GUJARAT TECHNOLOGICAL UNIVERSITY

Program Name: Engineering

Level: Diploma

Branch: Automation and Robotics

Course / Subject Code: DI03041011

Course / Subject Name: Robotics Simulation Practices

w. e. f. Academic Year:	2024-25
Semester:	3rd
Category of the Course:	ESC

Prerequisite:	Students are expected to have foundational knowledge and hands-on experience in the following areas before enrolling in this course: Basic Programming Skills: Ability to write, debug, and execute programs in at least one programming language (preferably Python or C++) for logical thinking and algorithm development. Fundamentals of Robotics: Understanding of robot components, coordinate systems, degrees of freedom, kinematics (forward and inverse), and basic robot control mechanisms. Electrical and Electronics Fundamentals: Familiarity with circuits, microcontrollers, sensors, and actuators commonly used in robotic systems. Basic Linux and Terminal Usage: Comfort with navigating the Linux environment and using command-line interfaces, especially relevant for working with ROS (Robot Operating System). Mathematical Foundation: Basic concepts of linear algebra, trigonometry, and calculus, particularly for understanding robotic movement and simulation.
Rationale:	This course has been designed for diploma students through which they can learn the basics of how to create virtual environments that mimic real-world scenarios, students can rigorously simulate and refine robotic systems without the constraints and expenses associated with physical prototypes. This approach mitigates risks by identifying potential issues before deployment, ensuring the safety and reliability of robots in diverse applications. Simulation enables iterative design simulation and rapid prototyping, accelerating the development cycle and fostering innovation. It promotes accessibility to a broader audience, allowing students and enthusiasts to experiment with robotics without the need for specialized hardware. Furthermore, simulations facilitate scalability testing, environmental exploration, and the generation of large datasets for training different models.

Course Outcome:

After Completion of the Course, Student will able to:

No	Course Outcomes	RBT Level
01	Illustrate concept of robotic simulation system	U
02	Demonstrate Proficiency in Robotic Simulation Tools	A
03	Apply programming functions to create robot system model	A
04	Implement algorithms in robotic simulation environment	A
05	Experiment with hardware and software interaction for robotic simulation	A

**Revised Bloom's Taxonomy (RBT)*

Teaching and Examination Scheme:

Teaching Scheme (in Hours)			Total Credits L+T+ (PR/2)	Assessment Pattern and Marks				Total Marks
				Theory		Tutorial / Practical		
L	T	PR	C	ESE (E)	PA(M)	PA(I)	ESE (V)	
0	0	6	3	0	0	20	30	50

Suggested Course Practical List:

The following practical outcomes (PrOs) are the subcomponents of the Course Outcomes (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'.

Sr. No.	Practical Outcomes (PrOs)	CO	Approx. Hrs. Required
1	Install and set up a robotic simulation environment, such as ROS, Gazebo, or V-REP.	CO1	2

Sr. No.	Practical Outcomes (PrOs)	CO	Approx. Hrs. Required
2	Design a basic robot model using the simulation software's modeling tools.	CO1	2
3	Simulate the basic motion of a robot, including forward and inverse kinematics	CO1	2
4	Integrate sensors (e.g., cameras, lidars) into the robot model and simulate their data output.	CO2	2
5	Implement a simple path planning algorithm (e.g., A* algorithm) for the robot to navigate through a predefined environment.	CO3	2
6	Introduce dynamic elements to the simulation, such as moving obstacles.	CO3	4
7	Implement collision detection mechanisms and avoidance. Strategies within the simulation	CO3	4
8	Simulate multiple robots working collaboratively on a task or navigating a shared environment.	CO4	4
9	Implement a PID controller for controlling the robot's movement and tune the controller parameters	CO4	4
10	Design and simulate a robotic arm performing manipulation tasks	CO3	4
11	Connect simulated robots to real-world hardware (e.g., microcontrollers) and observe the interaction.	CO5	4
12	Create a simulation where a robot picks an object from one location and places it in another	CO3	4
13	Simulate a robot that can avoid obstacles in its environment using sensors.	CO4	4
14	Design and simulate different types of grippers for a robotic arm.	CO3	4
15	Model and simulate a robotic welding process with accuracy and precision.	CO3	4
16	Develop a simulation of a soccer game where robots act as players.	CO4	4

