Shri Vile Parle Kelavani Mandal's

Dwarkadas J. Sanghvi College of Engineering

(Autonomous College Affiliated to the University of Mumbai)

Scheme and detailed Syllabus (DJ19)

of

Honours Degree Program

in

Robotics

Revision: 1 (2022)

With effect from the Academic Year: 2022-2023

Proposed scheme for Honours in Robotics
(Academic Year 2022-2023)

Sr.	Course Code	Course	Teaching Scheme (hrs.)				Continuous Assessment (A) (marks)			Semester End Assessment (B) (marks)					(A+B)	Total Credits
			Th	P	T	Credits	Th	T/W	Total CA (A)	Th / Cb	O	P	O & P	Total SEA (B)		
Sem V																
1	DJ19MEHN2C1	Introduction to Robotics	4	--	--	4	25	--	25	75	--	--	--	75	100	**4**
Sem VI																
2	DJ19MEHN2C2	Modelling and Deisgn of Robotics	4	--	--	4	25	--	25	75	--	--	--	75	100	**4**
3	DJ19MEHN2L1	Robotics Laboratory 1	--	2	--	1	--	25	25	--	--	--	25	25	50	**1**
Sem VII																
4	DJ19MEHN2C3	Advance Robotics	4	--	--	4	25	--	25	75	--	--	--	75	100	**4**
5	DJ19MEHN2L2	Robotics laboratory 2	--	2	--	1	--	25	25	--	--	--	25	25	50	**1**
Sem VIII																
6	DJ19MEHN2C4	AI and ML for Robotics	4	--	--	4	25	--	25	75	--	--	--	75	100	**4**
		Total	**16**	**4**	**0**	**18**	**100**	**50**	**150**	**300**	**0**	**0**	**50**	**325**	**500**	**18**

Honours in Robotics **Semester: V**

Program: Mechanical Engineering

Course: Introduction to Robotics (DJ19MEHN2C1)

Pre-requisite:

1. Knowledge of basic elements of mechanical engineering
2. Knowledge of electrical engineering like motors & drives
3. Knowledge of instrumentation related topics like sensors & applications
4. Basic knowledge of control systems engineering

Objectives:

1. To impart knowledge of the fundamental concepts of robotics in the modern-day world from the olden days.
2. Make the student know the anatomical structure of the fixed & mobile robots with actuating systems.
3. To develop the student's knowledge in various types of sensors & its applications.
4. Making the robotic system to know how to do robotic manipulation using different types of end-effectors, viz., the tools & grippers.
5. To introduce the basic principles, techniques, state of art techniques in robot programming with control strategies.
6. Make the learner know about the different types of applications of robots in the modern-day world.

Outcomes: On completion of the course, the learner will be able to:

1. Remember the basic structure of robots with their mathematical interpretations in the 3-dimensional analysis.
2. Understand the kinematic analysis while doing the PNPO.
3. Apply the knowledge of mathematics in developing all possible solutions to the inverse kinematic analysis while doing the PNPO.
4. Analyze the area in which the robot can do the effective PNPO with a well-defined optimized shortest path trajectory.
5. Evaluate the performance of difference learning schemes used for solving a typical robotic application using AI concepts.
6. Create a typical robotic application to solve any type of automated works without human intervention.

Module	Introduction to Robotics - DJ19MEHN2C1	Hours
1	**Introduction to Robotics :** to automation & its types, History & evolution of robotics, Definition of robots, Robotic manipulators, Types of robots, Generations of robots, Laws of robotics, Classification of robots & its applications, Specifications of robots.	9
2	**Robot Anatomy :** Anatomy of robots, Drive systems, Actuators and Power Transmission systems, Types of drives & its applications, Hydraulic drives, Pneumatic drives, Electric drives, Hybrid drives, Robot activation & feedback components.	9
3	**Sensors in robotics :** Touch Sensors, Tactile Sensors, Proximity & Range Sensors, Sensor Based Systems, Force Sensors, Light sensors, Pressure sensors, Ultrasonic sensors, Infra-red sensors, Pots, Encoders, Position & Velocity Sensors.	9
4	**Articulated Mechanical System:** Materials used for robot design & its properties, Transmission devices in robots & its types, End effectors, Types of end effectors, Tools & Grippers, Classification of tools & grippers, Types of tool & gripper actuations.	9
5	**Robot Controllers & Programming :** Robot brain, Controller & its types, Need for controller in robots, Robot simulation, Robot software, Robot Programming & the Languages, Types of robot programming, Industrial robot programming.	8
6	**Robot Applications :** Industrial applications of robots, Medical, Household, Entertainment, Space, Underwater, Defense, Social, Environmental & economic issues in robot applications, Advantages & Disadvantages of Robotization.	8
	Total	52

Books Recommended:

Text books:

