NEC NARASARAOPETA ENGINEERING COLLEGE
(AUTONOMOUS)

DEPARTMENT OF MECHANICAL ENGINEERING

COURSE FILE

Academic year	: 2022-23
Department	: ME
Course Name	: B.Tech
Student's Batch	: 2022-23
Regulation	: R19
Year and Semester	: IV B.Tech II Semester
Name of the Subject	: Robotics and applications
Subject Code	: 19BME8PE04
Faculty In charge	: CH. SEKHAR

Signature of Faculty

Head of the Department

NARASARAOPETA ENGINEERING COLLEGE

(AUTONOMOUS)

DEPARTMENT OF MECHANICAL ENGINEERING

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NARASARAOPETA ENGINEERING COLLEGE
(AUTONOMOUS)

DEPARTMENT OF MECHANICAL ENGINEERING

INSTITUTE VISION AND MISSION

NARASARAOPETA ENGINEERING COLLEGE
(AUTONOMOUS)

DEPARTMENT OF MECHANICAL ENGINEERING

INSTITUTE VISION AND MISSION

VISION:

To emerge as a **Centre of excellence** in technical education with a blend of effective **student centric teaching learning** practices as well as **research** for the transformation of **lives and community**.

MISSION:

1. Provide the best class infrastructure to explore the field of engineering and research.
2. Build a passionate and a determined team of faculty with student centric teaching, imbibing experiential and innovative skills.
3. Imbibe lifelong learning skills, entrepreneurial skills and ethical values in students for addressing societal problems.

PRINCIPAL

NARASARAOPETA
NEC ENGINEERING COLLEGE
(AUTONOMOUS)

DEPARTMENT OF MECHANICAL ENGINEERING

DEPARTMENT VISION AND MISSION

NARASARAOPETA ENGINEERING COLLEGE
(AUTONOMOUS)

DEPARTMENT OF MECHANICAL ENGINEERING

DEPARTMENT VISION AND MISSION

VISION:

To strive for making competent **Mechanical Engineering Professionals** to cater the real time needs of Industry and **Research** Organizations of high repute with **Entrepreneurial Skills and Ethical Values.**

MISSION:

M1. To train the students with State of Art Infrastructure to make them industry ready professionals and to promote them for higher studies and research.

M2. To employ committed faculty for developing competent mechanical engineering graduates to deal with complex problems.

M3. To support the students in developing professionalism and make them socially committed mechanical engineers with morals and ethical values.

HOD-ME

NARASARAOPETA
ENGINEERING COLLEGE
(AUTONOMOUS)

DEPARTMENT OF MECHANICAL ENGINEERING

PROGRAM EDUCATIONAL OBJECTIVES (PEOs)

AND

PROGRAM SPECIFIC OUTCOMES (PSOs)

NARASARAOPETA ENGINEERING COLLEGE
(AUTONOMOUS)

DEPARTMENT OF MECHANICAL ENGINEERING

PROGRAM EDUCATIONAL OBJECTIVES (PEOs)

PEO 1: Excel in profession with sound knowledge in mathematics and applied sciences

PEO 2: Demonstrate leadership qualities and team spirit in achieving goals

PEO 3: Pursue higher studies to ace in research and develop as entrepreneurs.

PROGRAM SPECIFIC OUTCOMES (PSOs)

PSO1. The students will be able to apply knowledge of modern tools in manufacturing enabling to conquer the challenges of Modern Industry.

PSO2. The students will be able to design various thermal engineering systems by applying the principles of thermal sciences.

PSO3. The students will be able to design different mechanisms and machine components of transmission of power and automation in modern industry.

HOD-ME

NARASARAOPETA
NEC ENGINEERING COLLEGE
(AUTONOMOUS)

DEPARTMENT OF MECHANICAL ENGINEERING

PROGRAM OUTCOMES
(POs)

NEC NARASARAOPETA ENGINEERING COLLEGE
(AUTONOMOUS)

DEPARTMENT OF MECHANICAL ENGINEERING

PROGRAM OUTCOMES (POs):

Engineering Graduates will be able to:

1. Engineering knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.

2. Problem analysis: Identify, formulate, review research literature, and analyse complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.

3. Design/development of solutions: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.

4. Conduct investigations of complex problems: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

5. Modern tool usage: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modelling to complex engineering activities with an understanding of the limitations.

6. The engineer and society: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.

7. Environment and sustainability: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

8. Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

9. Individual and team work: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

10. Communication: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.

11. Project management and finance: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

12. Life-long learning: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

HOD-ME

NARASARAOPETA
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DEPARTMENT OF MECHANICAL ENGINEERING

BLOOM'S TAXONOMY LEVELS

REVISED Bloom's Taxonomy Action Verbs

Definitions	I. Remembering	II. Understanding	III. Applying	IV. Analyzing	V. Evaluating	VI. Creating
Bloom's Definition	Exhibit memory of previously learned material by recalling facts, terms, basic concepts, and answers.	Demonstrate understanding of facts and ideas by organizing, comparing, translating, interpreting, giving descriptions, and stating main ideas.	Solve problems to new situations by applying acquired knowledge, facts, techniques and rules in a different way.	Examine and break information into parts by identifying motives or causes. Make inferences and find evidence to support generalizations.	Present and defend opinions by making judgments about information, validity of ideas, or quality of work based on a set of criteria.	Compile information together in a different way by combining elements in a new pattern or proposing alternative solutions.
Verbs	• Choose • Define • Find • How • Label • List • Match • Name • Omit • Recall • Relate • Select • Show • Spell • Tell • What • When • Where • Which • Who • Why	• Classify • Compare • Contrast • Demonstrate • Explain • Extend • Illustrate • Infer • Interpret • Outline • Relate • Rephrase • Show • Summarize • Translate	• Apply • Build • Choose • Construct • Develop • Experiment with • Identify • Interview • Make use of • Model • Organize • Plan • Select • Solve • Utilize	• Analyze • Assume • Categorize • Classify • Compare • Conclusion • Contrast • Discover • Dissect • Distinguish • Divide • Examine • Function • Inference • Inspect • List • Motive • Relationships • Simplify • Survey • Take part in • Test for • Theme	• Agree • Appraise • Assess • Award • Choose • Compare • Conclude • Criteria • Criticize • Decide • Deduct • Defend • Determine • Disprove • Estimate • Evaluate • Explain • Importance • Influence • Interpret • Judge • Justify • Mark • Measure • Opinion • Perceive • Prioritize • Prove • Rate • Recommend • Rule on • Select • Support • Value	• Adapt • Build • Change • Choose • Combine • Compile • Compose • Construct • Create • Delete • Design • Develop • Discuss • Elaborate • Estimate • Formulate • Happen • Imagine • Improve • Invent • Make up • Maximize • Minimize • Modify • Original • Originate • Plan • Predict • Propose • Solution • Solve • Suppose • Test • Theory

derson, L. W., & Krathwohl, D. R. (2001). A taxonomy for learning, teaching, and assessing, Abridged Edition. Boston, MA: Allyn and Bacon.

NARASARAOPETA
NEC ENGINEERING COLLEGE
(AUTONOMOUS)

DEPARTMENT OF MECHANICAL ENGINEERING

COURSE OUTCOMES
(COs)

NEC NARASARAOPETA ENGINEERING COLLEGE
(AUTONOMOUS)

DEPARTMENT OF MECHANICAL ENGINEERING
B.TECH – R20 REGULATION - COURSE OUTCOMES

Course Name: ROBOTICS AND APPLICATIONS (Professional Elective-II)		Course Code: C324
CO	**After successful completion of this course, the students will be able to:**	
C324.1	**Distinguish** between automation and robotics and identify various components of robot.	
C324.2	**Select** appropriate type of actuators and sensors for different applications.	
C324.3	**Analyze** kinematics of a robot	
C324.4	**Analyze** Dynamics of a robot	
C324.5	**Illustrate** present and future applications of robots.	

NARASARAOPETA
NEC ENGINEERING COLLEGE
(AUTONOMOUS)

DEPARTMENT OF MECHANICAL ENGINEERING

COURSE INFORMATION SHEET

NEC

Narasaraopeta Engineering College
(Autonomous)
Yallmanda(Post), Narasaraopet- 522601
Department of Mechanical Engineering

COURSE INFORMATION SHEET

PROGRAME: B.Tech Mechanical Engineering	
COURSE: ROBOTICS AND APPLICATIONS	Semester : VIII CREDITS: 3
COURSE CODE: 19BME8PE04 REGULATION: R19	COURSE TYPE (CORE /ELECTIVE / BREADTH/ S&H): PROFESSIONAL ELECTIVE
COURSE AREA/DOMAIN: Industrial Engineering/Automation	PERIODS: 06 Per Week.

COURSE PRE-REQUISITES:

C.CODE	COURSE NAME	DESCRIPTION	SEM
19BME4TH01	Kinematics of Machinery	Knowledge of links, pairs and joints	II-II
19BME4TH02	MANUFACTURING TECHNOLOGY	Knowledge of manufacturing concepts	II-II

COURSE OUTCOMES:

SNO	Course Outcome Statement
CO1	**Distinguish** between automation and robotics and **identify** various components of robot. [K4]
CO2	**Select** appropriate type of actuators and sensors for different applications. [K3]
CO3	**Analyze** kinematics of a robot. [K4]
CO4	**Analyze** Dynamics of a robot. [K4]
CO5	**Illustrate** present and future applications of robots .[K4]

SYLLABUS:

UNIT	DETAILS
I	**FUNDAMENTALS OF ROBOTICS** **INTRODUCTION TO ROBOTICS:** what is a robot, components of robot, Robot history, robotic controls and systems, classification, challenges and opportunities, The scenarios of industrial robotics and advanced robotics **HOMOGENOUS COORDINATES AND TRANSFORM REPRESENTATIONS:** Vector spaces, inner products, vector norms, orthogonality, Linear transformations, matrix multiplication, matrix groups, Coordinate transformations, rigid transformations, rotation matrices
II	**ACTUATORS AND SENSORS** **SENSORS:** Basic Elements, General Classification of Sensors, types and working, use of sensors in robotics. **ACTUATORS:** Types, working principles, applications and advancements (hydraulic devices, Electric motors such as DC servomotors and stepper motors, Pneumatic devices, as well as other novel actuators)
III	**ROBOT KINEMATICS** The fundamentals of kinematics, differential kinematics and statics- Kinematic chains, Forward kinematics, The Jacobian and its properties, Inverse kinematics- analytical methods
IV	**ROBOT DYNAMICS** Differential kinematics- Jacobian computation, singular configurations, Configuration space operation,Dynamics- Lagrange, Euler and Newton, Euler formations, Problems.

V	**ROBOT APPLICATIONS IN MANUFACTURING** Material Transfer, Material handling, loading and unloading, Processing, spot and continuous arc welding & spray painting, Assembly and Inspection. Future applications of robots. Path planning in robotics.

TEXT BOOKS	
T	**BOOK TITLE/AUTHORS/PUBLISHER**
T1	Industrial Robotics, Groover M P,Pearson Edu.
T2	Robotics and Control, Mittal R K &Nagrath I J,Tata McGraw Hill.
REFERENCE BOOKS	
R	**BOOK TITLE/AUTHORS/PUBLISHER**
R1	Robotics: Fundamental Concepts and Analysis, Ashitava Ghosal, Oxford Publications.
R2	Robotic Systems: Applications, Control and Programming; Edited by Ashish Dutta, Intech Open.
R3	Robotics, Fu K S, McGraw Hill.
R4	Robotic Engineering, Richard D. Klafter, Prentice Hall.

TOPICS BEYOND SYLLABUS/ADVANCED TOPICS:

SNO	DESCRIPTION	Associated PO & PSO
1	Trajectory Planning	PO3,PSO3

WEB SOURCE REFERENCES:

1	https://www.intechopen.com/books/robotic-systems-applications-control-andprogramming.
2	http://planning.cs.uiuc.edu/node659.html
3	https://www.edx.org/course/robot-mechanics-and-control-part-i
4	https://www.edx.org/course/robotics-foundation-ii-robot-control
5	https://nptel.ac.in/courses/112/105/112105249/
6	http://www.robotictutorials.com/ ▯ for tutorials
7	ARC lab material – in house Dept. of Mechanical Engineering, NEC
8	http://vlabs.iitkgp.ernet.in/rislab/
9	http://www.mind.ilstu.edu/teachers/labs/robot/
10	http://vlab.amrita.edu/?sub=3&brch=271&sim=1642&cnt=3525
11	https://www.virtualroboticstoolkit.com/
12	https://www.robotlab.com/blog/robotlab-is-offering-free-online-virtual-robotics-andcoding-courses-to-those-affected-by-covid-19

DELIVERY/INSTRUCTIONAL METHODOLOGIES:

√ Chalk & Talk	√ PPT	☐Active Learning
√Web Resources	☐ Students Seminars	☐Case Study
☐Blended Learning	√ Quiz	☐Tutorials
☐Project based learning	√ NPTEL/MOOCS	☐ Simulation
☐Flipped Learning	☐Industrial Visit	☐Model Demonstration
☐Brain storming	☐Role Play	☐Virtual Labs

MAPPING CO'S WITH PO'S

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	2	2	2	1	1	-	-	-	-	-	-	-	1	-	3
CO2	1	1	1	-	1	-	-	-	-	-	-	-	1	-	3
CO3	3	3	3	3	1	-	-	-	-	-	-	-	1	-	3
CO4	3	3	3	3	-	-	-	-	-	-	-	-	1	-	3
CO5	1	1	-	1	-	-	-	-	-	-	-	-	1	-	3
Average	2.00	2.00	2.25	2.00	1	-	-	-	-	-	-	-	1	-	3

MAPPING COURSE WITH POs & PSOs

Course	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
C421	2.00	2.20	2.25	2.00	1	-	-	-	-	-	-	-	1	-	3

<table>
<tr><th colspan="3">Course Outcome Assessment Methods</th><th colspan="2">Weightages</th><th rowspan="5">Final Course Outcome (100%)</th></tr>
<tr><td rowspan="4">Direct Assessment</td><td rowspan="3">Cumulative Internal Examinations (CIE)</td><td>Descriptive Test</td><td rowspan="3">30%</td><td rowspan="4">90%</td></tr>
<tr><td>Objective Test</td></tr>
<tr><td>Assignment Test</td></tr>
<tr><td colspan="2">Semester End Examinations (SEE)</td><td>70%</td></tr>
<tr><td>Indirect Assessment</td><td colspan="3">Course End Survey</td><td>10%</td><td></td></tr>
</table>

Rubrics for overall attainment of course outcomes:
If 50% of the students crossed 50% of the marks: Attainment Level 1
If 60% of the students crossed 50% of the marks: Attainment Level 2
If 70% of the students crossed 50% of the marks: Attainment Level 3

Note: Percentages mentioned in above rubrics can be slightly changed depending upon the complexity of your respected subject.

Course Instructor   Course Coordinator   Module Coordinator   Head of the Department

ANNEXURE I:

(A) PROGRAM OUTCOMES(POs) Engineering Graduates will be able to:

1. Engineering knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.

2. Problem analysis: Identify, formulate, review research literature, and analyze complex engineering problemis reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.

3. Design/development of solutions: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.

4. Conduct investigations of complex problems: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

5.Modern tool usage: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.

6. The engineer and society: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.

7. Environment and sustainability: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

8. Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

9. Individual and team work: Function effectively as an individual, and as a member or leader in diverse teams, and i multidisciplinary settings.

10. Communication: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.

11. Project management and finance: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

12. Life-long learning: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

(B) PROGRAM SPECIFIC OUTCOMES (PSOs) :

PSO1.The students will be able to understand the modern tools of machining which gives them good expertise on advanced manufacturing methods.

PSO2.The students will be able to design different heat transfer devices with emphasis on combustion and power production.

PSO3.The students are able to design different mechanisms and machine components suitable to automation industry.

Cognitive levels as per Revised Blooms Taxonomy:

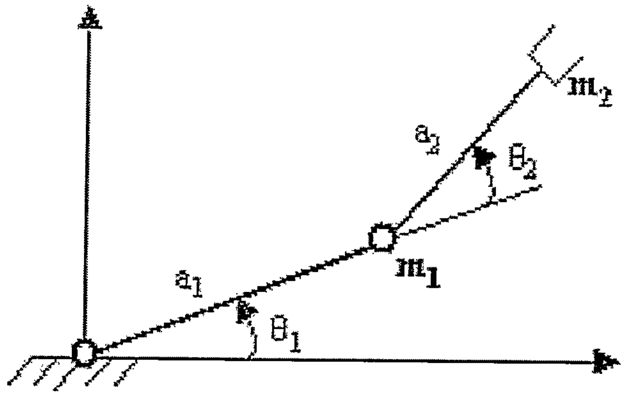
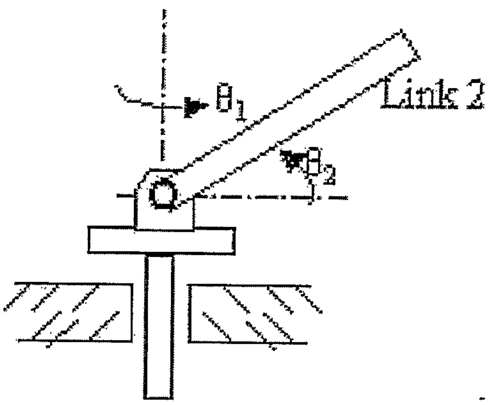
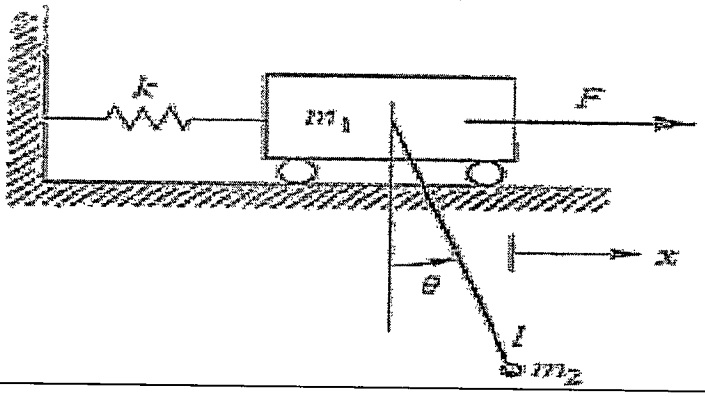
Cognitive Domain	LEVEL	Key words
Remember	K1	Defines, describes, identifies, knows, labels, lists, matches, names, outlines, recalls, recognizes, reproduces, selects, states.
Understand	K2	Comprehends, converts, defends, distinguishes, estimates, explains, extends, generalizes, gives an example, infers, interprets, paraphrases, predicts, rewrites, summarizes, translates.
Apply	K3	Applies, changes, computes, constructs, demonstrates, discovers, manipulates, modifies, operates, predicts, prepares, produces, relates, selects, shows, solves, uses.
Analyse	K4	Analyzes, breaks down, compares, contrasts, diagrams, deconstructs, differentiates, discriminates, distinguishes, identifies, illustrates, infers, outlines, relates, selects, separates.
Evaluate	K5	Appraises, compares, concludes, contrasts, criticizes, critiques, defends, describes, discriminates, evaluates, explains, interprets, justifies, relates, summarizes, supports
Create	K6	Categorizes, combines, compiles, composes, creates, devises, designs, explains, generates, modifies, organizes, plans, rearranges, reconstructs, relates, reorganizes, revises, rewrites, summarizes, tells, write

Unit wise Sample assessment questions

COURSE OUTCOMES: Students are able to

SNO	Course Outcome Statement
CO1	**Distinguish** between automation and robotics and **identify** various components of robot. [K4]
CO2	**Select** appropriate type of actuators and sensors for different applications. [K3]
CO3	**Analyze** kinematics of a robot. [K4]
CO4	**Analyze** Dynamics of a robot. [K4]
CO5	**Illustrate** present and future applications of robots .[K4]

S NO	QUESTION	KNOWLEDGE LEVEL	CO
	UNIT I		
1	**Discuss** the anatomy of Robot and **explain** the important parts of a robot with a neat sketch.	Evaluate (K5)	CO1
2	**Name** and **Explain** the four basic arm configurations that are used in robotic Manipulators.	Evaluate (K5)	CO1
3	**Explain** two views by **making use of sketch** to indicate the work envelope of a i) Cartesian robot. ii) Polar robot.	Evaluate (K5))	CO1
4	**Explain** the relationship of robotics with industrial automation and **illustrate** the same with a suitable example.	Evaluate (K5)	CO1
5	For the point Pxyz $=(8,3,6)^T$ perform following operations a). Rotate 60° about the Y-axis followed by translation of 4 units along x-axis? b). Rotate 30° about the Z-axis followed by rotation of 60° about X-axis? c). Translate 10 units along Z-axis followed by rotation of 45° along Z-axis?	Applying (K3)	CO1
	UNIT 2		
1	**Sketch** and **explain** a hydraulic drive system used for robots.	Applying (K3)	CO2
2	**Illustrate** different types of actuators used for robots?	Applying (K3)	CO2
3	**What** are the functions of sensors? **How** do you sense the positional accuracy of a robot? **Describe** the suitable type of sensor used to measure the position.	Applying (K3)	CO2
4	**Explain** in detail about safety sensors and safety Monitoring.	Evaluate (K5)	CO2
	UNIT 3		
1	**Compute** the homogeneous transformation representing a translation of 3 units along the x-axis and followed by rotation of 90° about the current z-axis followed by a translation of 1 unit along the fixed y-axis.	Applying (K3)	CO3
2	**Explain** and **derive** inverse kinematic solution for the variables of a cylindrical robot.	Evaluate (K5)	CO3
3	**Derive** the forward kinematics matrix for an articulated robot arm (3-axis) using DH convention?	Applying	CO3

		(K3)	
4	**Explain** the homogeneous transformation as applicable to rotation?	Evaluate (K5)	**CO3**
	UNIT 4		
1	**Determine** the dynamic equations for the two-link manipulator shown in Figure 1, using Lagrange-Euler formulation. Assume that the whole mass of the link can be considered as a point mass located at the outermost end of each link. The masses are m1 and m2 and the link lengths are a1 and a2. 	Applying (K3)	**CO4**
2	Consider a two-degree of freedom manipulator shown in Figure 1. Assuming that the inertia of the first moving link is negligible and that the second moving link is a slender homogeneous rod of mass m, **determine** the dynamic equations of motion by the Lagrangian method using θ1 and θ2 as the generalized coordinates. 	Applying (K3)	**CO4**
3	Using Lagrangian mechanics, **Derive** the equations of motion for the two-degreeof-freedom system shown in figure 1. 	Evaluate (K5)	**CO4**

4	**Explain** the steps involved in the formulation of Lagrange-Euler dynamic model.	Evaluate (K5)	**CO4**
	UNIT 5		
1	**Sketch** and **explain** a hydraulic drive system used for robots.	Evaluate (K5)	**CO5**
2	**Illustrate** different types of actuators used for robots?	Applying (K3)	**CO5**
3	**What** are the functions of sensors? **How** do you sense the positional accuracy of a robot? **Describe** the suitable type of sensor used to measure the position.	Applying (K3)	**CO5**
4	**Explain** in detail about safety sensors and safety Monitoring.	Evaluate (K5)	**CO5**

Narasaraopeta Engineering College (Autonomous)

Kotappakonda Road, Yellamanda (P.O), Narasaraopet- 522601, Guntur District, AP.

Subject Code: 19BME8PE04

IV B.Tech II Semester **Examinations, (Month Year)**

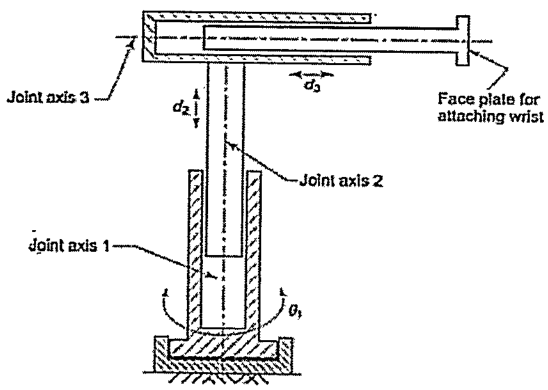
ROBOTICS AND APPLICATIONS

(ME)

Model Paper-1

Time: 3 hours **Max Marks: 60**

Note: Answer All **FIVE** Questions.
All Questions Carry Equal Marks (5X12=60M)

Q.No		Questions	Marks
		Unit - I	
1	a	**Name** and **Explain** the four basic arm configurations that are used in robotic Manipulators.	[12M]
		OR	
	b	For the point Pxyz =(8,3,6)T perform following operations a). Rotate 60° about the Y-axis followed by translation of 4 units along x-axis? b). Rotate 30° about the Z-axis followed by rotation of 60° about X-axis? c). Translate 10 units along Z-axis followed by rotation of 45° along Z-axis?	[12M]
		Unit - II	
2	a	**Sketch** and **explain** a hydraulic drive system used for robots.	[12M]
		OR	
	b	**Explain** the sensors, potentiometers and optical encoders.	[12M]
		Unit - III	
3	a	**Derive** the kinematics relationship between adjacent links of Robot Arm.	[12M]
		OR	
	b	**Formulate** the forward kinematic model of the three degree of freedom (RPP) manipulator as shown in fig 	[12M]
		Unit - IV	
4	a	**Determine** the equations of motion for 2DOF RR- planar manipulator arm using Lagrange-Euler Formulation.	[12M]

	b	**Derive** the jacobian matrix for a planar RRR manipulator?	[12M]
5		**Unit - V**	
	a	**Explain** the various types of material handling applications of Robots.	[12M]
		OR	
	b	**Explain** about welding operations of robot with neat sketch	[12M]

Narasaraopeta Engineering College (Autonomous)

Kotappakonda Road, Yellamanda (P.O), Narasaraopet- 522601, Guntur District, AP.

Subject Code: 19BME8PE04

IV B.Tech II Semester ... **Examinations,** ...th Year)

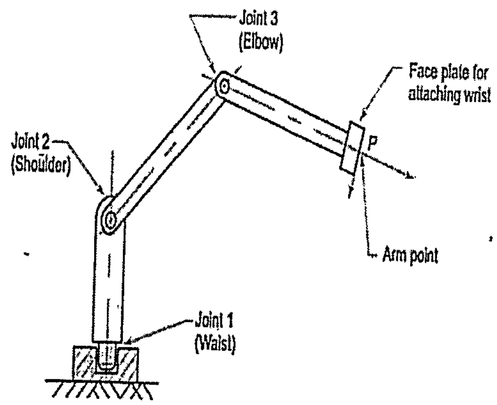
ROBOTICS AND APPLICATIONS

(ME)

Model Paper-2

Time: 3 hours **Max Marks: 60**

Note: Answer All **FIVE** Questions.
All Questions Carry Equal Marks (5X12=60M)

Q.No		Questions	Marks
		Unit - I	
1	a	**Classify** the robots based on the co-ordinate system and control system with neat diagram.	[12M]
		OR	
	b	**Explain** the Homogeneous transformation matrix and write the homogeneous matrix for Rotation and Translation.	[12M]
		Unit - II	
2	a	**Compare** the electric, hydraulic and pneumatic actuators used in robots.	[12M]
		OR	
	b	What are the functions of a sensor? **Explain** the suitable sensors used to measure the position	[12M]
		Unit - III	
3	a	**Explain** DH parameters with neat sketch.	[12M]
		OR	
	b	**Formulate** the forward kinematic model of the three degree of freedom (RRR) manipulator as shown in fig 	[12M]
		Unit - IV	
4	a	**Develop** algorithm for Lagrange-Euler formulation of Dynamic Equations.	[12M]
		OR	

	b	**Derive** the jacobian matrix for a planar RRR manipulator?	[12M]
5		**Unit - V**	
	a	**Explain** the various types of material handling applications of Robots.	[12M]
		OR	
	b	**Explain** about welding operations of robot with neat sketch	[12M]

NARASARAOPETA
ENGINEERING COLLEGE
(AUTONOMOUS)

DEPARTMENT OF MECHANICAL ENGINEERING

ACADEMIC CALENDAR

NEC NARASARAOPETA ENGINEERING COLLEGE
(AUTONOMOUS)

ACADEMIC CALENDAR
(B.Tech. 2019 Admitted Batch, Academic Year 2022-23)

2019 Batch 4th Year 1st Semester			
Description	**From Date**	**To Date**	**Weeks**
Commencement of Class Work	25-07-2022		
1st Spell of Instructions	25-07-2022	10-09-2022	7 Weeks
I Assignment Examination	08-08-2022	13-08-2022	
II Assignment Examination	29-08-2022	03-09-2022	
I Mid Examination	12-09-2022	17-09-2022	1 Week
2nd Spell of Instructions	19-09-2022	05-11-2022	7 Weeks
III Assignment Examination	03-10-2022	08-10-2022	
IV Assignment Examination	24-10-2022	29-10-2022	
II Mid Examination	07-11-2022	12-11-2022	1 Week
Preparation & Practicals	14-11-2022	19-11-2022	1 Week
End Examinations	21-11-2022	03-12-2022	2 Weeks
2019 Batch 4th Year 2nd Semester			
Commencement of II Semester Class work	05-12-2022		
1st Spell of Instructions	05-12-2022	21-01-2023	7 Weeks
I Assignment Examination	19-12-2022	24-12-2022	
II Assignment Examination	09-01-2023	14-01-2023	
I Mid Examination	23-01-2023	28-01-2023	1 Week
2nd Spell of Instructions	30-01-2023	18-03-2023	7 Weeks
III Assignment Examination	13-02-2023	18-02-2023	
IV Assignment Examination	06-04-2023	11-04-2023	
II Mid Examination	20-03-2023	25-03-2023	1 Week
Preparation & Practicals	27-03-2023	01-04-2023	1 Week
End Examinations	03-04-2023	15-04-2023	2 Weeks

PRINCIPAL

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DEPARTMENT OF MECHANICAL ENGINEERING

TIME TABLE

NARASARAOPETA ENGINEERING COLLEGE: NARASARAOPET (AUTONOMOUS)
DEPARTMENT OF MECHANICAL ENGINEERING
IV B.TECH II SEM TIME TABLE
Section-A

ROOM NO: 1315

Wef: 12/12/2022

	1	2	BREAK	3	4		5	6	7
TIMINGS	9.10-10.00	10.00-10.50	10.50-11.00	11.00-11.50	11.50-12.40	12.40-1.30	1.30-2.20	2.20-3.10	3.10-4.00
MON	ROB&A			PPC		L	Project Work		
TUE	Project Work					U	ROB&A		PPC
WED	PPC			ROB&A		N	Project Work		
THU	ROB&A			PPC		C	Project Work		
FRI	Project Work					H	Project Work		
SAT	Project Work						Project Work		

CODE	SUBJECT	FACULTY
ROB&A	Robotics & Applications	Mr.Ch. Sekhar
PPC	Production Planning & Control	Mrs. P.Sravani
Project Work	Project Work	Mr.Ch. Sekhar

Signature of HOD

Signature of Principal

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DEPARTMENT OF MECHANICAL ENGINEERING

SYLLABUS COPY

IV B.TECH II SEMESTER Professional Elective - 4	L	T	P	INTERNAL MARKS	EXTERNAL MARKS	TOTAL MARKS	CREDITS
	2	1	-	40	60	100	3
Code: 19BME8PE04	ROBOTICS AND APPLICATIONS						

COURSE OBJECTIVES

The course content enables students to:

- Introduce the concepts of Robotic system, its components and control related to robotics.
- Learn about analyzing robot kinematics.

COURSE OUTCOMES

After successful completion of this course, the students will be able to:

CO1 **Distinguish** between automation and robotics and **identify** various components of robot.
CO2 **Select** appropriate type of actuators and sensors for different applications.
CO3 **Analyze** kinematics of a robot
CO4 **Analyze** Dynamics of a robot
CO5 **Illustrate** present and future applications of robots

UNIT 1: FUNDAMENTALS OF ROBOTICS

INTRODUCTION TO ROBOTICS: what is a robot, components of robot, Robot history, robotic controls and systems, classification, challenges and opportunities, The scenarios of industrial robotics and advanced robotics

HOMOGENOUS COORDINATES AND TRANSFORM REPRESENTATIONS: Vector spaces, inner products, vector norms, orthogonality, Linear transformations, matrix multiplication, matrix groups, Coordinate transformations, rigid transformations, rotation matrices

UNIT 2: ACTUATORS AND SENSORS

SENSORS: Basic Elements, General Classification of Sensors, types and working, use of sensors in robotics.

ACTUATORS: Types, working principles, applications and advancements (hydraulic devices, Electric motors such as DC servomotors and stepper motors, Pneumatic devices, as well as other novel actuators)

UNIT 3: ROBOT KINEMATICS

The fundamentals of kinematics, differential kinematics and statics- Kinematic chains, Forward kinematics, The Jacobian and its properties, Inverse kinematics- analytical methods

UNIT 4: ROBOT DYNAMICS

Differential kinematics- Jacobian computation, singular configurations, Configuration space operation, Dynamics- Lagrange, Euler and Newton, Euler formations, Problems.

UNIT 5: ROBOT APPLICATIONS IN MANUFACTURING

Material Transfer, Material handling, loading and unloading, Processing, spot and continuous arc welding & spray painting, Assembly and Inspection. Future applications of robots. Path planning in robotics.

TEXT BOOKS:

1. Industrial Robotics, Groover M P, Pearson Education.
2. Robotics and Control, Mittal R K & Nagrath I J, Tata McGraw Hill.

REFERENCES:

1. Robotics: Fundamental Concepts and Analysis, Ashitava Ghosal, Oxford Publications.
2. Robotic Systems: Applications, Control and Programming; Edited by Ashish Dutta, Intech Open.
3. Robotics, Fu K S, McGraw Hill.
4. Robotic Engineering, Richard D. Klafter, Prentice Hall.

WEB RESOURCES:

1. https://www.intechopen.com/books/robotic-systems-applications-control-and-programming.
2. http://planning.cs.uiuc.edu/node659.html
3. https://www.edx.org/course/robot-mechanics-and-control-part-i
4. https://www.edx.org/course/robotics-foundation-ii-robot-control
5. https://nptel.ac.in/courses/112/105/112105249/
6. http://www.robotictutorials.com/ → for tutorials
7. ARC lab material – in house Dept. of Mechanical Engineering, NEC
8. http://vlabs.iitkgp.ernet.in/rislab/
9. http://www.mind.ilstu.edu/teachers/labs/robot/
10. http://vlab.amrita.edu/?sub=3&brch=271&sim=1642&cnt=3525
11. https://www.virtualroboticstoolkit.com/
12. https://www.robotlab.com/blog/robotlab-is-offering-free-online-virtual-robotics-and-coding-courses-to-those-affected-by-covid-19

NEC NARASARAOPETA ENGINEERING COLLEGE
(AUTONOMOUS)

DEPARTMENT OF MECHANICAL ENGINEERING

LESSON PLAN

Narasaraopeta Engineering College
(Autonomous)
Yallmanda(Post), Narasaraopet- 522601

DEPARTMENT OF MECHANICAL ENGINEERING
LESSON PLAN

Course Code	Course Title (Regulation)	Sem	Branch	Contact Periods/Week	Sections
19BME8PE04	ROBOTICS AND APPLICATIONS	VIII	Mechanical Engineering	7	A & B

COURSE OUTCOMES: Students are able to

SNO	Course Outcome Statement
CO1	**Distinguish** between automation and robotics and **identify** various components of robot. [K4]
CO2	**Select** appropriate type of actuators and sensors for different applications. [K3]
CO3	**Analyze** kinematics of a robot. [K4]
CO4	**Analyze** Dynamics of a robot. [K4]
CO5	**Illustrate** present and future applications of robots .[K4]

Unit No	Outcome		Topics/Activity	Ref Text book	Total Periods	Delivery Method
1	**CO1: Distinguish** between automation and robotics and identify various components of robot. [K4]		**UNIT– I : INTRODUCTION**			
		1.1	**INTRODUCTION TO ROBOTICS:** what is a robot, components of robot, Robot history	T1, T2, R1,R3	3	Chalk, Talk & PPT
		1.2	robotic controls and systems, classification, challenges and opportunities,	T1, T2, R1,R4	3	Chalk, Talk & PPT
		1.3	**HOMOGENOUS COORDINATES AND TRANSFORM REPRESENTATIONS:** Vector spaces, inner products, vector norms, orthogonality, Linear transformations,	T1, T2, R1,R3	3	Chalk, Talk & PPT
		1.4	Matrix multiplication, matrix groups, Coordinate transformations, rigid transformations, rotation matrices	T1, T2, R1,R3	3	Chalk, Talk & PPT
2	**CO2: Select** appropriate type of actuators and sensors for different applications . [K3]		**UNIT-II: ROBOT ACTUATORS AND SENSORS**			
		2.1	**SENSORS:** Basic Elements, General Classification of Sensors,	T1, T2, R1	2	Chalk, Talk & PPT
		2.2	Types of sensors and working, use of sensors in robotics.	T1, T2, R1	2	Chalk, Talk & PPT
		2.3	**ACTUATORS:** Types, working principles, applications and advancements	T1, T2, R1	2	Chalk, Talk & PPT
		2.4	Hydraulic Actuators	T1, T2, R1	2	Chalk, Talk & PPT
		2.5	Electric motors such as DC servomotors and stepper motors	T1, T2, R1	2	Chalk, Talk & PPT

		2.6	Pneumatic devices	T1, T2, R1	2	Chalk, Talk & PPT
3	**CO3: Analyze** kinematics of a robot. **[K4]**	**UNIT-III: ROBOT KINEMATICS**				
		3.1	The fundamentals of kinematics, differential kinematics and statics- Kinematic chains,	T1, T2, R2,R4	4	Chalk, Talk & PPT
		3.2	Forward kinematics analytical methods	T1, T2, R2,R4	4	Chalk, Talk & PPT
		3.3	Inverse kinematics- analytical methods	T1, T2, R2,R4	4	Chalk, Talk & PPT
4	**CO4: Analyze** Dynamics of a robot. **[K4]**	**UNIT-IV: ROBOT DYNAMICS**				
		4.1	Differential kinematics- Jacobian computation, singular configurations, Configuration space operation,	T1, T2, R2,R3	4	Chalk & Talk
		4.2	Dynamics- Lagrange, Euler and Newton,.	T1, T2, R2,R3	4	Chalk & Talk
		4.3	Euler formations, Problems	T1, T2, R2,R3	4	Chalk ,Talk,NPTEL
5	**CO5:** **Illustrate** present and future applications of robots .**[K4]**	**UNIT V: ROBOT APPLICATIONS IN MANUFACTURING**				
		5.1	Material Transfer, Material handling,	T1, T2, R3	2	Chalk, Talk & PPT
		5.2	Loading and unloading, Processing, spot and continuous arc welding & spray painting,	T1, T2, R3	2	Chalk, Talk & PPT
		5.3	Assembly and Inspection.	T1, T2, R3	3	Chalk, Talk & PPT
		5.4	Future applications of robots.	T1, T2, R3	2	Chalk, Talk & PPT
		5.5	Path planning in robotics.	T1, T2, R3	3	Chalk, Talk & PPT
				Total	60	

Text Books:

T1 Industrial Robotics, Groover M P,Pearson Edu.

T2 Robotics and Control, Mittal R K &Nagrath I J,Tata McGraw Hill.

Reference Books:

R1 Robotics: Fundamental Concepts and Analysis, Ashitava Ghosal, Oxford Publications.

R2 Robotic Systems: Applications, Control and Programming; Edited by Ashish Dutta, IntechOpen.

R3 Robotics, Fu K S, McGraw Hill.

R4 Robotic Engineering, Richard D. Klafter, Prentice Hall.

Faculty **HOD** **Principal**

NARASARAOPETA
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DEPARTMENT OF MECHANICAL ENGINEERING

CO-POs & CO-PSOs MAPPING (COURSE ARTICULATION MATRIX)

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DEPARTMENT OF MECHANICAL ENGINEERING
COURSE ARTICULATION MATRIX
R20-REGULATION

Explanation of Course Articulation Matrix Table to be ascertained:

- Course Articulation Matrix correlates the individual COs of a course with POs and PSOs.
- The Course Outcomes are mapped with POs and PSOs in the scale of 1 to 3.
- The strength of correlation is indicated as **3** for **Substantial (High)** correlation, **2** for **Moderate (Medium)** correlation, and 1 for **Slight (Low)** correlation.

