GUJARAT TECHNOLOGICAL UNIVERSITY (GTU)

Competency-focused Outcome-based Green Curriculum-2023 (COGC-2023)
Semester-VI

Course Title: Robotic Arm Manipulator
(Course Code: 4364102)

Diploma programmer in which this course is offered	Semester in which offered
Automation and Robotics	6th

1. RATIONALE

The increasing demand for automation and robotics in various industries has created a need for skilled technicians who can design, build, and operate robotic arm manipulators. This diploma-level course aims to provide students with the theoretical and practical knowledge required to work with robotic arm manipulators. Students will learn about the fundamentals of robotics, mechanical and electrical systems, control systems, and programming languages. Upon completion, graduates will be equipped to work in industries such as manufacturing, healthcare, and logistics, and contribute to the development of efficient and automated systems.

2. COMPETENCY

The course content should be taught and implemented by Mechanical Engineering Department and Instrumentation & Control Engineering Department faculties with the aim to develop required skills in the students so that they are able to acquire following competency:

- **Understanding, Operating and Maintaining Architecture and control of robotic arm**

1. COURSE OUTCOMES (COs)

The theory should be taught and practical should be performed in such a manner that students are able to acquire required learning outcomes in cognitive, psychomotor and affective domain to demonstrate following course outcomes:

CO1	Identify Industrial robots & its types
CO2	Identify and select various grippers and understand various steps in assembling process.
CO3	To control and understand functions of robotic components.
CO4	To understand about various robot simulator and application software
CO5	To understand various robot arm manipulator application and maintenance process.

4. TEACHING AND EXAMINATION SCHEME

Teaching Scheme (In Hours)			Total Credits (L+T+P/2)	Examination Scheme				
				Theory Marks		Practical Marks		Total Marks
L	T	P	C	CA	ESE	CA	ESE	
3	0	2	4	30	70	25	25	150

Legends: **L**-Lecture; **T** – Tutorial/Teacher Guided Theory Practice; **P** -Practical; **C** – Credit **ESE** -End Semester Examination; **CA** – Continuous Assessment.

5. SUGGESTED PRACTICAL EXERCISES:

The following practical outcomes (PrOs) that are the sub-components of the CO's. *Some of the **PrO's** marked **'*'** are compulsory, as they are crucial for that particular CO at the 'Precision Level' of Dave's Taxonomy related to 'Psychomotor Domain'*.

S. No.	Practical Outcomes (PrOs)	Unit No.	Approx. Hrs. required
1	Recognize & comply safe working practices in robotic arm manipulator	4	2Hrs
2	To test the working of servo motor with reference to robot arm.	2	2Hrs
3	Identify and explain various types of Industrial Robots and perform their configuration	3	4Hrs
4	Identify the Robotic Cell Components & Application tools	1	2Hrs
5	To test the operation of external robot sensor.	2	2Hrs
6	To test the operation of internal robot sensor.	2	2Hrs
7	Identify and select various grippers and understand various steps in assembling process of robot arm.	2	2Hrs
8	To study about robotic Coordinate system	2	4Hrs
9	Perform Importing, Exporting & Selection of robotic program	4	4Hrs
10	Perform Interfacing of work piece holding Grippers in Robot	3	2Hrs
11	Perform installation check of robot mechanically and Electrically	3	2Hrs
12	Power on the Robot and making the cell Healthy for programming	3	2Hrs
13	Perform Jogging of the industrial robot using virtual programming pendant	4	2Hrs
14	Identify the Industrial Robot simulation tool/ software	4	2Hrs
15	Explain the industrial need of robotic programming Simulation	5	2Hrs
16	To study about Maintenance and troubleshooting techniques in robot model	5	2Hrs
17	Run the existing program with manual mode.	4	4Hrs

Note:

*i. More **Practical Exercises** can be designed and offered by the respective course teacher to develop the industry relevant skills/outcomes to match theCOs.The above table is only a suggestive list.*

*ii. The following are some **sample** 'Process' and 'Product' related skills(more may be added/deleted depending on the course) that occur in the above listed **Practical Exercises** of this course required which are embedded in the COs and ultimately the competency.*

