, pinhole camera model, lens distortion, affine and metric geometry, 2d and 3d geometrical transformations, intrinsic and extrinsic camera parameters, calibration methods,
4. Stereo vision: epipolar geometry, triangulation**,** rotational matrix, fundamental matrix, stereo correspondence algorithms – feature based and correlation based, 3d

reconstruction.

5. Motion estimation and tracking : Optical flow estimation, object tracking with Kalman filtering, feature extraction & object recognition

6. Case studies/application : Face recognition, vehicle tracking, industrial robot guidance, demonstration of applications using computer vision toolbox and image processing toolbox.

References:

- Milan Sonka, Vaclav Hlavac, Roger Boyle, Image Processing, Analysis and Machine Vision", (2/e), 1998.
- Rafael C. Gonzalez, Richard E. Woods, Digital Image Processing, (2/e), Pearson education, 2003.
- Boguslaw Cyganek & J. Paul Siebert, An Introduction to 3D Computer Vision Techniques and Algorithms, Wiley, 2009.
- E.R. Davies, Royal Holloway, Machine Vision: Theory, Algorithms and Practicalities, (3/e), University of London, December 2004.
- R. Jain, R. Kasturi, B. G. Schunck, Machine Vision, McGraw-Hill, New York, 1995.

Paper 7: Industrial Safety Standards, Quality

1. Industrial safety : Safety in the use of Power Presses (all types), Shearing, Bending, Rolling, Drawing, Turning, Boring, Milling, Shaping, Planning broaching, planting, Grinding, CNCs. Preventive maintenance, periodic checks for safe operation. Associated hazards and their prevention. Workplace Inspection, type of workplace inspection, Importance of consultation in safety. PPE RIA Safety standards. Application Safety, Safety categories, OSHAS.

2. Electrical safety : Safe limits of amperages, voltages, distance from lines, etc., Joints and connections, Overload and Short circuit protection, Earthing standards and earth fault protection , Protection against voltage fluctuations, Effects of shock on human body Hazards from Borrowed neutrals,
Electrical equipment in hazardous atmosphere, Criteria in their selection, installation, maintenance and use, Control of hazards due to static electricity.

3. General safety consideration in material handling : Ropes, Chains, Sling, Hoops, Clamps, Arresting gears ,Prime movers. Ergonomic consideration in material handling,

design, installation, operation and maintenance of Conveying equipment, hoisting, traveling and slewing mechanisms.
4. Ergonomic consideration : in material handling, design, installation, operation and maintenance of driving gear for hoisting mechanism. Traveling mechanism Selection, operation and maintenance of Industrial Trucks, Mobile Cranes, Tower crane, Checklist, Competent persons. Storage and Retrieval of common goods of various shapes and sizes in a general store of a big industry.

5. Quality Control and Safety Standards : Quality objectives, Quality control, Quality Assurance – Process variability, ISO 9000 and TQM concepts ,
6. Quality management(7 hours): Quality circles, tools, Zero defect management, 6 sigma – Quality Function Deployment (QFD).
The Components and benefits of safety management system

Lab 3: Robot Programing Lab

Generation in Robot Language – Methods of programing a Robot, robot language structure, the textual robot languages. Online and Offline programming. Flex Pendent.

Cartesian Trajectories – joint space planning, Cartesian trajectories, path primitives. Coordinate system used to determine the position of TCP and direction of the tool.

Basic Syntax- RAPID introduction, Constant, data objects and variables, data declaration, expressions , using data and aggregates in expression , Functions , function call in expression , priority between operators, Various Instructions, WAIT , SIGNAL and DELAY commands.

Routine and subroutine – Input/output interrupts priority between interrupts, Program control and subroutine function call, task modules, error recovery, system and time, Built-in subroutines in RAPID, Intertask Objects

Lab 4: IMAGE PROCESSING LAB

Image capture, digitization, filtering, edge detection using MATLAB : Conversion from gray scale as RGB, applying median and averaging filters.

Basic Image Processing : Download an image, Read the image into MATLAB – see imread command and im2double, commands to convert to double precision numbers, Display the image on your screen – see imagesc and imshow commands, Play around with converting the image into different formats, e.g. grayscale, or hsv (use “help images” for a list of useful functions).Resize your image to be 0.5 its original size. Now resize your image to be size 32x32 pixels – see imresize command.

Image Manipulation : a second image (img2) from the web. Use the ginput command to get image locations in img1 where you want to insert img2. Remember to round the locations to get integer pixel values.Resize img2 so that it fits into the specified locations.Insert img2 into img1 in the rectangle specified by ginput.

Computing image representations : Convert img1 to the HSV color space.Calculate an image representation that is the average hue computed over all pixels in the image.Calculate an image representation that is the average hue computed over a spatial grid in the image (where grid regions are size 50x50 pixels).

Integrated vision – smart camera with embedded computer – using COGNEX

Lab 5: SCADA and HMI Lab

Supervisory control and data acquisition (SCADA) -Introduction to Supervisory Control and Data Acquisition-SCADA Functional requirements and Components-General features, Functions and Applications, Benefits-Configurations of SCADA, RTU (Remote Terminal Units) Connections-Power Systems SCADA and SCADA in Robotics System Automation-SCADA Communication requirements-SCADA Communication protocols: Past Present and Future.-Structure of a SCADA Communications Protocol.