Course Code: C324	Course Name: ROBOTICS AND APPLICATIONS (Professional Elective-II)														
COs	POs & PSOs														
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
C324.1	3	2	-	-	-	-	-	-	-	-	-	-	2	-	-
C324.2	3	2	-	-	-	-	-	-	-	-	-	-	2	2	-
C324.3	3	3	3	2	-	-	-	-	-	-	-	-	-	-	3
C324.4	3	3	3	2	-	-	-	-	-	-	-	-	-	-	3
C324.5	3	2	-	-	-	-	-	-	-	-	-	-	-	-	3
C324	3.00	2.40	3.00	2.00	-	-	-	-	-	-	-	-	2.00	2.00	3.00

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WEB REFERENCES

NARASARAOPETA ENGINEERING COLLEGE
(AUTONOMOUS)

DEPARTMENT OF MECHANICAL ENGINEERING

ROBOTICS AND APPLICATIONS

LIST OF E-RESOURCE

1 https://nptel.ac.in/downloads/112101098/

2 https://nptel.ac.in/courses/112101098/download/lecture-1.pdf

3 https://nptel.ac.in/courses/112101098/download/lecture-2.pdf

4 https://nptel.ac.in/courses/112101098/download/lecture-4.pdf

5 https://nptel.ac.in/courses/112101098/download/lecture-5.pdf

6 https://nptel.ac.in/courses/112101098/download/lecture-6.pdf

7 https://nptel.ac.in/courses/112101098/download/lecture-7.pdf

8 https://nptel.ac.in/courses/112101098/download/lecture-9.pdf

9 https://nptel.ac.in/courses/112101098/download/lecture-10.pdf

10 https://nptel.ac.in/courses/112101098/download/lecture-12.pdf

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DEPARTMENT OF MECHANICAL ENGINEERING

STUDENT'S ROLL LIST

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DEPARTMENT OF MECHANICAL ENGINEERING

19 BATCH IV-II PROMOTION LIST

S.No	H.T.NO	Name of the Candidate
1	19471A0301	ARIKATLA RAGHU RAMI REDDY
2	19471A0302	BADDETI RAMBABU
3	19471A0303	BANDARU PRASANNA BABU
4	19471A0304	BOBBILI VISHNU VARDHAN REDDY
5	19471A0305	CHAVA ASHOK
6	19471A0306	CHIRUGURI KARUNAKAR
7	19471A0307	DURGAMPUDI MAHESH REDDY
8	19471A0308	GANGAVARAPU SRI CHANDRASEKHAR
9	19471A0309	GANNEPALLI RAVI
10	19471A0311	GONA VAMSI
11	19471A0312	GORANTLA ANIL
12	19471A0313	GUDE JAYANTH KUMAR
13	19471A0315	JANDHAYALA SANDLEYA
14	19471A0316	JANGA NAGENDRA BABU
15	19471A0317	JONNALAGADDA MADHU
16	19471A0318	KAKANI NAGENDRA BABU
17	19471A0319	KAMBAMPATI AJITHKUMAR
18	19471A0320	KIKKURU PRUDHVI YASHWANT REDDY
19	19471A0321	KONDA JOHNY
20	19471A0322	LINGISETTY RAJASEKHAR
21	19471A0323	MAHANKALI RAKESH
22	19471A0326	MELAM STEPHEN WILLIAMS
23	19471A0327	NARENDRA BABU SADHE

24	19471A0328	NOORBASHA ANWAR BASHA
25	19471A0329	ONTERU VEERANJANEYULU
26	19471A0330	PATHAN AMEER KHAN
27	19471A0331	PEERLA HUSSIAN
28	19471A0333	PODILA GOPINADH
29	19471A0335	RAMAR SATISH KUMAR
30	19471A0336	SAVALAM MANI KUMAR
31	19471A0337	SHAIK JILANI
32	19471A0338	SHAIK MAHAMMAD BILAL
33	19471A0339	SHAIK MAHAMMAD RIYAZ
34	19471A0340	SHAIK SUBHANI
35	19471A0341	TALAKAYALA VINAY KUMAR
36	19471A0342	VADLAMUDI YASWANTH SAI
37	19471A0343	VEERLA KOTESWARA RAO
38	19471A0344	VEJARLA AVINASH
39	20475A0301	PUTTA RAJESH
40	20475A0302	LINGIREDDY GOPI REDDY
41	20475A0303	YELURI RAKESH
42	20475A0304	VANGAVOLU NAGA SESHU
43	20475A0305	GUNJI VENKATA BHASKAR
44	20475A0306	THAPPETA RADHAKRISHNA
45	20475A0307	EDEBOINA ASHOK
46	20475A0308	MARRI AJAY KUMAR
47	20475A0309	MADEM JAYANTH KUMAR
48	20475A0310	RAJABATHULA KISHORE
49	20475A0311	SHAIK SAMEER
50	20475A0312	SHAIK THUPAKULA MASTAN VALI
51	20475A0313	PARIMI GANESH
52	20475A0314	MUVVA VAMSI
53	20475A0315	RYALI M T SURYA PRAKASH
54	20475A0316	SHAIK DASTAGIRI

55	20475A0317	MANDA RAJA SEKHAR
56	20475A0318	DANDE VENKATA GOPAL
57	20475A0319	KOTA LAKSHMI VARAPRASAD
58	20475A0320	BALACHANDAR M
59	20475A0321	KUKKAMALLA NIKHIL KUMAR
60	20475A0322	PENUMALA KALYAN
61	20475A0323	KOTHAMSETTI ASHOK
62	20475A0324	NUNNA BALA NAVEEN
63	20475A0325	KOTHAMASU ANANTA KOTI SRIKRISHNA
64	20475A0326	NAGISETTY RAKESH
65	20475A0327	RAVURI SIVANJANEYULU
66	20475A0328	ANKEM NAGENDRA BABU
67	20475A0330	PARASA NAVEEN
68	20475A0331	DUPATI ANIL
69	20475A0332	SHAIK NARAVADA ALTHAF HUSSAIN
70	20475A0333	RAVURI ANIL
71	20475A0334	TELUKUTLA SIVAREDDY
72	20475A0335	KOTARU SAIRAGHU VAMSI
73	20475A0336	MIDDELA BAJIVALI
74	20475A0337	VATTIGORLA YOGANJANEYULU
75	20475A0338	GANTASALA GOPI CHAND
76	20475A0339	KOILADA PRADEEP
77	20475A0340	DASARI HEMAGURUNADH
78	20475A0341	JILABOINA KARUNAKAR
79	20475A0342	MALLAVARAPU JESUDASU
80	20475A0343	VANGARA AYYAPPA
81	20475A0344	YADARI RAJESH
82	20475A0345	KASUKURTHI AKASH
83	20475A0346	KANAPARTHI VENKATA KRISHNA
84	20475A0347	SHAIK AMEER
85	20475A0348	MEKA SAI VINAY

86	20475A0349	AVVARU YUGANDHAR
87	20475A0350	CHINTALAPUDI SRIRAM
88	20475A0351	ILLA RATNAM RAJU
89	20475A0352	GUNTAKA HARIKRISHNA REDDY
90	20475A0353	GADIBOYINA NAGAIAH
91	20475A0354	KOPPOLU BHANU PRASAD
92	20475A0355	CHOPPARA LAKSHMI SUMANTH
93	20475A0356	INDURI PRATHAP REDDY
94	20475A0357	INAGANTI NAGULMEERAVALI
95	20475A0358	BATTU JAGADEESH
96	20475A0359	VEMULA HEMANTH KUMAR
97	20475A0360	KAKARLAMUDI NAVEEN
98	20475A0361	KUMMARA PARAMESWARA RAO
99	20475A0362	BOKKA PRASANNA KUMAR
100	20475A0363	GANJI HASHWANTH PRAVEEN REDDY
101	20475A0364	URJANA SHANMUKHARAO
102	20475A0365	DAMERA SANTHOSH
103	20475A0366	MUVVA NAGA LAKSHMAIAH

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DEPARTMENT OF MECHANICAL ENGINEERING

HAND WRITTEN/PRINTED LECTURE NOTES

UNIT-1

INTRODUCATION

The field of robotics has its origins in science fiction. The term robot was derived from the English translation of a fantasy play written in Czechoslovakia around 1920. It took another 40 years before the modern technology of industrial robotics began. Today. Robots are highly automated mechanical manipulators controlled by computers. In this chapter. We survey some of the science fiction stories about robots, and we trace the historical development of robotics technology. Let us begin our chapter by denning the term robotics and establishing its place in relation to other types of industrial automation.

Robotics:-

Robotics is an applied engineering science that has been referred to as a combination of machine tool technology and computer science. It includes machine design, production theory, micro electronics, computer programming & artificial intelligence.

OR

"Robotics" is defined as the science of designing and building Robots which are suitable for real life application in automated manufacturing and other non-manufacturing environments.

Industrial robot:-

The official definition of an industrial robot is provided by the robotics industries association (RIA). Industrial robot is defined as an automatic, freely programmed, servo-controlled, multi-purpose manipulator to handle various operations of an industry with variable programmed motions.

Automation and robotics:-

Automation and robotics are two closely related technologies. In an industrial context, we can dean automation as a technology that is concerned with the use of mechanical, electronic, and computer-based systems in the operation and control of production Examples of this technology include transfer lines. Mechanized assembly machines, feedback control systems (applied to industrial processes), numerically controlled machine tools, and robots. Accordingly, robotics is a form of industrial automation.

Ex:- Robotics, CAD/CAM, FMS, CIMS

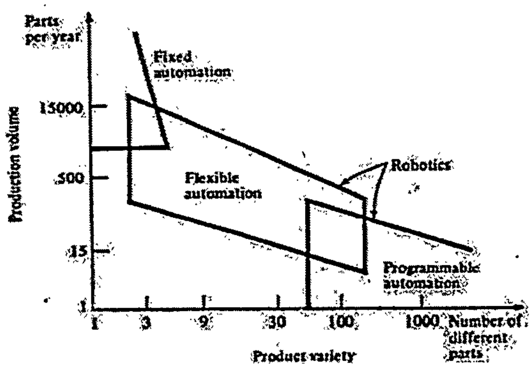
Types of Automation:-

Automation is categorized into three types. They are,

1)Fixed Automation

2) Programmable Automation

3) Flexible Automation.



Relationship of fixed automation, programmable automation, and flexible automation as a function of production volume and product variety.

(1) Fixed Automation:-

It is the automation in which the sequence of processing or assembly operations to be carried out are fixed by the equipment configuration. In fixed automation, the sequence of operations (which are simple) are integrated in a piece of equipment. Therefore, it is difficult to automate changes in the design of the product. It is used where high volume of production is required Production rate of fixed automation is high. In this automation, no new products are processed for a given sequence of assembly operations.

Features:-

i) High volume of production rates,

ii) Relatively inflexible in product variety (no new products are

produced). Ex:- Automobile industries ... etc.

(2) Programmable Automation:-

It is the automation in which the equipment is designed to accommodate various product configurations in order to change the sequence of operations or assembly operations by means of control program. Different types of programs can be loaded into the equipment to produce products with new configurations (i.e., new products). It is employed for batch production of low and medium volumes. For each new batch of different configured product, a new control program corresponding to the new product is loaded into the equipment. This automation is relatively economic for small batches of the product.

Features:-

i) High investment in general purpose,

ii) Lower production rates than fixed automation,

iii) Flexibility & Changes in products configuration,

iv) More suitable for batch production.

Ex:- Industrial robot, NC machines tools... etc.

(3) Flexible Automation:-

A computer integrated manufacturing system which is an extension of programmable automation is referred as flexible automation. It is developed to minimize the time loss between the changeover of the batch production from one product to another while reloading. The program to produce new products and changing the physical setup i.e., it produces different products with no loss of time. This automation is more flexible in interconnecting work stations with material handling and storage system.

Features:-

i) High investment for a custom engineering system.

ii) Medium Production rates

iii) Flexibility to deal with product design variation,

iv) Continuous production of variable mixtures of products. Ex:- Flexible manufacturing systems (FMS)

Advantages:-

1. High Production rates
2. Lead time decreases
3. Storing capacity decreases
4. Human errors are eliminated.
5. Labour cost is decreases.

Disadvantages:-

1. Initial cost of draw material is very high,
2. Maintenance cost is high,
3. Required high skilled Labour
4. Indirect cost for research development & programming increases.

Reasons for implementation of automated systems in manufacture industries:-

The reasons for the implementation of automated systems in manufacturing industries are as follows,

(i) To Increase the Productivity Rate of Labour
(ii) To Decrease the Cost of Labour
(iii) To Minimize the Effect of Shortage of Labour
(iv) To Obtain High Quality of Products
(v) A Non-automation nigh Cost is Avoided
(vi) To Decrease the Manufacturing Lead Time
(vii) To upgrade the Safety of Workers.

Need For using robotics in industries:-

Industrial robot plays a significant role in automated manufacturing to perform different kinds of applications.

1.Robots can be built a performance capability superior to those of human beings. In terms of strength, size, speed, accuracy...etc.

2. Robots are better than humans to perform simple and repetitive tasks with better quality and consistence's.

3. Robots do not have the limitations and negative attributes of human works .such as fatigue, need for rest, diversion of attention.....etc.

4. Robots are used in industries to save the time compared to human beings.

5. Robots are in value poor working conditions

6. Improved working conditions and reduced risks.

CAD/CAM & Robotics:-

CAD/CAM is a term which means computer aided design and computer aided manufacturing. It is the technology concerned with the use of digital computers to perform certain functions in design & production.

CAD:- CAD can be defined as the use of computer systems to assist in the creation modification, analysis OR optimization of design.

Cam:- CAM can be defined as the use of computer system to plan, manage & control the operation of a manufacturing plant, through either direct or in direct computer interface with the plants production resources.

Specifications of robotics:-

1.Axil of motion

2. Work stations

3. Speed

4. Acceleration

5. Pay load capacity

6. Accuracy

7. Repeatability etc...

Overview of Robotics:-

"Robotics" is defined as the science of designing and building Robots which are suitable for real life application in automated manufacturing and other non-manufacturing environments. It has the following objectives,

1. To increase productivity
2. Reduce production life
3. Minimize labour requirement
4. Enhanced quality of the products
5. Minimize loss of man hours, on account of accidents.
6. Make reliable and high speed production.

The robots are classified as,

* Programmable/Reprogrammable purpose

robots *Tele-operated, Man controlled robots

*Intelligent robots.

Robots are used in manufacturing and assembly units such as,

.:. Spot or arc welding

.:. Parts assembly

.:. Paint spraying

.:. Material, handling

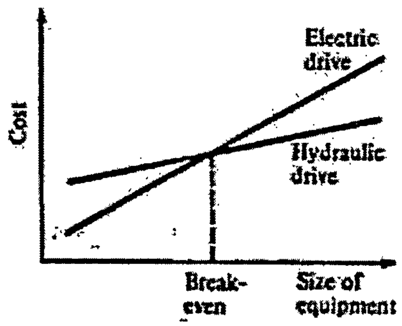
.:. Loading and unloading

The feature and capabilities of the robots are as follows,

* Intelligence
* Sensor capabilities
* Telepresence
* Mechanical design
* Mobility and navigation
* Universal gripper
* System integration and networking.

Types of drive systems:-

1. Hydraulic drive
2. Electric drive
3. Pneumatic drive



Cost vs. size for electric drive and hydraulic drive.

1. Hydraulic drive:-

Hydraulic drive and electric drive arc the two main types of drives used on more sophisticated robots.

Hydraulic drive is generally associated with larger robots, such as the Unimate 2000 series. The usual advantages of the hydraulic drive system are that it provides the robot with greater speed and strength. The disadvantages of the hydraulic drive system are that it typically adds to the floor space required by the robot, and that a hydraulic system is inclined to leak on which is a nuisance.

This type of system can also be called as non-air powered cylinders. In this system, oil is used as a working fluid instead of compressed air. Hydraulic system need pump to generate the required pressure and flow rate. This systems are quite complex, costly and requires maintenance.

2. Electric drive:-

Electric drive systems do not generally provide as much speed or power as hydraulic systems. However, the accuracy and repeatability of electric drive robots are usually better. Consequently, electric robots tend to be smaller. Require less floor space, and their applications tend toward more precise work such as assembly.

In this System, power is developed by an electric current. It required little maintenance and the operation is noise less.

3. Pneumatic drive:-

Pneumatic drive is generally reserved for smaller robots that possess fewer degrees of freedom (two- to four-joint motions).

In this system, air is used as a working fluid, hence it is also called air-powered cylinders. Air is compressed in the cylinder with the aid of pump the compressed air is used to generate the power with required amount of pressure and flow rates.

Applications of robots:-

Present Applications of Robots:-

(i) Material transfer applications

(ii) Machine loading and unloading

(iii) Processing operations like,

(a) Spot welding

(b) Continuous arc welding

(c) Spray coating

(d) Drilling, routing, machining operations

(e) Grinding, polishing debarring wire brushing

(g) Laser drilling and cutting etc.

(iv) Assembly tasks, assembly cell designs, parts mating.

(v) Inspection, automation or test equipment.

Future Applications of Robots:-

The profile of the future robot based on the research activities will include the following,

(i) Intelligence

(ii) Sensor capabilities

(iii) Telepresence

(iv) Mechanical design

(v) Mobility and navigation (walking machines)

(vi) Universal gripper

(vii) Systems and integration and networking

(viii) FMS (Flexible Manufacturing Systems)

(Ix) Hazardous and inaccessible non-manufacturing environments

(x) Underground coal mining

(xi) Fire fighting operations

(xii) Robots in space

(xiii) Security guards

(xiv) Garbage collection and waste disposal operations

(xv) Household robots

(xvi) Medical care and hospital duties etc.

Classification of Robots (or) Classification by co-ordinate system and control system:-

-> Co-ordinate systems:-

Industrial robots are available in a wide variety of sizes, shapes, and physical configurations. The vast majority of today's commercially available robots possess one of the basic configurations:

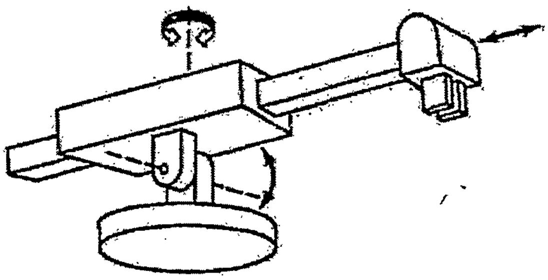
I. Polar configuration

2. Cylindrical configuration

3. Cartesian coordinate configurable

4. Jointed-arm configuration

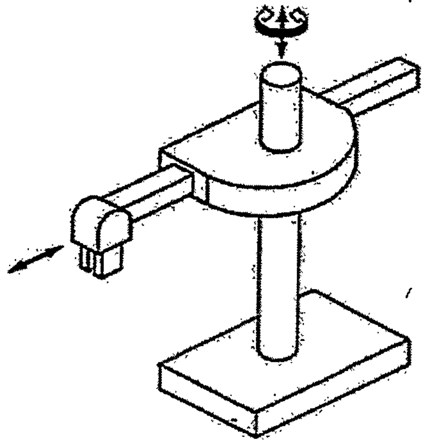
1. Polar configuration:-



Spherical

The polar configuration is pictured in part (a) of Fig. It uses a telescoping arm that can be raised or lowered about a horizontal pivot The pivot is mounted on a mta6ng base These various joints provide the robot with the capability to move its arm within a spherical space, and hence the name "spherical coordinate" robot is sometimes applied to this type. A number of commercial robots possess the polar configuration.

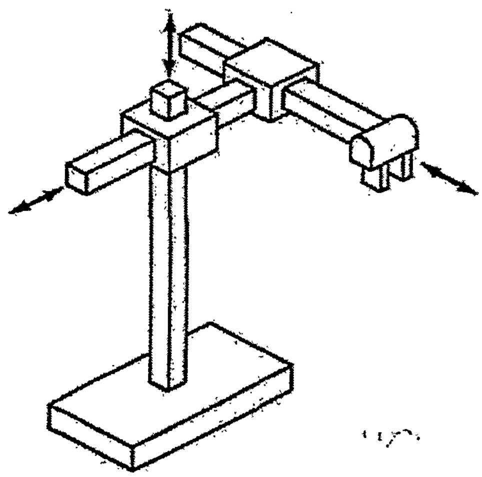
2. Cylindrical configuration:-



Cylindrical

The cylindrical configurable, as shown in fig, uses a vertical column and a slide that can be moved up or down along the column. The robot arm is attached to the slide so that it cm he moved radially with respect to the column. By routing the column, the robot is capable of achieving a work space that approximation a cylinder.

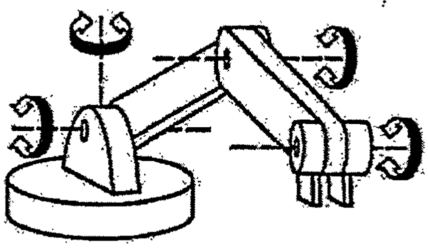
3. Cartesian coordinate configurable:-



Cartesian or xyz

The cartesian coordinate robot, illustrated in part Cc) of Fig, uses three perpendicular slides to construct the x, y, and z axes. Other names are sometimes applied W this configuration, including xyz robot and rectilinear robot, By moving the three slides relative to one another, the robot is capable of operating within a rectangular work envelope.

4. Jointed-arm configuration:-



Revolute

The jointed-arm robot is pictured in Fig. Its configuration is similar to that of the human arm. It consists of two straight components. Corresponding to the human forearm and upper arm, mounted on a vertical pedestal. These components are connected by two rotary joints corresponding to the shoulder and elbow.

-> **Control systems:-**

With respect to robotics, the motion control system used to control the movement of the end-effector or tool.

1. Limited sequence robots (Non-servo)
2. Playback robots with point to point (servo)
3. Play back robots with continuous path control,
4. Intelligent robots.

1. Limited sequence robots (Non-servo):-

1.Limited sequence robots do not give servo controlled to inclined relative positions of the joints, in stead they are controlled by setting limit switches & are mechanical stops. There is generally no feed back associated with a limited sequence robot to indicate that the desired position, has been achieved generally thin type of robots involves simple motion as pick & place operations.

2. Point to point motion:-

This type robots are capable of controlling velocity acceleration & path of motion, from the beginning to the end of the path. It uses complex control programs, PLC's (programmable logic controller's) computers to control the motion.

The point to point control motion robots are capable of performing motion cycle that consists of a series of desired point location. The robot is tough & recorded, unit.

3. Continuous path motion:-

In this robots are capable of performing motion cycle in which the path followed by the robot in controlled. The robot move through a series of closely space point which describe the desired path.

Ex:- Spray painting, arc welding & complicate assembly operations.

4. Intelligent robots:-

This type of robots not only programmable motion cycle but also interact with it's environment in a way that years intelligent. It taken make logical decisions based on sensor data receive from the operation.

There robots are usually programmed using an English like symbolic language not like a computer programing language.

Precision of movement (or) parameters of robot:-

The preceding discussion of response speed and stability is concerned with the dynamic performance of the robot. Another measure of performance is precision of the robot's movement. We will define precision as a function of three features:

1. Spatial resolution
2. Accuracy
3. Repeatability

These terms will be defined with the following assumptions.

(i) The definitions will apply at the robot's wrist end with no hand attached to the wrist.

(ii) The terms apply to the worst case conditions, the conditions under which the robot's precision will be at its wont. This generally means that the robot's arm is fully extended in the case of a jointed arm or polar configurable.

(iii) Third, our definitions will he developed in the context of a point-to-point robot.

1. Spatial resolution:-

The spatial resolution of a robot is the smallest increment of movement into which the robot can divide its work volume. Spatial resolution depends on two factors: the system's control resolution and the robot's mechanical inaccuracies. It is easiest to conceptualize these factors in terms of a robot with 1 degree of freedom.

The no of increments =2

Where n = the number of bits in the control memory.

The control resolution = ______________

Example 2-1 Using our robot with 1 degree of freedom as an illustration, we will assume it has one sliding joint with a full range of 1.0 m (39.37 in.). The robot's control memory has a 12-bit storage capacity. The problem is to determine the control resolution for this axis of motion.

The number of control increments can be determined as follows:

$$\text{Number of increments} = 2^{12} = 4096$$

The total range of 1 m is divided into 4096 increments. Each position will be separated by

$$1\ \text{m}/4096 = 0.000244\ \text{m} \quad \text{or} \quad 0.244\ \text{mm}$$

The control resolution is 0.244 mm (0.0096 in.).

2. Accuracy:-

Accuracy refers to a robot's ability to position its wrist end at a desired target point within the work volume. The accuracy of a robot can be denned in terms of spatial resolution because the ability to achieve a given target point depends on how closely the robot can define the control increments for each of its joint motions.

3. Repeatability:-

Repeatability is concerned with the robot's ability to position its wrist or an end effector attached to its wrist at a point in space is known as repeatability. Repeatability and accuracy refer to two different aspects of the robot's precision. Accuracy relates to the robot's capacity to be programmed to achieve a given target point. The actual programmed point will probably be different from the target point due to limitations of control resolution Repeatability refers to the robot's ability to return to the programmed point when commanded to do so.

THE END

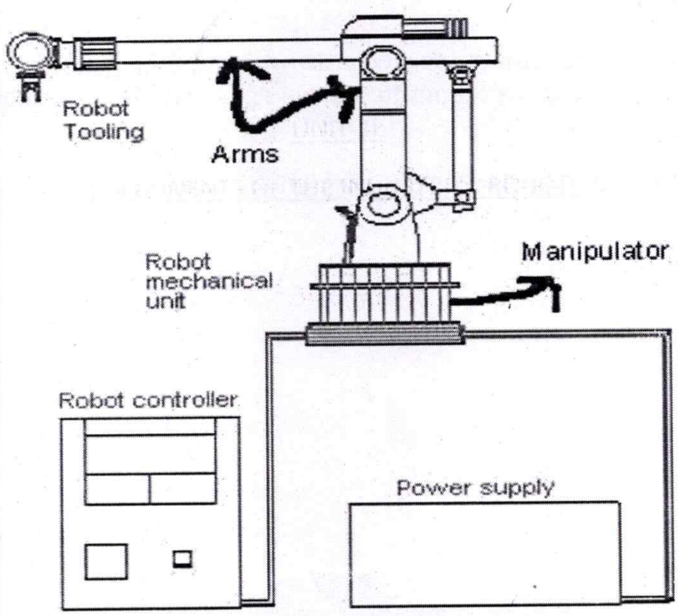
UNIT-1b

COMPONENTS OF THE INDUSTRIAL ROBOTICS

Main components of robot:-

A typical stand-alone robot shown in fig below, comprises of the following basic components, namely.

1. Manipulator
2. Sensors devices
3. Robot Tooling
4. Robot controller unit (RCU)



1. Manipulator:

It consists of base, arm, & wrist similar to a human arm. It also includes power source either electric, hydraulic or pneumatic on receiving signals from robot controller this mechanical unit will be activated. The movement of manipulator can be in relation to it's coordinate system. Which may be cartesian, cylindrical..etc.

Depending on the controller, movement may be point to point motion or continuous motion.

The manipulator is composed of 3 divisions,

i. The major linkages ii. The minor linkages (wrist components) iii. The end effectors (gripper or tool)

2. Sensors devices:

These elements in form the robot controller about the status of the manipulator. These sensors can be either analog or digital and combination. These are...

i. visual ii. Non – visual

3. Robot Tooling:

Robot tooling is nothing but hand or gripper of the robot also called as the "" end effector". It is provided at the end of the arm. It is design depends on the nature of the work to be performed by the robot.

4. Robot controller unit (RCU):

The instructions to the robot to perform the desired tasks are input through the key board of this unit. The controller converts the input programs to suitable signals which activate the manipulator to perform the desired tasks.

<u>Types of robot arms OR function line diagram representation of robot arms:-</u>

The arms of the robot classified as following:

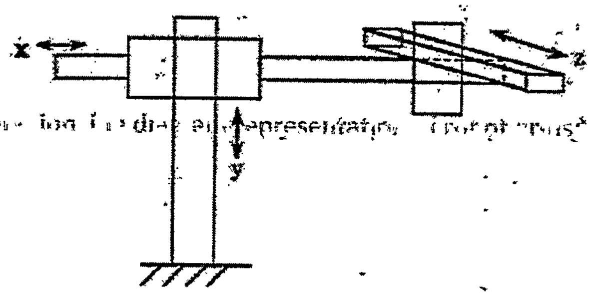
i. Cartesian robot

ii. Cylinder robot

iii. Polar robot

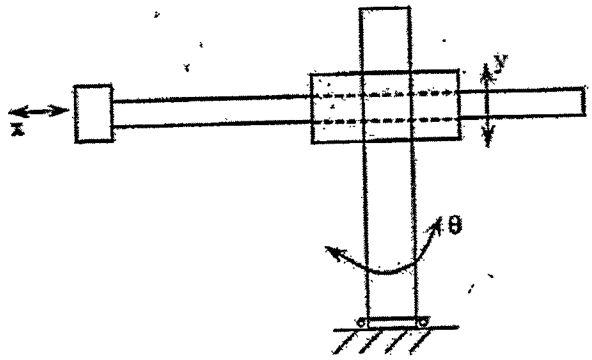
iv. Joint arm

i. cartesian robot:



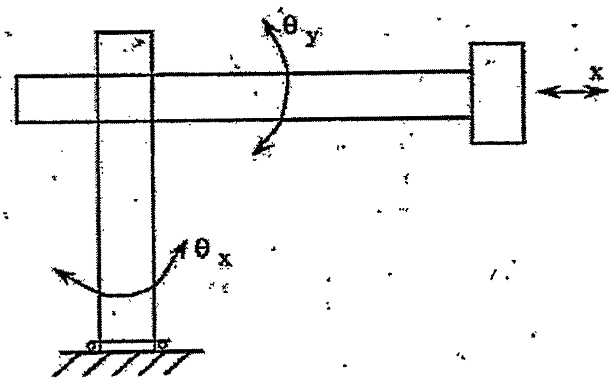
Cartesian robot has simplest configuration with prismatic joints. The work envelope of cartesian robot is cuboidal. It has large work volume but low density. It consists of 3 linear axes.

ii. Cylinder robot:



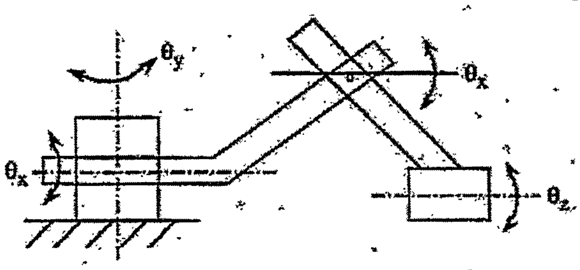
Cylinder robot makes use of two perpendicular prismatic joint and one revolute joint. The work envelope of cylinder robot approximates to a cylinder. It consists of two linear and one rotary axes.

iii. Polar robot:



Polar robot consists of a rotating base, a telescopic link which can be raised or lowered about a horizontal revolute joint. It has a work envelope of a partial spherical shell. It consists of one linear and two rotary axes.

iv. Joint arm robot:



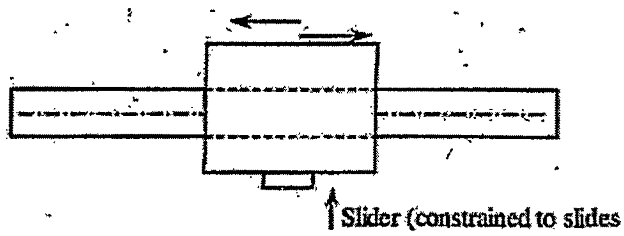
Joint arm robot also known as anthropomorphic robot. It functions similar to the human arm. It consists of two straight links. Similar to the human forearm and upper arm. These two links are mounted on rotary table and has a work envelope of spherical shape. It is the most dexterous one since all the joints are revolute joints. It consists of 3 rotary axes.

Different types of joints are used in robots:-

The different types of joint are used in robots are,

1. Prismatic Joint (Linear Motion)
2. Revolute Joint (Rotational Motion)
3. Screw Joint (Linear and Rotational Motion)
4. Spherical Joint
5. Planar Joint
6. Cylindrical Joint
7. Twisting Joint

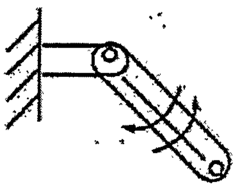
1. Prismatic Joint (Linear Motion):



Prismatic Joint

Prismatic joints are also called sliders, constituting purely linear motion along the joint axis. The joint slides in one, of the two directions along a singular axis. This type of motion is common in hydraulic or pneumatic cylinders, there is no rotation. The degree of freedom is one (i.e., translation).

2. Revolute Joint (Rotational Motion):



Revolute Joint

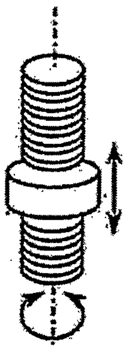
Revolute joints constitute purely rotation motion along the joint axis. Revolute joints are most commonly found in industrial robots. The degree of freedom is one. There is no translation motion.

Examples:

i. Elbow joint, waist joint.

ii. Most revolute joints cannot rotate through a full 3600, but are mechanically constrained.

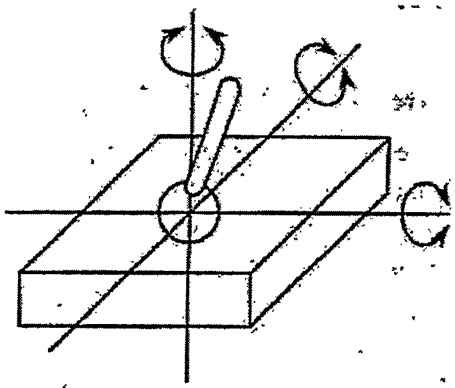
3. Screw Joint (Linear and Rotational Motion):



Screw Joint

Screw joints are a combination of first two types of joints. They constitute a simultaneous rotation and linear motion along a joint axis. Screw joints are more often used in tools for a robot end effector rather than a joint of motion for a robot. This joint follows the thread of the axis in spiral to move along axis.

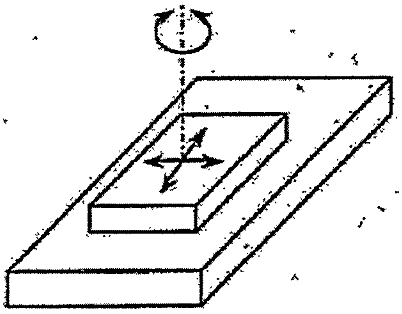
4. Spherical Joint:



Spherical Joint

Spherical joints are most utilized joints and just slide causing a revolving movement.

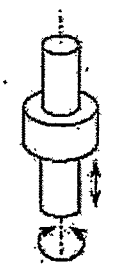
5. Planar Joint:



Planar Joint

It consists of three degrees of freedom as the figure i.e., one rotary and two sliding motions.

6. Cylindrical Joint:



Cylindrical Joint

It consists of two degrees of freedom as shown in figure i.e., one rotary and one sliding motion.

7. Twisting Joint:

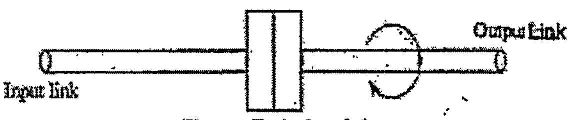


Figure: Twisting Joint

It consists of single degree of freedom as shown in the figure.

<u>**Number of degrees of freedom:-**</u>

Degrees of freedom:

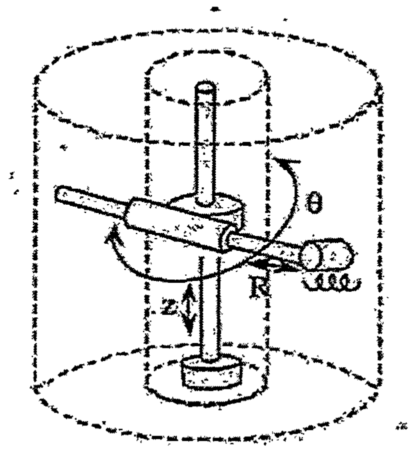
The number of independent motions or movement that an object can performed in 3-D space, is known as 'DOF'.

A rigid body free to move in space has got 6- degrees of freedom. i.e., 3 translations and 3 revolutions. A manipulator with 6 degrees of freedom is known as a spatial manipulator.

However, there are many manipulators that does not have full 6 degrees of freedom. Since not all tasks require 6 degrees of freedom.

Ex:

Cylindrical parts, can be picked up and placed codependent of gripper orientation with respect to the cylinder axis. Spatial manipulators having more than 6 DOF with us joints are known as redundant manipulators. These degrees of freedom enhance the robots capability in whirl the subspaces obstructed by objects by moving them. Depending on the application, the types and cement of the robot manipulator varies considerably.



Cylindrical Robot

As shown in the figure, cylindrical robots are made up of two prismatic joints and a revolute joint which allows three degrees of freedom i.e., two linear motions and one rotational motion. The work volume of a cylindrical robot is a cylinder as shown in the figure by dotted lines. The following are, the three relative motions of the joints,

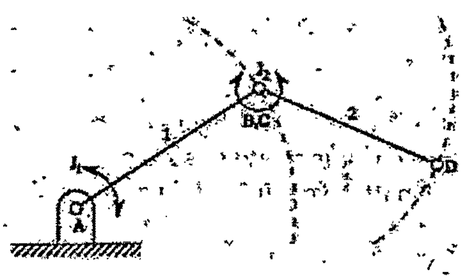
1. Radial (R) in or out translation of the horizontal arm.

2. Angular motion (q) about the vertical axis.

3. Up or down motion of the carriage in the z- direction.

<u>Representation of 6 DOF with respect to a co-ordinate frame:-</u>

Consider an open kinematic chain of two links with revolute joints at A and B (or C), as shown in figure.



Here the first link is connected to be ground by joint 'A'. Therefore link 1 can only rotate about joint 'A', and it contributes only 1 DOF. Link 2 can rotate with respect to contribute of joint 'B' so, other degrees of freedom. So, the above figure has got '2' DOF.

- ➔ The DOF is equal to non of links in an open kinematic chain.
- ➔ Robot with 6 DOF is called as spatial manipulator (arm, body &wrist)
- ➔ Robot is more than 6 DOF is called as redundant manipulator.

End effectors:-

In robotics, the physical construction of robot consists of body, arm and wrist of the machine. The body is attached to base and arm assembly attached to body. At the end of the arm wrist is attached, which consists number of components to allow variety position. Relative motion between body, arm and wrist are provided by joints. The joint motions are either or sliding. The body, arm and wrist assembly is also called as manipulator. Attached to the robot wrist is a hand (End effector). The end effector is not considered as part of robot. The arm and the body joints keeps the end effector in It is also called gripper.

Types of End- Effectors:

End- Effectors are categorized-into two types,

1. Grippers
2. Tools

1. Grippers:

Grippers would be utilized to grasp an object, usually the work part and hold it during the robot work cycle. The types of material used for grippers depends on orientation of part & friction between parts & grippers. The applications include material handling, machine loading, unloading, palletizing and other similar operations.

The operations performed by grippers are

i. To move the fingers with commanded speeds.

ii. To gripper handled part with not more than specified force.

iii. To open, move & also the fingers at specified positions.

iv. To measure dimension of a part.

Grippers are further classified as,

a. Mechanical grippers

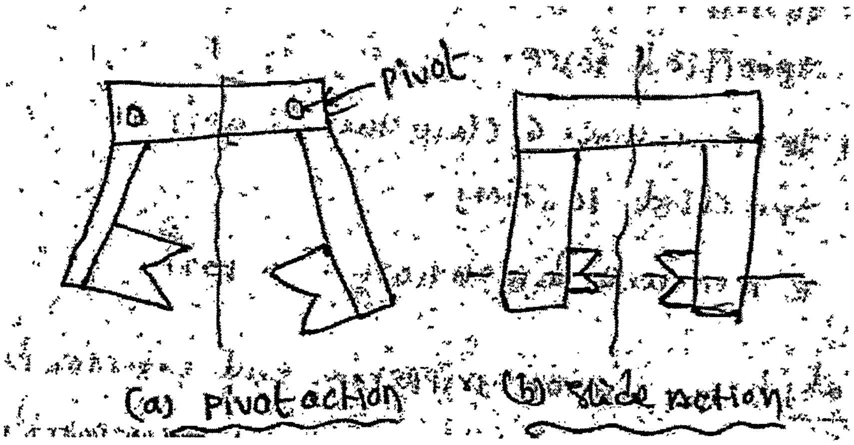
b. Magnetized grippers

c. Suctions or vacuum cups

d. Hooks

e. Scopes or ladles.

