Gujarat Technological University (GTU)

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

Semester – III

Course Title: Basics of Robotics

(Course Code: 1334102)

Diploma programme in which this course is offered	Semester in which offered
Automation and Robotics	3rd Semester

1. RATIONALE

The purpose of this course is to present an introduction to the multidisciplinary field of automation and robotics for industrial applications. The course initially covers the fundamental concepts of robot building and its application in real and industrial world. It covers the concepts of robot kinematics and methods in trajectory and motion planning of a robot.

2. COMPETENCY

The purpose of this course is to help the student to attain the following industry identified competency through various teaching learning experiences:

- **Able to select types of robots and its end effectors.**
- **Able to calculate the robot position and orientation.**
- **Able to understand concept of robot kinematics.**

3. COURSE OUTCOMES (COs)

The practical exercises, the underpinning knowledge and the relevant soft skills associated with this competency are to be developed in the student to display the following COs:

CO1	Classify types of robots and identify its subsystems.
CO2	Select an actuator and its gripper/s for a robot based on given application
CO3	Calculate robot position and orientation.
CO4	Identification of robot programming language.
CO5	Summarize various industrial and non-industrial applications of robots.

Practical COs:

CO1	Understanding working of robotic grippers.
CO2	Calculate robot position and orientation in given coordinate system.
CO3	Identification of robot programming language and its usage.

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	4	5	30*	70	25	25	150

(*): Out of 30 marks under the theory CA, 10 marks are for assessment of the micro-project to facilitate integration of COs and the remaining 20 marks is the average of 2 tests to be taken during the semester for the assessing the attainment of the cognitive domain UOs required for the attainment of the COs.

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

5. SUGGESTED PRACTICAL EXERCISES

The following practical outcomes (PrOs) that are the sub-components of the COs. *Some of the **PrOs** 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	To study history and laws of robotics.	1	2Hrs
2	To study various subsystem of robotics.	1	4Hrs
3	To study basic parts of robot.	1	4Hrs
4	To study Block diagram of actuator system.	2	2Hrs
5	To perform DC motor direction control using H Bridge IC.	2	4Hrs
6	To perform DC Motor speed control using PWM.	2	4Hrs
7	To study construction and control of Stepper motor	2	2Hrs
8	To Study construction and control of Servo motors	2	2Hrs
9	To study construction and control of Induction motors	2	2Hrs
10	To study various types of grippers used in robotics.	2	2Hrs
11	To study kinematics of robotic arm.	3	2Hrs
12	To calculate position of a point in Cartesian coordinate system.	3	2Hrs
13	To study close chain and open chain mechanism in kinematics.	3	2Hrs
14	To classify robots based on coordinate system. Conversion of coordinates form one system to other	4	4Hrs
15	To study structure of robot language.	4	2Hrs
16	Introduction to V-REP Software.	4	4Hrs
17	Create a Program in V-REP for moving robot from one location to other	4	4Hrs
18	Introduction to robotics toolkit in MATLAB	4	4Hrs
19	Simulate a walking robot in MATLAB.	4	4Hrs
20	Study various robots models on RoboDK and prepare report on any 3.	5	2Hrs
21	Write offline program in MATLAB for Pick and place operation.	4	2Hrs
22	Write offline program in MATLAB for stacking operation.	4	2Hrs

Note

*i. More **Practical Exercises** can be designed and offered by the respective course teacher to develop the industry relevant skills/outcomes to match the COs. 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

This major equipment with broad specifications for the PrOs is a guide to procure them by the administrators to usher in uniformity of practical in all institutions across the state.

Sr. No.	Equipment Name	PrO. No.
1	DC Motors, motor drivers (L293D) and power supply. Connectors, function generators etc.	5,6
2	MATLAB Simulation software	15,16,18,19
3	V-REP software	13,14

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 Mirco project.
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 robotics.	1a. Understand Evolution of robotics over time. 1b. Define robot. 1c. Classify robot based on application and environment.	1.1: Brief History of robotics. 1.1.1: Laws of robotics. 1.2: Definition of a ROBOT. 1.3: Types of robots: 1.3.1: Based on Application

		1.3.1.1: Industrial robots 1.3.1.2: Service robots. 1.3.2: Based on Environment. 1.3.2.1: Fixed robots. 1.3.2.2: Mobile robots.
	1d. Discuss factors affecting cost of a robot.	1.4: Robot economics: 1.4.1: Price of robot. 1.4.2: Special tools. 1.4.3: Installation cost. 1.4.4: Maintenance. 1.4.5: Operating power. 1.4.6: Finance. 1.4.7: Depreciation. 1.4.8: Enhanced Productivity. 1.4.9: Improved Quality.
	1e. Explain safety measures to be followed while working with and around robots.	1.5: Safety practices with robots.
	1f. Explain Robot subsystems and its components.	1.6: Robot Subsystems: 1.6.1: Motion Subsystem: 1.6.1.1: Manipulators. 1.6.1.2: End-Effectors. 1.6.1.3: Actuators. 1.6.1.4: Transmission. 1.6.2: Recognition Subsystem: 1.6.2.1: Sensors. 1.6.2.2: Analog to digital converter. 1.6.3: Control Subsystem. 1.6.3.1: Digital Controller. 1.6.3.2: Digital to analog Converter. 1.6.3.3: Amplifiers.
	1g. Classification of robots based on coordinate system they use, actuator they use and control method used by them.	1.7: Classification of robots based on coordinate systems, actuators, and control method: 1.7.1: Coordinate system: 1.7.1.1: Cartesian. 1.7.1.2: Cylindrical. 1.7.1.3: Spherical. 1.7.1.4: Articulated. 1.7.2: Actuators systems. 1.7.3: Control Methods: 1.7.3.1: Servo/Non-Servo Control. 1.7.3.2: Motion Control.

