Robotics

Faculty Name : Narayanan Kallingal

Course Code: EXC 8041

Subject Name: Robotics

Academic year and term : 2018-19 Jan – April 2019

1. Syllabus

Subject Code	Subject Name	Teaching Scheme			Credits Assigned			
		Theory	Practical	Tutorial	Theory	TW/Practical	Tutorial	Total
EXC8041	Robotics	04	--	--	04	--	--	04

Subject Code	Subject Name	Examination Scheme							
		Theory Marks				Term Work	Practical	Oral	Total
		Internal assessment			End Sem. Exam				
		Test 1	Test 2	Avg. of Test 1 and Test 2					
EXC8041	Robotics	20	20	20	80	--	--	--	100

Module No.	Unit No.	Topics	Hrs.
1		**Fundamentals of Robotics**	03
	1.1	Robot Classification, Robot Components, Degrees of freedom, Joints, Coordinates, Coordinate frames, workspace, applications	
2		**Forward & Inverse Kinematics of Robots**	09
	2.1	Homogeneous transformation matrices, Inverse transformation matrices, Forward and inverse kinematic equations – position and orientation	
	2.2	Denavit-Hatenberg representation of forward kinematics, Inverse kinematic solutions, Case studies	
3		**Velocity Kinematics & Dynamics**	14
	3.1	**Differential motions and velocities :** Differential relati onship, Jacobian, Differential motion of a frame and ro bot, Inverse Jacobian,Singularities.	
	3.2	**Dynamic Analysis of Forces :** Lagrangian mechanics, Newton Euler formulation, Dynamic equations of robots, Transformation of forces and moment between coordinate frames	
4		**Robot Motion Planning**	04
	4.1	Concept of motion planning, Bug Algorithms – Bug1, Bug2, Tangent Bug	
5		**Potential Functions and Visibility Graphs**	08
	5.1	Attractive/Repulsive potential, Gradient descent, wave-front planner, navigation potential functions, Visibility map, Gene ralized Voronoi diagrams and graphs, Silhouette methods	
6		**Trajectory planning**	08
	6.1	Trajectory planning , Joint-space trajectory planning, Cartesian-space trajectories	
7		**Robot Vision**	06
	7.1	Image representation, Template matching, Polyhedral objects, Shape analysis, Segmentation, Iterative processing, Perspective transform.	
		Total	**52**

2. Course Outcomes:

Upon completion of this course students will be able to:

EXC8041.1: Describe the basics of Robotics
EXC8041.2: Describe and derive kinematics and dynamics of stationary and mobile robots.
EXC8041.3: Describe concepts of robot motion planning algorithms
EXC8041.4: Apply trajectory planning algorithms
EXC8041.5: Apply image processing in robotic vision

CO Level (Bloom's Taxonomy)

EXC8041.1: Understand
EXC8041.2: Understand
EXC8041.3: Understand
EXC8041.4: Apply
EXC8041.5: Apply

Relationship of course outcomes with program outcomes: Indicate 1 (low importance), 2 (Moderate Importance) or 3 (High Importance) in respective mapping cell.

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO 10**	**PO 11**	**PO 12**	**PSO 1**	**PSO 2**
EXC8041.1	3	-	-	-	-	-	-	-	-	-	-	-	-	-
EXC8041.2	3	3	-	-	-	-	-	-	-	-	-	-	-	-
EXC8041.3	3	3	-	-	-	-	-	-	-	-	-	-	-	-
EXC8041.4	3	3	-	-	-	-	-	-	-	-	-	-	-	-
EXC8041.5	3	3	-	-	-	-	-	-	-	-	-	-	-	-
Course Average	3	3	0	0	0	0	0	0	0	0	0	0	0	0