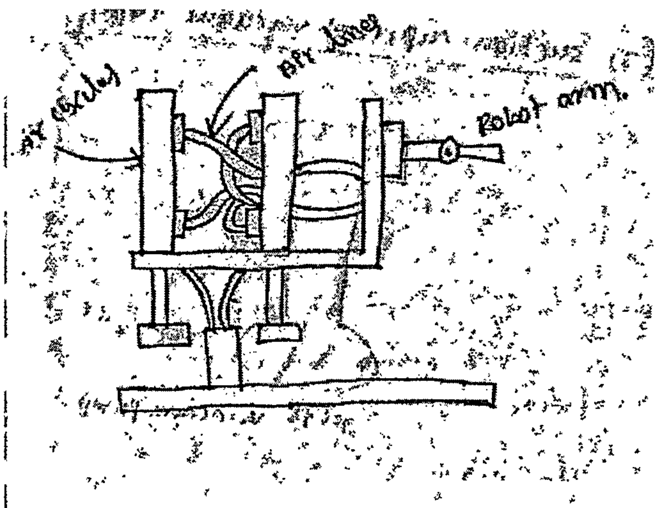
a. Mechanical grippers:



Mechanical gripper in an end effector, that uses mechanical fingers actuated by a mechanism to grasp an object. The fingers are either attached to the mechanism.

- ➔ The function of the gripper mechanism is to translate some form of power input into the grasping action.
- ➔ The power input is supplied from the robot and can be pneumatic, hydraulic, and electrical.
- ➔ The mechanism must be able to open and close the fingers.

b. Magnetized grippers:



Magnetic grippers are be divided into 2 types:

i. Electro magnetic
ii. Permanent magnetic.

i. Electromagnetic

Electromagnetic grippers include a *controller unit* and a *DC power* for handling the materials. This type of grippers is easy to control, and very effective in releasing the part at the end of the operation than the permanent magnets. If the work part gripped is to be released, the polarity level is minimized by the controller unit before the electromagnet is turned off.

ii. Permanent magnetic

The permanent magnets do not require any sort of external power as like the electromagnets for handling the materials. After this gripper grasps a work part, an additional device called as*stripper push – off pin* will be required to separate the work part from the magnet. This device is incorporated at the sides of the gripper.

- This gripper only requires *one surface* to grasp the materials.
- The grasping of materials is done *very quickly.*
- It does not require *separate designs* for handling different size of materials.
- It is capable of grasping materials with *holes,* which is unfeasible in the vacuum grippers.

c. Suctions or vacuum cups:

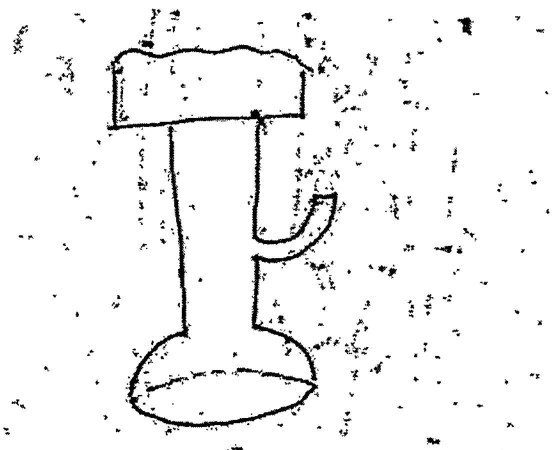


fig:- vacuum pump.

It is used to left the flat glass of the work. This type of gripper are typical made of elastic material such as rubber, soft plastic. The shape of the vacuum is shown in figure Commonly used round type. It means of removing the air between the up and part surface to create the vacuum tin required the vacuum pump & venture in of to common devices and for those purpose.

The lift capacity of suction cup depend upon the effective area of the cup. The negative air pressure between cup & the object.

$$F=PA$$

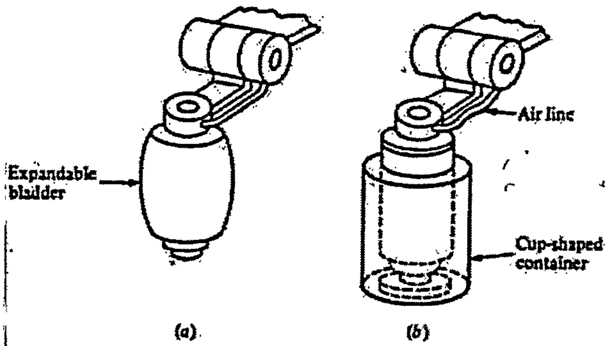
Where,

F=force, P=negative pressure, A= total effective area of the suction cup used to create the vacuum.

d. Hooks gripper:

Hooks can be used as end effectors to handle containers of parts to load and unload parts, hanging from, power head conveyors. The items to be handled by a hook must have some soft handle to enable the hook to hold it.

e. Scopes or ladles:



Expansion bladder used to grasp inside of a cup-shaped container.

Scopes or ladles can be used to handle certain materials in liquid or powder form, chemically in liquid or powder form, good materials etc. that can be handled by a robot using method of handling.

<u>Types of Mechanical gripper actuations:-</u>

There are various ways of classifying mechanical grippers and their actuating mechanisms. One method is according to the type of finger movement used by the gripper. In this classification, the grippers can actuate the opening and closing of the Rogers by one of the following motions:

1. Pivoting movement

2. Linear or translational movement

In the pivoting movement. The fingers rotate about fixed pivot points on the gripper to open and close. The motion is usually accomplished by some kind of linkage mechanism. In the linear movement, the Hagen open and close by moving in parallel to each other. This is accomplished by means of guide rails so that each finger base slides along a guide rail during actuation. The translational finger movement might also be accomplished by means of a linkage which would maintain the Rogers in a parallel orientation to each other during actuation.

Mechanical grippers can also be classed according to the type of kinematic device used to actuate the Roger movement. In this classification we have the following types:

i. Linkage actuation, ii. Gear & rack actuation, iii. Cam actuation, iv. Screw actuation, v. Rope & pulley actuation.

i. Linkage actuation:

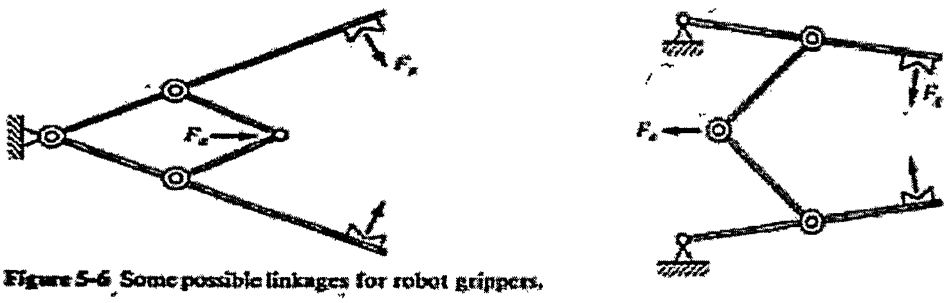


Figure 5-6 Some possible linkages for robot grippers.

The linkage category covers a wide range of design possibilities to actuate the opening and closing of the gripper. The design of the linkage determines how the input force ' ' to the gripper is converted into the gripping force' ' applied by the fingers. The 'linkage configuration also determines other operational features such as how wide the gripper fingers will open and how quickly the gripper will actuate.

ii. Gear & rack actuation:

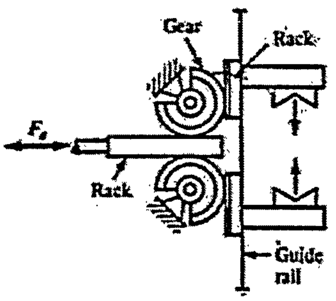


Figure 5-7 Gear-and-rack method of actuating the gripper.

These are some other mechanism that would provide a linear motion, movement of the rack would drive to partial pinion gears and these would in turn open and close the finger.

iii. Cam actuation:

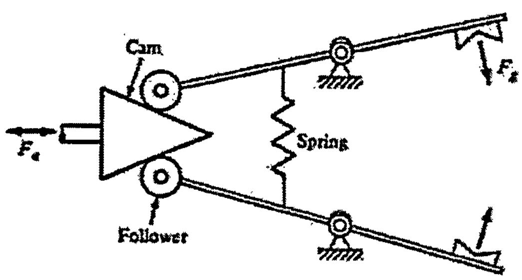


Figure 5-8 Cam-actuated gripper.

The cam actuated gripper Includes a vanity possible designs, one of which is shown in Fig. A cam-and - follower arrangement, often using & spring-loaded follower, can provide the opening and closing action of the gripper. For example, movement of the cam in one direction would force the gripper to open. while movement of the cam in the opposite direction would cause the spring to force the gripper to close. The advantage of this arrangement is that the spring action would accommodate different sized parts. This might be desirable, for example, in a machining operation where a single gripper is used to handle the raw work part and the finished part. The finished part might be significantly smaller after machining.

iv. Screw actuation:

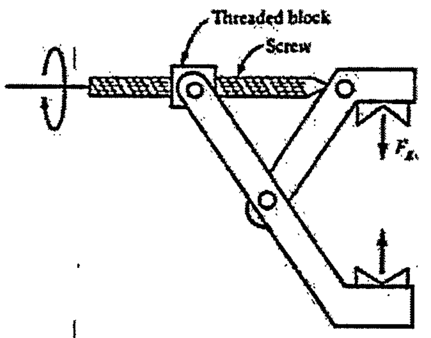
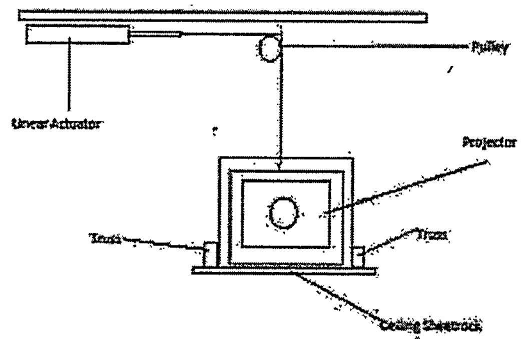


Figure 5-9 Screw-type gripper actuation.

The screw is turned by a motor. Usually accompanied by a speed reduction mechanism. When the screw is rotated in one direction, this causes a threaded block to be translated in one direction. When the screw is rotated in the opposite direction. The threaded block moves in the opposite direction. The threaded block is, in turn, connected to the gripper Buyers to cause the corresponding opening and closing action.

v. Rope & pulley actuation:



Rope & pulley actuating can be design to open & closing a mechanical gripper.

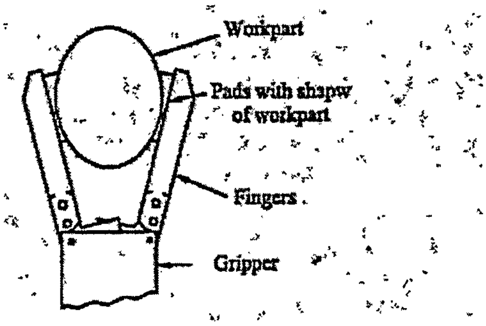
<u>Construction the path in the grippers:-</u>

There are two ways of construction the path in the gripper.

(i) Physical construction of the path with in the finger.

(ii) Holding the path by friction between the finger and the work path.

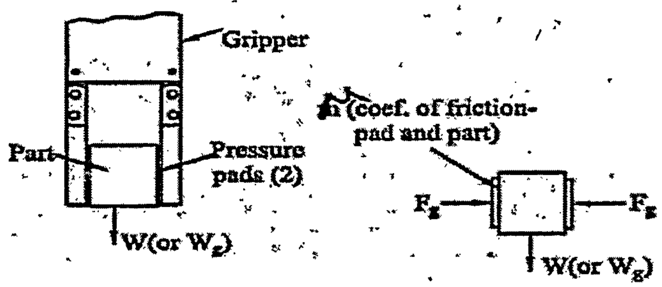
(i) Physical type:



Physical construction method of finger design

In this approach, the gripper fingers enclose the part to some extent, thereby constraining the surface of the fingers to be in the approximate shape of the part geometry.

(ii) Holding Method:



(a) (b)

Force against part parallel to finger surfaces tending to pull part out of gripper

In this approach, the fingers must apply a force that is sufficient for friction, to retain the part against gravity, acceleration and any other force that might arise during the holding portion of the work cycle.

The fingers or the pads attached to the fingers which make contact with the part. This tends to increase the coefficient of friction between the part and the contacting finger surface.

If a force of sufficient magnitude is applied against the part in a direction parallel to the friction surfaces of the fingers as shown above fig. the part might ship out of the gripper.

The following force equal can be used to determine the required magnitude of the gripper force as a function of these factors.

where

=coefficient of friction of the finger contact surface against the part surface

=number of contacting fingers;

= gripper force, W = wt. of the part or object being gripped.

Engelberger suggests that in a high-speed handling operation the acceleration (or deceleration) of the part could exert a force that is twice the weight of the part. He reduces the problem to the use of a g factor in a revised version of equation (1) as follows:

$$\mu n_f F_g = w g \qquad (2)$$

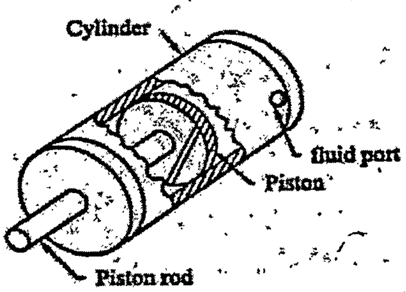
where g = the g factor.

The g factor is supposed to take account of the combined effect of gravity and acceleration. If the acceleration force is applied in the same direction as the gravity force, then the g value = 3.0. If the acceleration is applied in the opposite direction, then the g value = 1.0 (2 × the weight of the part due to acceleration minus 1 × the weight of the part due to gravity). If the acceleration is applied in a horizontal direction, then use $g = 2.0$.

Locomotive devices or drive systems:-

Actuators are the devices which provide the actual motive force for the robot joints. They commonly get their power from one of three sources compressed air, pressurized fluid, or electricity. They are called, respectively, pneumatic, hydraulic, or electric actuators.

(i) Pneumatic Actuators:



Cylinder and piston

Pneumatic and hydraulic actuators are both powered by moving fluids. In the first case the fluid is compressed air and in the second case the fluid is usually pressurized oil. The operation of these actuators is generally similar except in their ability to contain the pressure of the fluid. Pneumatic systems typically operate at about 100 lb/ ^{2} and hydraulic systems at 1000 to 3000 lb/ ^{2}.

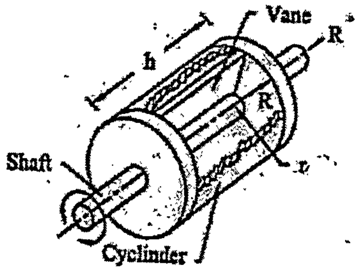
The simplest flied power device is the cylinder as illustrating in fig, which could be used to actuate a linear joint by means of a moving piston. This example is called a single-ended cylinder as the piston rod only comes out of the cylinder at one end. Other types of cylinders include double-ended cylinders and rod less cylinders.

There are two relationships of particular interest when discussing actuators: the velocity of actuator with respect to the input power and the force of the actuator with respect to the input power and the force of the actuator with respect to the input power. For the cylinder type actuator these relationships are given by

$$() = \frac{()}{}$$

Where,

V(t) is the velocity of the piston, f (t) is the fluid How rate`(volumetric), F (t) is the force, P(t) is the pressure of the fluid, and A is the area of the piston.



Vane actuator

Since the requirements of a robot are to carry a payload at a given speed we can use the relations described for choosing the appropriate actuator.

Another type of fluid power actuator is the rotary Vane actuator, shown in Fig. In a rotary actuator we are interested in the angular velocity, , and the torque, T. The relations describing the output of a rotary actuator are

$T(t) = 2 P(t) h (R-r)(R+r)$ $() = (2 \; 2()$

Where,

R is the outer radius of the vane, r is the inner radius of the vane, h is the thickness of the vane, is the angular velocity in radians per/sec, and T is the torque.

(ii) Electric actuators:

As their capabilities improve, electric motors are becoming more and more the actuator of choice in the design of robots. They provide excellent controllability with a minimum of maintenance required. Here are a variety of types of moors in use in robots; the most common are dc servomotors, stepper motors, and ac servomotors.

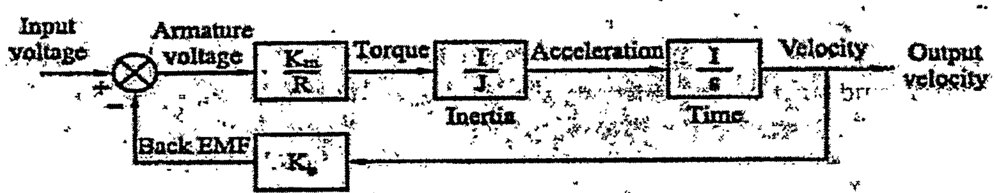
(a) Dc servomotor:

Main components in dc servomotor are the rotor and the stator. Usually, the rotor include the armature and the commutator assembly and the stator includes the permanent magnet and brush assemblies.

When current flows through the windings of the armature it sets up a magnetic field, opposing the field set up by the magnets. This produces a torque on the rotor. As the rotor rotates, the brush and commutator assemblies switch the current to the armature. So, that the field remains opposed to the one set up by the magnets. In this way the torque, produced by the rotor is constant through the rotation. Since the field strength of the rotor is a function of the current through it, it can be shown that for Dc servomotor.

Where,
= torque of the motor.

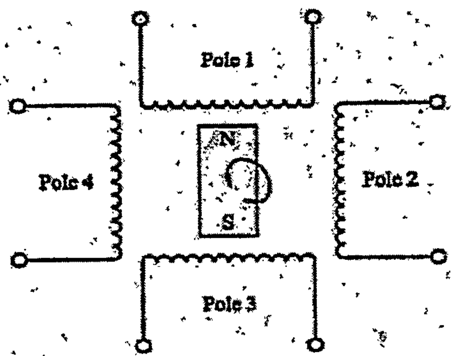
= motor torque constant, = current flowing through armature.



DC motor block diagram

(b) Stepper motors:

Stepper motors (also called stepping motors) are a unique type of actuator and have been used mostly in computer peripherals. A stepper motor provides output in the form of discrete angular motion increments. In robotics, stepper motors are used for relatively light duty applications. Also stepper motors are typically used in open-loop systems rather than the closed - loop systems one which we have been concentrating.



Stepper motor schematic

PRECISION OF MOVEMENT:

The preceding discussion of response speed and stability is concerned with the dynamic performance of the robot. Another measure of performance is precision of the robot's movement. We will define precision as a function of three features:

1. Spatial resolution

2. Accuracy

3. Repeatability

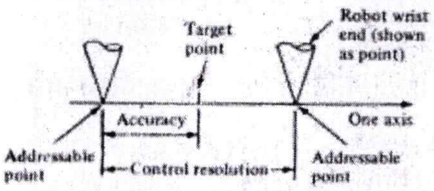
These terms will be defined with the following assumptions,

1. Spatial resolution:

The spatial resolution of a robot is the smallest increment of movement into robot can divide its work volume. Spatial resolution depends on two the system's control resolution and the robot's mechanical inaccuracies. It is easiest to conceptualize these factors in terms of a robot with 1 degree of freedom.
Number of increments = 2

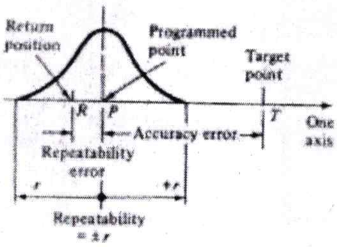
n = the number of bits in the control memory.

2. Accuracy:



Accuracy refers to a robot's ability to position its wrist end at a desired target point within the work volume. The accuracy of a robot can be defined in terms of spatial resolution because the ability to achieve a given target point depends on how closely the robot can define the control increments for each of its joint motions.

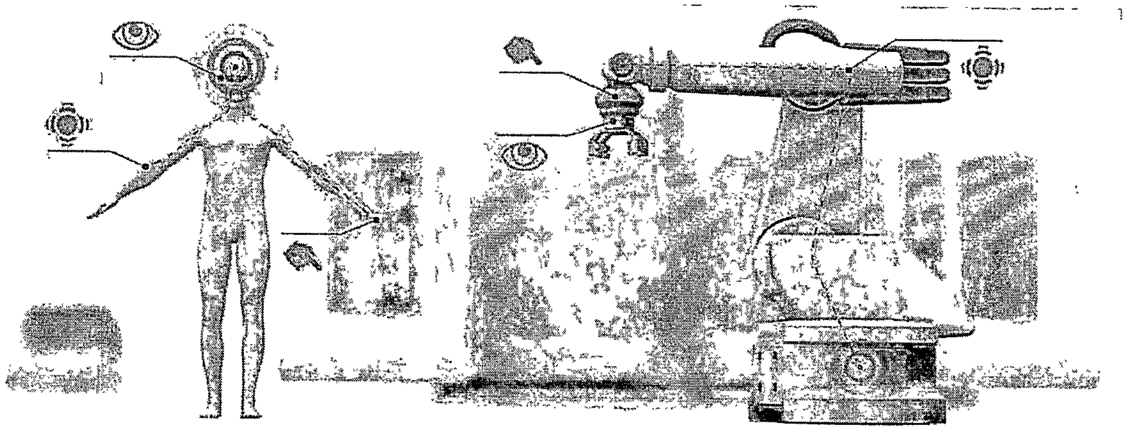
3. Repeatability:



Repeatability is concerned with the robot's ability to position its wrist or an end effectors attached to its wrist at a point in space that had previously been taught to the robot. Repeatability and accuracy refer to two different aspects of the robot precision. Accuracy relates to the robot's capacity to be programmed to achieve a given target point.

Q&A Unit -2

Sensors



What is a sensor?

A sensor is a "Sensory organ" of a machine which transforms the physical size (/ a signal) of an object to be measured into an electrical size (/ a signal).

How sensors work?

A sensor converts the physical action to be measured into an electrical equivalent and processes it so that the electrical signals can be easily sent and further processed. The sensor can output whether an object is present or not present (binary) or what measurement value has been reached (analog or digital).

Briefly describe the main components of a sensor.

A sensor consists of three main components:
(1) The sensing section contains the sensor itself which is based on a particular technology. The variety of technologies means you can select a sensor technology which fits your application.
(2) The processing circuitry converts the physical variable into an electrical variable.
(3) The signal output contains the electronics connected to a control system.

What are the various sensor technologies and their functions?
The various sensor technologies in detecting or measuring objects, they depends on the technology of the sensors output that may be a switching signal or a measurement value:

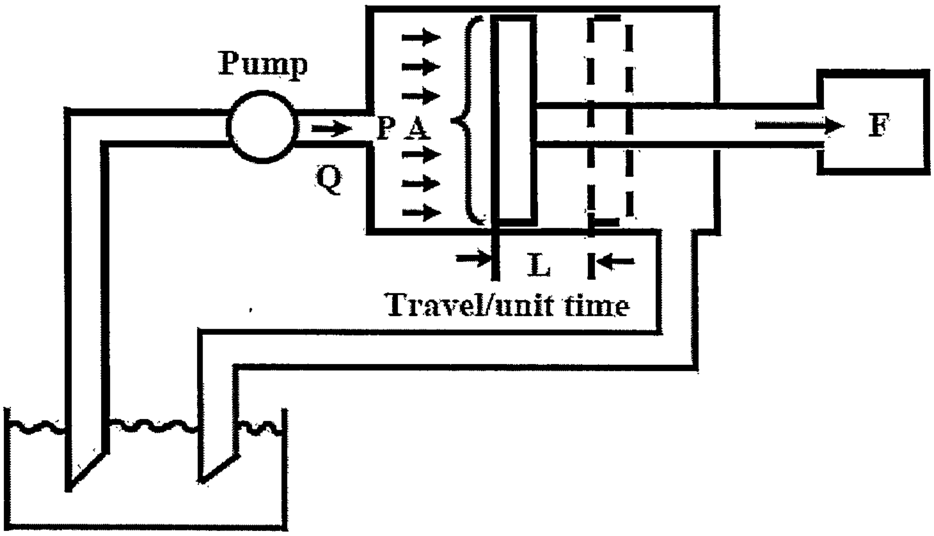
- **Inductive sensors** generate an electromagnetic field. This in turn generates eddy currents in objects made of metal. The sensor detects this change.
- **Capacitive sensors** generate a capacitive measuring field. An entering object results in a change to the measuring field. The sensor responds to this change.
- **Photoelectric sensors** (light curtains) always consist of an emitter and a receiver. There are diffuse, retro-reflective and through-beam types.

- **Ultrasonic sensors** send out a sound pulse in the inaudible range. The echo from the object is processed.
- **Magnetic field sensors** detect an external magnet. The field strength generated by the magnet is processed.
- **Magnetostrictive sensors** detect the position of an external magnet using propagation time measurement.

In robotics, finding position and velocity are the major functions of a sensor.
Position & Velocity sensors are used in robotics as feed back devices, while actuators & power transmission devices are used to accomplish the control actions indicated by the controller.

Can you give an analogy of the force amplification in hydraulic system from an electrical system?
Ans: The electrical analogy of force is voltage. Both are called across variables, while the electrical analogy of flow rate is current, both which are called through variables. Note that the product of force and flow rate is power as is the product of voltage and current. Thus the analogy of force amplification is voltage amplication as can be achieved by transformers.

Can you imagine what would happen, if the cylinder piston in Fig. below is stopped forcefully?



Ans: If the cylinder is stopped, there cannot be any flow through the system. However, the prime mover to the pump would attempt to rotate the drive shaft and deliver fluid. Thus the operating pressure of the pump and load on the prime mover would tend to rise. Practically, this operating pressure would be contained by a relief valve which would open a low flow resistance path for the fluid to flow bypassing the cylinder (not shown in the Figure 26.1). Otherwise the load on the prime mover would be so high that it would stall. Thirdly, due to extremely high pressures fluid lines or pump may rupture.

What would happen if orifices of valves are blocked by, say, a metal chip in the hydraulic oil?

Ans: Immediately the pressure difference across the hydraulic cylinder, which moves the cylinder against load, would be neutralized. Thus the load motion would stop. At the same time the pressure difference across the jammed orifice would rise. Sometime this resulting force can dislodge or shear the chip that causes the jam.

Why do gear pumps usually operate at comparatively low pressures?
Ans: The load imposed by the drive shaft depends on the operating pressure. By construction, this load is unbalanced in the gear pump and therefore, considerable side loading on the drive shaft exists. To limit this loading, operating pressures have to be kept low. Note that due to the symmetry of the inlet and out let ports such forces do not arise in balanced vane pumps.

Why is stalling an electric motor is likely to cause damage? What can be done to prevent it?
Ans: Stalling an electric motor reduces the back emf in the motor to zero. Therefore very high current flows in the motor causing thermal damage. To prevent such damages, current control techniqies are applied in all motor drives which sense the current and reduce the motor terminal voltage whenever the current exceeds its limit. In other cases, where such rise of current is considered to be due to fault, over current trip mechanisms are employed that switch off supply to the motor.

Consider two types of variable speed drives. In the first one an electric motor with a power electronic servo drive is directly coupled to the load through a mechanism. In the second one an electric motor with a constant speed drive drives the pump in a hydraulic system which provides the variable speed drive to the load. Which one of these two is more energy efficient?
Ans: The first one is likely to be more efficient. This is because the overall efficiency of both the systems would include the efficiency of the motor and the efficiency of the final mechanism that connects the load with the actuator, such a gear or a ball screw. However, the hydraulic system would further involve the efficiency of the pump and cylinder as well as that of other speed control equipment such control valves. For the first system this would involve only the efficiency of the power electronic converter, which is likely to be higher. Thus the lesson is that hydraulic systems are not used for their energy efficiency, but rather for their small size, high power handling capacity and ease of control under high loads.

Sensor element: The fundamental transduction mechanism (e.g., a material) that converts one form of energy into another. Some sensors may incorporate more than one sensor element (e.g., a compound sensor).
Sensor: A sensor element including its physical packaging and external connections (e.g., electrical or optical).
Sensor system: A sensor and its assorted signal processing hardware (analog or digital) with the processing either in or on the same package or discrete from the sensor itself.

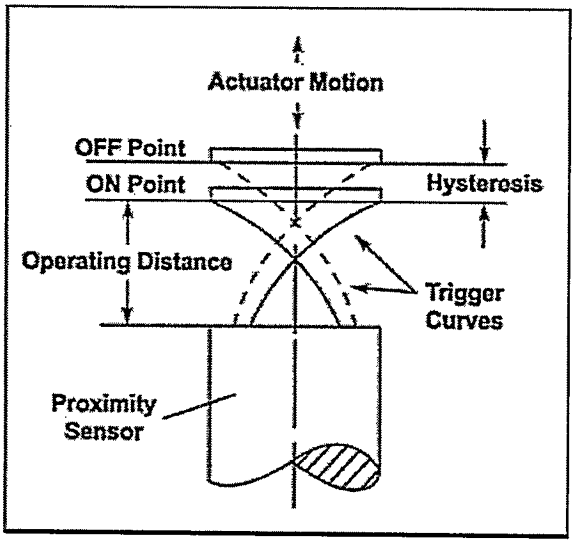
Characteristics of sensors:

Static	Dynamic
Accuracy	Dynamic error response
Distortion	Hysteresis

Hysteresis	Instability and drift
Minimum detectable signal	Noise
Nonlinearity	Operating range
Selectivity/Specificity	Repeatability
Sensitivity	Step response
Threshold	

Explain hysteresis effect in sensors.

The distance between the switching "ON" point of the actuator approach and the switching "OFF" point of the actuator retreat. This distance reduces false triggering. Its value is given as a percent of the operating distance or as a distance.



What are the major difficulties of using sensors?

The main difficulties are an insufficient robustness of sensors to operate in the industrial environment (temperature range, humidity, vibrations, etc), and control algorithms that are to use the sensor information in real-time.

Describe position sensors and its types.

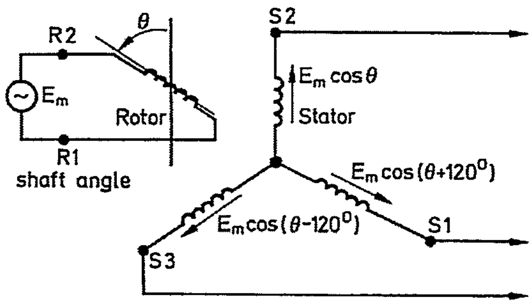
Positional sensors play an important role in the control of manipulation robots. They provide information about the robot position, and are used in forming the control signals for servos.

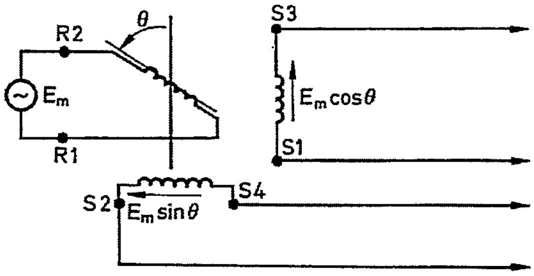
Resolvers (and synchronous) belong to electromechanical positional transducers. The resolver is a rotary transformer, where the primary coils are on the rotor and the secondary coils are on the stator. The secondary coils consist of two coils displaced 90 degrees on the shaft, while synchronous has three secondary coils displaced 120 degrees on the shaft.

The principle of the resolver (Fig. below) operation is similar to the transformer: an alternate voltage is applied on primary coils and the secondary voltage is measured. The ratio of the primary and the secondary voltage is the function of the shaft position, and does not depend on the amplitude and frequency variation of the primary voltage, temperature, electrical load of the stator, humidity.

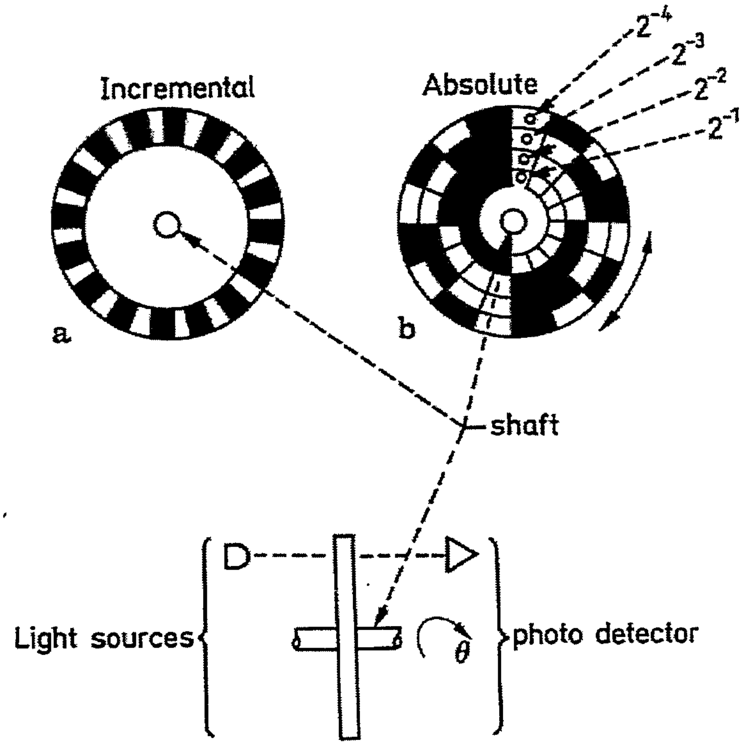
The typical accuracy of the resolver is on average three arc minutes, but it can be significantly increased by the use of "reduction". The "reduction" is achieved electrically, using multiple pairs of poles on the stator. When using n pairs of poles, resolution and accuracy is increased

n times, thus, for n = 16 the resolution would be 3'/16-11". Since one shaft revolution corresponds to n periods of amplitude change of the electrical output, one independent pair of poles is needed to determine in which period the angle is measured.
Because electromechanical transducers are converting the angle into the voltage amplitude, they cannot be applied in the digital control systems without appropriate convertors. There are now sufficiently reliable and cheap components on the market that perform the conversion of the voltage amplitude into digital information about the position and even provide a digital tachometer information.





Encoders: Shaft encoders are angle positional sensors which, because of the specific construction, convert the angle position directly into digital information. There are several types of encoders (optical, contact, magnetic), but in practice optical encoders are mostly used, having some advantages over others. Optical encoders may be absolute and incremental. An incremental encoder detects the quantum of the change of the angular position, and an absolute one shows the absolute angular position. The encoder consists of the disk (see Figure below) which is connected to the rotating shaft.
The disk has concentric ring(s) with alternate transparent and opaque segments. On one side of the disk there are light sources (usually LEDs), and on the other side light detectors are situated. The signal from the detector is led to the electronics for the signal conditioning and then to the control system.
The advantage of the incremental encoder over the absolute one is the use of only one pair of light source and detector, while the absolute uses *n* pairs, where *n* is its resolution in bits. In the same ratio is the number of wires needed to transmit the signals.
Because of the more complex construction, absolute encoders are more expensive and less reliable than incremental ones. The advantage of the absolute encoder over the incremental one is that it does not accumulate the error induced by disturbances, and after reconnecting to power supplies it shows the absolute position at once, while the incremental encoder has to be brought into the referent position first.

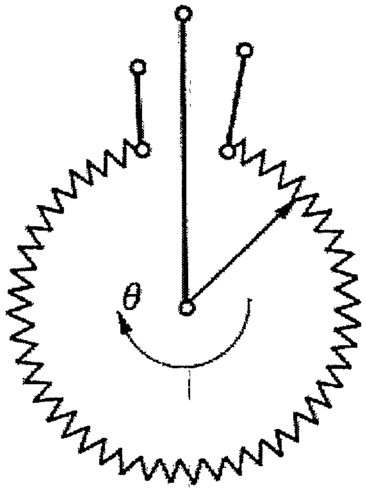


Potentiometers

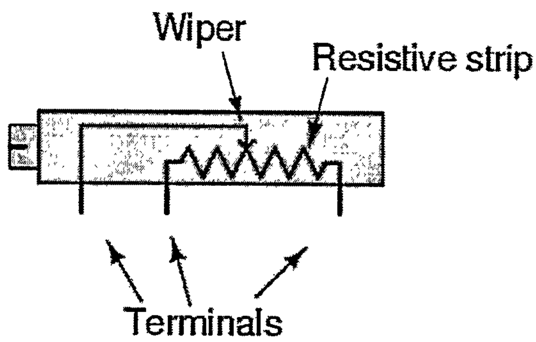
Position Sensors ➡ Potentiometers

- Potentiometers are analog devices whose output voltage is proportional to the position of wiper.
- Potentiometers offer a low cost method of contact displacement measurement.
- Depending upon their design, they may be used to measure either rotary or linear motion.
- In either case, a movable slide or wiper is in contact with a resistive material or wire winding. The slide is attached to the target object in motion.
- A DC or an AC voltage is applied to the resistive material.
- When the slide moves relative to the material, the output voltage varies linearly with the total resistance included within the span of the slide.
- An advantage of potentiometers is that they can be used in applications with a large travel requirement.
- It is possible to use pots to provide a limited amount of feedback control in robots where high proportional resolution and accuracy are not required.

Potentiometers (Fig. below) are the simplest positional transducers. They consist of a circular resistor (made of wire, carbon or some other resistive material) with the sliding contact on it connected to the rotating shaft. The resistance between the connections of the potentiometer is the function of the relative position of the shaft with the slider to the circular resistor. This signal is converted into digital information by means of the appropriate measuring electronics.



Linear potentiometer construction



- Benefits:

  Relatively Inexpensive

  Can be used for Distance and Direction

  Low software overhead – Not dependent on interrupts

  Can Sense Speed and Distance

- Drawbacks:

  Sample Rate issues can limit max useable Speed

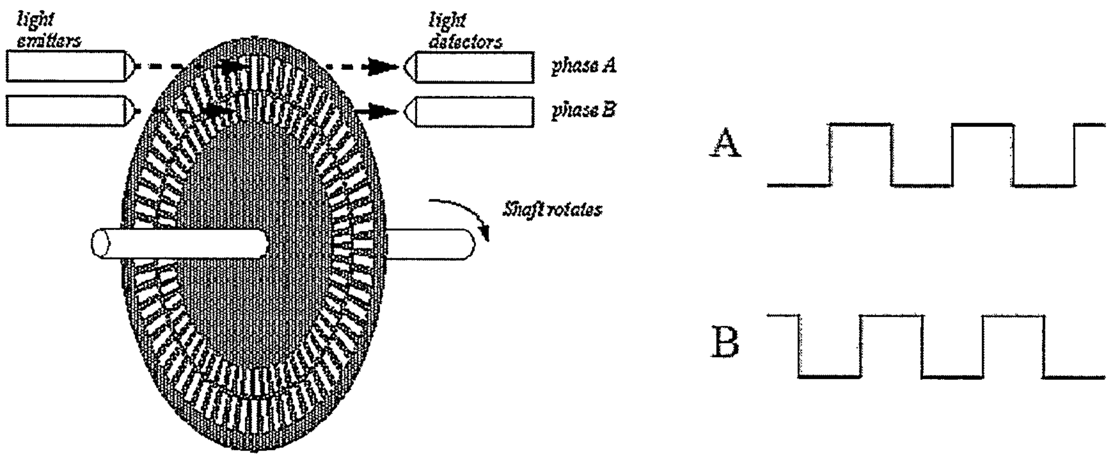
  Small "Dead" zone, though usually not a big problem

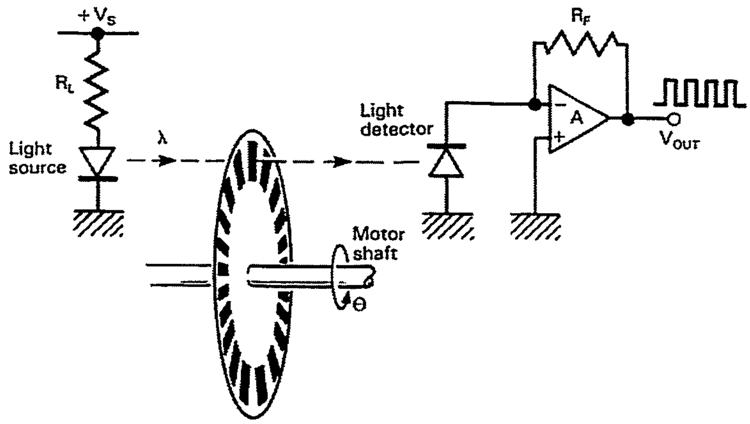
Describe about optical encoders.