1. Dr. T.C.Manjunath, "Fundamentals of Robotics", Nandu Publishers, 5th Edn., India, 2005.
2. Elaine Rich & Kevin Knight, "Artificial Intelligence", Mac Graw Hill, Singapore, 3rd Edn., 2017.
3. Dr. T.C.Manjunath, "Fast Track to Robotics", Nandu Publishers, 2nd Edn., Mumbai, Maharashtra, India, 2005.
4. K.S. Fu, R.C. Gonzalez, C.S.G. Lee, "Robotics: Control Sensing Vision & Intelligence", Mac Graw Hill, USA, 5th Edition, 2010.
5. Robin R. Murphy, "Introduction to AI and Robotics", MIT Press, Second Edition, 648 pp., Oct. 2019.

Reference Books:

1. Industrial Robotics, Technology, Programming & Applications, Grover, Weiss, Nagel, Ordey,Mc Graw Hill.
2. Robotic technology & Flexible Automation, S R Deb. TMH.
3. Robotics for Engineers, Yoram Koren, Mc Graw hill.

4. Fundamentals of Robotics, Larry Health.

5. Robot Analysis & Control, H Asada, JJE Slotine.

6. Robot Technology, Ed. A Pugh, Peter Peregrinus Ltd. IEE, UK. 8. Handbook of Industrial Robotics, Ed. Shimon. John Wiley

7. Roland Siegwart, Illah Reza Nourbakhsh, and Davide Scaramuzza, “Introduction to Autonomous Mobile Robots”, Bradford Company Scituate, US

8. Fundamentals of Robotics – Analysis & Controls, Robert Schilling, Prentice Hall Inc, India.

9. Robotics – Amitaabh Bhattacharya

10. P.A. Janaki Raman, "Robotics and Image Processing an Introduction", Tata McGraw Hill Publishing company Ltd., 1995.

Honours in Robotics **Semester: VI**

Program: Mechanical Engineering

Course: Modelling & Design of Robots (DJ19MEHN2C2)

Pre-requisites :

1. Knowledge of basics of mechanics like kinematics
2. Knowledge of basics knowledge of mathematics like vector algebra
3. Knowledge of basics knowledge of mathematics like vector matrices

Objectives :

1. To impart knowledge of the fundamental concepts of robotics & its mathematical interpretations in 3- dimensional analysis.
2. Make the student to develop the direct kinematic & inverse kinematic model for successful robotic manipulation
3. Make the student to develop the inverse kinematic model for successful robotic manipulation to do a PNP operation.
4. To develop the student's knowledge in various robot structures to work effectively in its workspace.
5. Making the robotic system to follow a well-defined trajectory from source to destination during manipulation.
6. Objective of this module is to introduce the basic principles, techniques, state of art techniques in modelling & design of robots using direct & inverse dynamics

Outcomes :

1. Remember the basic concepts of AI & its types.
2. Understand the concepts of ML for different robotic applications.
3. Apply the knowledge of heuristics & search techniques for performing different robot tasks.
4. Analyze the work space area for solving a typical robotic task planning.
5. Evaluate the performance of the captured object in the image for different parameters.
6. Create a noise free image of the object for automatic robotic manipulation using robot vision

Modelling & Design of Robots (DJ19MEHN2C2)		
Unit	**Description**	**Duration**
1	**Modelling of robots** : An introduction (Kinematic & dynamical models), Design of Robots – An introduction (Kinematic & dynamical design), Mathematical Notations & Symbols, Coordinate Frames & its different types of Transformations with matrices, Dot & Cross products, Orthogonality & Orthonormality, Coordinate Frames, Coordinate Transformations, Rotation Matrices (RM-Fundamental & Composite), Homogeneous Coordinate Transformation Matrices (HCTM-Fundamental & Composite), Inverse matrices, Screw Transformation Matrices (STM), Problems.	9
2	**Robot Direct / Forward Kinematics Modelling & Design** : Introduction to robot arm direct kinematics, Kinematic model, Kinematic parameters (Joint & Link parameters), General Link Coordinate Transformation matrix, Arm matrix & arm equation, Link Coordinate Diagram (LCD), Kinematic Parameter Table (KPT), Denavit Hartenberg Representation, Direct Kinematic model of 1 axis robot, Direct Kinematic model of 2 axis robot, Direct Kinematic	9

