GUJARAT TECHNOLOGICAL UNIVERSITY (GTU)

Competency-focused Outcome-based Green Curriculum-2021 (COGC-2021)
VI – Semester

Course Title: **Robotic Operating System**
(Course Code: 4364104)

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

1. RATIONALE

The field of robotics is expanding rapidly, and with it comes the need for standardized, modular software frameworks that facilitate the development, simulation, and deployment of robotic systems. One of the most widely used platforms for these purposes is the **Robotic Operating System (ROS)**. A course focused on ROS is essential for a variety of reasons, ranging from the growing demand for automation and AI-driven technologies to the need for effective development tools in robotics

2. COMPETENCY

The course content should be taught and implemented with the aim to develop different types of skills so that students are able to acquire following competency. Below are the key competencies students should acquire upon completing the course.

1. Foundational Knowledge of Robotics and ROS.
2. Hands-on Proficiency with ROS Core Concepts
3. Working with ROS Tools.
4. Simulation and Virtual Environments
5. Software Development Practices

3. COURSE OUTCOMES (COs)

The practical exercises, the underpinning knowledge and the relevant soft skills associated with the identified competency are to be developed in the student for the achievement of the following COs:

CO-1	Understand Basic Knowledge of ROS dedicated to Robot.
CO-2	Demonstrate ROS Basic tools and command in different application.
CO-3	Understand different embedded system for ROS
C0-4	Use the Knowledge of C ++ and python language for Robot Programming in ROS
CO-5	Understanding and getting started with ROS-Industrial packages

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

(*):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

Following practical outcomes (PrOs) are the sub-components 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)	Unit No.	Approx. Hrs. Required
1	To provide a foundational understanding of robotics and the robot operating system (ROS) including its core concepts, categories and real world application.	**1**	**2**
2	To install Linux Ubuntu 22.01 LTS On window 11 using oracle Virtulbox.	1	2
3	Implement virtual machine Concept and installation of ROS environment.	1	2
4	Creation of basic inters nodes and communications between Talker listener nodes.	2	2
5	Create RSO 2 Nodes using the Turtlesim simulator of the ROS environment.	3	4
6	Install and configure the Python environment. Run basic Python commands to verify the Python environment.	4	4
7	Write a NumPy program to implement operation.	4	4
8	Write a Pandas program to implement operation	4	4
9	Installing ROS-Industrial packages	5	2
10	Creating the MoveIt configuration for an industrial robot	5	2
		Total	**28**

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. *Care must be taken in assigning and assessing study report as it is a Second-year study report. Study report, data collection and analysis report must be assigned in a group. Teacher has to discuss about type of data (which and why) before group start their market survey.*

6. MAJOR EQUIPMENT/ INSTRUMENTS REQUIRED

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

Sr. No.	Equipment Name with Broad Specifications	PrO. No.
1.	Computer with latest configuration with Windows/Linux/Unix Operating System.	ALL
2.	A CAD tools such as Autodesk Fusion 360, SolidWorks, Blender, And many others.	3,10
3.	Robot simulation Software Gazebo , CoppeliaSim, Turtlesim and Webots,Apache 2.0.	3,9,10
4.	Python and C ++	6,7,8

*Account in Autodesk website, documents, authority letter, transcript, I-card required

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 fulfill the development of this course competency.

a) Work as a leader/a team member.
b) Follow safety practices.
c) Follow ethical practices
d) Maintain tools and equipment
e) Practice environment friendly methods and processes. (Environment related)

The ADOs are best developed through the laboratory/field-based exercises. Moreover, the level of achievement of the ADOs according to Krathwohl's 'Affective Domain Taxonomy' should gradually increase as planned below:

i. 'Valuing Level' in 1st year
ii. 'Organization Level' in 2nd year.
iii. 'Characterization Level' in 3rd year.

8. UNDERPINNING THEORY

The major underpinning theory is given below based on the higher level UOs of *Revised Bloom's taxonomy* that are formulated for development of the COs and competency. If required, more such UOs could be included by the course teacher to focus on attainment of COs and competency.