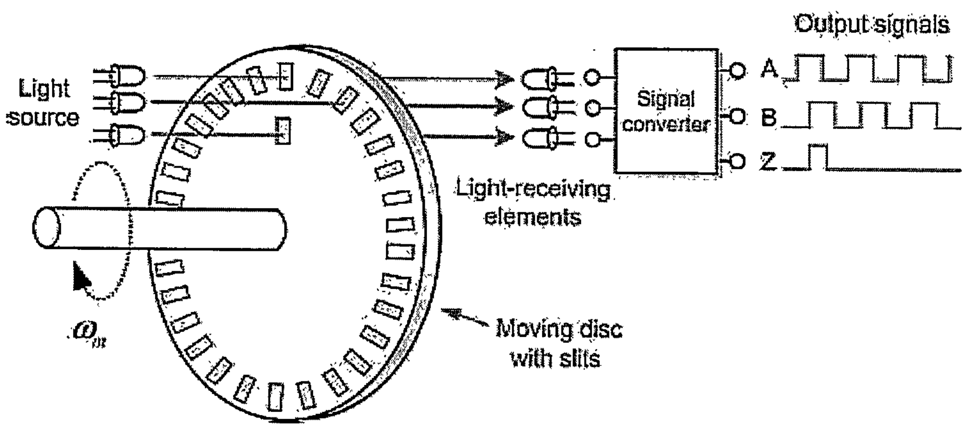
An optical encoder is an electromechanical device which has an electrical output in digital form proportional to the angular position of the input shaft. Optical encoders enable an angular displacement to be converted directly into a digital form.

- An optical encoder is an angular position sensor.
- It has a shaft mechanically coupled to an input driver which rotates a disc rigidly fixed to it. A succession of opaque and clear segments are marked on the surface of the disc.

- Light from infrared emitting diodes reaches the infrared receivers through the transparent slits of the rotating disc. An analogue signal is created.
- Then electronically, the signal is amplified and converted into digital form. This signal is then transmitted to the data processor.







Position Sensors:

https://www.thomasnet.com/articles/instruments-controls/all-about-position-sensors/#:~:text=Position%20sensors%20are%20devices%20that.an%20object%20or%20its%20absence.

Compare Ac and DC drives in Robotics.

DC drives are famous for providing high start up torque, having simple circuits and are good for applications with constant speed, they are also believed to have more problems especially because of the requirement of commutators and brush assemblies in the DC Motors (which require lots of maintenance, can wear over time and often have mechanical problems). On the other hand AC drives are more energy sufficient and they can handle rapid speed changes better because of running induction motors. They often have hundreds of different programmable parameters for failsafe protections. Even though this makes the AC drive more complicated in a lot of ways, advancements in programming software provided by drive manufacturers is making them easier than ever to install and use.

Though in the past DC drives were often utilized due to their simplicity, most machine manufacturers now prefer to use AC drives (especially for servo applications). The complexity of an AC drive has been simplified over time and has many advantages. From the ability to be controlled on a network, ease of monitoring and simple transference of all data and parameters to a new drive in case you need to replace a unit.

D.C. Drives	A.C. Drives
Power circuit and control circuit is simple	Power and Control circuit is complex
Frequent Maintenance.	Less Maintenance.
Commutator makes bulky , costly and heavy	Problems are not there, particularly squirrel cage motor.
Speed and design rating are limited due to commutation.	Ratings have no upper limits.
This is used in certain location	Used in all location
Fast response and wide speed range smooth achieved by conventional and solid state control	In solid state control speed range is wide and conventional method it is stepped and limited.
Poor PF, harmonic distortion of the current	For Regenerative drives the line pf is poor, for non-regenerative drives the line PF is better.
Power / weight ratio is small	Power / weight ratio is large.

DC, AC drives: https://gesrepair.com/difference-between-ac-dc/

https://www.instructables.com/Complete-Motor-Guide-for-Robotics/

What are the motor specifications to choose a motor? Explain motor selection procedure.

To choose the electric motors that can fit for your project you should consider some important motor specifications:

- Torque
- Speed
- Precision and Accuracy
- Voltage
- Cost
- Form Factor

Torque is a measure of a motor's ability to provide a "turning force". In a robot, the motor torque is conveyed to a wheel or a lever, which then causes the robot to move or the lever to lift, push, or pull something. Torque is measured in terms of force times the perpendicular distance between the force and the point of rotation, i.e. the shaft of motor.

Estimating the required torque is a difficult task. We need to know the mass of the load/rover and the friction in order to determine the torque for motor selection. Getting a mass estimate (or even better an actual mass) is critical for choosing a motor. If you are designing based on a mass estimate you should apply a good margin for mass bloating. Friction is a force than opposes the motion between two surfaces in contact with one another. You have to consider static friction, dynamic friction and rolling friction to accurately measure the torque.

In order to drive the robot, the motor torque must at a minimum overcome the external torque of the friction force acting on the radius of the wheel.

A motor can maintain a constant speed only if the torque is greater than the combined forces in opposite of the robot movement. In case that the motor torque is smaller than the opposition torque, the motor will stop and may be damaged since the electrical energy cannot be converted into torque.

After determining how much force/torque you need, the next step is to determine the speed that the wheel needs to turn. Speed requirement is easier to estimate and depends on how fast your robot should run. DC motors run at speeds of thousands of RPMs with low torque but most robots required less speed compare to this. The output torque is much too low to move the robot. So, this is not suitable for driving a robot. In order to use the motor, we add a gearbox to reduce the motor speed and increase the output torque. The same motor may produce different torque and speed ratings depending on the gearing used between the motor and the gearbox output shaft. Many DC motors come with a gearbox already attached and these are simply called DC gear motors and are the type of motors. By reducing the speed, you also increase the positional accuracy of the motor. The speed, torque and accuracy of a gear motor are affected directly by the gear ratio, as seen in these equations:

Output Speed = Motor Speed / Gear Ratio

Output Accuracy = Motor Accuracy / Gear Ratio

Although the reduction ratio plays a large part in determining the Gearbox Output Torque, there is also an inefficiency that is introduced through the use of a gearbox. Some of the torque of the motor is converted into heat and lost due to friction between the gears. Another disadvantage is that gear motors are not precise. That is, two motors of the same model, manufactured on the same day, and operated with identical current and voltages, will NOT turn at exactly the same rate. Thus a robot with two drive motors, the most common configuration, will not move in a straight line without some way of controlling individual motor speeds.

With gearboxes, torque and speed can be seen as one interchangeable characteristic: If you need more torque and less speed, try to find the same motor with a gearbox with a higher reduction ratio. If you need more speed and less torque, try to find the same motor with a gearbox with a lower reduction ratio. However, it is not advisable buy gearboxes and motors separately to mix and match, unless they are specifically designed for each other. There's a lot that can go wrong in gearbox customization and for most users it's a lot less hassle to simply buy a motor with a gearbox already attached.

One main disadvantage is that gear head motors are not precise. Some applications have need of very precise movements and angles like robotic arms and model plane control surfaces. Stepper motors and servo motors are best suited to these sorts of applications. Servo motors have internal position regulation and are geared down to lower speeds, resulting in very precise position control. Stepper motors move step by step, using magnetic fields to move the motor in discrete increments. Depending on the step size of the motor and the step pattern of the controller stepper motors can achieve extremely accurate position. Often stepper motors have step angles as low as 1.8° and with micro-stepping controllers can be advanced one sixteenth of a step at a time. Stepper motors also have the advantage of high holding torque- when the motor is stopped but still powered, it will hold its position firmly.

In general, servo motors are smaller in size and have less torque than a stepper motor. Most servos also have limited range of motion. A typical servo motor has a rotation range of 180° or less, although there are some that are capable of multiple revolutions or even continuous rotation. Servos are most common in RC (remote control) applications where it is not necessary to have high torque or a large range of motion. Stepper motors, on the other hand, are used in applications where extreme precision or high torque is required. CNC (computer numerical control) machines are a prime example of what stepper motors are used for.

Some applications require high speed and light weight such as multi copter and drone, in that case high efficient brushless dc motor is used.

Another important consideration is operating voltage. Before planning what battery packs will be used in the project, you have to find the nominal voltage where the motor runs Typically the higher the voltage the higher the speed of the motor. You can look at the Voltage Constant from the motor data sheet to figure out how fast you will go per volt.

Most common electric motors used in robotics projects are the DC motors. Common preferred voltages for DC motors are 3, 6, 12 and 24 Volts. If to a motor is applied a voltage lower than the voltage listen in the data sheet, the torque will not overcome the internal friction – mostly from the brushes. Also, if a higher voltage than that supported is applied to the motor, it may heat up and can be damaged.

https://www.robotshop.com/community/blog/show/drive-motor-sizing-tool

Hydraulic Drives

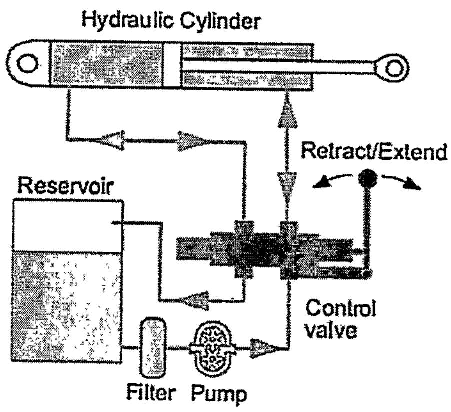
A hydraulic drive is a method of providing movement to a robot manipulator. It uses a special hydraulic fluid, usually oil-based, to transfer forces to various joints, telescoping sections, and end effectors.

The hydraulic drive consists of a power supply, one or more motors, a set of pistons and valves, and a feedback loop. The valves and pistons control the movement of the hydraulic fluid. Because the hydraulic fluid is practically incompressible, it is possible to generate large mechanical forces over small surface areas, or, conversely, to position large-area pistons with extreme accuracy. The feedback loop consists of one or more force sensors that provide error correction and ensure that the manipulator follows its intended path.

Hydraulically driven manipulators are used when motions must be rapid, precise, and repeated numerous times. Hydraulic systems are also noted for the ability to impart considerable force, so they are good for applications involving heavy lifting or the application of large amounts of pressure or torque. In addition, hydraulically driven robot manipulators resist unwanted movement in the presence of external forces.

Write brief notes on hydraulic actuators.

Hydraulic actuators are frequently used as joint or leg actuators in robotics applications requiring high payload lifting capability. Hydraulic actuators output mechanical motion through the control of incompressible fluid flow or pressure. Because incompressible fluid is used, these actuators are well suited for force, position, and velocity control. In addition, these actuators can be used to suspend a payload without significant power consumption. Another useful option when using hydraulics is that mechanical damping can be incorporated into the system design.



The primary components in a hydraulic actuation system include:

1. A pump—converts input electrical power to hydraulic pressure

2. Valves—to control fluid direction, flow, and pressure

3. An actuator—converts fluid power into output mechanical energy

4. Hoses or piping—used to transport fluids in the system

5. Incompressible fluid—transfers power within the system

6. Filters, accumulator, and reservoirs

7. Sensors and controls

Positive displacement pumps are used in hydraulic actuator systems and include gear, rotary vane, and piston pumps. The valves that are used include directional valves (also called distributors), on-off or check valves, pressure regulator valves, flow regulator valves, and proportional or servovalves.

Both linear and rotary hydraulic actuators have been developed to convert fluid power into output motion. A linear actuator is based on a rod connected to a piston which slides inside of a cylinder. The rod is connected to the mechanical load in motion. The cylinder may be single or double action. A single action cylinder can apply force in only one direction and makes use of a spring or external load to return the piston to its nominal position. A double action cylinder can be controlled to apply force in two directions. In this case, the hydraulic fluid is applied to both faces of the piston.

Rotary hydraulic actuators are similar to hydraulic pumps. Manufacturers offer gear, vane, and piston designs. Another type of rotary actuator makes use of a rack and pinion design where a piston is used to drive the rack and the pinion is used for the output motion.

Working pressures for hydraulic actuators vary between 150 and 300 bar. When using these actuators, typical concerns include hydraulic fluid leaking and system maintenance. However, these can be mitigated through intelligent engineering design.

Explain Pneumatic drive system used in Robotics.

Pneumatic technology deals with the study of behavior and applications of compressed air in our daily life in general and manufacturing automation in particular. Pneumatic systems use air as the medium which is abundantly available and can be exhausted into the atmosphere after completion of the assigned task.

Important components of a pneumatic system are:

a) Air filters: These are used to filter out the contaminants from the air.

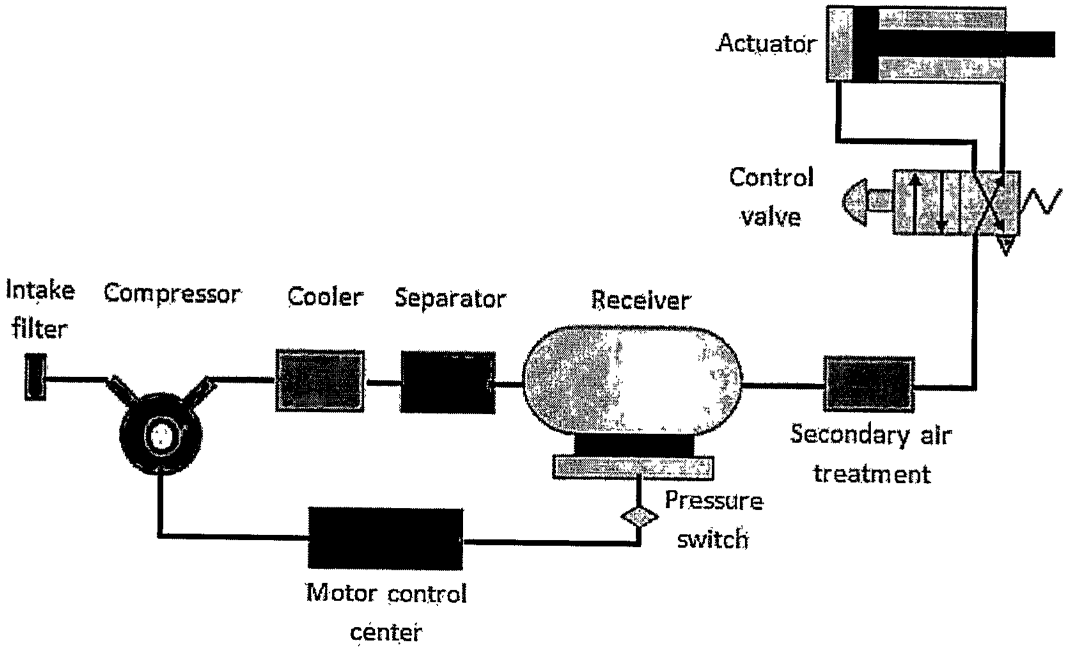
b) Compressor: Compressed air is generated by using air compressors. Air compressors are either diesel or electrically operated. Based on the requirement of compressed air, suitable capacity compressors may be used.

c) Air cooler: During compression operation, air temperature increases. Therefore coolers are used to reduce the temperature of the compressed air.

d) Dryer: The water vapor or moisture in the air is separated from the air by using a dryer.

e) Control Valves: Control valves are used to regulate, control and monitor for control of direction flow, pressure etc.

f) Air Actuator: Air cylinders and motors are used to obtain the required movements of mechanical elements of pneumatic system.



Robot Actuators & Feed back components

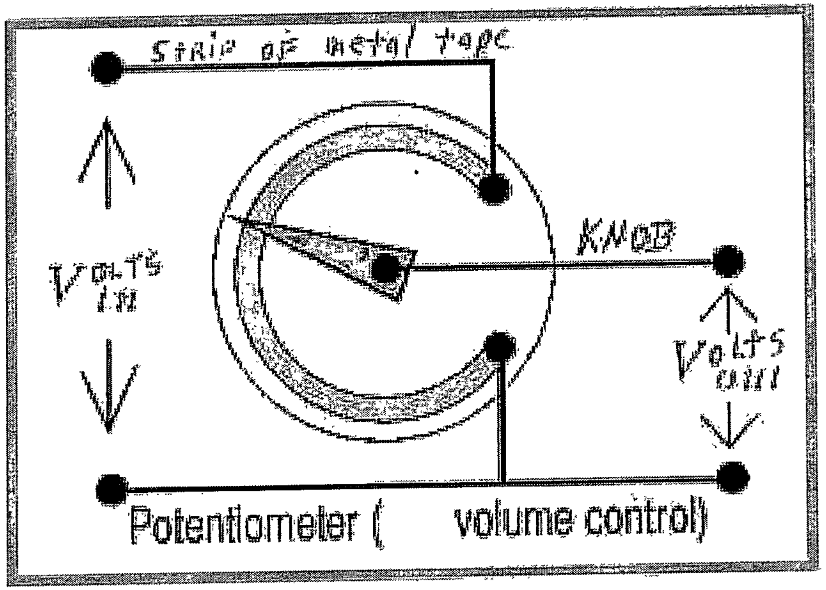
Unit-II

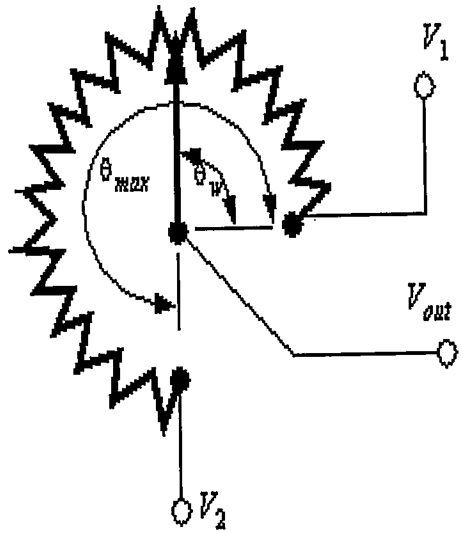
Introduction

- Position & Velocity sensors are used in robotics as feed back devices, while actuators & power transmission devices are used to accomplish the control actions indicated by the controller.
- Actuators are the muscles of robots. If you imagine that the links and the joints are the skeleton of the robot, the actuators act as muscles, which moves or rotate the links to change the configuration of robots. The actuators must have enough power to accelerate and decelerate the links and to carry the loads, yet be light, economical, accurate, responsive, reliable and easy to maintain.
- Position sensors provide the necessary means for determining whether the joints have moved to correct linear or rotational locations in order to achieve the required position & orientation.
- The speed with which the manipulator is moved is another performance feature which must be regulated. Robots utilize a feedback system to ensure proper speed control.
- It is important that a sophisticated control system has to be developed to fine tune the dynamic performance of manipulator during acceleration & deceleration as it moves between the points in work space.

Position Sensors ➡ Potentiometers

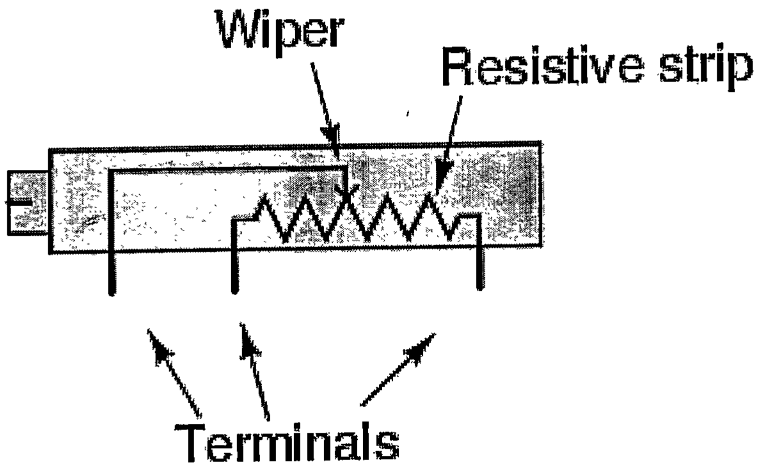
- Potentiometers are analog devices whose output voltage is proportional to the position of wiper.
- Potentiometers offer a low cost method of contact displacement measurement.
- Depending upon their design, they may be used to measure either rotary or linear motion.
- In either case, a movable slide or wiper is in contact with a resistive material or wire winding. The slide is attached to the target object in motion.
- A DC or an AC voltage is applied to the resistive material.
- When the slide moves relative to the material, the output voltage varies linearly with the total resistance included within the span of the slide.
- An advantage of potentiometers is that they can be used in applications with a large travel requirement.
- It is possible to use pots to provide a limited amount of feedback control in robots where high proportional resolution and accuracy are not required.

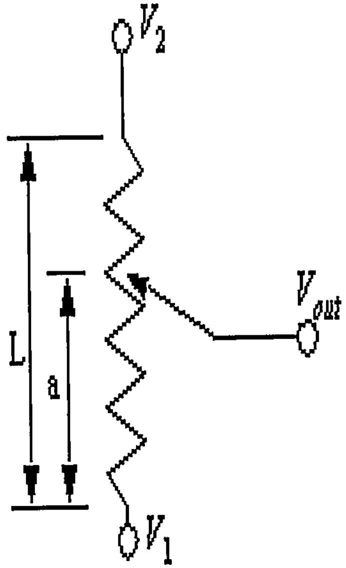




$$V_{out} = (V_2 - V_1)\left(\frac{\theta_w}{\theta_{max}}\right) + V_1$$

Linear potentiometer construction





$$V_{out} = V_1 + (V_2 - V_1)\left(\frac{a}{L}\right)$$

Position Sensors ➡ Resolvers

- A **resolver** is a type of rotary electrical transformer used for measuring degrees of rotation. It is an analog device whose output is proportional to the angle of rotating element with respect to fixed element.
- The primary winding of the transformer, located on rotor shaft, is excited by a sinusoidal electric current, which by electromagnetic induction induces current to flow through the secondary windings located on the stator.
- The two two-phase windings, fixed at right (90°) angles to each other on the stator, produce a sine and cosine feedback current by the same induction process.
- The relative magnitudes of the two-phase voltages are measured and used to determine the angle of the rotor relative to the stator.
- Since a resolver is a rotary transformer we must require an AC signal for excitation. If Dc signal is used there will be no output signal.

Position Sensors ➡ Encoders

- Encoders are sensors which converts linear or angular displacement in to digital code or pulse signals.
- Encoders are mainly classified as Linear encoder and rotary encoder.
- They are also classified as Absolute encoder and incremental encoders.
- Rotary encoders are used to measure the angular position and direction of a motor or mechanical drive shaft.
- Linear encoders measure linear position and direction. They are often used in linear stages or in linear motors.
- Absolute encoders provide actual position relative to a fixed reference position.
- Incremental encoders sense the position from previous position. A robot utilizing an incremental encoder must execute a calibration sequence before position information obtained.

Velocity Sensors ➡ Tachometers

- A **tachometer** (also called a **revolution-counter**, **rev-counter**, or **RPM gauge**) is an instrument that measures the rotation speed of a shaft or disk, as in a motor or other machine. The device usually displays the revolutions per minute (RPM) on a calibrated analogue dial, but digital displays are increasingly common.
- Tachometers can be divided in to

1. DC (Digital)tachometer
2. AC (analog) tachometer

In robotics mostly DC tachometer is used.

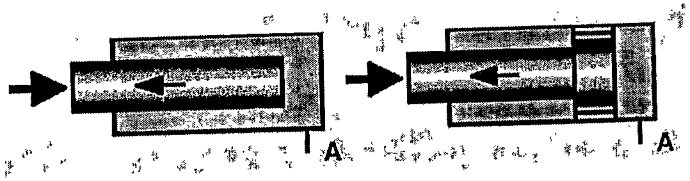
Types of Hydraulic actuators: Cylinders & Motors

Cylinder types:

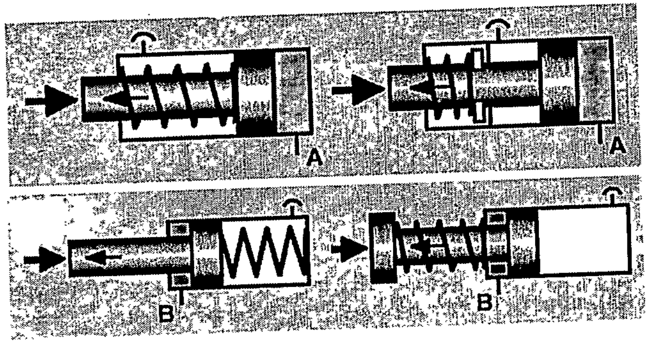
Single acting:

work can be done only in one direction

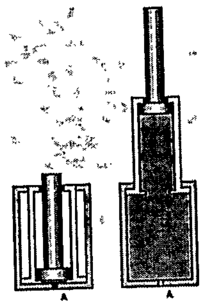
Plunger



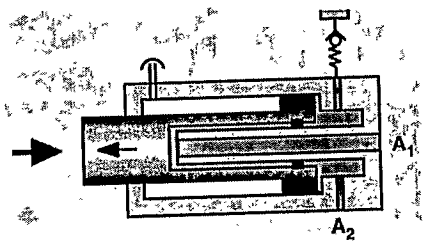
Piston



Telescopic

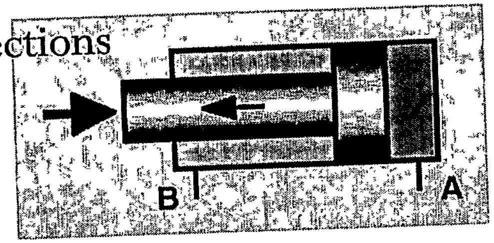


Fast moving

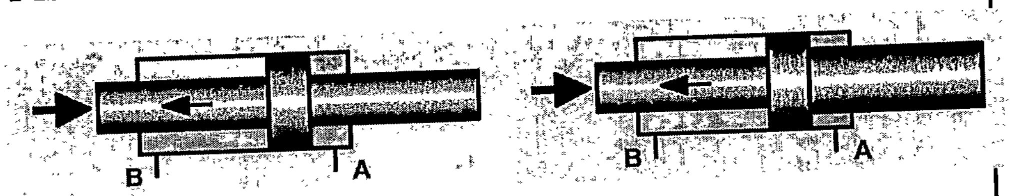


Double acting piston:

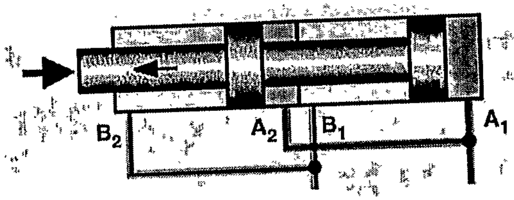
Work is done in both directions



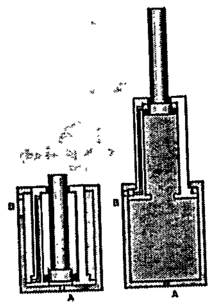
Piston rod on both sides



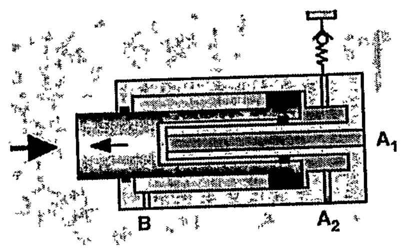
Tandem



Telescopic



Fast moving

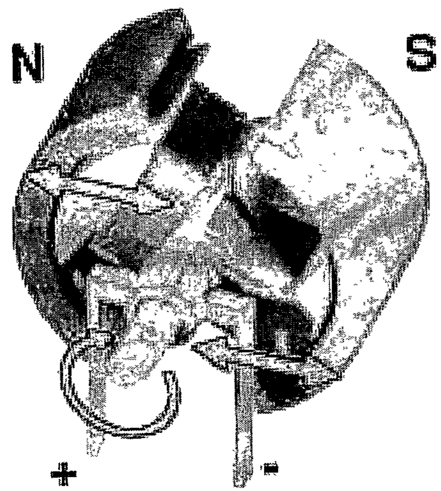


- **DC Motors:**
- DC motors are very common in industry and have been used for a long time. In DC motors, the stator is a set of fixed permanent magnets, creating a fixed magnetic field, while the rotor carries a current. Through brushes and commutators, the direction of current is changed continuously, causing the rotor to rotate continuously.
- **AC Motors:**
- Electric AC motors are similar DC motors except that the rotor is permanent magnet, the stator houses the windings, and all commutators and brushes are eliminated.
- **Servo Motors:**
- A Servomotor is a DC,AC, brushless, or even stepper motor with feedback that can be controlled to move at a desired speed (and consequently, torque), for a desired angle of rotation. To do this, a feedback device sends signals to the controller circuit of the servomotor reporting its angular position and velocity. If as a result of higher loads, the velocity is larger than desired set value, the current is increased until the speed is equal to the desired value. If the speed signal shows that the velocity is larger than the desired, the current is reduced accordingly. If position feedback is used as well, the position signal is used to shut off the motor as the rotor approaches the desired angular position.

Components of a DC Electric Motor

- The principle components of an electric motor are:
  - North and south **magnetic poles** to provide a strong magnetic field. Being made of bulky ferrous material they traditionally form the outer casing of the motor and collectively form the **stator**
  - An **armature**, which is a cylindrical ferrous core rotating within the stator and carries a large number of windings made from one or more conductors

How Do Electric Motors Work? (cont...)



A simple DC electric motor: when the coil is powered, a magnetic field is generated around the armature. The left side of the armature is pushed away from the left magnet and drawn toward the right, causing rotation

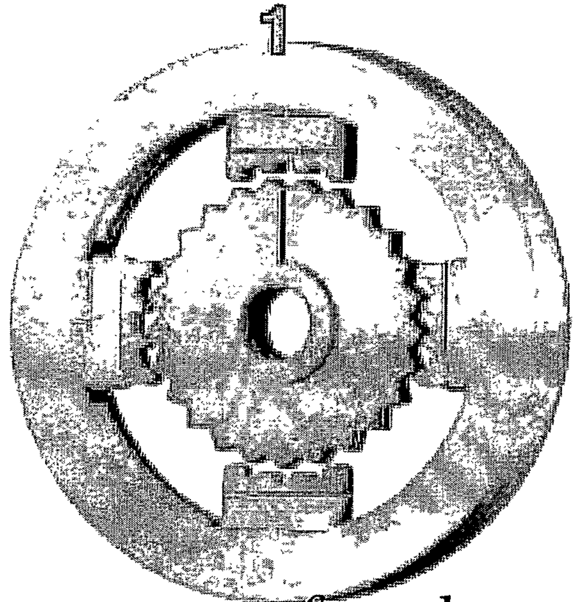
Electric Motors

- Electric motors usually have a small rating, ranging up to a few horsepower
- They are used in small appliances, battery operated vehicles, for medical purposes and in other medical equipment like x-ray machines
- Electric motors are also used in toys, and in automobiles as auxiliary motors for the purposes of seat adjustment, power windows, sunroof, mirror adjustment, blower motors, engine cooling fans and the like

Stepper Motors

- When incremental rotary motion is required in a robot, it is possible to use **stepper motors**
- A stepper motor possesses the ability to move a specified number of revolutions or fraction of a revolution in order to achieve a fixed and consistent angular movement
- This is achieved by increasing the numbers of poles on both rotor and stator
- Additionally, soft magnetic material with many teeth on the rotor and stator cheaply multiplies the number of poles (reluctance motor)

Stepper Motors



- This figure illustrates the design of a stepper motor, arranged with four magnetic poles arranged around a central rotor
- Note that the teeth on the rotor have a slightly tighter spacing to those on the stator, this ensures that the two sets of teeth are close to each other but not quite aligned throughout

Comparison of Actuating Systems:

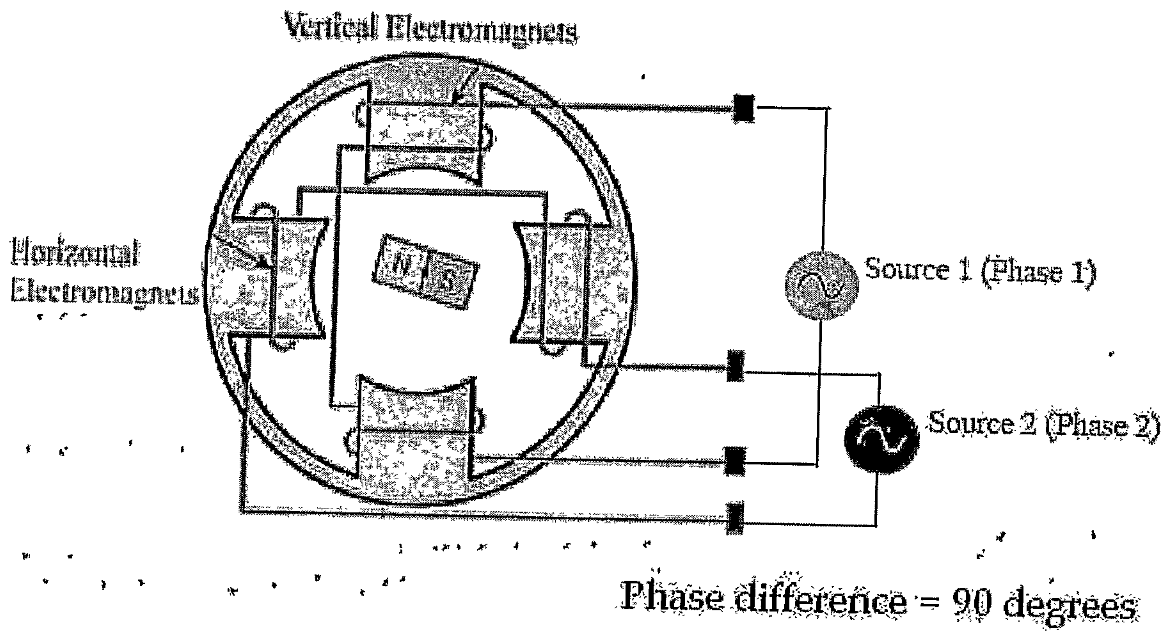
Hydraulic	Electric	Pneumatic
+ Good for large robots and heavy payload	+ Good for all size of Robots	+ Many components are usually off-the-shelf
+Highest Power/Weight Ratio	+Better control, good for high precision robots	+Reliable components.
+Stiff system, High accuracy, better response	+Higher Compliance that Hydraulics	+No leaks or sparks
+No reduction gear needed	+Reduction gears used reduce inertia on the motor	+Inexpensive and simple
+Can work in wide range of speeds without difficulty	+does not leak, good for clean room	+Low pressure compared to hydraulics
+Can be left in position without any damage	+Reliable, low maintenance	+ Good for on-off applications and for pick and place

Comparison of Actuating Systems: (contd.)

Hydraulic	Electric	Pneumatic
- May leak. Not fit for clean room application	+Can be spark-free. Good for explosive environment.	+Complaint systems.
-Requires pump, reservoir, motor, hoses etc.	-Low stiffness	-Noisy systems.
-Can be expensive and noisy, requires maintenance.	-Needs reduction gears, increased backlash, cost, weight, etc.	- Require air pressure, filter, etc.
-Viscosity of oil changes with temperature	-Motor needs braking device when not powered. Otherwise, the arm will fail.	-Difficult to control their linear position
-Very susceptible to dirt and other foreign material in oil	-	-Deform under load constantly
-Low compliance	-	-Very low stiffness. Inaccurate response.
-High torque, High pressure, large inertia on the actuator.	-	-Lowest power to weight ratio

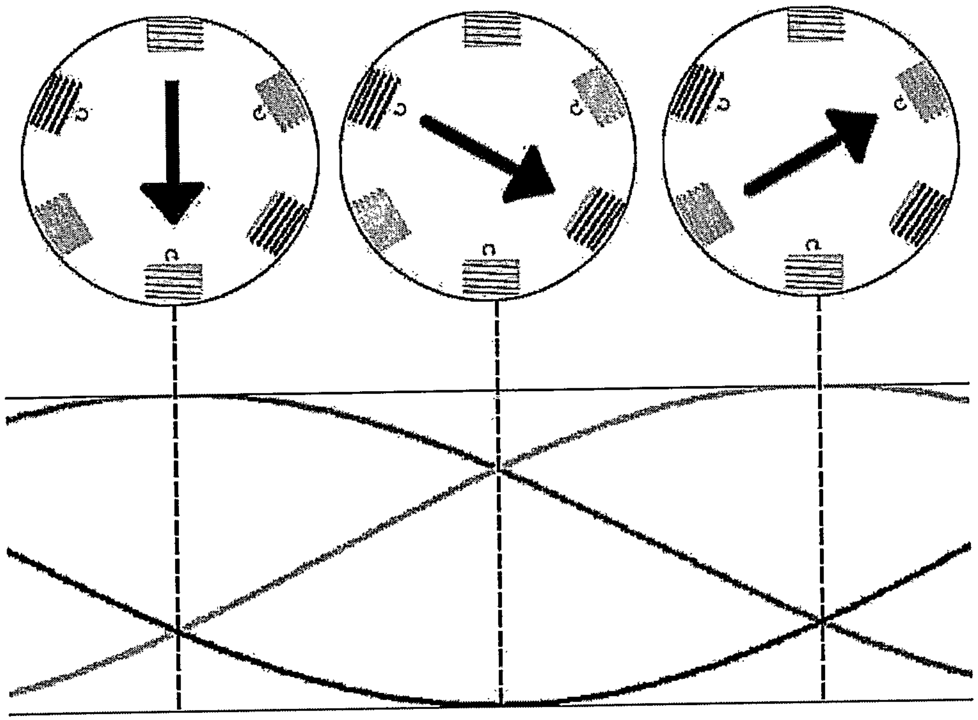
AC Motors

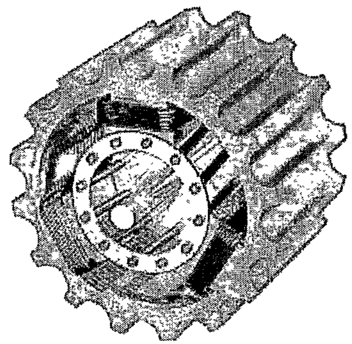
- Two main types of AC motor, Synchronous and Induction.
- Synchronous motors supply power to both the rotor and the stator, where induction motors only supply power to the stator coils, and rely on induction to generate torque.