	model of 3 axis robot, Direct Kinematic model of 4 axis robot, Problems.	
3	**Robot Inverse / Backward Kinematics Modelling & Design** : Introduction to robot inverse kinematics problems, Definition of IK, Inverse kinematic model, Uniqueness of IK solutions, Properties of solutions, Block-Diagrammatic representation, Approaches to IK problem, Relation between DK & IK, Tool Configuration & its Space (TCS), Joint Space (JS), Tool Configuration Vector (TCV), Inverse Kinematic model of 1 axis robot, Inverse Kinematic model of 2 axis robot, Inverse Kinematic model of 3 axis robot, Inverse Kinematic model of 4 axis robot.	9
4	**Robot Work Space Analysis Modelling & Design** : Work space, Definition, Work space envelope, Definition, Types of work envelopes, Types of work space envelopes, Joint space work envelope design, Total work envelope design, Dexterous work envelope design, Work space analysis of 1 axis robot, Work space analysis of 2 axis robot, Work space analysis of 3 axis robot, Work space analysis of 4 axis robot, A case study of work space & work envelope design for a specific robot application, Work space fixtures, A case study for the design of a work space fixture for a specific application, Problems.	9
5	**Robot Trajectory Planning Modelling & Design** : Robot Path, Robot Trajectory, Shape of trajectory, Speed Distribution Functions(SDF), Types of robot motions, Pick & Place trajectory design, Point to Point trajectory design, Interpolated trajectory design, Piecewise linear interpolated trajectory design, Cubic polynomial path & trajectory design, Use of parabolic blends in robot motion, Design of a parabolic blend & its mathematical model, Continuous path motion trajectory design, Straight line motion trajectory, A case study for the trajectory design for a specific robot motion application, Problems.	8
6	**Robot Dynamics** : Robot dynamical model, Kinetic energy model, Potential energy model, Lagrange-Euler Dynamical model, Dynamical modelling & design of a 1-axis robot, Direct dynamical & Inverse dynamical model, Tool configuration Jacobian matrix, TCJM of a 1-axis, 2-axis & 3-axis robot, Problems.	8
	Total	**52**

Books Recommended:

Text books:

1. 1. Dr. Pavithra, Dr. T.C.Manjunath, et.al., “Playing Smart – Artificial Intelligence”, Notion Publishers, India, 2022
2. 2. Stuart J. Russell and Peter Norvig, "Artificial Intelligence a Modern Approach —Second Edition" Pearson Education.
3. 3. Elaine Rich and Kevin Knight —Artificial Intelligence, Third Edition, Tata McGraw-Hill Education Pvt. Ltd., 2008.
4. 4. George F Luger “Artificial Intelligence” Low Price Edition, Pearson Education, Fourth edition. 5. Deepak Khemani, A first course in Artificial Intelligence, Mc Graw Hill.

Reference Books:

1. Robin R. Murphy, “Introduction to AI and Robotics”, MIT Press, Second Edition,
2. Dr. T.C.Manjunath, “Fundamentals of Robotics”, Nandu Publishers, 5th Edn., India, 2005.
3. Dr. T.C.Manjunath, “Fast Track to Robotics”, Nandu Publishers, 2nd Edn., Mumbai, Maharashtra, India, 2005.
4. Fundamentals of Robotics – Analysis & Controls, Robert Schilling, Prentice Hall Inc,

India.
5. Dr. Pavithra, et.al., "Machine Learning for Web Applications", Notion Publishers, India, 2021
6. Dr. T.C.Manjunath, et.al., "Image Processing & Machine Vision", Notion Publishers, India, 2022
7. Dr. Pavithra, et.al., "Computer Vision Techniques", Notion Publishers, India, 2022
8. Dr. Pavithra, et.al., "Deep Learning & its Techniques", Notion Publishers, India, 2021
9. Dr. T.C.Manjunath, et.al., "Computational Intelligence", Notion Publishers, India, 2021 10. AI books for beginners - Authors: Luca Massaron, John Mueller

Continuous Assessment (A):

Course	Assessment Tools	Marks	Time (hrs.)
Theory	One Term test (based on 40 % syllabus)	25 each (Avg.25)	1
	Second Term test (next 40 % syllabus) / presentation / assignment / course project / group discussion / any other.		As applicable
Audit course	Performance in the assignments / quiz / power point presentation / poster presentation / group project / any other tool.	--	
Laboratory	Performance in the laboratory and documentation.	--	
Tutorial	Performance in each tutorial & / assignment.	--	
Laboratory &Tutorial	Performance in the laboratory and tutorial.	--	

Semester End Assessment (B):

Course	Assessment Tools	Marks	Time (hrs.)
Theory	Written paper based on the entire syllabus.	75	3
Oral	Questions based on the entire syllabus.	--	--
Practical	Performance of the practical assigned during the examination and the output / results obtained.	--	--
Oral & Practical	Project based courses - Performance of the practical assigned during the examination and the output / results obtained. Based on the practical performed during the examination and on the entire syllabus.	--	--

The final certification and acceptance of term work will be subject to satisfactory performance uponfulfilling minimum passing criteria in the term work / completion of audit course.