S. No.	Sample Performance Indicators for the PrOs	Weightage in %
1	Prepare experimental setup	20
2	Operate the equipment setup or circuit	20
3	Follow safe practices measures	10
4	Record observations correctly	20
5	Interpret the result and conclude	30
Total		**100**

6. MAJOR EQUIPMENT/ INSTRUMENTS REQUIRED

Sr. No.	Equipment Name with Broad Specifications	PrO. No.
1	Servo motor tester	
2	Industrial robot model	
3	Various sensors to be attached in robot	
4	Robotics Operating system	

7. AFFECTIVE DOMAIN OUTCOMES

The following ***sample*** Affective Domain Outcomes (ADOs) are embedded in many of the above-mentioned COs and PrOs. More could be added to fulfil the development of this competency.

a) Work as a leader/a team member for assigned student activity.
b) Follow safety practices and procedure in Lab.
c) Realize the importance of engineering for societal development.
d) Develop gradually the engineering mindset in day-to-day observation.

8. UNDERPINNING THEORY:

Unit	Unit Outcomes (UOs)	Topics and Sub-topics
Unit – I Introduction to Robotic Arm Manipulators	- Define the term "robotics" and explain its significance in modern industry - Describe the basic concepts and principles of robotics - Identify the key differences between robotics and automation - Classify robotic arm manipulators into industrial, medical, and service categories - Describe the characteristics and applications of each type of robotic arm manipulators - Explain the advantages and limitations of each type - Identify various applications of robotic arm manipulators in industries such as manufacturing, healthcare, and logistics - Identify and describe the basic components of a robotic arm manipulator, including sensors, actuators, and controllers - Explain the functions and interactions of these components	1.1. Introduction to Robotics and Robotic Arm Manipulators -Types of Robotic Manipulators: Basic classification based on structure, mobility, and function. -Challenges in Robotic Arm Design: Issues such as precision, stability, and control in manipulator systems. 1.2. Types of Robotic Arm Manipulators (Industrial, Medical, and Service) -Industrial Robotic Arms: Characteristics, uses in manufacturing, and automation processes. -Medical Robotic Arms: Robotic surgery, rehabilitation, and assistive devices in healthcare. -Service Robotic Arms: Robots used in customer service, hospitality, and logistics. -Comparison of Types of Robotic Arms: Advantages and limitations of each type in their respective fields. 1.3. Applications of Robotic Arm Manipulators -Manufacturing and Automation: Robotic arms in assembly lines, packaging, and material handling. -Medical Applications: Robotic-assisted surgery, diagnostics, and prosthetics. Agriculture: Use of robotic arms for planting, harvesting, and processing crops. -Space Exploration: Robotic arms in spacecraft for maintenance and exploration tasks. 1.4. Basic Components of a Robotic Arm Manipulator (Sensors, Actuators, and Controllers)

Unit – II Robot Arm Components.	- Identify and describe different types of joints (e.g., revolute, prismatic, spherical) and linkages (e.g., serial, parallel, hybrid) - list the advantages and limitations of different joint and linkage configuration - Identify and compare different types of actuators (e.g., motors, cylinders, pumps) - list the advantages and limitations of different gear and transmission configurations - Identify and describe different types of end-effectors (e.g., grippers, suction cups, tool changers) -list the advantages and limitations of different end-effector designs	2.1. Types of Joints and Linkages -Revolute Joints: Rotational movement, applications, and limitations. -Prismatic Joints: Linear motion, use cases, and design considerations. -Spherical and Universal Joints: Applications in robotic arms that require multi-axis rotation. -Serial vs. Parallel Linkages: Comparison of linkage systems for different manipulator designs. 2.2. Actuation Systems (Electric) -Electric Actuators: Characteristics, advantages, and typical applications in robotics. -Comparison of Actuation Systems: Evaluating the performance, cost, and energy requirements of each actuation type. 2.3. Gear Systems and Transmission Mechanisms -Gear Types (Spur, Helical, and Planetary Gears): Their roles in transmitting motion and torque in robotic systems. -Transmission Mechanisms: Belt, chain, and shaft drive systems used in robotic arms. -Gear Reduction and Speed Control: Importance in controlling precision and torque. -Torque and Power Transmission Efficiency: How gear systems optimize performance in robotic manipulators. 2.4. End-effectors and Grippers -Types of End-effectors: Tools like welding torches, screwdrivers, or drills used for specific tasks. -Gripper Types: Mechanical, vacuum, and magnetic grippers, and their applications. -Custom End-effectors: Designing end-effectors for specialized tasks like assembly, inspection, or medical procedures. -Sensor Integration in End-effectors: Using sensors for feedback and improving grasping force or precision in robotic tasks.