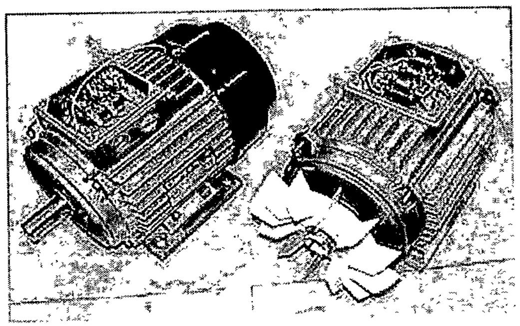


AC Induction Motors (3 Phase)

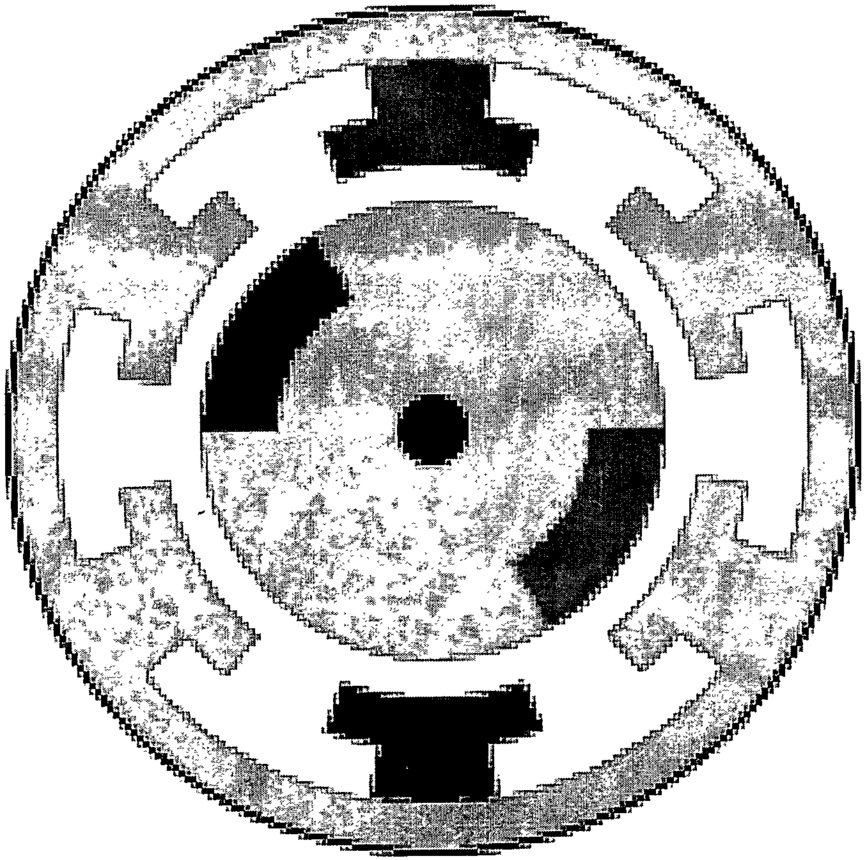
- Use poly-phase (usually 3) AC current to create a rotating magnetic field on the stator
- This induces a magnetic field on the rotor, which tries to follow stator - slipping required to produce torque
- Workhorses of the industry - high powered applications





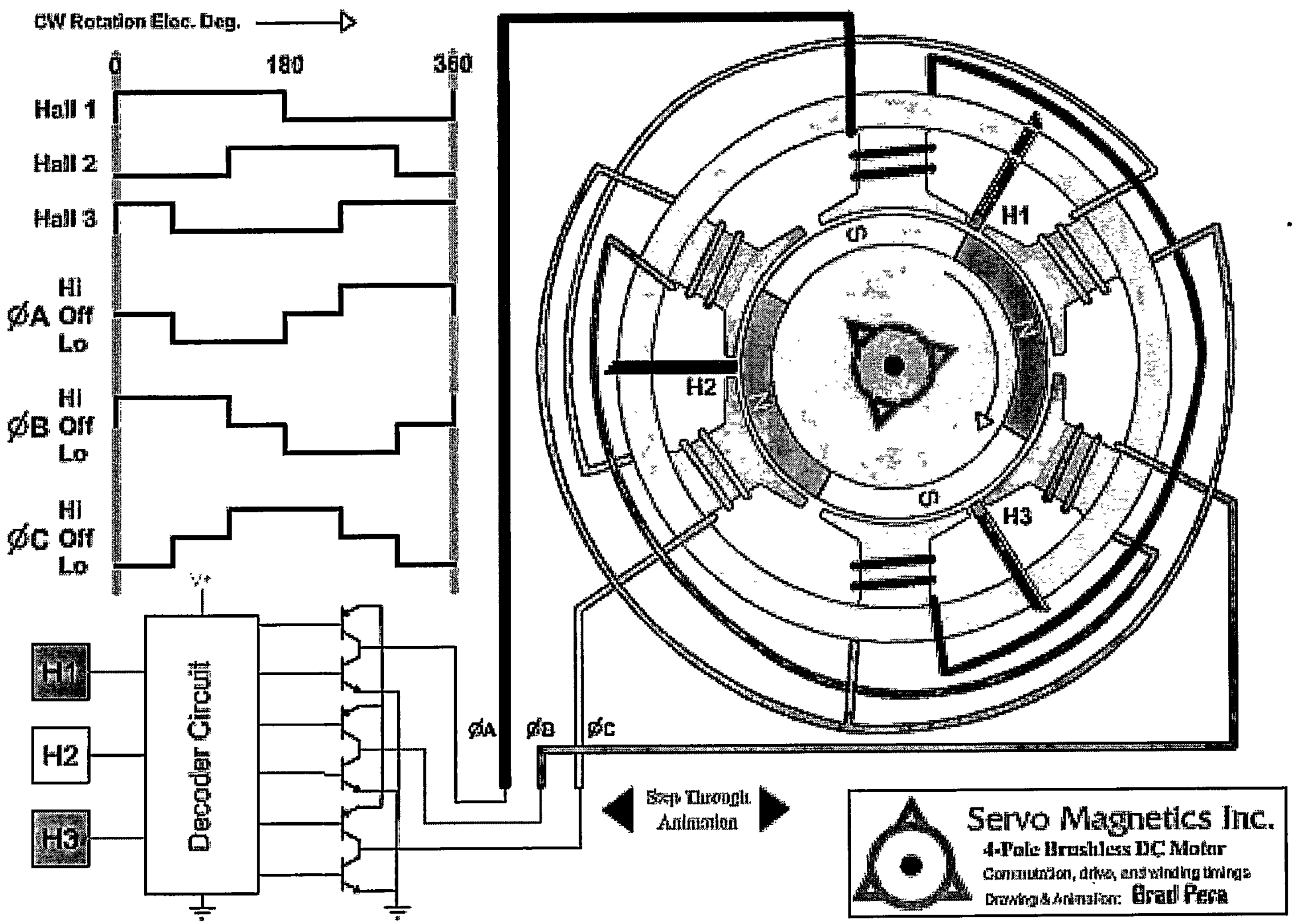


DC STEPPER MOTORS



- Stepping motors are electric motors without commutators
- Commutation is handled externally by the motor controller
- Controller charges opposite coils attracting the center rotor magnets

DC STEPPER MOTORS



UNIT-3

ROBOT APPLICATIONS IN MANUFACTURING

Introduction:-

There are many robot applications in which the robot is required to move a workpart or other material from one location to another. The most basic of these applications is where the robot picks the part up from one position and transfers it to another position. In other applications, the robot is used to load and/or unload a production machine of some type. We divide material-handling applications into two specific categories:

1. Material transfer applications

2. Machine loading/unloading applications.

➢ GENERAL CONSIDERATIONS IN ROBOT MATERIAL HANDLING:-

In planning an application in which the robot will be used to transfer parts, load a machine, or other similar operation, there are several considerations that must be reviewed.

1. Part positioning and orientation: In most parts-handling applications the parts must be presented to the robot in a known position and orientation.

2. Gripper design: Special end effectors must be designed for the robot to grasp and hold the workpart during the handling operation

3. Minimum distances moved: The material-handling application should be planned so as to minimize the distances that the parts must be moved.

4. Robot work volume: The cell layout must be designed with proper consideration given to the robot's capability to reach the required extreme locations in the cell and still allow room to maneuver the gripper.

5. Robot weight capacity: There is an obvious limitation on the material handling operation that the load capacity of the robot must not be exceeded. A robot with sufficient weight-carrying capacity must be specified for the application.

6. Accuracy and repeatability: Some applications require the materials to be handled with very high precision. Other applications are less demanding in this respect.

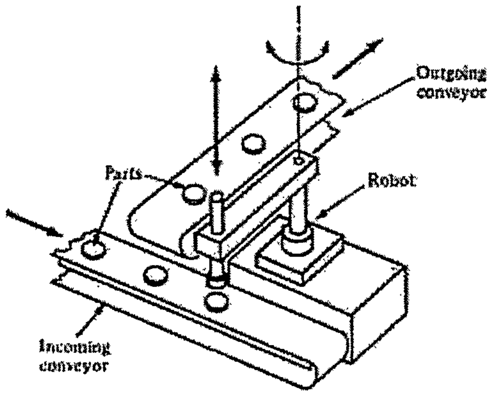
7. Robot configuration, degrees of freedom, and control: Many parts transfer operations are simple enough that they can be accomplished by a robot with two to four joints of motion. Machine-loading applications often require more degrees of freedom. Palletizing operations, and picking parts from a moving conveyor are examples where the control requirements are more demanding

8. Machine utilization problems: It is important for the application to effectively utilize all pieces of equipment in the cell. In a machine loading/unloading operation, it is common for the robot to be idle while the machine is working, and the machine to be idle while the robot is working.

MATERIAL TRANSFER APPLICATIONS OF ROBOT:

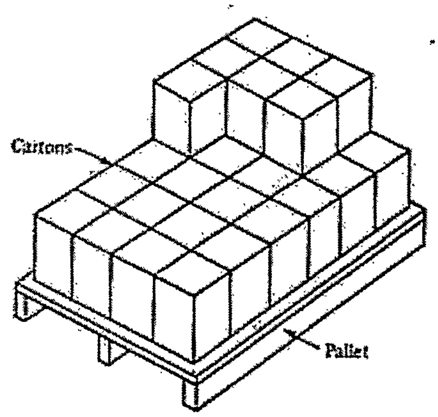
Material transfer applications are defined as operations in which the primary objective is to move a part from one location to another location. They are usually considered to be among the most straightforward of robot applications to implement.

Pick-and-Place Operations:



In pick and-place operation, the robot pick up the part at one location and moves it to another location. The part is available to the robot by mechanical feeding device or belt conveyor in a known location and orientation. A simple limit switch is used to stop the component to allow the part to grasp by robot pick up, move with part and position the part at a desired location. The orientation of the part remains unchanged during the travelling. The basic operation are shown in figure. In this case, 2 DOF is involved, one degree of freedom is required to lift the component from pickup point and put it down at the drop-off point and second! DOF is needed to move the part between these two positions. In some cases, a reorientation of the component is accomplished during the move period.

Palletizing and related operations:



In material transfer application of robot, the use of pallets for material handling and storage is done. Large number of containers are placed on a pallet for material handling and storage is done. Large number of containers are placed on a pallet, instead of handling instead of handling individual cartons. The pallets are moved mechanically within the manufacturing plant or warehouse by fork lift trucks or conveyors. The only handling of the individual cartons arises when the component is placed onto the pallet or when it is removed from the pallet. The loading of cartons onto pallets is typically heavy work performed manually by unskilled labour. A typical pallet configuration is shown configure below. Each carton is placed at a different location on the pallet, the variation in carton location is in three dimensions. The pallets are usually stacked on top of each other in layers as shown in figure.

MACHINE LOADING AND UNLOADING OF ROBOT:-

These applications are material-handling operations in which the robot is us to service a production machine by transferring parts to and/or from the machine. There are three cases that tit into this application category:

Machine load/unload: The robot loads a raw workpart into the process and unloads a finished part. A machining operation is an example of this case.

Machine loading: The robot must load the raw workpart or materials into if machine but the part is ejected from the machine by some other means a press working operation the robot may be programmed to load metal blanks into the press but the finished parts are allowed to drop out of the press by gravity.

Machine unloading: The machine produces finished parts from raw material that are loaded directly into the machine without robot assistance. The robot unloads the part from the machine. Examples in this category include die casting and plastic modeling applications.

Robots have been successfully applied to accomplish the loading and/or unloading function in the following production operations:

1. Die casting
2. Plastic molding
3. Forging and related operations
4. Machining operations
5. Stamping press operations

1. Die casting:

Die casting is a manufacturing process in which molten metal is forced into the cavity of a mold under high pressure. The mold is called a die (hence the name, die casting). The process is used to cast metal parts with sufficient accuracy so that subsequent finishing operations are usually not required. Common metals used for die-casted parts include alloys of zinc, tin, lead, aluminum, magnesium, and copper.

The die consists of two halves that are opened and closed by a die casting machine. During operation the die is closed and molten metal is injected into the cavity by a pump. To ensure that the cavity is filled, enough molten metal is forced into the die that it overflows the cavity and creates "flash" in the space between the die halves. When the metal has solidified, the die is opened and the cast part is ejected, usually by pins which push the part away from the mold cavity. When the part is removed from the machine, it is often quenched (to cool the part) in a water bath. The flash that is created during the casting process must be removed subsequently by a trimming operation which cuts around the periphery of the part. Thus, the typical die-casting production cycle consists of casting, removing the part from the machine, quenching, and trimming.

The production rates in the die-casting process range from about 100 up to 700 openings of the die per hour, depending on type of machine, the metal being cast, and the design of the part.

The die-casting process represents a relatively straightforward application for industrial robots.

2. Plastic Molding:

Plastic molding is a batch-volume or high-volume manufacturing process used to make plastic parts to final shape and size. The term plastic molding covers a number of processes, including compression molding, injection molding, thermoforming, blow molding, and extrusion. Injection molding is the most important commercially, and is the process in this group for which robots are most often used. The injection-molding operation is quite similar to die casting except for the differences in materials being processed. A thermoplastic material is introduced into the process in the form of small pellets or granules from a storage hopper. It is heated in a heating chamber to 200 tó 300 C to transform it into semifluid (plastic) state and injected into the mold cavity under high pressure. The plastic travels from the heating chamber into the part cavity through a sprue-and-runner network that is designed into the mold. If too much plastic is injected into the mold Hash is created where the two halves of the mold come together. If too little material is injected into the unacceptable. When the plastic material has hardened sufficiently the mold opens and the part(s) are removed from the mold.

3. Forging and related operations:

Forging is a metalworking process in which metal is pressed or hammered into the desired shape. It is one of the oldest processes and derived from the kinds of metalworking operations performed by blacksmiths in ancient times. It is most commonly performed as a hot working process in which the metal is heated to a high temperature prior to forging. It can also be done as a' cold working process. Cold forging adds considerable strength to the metal and is used for high-quality products requiring this property such as hand tools (e.g., hammers and wrenches). Even in #hot forging, the metal flow induced by the hammering process adds strength to the formed part.

4. Machining operations:

Machining is a metal working process in which the shape of the part is changed by removing excess material with a cutting tool. It is considered to be a secondary process in which the final form and dimensions are given to the part after a process such as casting or forging has provided the basic shape of the part. There are a number of different categories of machining operations. The principal types include turning, drilling, milling, shaping, planing, and grinding.

The machine tools that perform machining operations have achieved a relatively high level of automation after many years of development. In particular the use of computer control (e.g., computer numerical control and direct numerical control) permits this type of equipment to be interfaced with relative ease to similarly controlled equipment such as robots.

Robots have been successfully utilized to perform the loading and unloading functions in machining operations. The robot is typically used to load a law workpart (a casting, forging, or other basic form) into the machine tool and to unload the finished part at the completion of the machining cycle.

The following robot features generally contribute to the success of the machine tool load/unload application:

Dual gripper: The use of a dual gripper permits the robot to handle the raw workpart and the finished part at the same time. This permits the production cycle time to be reduced.

Up to six joint motions: A large number of degrees of freedom of the arm and wrist are required to manipulate and position the part in the machine tool.

Good repeatability: A relatively high level of precision is required to properly position 'the part into the chuck or other work holding fixture in the machine tool.

Palletizing and depalletizing capability: In mid volume production, the raw parts are sometimes most conveniently presented to the workcell and delivered away from the workcell on pallets. The robot's controller and programming capabilities must be sufficient to accommodate this requirement.

Programming features: There are several desirable programming features that facilitate the use of robots in machining applications. In machine cells used for batch production of different parts, there is the need to perform some sort of changeover of the setup between batches. Part of this changeover procedure involves replacing the robot program for the previous batch with the program for the next batch. The robot should be able to accept disk, tape, or other storage medium for ease in changing programs. Another programming feature needed for machining is the capability to handle irregular elements, such, as tool changes or pallet changes, in the program.

5. Stamping press operations:

Stamping press operations are used to cut and form sheet metal parts. The process is performed by means of a die set held in a machine tool called a press (or stamping press). The sheet metal stock used as the raw material in the process comes in several forms, including coils, sheets, and individual flat blanks. When coil stock is fed into the press, the process can be made to operate in a highly automated manner at very high cycle rates. When the starting material consists of large flat sheets or individual blanks, automation becomes more difficult. These operations have traditionally been performed by human workers, who must expose themselves to considerable jeopardy by placing their hands inside the press in order to load the blanks. During the last decade, the Occupational Safety and Health Act (OSHA) has required certain alterations in the press in order to make its operation safer. The economics of the OSHA requirements have persuaded many manufacturers to consider the use of robots for press loading as alternatives to human operators. Noise is another factor which makes press working an unfriendly environment for humans.

PROCESSING OPERATIONS:-

In processing operations, the robots uses a tool as end effector to accomplish some processing operations on a work part. Manipulates the tooling relative to the working part during the cycle.

In processing operation, the robot performed by the following categories:

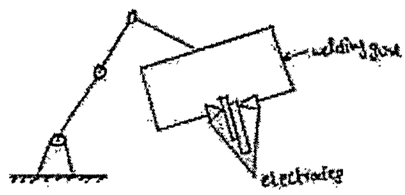
1. Spot welding

2. Continuous arc welding

3. Spray coating

4. Other processing operations.

1. Spot welding:



Spot welding.

As the term suggests, spot welding is a process in which two sheet metal parts are fused together at localized points by passing a large electric current through the parts where the weld is to be made. The fusion is accomplished at relatively low voltage levels by using two copper (or copper alloy) electrodes to squeeze the parts together at the contact points and apply the current to the weld area. The electric current results in sufficient heat in the contact area to fuse the two metal parts, hence producing the weld.

Spot welding has traditionally been performed manually by either of two methods. The first method uses a spot-welding machine in which the parts are inserted between the pair of electrodes that are maintained in a fixed position. This method is normally used for relatively small, parts that can be easily handled.

The second method involves manipulating a portable spot-welding gun into position relative to the parts. This would be used for larger work such as automobile bodies. The word "portable" is perhaps an exaggeration. The welding gun consists of the pair of electrodes and a frame to open and close the electrodes. In addition, large electrical cables are used to deliver the current to the electrodes from a control panel located near the workstation. The welding gun with cables attached is quite heavy and can easily exceed 100 lb in weight.

Capabilities and features of robot in spot welding:-

i. The robot must be relatively large.

ii. It must be sufficient payload capacity.

iii. The work volume must be adequate for the size of the product.

iv. It should have increase number of DOF

v. The controller memory must have enough capacity to accomplish the many positioning steps required for the spot welding.

vi. The robot must be able to switch from one program holding sequence to another as the model change.

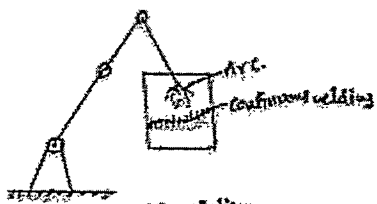
Benefits of robot in spot welding:

i. Improved production quality

ii. Operator safety

iii. Better control over the production.

2. Continuous arc welding



Arc welding

Arc welding is a continuous welding process as opposed to spot welding which might be called a discontinuous process. Continuous arc welding is used to make long welded joints in which an airtight seal is often required between the two pieces of metal being joined. The process uses an electrode in the form of a rod or wire of metal to supply the high electric current needed for establishing the arc. Currents are typically 100 to 300A at voltages of 10 to 30 V. The arc between the welding rod and the metal parts to be joined produces temperatures that are sufficiently high to form a pool of molten metal to fuse the two pieces together. The electrode can also be used to contribute to the molten pool, depending on the type of welding process.

The high temperatures created in arc welding and the resulting molten metals are inherently dangerous. The high electrical current used to create the arc is also unsafe; Sparks and smoke are generated during the process and these are a potential threat to the operator.

Features of the Welding Robot:

i. Work volume and degrees of freedom: The robot's work volume must be large enough for the sizes of the parts to be welded.

ii. Motion control system: Continuous-path control is required for are welding. The robot must be capable of a smooth continuous motion in order to maintain uniformity of the welding seam.

iii. Precision of motion: The accuracy and repeatability of the robot determines to a large extent the quality of the welding job.

iv. Interface with other systems: The robot must be provided with sufficient input/output and control capabilities to work with the other equipment in the cell.

v. Programming: Programming the robot for continuous arc welding must be considered carefully.

Advantages and Benefits of Robot Arc Welding:

A robot arc-welding cell for batch production has the potential for achieving a number of advantages over a similar manual operation. These advantages include the following:

1. Higher productivity

2. Improved safety and quality-of-work life

3. Greater quality of product

4. Process rationalization.

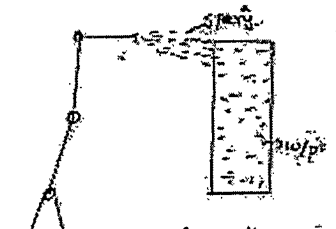
Sensors in Robotic Arc –Welding:

The robotic arc-welding sensor systems considered here are all designed to track the welding seam and provide information to the robot controller to help guide the welding path. The approaches used for this purpose divide into two basic categories: contact and noncontact sensors. There are two types of sensor systems,

i) Contact arc-welding sensors

ii) Noncontact arc-welding sensors.

3. Spray coating:



Spray coating

Most products manufactured from metallic materials require some form of painted finish before delivery to the customer. The technology for applying these finishes varies in complexity from simple manual methods to highly sophisticated automatic techniques. We divide the common industrial coating methods into two categories:

1. Immersion and How-coating methods

2. Spray-coating methods.

Immersion and flow-coating methods are generally considered to be low-technology methods of applying paint to the product. Immersion involves simply dipping the part or product into a tank of liquid paint. When the object is removed, the excess paint drains back into the tank. The tanks used in the process can range in size from 1 or 2 gallons for small objects to thousands of gallons for large fabricated metal prOducts.

The second major category of industrial painting is spray coating. This method involves the use of spray guns to apply the paint or other coating to the object. Spray painting is typically accomplished by human workers who manually direct the spray at the object so as to cover the desired areas. The paint spray systems come in various designs, including conventional air spray, airless spray, and electrostatic spray.

In general, the requirements of the robot for spray-coating applications are the following:

1. Continuous-path control

2. Hydraulic drive

3. Manual lead through programming

4. Multiple program storage.

Benefits oi Robot Spray Coating:

1. Removals of operators from hazardous environment

2. Lower energy consumption

3. Consistency of finish

4. Reduced coating material usage

5. Greater productivity.

4. OTHER PROCESSING OPERATIONS USING ROBOTS:

In addition to spot welding, arc welding, and spray coating, there are a number of other robot applications which utilize some form of specialized tool as the end effector. Operations which are in this category include:

Drilling, routing, and other machining operations,

Grinding, polishing, deburring, wire brushing, and similar operations,

Riveting,

Waterjet cutting,

Laser drilling and cutting.

- **Assembly operations:**

The term assembly is defined here to mean the fitting together of two or more discrete parts to form a new subassembly. The assembly operations are,

1. Parts presentation methods

2. Assembly tasks

3. Assembly cell designs.

1. Parts presentation methods:

In order for a robot to perform an assembly task, the part that is to be assembled must be presented to the robot. There are several ways to accomplish this presentation function, involving various levels of structure in the workplace:

i) Parts located within a specific area (parts not positioned or oriented)

ii) Parts located at a known position (parts not oriented)

iii) Parts located in a known position and orientation.

i) Parts located within a specific area (parts not positioned or oriented):

In this case, the robot is required to use some form of sensory input to guide it to the part location and to pick up the part.

ii) Parts located at a known position (parts not oriented):

In the second case, the robot would know where to go to get the part, but would then have to solve the orientation problem. This might require the robot to perform an additional handling operation to orient the part.

iii) Parts located in a known position and orientation:

The third way of presenting the part to the robot (known position and orientation) is the most common method currently used, and is in fact the method used in automatic assembly that precedes the advent of robotics.

There are a number of methods for presenting parts in a known position and orientation, they are

i. Bowl feeders

ii. Magazine feeders

iii. Trays and pallets

2. Assembly tasks:

Assembly operations can be divided into two basic categories:

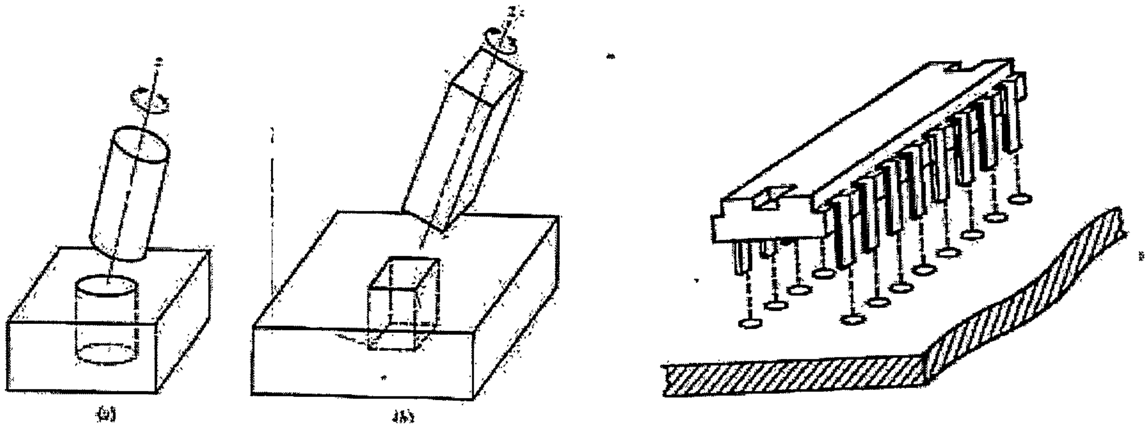
i. parts mating and

ii. parts joining.

i) parts mating :

In parts mating, two (or more) parts are brought into contact with each other.

The variety of parts mating operations include the following assembly situations:



I. Peg-in-hole. This operation involves the insertion of one part (the peg) into another part (the hole). It represents the most common assembly task.

II. Hole-on-peg. This is a variation of the peg-in-hole task. Similar problems exist in defining the degrees of freedom needed to execute the mating of the two parts. A typical example of the hole-on-peg task would be the placement of a bearing or gear onto a shaft.

III. Multiple peg-in-hole. This is another variation on case 1 except that one.

ii) parts joining:

In parts joining, two (or more) parts are mated and then additional steps are taken to ensure that the parts will maintain their relation- ship with each other.

The possible joining operations include the following:

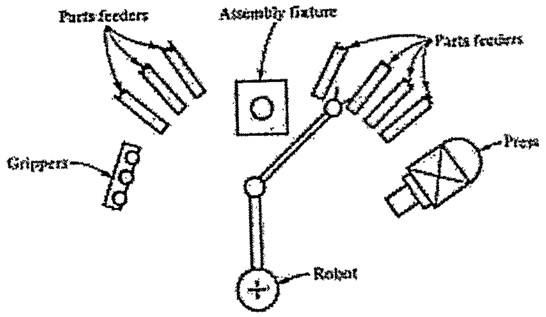
I. Fastening screws
II. Retainers
III. Press fits
IV. Snap fits
V. Welding and related joining methods
VI. Adhesives VII. Crimpling VIII. Sewing.

ASSEMBLY SYSTEM CONFIGURATIUNS:

There are two basic configurations of assembly systems, a single workstation, and a series of workstations (an assembly line). Combinations of these two basic types are also possible.

Single-Workstation Assembly:

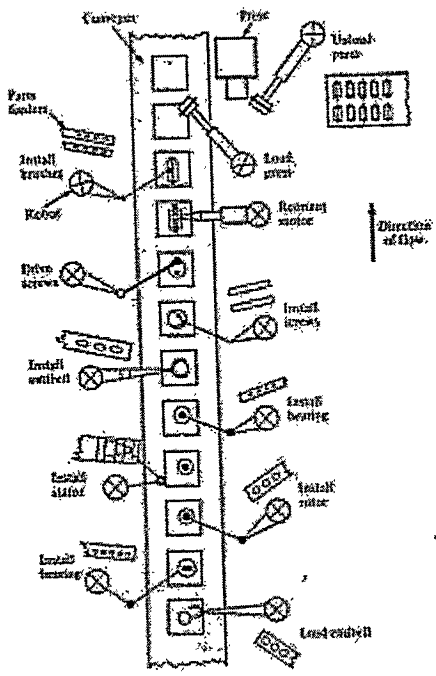
In this configuration all of the parts which are required to complete the desired assembly are presented to the operator or robot at a single workstation. All of the parts mating and joining tasks for the assembly are accomplished at the single workstation. In manual assembly, this configuration is generally warranting the use of this configuration are different from those for manual assembly. A single-station robotic assembly system would typically be used for low- and medium-volume work in which there were a limited number of assembly tasks and parts to be handled. This means that the product is of low to medium complexity. The features and problems of this configuration are illustrated by means of an example.



Single station robotic workcell

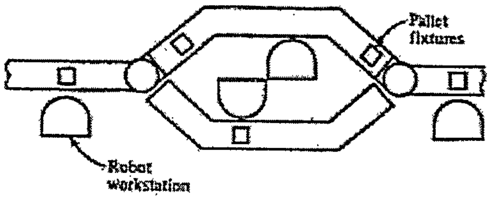
Series Assembly Systems:

The manual assembly line is the most familiar assembly configuration. It constitutes the series assembly system. This configuration is used in many medium- and high-production assembly situations, such as automobiles, household appliances, small power tools, and other products made in large quantities. The assembly line consists of a series of workstations at which only a few operations are performed on the product at each station. Each station is working on a different product, and the products are gradually built up as they move down the line.



Series assembly cell

Parallel Assembly Systems:



The concept of a parallel arrangement in a robotic workcell is pictured in Fig. In essence the work can take either of two (or more) routes to have the same operations performed. There are two conditions under which parallel workstations would normally be considered.

3. Assembly cell designs:-

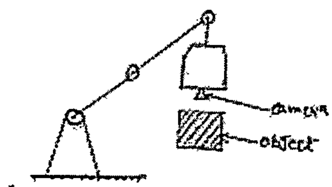
- Certain assembly tasks are more difficult for a robot to perform than others. If possible, this difficulty factor should be considered in the design of the product. As an example, for a robot to accomplish the screw-fastening operation without the use of an automatic screwdriver is difficult. Even with a powered device to perform the operation, the process of turning the screw into the part requires time. If the objective of using a threaded fastener is to allow for subsequent disassembly (e.g., for service of the product), then the use of screws may be an appropriate design decision.

➤ **Inspection operations:**

Inspection is a quality control operation that involves the checking of parts, assemblies, or products for conformance to certain criteria generally specified by the design engineering department. The inspection function is commonly done for incoming raw materials at various stages of the production process, and at the completion of manufacturing prior to shipping the product. Testing is another quality control operation often associated with inspection. The distinction between the two terms is that testing normally involves the functional aspects of the product, such as testing to ensure that the product operates properly, fatigue testing, environmental testing, and similar procedures.

- Robotics can be used to accomplish inspection or testing operations for mechanical dimensions and other physical characteristics, and product function and performance. Generally the robot must work with other pieces of equipment in order to perform the operations. Examples include machine vision systems, robot manipulated inspection and/or testing equipment, and robot loading and unloading operation with automatic test equipment. The following subsections will discuss these three categories of robotic inspection systems.

Vision Inspection Systems:



Robot Vision

Machine vision as a sensor in robotics was discussed in Chap. Some of the robotic applications of vision systems include part location, parts identification, and bin picking. Machine vision can also be used to implement a robotic inspection system. Typical robotic vision systems are capable of analyzing two-dimensional scenes by extracting certain features from the images. Examples of inspection tasks carried out by this procedure include dimensional accuracy, surface finish, and completeness and correctness of an assembly or product.

Robot-Manipulated Inspection or Test Equipment:

This method of robotic inspection involves the robot moving an inspection or testing device around the part or product. An example would be for a robot to manipulate an electronic inspection probe or a laser probe along the surface of the object to be measured. As long as the accuracy of the measurement is not required to exceed the repeatability of the robot, the approach is feasible.

Robot-Loaded Test Equipment:

The third application area in robotic inspection is loading and unloading inspection and testing equipment. This application is very similar to machine tool loading/unloading. There are various types of inspection and testing equipment that can be loaded by a robot. These include mechanical, electrical, and pnemnatic gauges, and functional testing devices.

****************THE END (www.scrmechrocks.com)********************

UNIT-3

Unit-4

Explain the homogeneous transformations as applicable to rotation.

OR

Define and explain about homogeneous transformations.

Answer :

It is a general method for solving the kinematic equation of a robot manipulator with many joints. It is described by a single matrix that combines the effect of translation and rotation.

The rotation transformation operates on homogenous coordinates and perform rotation about a given axis of the reference coordinate system.

The reference co-ordinate system is given as follows.

(a) Rotation 'α' degrees about the x-axis,

$$\text{Rot}(x, \alpha) = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & \cos\alpha & -\sin\alpha & 0 \\ 0 & \sin\alpha & \cos\alpha & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

(b) Rotation 'α' degrees about the y-axis,

$$\text{Rot}(y, \alpha) = \begin{bmatrix} \cos\alpha & 0 & \sin\alpha & 0 \\ 0 & 1 & 0 & 0 \\ -\sin\alpha & 0 & \cos\alpha & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

(c) Rotation 'α' degrees about the z-axis,

$$\text{Rot}(z, \alpha) = \begin{bmatrix} \cos\alpha & -\sin\alpha & 0 & 0 \\ \sin\alpha & \cos\alpha & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

The general form of the homogenous transformation can be partitioned into sub-matrix in tabular form.

Rotation matrix (3×3)	Partition vector (3×1)
Perspective transform (1×3)	Scaling factor (1×1)

The entry (3 × 3) matrix is for rotation, (3 × 1) for translation and other two sub-matrix for perspective transform and scaling factor.

Vector and position nomenclature for homogenous transformation matrix.

$$H = \left[\begin{array}{ccc|c} h_x & o_x & a_x & p_x \\ h_y & o_y & a_y & p_y \\ h_z & o_z & a_z & p_z \\ \hline 0 & 0 & 0 & 1 \end{array}\right]$$

Homogenous transformation is based on mapping an N-dimensional space into $(N+1)$ dimensional space i.e., one more coordinate is added to represent the position of a point.

Example

A 3-dimensional space point has coordinates (x, y, z) is represented by vector (x, y, z, w) in homogenous transformations in which 'w' is a dummy coordinate that on normalization gives $\left(\frac{x}{w}, \frac{y}{w}, \frac{z}{w}, 1\right)$. This additional 1 serves as a tool to accomplish the addition of matrices required in translation by matrix multiplication.

Rotation transformation :-

1) Find the rotation of vector $v = 5\hat{i} + 3\hat{j} + 8\hat{k}$ by the angle of $90°$ about x-axis.

$$H = Rot(x, 90°) = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\theta & -\sin\theta \\ 0 & \sin\theta & \cos\theta \end{bmatrix}$$

$$= \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos 90° & -\sin 90° \\ 0 & \sin 90° & \cos 90° \end{bmatrix}$$

$$= \begin{bmatrix} 1 & 0 & 0 \\ 0 & 0 & -1 \\ 0 & 1 & 0 \end{bmatrix}$$

Given vector $v = \begin{bmatrix} 5 \\ 3 \\ 8 \end{bmatrix}$.

$$\therefore \quad u = H \cdot v = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 0 & -1 \\ 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} 5 \\ 3 \\ 8 \end{bmatrix} = \begin{bmatrix} 5 \\ -8 \\ 3 \end{bmatrix}$$

2) The coordinates of point p in frame $\{1\}$ are $[3.0\ 2.0\ 1.0]^T$. The position vector p is rotated about the z-axis by $45°$. Find the coordinates of point Q, the new position of point p.

The $45°$ rotation of $\vec{p}$ about the z-axis of frame 2.2

$$R(z,45°) = \begin{bmatrix} \cos 45° & -\sin 45° & 0 \\ \sin 45° & \cos 45° & 0 \\ 0 & 0 & 1 \end{bmatrix} = \begin{bmatrix} 0.707 & -0.707 & 0 \\ 0.707 & 0.707 & 0 \\ 0 & 0 & 1 \end{bmatrix} \quad \text{—(i)}$$

For the rotation of vectors, $Q' = R(z,45°) \cdot V$

where, $V = \begin{bmatrix} 3.0 \\ 2.0 \\ 1.0 \end{bmatrix}$

$$\therefore Q' = \underset{3\times3}{\begin{bmatrix} 0.707 & -0.707 & 0 \\ 0.707 & 0.707 & 0 \\ 0 & 0 & 1 \end{bmatrix}} \underset{3\times1}{\begin{bmatrix} 3.0 \\ 2.0 \\ 1.0 \end{bmatrix}} = \underset{3\times1}{\begin{bmatrix} 0.707 \\ 3.535 \\ 1 \end{bmatrix}}$$

Thus, the coordinates of the new point Q' relative to frame {i} are $[0.707 \; 3.535 \; 1.0]^T$.

3) A coordinate frame {B} is located initially coincident with a coordinate frame {A}. If the frame {B} is rotated through 30° about Z_B and 60° about current Y_B. Find the rotation matrix that will describe a vector of frame {B} in frame {A}.

A) θ = Angle made by frame {B} about Z-axis = 30°

ϕ = Angle made by frame {B} about Y-axis = 60°

we know ${}^A_B R = R(z,30°) \cdot R(y,60°)$

$$\Rightarrow {}^A_B R = \begin{bmatrix} \cos\theta & -\sin\theta & 0 \\ \sin\theta & \cos\theta & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \cos\phi & 0 & \sin\phi \\ 0 & 1 & 0 \\ -\sin\phi & 0 & \cos\phi \end{bmatrix}$$

$$ {}^{A}_{B}R = \begin{bmatrix} \cos 30^\circ & -\sin 30^\circ & 0 \\ \sin 30^\circ & \cos 30^\circ & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \cos 60^\circ & 0 & \sin 60^\circ \\ 0 & 1 & 0 \\ -\sin 60^\circ & 0 & \cos 60^\circ \end{bmatrix} $$

$$ = \begin{bmatrix} 0.866 & -0.5 & 0 \\ 0.5 & 0.866 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 0.5 & 0 & 0.866 \\ 0 & 1 & 0 \\ -0.866 & 0 & 0.5 \end{bmatrix} $$

$$ = \begin{bmatrix} 0.433 & -0.5 & 0.749 \\ 0.25 & 0.866 & 0.433 \\ -0.866 & 0 & 0.5 \end{bmatrix} $$

4) A mobile body reference frame OABC is rotated 60° about OZ axis of the fixed base reference frame OXYZ. If $P_{xyz} = [-1, 2, 4]^T$ and $Q_{xyz} = [2, -3, 3]^T$ are the coordinates with respect to oxyz frame, determine coordinates of P and Q with respect to the OABC frame.

Ⓐ $P_{xyz} = [-1, 2, 4]^T$, $Q_{xyz} = [2, -3, 3]^T$

Frame OABC is rotated 60° about oz axis of fixed base oxyz.

$$ \therefore P_{ABC} = R(z, 60^\circ)^T P_{xyz} $$

$$ Q_{ABC} = R(z, 60^\circ)^T Q_{xyz} $$

$$ \Rightarrow R(z, 60^\circ) = \begin{bmatrix} \cos 60^\circ & -\sin 60^\circ & 0 \\ \sin 60^\circ & \cos 60^\circ & 0 \\ 0 & 0 & 1 \end{bmatrix} = \begin{bmatrix} 0.5 & -0.866 & 0 \\ 0.866 & 0.5 & 0 \\ 0 & 0 & 1 \end{bmatrix} $$

$$ R(z, 60^\circ)^T = \begin{bmatrix} 0.5 & 0.866 & 0 \\ -0.866 & 0.5 & 0 \end{bmatrix} $$

$\therefore\ P_{ABC} = \begin{bmatrix} 0.5 & 0.866 & 0 \\ -0.866 & 0.5 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} -1 \\ 2 \\ 4 \end{bmatrix} = \begin{bmatrix} 1.232 \\ 1.866 \\ 4 \end{bmatrix}$

And, $Q_{ABC} = \begin{bmatrix} 0.5 & 0.866 & 0 \\ -0.866 & 0.5 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 2 \\ -3 \\ 3 \end{bmatrix} = \begin{bmatrix} -1.598 \\ -3.232 \\ 3 \end{bmatrix}$

5) For the following rotation matrix determine the axis of rotation and the angle of rotation about the same axis.

$$\begin{bmatrix} \sqrt{3}/2 & 0 & 0.5 \\ 0 & 1 & 0 \\ -0.5 & 0 & \sqrt{3}/2 \end{bmatrix}$$

A)

Rotation matrix, $R = \begin{bmatrix} \sqrt{3}/2 & 0 & 0.5 \\ 0 & 1 & 0 \\ -0.5 & 0 & \sqrt{3}/2 \end{bmatrix}$ —(i)

The above matrix is in the form of $R(y, \theta) = \begin{bmatrix} \cos\theta & 0 & \sin\theta \\ 0 & 1 & 0 \\ -\sin\theta & 0 & \cos\theta \end{bmatrix}$ —(ii)

From equations (i) & (ii), we get

$\cos\theta = \frac{\sqrt{3}}{2}$ and $\sin\theta = 0.5$

$\therefore\ \theta = 30^\circ$

$\therefore$ axis of rotation is y-axis and angle of rotation is 30°.