Honours in Robotics **Semester: VI**

Program: Common for All Programs (except Mechanical Engineering)

Course: Robotics Laboratory 1 (DJ19MEHN2L1)

Pre-requisites :
1. Knowledge of Python Programming Basics
2. Knowledge of Matlab Programming & Simulink in Matlab
3. Knowledge of C/C++, Java, LabVIEW

Objectives:
1. To know the basic programming skills to develop simulations for workspace of a robot arm.
2. To know the basic programming skills to develop simulations for pick & place applications. 3. To know the basic programming skills to develop simulations to solve direct kinematics problems.
4. To know the basic programming skills to develop simulations for solving inverse solution problems.
5. To know the basic programming skills to develop simulations for finding the routes form source to destination by searching paths in the 2D environment.
6. To know the basic programming skills to develop simulations for simulating the different types of robot work envelopes.

Robotics Laboratory 1 - DJ19MEHN2L1	
Exp.	**Suggested experiments**
1	Graphical simulation of a 4-axis SCARA robot arm (2D & 3D View)
2	Work-space analysis of a 4-axis SCARA robot arm
3	Direct Kinematic Analysis of a 4-axis SCARA robot arm
4	Inverse Kinematic Analysis of a 4-axis SCARA robot arm
5	Graphical simulation of a 3-axis planar articulated robot arm (2D & 3D View)
6	Graphical simulation of a cylindrical coordinate robot arm (2D & 3D View)
7	Graphical simulation of any one type of robot arm (2D & 3D View), either a rectangular or cylindrical or polar or articulated robot arm.
8	Work Space Envelope of 3-axis Cartesian coordinate robot
9	Work Space Envelope of 3-axis Polar coordinate robot.
10	Robot Path Planning using General Voronoi Diagram (GVD) methods – generation of path from source to goal (2D)
11	Trajectory-planning (linear interpolation) from source to goal.
12	Development of a program to show Bounded Deviation Algorithm for achieving straight line motion in the TCS.

A minimum of six experiments from the above-suggested list or any other experiment based on syllabus may be included, which would help the learner to apply the concept learnt. A case study or seminar report relevant to the topics may be included, which would help the learner to apply the concept learnt.

Text Books Recommended :

1. Dr. T.C.Manjunath, “Fundamentals of Robotics”, Nandu Publishers, 5th Edn., India, 2005 (Programming with CD/DVD)
2. Kenneth Lambert – “Fundamentals of Python_ Data Structures”, Cengage Learning PTR (2013).
3. Gowrishankar S, Veena A, “Introduction to Python Programming”, 1st Edition, CRC Press/Taylor

& Francis, 2018. ISBN-13: 978-0815394372.

4. http://do1.drchuck.com/pythonlearn/EN_us/pythonlearn.pdf
5. Allen B. Downey, "Think Python: How to Think Like a Computer Scientist", 2nd Edition, Green Tea Press, 2015. (http://greenteapress.com/thinkpython2/thinkpython2.pdf)
6. On-Line Materials & Resources (NPTEL courses / Video lectures / You-tube Videos / Power points / On-line notes / web-links :
7. https://nptel.ac.in/courses/106/106/106106182/
8. https://nptel.ac.in/courses/115/104/115104095/
9. https://www.edx.org/learn/python
10. https://www.coursera.org/courses?query=python
11. https://www.udemy.com/topic/python/
12. https://online-learning.harvard.edu/subject/python
13. https://www.codecademy.com/learn/learn-python
14. https://www.geeksforgeeks.org/python-programming-language/
15. https://www.lynda.com/Python-training-tutorials/415-0.html
16. https://www.python.org/
17. Fundamentals of C/C++, Kernigan & Ritche
18. Fundamentals of C Programming, Bal Guruswamy.
19. MATLAB Programming for Engineers MATLAB Programming for Engineers by Stephen J. Chapman
20. https://www.mathworks.com/

Honours in Robotics **Semester: VII**

Program: Mechanical Engineering

Course: Advance Robotics (DJ19MEHN2C3)

Pre-requisites :

1. Knowledge of basics of mechanics like kinematics
2. Knowledge of basics knowledge of mathematics like vector algebra
3. Knowledge of basics knowledge of mathematics like matrix theory & algebra
4. Knowledge of integration, differentiation & numerical methods

Objectives :

1. To impart knowledge of the fundamental concepts of robotics & its mathematical interpretations in 3-dimensional analysis.
2. Make the student to develop the direct kinematic & inverse kinematic model for successful robotic manipulation
3. Make the student to develop the inverse kinematic model for successful robotic manipulation to do a PNP operation.
4. To develop the student's knowledge in various robot structures to work effectively in its workspace.
5. Making the robotic system to follow a well-defined trajectory from source to destination during manipulation.

Outcomes :

7. Develop a strategy to solve a given PNP operation in a workspace of the robot arm, whether it is a stationary robot or a mobile robot.