Unit – II Actuators and Grippers	2a. Explain robotic actuators and its components. 2b. Classify robotics actuators and explain their working. 2c. Explain factors affecting selection of actuators. 2d. Explain robotic grippers. 2e. Classify robotic grippers. 2f. Explain factors affecting design and selection of grippers.	2.1: Introduction to robotic actuators: 2.1.1: Block Diagram of an actuator system 2.1.2: Subsystems of actuator system: 2.1.2.1: Power supply, 2.1.2.2: Power amplifier, 2.1.2.3: Servomotor, and 2.1.2.4: Transmission system. 2.2: Classification of actuators: 2.2.1: Pneumatic actuators, 2.2.2: Hydraulic actuators, 2.2.3: Electric actuators: 2.2.3.1: DC motor. 2.2.3.2: AC motor. 2.2.3.3: Induction motor. 2.2.3.4: Stepper motors. 2.2.3.5: Linear actuators. 2.3: Factors affecting selection of actuators. 2.4: Introduction to Grippers. 2.5: Classification of grippers: 2.5.1: Mechanical grippers. 2.5.2: Magnetic grippers. 2.5.3: Vacuum grippers. 2.5.4: Adhesive grippers. 2.5.5: Tools as grippers. 2.6: Factors affecting design and Selection of grippers.
Unit – III Introduction to Kinematics	3a. Introduction to kinematics. 3b. types of links in kinematics. 3c. Explain kinematic constrains. 3d. Explain types of joints used in robots. 3e. Explain Chain in kinematics. 3f. Explain and calculate Degree of freedom for given body. 3g. Explain and calculate position and orientation of rigid body in space.	3.1: What is kinematics? 3.2: Types of kinematic links: 3.2.1: Rigid link. 3.2.2: Flexible link. 3.2.3: Floating link. 3.3: Kinematic pair/constrains. 3.3.1: Types of constrains 3.3.2: Classification of kinematic pairs. 3.4: Common types of robotic joints 3.5: Kinematic chain: 3.5.1: Closed chain mechanism. 3.5.2: Open chain mechanism. 3.6: Degree of freedom (DOF) 3.7: Position and orientation of rigid body in space. 3.7.1: Configuration space 3.7.2: Coordinate systems 3.7.2.1: Cartesian coordinate system 3.7.2.2: Cylindrical coordinate

	3h. Identification of position of a point and vector in given coordinate system.	system 3.7.2.3: Spherical Coordinate system 3.8: Representation of points and vectors in coordinate systems.
Unit – IV Control Hardware and Robot Programming	4a. Control considerations in robot. 4b. Explain hardware architecture for control of robot. 4c. Explain Joints control in robots. 4d. Explain computational speed for various mathematical operations. 4e. Explain languages and its structure used for robot programming. 4f. Explain methods used for programming a robot.	4.1: Control Considerations 4.1.1: Control modules 4.1.2: Modules for advance robots 4.2: Hardware Architecture 4.2.1: BUS 4.2.2: System board 4.2.3: Kinematics board 4.2.4: Servo board 4.2.5: force board & vision board 4.3: Hardware for Joint Controllers 4.4: Computational Speed: 4.4.1: Using Integer Arithmetic 4.4.2: Computing Trigonometric Functions 4.4.3: Matrix Operations 4.4.4: Hardware Considerations 4.5: Robot Languages 4.5.1: Requirement for robot language 4.5.2: Structure of robot language 4.5.3: Different robot languages 4.6: Robot Programming 4.6.1: Online Programming 4.6.2: Offline programming 4.6.3: Robot oriented programming 4.6.4: Task level programming
Unit - V Robotics Industry and Robotics in Industry.	5a. Introduction to robotics industry. 5b. List and explain various applications of robot in industry. 5c. Space technology applications of robotics. 5d. Defense applications of robotics 5e. Medical and health service applications of robotics.	5.1: Introduction to robotic industry. 5.2: Industrial Applications of robots: 5.2.1: Material Handling 5.2.2: Processing 5.2.2.1: Welding (Spot, Arc) 5.2.2.2: Spray painting 5.2.2.3: Machining (Drilling, Deburring) 5.2.2.4: Cutting. 5.1.3: Assembling. 5.3: Application of robotics in space technology 5.4: Defense and military applications of robots. 5.5: Medical and health service applications.