Composite rotation matrix:-

1). Determine a composite rotation matrix for the following,

(i) Rotation of angle α about x-axis

(ii) Rotation of angle B about y-axis

1) (i) Rotation of Angle α about X-axis

$$R(x,\alpha) = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\alpha & -\sin\alpha \\ 0 & \sin\alpha & \cos\alpha \end{bmatrix}$$

(ii) $$R(y,\beta) = \begin{bmatrix} \cos\beta & 0 & \sin\beta \\ 0 & 1 & 0 \\ -\sin\beta & 0 & \cos\beta \end{bmatrix},$$ (iii) $$R(z,\gamma) = \begin{bmatrix} \cos\gamma & -\sin\gamma & 0 \\ \sin\gamma & \cos\gamma & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

The composite rotation matrix (R) following the sequence of rotations can be obtained by,

$$R = R(x,\alpha) \cdot R(y,\beta) \cdot R(z,\gamma)$$

$$= \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\alpha & -\sin\alpha \\ 0 & \sin\alpha & \cos\alpha \end{bmatrix} \begin{bmatrix} \cos\beta & 0 & \sin\beta \\ 0 & 1 & 0 \\ -\sin\beta & 0 & \cos\beta \end{bmatrix} \begin{bmatrix} \cos\gamma & -\sin\gamma & 0 \\ \sin\gamma & \cos\gamma & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

$$= \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\alpha & -\sin\alpha \\ 0 & \sin\alpha & \cos\alpha \end{bmatrix} \begin{bmatrix} \cos\beta\cos\gamma & -\cos\beta\sin\gamma & \sin\beta \\ \sin\gamma & \cos\gamma & 0 \\ -\sin\beta\cos\gamma & \sin\beta\sin\gamma & \cos\beta \end{bmatrix}$$

$$= \begin{bmatrix} \cos\beta\cos\gamma & -\cos\beta\sin\gamma & \sin\beta \\ \cos\alpha\sin\gamma + \sin\alpha\sin\beta\cos\gamma & \cos\alpha\cos\gamma - \sin\alpha\sin\beta\sin\gamma & -\sin\alpha\cos\beta \\ \sin\alpha\sin\gamma - \cos\alpha\sin\beta\cos\gamma & \sin\alpha\cos\gamma + \cos\alpha\sin\beta\sin\gamma & \cos\alpha\cos\beta \end{bmatrix}$$

Translation:-

1) For the vector $v = 25I + 10J + 20K$ perform of 8 in x-direction, 5 in y-direction and 0 in z-direction.

A) $$H = Trans(8, 5, 0) = \begin{bmatrix} 1 & 0 & 0 & 8 \\ 0 & 1 & 0 & 5 \end{bmatrix}$$

$$V = \begin{bmatrix} 25 \\ 10 \\ 20 \\ 1 \end{bmatrix}$$

$$\therefore u = H \cdot v = \begin{bmatrix} 1 & 0 & 0 & 8 \\ 0 & 1 & 0 & 5 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}_{4\times4} \begin{bmatrix} 25 \\ 10 \\ 20 \\ 1 \end{bmatrix}_{4\times1} = \begin{bmatrix} 33 \\ 25 \\ 20 \\ 1 \end{bmatrix}_{4\times1}$$

2) A vector v is 3i + 2J + 5K is translated 3 units along y and x axis, and 2 units in z-direction. Find the final vector.

A)

$$H = \text{Tran}(3, 3, 2) = \begin{bmatrix} 1 & 0 & 0 & 3 \\ 0 & 1 & 0 & 3 \\ 0 & 0 & 1 & 2 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$V = \begin{bmatrix} 3 \\ 2 \\ 5 \\ 1 \end{bmatrix}$$

$$u = H \cdot V = \begin{bmatrix} 1 & 0 & 0 & 3 \\ 0 & 1 & 0 & 3 \\ 0 & 0 & 1 & 2 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 3 \\ 2 \\ 5 \\ 1 \end{bmatrix} = \begin{bmatrix} 6 \\ 5 \\ 7 \\ 1 \end{bmatrix}$$

Rotation and translation transformation :-

1) Find the transformation matrices for the following operations on the point 4i + 5J − 2K.

i) Rotate 60° about x-axis and then translate 3 units along y-axis.

ii) Translate 6 units along y-axis and rotate 30° about x-axis.

1) The vector matrix for the given vector 4i + 5J − 2K is

$$V = \begin{bmatrix} 4 \\ 5 \end{bmatrix}$$

i) The Homogeneous transformation matrix (T) to perform rotation of 60° about x-axis and then translation of -3 units along y-axis is given by $T = Tran(y,-3) \times Rot(x, 60°)$.

$$T = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & -3 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & \cos 60° & -\sin 60° & 0 \\ 0 & \sin 60° & \cos 60° & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$T = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & -3 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 0.5 & -0.866 & 0 \\ 0 & 0.866 & 0.5 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 0.5 & -0.866 & -3 \\ 0 & 0.866 & 0.5 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

The trasformed vector, $V = T.u$

$$V = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 0.5 & -.866 & -3 \\ 0 & 0.866 & 0.5 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 4 \\ 5 \\ -2 \\ 1 \end{bmatrix} = \begin{bmatrix} 4 \\ 1.232 \\ 3.330 \\ 1 \end{bmatrix}$$

ii)

$$T = Rot(x, 30°) \times Tran(y, 6)$$

$$T = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & \cos 30° & -\sin 30° & 0 \\ 0 & \sin 30° & \cos 30° & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 6 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$T = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 0.866 & -0.5 & 0 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 6 \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 0.866 & -0.5 & 5.196 \end{bmatrix}$$

The transformed vector, $V = T.u$

$$V = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 0.866 & -0.5 & 5.196 \\ 0 & 0.5 & 0.866 & 3 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 4 \\ 5 \\ -2 \\ 1 \end{bmatrix} = \begin{bmatrix} 4 \\ 10.526 \\ 3.768 \\ 1 \end{bmatrix}$$

2) Find the transformation matrices for the following operations on the point $2i - 5J + 4K$.

(i) Rotate 60° about x-axis and then translate 4 units along Y-axis.

(ii) Translate -6 units along y-axis and rotate 30° about x-axis.

A) given vector = $2i - 5J + 4K$.

∴ The vector matrix for the given vector is $u = \begin{bmatrix} 2 \\ -5 \\ 4 \\ 1 \end{bmatrix}$

i) $T = Tran(y, 4) \times Rot(x, 60°)$

$$T = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 4 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 0.5 & -0.866 & 0 \\ 0 & 0.866 & 0.5 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 0.5 & -0.866 & 4 \\ 0 & 0.866 & 0.5 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

The transformed vector, $V = T.u$

$$V = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 0.5 & 0.866 & 4 \\ 0 & 0.866 & 0.5 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 2 \\ -5 \\ 4 \\ 1 \end{bmatrix} = \begin{bmatrix} 2 \\ -1.964 \\ -2.33 \\ 1 \end{bmatrix}$$

ii) $T = Rot(x, 30°) \times Tran(y, -6)$

$$T = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 0.866 & -0.5 & 0 \\ 0 & 0.5 & 0.866 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & -6 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 0.866 & -0.5 & -5.196 \\ 0 & 0.5 & 0.866 & -3 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

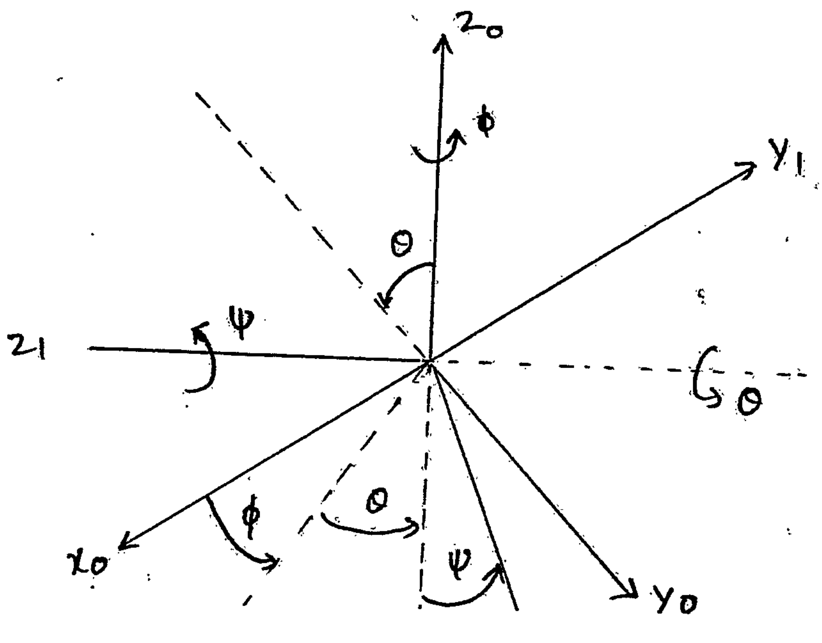
The transformed vector, $v = T \cdot u$

$$v = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 0.866 & -0.5 & -5.196 \\ 0 & 0.5 & 0.866 & -3 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 2 \\ -5 \\ 4 \\ 1 \end{bmatrix} = \begin{bmatrix} 2 \\ -11.526 \\ -2.036 \\ 1 \end{bmatrix}$$

Euler angles :-

A body possesses 3-rotational DOF. Three independent quantities are required to represent "Euler Angles".

* A method to specify a rotation matrix in terms of 3 independent quantities is known as "Euler angles".
* Figure shows the fixed co-ordinate frame x_0, y_0 and z_0 and the rotated frame $ox_0y_0z_0$ by angles (θ, ϕ, ψ) known as "Euler angles".



Q) obtain the rotation matrix corresponding to the set of Euler angles with respect to fixed XZX axes.

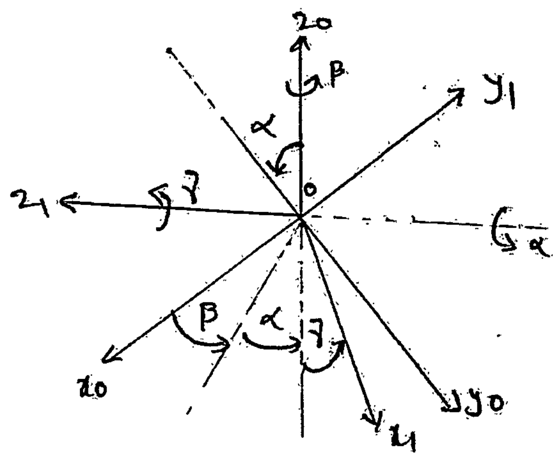
A) Rotation matrices must be multiplied together to represent a sequence of rotations about principle axes of the OXYZ coordinate system.

(i) Rotation of angle 'α' about x-axis i.e., $R(x,\alpha)$

(ii) Rotation of angle 'β' about z-axis i.e., $R(z,\beta)$

(iii) Rotation of angle 'γ' about x-axis i.e., $R(x,\gamma)$

$$R(x,\alpha) = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\alpha & -\sin\alpha \\ 0 & \sin\alpha & \cos\alpha \end{bmatrix}$$



$$R(z,\beta) = \begin{bmatrix} \cos\beta & -\sin\beta & 0 \\ \sin\beta & \cos\beta & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

$$R(x,\gamma) = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\gamma & -\sin\gamma \\ 0 & \sin\gamma & \cos\gamma \end{bmatrix}$$

Now, the resultant rotation matrix can be obtained by,

$$R = R(x,\alpha)\, R(z,\beta)\, R(x,\gamma)$$

$$= \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\alpha & -\sin\alpha \\ 0 & \sin\alpha & \cos\alpha \end{bmatrix} \begin{bmatrix} \cos\beta & -\sin\beta & 0 \\ \sin\beta & \cos\beta & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\gamma & -\sin\gamma \\ 0 & \sin\gamma & \cos\gamma \end{bmatrix}$$

$$= \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\alpha & -\sin\alpha \end{bmatrix} \begin{bmatrix} \cos\beta & -\sin\beta\cos\gamma & \sin\beta\sin\gamma \\ \sin\beta & \cos\beta\cos\gamma & -\cos\beta\sin\gamma \end{bmatrix}$$

$$R = \begin{bmatrix} \cos\beta & -\sin\beta\cos\gamma & \sin\beta\sin\gamma \\ \cos\alpha\sin\beta & \cos\alpha\cos\beta - \sin\alpha\sin\gamma & -\cos\alpha\cos\beta\sin\gamma - \sin\alpha\cos\gamma \\ \sin\alpha\sin\beta & \sin\alpha\cos\beta\cos\gamma + \cos\alpha\sin\gamma & -\sin\alpha\cos\beta\sin\gamma + \cos\alpha\cos\gamma \end{bmatrix}$$

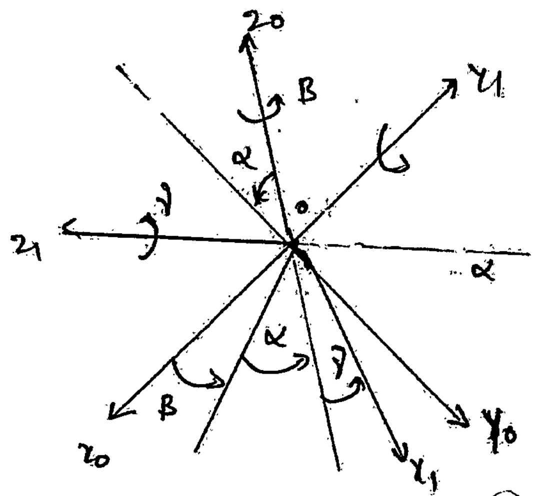
3) obtain the rotation matrix corresponding to the set of Euler angles with respect to the fixed zyx axes.

A) (i) Rotation of angle 'α' about z-axis i.e., $R_{(z,\alpha)}$

(ii) Rotation of angle 'β' about y-axis i.e., $R(y,\beta)$

(iii) Rotation of angle 'γ' about x-axis i.e., $R(x,\gamma)$

$$R(z,\alpha) = \begin{bmatrix} \cos\alpha & -\sin\alpha & 0 \\ \sin\alpha & \cos\alpha & 0 \\ 0 & 0 & 1 \end{bmatrix}$$



$$R(y,\beta) = \begin{bmatrix} \cos\beta & 0 & \sin\beta \\ 0 & 1 & 0 \\ -\sin\beta & 0 & \cos\beta \end{bmatrix}$$

$$R(x,\gamma) = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\gamma & -\sin\gamma \\ 0 & \sin\gamma & \cos\gamma \end{bmatrix}$$

Now, the resultant rotation matrix can be obtained by,

$$R = R(z,\alpha) \cdot R(y,\beta) \cdot R(x,\gamma)$$

$$= \begin{bmatrix} \cos\alpha & -\sin\alpha & 0 \\ \sin\alpha & \cos\alpha & 0 \end{bmatrix} \begin{bmatrix} \cos\beta & 0 & \sin\beta \\ 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\gamma & -\sin\gamma \end{bmatrix}$$

$$= \begin{bmatrix} \cos\alpha & -\sin\alpha & 0 \\ \sin\alpha & \cos\alpha & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \cos\beta & \sin\beta\sin\gamma & \sin\beta\cos\gamma \\ 0 & \cos\gamma & -\sin\gamma \\ -\sin\beta & \cos\beta\sin\gamma & \cos\beta\cos\gamma \end{bmatrix}$$

$$= \begin{bmatrix} \cos\alpha\cos\beta & \cos\alpha\sin\beta\sin\gamma - \sin\alpha\cos\gamma & \cos\alpha\sin\beta\cos\gamma + \sin\alpha\sin\gamma \\ \sin\alpha\cos\beta & \sin\alpha\sin\beta\sin\gamma + \cos\alpha\cos\gamma & \sin\alpha\sin\beta\cos\gamma - \cos\alpha\sin\gamma \\ -\sin\beta & \cos\beta\sin\gamma & \cos\beta\cos\gamma \end{bmatrix}$$

Different problem :-

1) A Frame B is initially coincident with coordinate frame A. The frame B is then rotated about the vector $0.707i + 0.707j$, defined in frame A and passing through a point (1, 2, 3) through an angle 60°. Give description of the frame B' with respect to A.

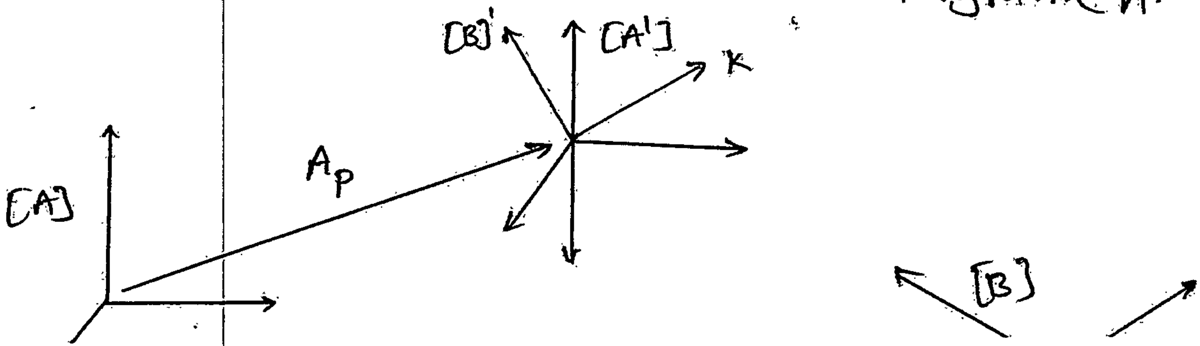
A). Given vector $= 0.707i + 0.707j + 0k$.

∴ The vector matrix for the given vector is

$$\hat{k} = [0.707 \; 0.707 \; 0]^T$$

Point $P = [1, 2, 3]$, and $\theta = 60^\circ$.

Case (i) :: Frame B' is initially coincident with frame A.



Considering two frames [A'], [B'] as shown in fig. Before the rotation of [B] about the vector, [A'] and [B'] are coincident with same orientation (i.e., [A] and [B]) to each other

Description of [A] in terms of [A']

$$\therefore {}^{A}_{A'}[T] = \begin{bmatrix} 1 & 0 & 0 & 1 \\ 0 & 1 & 0 & 2 \\ 0 & 0 & 1 & 3 \\ 0 & 0 & 0 & 1 \end{bmatrix} \text{ and } {}^{B'}_{B}[T] = \begin{bmatrix} 1 & 0 & 0 & -1 \\ 0 & 1 & 0 & -2 \\ 0 & 0 & 1 & -3 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Case (ii):- Rotation of B about a vector through an Angle 60°.

Now, considering the equivalent rotation of matrix

$${}^{A'}_{B'}[T] = \begin{bmatrix} K_x^2 V\theta + \cos\theta & K_x K_y V\theta - K_z \sin\theta & K_x K_z V\theta + K_y \sin\theta \\ K_x K_y V\theta + K_z \sin\theta & K_y^2 V\theta + \cos\theta & K_y K_z V\theta - K_x \sin\theta \\ K_x K_z V\theta - K_y \sin\theta & K_x K_z V\theta + K_x \sin\theta & K_z^2 V\theta + \cos\theta \end{bmatrix}$$

where $V\theta = (1-\cos\theta)$, $K_x = 0.707$, $K_y = 0.707$, $K_z = 0$, we get

$$\therefore {}^{A'}_{B'}[T] = \begin{bmatrix} 0.7499 & 0.2499 & 0.6122 & 0 \\ 0.2499 & 0.7499 & -0.6122 & 0 \\ -0.6122 & 0.6122 & 0.5 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

Desired frame is obtained by writing a transformed equation i.e.,

$${}^{A}_{B}[T] = {}^{A}_{A'}[T] \cdot {}^{A'}_{B'}[T] \; {}^{B'}_{B}[T]$$

$${}^{A}[T] = \begin{bmatrix} 0.750 & 0.250 & 0.612 & -2.086 \\ 0.250 & 0.750 & -0.612 & 2.086 \end{bmatrix}$$

unit 5

3. PATH AND TRAJECTORY PLANNING

General problems of path and trajectory planning Obstacles and collision detection Environment identification Strategies of path planning and navigation in the condition of obstacles Planning of manipulator motion and motion diagrams

3.1. General problems of path and trajectory planning

Industrial robots must have high flexibility to execute different technological operations and work together with human workers. Compared with human flexibility, a robot has a multitude of problems to realize even simple motions in a working space. To move between two space points, different tasks must be solved. The best trajectory must be found, obstacles and collisions must be avoided, other limitations must be considered, and the high efficiency and work productivity must be achieved. To control the robot's motion normally the previous motion planning is used. The **path planning** is the planning of the whole way from point A to point B, including stopping in defined path points. The path includes several continuous motion trajectories that need the **trajectory planning**. If a path can not be previously planned because of limited previous information, the motion task is named as **path finding**.

Tasks of robot control can be classified in different ways. For example, different path planning strategies can be used in the case of different situations. There are two types of constraints that must be considered in path planning. First, the motion of a robot can be restricted by obstacles and **obstacle constraints** have to be used. On the other hand there can be some kind of constraints for path selection. These constraints are known as **path constraints**.

In the case of obstacle constraints it will be assumed that some points in the robot motion space are occupied and the robot cannot plan the path through these areas. In the case of path constraints, there can be some referred points that must be necessarily passed through.

The following path planning strategies exist:

- path constrained (signed path) off-line or on-line path planning with collision avoidance
- position controlled motion with on-line obstacle identification and collision avoidance (without path constraints, i.e. path signs)
- path constrained off-line path planning or on-line pass through the signed path (collisions are possible)
- position controlled motion without obstacle identification (collisions are possible)

These strategies can be used to solve path planning tasks in robotics in most of the cases. The **position controlled motion** is the motion along interpolated trajectories between signed and referred path points. The **signed path** is the path having regular defined points that must be unconditionally passed through.

The main path planning tasks for a robot are as follows:

- grasping and releasing objects
- moving from place to place
- following previously specified paths
- following moving objects
- working with other manipulators
- exerting forces (i.e. pushing, pulling and holding)
- exerting torques
- collecting data
- using tools

Robots are subject to all of the constraints of mechanics. In the case of manipulators with many joints (prismatic or revolute), the physical limits of motion become evident. For the best solution, the limits of joint and actuator positions, velocity, acceleration, and jerk must be considered. The physical nature of the device also means that there are dimensions which must be considered, thus kinematics and collision avoidance come into play. When a robot makes any move, it expends energy to accelerate, hold and brake. This also means that the energy efficiency of the manipulator should be optimized by reducing unnecessary expenditures of energy. Most importantly, if robots are to be cost effective, then their speed is of concern. In a high production situation, a cycle time that is 10% faster could save millions of dollars. Thus, the time of path traversal can most often be the most important path planning factor.

Essential performances of a robot:

- time for path traversal
- velocity of manipulator links or joints
- stored energy
- actuator forces
- proximity to obstacles

Mechanical constraints of a manipulator:

- joint positions, velocities, accelerations and jerks
- actuator forces and motion dynamics
- kinematics (including singularities)
- collisions with obstacles
- time when moving obstacles are involved

General requirements, evaluation criteria:

- dimensions of space (2D, 2.5D, 3D)
- collision avoidance (none, contact detection, proximity calculation)
- multilink manipulators
- rotations of payload or mobile robot
- moving workspace obstacles
- multi robot coordination
- degree of automation (automated or manual path planning)

Evaluation criteria of information setup:

- information source (knowledge based, sensor based)
- world modeling (world model)

Evaluation criteria of the control method:

- path planning strategies for information passing (e.g. hierarchical)
- path planning methods (algorithms used for path planning)
- internal representations of path or trajectory
- minimization (which costs are minimized?)
- limits (which limits are considered?)
- solution type (robot, joint space, Cartesian space, straight line, via points with rotations, using of splines, etc.)

Evaluation criteria of implementation:

- execution time, machine type, programming language
- testing (what are the experimental results?)

The optimization of path planners

To aid the description of the path planning problem, a generalized statement of the optimization criteria will be given. This will be presented for both the measure of performance and constraints. The first most important measure of performance is time for the path. To find this and other factors, a number of relations will be derived. First assume that the path is made up of a number of discrete segments (trajectories). These segments are linked together to form the path of motion. Motion along the path will then have a few characteristics, and these provide the basis for some equations.

More information about path planners can be found on website:
http://claymore.engineer.gvsu.edu/~jackh/eod/mechtron/mechtron-453.html

3.2. Obstacles and collision detection

A 2D problem is relatively simple and good solutions already exist for finding paths in this representation. This 2.5D problem is also within the grasp of current problem solving routines.

Normally in the working space of a robot other machines, different constructions or devices exist. These can be considered as obstacles that have different dimensionality. The obstacles make programming of a robot more complicated. If the robot has planar motion and two dimension obstacles exist, the two-dimensional path planning is used. Generally, the obstacles can be classified as follows (see Fig. 4.1).

2D – Planar motion around obstacles is a relatively simple task, and good solutions already exist for finding paths in this case.

2,5D – Planar motion of a robot considering the height of obstacles is a 2.5D problem for path planners.

3D – Motion through the three dimensional openings is the 3D problem for path planners (considering openings and robot dimensions is needed)

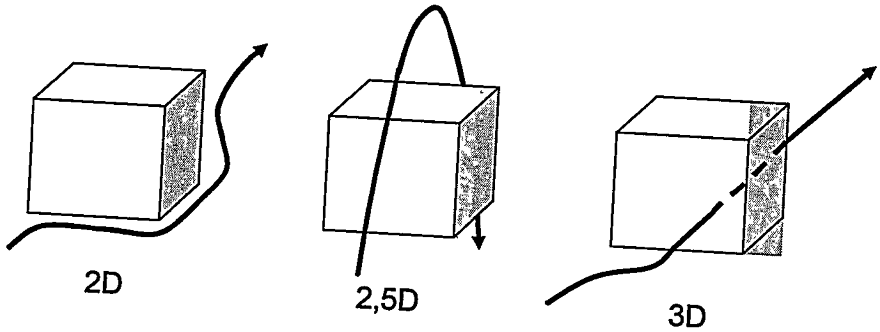


Figure 3.1 Dimensionality of obstacles

Obstacles and collision avoidance in 2D and 2.5D space

A wellknown problem of collision avoidance is moving high dimensional objects in rubbish environment. This is known as the piano mover's problem in a little apartment if the piano cannot be lifted up.

In this case the obstacles are considered as infinitely high. The method is useful if the manipulator of the robot is operating in clear workspace and fulfils picking and placing type operations. Path finding problem in that kind of **2D** space can be easily solved.

If the height of the obstacle is known, then the robot operates in 2.5D space. The problem of avoiding collision with obstacles can be solved in different ways. First, all pick and place type operations may be organized above obstacles and all moving manipulator's links of the robot must be also above the obstacles. Secondly, different algorithms may be found for passing of obstacles. This first method is normally used by people if something is needed to be transferred in a classroom with many tables. It is easier to transfer an object above the tables not to find the way how to pass them.

Obstacles and collision avoidance in 3D space

Sometimes a 3D image can be substituted with a 2D image and the 2D method of path finding may be used. If a possibility to find a path in a 2D space exists, then it may exist also in a 3D space. Using of 2D images simplifies the solution of the path finding problem.

The image of moving objects can also be simplified and simple boxes or cylinders may be used instead of complex form objects. To avoid collisions with moving objects, additional free space must be considered around these objects.

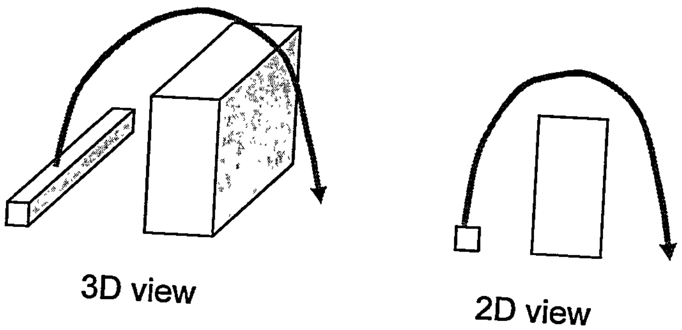


Figure 3.2 Collision avoidance in 3D space or and using 2D view

Collision detection and collision avoidance

Collision detection is the most important factor of Path Planning. Without automatic collision avoidance, the robotic work cell must be engineered to be collision free, or sub-optimal paths must be chosen by a human programmer.

Local collision detection is important when moving through an unknown or uncertain environment. These allow for feedback to the planner, for halting paths which contain collisions. Global Collision Avoidance may be done for planning paths which should avoid objects by a certain margin of safety.

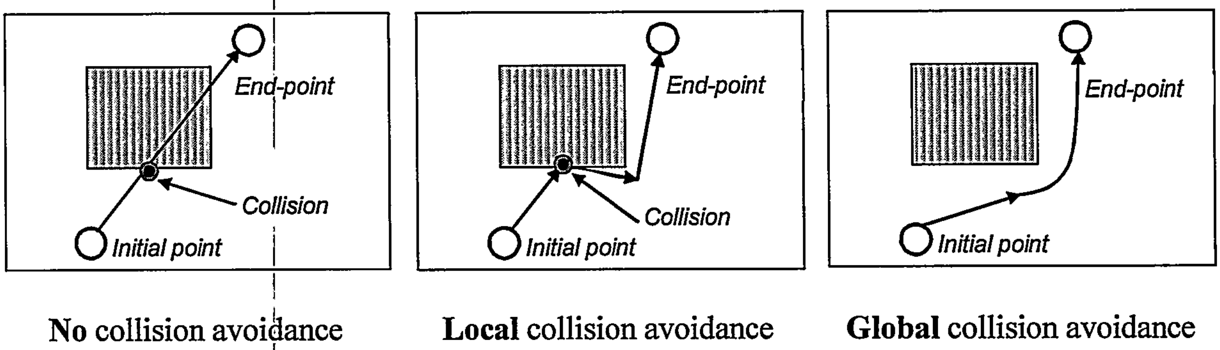


Figure 3.3 Collision avoidance

The **number of degrees of freedom** is also important in robot applications. If a manipulator has 6 degrees of freedom, then it can obtain any position or orientation in space. Some specific cases of problems require only 3 or 4 degrees of freedom. This can be a great time saver.

When an **environment is cluttered,** then it may be desirable to have a higher number of degrees of freedom than six, so that the redundancy of the robot can move through the environment. The complexity of most routines increases exponentially with the number of degrees of freedom, thus it is best to match the manipulator degrees of freedom to the complexity of the task to be done.

One assumption that helps reduce the problem complexity is the approximation of **motion in a single plane**. The net result of this effort is that the robot is reduced to 2 or 3 degrees of freedom. The gripper, tool or payload may also be neglected, or fixed, and thus the degrees of freedom are reduced.

A second approach is to approximate the volume of the links swept out over a small volume in space. This volume is then checked against obstacles for collisions. A payload on a manipulator may sometimes be approximated as part of the robot if it is small, or it is symmetrical. This means that the number of degrees of freedom for a manipulator may be reduced, and thus the problem is simplified in some cases.

Multilink manipulators have a variety of configurations. For different configurations different coordinate systems exist in which the best path planning solutions could be achieved. For example

- cartesian (i.e. x, y, z motions)
- cylindrical

- spherical (Stanford manipulator)
- vertically articulated or Revolute (like human arm)
- horizontally articulated (SCARA)

The various robot configurations are fundamentally different. Many approaches have tried to create general solutions for all configurations, or alternate solutions for different specific manipulators. The fastest solutions are the ones which have been made manipulator specific. With a manipulator it is also possible to describe motions in both Joint Space (Manipulator Space) and Cartesian Space (Task Space). There are approaches which use one or both of these.

Rotation problems

Rotations can be also a problem for some path planners. It can be difficult to rotate during motion, thus some will not rotate, some will rotate only at certain points, and some will rotate along a complete path (Fig. 3.4).

- no rotation
- rotation at discrete points
- continuous rotation

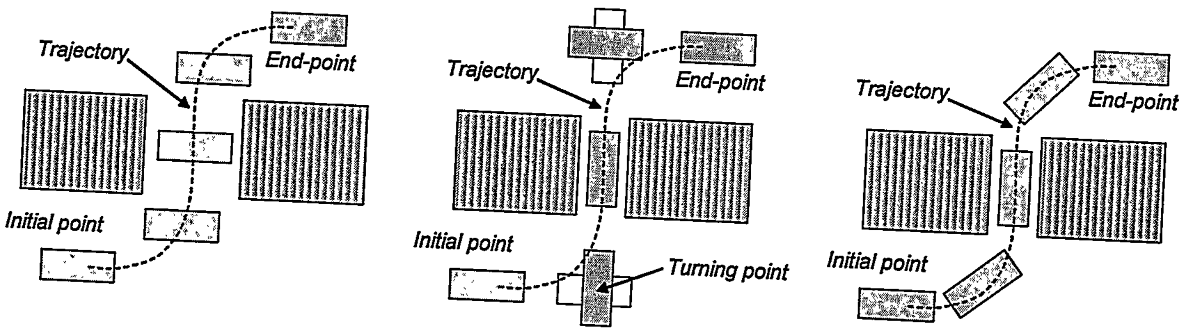
The best scenario is when rotations may be performed to avoid collisions.

Motion of obstacles

Motion of obstacles can cause significant path planning problems. Motion occurs in the form of rotation and translation. In most cases an obstacle in the environment may be categorized into motion categories:

- static (un-moving),
- deterministic (has predictable occurrence and positions), and
- random (Freely moving, with no regular occurrence).

All of these are of interest because most parts fixed in a workcell are static, workpieces from feeders and conveyors are deterministic, and human intruders are random. Random obstacle motion usually occurs so quickly that path planning may only be able to escape the path of the obstacle, not compensate it. In the case of random moving obstacles a robot must have sensors for the detection of obstacles to avoid collisions.



Parallel motion | Turning in definite points | Continuous turning

Figure 3.4 Problems of robot motion if turning is needed to avoid collision

Coordination of two or more robots

If working envelopes of robots intersect, then these robots have common working space and measures must be applied to avoid collisions between different manipulators. The solution of this problem may be a common operation strategy of two or more robots. To realize this common strategy, the common memory of status vector or status link is needed.

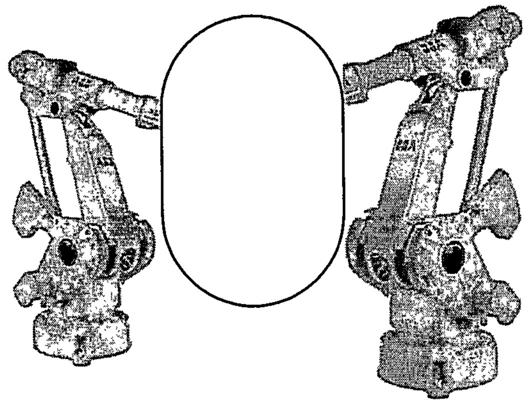


Figure 3.5 The common working envelope of two robots

To work together with another robot, the first robot must have information about its path planning strategy in the common working envelope. In the case of common path planning, first the trajectory of the second robot that seems as the moving obstacle for the first robot will be realized. Then the robot plans its own motion. If the working space of the robot is organized and fully determined (no occasional events), then more simplified path planning algorithms can be used. Generally, if two robots have a common working envelope, then the following strategies may be used:

- coordination of different motions
- common trajectory memory
- common path planning strategy considering both robots and trajectories

Common work organizion for two or more robots is especially complicated if robots have different or opposite destination functions, e.g. in the case of robots competition.

3.3. Environment identification and modelling

Environment models

To solve path planning tasks, the surroundings of the robot environment must be adequately described. The description of the environment surrounding a robot is named also the world model of a robot. This model includes obstacles that must be considered when planning the path for robot motion. Normally all obstacles are considered to be solid and rigid. The conclusion is that no resilient deformations exist.

The environment and objects can be described by the use of different images (Fig 3.12), e.g. matrixes, multi matrixes, rectangles, polygons or the special language named **Constructive Solid Geometry** (CSG). The language of constructive geometry is based on the logic description of different images and their mutual position in the environment. In the case of 3D space the polyhedras, analytically described surfaces, matrixes, oct-trees etc. are used. Each method of description defines limits for image selection. The selected method can be used together with CAD systems.

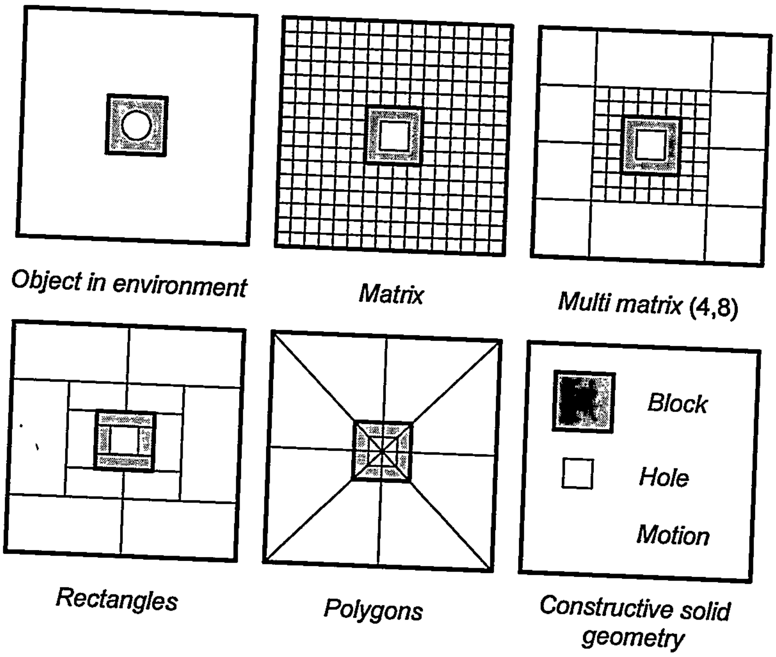


Figure 3.12 Description of the environment surrounding a robot

The most common method of representing objects (in all dimensions) is with convex polygons. These are ideal when working with flat surfaces in the real world. Curved surfaces use flat polygons to approximate their surfaces. One factor that makes the polygons an excellent representation is that if a point is found to lie outside one wall of a polygon, then it may be declared to be outside the entire polygon. Most methods do not allow for concave polygons, because they are much more difficult to deal with in computation. The way to overcome this is to use overlapping convex polygons, to represent a concave polygon. These types of representations can typically be derived from most CAD systems. This form allows easy use of existing facilities.

For the **modeling of obstacles,** the imaginary potential field near the bounders of obstacles can be used. For the description of a potential field, the two dimensional Laplacian of Gaussean (*2D Laplacian of Gaussian*) can be used. The 3D image of Laplacian of Gaussean is shown in Fig. 3.13. The form of functions image is similar to the form of a Mexican cap. In this case we can say that the robot's navigation in the environment having obstacles can be organized according to a Mexican cap. This function (Laplacian of Gaussean) becomes popular for robots that have artificial sight. Generally, also other functions are used to describe obstacles in the robot environment.

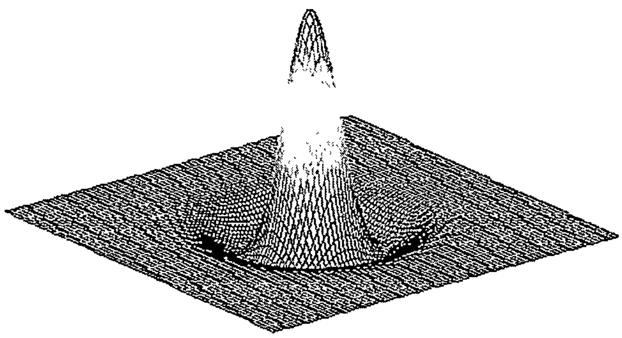


Figure 3.13 A 3D image described by the Laplacian of Gaussian

In the case of several obstacles near each other the composite emergency function as the superposition of obstacles emergency fields can be composed. The form of the emergency field considers the dimensions of the robot and conditions for passing an obstacle (rotations). If many obstacles are near each other in a row, then they form a canyon for robot navigation.

The planned path near the obstacles must consider the robot and its load dimensions and also conditions for turning. Figure 4.14 shows the path planning using the Laplacian of Gaussean or the Mexican cap. The experiments were made by scientist James Mentez from the University of Virginia and the photos are shown in the Internet.

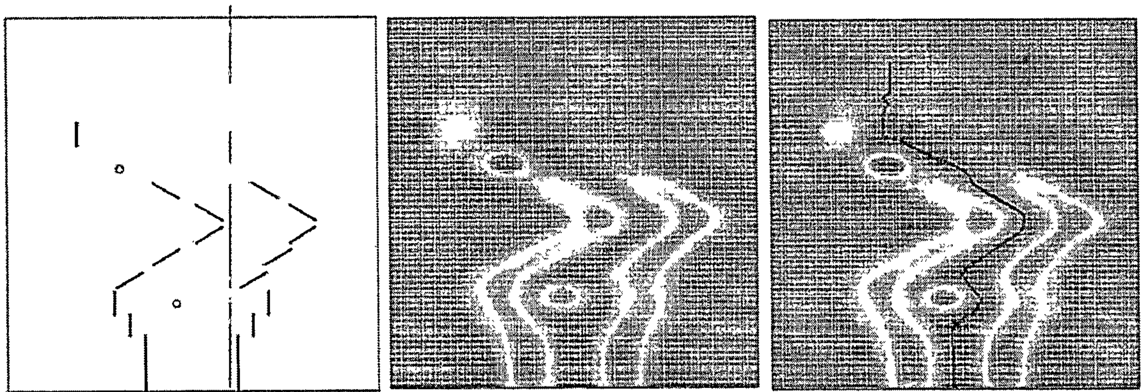


Figure 3.14 An example of robot navigation if obstacles are described using *The Laplacian of Gaussian*

3.4. Automated path planning

Path and trajectory

A path will refer to the complete route traced from the start to the goal end point. The path is made up of a number of segments and each of these path segments is continuous (no stop points). Another name for a path segment could be a trajectory. This is significant, when considering a trajectory planner, which basically chooses a locally optimal direction, as opposed to a complete path. Only some path planners use trajectory based planning, which is easier and faster to compute, but generally produces sub-optimal paths.