8. Develop the analysis how to do the direct & inverse kinematics of the robot arm, whether it is a stationary robot or a mobile robot.

9. Develop the ideas how to generate a path & trajectory in the 2D/3D workspace of the robot arm, whether it is a stationary robot or a mobile robot.

10. Develop ideas how to avoid the obstacles in the path of motion of the robot arm.

Advance Robotics - DJ19MEHN2C3		
Unit	**Description**	**Duration**
1	**Modelling of robots :** An introduction (Kinematic & dynamical models), Design of Robots – An introduction (Kinematic & dynamical design), Mathematical Notations & Symbols, Coordinate Frames & its different types of Transformations with matrices, Dot & Cross products, Orthogonality & Orthonormality, Coordinate Frames, Coordinate Transformations, Rotation Matrices (RM-Fundamental & Composite), Homogeneous Coordinate Transformation Matrices (HCTM-Fundamental & Composite), Inverse matrices, Screw Transformation Matrices (STM), Problems.	9
2	**Robot Direct / Forward Kinematics Modelling & Design :** Introduction to robot arm direct kinematics, Kinematic model, Kinematic parameters (Joint & Link parameters), General Link Coordinate Transformation matrix, Arm matrix & arm equation, Link Coordinate Diagram (LCD), Kinematic Parameter Table (KPT), Denavit Hartenberg Representation, Direct Kinematic model of 1 axis robot, Direct Kinematic model of 2 axis robot, Direct Kinematic model of 3 axis robot, Direct Kinematic model of 4 axis robot, Problems.	9
3	**Robot Inverse / Backward Kinematics Modelling & Design :** Introduction to robot inverse kinematics problems, Definition of IK, Inverse kinematic model, Uniqueness of IK solutions, Properties of solutions, Block-Diagrammatic representation, Approaches to IK problem, Relation between DK & IK, Tool Configuration & its Space (TCS), Joint Space (JS), Tool	9

	Configuration Vector (TCV), Inverse Kinematic model of 1 axis robot, Inverse Kinematic model of 2 axis robot, Inverse Kinematic model of 3 axis robot, Inverse Kinematic model of 4 axis robot.	
4	**Robot Work Space Analysis Modelling & Design :** Work space, Definition, Work space envelope, Definition, Types of work envelopes, Types of work space envelopes, Joint space work envelope design, Total work envelope design, Dexterous work envelope design, Work space analysis of 1 axis robot, Work space analysis of 2 axis robot, Work space analysis of 3 axis robot, Work space analysis of 4 axis robot, A case study of work space & work envelope design for a specific robot application, Work space fixtures, A case study for the design of a work space fixture for a specific application, Problems.	9
5	**Robot Trajectory Planning Modelling & Design :** Robot Path, Robot Trajectory, Shape of trajectory, Speed Distribution Functions(SDF), Types of robot motions, Pick & Place trajectory design, Point to Point trajectory design, Interpolated trajectory design, Piecewise linear interpolated trajectory design, Cubic polynomial path & trajectory design, Use of parabolic blends in robot motion, Design of a parabolic blend & its mathematical model, Continuous path motion trajectory design, Straight line motion trajectory, A case study for the trajectory design for a specific robot motion application, Problems.	8
6	**Robot Dynamics :** Robot dynamical model, Kinetic energy model, Potential energy model, Lagrange-Euler Dynamical model, Dynamical modelling & design of a 1-axis robot, Direct dynamical & Inverse dynamical model, Tool configuration Jacobian matrix, TCJM of a 1-axis, 2-axis & 3-axis robot, Problems.	8
	Total	**52**

Books Recommended:

Text books:

5. Dr. T.C.Manjunath, “Fundamentals of Robotics”, Nandu Publishers, 5th Edn., India, 2005.
6. K.S. Fu, R.C. Gonzalez, C.S.G. Lee, “Robotics: Control Sensing Vision & Intelligence”, Mac Graw Hill, USA, 5th Edition, 2010.
7. Dr. T.C.Manjunath, “Fast Track to Robotics”, Nandu Publishers, 2nd Edn., Mumbai, Maharashtra, India, 2005.
8. Robin R. Murphy, “Introduction to AI and Robotics”, MIT Press, Second Edition, 648 pp., Oct. 2019.
9. Fundamentals of Robotics – Analysis & Controls, Robert Schilling, Prentice Hall Inc, India.