Justification of PO to CO mapping

EXC8041.1	**PO1**	Acquire the basic knowledge of Robotics
EXC8041.2	**PO1**	Acquire the basic knowledge of mathematics to analyze Direct and inverse kinematics
	PO2	Analyze Direct and inverse kinematics problems using basic knowledge of mathematics
EXC8041.3	**PO1**	Understand the concepts of robot motion planning algorithms
	PO2	Analyze robotic motion planning
EXC8041.4	**PO1**	Understand trajectory planning algorithms
	PO2	Apply trajectory planning algorithms
EXC8041.5	**PO1**	Acquire the knowledge of image processing in robotic vision
	PO2	Apply the knowledge of image processing in Robotic vision

Contribution to outcomes will be achieved through content delivery:
Modes of Content Delivery:

Modes of delivery

Modes of Delivery	**Brief description of content delivered**	**Attained COs**	**Attained POs**
Class room lecture	All modules	ALL	PO1,PO2
PPT	All modules	ALL	PO1,PO2

Assessment tool:	**Rubrics**		
Assignment	Timeline (2)	Level of content (4)	Reading and Understanding (4)
Laboratory Experiment	Timeline (2)	Understanding (4)	Performance (4)

CO Assessment Tools:

Course Outcome	***Assessment Method***					
	Direct Method (80 %)					***Indirect Method (20%)***
	Unit Tests		Assignments	Laboratory	Semester End Examination	Course exit survey
	1	2				
EXC8041.1	20%		15%	15%	50 %	100%
EXC8041.2	20%		15%	15%	50 %	100%
EXC8041.3		20%	15%	15%	50 %	100%
EXC8041.4		20%	15%	15%	50 %	100%
EXC8041.5		20%	15%	15%	50 %	100%

Lesson Plan

CLASS		BE Electronics, Semester VIII	
Academic Term		January – April 2019	
Subject		**Robotics (EXC 8041)**	
Periods (Hours) per week	***Lecture***	4	
	Practical	*--*	
	Tutorial	*--*	
Evaluation System		***Hours***	***Marks***
	Theory examination	3	80
	Internal Assessment	--	20
	Practical Examination	--	--
	Oral Examination	--	--
	Term work	--	--
	Total	--	100

Time Table	***Day***	***Time***
	Tuesday	12.00 noon – 1.00 pm
	Wednesday	11.00 am – 12.00 noon
	Thursday	11.00 am – 12.00 noon
	Friday	11.00 am – 12.00 noon

Course Content and Lesson plan

Module – 1 Models for Control Systems

	Lecture No.	**Date**		**Topic**	**Remarks(If any)**
		Planned	**Actual**		
	1	01 – 01 – 19	08 – 01 – 19	Robot classification, Robot components	Special Time Table
	2	02 – 01 – 19	09 – 01 – 19	Degree of freedom, Joints, Coordinates	
	3	03 – 01 – 19	09 – 01 – 19	Coordinate frames, work space, Applications	