***Note**: The UOs need to be formulated at the 'Application Level' and above of Revised Bloom's Taxonomy' to accelerate the attainment of the COs and the competency.*

9. SUGGESTED SPECIFICATION TABLE FOR SEMINAR FINAL ESE (VIVA) DESIGN

Unit No.	Unit Title	Teaching Hours	Distribution of Theory Marks			
			R Level	U Level	A Level	Total Marks
I	Introduction to robotics and its industrial applications.	8	4	6	4	14
II	Actuators and Grippers	10	4	4	6	14
III	Introduction to Kinematics	8	6	4	4	14
IV	Control Hardware and Robot Programming	8	4	4	6	14
V	Robotics Industry and Robotics in Industry.	8	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 the UOs. 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:

a) Prepare cardboard models of 2 DOF and 3 DOF robotic arms.
b) Give seminar on drones and its controls.
c) Undertake a market survey of different types of robots used in industries.
d) Give seminar on advancement in robotics with development of AI.

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 robotics, instruct them to take notes in form of summary
b) Prepare a short note on applications of robot in defense industry.
c) Guide students to make presentation on various applications of robotics in medical field in small groups.
d) List out various programming languages used in robotics along with their advantages and limitations.

e) Make a model for 3D Cartesian coordinate system and explain calculation of position of point, vector and plane in it.

12. SUGGESTED MICRO-PROJECTS

The micro-project could be industry application based, internet-based, workshop based, laboratory-based or field-based. Each micro-project should encompass two or more COs which are in fact, an integration of PrOs, UOs and ADOs. Each student will have to maintain a dated work diary consisting of individual contributions in the project work and give a seminar presentation of it before submission. The total duration of the micro-project should not be less than 16 (sixteen) student engagement hours during the course. The student ought to submit a micro-project by the end of the semester to develop the industry oriented COs. A suggestive list of micro-projects is given here. This has to match the competency and the COs. Similar micro-projects could be added by the concerned course teacher:

1) Prepare a cardboard model of 2DOF robotic arm.
2) Prepare a cardboard model of 3DOF robotic arm.
3) Prepare a cardboard model of pick and place robot.
4) Prepare a model for demonstration of hydraulics.
5) Prepare a model for demonstration of Gripper mechanism.
6) Prepare a cardboard model for demonstration of rigid links
7) Prepare a cardboard model for demonstration of flexible links
8) Prepare a cardboard model for demonstration of floating links

13. SUGGESTED LEARNING RESOURCES (MUST READ ONES!!!)

S. No.	Title of Book	Author	Publication with place, year and ISBN
1	Introduction to robotics	Prof. Subair kumar Shah	McGraw Hill Education (India) Private Limited ISBN (13): 978-93-3290-280-0 ISBN (10): 93-3290-280-1
2	Robotics Simplified	Dr. Jisu Elsa Jacob Manjunath N	BPB Publications India ISBN: 978-93-91030-26-1
3	Fundamentals of Robotics	Prof. Dilip Kumar Pratihar	Narosa Publication House Pvt. Ltd., New Delhi, ISBN (13): 978-8184875775 ISBN (10): 8184875770
4	Robotics and Control	R K Mittal; I Nagrath	McGraw Hill Education ISBN (10): 9780070482937
5	Fundamentals of Robot Technology	D J Todd	Kogan Page Ltd 120 Pentonville Road, London Nl 9JN ISBN-13: 978-94-011-6770-3 e-ISBN-13: 978-94-011-6768-0

14. SOFTWARE/LEARNING WEBSITES

1. **MATLAB**
2. **V-REP**
3. **https://www.futurelearn.com/**
4. **https://ocw.mit.edu/ (MIT open course)**
5. **ProE**
6. **Solid Edge.**

15. PO-COMPETENCY-CO MAPPING

Semester III	Basics of Robotics (Course Code: 1334102)						
	POs						
Competency & Course Outcomes	PO 1 Basic & Discipline specific knowledge	PO 2 Problem Analysis	PO 3 Design/ development of solutions	PO 4 Engineering Tools, Experimentation &Testing	PO 5 Engineering practices for society, sustainability & environment	PO 6 Project Management	PO 7 Life-long learning
Classify types of robots and identify its subsystems.	3	1	-	-	-	1	-
Select an actuator and its gripper/s for a robot based on given application	2	2	1	2	-	1	2
Calculate robot position and orientation.	3	3	2	2	-	1	2
Identification of robot programming language.	2	2	1	2	1	-	2
Summarize various industrial and non-industrial applications of robots.	3	1	-	-	-	1	1

Legend: '**3**' for high, '**2**' for medium, '**1**' for low or '**-**' for the relevant correlation of each competency, CO, with PO/ PSO

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

Prof. Urvish P. Soni, IC Engineering, Government Polytechnic, Ahmedabad

Prof. Parth S. Thaker, IC Engineering, Government Polytechnic, Gandhinagar

Prof. Zankhana D. Mehta, IC Engineering, Government Polytechnic, Ahmedabad

GTU Resource Persons

Prof. Jigar V. Jariwala, IC Engineering, Government Polytechnic, Gandhinagar

Prof. Parth S. Thaker, IC Engineering, Government Polytechnic, Gandhinagar