Reference Books:

1. Industrial Robotics, Technology, Programming & Applications, Grover, Weiss, Nagel, Ordey, Mc Graw Hill.
2. Robotic technology & Flexible Automation, S R Deb. TMH.
3. Robotics for Engineers, Yoram Koren, Mc Graw hill.
4. Fundamentals of Robotics, Larry Health.
5. Robot Analysis & Control, H Asada, JJE Slotine.
6. Robot Technology, Ed. A Pugh, Peter Peregrinus Ltd. IEE, UK. 8. Handbook of Industrial Robotics, Ed. Shimon. John Wiley
7. Roland Siegwart, Illah Reza Nourbakhsh, and Davide Scaramuzza, “Introduction

to Autonomous Mobile Robots", Bradford Company Scituate, US
8. Fundamentals of Robotics – Analysis & Controls, Robert Schilling, Prentice Hall Inc, India.
9. Robotics – Amitabh Bhattacharya
10. P.A. Janaki Raman, "Robotics and Image Processing an Introduction", Tata McGraw Hill Publishing company Ltd., 1995.

Continuous Assessment (A):

Course	Assessment Tools	Marks	Time (hrs.)
Theory	One Term test (based on 40 % syllabus)	25 each (Avg.25)	1
	Second Term test (next 40 % syllabus) / presentation / assignment / course project / group discussion / any other.		As applicable
Audit course	Performance in the assignments / quiz / power point presentation / poster presentation / group project / any other tool.	--	
Laboratory	Performance in the laboratory and documentation.	25	
Tutorial	Performance in each tutorial & / assignment.	--	
Laboratory &Tutorial	Performance in the laboratory and tutorial.	--	

Semester End Assessment (B):

Course	Assessment Tools	Marks	Time (hrs.)
Theory	Written paper based on the entire syllabus.	75	3
Oral	Questions based on the entire syllabus.	--	--
Practical	Performance of the practical assigned during the examination and the output / results obtained.	--	--
Oral & Practical	Project based courses - Performance of the practical assigned during the examination and the output / results obtained. Based on the practical performed during the examination and on the entire syllabus.	25	2

The final certification and acceptance of term work will be subject to satisfactory performance uponfulfilling minimum passing criteria in the term work / completion of audit course.

Honours in Robotics **Semester: VII**

Program: Common for All Programs (except Mechanical Engineering)

Course: Robotics Laboratory 2 (DJ19MEHN2L2)

Pre-requisite:
1. Knowledge of Python Programming Basics
2. Knowledge of Matlab Programming & Simulink in Matlab
3. Knowledge of C/C++, Java, LabVIEW

Objectives:
1. To know the basic programming skills to develop simulations for workspace of a robot arm.
2. To know the basic programming skills to develop simulations for pick & place applications.
3. To know the basic programming skills to develop simulations to solve direct kinematics problems.
4. To know the basic programming skills to develop simulations for solving inverse solution problems.
5. To know the basic programming skills to develop simulations for finding the routes form source to destination by searching paths in the 2D environment.
6. To know the basic programming skills to develop simulations for simulating the different types of robot work envelopes.

Outcomes: On completion of the course, the learner will be able to:
1. Develop a strategy to solve a given PNP operation in a workspace of the robot arm, whether it is a stationary robot or a mobile robot.
2. Develop the analysis how to do the direct & inverse kinematics of the robot arm, whether it is a stationary robot or a mobile robot.
3. Develop the ideas how to generate a path & trajectory in the 2D/3D workspace of the robot arm, whether it is a stationary robot or a mobile robot.
4. Develop ideas how to avoid the obstacles in the path of motion of the robot arm.

Robotics Laboratory 2 - DJ19MEHN2L2	
Exp.	**Suggested experiments**
1	To develop the work-space model, trajectory planning & a pick-place operation of a four axis SCARA robot arm.
2	To do the DK & IK of a four axis SCARA robot arm.
3	To develop the work-space model, trajectory planning & a pick-place operation of a three-axis planar articulated robot arm.
4	To do the DK & IK of a three-axis planar articulated robot arm.
5	To develop the work-space model, trajectory planning & a pick-place operation of a two-axis planar articulated robot arm.
6	To do the DK & IK of a two-axis planar articulated robot arm.
7	Graphical simulation of any one type of robot arm (2D & 3D View), either a rectangular or cylindrical or polar or articulated robot arm.
8	Design a Robot Path Planning, i.e., the generation of path from source to goal (2D) using configuration space method, General Voronoi Method, Dijkstra's methods.
9	Design a robotic path, i.e., do the Interpolation using parabolic blends & Trajectory-planning (linear interpolation) from source to goal for the movement of the robot.
10	Write a program to find the coordinates of the point p w.r.t. F frame given the

	coordinates of the point p w.r.t. M frame with both rotations & translations, i.e., both.
11	Write a program to develop the graphical display of the link coordinate diagram (LCD) of a 2-axis PARA, 3-axis PARA & a 4-axis SCARA robot arm.
12	Develop a program to develop Screw Transformations (ST) & to show the navigation through obstacles using Shortest Path from source to goal along with the Bounded Deviation Algorithm for achieving straight line motion in the TCS.