Unit – III Control Systems for Robotic Arm Manipulators	- Define the concept of control systems and their importance in robotic arm manipulators - Identify the types of control systems used in robotic arm manipulators - Distinguish between open-loop and closed-loop control systems - Identify applications of open-loop and closed-loop control systems in robotic arm manipulators - Explain the principles of feedback systems and their importance in control system. - Analyze the advantages and limitations of each control algorithm - Apply PID and on/off control algorithms to simple control systems in robotic arm manipulators	3.1. Introduction to Control Systems -Definition and Importance of Control Systems: Overview of control systems and their role in automation. -Basic Components of a Control System: Understanding sensors, controllers, and actuators. -Control Systems in Robotics: How control systems help in managing robotic movements and behaviors. 3.2. Types of Control Systems (Open-loop and Closed-loop) Open-loop Control Systems: Characteristics, advantages, and limitations in robotics. Closed-loop Control Systems: How feedback is used for real-time adjustments and more accurate control. Comparison of Open-loop and Closed-loop Systems: When to use each type in different robotic applications. 3.3. Sensors and Feedback Systems -Role of Sensors in Feedback Systems: How sensors provide essential data for control algorithms. -Types of Sensors Used in Robotics: Examples include position, velocity, force, and proximity sensors. -Feedback Loops: How continuous data from sensors help fine-tune robotic movements and actions. -Sensor Integration Challenges: Issues related to accuracy, noise, and sensor fusion in complex systems. 3.4. Basic Control Algorithms (PID and On/Off Control) -PID Control Algorithm: Explanation of Proportional, Integral, and Derivative control and its application in robotics. -Tuning PID Parameters: Methods for adjusting PID gains to achieve optimal performance.

Unit – IV Programming and Operation of Robotic Arm Manipulators	- Identify and describe the basic features of programming languages such as C, Python, and PLC - Write simple programs using C, Python, and PLC - Explain the concept of graphical user interfaces (GUIs) in programming robotic arm manipulators - Identify and describe different GUIs used in robotic arm manipulators - Explain the concept of teach pendants in operating robotic arm manipulators - Identify and describe the basic components of a teach pendant - Identify and describe safety precautions when working with robotic arm manipulators - Troubleshoot common problems in robotic arm manipulators using logical and methodical approaches	4.1. Introduction to Programming Languages (C, Python, and PLC) -C Programming for Robotics: Low-level control, memory management, and real-time applications. -Python in Robotics: High-level scripting for automation, sensor integration, and data processing. -PLC (Programmable Logic Controllers) in Robotics: Industrial control, sequence control, and its role in robotic arm programming. 4.2. Programming a Robotic Arm Manipulator Using a Graphical User Interface -Overview of Graphical User Interfaces (GUIs): How GUIs simplify programming for users without extensive coding knowledge. -Programming Software for Robotic Arms: Examples of software like RoboDK, VEX Robotics, and others that enable GUI-based programming. -Creating Movement Sequences via GUI: Programming robot arm motions using drag-and-drop actions and visual tools. 4.3. Operating a Robotic Arm Manipulator Using a Teach Pendant -Teach Pendant Overview: Functionality of teach pendants in programming and operating robotic arms. -Manual and Automatic Mode: Switching between manual mode for teaching positions and automatic mode for execution. 4.4. Safety Precautions and Troubleshooting -Safety Standards and Protocols: International safety guidelines, such as ISO 10218 and OSHA regulations, for operating robotic arms. Emergency Stop Mechanisms: Importance of having physical and software-based emergency stop features. Troubleshooting Techniques: Step-by-step approaches for diagnosing and fixing common robotic arm problems.