A path or a trajectory of robot can be planned by an operator using special software for a robot (e.g. virtual robotics software) or by using programming by teaching. The path or trajectory needed will be programmed during a special teaching process when several paths or trajectory points will be stored in robot memory.

These methods are easily used if industrial robots will be programmed. Normally these robots are working in the same mode for several weeks or months. The problem happens if it is needed to reprogram a robot every day and a lot of time must be spent on programming. In this case the best solution is **automated path planning.**

The information source that will be used is the most important to select a method of path planning.

The environment can be identified previously before the start to the path by environment mapping or during the path through going by obstacle detection. Consequently, two general ways for path planning exist:

- Collision Detection and Local or Trajectory Path Planners that are using information about collision detection
- Obstacle Information Global Path Planners that are using information about previously detected obstacles

Path planners listed in website
http://claymore.engineer.gvsu.edu/~jackh/eod/mechtron/mechtron-453.html
are as follows:

- knowledge-based simple path planner
- knowledge-based hybrid path planner
- sensor-based path planner
- static knowledge- and sensor-based hierarchical path planner
- dynamic knowledge- and sensor-based path planner
- path planner based on *off-line programming*
- path planner based on *on-line programming*

Knowledge based path planning

It is much easier to solve a problem if all the information is available at the beginning of the solution. For a robot the paths can be planned before their execution if some knowledge of the environment is known. This is strictly a **"blind"** strategy that trusts the knowledge of the environment provided. Planning paths before execution allow efforts to get a shorter path time, more efficient dynamics, and absolute collision avoidance. When working in this mode knowledge known before is used. Different techniques are available to solve a variety of problems, when given the a priori information. Some of the knowledge which we use for a priori path planning may come from vision systems, engineering specifications, or CAD programs.

Prior knowledge may be applicable to moving objects if they have a predictable frequency or motion. This may not be used for unpredictable or **random motion** if there is no detection method allowed. Prior knowledge may be derived from the results of modelling or with the help of high level sensors. These sensors are like laser scanners or video systems. These sensors are slow and typically drive a World modeler in an off-line programmer. Video system is the most desired information collector for robotics in the future. Some of these sensors require knowledge from the world modeler for object recognition purposes. In general, these sensors are slower because of their need to interpret low level data, before providing high level descriptions.

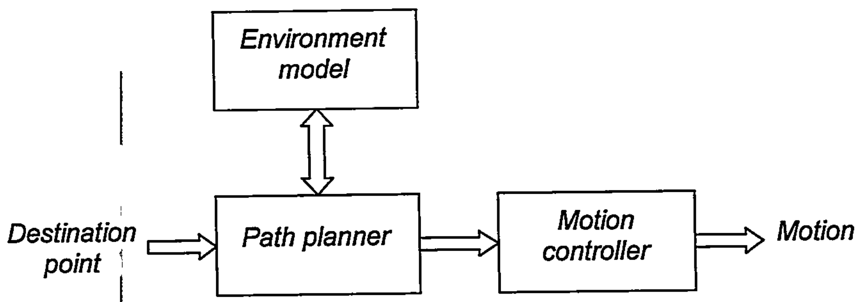


Figure 4.6 The control of robot's motion using knowledge-based path planning

Knowledge-based simple path planner

A simple path planner uses environmental information (incl. position coordinate values) for motion start and end points. Then using an algorithmic process the trajectory via points between the start and end point will be calculated, segments of trajectory will be determined by mathematical description in the defined coordinate system. For example, in the base coordinates of a manipulator or in the world coordinates of a robot system.

Knowledge-based hybrid path planner

If knowledge-based hybrid path planner is used, first a number of possible path variants will be determined. Then the optimal path variant from the possible variants will be selected. This method is more complex than other methods, but gives more chances to find the best path for a robot.

Sensor-based path planning

In this case (Fig. 3.7) information is not available when we begin to solve a problem of path planning. Thus we must solve the problem in stages as the information from the sensors (known after knowledge) becomes available. Sensor-based planning is an indispensable function when environments change with time, are unknown, or there are inaccuracies in the robotic equipment. Subsequent knowledge may be used to find the next trajectory in a path (by collecting information about the outcome of the previous trajectory) or even be used strictly to guide the robot in a random sense when exploring an environment. Sensors that will be used may be very different: from simple contact switches and tactile sensors up to complicated video systems.

These sensors will typically detect various expected conditions. The sensors can give a signal when contact is made with obstacles, or measure a force being applied. When sensors are used in a feedback loop, they may provide actual joint position for a position control algorithm. High level sensors also have the ability to provide low level data and may be used to detect events.

The amount of knowledge which a path planner has may be very limited. If the robot has no previous knowledge of the environment, then information must be gathered while the robot is in motion. Trajectory planners rely on feedback for finding new trajectories and detecting poor results. Contact or distance sensors are used to detect an obstacle and the manipulator trajectory is altered to avoid collision. This method will typically guarantee a solution (if it exists or if it does not encounter a blind alley), but at a much higher time cost, and a longer path. The collection of current data becomes critical when dealing with moving obstacles that do not have a periodic cycle.

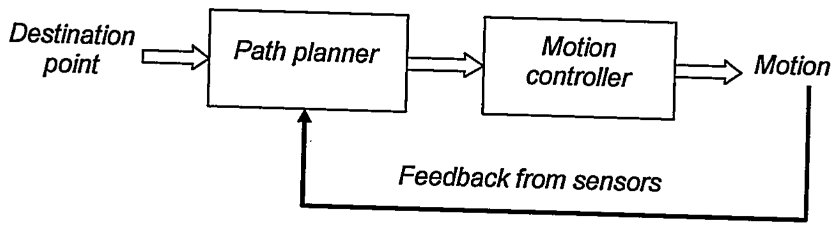


Figure 3.7 The control of robot's motion using sensor-based path planning

Combined path planning
Advanced robots are using combined path planning methods based on the use of knowledge- and sensor-based information. Part of information is gathered before the path planning. During the path through passing they check this information using sensor signals. Combining of two path planning principles gives the best result (Fig. 4.8).

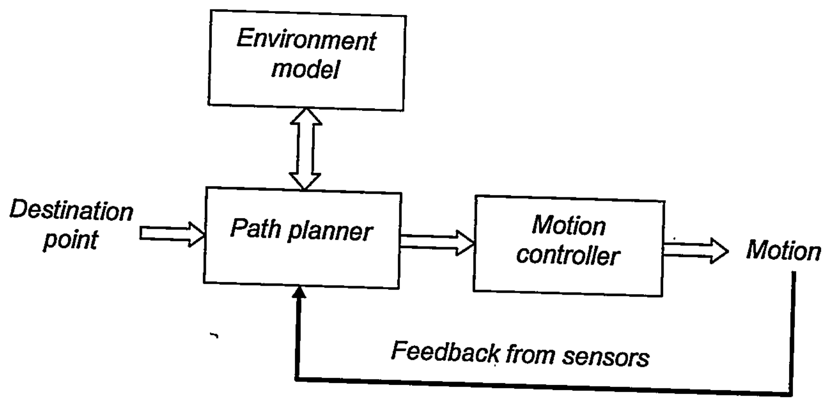


Figure 3.8 The control of robot's motion using combined knowledge-based and sensor-based path planning

Hierarchical path planning
If the best of both controllers is desired in a single system, it is possible to use a high level prior knowledge planner to produce rough paths, and then use a low level sensor-based

planner when executing the path. This would make the planner able to deal with a complex unexpected situation. This also has the ability to do rough path planning in the prior knowledge level, and let the subsequent level to smooth the corners.

Dynamic path planning

Dynamical path planners are a combination from knowledge- and sensor-based path planners. The knowledge-based path planner could plan a path with limited or inaccurate information. If during the execution of this path, a sensor detects a collision, the knowledge-based path planner is informed, and it updates its world or **environment model**, and then finds a new path.

The dynamic Planner is characterized by separate **path planning** and **path execution** modules, in which the execution module may give feedback to the planning module (Fig. 3.10). This is definitely a preferred path planner for truly intelligent robotic systems. Some dynamic planners have been suggested which would allow motion on a path, while the path is still being planned, to overcome the path planning bottle neck of computation time.

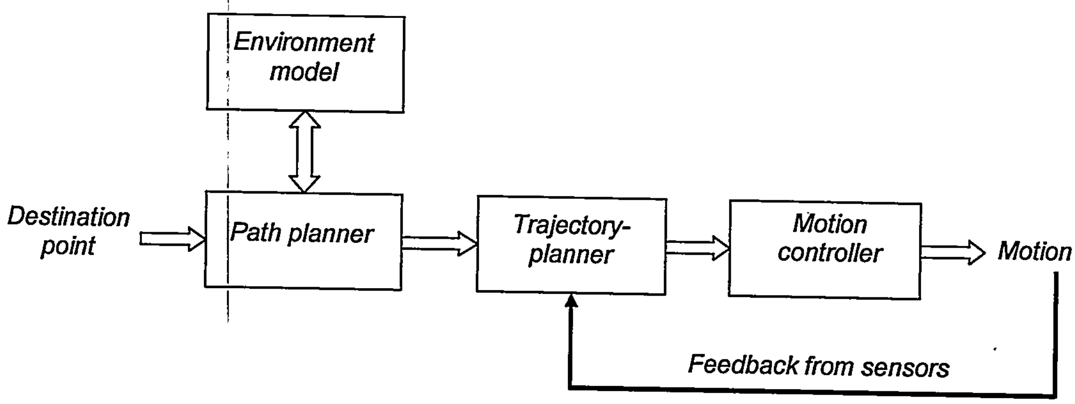


Figure 4.9 Hierarchical path planning

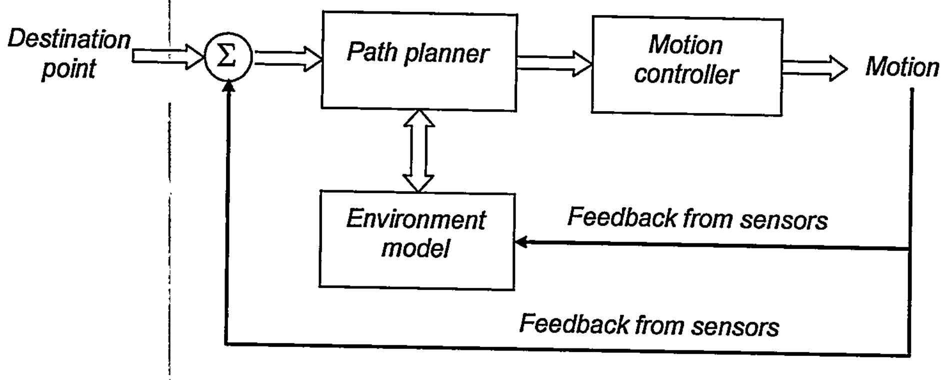


Figure 3.10 Dynamical path planning

The comparison of knowledge- and sensor-based path planning methods is illustrated in Fig. 3.11. Using knowledge-based path planning, the characteristic points of the path that must be passed through during path finding are determined. The sensor information is used to correct the motion if an obstacle appears near the robot and to avoid the collision with the obstacle.

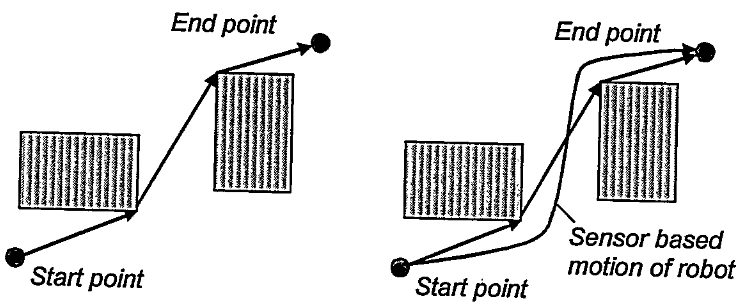


Figure 3.11 Comparison of knowledge- and sensor-based path planning methods

On-line programming methods
These methods for optimal path planning include: methods of mapped space, field methods, gradient methods, etc. Path optimization can be done in a global or local space of a robot. The local path planning methods try to avoid collisions. Global path planning methods try to avoid extra long path and non-effective passing of obstacles on the path. An optimal solution will be calculated using mathematical methods. For example, an optimal solution can be found by using the calculus of variations and dynamic programming.

Method of mapped space
First, the room map will be composed, then optimal path can be found.

Field methods
Field methods are based on the evaluation of collision danger, calculating potential value of danger by special mathematical functions (like the Mexican cap). When path planning occurs, the potential value will be given also to the start and end point of motion.

Gradient method
The gradient method is very similar to field methods. The direction of motion will be calculated using information about the maximum value of the field gradient.

3.5. Methods of path evaluation

The selected path planning method in some cases may have very good properties, but in other cases it can be useless. As the result of theoretical investigations, numerous path planning strategies have been found, but many of them may not have been practically tested. Consequently, the standardization of testing methods of path planning algorithms will be needed.

The criteria most essential for path planning as follows:
- purpose of the manipulator (e.g. 2D mobile robots or 3D manipulators)
- realization of the trajectory
- time of computation (solution calculation)
- time for passing the path

- path longitude
- maximum forces or maximum torques
- energy consumption

Methods of evaluation of path planning

The ultimate path planning test could be a **needle through a hole.** In this case, a box with a hole in it could be held at an odd angle in space (Fig. 3.12). The cylinder could be picked up off the ground and inserted into the hole. The manipulator could then force the cylinder through the hole as far as possible, and then remove the cylinder from the other side and return it to its original position. This could also be approached as a single path or as many as twelve separate paths.

1. Move the arm near the cylinder.
2. Move to and grasp the cylinder.
3. Move near the hole.
4. Insert the peg in the hole and release.
5. Move the arm away from the cylinder.
6. Move the arm near the other side of the cylinder.
7. Grasp the cylinder.
8. Remove the cylinder from the hole.
9. Move the peg the near original position.
10. Place the cylinder on the ground and release.
11. Move away from the cylinder.
12. Move the arm to start position.

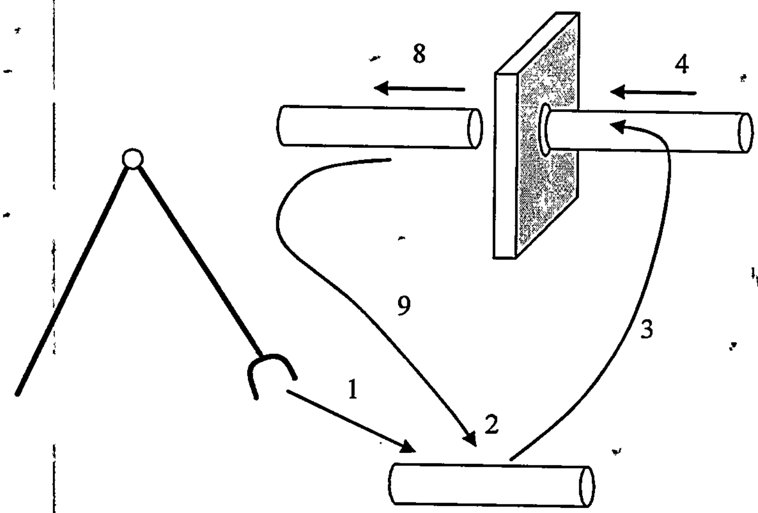


Figure 3.12 Evaluation of robot's path planning using a test needle through the hole

3.6. Planning of manipulator motion

When planning and programming the motion of the manipulator, several **limits of motion** can exist. In the case of linear motion and straight line trajectory, the programmed trajectory can not go out of the working envelope (Fig 3.13, *a*), because that motion is not possible. In another case (Fig. 3.13, *b*), the change of the pose may be needed to reach the end point of the trajectory. It is not possible to realize the motion because the change of the pose during continuous motion along a straight line trajectory is not possible. In some cases inverse kinematics tasks may be complicated to solve, because more than one solution exists. It means that the manipulator gripper or tool can reach the destination point with the help of different configurations (poses) of the manipulator. When planning the motion of the manipulator it must be considered that a mathematically described motion in some cases may not be realized without setting of additional conditions. That kind of situations are named manipulator singularities.

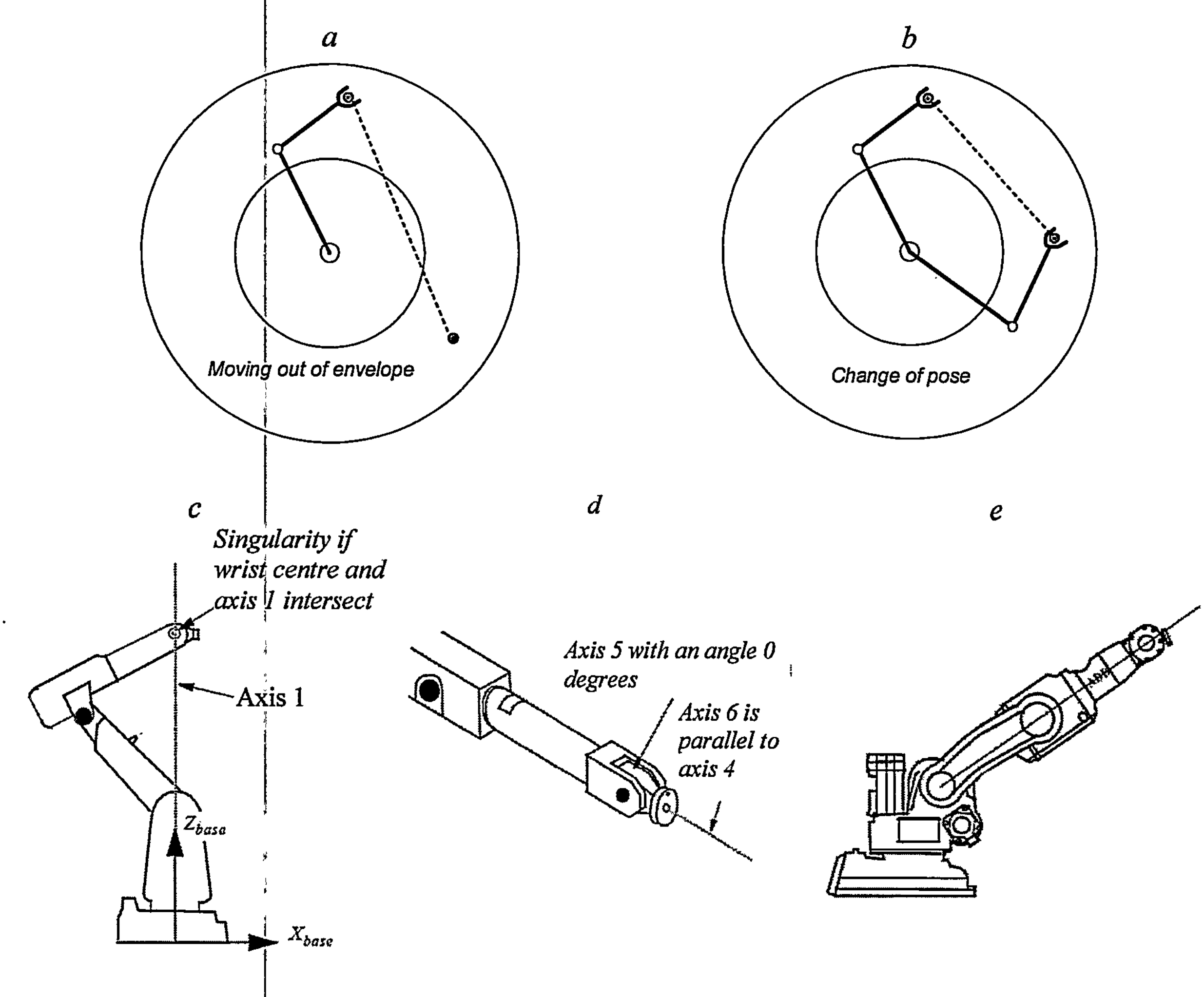


Figure 3.13 Limitations for manipulator motion and singularities

NARASARAOPETA
ENGINEERING COLLEGE
(AUTONOMOUS)

DEPARTMENT OF MECHANICAL ENGINEERING

MID & ASSIGNMENT EXAMINATION QUESTION PAPERS WITH SCHEME AND SOLUTIONS

NARASARAOPETA ENGINEERING COLLEGE (AUTONOMOUS): NARASARAOPET

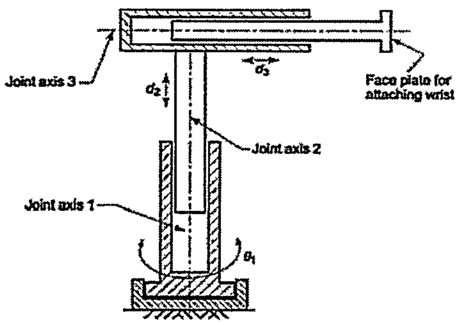
DEPARTMENT OF MECHANICAL ENGINEERING

IV B.TECH II-SEMESTER II-MID EXAMINATION, March- 2023

Subject: ROBOTICS AND APPLICATIONS Date :29-03-2023

Duration : 90 Min Max Marks: 30M

Answer All Questions

Q. No		Questions	Course Outcome (CO)	Knowledge Level as Per Bloom's Taxonomy	Marks
1	a	**Formulate** the forward kinematic model of the three degree of freedom (RPP) manipulator as shown in fig 	3	Evaluating (K5)	5
2	a	**Determine** the equations of motion for 2DOF RR- planar manipulator arm using Lagrange-Euler Formulation.	4	Evaluating (K5)	5
	b	**Derive** Jacobian Matrix for RR Manipulator.	4	Evaluating (K5)	5
3	a	**Explain** the General Considerations in Robot Material Handling applications.	5	Analyzing (K4)	5
	b	**Explain** in brief about spray painting and Welding application in robots	5	Analyzing (K4)	5

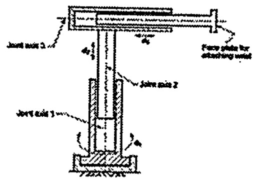
NEC NARASARAOPETA ENGINEERING COLLEGE
(AUTONOMOUS)

DEPARTMENT OF MECHANICAL ENGINEERING

Robotics and Applications Scheme of Evaluation

IV B. TECH II – SEMESTER MID TEST–II, March- 2023

1. **Formulate** the forward kinematic model of the three degree of freedom (RPP) manipulator as shown in fig :1

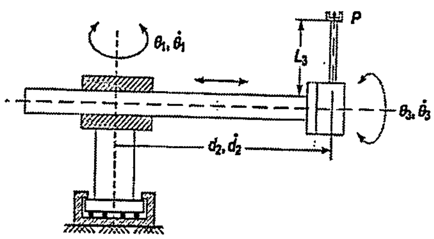


   Formula --------------------2 M
   Derivation------------------ 3 M
2. a. Determine the equations of motion for 2DOF RR- planar manipulator arm using Lagrange-Euler Formulation.
   Formulation --------------------2 M
   Derivation---------------------- 3 M
   b. **Derive** Jacobian Matrix for RR Manipulator.
   Coordinate Frame------2.5 M
   DH Table-----------------2.5 M
3. **a.Explain** the General Considerations in Robot Material Handling applications.
   Considerations---------- 2.5 M
   Applications--------------2.5 M
   b.Explain in brief about spray painting and Welding application in robots.
   spray painting application----------------- 2.5 M
   Welding application -------------------------2.5

NARASARAOPET ENGINEERING COLLEGE (AUTONOMOUS): NARASARAOPET
DEPARTMENT OF MECHANICAL ENGINEERING
IV B.TECH II - SEMESTER ASSIGNMENT TEST – IV, March– 2023

SUBJECT: ROBOTICS AND APPLICATIONS **DATE:** 10-03-2023

DURATION: 30 MIN **MAX MARKS:** 10

Q. No	Questions	Course Outcome (CO)	Knowledge Level as Per Bloom's Taxonomy	Marks
1	**Derive** Lagrange equation for 2DOF RR- planar manipulator arm	4	Evaluating (K5)	5
2	**Determine** the equations of motion for 2DOF RR- planar manipulator arm using Lagrange-Euler Formulation.	4	Evaluating (K5)	5
3	**Develop** algorithm for Lagrange-Euler formulation of Dynamic Equations.	4	Analyzing (K4)	5
4	**Formulate** the Jacobian matrix of the three degree of freedom (RPR) manipulator as shown in fig 	4	Evaluating (K5)	5
5	**Explain** the General Considerations in Robot Material Handling applications.	5	Analyzing (K4)	5
6	**Explain** Material Transfer Applications of Robot.	5	Analyzing (K4)	5
7	**Explain** in brief about spray painting and Welding application in robots	5	Analyzing (K4)	5
8	Define material transfer application? **Explain** about simple pick and operation with neat sketch.	5	Analyzing (K4)	5
9	**Explain** the requirements of the robot for spray-coating applications	5	Analyzing (K4)	5

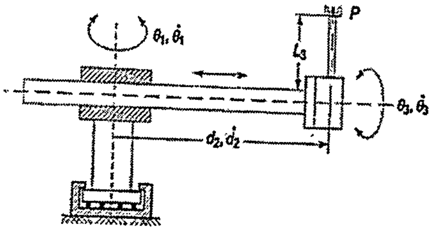
NARASARAOPETA
NEC ENGINEERING COLLEGE
(AUTONOMOUS)

DEPARTMENT OF MECHANICAL ENGINEERING

Robotics and Applications Scheme of Evaluation

IV B. TECH II – SEMESTER ASSIGNMENT TEST–IV, March– 2023

1. **Derive** Lagrange equation for 2DOF RR- planar manipulator arm.
   Formulation ----------------------2 M
   Derivation----------------------- 3 M
2. **Determine** the equations of motion for 2DOF RR- planar manipulator arm using Lagrange-Euler Formulation.
   Formulation ----------------------2 M
   Derivation----------------------- 3 M
3. **Develop** algorithm for Lagrange-Euler formulation of Dynamic Equations.
   Algorithm---------------5 M
4. **Formulate** the Jacobian matrix of the three degree of freedom (RPR) manipulator as shown in fig
   Diagram --------2 M
   Formulation----3 M

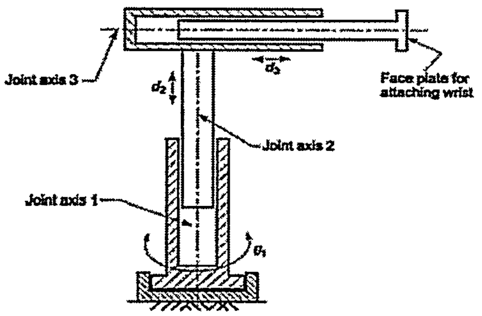
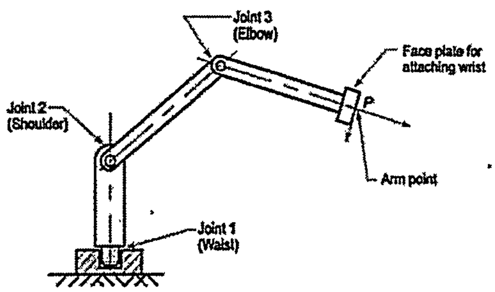


5. **Explain** the General Considerations in Robot Material Handling applications.
   Considerations---------- 2.5 M
   Applications---------------2.5 M
6. **Explain** Material Transfer Applications of Robot.
   List-----------------------------2 M
   Explanation --------------- 3 M
7. **Explain** in brief about spray painting and Welding application in robots.
   spray painting application----------------- 2.5 M
   Welding application -----------------------2.5 M
8. Define material transfer application? **Explain** about simple pick and operation with neat sketch.
   Definition ------------2 M
   Explanation ---------3 M
9. **Explain** the requirements of the robot for spray-coating applications.
   List -------------2 M
   Explanation---3 M

NARASARAOPET ENGINEERING COLLEGE (AUTONOMOUS): NARASARAOPET
DEPARTMENT OF MECHANICAL ENGINEERING
IV B.TECH II - SEMESTER ASSIGNMENT TEST – III, February– 2023

SUBJECT: ROBOTICS AND APPLICATIONS **DATE:** 16-02-2023

DURATION: 30 MIN **MAX MARKS:** 10

Q. No	Questions	Course Outcome (CO)	Knowledge Level as Per Bloom's Taxonomy	Marks
1	**Explain** DH parameters with neat sketch.	3	Evaluating (K5)	5
2	**Assign** the coordinate frames and DH Parameter table for the model of the three degree of freedom (RPP) manipulator as shown in fig  Fig: 1	3	Evaluating (K5)	5
3	**Formulate** the forward kinematic model of the three degree of freedom (RPP) manipulator as shown in fig :1	3	Evaluating (K5)	5
4	**Assign** the coordinate frames and DH Parameter table for model of the three degree of freedom (RRR) manipulator as shown in fig  Fig: 2	3	Evaluating (K5)	5
5	**Formulate** the forward kinematic model of the three degree of freedom (RRR) manipulator as shown in fig: 2	3	Evaluating (K5)	5
6	**Derive** Jacobian Matrix For RR manipulator.	4	Evaluating (K5)	5
7	What do you mean by Jacobian matrix? Write the question of Jacobian Matrix for Rotational joint and Translation joint.	4	Evaluating (K5)	5

NEC NARASARAOPETA ENGINEERING COLLEGE
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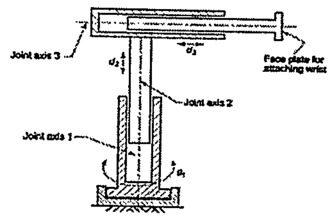
DEPARTMENT OF MECHANICAL ENGINEERING

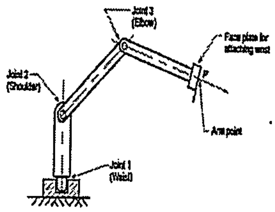
Robotics and Applications Scheme of Evaluation

IV B. TECH II – SEMESTER ASSIGNMENT TEST–III, February– 2023

1. **Explain DH parameters with neat sketch.**
   Diagram --------------------2 M
   Explanation --------------- 3 M
2. **Assign** the coordinate frames and DH Parameter table for the model of the three degree of freedom (RPP) manipulator as shown in fig.
   Coordinate Frame-------2.5 M
   DH Table-----------------2.5 M



3. **Formulate** the forward kinematic model of the three degree of freedom (RPP) manipulator as shown in fig :1
   Formula --------------------2 M
   Derivation----------------- 3 M
4. **Assign** the coordinate frames and DH Parameter table for model of the three degree of freedom (RRR) manipulator as shown in fig Define Robot and **List** the Laws of Robotics.
   Coordinate Frame------2.5 M
   DH Table-----------------2.5 M



5. **Formulate** the forward kinematic model of the three degree of freedom (RRR) manipulator as shown in fig: 2.
   Formulation------------- 2 M
   Derivation----------------2 M
6. **Derive** Jacobian Matrix For RR manipulator.
   Diagram --------------------2 M
   Derivation----------------- 3 M
7. What do you mean by Jacobian matrix? Write the question of Jacobian Matrix for Rotational joint and Translation joint.
   Definition ---------------------- 2 M
   Derivation ----------------------3 M

NARASARAOPETA ENGINEERING COLLEGE (AUTONOMOUS): NARASARAOPET

DEPARTMENT OF MECHANICAL ENGINEERING

IV B.TECH II-SEMESTER I-MID EXAMINATION, January- 2023

Subject: ROBOTICS AND APPLICATIONS Date :27-01-2023

Duration : 90 Min Max Marks: 30M

Answer All Questions

Q. No		Questions	Course Outcome (CO)	Knowledge Level as Per Bloom's Taxonomy	Marks
1	a	**Classify** the robots based on the co-ordinate system with neat diagram.	1	Analyzing (K4)	5
	b	If a point (8i+5j+6k) is translated 4 units along Y-axis and then rotated 30° about X-axis, obtain the co-ordinates after transformation?	1	Evaluating (K5)	5
2	a	**Compare** the electric, hydraulic and pneumatic actuators used in robots.	2	Evaluating (K5)	5
	b	**Explain** the sensors, potentiometers and optical encoders.	2	Evaluating (K5)	5
3	a	**Derive** the kinematics relationship between adjacent links of Robot Arm.	3	Evaluating (K5)	5

NEC NARASARAOPETA ENGINEERING COLLEGE
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DEPARTMENT OF MECHANICAL ENGINEERING

Robotics and Applications Scheme of Evaluation

IV B. TECH II – SEMESTER MID TEST–I, January- 2023

1. **a.Classify** the robots based on the co-ordinate system with neat diagram.
   Diagram --------------------2 M
   Explanation ---------------- 3 M
   b).If a point (8i+5j+6k) is translated 4 units along Y-axis and then rotated 30° about X-axis, obtain the co-ordinates after transformation?
   Formula -------------2 M
   Answers -------------3 M
2. a. **Compare** the electric, hydraulic and pneumatic actuators used in robots..
   Minimum five comparisons -------------5 M
   b.Explain the sensors, potentiometers and optical encoders.
   Diagrams----------2 M
   Explanations------3 M
3. **Derive** the kinematics relationship between adjacent links of Robot Arm.
   Diagram -------------2 M
   Derivation -------------3 M

NARASARAOPET ENGINEERING COLLEGE (AUTONOMOUS): NARASARAOPET
DEPARTMENT OF MECHANICAL ENGINEERING
IV B.TECH II - SEMESTER ASSIGNMENT TEST – II, January– 2023

SUBJECT: ROBOTICS & APPLICATIONS **DATE:** -01-2023
DURATION: 30 MIN **MAX MARKS:** 10

Q. No	Questions	Course Outcome (CO)	Knowledge Level as Per Bloom's Taxonomy	Marks
1	**Sketch** and **Explain** hydraulic drive system used in Robotics.	2	Evaluating (K5)	5
2	**Sketch** and **Explain** Pneumatic drive system used in Robotics.	2	Evaluating (K5)	5
3	**Compare** the electric,.hydraulic and pneumatic actuators used in robots.	2	Evaluating (K5)	5
4	**Explain** the working Principle of DC Motor.	2	Evaluating (K5)	5
5	**Compare** A.C and D.C motor drives used in Robots.	2	Evaluating (K5)	5
6	What are the functions of a sensor? **Explain** the suitable sensors used to measure the position.	2	Evaluating (K5	5
7	**Explain** the sensors, potentiometers and optical encoders.	2	Evaluating (K5)	5
8	**Explain** characteristics of sensors.	2	Evaluating (K5)	5

NARASARAOPETA ENGINEERING COLLEGE
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DEPARTMENT OF MECHANICAL ENGINEERING

Robotics and Applications Scheme of Evaluation

IV B. TECH II – SEMESTER ASSIGNMENT TEST–II, January– 2023

1. **Sketch** and **Explain** hydraulic drive system used in Robotics.
   Diagram --------------------2 M
   Explanation --------------- 3 M
2. **Sketch** and **Explain** Pneumatic drive system used in Robotics.
   Diagram --------------------2 M
   Explanation --------------- 3 M
3. **Compare** the electric, hydraulic and pneumatic actuators used in robots.
   Minimum five comparisons-------------------5 M
4. **Explain** the working Principle of DC Motor.
   Diagram --------------------2 M
   Explanation --------------- 3 M
5. **Compare** A.C and D.C motor drives used in Robots.
   Minimum five comparisons-------------------5 M
6. What are the functions of a sensor? **Explain** the suitable sensors used to measure the position.
   Fuctions --------------------2 M
   Explanation --------------- 3 M
7. **Explain** the sensors, potentiometers and optical encoders.
   Diagram -------------------------- 2 M
   Explanation ---------------------3 M
8. **Explain** characteristics of sensors.
   List -------------2 M
   Explanation ---3 M

NARASARAOPET ENGINEERING COLLEGE (AUTONOMOUS): NARASARAOPET
DEPARTMENT OF MECHANICAL ENGINEERING
IV B.TECH II - SEMESTER ASSIGNMENT TEST – I, December– 2022

SUBJECT: ROBOTICS & APPLICATIONS **DATE:** -12-2022

DURATION: 30 MIN **MAX MARKS:** 10

Q. No	Questions	Course Outcome (CO)	Knowledge Level as Per Bloom's Taxonomy	Marks
1	**Classify** the robots based on the co-ordinate system with neat diagram.	1	Analyzing (K4)	5
2	**List** the advantages and disadvantage of Industrial Robots.	1	Analyzing (K4)	5
3	**Explain** the basic components of Robot with sketch.	1	Evaluating (K5)	5
4	Define Robot and **List** the Laws of Robotics.	1	Analyzing (K4)	5
5	**List** the present and Future applications of Robots.	1	Analyzing (K4)	5
6	**Classify** the robots based on the control system with neat diagram.	1	Analyzing (K4)	5
7	**Explain** the Homogeneous transformation matrix.	1	Evaluating (K5)	5
8	For the point $P_{xyz}=(8,3,6)^T$ perform following operations a). Rotate 60° about the Y-axis followed by translation of 4 units along x-axis? b). Rotate 30° about the Z-axis followed by rotation of 60° about X-axis? **Obtain** new position of point P	1	Evaluating (K5	5
9	Obtain the Homogeneous transformation matrix that represent a rotation of 'α ' degrees about the current X axis followed by a translation ' b' units along the current X axis, followed by a translation ' d ' units along the Z axis , followed by a rotation of ' ө ' degrees about the current Z axis.	1	Evaluating (K5)	5
10	If a point (8i+5j+6k) is translated 4 units along Y-axis and then rotated 30° about X-axis, obtain the co-ordinates after transformation?	1	Evaluating (K5)	5

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DEPARTMENT OF MECHANICAL ENGINEERING

Robotics and Applications Scheme of Evaluation

IV B. TECH II - SEMESTER ASSIGNMENT TEST–I, December– 2022

1. **Classify** the robots based on the co-ordinate system with neat diagram.
   Diagram ---------------------2 M
   Explanation ----------------- 3 M
2. **List** the advantages and disadvantage of Industrial Robots.
   Advantages -----------------3 M
   Disadvantage ---------------- 2 M
3. **Explain** the basic components of Robot with sketch.
   Diagram ---------------------2 M
   Components ----------------- 3 M
4. Define Robot and **List** the Laws of Robotics.
   Definition --------2 M
   Laws --------------3 M
5. **List** the present and Future applications of Robots.
   Present applications------------- 2.5 M
   Future Applications--------------2.5 M
6. **Classify** the robots based on the control system with neat diagram.
   Diagram --------------------2 M
   Explanation ---------------- 3 M
7. **Explain** the Homogeneous transformation matrix.
   Definition --------------------------- 2 M
   Explanation ---------------------------3 M
8. For the point Pxyz =(8,3,6)T perform following operations
   a). Rotate 60° about the Y-axis followed by translation of 4 units along x-axis?
   b). Rotate 30° about the Z-axis followed by rotation of 60° about X-axis? Obtain new position of point P
   Formula -------------2 M
   Answers ------------3 M
9. Obtain the Homogeneous transformation matrix that represent a rotation of 'α ' degrees about the current X axis followed by a translation ' b' units along the current X axis, followed by a translation ' d ' units along the Z axis , followed by a rotation of ' θ ' degrees about the current Z axis.
   Formula -------------2 M
   Answers ------------3 M
10. If a point (8i+5j+6k) is translated 4 units along Y-axis and then rotated 30° about X-axis, obtain the co-ordinates after transformation?
    Formula -------------2 M
    Answers -------------3 M