Unit	Unit Outcomes (UOs)	Topics and Sub-topics
Unit I. Robot Operating System ROS	1.a. explain Meta-operating system 1.b. List the objectives of ROS 1.c. List the components of ROS 1.d. Explain ROS ecosystem 1.e. Explain the History of ROS 1.f. Explain different versions of ROS 1.g. Explain Architecture of ROS 1.h. List Key Features of ROS 1.i. List the Applications of ROS 1.j. List the pros & cons of ROS 1.k. List different types of ROS 1.l. Explain popular ROS computing platform 1.m. List robots and sensors supporting ROS	1.1 Introduction to ROS 1.2 Meta-Operating System 1.3 Objectives of ROS 1.4 Components of ROS 1.5 ROS Ecosystem 1.6 History of ROS 1.7 ROS Versions 1.7.1 Version Rules 1.7.2 Version Release Period 1.7.3 Selecting a Version 1.8 Architecture of ROS 1.9 Key Features of ROS 1.10 Applications of ROS 1.11 Pro and Cons of ROS 1.12 Specification 1.13 Types of ROS 1.14 Popular ROS Computing Platform 1.15 Robots and Sensors Supporting ROS
Unit II: ROS Basics Tools And Commands	3.a Explain different ROS terminology. 3.b Explain Message Communication etween Nodes. 3.c Describe Message Communication Flow. 3.d How to use ROS	2.1. ROS Terminology 2.2. Message Communication 2.2.1. Topic 2.2.2. Service 2.2.3. Action 2.2.4. Parameter 2.2.5. Message Communication Flow 2.3. Message

Unit	Unit Outcomes (UOs)	Topics and Sub-topics
	message data types as an array, corresponding C ++ and Python data types. 3.e Describe Coordinate Transformation (TF). 3.f Explain ommunication between heterogenous Devices. 3.g Explain ROS Commands . 3.h Prepare list of ROS shell 3.i Command, ROS Execution 3.j Commands and ROS 3.k Information Commands	2.3.1. msg File 2.3.2. srv File 2.3.3. action File 2.4. Name 2.5. Coordinate Transformation (TF) 2.6. Client Library 2.7. Communication between Heterogeneous Devices 2.8. ROS Command List 2.9. ROS Shell Commands 2.9.1. roscd: ROS Change Directory 2.9.2. rosls: ROS File List 2.9.3. rosed: ROS Edit Command 2.10. ROS Execution Commands 2.10.1. roscore: Run roscore 2.10.2. rosrun: Run ROS Node 2.10.3. roslaunch: Launch Multiple Nodes 2.10.4. rosclean: Examine and Delete ROS Logs 2.11. ROS Information Commands 2.11.1. Run Node 2.11.2. rosnode: ROS Node 2.11.3. rostopic: ROS Topic 2.11.4. rosservice: ROS Service 2.11.5. rosparam: ROS Parameter 2.11.6. rosmsg: ROS Message Information 2.11.7. rossrv: ROS Service Information 2.11.8. rosbag: ROS Log Information 2.12. ROS Catkin Commands 2.13. ROS Package Commands
Unit 3: Embedded System for ROS	3.l Explain OpenCR interface configuration. 3.m Explain OpenCR block diagram 3.n Explain rosserial server (for PC) and client (for embedded system) 3.o Draw Structure of the rosserial Packet 3.p Explain rosserial server (for PC) and client (for embedded system). 3.q Draw Structure of the rosserial Packet. 3.r Explain each ROS ersion 3.s Explain controlling a robot using topics	3.1. OpenCR 3.1.1. Characteristics 3.1.2. Board Specification 3.1.3. Establish Development Environment 3.1.4. OpenCR Examples 3.2. rosserial 3.2.1. rosserial server 3.2.2. rosserial client 3.2.3. rosserial Protocol 3.2.4. Constraints of rosserial 3.2.5. Installing rosserial 3.2.6. Examples of rosserial 3.3. TurtleBot3 Firmware 3.3.1. TurtleBot3 Burger Firmware 3.3.2. TurtleBot3 Waffle and Waffle Pi Firmware 3.3.3. TurtleBot3 Setup Firmware 3.4. Robot Supported by ROS 3.5. TurtleBot3 Series