Unit – V Applications and Maintenance of Robotic Arm Manipulators	- Identify and describe various industrial applications of robotic arm manipulators (e.g., welding, assembly, material handling) - Explain the benefits and advantages of using robotic arm manipulators in industrial settings - Analyze case studies of successful industrial applications of robotic arm manipulators - Identify and describe various medical and service applications of robotic arm manipulators (e.g., surgery, rehabilitation, service robotics) - Explain the benefits and advantages of using robotic arm manipulators in medical and service settings - Analyze case studies of successful medical and service applications of robotic arm manipulators - Identify and describe common maintenance tasks for robotic arm manipulators (e.g., cleaning, lubrication, software updates) - Explain the importance of troubleshooting in maintaining robotic arm manipulators - Develop a maintenance schedule and troubleshooting plan for a robotic arm manipulator - Identify and describe emerging trends and developments in robotic arm manipulators (e.g., collaborative robots, artificial intelligence, IoT integration) - Explain the potential impact of these trends on industries and society - Discuss the challenges and opportunities associated with the future development of robotic arm manipulators	5.1. Industrial Applications of Robotic Arm Manipulators -Assembly Line Automation: Use of robotic arms in mass production for tasks like welding, screwing, and component placement. -Material Handling and Packaging: Robotic arms in sorting, packing, and transporting goods in warehouses and factories. -Precision Manufacturing: Robotic arms used in high-precision tasks such as electronics assembly and automotive manufacturing. 5.2. Medical and Service Applications of Robotic Arm Manipulators -Robotic Surgery: The role of robotic arms in minimally invasive surgery, such as the Da Vinci Surgical System. -Rehabilitation Robotics: Robotic arms used for physical therapy and assistive devices to aid in patient recovery. -Medical Diagnostics: Use of robotic arms in laboratories for sample handling, testing, and analysis. 5.3. Maintenance and Troubleshooting Techniques -Routine Maintenance of Robotic Arms: Preventive measures like cleaning, lubrication, and calibration to ensure optimal performance. -Diagnosing and Fixing Common Failures: Troubleshooting issues such as power failure, actuator malfunction, or software bugs. -Troubleshooting Techniques: Methods for diagnosing sensor issues, actuator faults, and communication errors. 5.4. Future Trends and Developments in Robotic Arm Manipulators -Artificial Intelligence and Machine Learning: How AI is being integrated into robotic arms for enhanced autonomy, decision-making, and adaptive learning. -Collaborative Robots (Cobots): The rise of robots designed to work alongside humans in shared workspaces, enhancing safety and productivity.

9. SUGGESTED SPECIFICATION TABLE FOR QUESTIONPAPER DESIGN:

Unit No.	Unit Title	Teaching Hours	Distribution of Theory Marks			
			R Level	U Level	A Level	Total Marks
I	Introduction to Robotic Arm Manipulators	6	4	6	4	14
II	Robot Arm Control System & Sensors	8	4	4	6	14
III	Control Systems for Robotic Arm Manipulators	8	6	4	4	14
IV	Programming and Operation of Robotic Arm Manipulators	10	4	4	6	14
V	Applications and Maintenance of Robotic Arm Manipulators	10	4	6	4	14
Total		**42**	**22**	**24**	**24**	**70**

Legends: *R=Remember, U=Understand, A=Apply and above (Revised Bloom's taxonomy)*

Note*: This specification table provides general guidelines to assist student for their learning and to teachers to teach and question paper designers/setters to formulate test items/questions assess the attainment of theUOs. The actual distribution of marks at different taxonomy levels (of R, U and A) in the question paper may vary slightly from above table.*

10. SUGGESTED STUDENT ACTIVITIES

Other than the classroom and laboratory learning, following are the suggested student-related ***co-curricular*** activities which can be undertaken to accelerate the attainment of the various outcomes in this course: Students should conduct following activities in group and prepare reports of about 5 pages for each activity, also collect/record physical evidences for their (student's) portfolio which will be useful for their placement interviews:

1. Design and Build a Robotic Arm: Divide students into teams and ask them to design and build a robotic arm using everyday materials like cardboard, motors, and sensors. This activity encourages creativity, problem-solving, and hands-on learning.
2. Programming Challenge: Provide students with a robotic arm simulator or a real robotic arm and challenge them to program it to perform a specific task, such as picking and placing objects. This activity develops programming skills and problem-solving abilities.