Module - 2 Forward and Inverse Kinematics

	Lecture No.	**Date**		**Topic**	**Remarks(If any)**
		Planned	**Actual**		

	4	04 – 01 – 19	10 – 01 – 19	Transformation matrices, Inverse Transformation matrices	Special Time Table
	5	08 – 01 – 19	11 – 01 – 19	Homogeneous transformation matrices, Screw transformations	
	6	09 – 01 – 19	11 – 01 – 19	Forward kinematics, Arm matrix	
	7	10 – 01 – 19	15– 01 – 19	D-H algorithm	
	8	11 – 01 – 19	16 – 01 – 19	Case study	
	9	15 – 01 – 19	17– 01 – 19	Inverse kinematics	
	10	16 – 01 – 19	18 – 01 – 19	Inverse kinematics	
	11	17– 01 – 19	22 – 01 – 19	Inverse kinematics, solutions	
	12	18 – 01 – 19	23 – 01 – 19	Case study	
Module – 6 Trajectory planning					
	13	22 – 01 – 19	24– 01 – 19	Trajectory planning	
	14	23 – 01 – 19	25 – 01 – 19	Trajectory planning	
	15	24– 01 – 19	29 – 01 – 19	Joint space Trajectory planning	
	16	25 – 01 – 19	30 – 01 – 19	Joint space Trajectory planning	
	17	29 – 01 – 19	01 – 02 – 19	Cartesian space Trajectory planning	
	18	30 – 01 – 19	26 – 02 – 19	Cartesian space Trajectory planning	
Module –4 Robot Motion Planning					
	Lecture No.	**Date**		**Topic**	**Remarks(If any)**
		Planned	**Actual**		
	19	01 – 02 – 19	27 – 02 – 19	Concept of motion planning	
		04 – 02 – 19			Unit Test 1
	20	07 – 02 – 19	28 – 02 – 19	Bug Algorithms – Bug 1	
	21	08 – 02 – 19	01 – 03 – 19	Bug Algorithms – Bug 2	
	22	12 – 02 – 19	05 – 03 – 19	Bug Algorithms – Tangent Bug	
Module –7 Robotic Vision					
	Lecture No.	**Date**		**Topics**	**Remarks (If Any)**
		Planned	**Actual**		
	23	20 – 02 – 19	06 – 03 – 19	Image representation, Template matching	
	24	21 – 02 – 19	07 – 03 – 19	Polyhedral objects, Shape analysis	
	25	22 – 02 – 19	08 – 03 – 19	Segmentation	

	26	26 – 02 – 19	12 – 03 – 19	Iterative processing, Perspective transform.	
Module – 3 Velocity Kinematics and Dynamics					
	27	27 – 02 – 19	14 – 03 – 19	Differential Relationship	
	28	28 – 02 – 19	19 – 03 – 19	Differential Relationship Jacobian	
	29	01 – 03 – 19	20 – 03 – 19	Differential motion of a frame and Robot	
	30	05 – 03 – 19	22 – 03 – 19	Differential motion of a frame and Robot	
	31	06 – 03 – 19	26 – 03 – 19	Inverse Jacobian	
	32	07 – 03 – 19	27 – 03 – 19	Singularities	
	33	08 – 03 – 19	28 – 03 – 19	Lagrangian mechanics	
	34	12 – 03 – 19	29 – 04 – 19	Newton Euler formulation	
	35	13 – 03 – 19	02 – 04 – 19	Dynamic equation of Robotics	
	36	14 – 03 – 19	03 – 04 – 19	Transformation of forces and moment between coordinate frames	
Module – 5 Potential Functions and Visibility graphs					
	Lecture No.	**Date**		**Topic**	**Remarks(If any)**
		Planned	**Actual**		
	37	15 – 03 – 19	04 – 04 – 19	Attractive /Repulsive potential, Gradient Descent	
	38	19 – 03 – 19	05 – 04 – 19	Wave-front planner, navigation potential functions	
	39	20 – 03 – 19		Visibility map	
	40	22 – 03 – 19		Generalized Voronoi diagrams and graphs	
	41	26 – 03 – 19		Silhouette methods	
		08 – 04 – 19			Unit Test 2

Text Books:

1. Robert Shilling, Fundamentals of Robotics - Analysis and control, Prentice Hall of India
2. Saeed Benjamin Niku, “Introduction to Robotics – Analysis, Control, Applications”, Wiley India Pvt. Ltd., Second Edition, 2011
3. Howie Choset, Kevin M. Lynch, Seth Hutchinson, George Kantor, Wolfram Burgard, Lydia E. Kavraki and Sebastian Thrun, “Principles of Robot Motion – Theory, Algorithms and Implementations”, Prentice-Hall of India, 2005.
4. Mark W. Spong , Seth Hutchinson, M. Vidyasagar, “Robot Modeling & Control ”, Wiley India Pvt. Ltd., 2006

5. John J. Craig, “Introduction to Robotics – Mechanics & Control”, Third Edition, Pearson Education, India, 2009
6. Aaron Martinez & Enrique Fernandez, “Learning ROS for Robotics Programming”, Shroff Publishers, First Edition, 2013.
7. Mikell P. Groover et.al, ”Industrial Robots-Technology, Programming & applications” ,McGraw Hill , New York, 2008

Internal Assessment: (IA):

Two tests must be conducted which should cover atleast 80% of the syllabus. The average marks of both the test will be considered as final IA marks.