Unit	Unit Outcomes (UOs)	Topics and Sub-topics
		3.6. TurtleBot3 Hardware 3.7. TurtleBot3 Software 3.8. TurtleBot3 Topic 3.8.1. Subscribed Topic 3.8.2. Controlling a Robot using Subscribe Topic 3.8.3. Published Topic 3.8.4. Verify Robot Status using Published Topics
Unit 4: Fundamentals of C++ and Python for Robot programming	4.a Understand the the fundamentals of Object Oriented Concepts in C++. 4.b Differentiate between C++ classes and structs in C++, 4.c Explain object-oriented programming concepts, such as access modifiers and inheritance, file operations, namespaces, exception handling, and the fundamentals of Python programming in Ubuntu Linux. 4.d Apply the knowledge of Python programming for working with ROS. 4.e Apply the fundamentals of Python, such as handling input, output, Python loops, functions, and class operations 4.f Understand concepts of Machine Learning and Deep Learning for ROS	4.1 Timeline: The C++ Language 4.2 The Differences Between Classes and Structs 4.3 C++ Classes and Objects 4.4 Class Access Modifier 4.5 C++ Inheritance 4.6 C++ Files and Streams 4.7 Namespaces in C++ 4.8 C++ Exception Handling 4.9 Timeline: The Python Language 4.10 Python in Ubuntu Linux 4.10.1 Introduction to Python Interpreter 4.11 Python Basics 4.11.1 Static and Dynamic Typing 4.11.2 Code Indentation 4.11.3 Semicolons 4.11.4 Python Variables 4.11.5Python Input and Conditional statement 4.11.6 Python: Loops 4.11.7 Python: Functions 4.11.8 Python: Handling Exception 4.11.9 Python: Classes 4.11.10 Python: Files 4.11.11 Python: Modules 4.12 Python: Machine Learning and Deep Learning 4.13 Python: Computer Vision 4.14 Python: Robotics
Unit 5: ROS for Industrial Robots	5.a Understanding and getting started with ROS-Industrial packages 5.b Creating a URDF for an industrial robot and interfacing it with MoveIt 5.c Working with the MoveIt configuration for a Universal Robots arm	5.1 Understanding ROS-Industrial packages 5.2 ROS-Industrial – a brief history 5.2.1ROS-Industrial packages 5.2.2 Block diagram of ROS-Industrial packages 5.3 Creating a URDF for an industrial robot 5.4 Creating the MoveIt configuration for an industrial robot

Unit	Unit Outcomes (UOs)	Topics and Sub-topics
	5.d Understanding ROS-Industrial robot support packages 5.e Understanding ROS-Industrial robot client and driver packages 5.f Working with IKFast algorithms and the MoveIt IKFast plugin	5.5 Updating the MoveIt configuration files 5.6 The ROS interface for Universal Robots 5.7 Understanding the MoveIt configuration of a Universal Robots arm 5.8 Working with MoveIt configuration for ABB Robots

9. SUGGESTED SPECIFICATION TABLE FOR QUESTION PAPER DESIGN

Unit No.	Unit Title	Teaching Hours	Distribution of Theory Marks			
			R Level	U Level	A Level	Total Marks
1	**Robot Operating System ROS**	**6**	**3**	**4**	**-**	**7**
2	**ROS Basics Tools And Commands**	10	**6**	**6**	**7**	**19**
3	**Embedded System for ROS**	**6**	**3**	**4**	**-**	**7**
4	**Fundamentals of C++ and Python for Robot programming**	**12**	**9**	**7**	**7**	**23**
5	**ROS for Industrial Robots**	**8**	**3**	**4**	**7**	**14**
Total		**42**	**17**	**23**	**30**	**70**

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

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

a) Select two industrial components (approved by teacher) and list various machine tools and operations used to produce these components.
b) Prepare a list of surrounded items which are prepared by machining processes.
c) Collect/download at least four different machine tool catalogues and make report of that with price.
d) List various machine tools (min. 5 machine) currently using in market for different operation to perform.
e) Identify the process use for re-sharpening different types of tools and prepare report for minimum 3 tools

11. SUGGESTED SPECIAL INSTRUCTIONAL STRATEGIES (if any)

These are sample strategies, which the teacher can use to accelerate the attainment of the various outcomes in this course:

a) Massive open online courses (***MOOCs***) may be used to teach various topics/sub topics.

b) To acquire knowledge of basic machine, tool and their operation arrange two or more **industrial visit** of production industry. After visit student must be submit their industrial visit report.

c) Guide student(s) in undertaking micro-projects.

d) ***'L' in section No. 4***means different types of teaching methods that are to be employed by teachers to develop the outcomes.

e) About ***20% of the topics/sub-topics*** which are relatively simpler or descriptive in nature is to be given to the students for ***self-learning***, but to be assessed using different assessment methods.

f) With respect to ***section No.10***, teachers need to ensure to create opportunities and provisions for ***co-curricular activities***.