HMI : HMI Evolution. HMI System Overview. HMI Hardware Overview. Field Control Station Overview. <https://ipcsautomation.com/HMI-Training/Operation of Standard Display Panels.> Tuning Parameter Display. Tuning Parameters Description. Operation of Standard. Display Panels. Feedback Control. Instruments Operation. Sequence Control Instruments Operation. Real time Graphic Display Features. Process Alarm Management. Operator Guide Message Management. Human Interface System Utility Functions. Peripheral Device Connectivity. Human Interface Station Configuration. Field Control Station Configuration. Field Wiring Schematics for Analog & Digital Signals. Control Drawing Builder. Feedback Control Instrument. Generation-Operation Windows Configuration. Control Group Display. Process Overview Display. Trend recording Display. Process Report. Historical Report. Image File Utility. System Status Display. https://ipcsautomation.com/HMI-Training/ Sequence Tables. Logic Charts. Graphic Builder. Message Definition. Hardware Configuration. Project Common Definition. I/O module Configuration. Generation of interlocks. Operation Group Overview.

REFERENCES:

- The Digital I/O Handbook - A Practical Guide to Industrial Input and Output Applications.
- Handschin, E. “Energy Management Systems”, Springer Verlag, 1990.
- Handschin, E. “Real Time Control of Electric Power Systems”, Elsevier, 1972.
- John D Mc Donald, “Electric Power Substation Engineering”, CRC press, 2001.

- Wood, A. J and Wollenberg, B. F, “Power Generation Operation and Control”, 2nd Edition John Wiley and Sons, 2003.
- Green, J. N, Wilson, R, “Control and Automation of Electric Power Distribution Systems”, Taylor and Francis, 2007.
- Turner, W. C, “Energy Management Handbook”, 5th Edition, 2004.

Paper 8: Internship

During this period the student should develop the project by defining the scope, literature search and making detailed plan of work. At the end of the semester the student is expected to submit a report containing objectives literature status, and proposed solution.

nnexure - A

Rashtrasant Tukdoji Maharaj Nagpur University, Nagpur
Faculty of Engineering & Technology
Course and Examination Scheme of Post Graduate Diploma in Industrial Robotics
First Semester

Subject Code	Hours	Subject	Teaching Scheme				Examination Scheme								
			Hours per week			No. of Credits	Theory					Practical			
			L	T	P		Duration of Paper (Hrs.)	Max. Marks University Assessment	Max. Marks College Assessment	Total Marks	Min. Passing Marks	Max. Marks University Assessment	Max. Marks College Assesment	Total Marks	Min. Passing Marks
PGDIR101T	90	Introduction to Robotics	06	01	-	06	03	80	20	100	50	-	-	-	-
PGDIR102T	80	Sensors, Drives and Actuators	05	-	-	05	03	80	20	100	50	-	-	-	-
PGDIR102P	90	Sensors, Drives and Actuators	--	-	06	03	-	-	-	-	--	25	25	50	25
PGDIR103T	80	Control Systems	05	-	--	05	03	80	20	100	50	-	-	-	-
PGDIR104T	30	Soft Skills	01	01	-	02	01	30	20	50	25	-	-	-	-
PGDIR105P	80	Simulation and Design	-	-	05	05	-	-	-	-	-	75	75	150	75
Total	**450**		**17**	**02**	**11**	**26**	**-**	**270**	**80**	**350**	**-**	**100**	**100**	**200**	
	Semester Total		**30 Hrs**			**26 Cr**	**Marks 550**								

Rashtrasant Tukdoji Maharaj Nagpur University, Nagpur
Faculty of Engineering & Technolog
Course and Examination Scheme of Post Graduate Diploma in Industrial Robotics
Second Semester

Subject Code	HR	Subject	Teaching Scheme				Examination Scheme								
			Hours per week			No. of Credits	Theory					Practical			
			L	T	P		Duration of Paper (Hrs.)	Max. Marks University Assessment	Max. Marks College Assessment	Total Marks	Min. Passing Marks	Max. Marks University Assessment	Max. Marks College Assesment	Total Marks	Min. Passing Marks
PGDIR201T	80	Robot Applications in Industry	05	-	-	05	03	80	20	100	50	-	-	-	-
PGDIR202T	70	Machine vision & Image Processing	04	-	-	04	03	80	20	100	50	-	-	-	-
PGDIR203T	50	Industrial Safety Standards and Quality Standards	03	-	-	03	02	40	10	50	25	-	-	-	-
PGDIR204P	80	Robot Programming Lab.	-	-	05	05	-	-	-	-	-	25	25	50	25
PGDIR205P	70	Image Processing Lab.	--	--	04	02	-	-	-	-	-	25	25	50	25
PGDIR206P	50	SCADA & HMI LAB.	-	-	03	03	-	-	-	-	-	25	25	50	25
PGDIR207P	60	Internship	--	-	04	04	-	-	-	-	-	125	125	250	125
Total	**460 Hr**		**12**	**-**	**16**	**-**	**-**	**200**	**50**	**250**	**-**	**200**	**200**	**400**	**-**
	Semester Total		**28 Hours**			**26 Cr**	**Marks 650**								