End Semester Examination:

1. Question paper will comprise of 6 questions, each carrying 20 marks.
2. The students need to solve total 4 questions.
3. Question No. 1 will be compulsory and based on entire syllabus.
4. Remaining question (Q.2 to Q.6) will be set from all the modules.
5. Weightage of marks will be as per Blueprint.

Practical Plan

CLASS	BE Electronics Semester VIII
Academic Term	January– April 2019 (2018 – 19)
Subject	**Robotics (EXL8041)**

Time Table	Day	Batch	Time
	Tuesday	D	1.30 pm – 3.30 pm
	Wednesday	A	1.30 pm – 3.30 pm

Title of Experiments

Sr.No.	Title	Module	POs
1	Coordinate Transformations	Fundamentals Robotics	PO1
2	Homogeneous coordinate Transformations	Fundamentals Robotics	PO1
3	Study of a SCARA robot	Forward &Inverse Kinematics	PO1, PO2
4	Study of 5 axis Articulated Robot	Forward &Inverse Kinematics	PO1, PO2
5	Workspace Analysis	Forward &Inverse Kinematics	PO1, PO2
6	Joint space trajectory planning	Trajectory planning	PO1, PO2

7	Template matching	Potential Functions and Visibility Graphs	PO1, PO2
8	Segmentation and Edge detection	Motion Planning	PO1, PO2
9	Bug Algorithms	Robot Vision	PO1, PO2
10	Gradient Descent Algorithm	Robot Vision	PO1, PO2

Practical Plan

Experiment No. 1 *Coordinate Transformations*

Batch	*Dates*		
	Planned	*Actual*	
A	*16 – 01 – 2019*	*16 – 01 – 2019*	
D	*15 – 01 – 2019*	*15 – 01 – 2019*	
Experiment No. 2 *Homogeneous Coordinate Transformations*			
A	*23 – 01 – 2019*	*23 – 01 – 2019*	
D	*22 – 01 – 2019*	*22 – 01 – 2019*	
Experiment No. 3 Study of a SCARA robot			
A	*30 – 01 – 2019*	*30 – 01 – 2019*	
D	*29 – 01 – 2019*	*29 – 01 – 2019*	
Experiment No. 4 Study of 5 axis Articulated Robot			
A	*13 – 02 – 2019*	*27 – 02 – 2019*	
D	*12 – 02 – 2019*	*26 – 02 – 2019*	
Experiment No. 5 Workspace Analysis			
A	*20 – 02 – 2019*	*06 – 03 – 2019*	
D	*26 – 02 – 2019*	*26 – 02 – 2019*	
Experiment No. 6 Joint space trajectory planning			
A	*27 – 02 – 2019*	*06 – 03 – 2019*	
D	*05 – 03 – 2019*	*05 – 03 – 2019*	
Experiment No. 7 Template matching			
A	*06 – 03 – 2019*	*13 – 03 – 2019*	
D	*12 – 03 – 2019*	*05 – 03 – 2019*	
Experiment No. 8 Segmentation and Edge detection			
A	*13 – 03 – 2019*	*13 – 03 – 2019*	

D	*19 – 03 – 2019*	*12 – 03 – 2019*	
Experiment No. 9 Bug Algorithms			
A	*20 – 03 – 2019*	*20 – 03 – 2019*	
D	*26 – 03 – 2019*	*19 – 03 – 2019*	
Experiment No. 10 Gradient Descent Algorithm			
A	*27 – 03 – 2019*	*27 – 03 – 2019*	
D	*02 – 04 – 2019*	*26 – 03 – 2019*	