12. SUGGESTED MICRO-PROJECTS

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. In the first four semesters, the micro-projects are group-based (group of 3 to 5). However, **in the fifth and sixth semesters**, the number of students in the group should ***not exceed three.***

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 dated work diary consisting of individual contribution in the project work and give a seminar presentation of it before submission. The duration of the micro project should be about **14-16** ***(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:

1. STUDY OF Raspbeery pi.
2. Understanding the line follower system.
3. Create an electronics obstacles avoidance system.
4. Design a gesture control flow in robotics Applications.
5. Implement GaZebo in ROS
6. Path planning robot using Raspberry and ROS.
7. Robotics Arm Simulation using ROS.

13. SUGGESTED LEARNING RESOURCES

Sr. No	Title of Book	Author	Publication with place, year and ISBN
1	ROS Robot Programming From the basic concept to practical programming and robot application	YoonSeok Pyo HanCheol Cho RyuWoon Jung TaeHoon Lim	Published by ROBOTIS Co.,Ltd, ISBN 979-11-962307-1-5 1st edition 2017
2	Robot Operating System for Absolute Beginners Robotics Programming Made Easy	Lentin Joseph	Apress ISBN-13 (pbk): 978-1-4842-3404-4 ISBN-13 (electronic): 978-1-

Sr. No	Title of Book	Author	Publication with place, year and ISBN
			4842-3405-1
3	Mastering ROS for Robotics Programming Third Edition	Lentin Joseph Jonathan Cacace	Published by Packt Publishing Ltd. ISBN 978-1-80107-102-4 2021

14. SOFTWARE/LEARNING WEBSITES

Sr no	Resource name	Link
1	TurtleBot Homepage	http://www.turtlebot.com
2	TurtleBot3 Wiki Page	http://turtlebot3.robotis.com
3	TurtleBot3 Video	https://www.youtube.com/c/ROBOTISOpenSourceTeam
4	Lecture Material	https://github.com/ROBOTIS-GIT/ros_seminar
5	Reference Material	https://github.com/ROBOTIS-GIT/ros_book
6	Source Code for Tutorials	https://github.com/ROBOTIS-GIT/ros_tutorials
7	OpenCR (	https://github.com/ROBOTIS-GIT/OpenCR-Hardware
8	OpenManipulator	Chain: http://www.robotis.com/service/download.php?no=690 SCARA: http://www.robotis.com/service/download.php?no=691 Link: http://www.robotis.com/service/download.php?no=692
9	Source Code for Tutorials	https://github.com/ROBOTIS-GIT/ros_tutorials

15. PO-COMPETENCY-CO MAPPING

Semester VI	ROBOT OPERATING SYSTEM						
	POs						
	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7
Competency & Course Outcomes	Basic & Discipline specific knowledge	Problem Analysis	Design/ development of solutions	Engineering Tools, Experimentation & Testing	Engineering practices for society, sustainability & environment	Project Management	Life-long Learning

CO 1.Understand Basic Knowledge of ROS dedicated to Robot.	**2**	**-**	**2**	**2**	**2**	**3**	**2**
CO 2.Demonstrate ROS Basic tools and command in different application.	**2**	**-**	**3**	**2**	**3**	**2**	**2**
CO 3.Understand different embedded system for ROS	**2**	**-**	**3**	**3**	**2**	**3**	**3**
CO 4.Use the Knowledge of C ++ and python language for Robot Programming in ROS	**2**	**-**	**3**	**3**	**3**	**3**	**3**
CO 5.Understanding and getting started with ROS-Industrial packages	**2**	**-**	**2**	**2**	**2**	**2**	**2**

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

16. COURSE CURRICULUM DEVELOPMENT COMMITTEE

GTU Resource Persons

Sr. No	Name and Designation	Institute
1.	PATEL TARLESHKUMAR THAKORBHAI Lecturer In Mechanical Engineering	Government Polytechnic DAHOD
2.	Jigar Vimalkumar Jariwala Lecturer In Instrumentation & Control	Government Polytechnic, Gandhinagar

BOS Resource Persons

Sr. No.	Name and Designation	Institute
1.	Prof. Suresh Z. Shyara IC Engineering,	AVPTI, Rajkot.
2.	Prof. Parth S. Thaker, IC Engineering	Government Polytechnic, Gandhinagar