3. Case Study Presentation: Assign students a case study of a company that uses robotic arm manipulators in their production process. Ask them to research and present on the benefits, challenges, and future prospects of using robotic arm manipulators in that industry.

4. Robotics Arm Manipulator Scavenger Hunt: Create a scavenger hunt that requires students to find and identify different components of a robotic arm manipulator, such as motors, sensors, and control systems. This activity encourages active learning and familiarizes students with the hardware components.

5. Group Discussion: Ethics and Safety: Organize a group discussion on the ethics and safety considerations of using robotic arm manipulators in various industries. Ask students to consider

questions like "What are the potential risks and benefits of using robotic arm manipulators?" and "How can we ensure the safe operation of robotic arm manipulators?"

6. Project-Based Learning: Automated Work cell: Divide students into teams and ask them to design and propose an automated work cell that incorporates a robotic arm manipulator. The work cell should perform a specific task, such as assembly or inspection. This activity encourages students to apply theoretical knowledge to real-world problems and develop problem-solving skills.

11. SUGGESTED SPECIAL INSTRUCTIONAL STRATEGIES

Following Sample strategies teacher can use to accelerate the attainment of the various outcomes in this course:

a) Inspire Student to read books on development and evolution of industrial robot & its application.
b) Prepare a short note on applications of programming languages.
c) Guide students to make presentation on applications of Robot arm manipulator
d) List out various models used in data communications along with their advantages and limitations.
e) Guide students to make presentation on applications of Robot.

12. SUGGESTED PROJECT LIST:

NA

13. SUGGESTED LEARNING RESOURCES

S. No.	Title of Book	Author	Publication with place, year and ISBN
1.	Robotics, Vision & Control: Fundamental Algorithms in MATLAB	Peter Corke	Springer, 2017, ISBN: 3319544136, 9783319544137
2.	Industrial Robotics: Fundamentals	Larry T. Ross, Michael F. Walach, and Stephen Fardo	Goodheart-Willcox 2017 Third Edition, Textbook 978-1631269417
3.	Control Systems Engineering	Norman S. Nise	Wiley Publication, January 2018, 978-8126571833
4.	Robotics: Modelling, Planning and Control	Bruno Siciliano, Lorenzo Sciavicco, Luigi Villani, and Giuseppe Oriolo	Springer Nature, December 2008 978-1846286414

14. SOFTWARE/LEARNING WEBSITES:

i. V-REP
ii. Gazebo
iii. RoboDK
iv. Webots
v. ROBOguide
vi. Robostudio

15. PO-COMPETENCY-CO MAPPING:

Semester V	Robotic Arm Manipulator						
	POs						
Competency & Course Outcomes	**PO 1 Basic & Discipline specific knowledge**	**PO 2 Problem Analysis**	**PO 3 Design/ development of solutions**	**PO 4 Engineering Tools, Experiment-ation &Testing**	**PO 5 Engineering practices for society, sustainability & environment**	**PO 6 Project Management**	**PO 7 Life-long learning**
Competency	**Maintain various types of A.C. machines and three -phase transformers safely.**						
Identify Industrial robots & its types	3			3	1		3
Identify and select various grippers and understand various steps in assembling process.	3		2		2	1	3
To control and understand functions of robotic components.	3			3	1		2
To understand about various robot simulator and application software	2	2	1	2		1	3
To understand various robot arm manipulator application and maintenance process.	2	3	1	2		1	3

*Legend: '**3'** for high, '**2**' for medium, **'1'** for low and **'-'** for no correlation of each CO with PO.*

16. COURSE CURRICULUM DEVELOPMENT COMMITTEE

Member – Board of Studies (GTU), Electrical and Allied branches

Prof. Suresh Z. Shyara, IC Engineering, AVPTI, Rajkot

Prof. Mahesh J. Vadhavaniya, IC Engineering, Government Polytechnic, Palanpur

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