A minimum of six experiments from the above-suggested list or any other experiment based on syllabus may be included, which would help the learner to apply the concept learnt. A case study or seminar report relevant to the topics may be included, which would help the learner to apply the concept learnt.

Text Books Recommended :

21. Dr. T.C.Manjunath, "Fundamentals of Robotics", Nandu Publishers, 5th Edn., India, 2005 (Programming with CD/DVD)
22. Kenneth Lambert – "Fundamentals of Python_ Data Structures", Cengage Learning PTR (2013).
23. Gowrishankar S, Veena A, "Introduction to Python Programming", 1st Edition, CRC Press/Taylor & Francis, 2018. ISBN-13: 978-0815394372.
24. http://do1.drchuck.com/pythonlearn/EN_us/pythonlearn.pdf
25. Allen B. Downey, "Think Python: How to Think Like a Computer Scientist", 2nd Edition, Green Tea Press, 2015. (http://greenteapress.com/thinkpython2/thinkpython2.pdf)
26. On-Line Materials & Resources (NPTEL courses / Video lectures / You-tube Videos / Power points / On-line notes / web-links :
27. https://nptel.ac.in/courses/106/106/106106182/
28. https://nptel.ac.in/courses/115/104/115104095/
29. https://www.edx.org/learn/python
30. https://www.coursera.org/courses?query=python
31. https://www.udemy.com/topic/python/
32. https://online-learning.harvard.edu/subject/python
33. https://www.codecademy.com/learn/learn-python
34. https://www.geeksforgeeks.org/python-programming-language/
35. https://www.lynda.com/Python-training-tutorials/415-0.html
36. https://www.python.org/
37. Fundamentals of C/C++, Kernigan & Ritche
38. Fundamentals of C Programming, Bal Guruswamy.
39. MATLAB Programming for Engineers MATLAB Programming for Engineers by Stephen J. Chapman
40. https://www.mathworks.com/

Honours in Robotics **Semester: VIII**

Program: Mechanical Engineering

Course: AI and ML for Robotics (DJ19MEHN2C4)

Pre-requisites :

1. Knowledge of basics of image processing
2. Some basic ideas about the cameras & its operations
3. Knowledge of basics knowledge of AI & ML
4. Knowledge of logical thinking for solving simple problems.

Objectives :

1. To impart knowledge of the use of Artificial Intelligence in solving robotic problems.
2. Make the student understand different types of machine learning approaches in robotics.
3. To develop the different types of motion planning techniques to find the paths in the space.
4. Making the robotic system know how to solve the given task using task planners.
5. To introduce the student to know the fundamental concepts lying under the robotic vision.
6. Make the learner know the concepts of digital imaging & vision to identify objects using camera.

Outcomes :

1. Remember the basic concepts of AI & its types.
2. Understand the concepts of ML for different robotic applications.
3. Apply the knowledge of heuristics & search techniques for performing different robot tasks.
4. Analyze the work space area for solving a typical robotic task planning.
5. Evaluate the performance of the captured object in the image for different parameters.
6. Create a noise free image of the object for automatic robotic manipulation using robot vision

AI and ML for Robotics (DJ19MEHN2C4)		
Unit	**Description**	**Duration**
1	**AI in Robotics** : Human Intelligence, Artificial Intelligence, Definition, Types of Artificial Intelligence, Goals of AI, Tenets of AI, Applications of AI, Problem representation in AI, Knowledge representation & Reasoning, Intelligent Agents, Swarm Intelligence, Distributed Intelligence, Imitation learning, Multi agent learning, Project based learning, Artificial Neural Networks, Convolution Neural Networks, Recurrent Neural Networks, Natural Language Processing, Speech Recognition, Cognitive Sciences, Expert Systems, AI based programming languages, Future research trends in AI, A case study to solve a typical robotic problem using AI, Problems.	9
2	**Machine Learning in Robotics** : Supervised learning, Unsupervised learning, Reinforcement learning, Deep learning, Automated Machine Learning, Convergence of IoT & ML, ML algorithms, Classification, Clustering, Prediction, Motion Heuristics, Types, State space search techniques, Graph theory techniques, AND/OR graphs, Breadth first search techniques, Hill Climbing, Best first search techniques, Semantic networks and petri-nets, Dijkstra's algorithm, Wide Path Motion Heuristics Method of Path Planning, Sophisticated Motion Heuristics, A case study to solve a typical robotic problem using ML, Problems.	9