Sr. No.	Practical Outcomes (PrOs)	CO	Approx. Hrs. Required
17	Implement a teleoperation system where a robot is controlled remotely.	CO5	4
18	Simulate a robot performing a warehouse automation task (e.g., retrieving and placing packages using AGV).	CO4	4
19	Integrate voice command controls into a robotic simulation using speech recognition tools (e.g., ROS + Google Speech API).	CO5	4
20	Simulate an industrial inspection task using a robot equipped with a camera and image recognition.	CO4	4
21	Develop a simulation of a robot performing painting or spraying in a constrained environment.	CO4	4
22	Implement a learning algorithm (e.g., reinforcement learning) for obstacle avoidance or navigation.	CO5	4
23	Create a simulation of a service robot in a smart home environment (e.g., delivering items or assisting with tasks).	CO4	4
24	Model a drone (UAV) in a 3D simulation environment and simulate basic flight controls and object tracking.	CO4	4
25	Simulate a human-robot interaction scenario using gesture or touch-based input in a virtual environment.	CO5	4
	TOTAL 90 Hrs		

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.*

Sr. No.	Sample Performance Indicators for the PrOs	Weightage in % *
1	Conceptual clarity.	20
2	Experimental setup, Procedure and conduction by following safety practices.	50
3	Interpretation of Results and Ethical values.	30
Total		**100**

List of Laboratory/Learning Resources Required:

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

Sr.No.	Equipment Name with Broad Specifications	PrO. No.
1	Computer system with latest operating system.	All
2	Robotic Arm Kit	9,10,11,12, 14,15

Suggested Project List:

Only one micro-project is planned to be undertaken by a student that needs to be assigned to him/her in the beginning of the semester. Micro-projects are group-based (group of 3 to 5). 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 duration of the micro project should be about **12-14 *(fourteen to sixteen) student engagement hours*** during the course. The students ought to submit 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:

a) Simulate the movement of a robotic arm using forward and inverse kinematics.
b) Create a simulation where a robot picks an object from one location and places it in another
c) Implement a path planning algorithm for a robot to navigate through obstacles.
d) Develop a simulation where a robot uses computer vision to recognize objects
e) Simulate the navigation of a mobile robot in an indoor environment.
f) Implement collision detection algorithms to prevent robot collisions with objects.
g) Integrate a simulated robot with the Robot Operating System (ROS).
h) Simulate a swarm of robots cooperating to achieve a common goal.
i) Optimize the trajectory of a robotic arm to achieve faster and smoother movements.

Suggested Activities for Students:

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 perform following activities in group (or individual) and prepare reports of about 5 pages for each activity. They should also collect/record physical evidence for their (student's) portfolio which may be useful for their placement interviews:

a. Present seminar on various topics from course content
b. Undertake micro-projects in teams
c. Mini project for industrial robotic application
d. Students are encouraged to register themselves in various MOOCs such as: Swayam, edx, Coursera, Udemy etc to further enhance their learning

e. Encourage students to participate in different competitions like hackathon, online competitions on codechef etc

Suggested Learning Resources

Sr. No.	Title of Book	Author	Publication with place, year and ISBN
1	Robotics, Vision, and Control: Fundamental Algorithms in MATLAB	Peter Corke	Springer
2	Introduction to Robotics: Mechanics and Control	John Craig	Pearson
3	Modern Robotics Mechanics, Planning, and Control	Kevin M. Lynch,Frank C. Park	Amazon
4	Introduction to autonomous mobile robots	Roland Siegwart, Illah Reza Nourbakhsh, Davide Scaramuzza.	MIT Press

Software/Learning Websites

a) http://www.kronotech.com/
b) http://www.ros.org/
c) http://gazebosim.org/
d) http://www.coppeliarobotics.com/
e) https://cyberbotics.com/
f) https://morse-simulator.github.io/
g) https://www.mathworks.com/products/robotics.html
h) https://pybullet.org/wordpress/
i) https://gym.openai.com/
j) http://vlabs.iitkgp.ernet.in/mr/

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