3	**AI based Robot Task Planning - 1** : Task Planners, Automatic Program Generators, Uncertainty – Introduction, Illustration of Uncertainty Using an Example, Robot Motion Planning Techniques, Methods, Gross Motion Planning, Configuration space method & the GVD method, Fine motion planning, Guarded & Compliant motion, Grasp planning, Safe grasp planning, Secured grasp planning, Reachable grasp planning.	9
4	**AI based Robot Task Planning - 2** : Computation of Sector Boundaries, Peg in a Hole Problem, Simulation of Planar Motion, Polygon Penetration Algorithm, A Task Planning Simulation Problem – Introduction, Source and Goal Scenes, Task Planning Sub-Problems, Scene analysis & Part ordering, Autonomous vehicles, Application to Chandrayan, Mars Rovers, Problems	9
5	**Introduction to Robotic Vision – 1** : Features of Robotic Vision, Image Representation & Analysis, Digitization of Images, Sampling - Quantization - Coding of Images, Digital, Black-White & Gray Scale Image, Template Matching, Performance Index, Normalized Cross-Correlation, Comparison, Explanation Using an Example, Polyhedral Objects (Edge Detection and Corner Point Detection Algorithms), Selection of the Edge Threshold, Corner Point Detection, Principle of CP Detection & its Algorithm, Perspective & Inverse Perspective Transformations, Camera Calibration, Illumination Techniques, Case study of Robot Vision in Engineering-1, Problems.	8
6	**Introduction to Robotic Vision – 2** : Pattern Recognition, Shape Analysis & Methods of Performing Shape Analysis, Line & Area Descriptors, Moments, Segmentation & its types, Region, Thresholding, Histogram, Region Labelling and Region Growing Algorithm, Iterative Processing of Images & its methods, Pixel Function Definition, Shrink, Bulk & Swell Operators, Applications, Euler Number & its uses, Connectedness, Types of lighting schemes (Back, Front, Side, Advanced), Ranging Techniques, Triangulation, Image Compression Techniques, Types, Run Length Coding, Case study of Robot Vision in Engineering-2, Problems.	8
	Total	**52**

Books Recommended:

Text books:

10. 1. Dr. Pavithra, Dr. T.C.Manjunath, et.al., “Playing Smart – Artificial Intelligence”, Notion Publishers, India, 2022
11. 2. Stuart J. Russell and Peter Norvig, "Artificial Intelligence a Modern Approach —Second Edition" Pearson Education.
12. 3. Elaine Rich and Kevin Knight —Artificial Intelligence, Third Edition, Tata McGraw-Hill Education Pvt. Ltd., 2008.
13. 4. George F Luger “Artificial Intelligence” Low Price Edition, Pearson Education, Fourth edition. 5. Deepak Khemani, A first course in Artificial Intelligence, Mc Graw Hill.

Reference Books:

1. Robin R. Murphy, “Introduction to AI and Robotics”, MIT Press, Second Edition,
2. Dr. T.C.Manjunath, “Fundamentals of Robotics”, Nandu Publishers, 5th Edn., India, 2005.
3. Dr. T.C.Manjunath, “Fast Track to Robotics”, Nandu Publishers, 2nd Edn., Mumbai, Maharashtra, India, 2005.
4. Fundamentals of Robotics – Analysis & Controls, Robert Schilling, Prentice Hall Inc, India.
5. Dr. Pavithra, et.al., “Machine Learning for Web Applications”, Notion Publishers, India, 2021

6. Dr. T.C.Manjunath, et.al., "Image Processing & Machine Vision", Notion Publishers, India, 2022
7. Dr. Pavithra, et.al., "Computer Vision Techniques", Notion Publishers, India, 2022
8. Dr. Pavithra, et.al., "Deep Learning & its Techniques", Notion Publishers, India, 2021
9. Dr. T.C.Manjunath, et.al., "Computational Intelligence", Notion Publishers, India, 2021 10. AI books for beginners - Authors: Luca Massaron, John Mueller

Continuous Assessment (A):

Course	Assessment Tools	Marks	Time (hrs.)
Theory	One Term test (based on 40 % syllabus)	25 each (Avg.25)	1
	Second Term test (next 40 % syllabus) / presentation / assignment / course project / group discussion / any other.		As applicable
Audit course	Performance in the assignments / quiz / power point presentation / poster presentation / group project / any other tool.	--	
Laboratory	Performance in the laboratory and documentation.	--	
Tutorial	Performance in each tutorial & / assignment.	--	
Laboratory &Tutorial	Performance in the laboratory and tutorial.	--	

Semester End Assessment (B):

Course	Assessment Tools	Marks	Time (hrs.)
Theory	Written paper based on the entire syllabus.	75	3
Oral	Questions based on the entire syllabus.	--	--
Practical	Performance of the practical assigned during the examination and the output / results obtained.	--	--
Oral & Practical	Project based courses - Performance of the practical assigned during the examination and the output / results obtained. Based on the practical performed during the examination and on the entire syllabus.	--	--

The final certification and acceptance of term work will be subject to satisfactory performance uponfulfilling minimum passing criteria in the term work / completion of audit course.