NARASARAOPETA ENGINEERING COLLEGE (AUTONOMOUS) : : NARASARAOPET

(R19) 2019 BATCH IV B.TECH II SEM I-ASSIGNMENT TEST MARKS - AWARD LIST December -2022

Branch : ME-A Subject: Robotics & Applications Date:29-12-22

SNO.	H.T.NO.	Q.NO.	CO	MARKS	Q.NO.	CO	MARKS	TOTAL MARKS (10M)
1	19471A0301	5	1	5	5	1	2	7
2	19471A0302	1	1	3	10	1	5	8
3	19471A0303	4	1	5	6	1	4	9
4	19471A0304	1	1	4	10	1	5	9
5	19471A0305	7	1	5	8	1	4	9
6	19471A0306	1	1	4	10	1	5	9
7	19471A0307	4	1	4	6	1	4	8
8	19471A0308	4	1	5	6	1	4	9
9	19471A0309	7	1	5	8	1	4	9
10	19471A0311	3	1	3	5	1	5	8
11	19471A0312	1	1	3	10	1	5	8
12	19471A0313	4	1	5	6	1	5	10
13	19471A0315	2	1	5	9	1	4	9
14	19471A0316	7	1	5	8	1	5	10
15	19471A0317							A
16	19471A0318	3	1	5	5	1	5	10
17	19471A0319	2	1	5	9	1	5	10
18	19471A0320	3	1	5	5	1	5	10
19	19471A0321	3	1	3	5	1	5	8
20	19471A0322	2	1	4	9	1	4	8
21	19471A0323	4	1	5	6	1	3	8
22	19471A0326	7	1	5	8	1	5	10
23	19471A0327	3	1	5	5	1	5	10
24	19471A0328	2	1	5	9	1	5	10
25	19471A0329	1	1	5	10	1	4	9
26	19471A0330	2	1	3	9	1	5	8
27	19471A0331	1	1	4	10	1	5	9
28	19471A0333	7	1	5	8	1	5	10

29	19471A0335	4	1	5	6	1	4	9
30	19471A0336	7	1	5	8	1	5	10
31	19471A0337	1	1	3	10	1	4	7
32	19471A0338	4	1	5	6	1	5	10
33	19471A0339	7	1	5	8	1	5	10
34	19471A0340	2	1	5	9	1	5	10
35	19471A0341	2	1	5	9	1	5	10
36	19471A0342	3	1	5	5	1	5	10
37	19471A0343	2	1	3	9	1	5	8
38	19471A0344	7	1	5	8	1	5	10
39	20475A0354	7	1	5	8	1	5	10
40	20475A0355							A
41	20475A0356	3	1	5	5	1	5	10
42	20475A0357	3	1	5	5	1	5	10
43	20475A0358	1	1	4	10	1	5	9
44	20475A0359	4	1	5	6	1	4	9
45	20475A0360	1	1	4	10	1	5	9
46	20475A0361	2	1	5	9	1	5	10
47	20475A0362							A
48	20475A0363	7	1	5	8	1	5	10
49	20475A0364							A
50	20475A0365							A
51	20475A0366	7	1	5	8	1	5	10

Name of the Staff Member CH.S.SEKHAR

Signature of the Staff Member

Signature of the HOD

NARASARAOPETA ENGINEERING COLLEGE (AUTONOMOUS) : : NARASARAOPET

(R19) 2019 BATCH IV B.TECH II SEM II-ASSIGNMENT TEST MARKS - AWARD LIST -2022

Branch : ME-A Subject: Robotics & Applications Date: 18-01-2023

SNO.	H.T.NO.	Q.NO.	CO	MARKS	Q.NO.	CO	MARKS	TOTAL MARKS (10M)
1	19471A0301	7	2	3	8	2	4	7
2	19471A0302	3	2	4	7	2	4	8
3	19471A0303							AB
4	19471A0304	7	2	4	8	2	5	9
5	19471A0305	1	2	5	2	2	5	10
6	19471A0306							AB
7	19471A0307	7	2	4	8	2	5	9
8	19471A0308	5	2	5	6	2	5	10
9	19471A0309	7	2	5	8	2	5	10
10	19471A0311							AB
11	19471A0312	3	2	5	7	2	4	9
12	19471A0313	3	2	5	4	2	4	9
13	19471A0315	3	2	5	4	2	4	9
14	19471A0316							AB
15	19471A0317							AB
16	19471A0318	7	2	4	8	2	5	9
17	19471A0319	1	2	4	2	2	4	8
18	19471A0320	5	2	5	6	2	5	10
19	19471A0321	7	2	4	8	2	5	9
20	19471A0322							AB
21	19471A0323							AB
22	19471A0326	7	2	4	8	2	5	9
23	19471A0327	3	2	5	7	2	5	10
24	19471A0328	5	2	5	6	2	3	8
25	19471A0329	3	2	5	4	2	5	10
26	19471A0330							AB
27	19471A0331	5	2	5	6	2	4	9
28	19471A0333	1	2	4	2	2	4	8

29	19471A0335							AB
30	19471A0336	3	2	5	7	2	5	10
31	19471A0337	3	2	5	4	2	4	9
32	19471A0338	7	2	5	8	2	5	10
33	19471A0339	1	2	5	2	2	4	9
34	19471A0340	3	2	5	7	2	4	9
35	19471A0341	5	2	5	6	2	4	9
36	19471A0342	3	2	5	4	2	4	9
37	19471A0343	3	2	5	7	2	4	9
38	19471A0344	5	2	5	6	2	4	9
39	20475A0354							AB
40	20475A0355							AB
41	20475A0356	3	2	4	4	2	5	9
42	20475A0357							AB
43	20475A0358	1	2	5	2	2	4	9
44	20475A0359	1	2	4	2	2	5	9
45	20475A0360							AB
46	20475A0361							AB
47	20475A0362							AB
48	20475A0363							AB
49	20475A0364							AB
50	20475A0365	3	2	5	7	2	4	9
51	20475A0366							AB

Name of the Staff Member

Signature of the Staff Member

Signature of the HOD

NARASARAOPETA ENGINEERING COLLEGE (AUTONOMOUS) : : NARASARAOPET

(R19) 2019 BATCH IV B.TECH II SEM I MID & QUIZ MARKS - AWARD LIST January -2023

Branch : ME-A Subject: Robotics and applications Date:27-01-2023

Sl. No.	H.T.NO.	CO No.	1	1	2	2	3	Total Marks (25M)	Reduced To (20M)	Quiz (10M)
		Max.Marks	5	5	5	5	5			
		Q.No.	1 (a)	1 (b)	2 (a)	2(b)	3			
1	19471A0301			5	5		5	15	12	10
2	19471A0302		1	5	5	3	4	18	15	3
3	19471A0303			5	5	3	5	18	15	10
4	19471A0304			5	5	3	5	18	15	3
5	19471A0305		5	5	5	3	5	23	19	10
6	19471A0306			5	5	3	3	16	13	7
7	19471A0307			5	5	3	5	18	15	10
8	19471A0308		4	5	5	4	5	23	19	10
9	19471A0309		4	5	4	3	4	20	16	7
10	19471A0311		4	5	5	3	5	22	18	10
11	19471A0312		4	5	5	4	5	23	19	10
12	19471A0313		2	5	5	4	5	21	17	10
13	19471A0315			5	4	3	4	16	13	9
14	19471A0316		5	5	5	3	4	22	18	10
15	19471A0317			5	5		5	15	12	2
16	19471A0318		3	5	5	4	5	22	18	9
17	19471A0319		4	4	5	3	4	20	16	9
18	19471A0320		1	5	5	5	5	21	17	10
19	19471A0321			5	5	3	5	18	15	10
20	19471A0322			5	5	4	5	19	16	9
21	19471A0323							A	A	A
22	19471A0326		5	5	5	4	5	24	20	A
23	19471A0327		4	5	5	2	5	21	17	9
24	19471A0328		4	5	4	5	4	22	18	10
25	19471A0329		3	5	5	4	5	22	18	10
26	19471A0330		4	5	5	4	4	22	18	7
27	19471A0331		5	5	5	3	5	23	19	8
28	19471A0333		5	5	5	3	5	23	19	10
29	19471A0335			5	5			10	8	10
30	19471A0336		0	5	5	4	0	14	12	3

31	19471A0337		0	1	1.5	1.5	0	4	4	6
32	19471A0338		1	5	5	5	4	20	16	10
33	19471A0339		0	5		4	5	14	12	9
34	19471A0340		4	5	5	4	4	22	18	10
35	19471A0341			5	4	4		13	11	3
36	19471A0342			3	5		1	9	8	9
37	19471A0343		0	5	5	5	5	20	16	10
38	19471A0344		4	4	2	4	3	17	14	7
39	20475A0354		3	5	1		2	11	9	10
40	20475A0355		1	5	5			11	9	10
41	20475A0356		2	5	5	3	1	16	13	10
42	20475A0357			5	5		4	14	12	10
43	20475A0358		1	5	5		5	16	13	10
44	20475A0359		2		5	2		9	8	10
45	20475A0360		1		5	5	5	16	13	9
46	20475A0361		1	5	5	3	2	16	13	10
47	20475A0362			5	4		4	13	11	10
48	20475A0363			5	5	3	4.5	18	15	10
49	20475A0364		5	5	5	5	3	23	19	9
50	20475A0365		5	5	5	4		19	16	9
51	20475A0366			5	5	2		12	10	10

Name of the Staff Member CH. SEKHAR

Signature of the Staff Member

Signature of the HOD

NARASARAOPETA ENGINEERING COLLEGE (AUTONOMOUS) : : NARASARAOPET

(R19) 2019 BATCH IV B.TECH II SEM III-ASSIGNMENT TEST MARKS - AWARD LIST FEB -2022

Branch : ME-A Subject: Robotics & Applications Date: 16-02-2023

SNO.	H.T.NO.	Q.NO.	CO	MARKS	Q.NO.	CO	MARKS	TOTAL MARKS (10M)
1	19471A0301	1	3	4	6	4	3	7
2	19471A0302	6	4	5	7	4	0	5
3	19471A0303	2	3	5	3	3	4	9
4	19471A0304	6	4	5	7	4		5
5	19471A0305	2	3	5	3	3	5	10
6	19471A0306	4	3	5	5	3	4	9
7	19471A0307	1	3	3	6	4	5	8
8	19471A0308	4	3	3	5	3	1	4
9	19471A0309	1	3	1	6	4	5	6
10	19471A0311	6	4	5	7	4		5
11	19471A0312	1	3	4	6	4	5	9
12	19471A0313	6	4	5	7	4	2	7
13	19471A0315	2	3	4	3	3	5	9
14	19471A0316	2	3	4	3	3	5	9
15	19471A0317							AB
16	19471A0318	1	3	3	6	4	5	8
17	19471A0319	1	3	1	6	4	5	6
18	19471A0320	1	3	4	6	4	5	9
19	19471A0321	4	3	3	5	3	1	4
20	19471A0322	2	3	5	3	3	4	9
21	19471A0323	1	3		6	4	5	5
22	19471A0326	2	3	5	3	3	5	10
23	19471A0327	6	4	5	7	4	3	8
24	19471A0328							AB
25	19471A0329	6	4	5	7	4	3	8
26	19471A0330	1	3		6	4	5	5
27	19471A0331	4	3	3	5	3	1	4
28	19471A0333	2	3	5	3	3	5	10

29	19471A0335	2	3	4	3	3	5	9
30	19471A0336	2	3	4	3	3	5	9
31	19471A0337	4	3	3	5	3	1	4
32	19471A0338	1	3	2	6	4	5	7
33	19471A0339	1	3	2	6	4	5	7
34	19471A0340	4	3	5	5	3	5	10
35	19471A0341	1	3	1	6	4	5	6
36	19471A0342	1	3	1	6	4	5	6
37	19471A0343	1	3	1	6	4	5	6
38	19471A0344	1	3	1	6	4	5	6
39	20475A0354	2	3	5	3	3	4	9
40	20475A0355	6	4	5	7	4	3	8
41	20475A0356	2	3	4	3	3	4	8
42	20475A0357	6	4	5	7	4	3	8
43	20475A0358	6	4	5	7	4	5	10
44	20475A0359	6	4	5	7	4	3	8
45	20475A0360	4	3	5	5	3	4	9
46	20475A0361	1	3	3	6	4	5	8
47	20475A0362	4	3	4	5	3	5	9
48	20475A0363	4	3	5	5	3	4	9
49	20475A0364	6	4	5	7	4	4	9
50	20475A0365	2	3	4	3	3	5	9
51	20475A0366	1	3	3	6	4	5	8

Name of the Staff Member CH. SEKHAR

Signature of the Staff Member

Signature of the HOD

NARASARAOPETA ENGINEERING COLLEGE (AUTONOMOUS) : : NARASARAOPET

(R19) 2019 BATCH IV B.TECH II SEM IV-ASSIGNMENT TEST MARKS - AWARD LIST March -2022

Branch : ME-A Subject: Robotics & Applications Date: 10-03-2023

SNO.	H.T.NO.	Q.NO.	CO	MARKS	Q.NO.	CO	MARKS	TOTAL MARKS (10M)
1	19471A0301	4	4	3	5	5	5	8
2	19471A0302	3	4	4	5	5	4	8
3	19471A0303	8	5	4	9	5	4	8
4	19471A0304	1	4	5	2	4	2	7
5	19471A0305	6	5	4	7	5	4	8
6	19471A0306							AB
7	19471A0307	6	5	5	7	5	4	9
8	19471A0308	4	4	5	5	5	5	10
9	19471A0309							AB
10	19471A0311	6	5	4	7	5	3	7
11	19471A0312	1	4	0	2	4	4	4
12	19471A0313	1	4	5	2	4	5	10
13	19471A0315	1	4	0	2	4	0	0
14	19471A0316	8	5	5	9	5	5	10
15	19471A0317	8	5	4	9	5	4	8
16	19471A0318	3	4	5	5	5	5	10
17	19471A0319	3	4	1	5	5	0	1
18	19471A0320	3	4	5	5	5	5	10
19	19471A0321	4	4	4	5	5	5	9
20	19471A0322							AB
21	19471A0323							AB
22	19471A0326	6	5	4	7	5	4	8
23	19471A0327							AB
24	19471A0328	3	4	4	5	5	5	9
25	19471A0329	4	4	4	5	5	5	9
26	19471A0330	8	5	2	9	5	4	6
27	19471A0331	4	4	5	5	5	1	6
28	19471A0333	6	5	4	7	5	4	8

29	19471A0335							AB
30	19471A0336	3	4	2	5	5	5	7
31	19471A0337	8	5	4	9	5	4	8
32	19471A0338	8	5	4	9	5	4	8
33	19471A0339	8	5	4	9	5	5	9
34	19471A0340	6	5	4	7	5	4	8
35	19471A0341	3	4	4	5	5	4	8
36	19471A0342	8	5	4	9	5	4	8
37	19471A0343	1	4	4	2	4	5	9
38	19471A0344	1	4	5	2	4	2	7
39	20475A0354	6	5	4	7	5	4	8
40	20475A0355	3	4	5	5	5	5	10
41	20475A0356	3	4	4	5	5	5	9
42	20475A0357							AB
43	20475A0358	6	5	3	7	5	4	7
44	20475A0359	6	5	4	7	5	4	8
45	20475A0360							AB
46	20475A0361							AB
47	20475A0362							AB
48	20475A0363							AB
49	20475A0364							AB
50	20475A0365							AB
51	20475A0366	1	4	3	2	4	4	7

Name of the Staff Member

Signature of the Staff Member

Signature of the HOD

NARASARAOPETA ENGINEERING COLLEGE (AUTONOMOUS) : : NARASARAOPET

(R19) 2019 BATCH IV B.TECH II SEM II MID & QUIZ MARKS - AWARD LIST April -2023

Branch : ME-A Subject: Robotics and applications Date:05-04-2023

Sl. No.	H.T.NO.	CO No.	3	4	4	5	5	Total Marks (25M)	Reduced To (20M)	Quiz (10M)
		Max.Marks	5	5	5	5	5			
		Q.No.	1	2 (a)	2(b)	3(a)	3(b)			
1	19471A0301		5		5	5		15	12	10
2	19471A0302		4	4	5	4		17	14	7
3	19471A0303		4	4	5			13	11	9
4	19471A0304		5	4	3			12	10	9
5	19471A0305		5	3	4	5	5	22	18	10
6	19471A0306		4	3	4	3		14	12	9
7	19471A0307		4	4	4	4		16	13	9
8	19471A0308		4	4	4	5	3	20	16	9
9	19471A0309		4	4	4			12	10	10
10	19471A0311		4	4	4	4		16	13	8
11	19471A0312		5	4	4	5	4	22	18	10
12	19471A0313		5	5	4	4	4	22	18	10
13	19471A0315		4	5	4	4	4	21	17	10
14	19471A0316		5	5	4	5	4	23	19	10
15	19471A0317				2			2	2	9
16	19471A0318		4	4	4			12	10	10
17	19471A0319		4	3	3	2	2	14	12	10
18	19471A0320		5	4	5	5	4	23	19	10
19	19471A0321		4	4	4			12	10	9
20	19471A0322							AB	AB	AB
21	19471A0323		4	3	4	2	2	15	12	7
22	19471A0326		5	5	4	0	2	16	13	10
23	19471A0327		4	4	4	5	2	19	16	9
24	19471A0328		4	4	4	4	1	17	14	9
25	19471A0329		4	4	4	4	3	19	16	9
26	19471A0330		3	3	4			10	8	5
27	19471A0331		4	4	4	0		12	10	9
28	19471A0333		5	4	5	5	3	22	18	10
29	19471A0335							AB	AB	AB
30	19471A0336		5	5	4	4	4	22	18	10

31	19471A0337		4	3	3	2	2	14	12	10
32	19471A0338		4	4	4	1	1	14	12	9
33	19471A0339		4	3	4	2	2	15	12	10
34	19471A0340		4	4	4	2	3	17	14	9
35	19471A0341		4		3	0	3	10	8	10
36	19471A0342		3		4		3	10	8	10
37	19471A0343		4	4	3	1	3	15	12	8
38	19471A0344		4	4	4		3	15	12	10
39	20475A0354		4	4	4	4	2	18	15	3
40	20475A0355		4	4	4	5	2	19	16	10
41	20475A0356		4	4	5	4	5	22	18	10
42	20475A0357		5	4	5	4	3	21	17	0
43	20475A0358		4	4	4	5	3	20	16	10
44	20475A0359		4	4	4	3	3	18	15	9
45	20475A0360		4	4	4	4	2	18	15	5
46	20475A0361		4	3	5	4	4	20	16	10
47	20475A0362		3	4	4	3	3	17	14	9
48	20475A0363		5	5	5	3		18	15	4
49	20475A0364		4	1	5	4	3	17	14	10
50	20475A0365		4	4	4	4	2	18	15	1
51	20475A0366		4	4	4	3	2	17	14	10

Name of the Staff Member CH.J.SEKHAR

Signature of the Staff Member

Signature of the HOD

NARASARAOPETA ENGINEERING COLLEGE (AUTONOMOUS) : : NARASARAOPET

(R19) 2019 BATCH IV B.TECH II SEM IV-ASSIGNMENT TEST MARKS - AWARD LIST March -2022

Branch : ME-A Subject: Robotics & Applications Date: 10-03-2023

SNO.	H.T.NO.	Q.NO.	CO	MARKS	Q.NO.	CO	MARKS	TOTAL MARKS (10M)
1	19471A0301	4	4	3	5	5	5	8
2	19471A0302	3	4	4	5	5	4	8
3	19471A0303	8	5	4	9	5	4	8
4	19471A0304	1	4	5	2	4	2	7
5	19471A0305	6	5	4	7	5	4	8
6	19471A0306							AB
7	19471A0307	6	5	5	7	5	4	9
8	19471A0308	4	4	5	5	5	5	10
9	19471A0309							AB
10	19471A0311	6	5	4	7	5	3	7
11	19471A0312	1	4	0	2	4	4	4
12	19471A0313	1	4	5	2	4	5	10
13	19471A0315							AB
14	19471A0316							AB
15	19471A0317	8	5	4	9	5	4	8
16	19471A0318	3	4	5	5	5	5	10
17	19471A0319	3	4	1	5	5	0	1
18	19471A0320	3	4	5	5	5	5	10
19	19471A0321	4	4	4	5	5	5	9
20	19471A0322							AB
21	19471A0323							AB
22	19471A0326	6	5	4	7	5	4	8
23	19471A0327							AB
24	19471A0328	3	4	4	5	5	5	9
25	19471A0329	4	4	4	5	5	5	9
26	19471A0330	8	5	2	9	5	4	6
27	19471A0331	4	4	5	5	5	1	6
28	19471A0333	6	5	4	7	5	4	8

29	19471A0335							AB
30	19471A0336							AB
31	19471A0337	8	5	4	9	5	4	8
32	19471A0338	8	5	4	9	5	4	8
33	19471A0339	8	5	4	9	5	5	9
34	19471A0340	6	5	4	7	5	4	8
35	19471A0341	3	4	4	5	5	4	8
36	19471A0342	8	5	4	9	5	4	8
37	19471A0343	1	4	4	2	4	5	9
38	19471A0344	1	4	5	2	4	2	7
39	20475A0354	6	5	4	7	5	4	8
40	20475A0355	3	4	5	5	5	5	10
41	20475A0356	3	4	4	5	5	5	9
42	20475A0357							AB
43	20475A0358	6	5	3	7	5	4	7
44	20475A0359	6	5	4	7	5	4	8
45	20475A0360							AB
46	20475A0361							AB
47	20475A0362							AB
48	20475A0363							AB
49	20475A0364							AB
50	20475A0365							AB
51	20475A0366	1	4	3	2	4	4	7

Name of the Staff Member CH.SEKHAR

Signature of the Staff Member ch.k

Signature of the HOD

NARASARAOPETA ENGINEERING COLLEGE (AUTONOMOUS) : : NARASARAOPET

(R19) 2019 BATCH IV B.TECH II SEM I-ASSIGNMENT TEST MARKS - AWARD LIST December -2022

Branch : ME-A Subject: Robotics & Applications Date:29-12-22

SNO.	H.T.NO.	Q.NO.	CO	MARKS	Q.NO.	CO	MARKS	TOTAL MARKS (10M)
1	19471A0301	5	1	5	5	1	2	7
2	19471A0302	1	1	3	10	1	5	8
3	19471A0303	4	1	5	6	1	4	9
4	19471A0304	1	1	4	10	1	5	9
5	19471A0305	7	1	5	8	1	4	9
6	19471A0306	1	1	4	10	1	5	9
7	19471A0307	4	1	4	6	1	4	8
8	19471A0308	4	1	5	6	1	4	9
9	19471A0309	7	1	5	8	1	4	9
10	19471A0311	3	1	3	5	1	5	8
11	19471A0312	1	1	3	10	1	5	8
12	19471A0313	4	1	5	6	1	5	10
13	19471A0315	2	1	5	9	1	4	9
14	19471A0316	7	1	5	8	1	5	10
15	19471A0317							A
16	19471A0318	3	1	5	5	1	5	10
17	19471A0319	2	1	5	9	1	5	10
18	19471A0320	3	1	5	5	1	5	10
19	19471A0321	3	1	3	5	1	5	8
20	19471A0322	2	1	4	9	1	4	8
21	19471A0323	4	1	5	6	1	3	8
22	19471A0326	7	1	5	8	1	5	10
23	19471A0327	3	1	5	5	1	5	10
24	19471A0328	2	1	5	9	1	5	10
25	19471A0329	1	1	5	10	1	4	9
26	19471A0330	2	1	3	9	1	5	8
27	19471A0331	1	1	4	10	1	5	9
28	19471A0333	7	1	5	8	1	5	10

29	19471A0335	4	1	5	6	1	4	9
30	19471A0336	7	1	5	8	1	5	10
31	19471A0337	1	1	3	10	1	4	7
32	19471A0338	4	1	5	6	1	5	10
33	19471A0339	7	1	5	8	1	5	10
34	19471A0340	2	1	5	9	1	5	10
35	19471A0341	2	1	5	9	1	5	10
36	19471A0342	3	1	5	5	1	5	10
37	19471A0343	2	1	3	9	1	5	8
38	19471A0344	7	1	5	8	1	5	10
39	20475A0354	7	1	5	8	1	5	10
40	20475A0355							10
41	20475A0356	3	1	5	5	1	5	A
42	20475A0357	3	1	5	5	1	5	10
43	20475A0358	1	1	4	10	1	5	10
44	20475A0359	4	1	5	6	1	5	9
45	20475A0360	1	1	4	10	1	4	9
46	20475A0361	2	1	5	9	1	5	9
47	20475A0362							10
48	20475A0363	7	1	5	8	1	5	A
49	20475A0364							10
50	20475A0365							A
51	20475A0366	7	1	5	8	1	5	A

Name of the Staff Member CH.SEKHAR

Signature of the Staff Member ch.k

Signature of the HOD

NARASARAOPETA ENGINEERING COLLEGE (AUTONOMOUS) : : NARASARAOPET

(R19) 2019 BATCH IV B.TECH II SEM II-ASSIGNMENT TEST MARKS - AWARD LIST -2022

Branch : ME-A Subject: Robotics & Applications Date: 18-01-2023

SNO.	H.T.NO.	Q.NO.	CO	MARKS	Q.NO.	CO	MARKS	TOTAL MARKS (10M)
1	19471A0301	7	2	3	8	2	4	7
2	19471A0302	3	2	4	7	2	4	8
3	19471A0303							AB
4	19471A0304	7	2	4	8	2	5	9
5	19471A0305	1	2	5	2	2	5	10
6	19471A0306							AB
7	19471A0307	7	2	4	8	2	5	9
8	19471A0308	5	2	5	6	2	5	10
9	19471A0309	7	2	5	8	2	5	10
10	19471A0311							AB
11	19471A0312	3	2	5	7	2	4	9
12	19471A0313	3	2	5	4	2	4	9
13	19471A0315	3	2	5	4	2	4	9
14	19471A0316							AB
15	19471A0317							AB
16	19471A0318	7	2	4	8	2	5	9
17	19471A0319	1	2	4	2	2	4	8
18	19471A0320	5	2	5	6	2	5	10
19	19471A0321	7	2	4	8	2	5	9
20	19471A0322							AB
21	19471A0323							AB
22	19471A0326	7	2	4	8	2	5	9
23	19471A0327	3	2	5	7	2	5	10
24	19471A0328	5	2	5	6	2	3	8
25	19471A0329	3	2	5	4	2	5	10
26	19471A0330							AB
27	19471A0331	5	2	5	6	2	4	9
28	19471A0333	1	2	4	2	2	4	8

29	19471A0335							AB
30	19471A0336	3	2	5	7	2	5	10
31	19471A0337	3	2	5	4	2	4	9
32	19471A0338	7	2	5	8	2	5	10
33	19471A0339	1	2	5	2	2	4	9
34	19471A0340	3	2	5	7	2	4	9
35	19471A0341	5	2	5	6	2	4	9
36	19471A0342	3	2	5	4	2	4	9
37	19471A0343	3	2	5	7	2	4	9
38	19471A0344	5	2	5	6	2	4	9
39	20475A0354							AB
40	20475A0355							AB
41	20475A0356	3	2	4	4	2	5	9
42	20475A0357							AB
43	20475A0358	1	2	5	2	2	4	9
44	20475A0359	1	2	4	2	2	5	9
45	20475A0360							AB
46	20475A0361							AB
47	20475A0362							AB
48	20475A0363							AB
49	20475A0364							AB
50	20475A0365	3	2	5	7	2	4	9
51	20475A0366							AB

Name of the Staff Member CH.SEKHAR

Signature of the Staff Member

Signature of the HOD

NARASARAOPETA ENGINEERING COLLEGE (AUTONOMOUS) : : NARASARAOPET

(R19) 2019 BATCH IV B.TECH II SEM II MID & QUIZ MARKS - AWARD LIST April -2023

Branch : ME-A Subject: Robotics and applications Date:05-04-2023

Sl. No.	H.T.NO.	CO No.	3	4	4	5	5	Total Marks (25M)	Reduced To (20M)	Quiz (10M)
		Max.Marks	5	5	5	5	5			
		Q.No.	1	2 (a)	2(b)	3(a)	3(b)			
1	19471A0301		5		5	5		15	12	10
2	19471A0302		4	4	5	4		17	14	7
3	19471A0303		4	4	5			13	11	9
4	19471A0304		5	4	3			12	10	9
5	19471A0305		5	3	4	5	5	22	18	10
6	19471A0306		4	3	4	3		14	12	9
7	19471A0307		4	4	4	4		16	13	9
8	19471A0308		4	4	4	5	3	20	16	9
9	19471A0309		4	4	4			12	10	10
10	19471A0311		4	4	4	4		16	13	8
11	19471A0312		5	4	4	5	4	22	18	10
12	19471A0313		5	5	4	4	4	22	18	10
13	19471A0315							AB	AB	AB
14	19471A0316							AB	AB	AB
15	19471A0317				2			2	2	9
16	19471A0318		4	4	4			12	10	10
17	19471A0319		4	3	3	2	2	14	12	10
18	19471A0320		5	4	5	5	4	23	19	10
19	19471A0321		4	4	4			12	10	9
20	19471A0322							AB	AB	AB
21	19471A0323		4	3	4	2	2	15	12	7
22	19471A0326		5	5	4	0	2	16	13	10
23	19471A0327		4	4	4	5	2	19	16	9
24	19471A0328		4	4	4	4	1	17	14	9
25	19471A0329		4	4	4	4	3	19	16	9
26	19471A0330		3	3	4			10	8	5
27	19471A0331		4	4	4	0		12	10	9
28	19471A0333		5	4	5	5	3	22	18	10
29	19471A0335							AB	AB	AB
30	19471A0336							AB	AB	AB
31	19471A0337		4	3	3	2	2	14	12	10
32	19471A0338		4	4	4	1	1	14	12	9
33	19471A0339		4	3	4	2	2	15	12	10

34	19471A0340		4	4	4	2	3	17	14	9
35	19471A0341		4		3	0	3	10	8	10
36	19471A0342		3		4		3	10	8	10
37	19471A0343		4	4	3	1	3	15	12	8
38	19471A0344		4	4	4		3	15	12	10
39	20475A0354		4	4	4	4	2	18	15	3
40	20475A0355		4	4	4	5	2	19	16	10
41	20475A0356		4	4	5	4	5	22	18	10
42	20475A0357		5	4	5	4	3	21	17	0
43	20475A0358		4	4	4	5	3	20	16	10
44	20475A0359		4	4	4	3	3	18	15	9
45	20475A0360		4	4	4	4	2	18	15	5
46	20475A0361		4	3	5	4	4	20	16	10
47	20475A0362		3	4	4	3	3	17	14	9
48	20475A0363		5	5	5	3		18	15	4
49	20475A0364		4	1	5	4	3	17	14	10
50	20475A0365		4	4	4	4	2	18	15	1
51	20475A0366		4	4	4	3	2	17	14	10

Name of the Staff Member CH. SEKHAR

Signature of the Staff Member

Signature of the HOD

NEC NARASARAOPETA ENGINEERING COLLEGE
(AUTONOMOUS)

DEPARTMENT OF MECHANICAL ENGINEERING

UNIT WISE IMPORTANT QUESTIONS

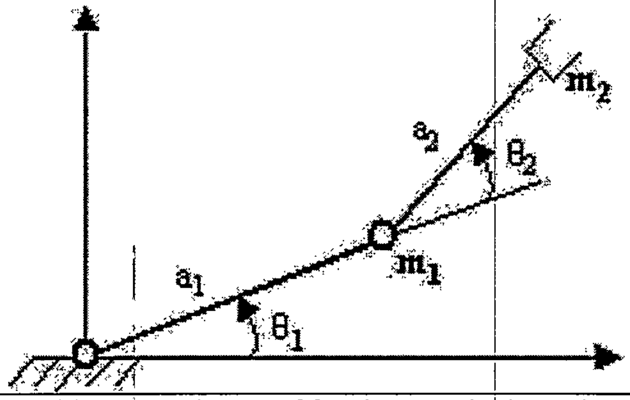
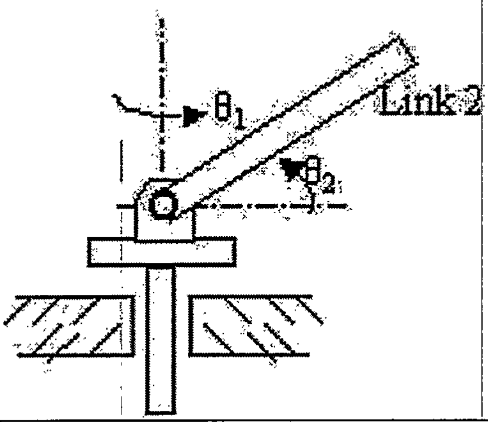
NEC NARASARAOPETA ENGINEERING COLLEGE
(AUTONOMOUS)

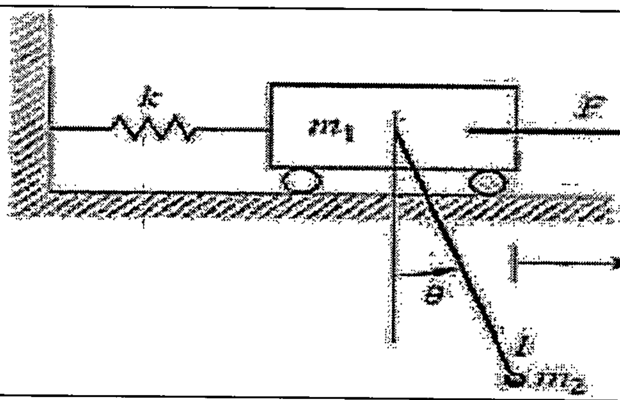
DEPARTMENT OF MECHANICAL ENGINEERING

ROBOTICS AND APPLICATIONS

UNIT WISE SAMPLE QUESTIONS

S NO	QUESTION	KNOWLEDGE LEVEL	CO
	UNIT I		
1	**Discuss** the anatomy of Robot and **explain** the important parts of a robot with a neat sketch.	Evaluate (K5)	CO1
2	**Name** and **Explain** the four basic arm configurations that are used in robotic Manipulators.	Evaluate (K5)	CO1
3	**Explain** two views by **making use of sketch** to indicate the work envelope of a i) Cartesian robot. ii) Polar robot.	Evaluate (K5))	CO1
4	**Explain** the relationship of robotics with industrial automation and **illustrate** the same with a suitable example.	Evaluate (K5)	CO1
5	For the point Pxyz $=(8,3,6)^T$ perform following operations a). Rotate 60° about the Y-axis followed by translation of 4 units along x-axis? b). Rotate 30° about the Z-axis followed by rotation of 60° about X-axis? c). Translate 10 units along Z-axis followed by rotation of 45° along Z-axis?	Applying (K3)	CO1
	UNIT 2		
1	**Sketch** and **explain** a hydraulic drive system used for robots.	Applyi ng (K3)	CO2
2	**Illustrate** different types of actuators used for robots?	Applying (K3)	CO2
3	**What** are the functions of sensors? **How** do you sense the positional accuracy of a robot? **Describe** the suitable type of sensor used to measure the position.	Applying (K3)	CO2
4	**Explain** in detail about safety sensors and safety Monitoring.	Evaluate (K5)	CO2
	UNIT 3		
1	**Compute** the homogeneous transformation representing a translation of 3 units along the x-axis and followed by rotation of 90° about the current z-axis followed by a translation of 1 unit along the fixed y-axis.	Applying (K3)	CO3
2	**Explain** and **derive** inverse kinematic solution for the variables of a cylindrical robot.	Evaluate (K5)	CO3

3	**Derive** the forward kinematics matrix for an articulated robot arm (3-axis) using DH convention?	Applying (K3)	**CO3**
4	**Explain** the homogeneous transformation as applicable to rotation?	Evaluate (K5)	**CO3**
	UNIT 4		
1	**Determine** the dynamic equations for the two-link manipulator shown in Figure 1, using Lagrange-Euler formulation. Assume that the whole mass of the link can be considered as a point mass located at the outermost end of each link. The masses are m1 and m2 and the link lengths are a1 and a2.  	Applying (K3)	**CO4**
2	Consider a two-degree of freedom manipulator shown in Figure 1. Assuming that the inertia of the first moving link is negligible and that the second moving link is a slender homogeneous rod of mass m, **determine** the dynamic equations of motion by the Lagrangian method using θ1 and θ2 as the generalized coordinates.  	Applying (K3)	**CO4**
3	Using Lagrangian mechanics, **Derive** the equations of motion for the two-degreeof-freedom system shown in figure 1.	Evaluate (K5)	**CO4**

			
4	**Explain** the steps involved in the formulation of Lagrange-Euler dynamic model.	Evaluate (K5)	**CO4**
	UNIT 5		
1	**Sketch** and **explain** a hydraulic drive system used for robots.	Evaluate (K5)	**CO5**
2	**Illustrate** different types of actuators used for robots?	Applying (K3)	**CO5**
3	**What** are the functions of sensors? **How** do you sense the positional accuracy of a robot? **Describe** the suitable type of sensor used to measure the position.	Applying (K3)	**CO5**
4	**Explain** in detail about safety sensors and safety Monitoring.	Evaluate (K5)	**CO5**

NARASARAOPETA
NEC ENGINEERING COLLEGE
(AUTONOMOUS)
DEPARTMENT OF MECHANICAL ENGINEERING

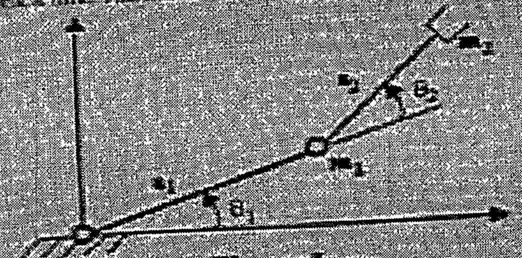
PREVIOUS QUESTION PAPERS

NEC NARASARAOPETA ENGINEERING COLLEGE
(AUTONOMOUS)

IV B.Tech II Semester Regular Examinations, April-2023
ROBOTICS AND APPLICATIONS
(ME)

Sub Code: 19BME8PE[illegible] Max. Marks: 60
Time: 3 Hours

Note: Answer All FIVE Questions
All Questions Carry Equal Marks (5 X 12 = 60M)

Q.No		Questions	KL	CO	M
		Unit-I			
1	a	Sketch and explain the four basic robot configurations classified according to the coordinate system.	K2	CO1	12M
		OR			
	b	Determine the transformation matrix T that represents a translation of 'a' units along x-axis, followed by a rotation of β about x-axis and followed by a rotation of θ about z-axis.	K3	CO1	12M
		Unit-II			
2	a	i) What are the uses of sensor in robotics? Explain the types of sensors used in robotics?	K4	CO2	6M
		ii) Distinguish between Internal and external sensors with applications.	K4	CO2	6M
		OR			
	b	Discuss the performance characteristics of actuators. Compare electrical, pneumatic & hydraulic actuators for their characteristics.	K3	CO2	12M
		Unit-III			
3	a	Determine the manipulator jacobian matrix and singularities for the 3-DOF articulated arm.	K4	CO3	12M
		OR			
	b	Derive the Inverse kinematics of the 3-DOF manipulator by considering an example.	K4	CO3	12M
		Unit-IV			
4	a	Determine the dynamic equations for the two-link manipulator shown in Figure 1, using Lagrange-Euler formulation. Assume that the whole mass of the link can be considered as a point mass located at the outermost end of the link. The masses are m1 and m2 and the link lengths are a_1 and a_2 each link.  Figure1	K4	CO4	12M
		OR			
	b	Explain about Newton – Euler formulations by considering an example.	K4	CO4	12M
		Unit-V			
5	a	i) Explain the applications of [illegible]	K4	CO5	6M
		ii) What are general [illegible]?	K4	CO5	6M
		OR			
	b	i) [illegible]	K4	CO5	6M
		ii) Explain the use of robot in [illegible]	K4	CO5	6M

KL: Knowledge Level CO: Course Outcome M: Marks

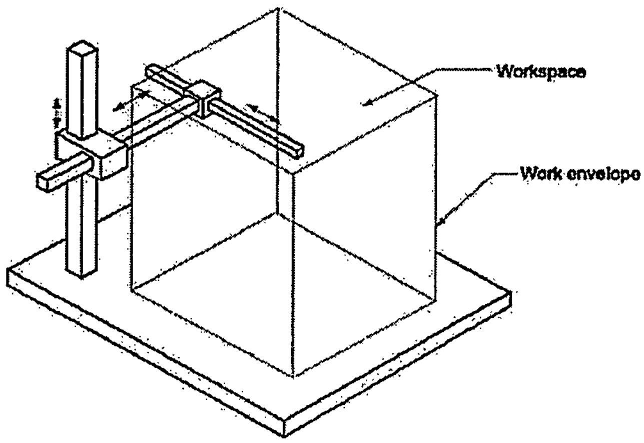
1.(a) **THE FOUR BASIC CONFIGURATIONS ARE:**
(i) Cartesian (rectangular) configuration - all three P joints.
(ii) Cylindrical configuration – one) - and two P joints.
(iii) Polar (spherical) configuration - two R and one P joint
(iv) Articulated (Revolute or Jointed-arm) Configuration - all three R joints.

Each of these arm configurations is now discussed briefly.

(i) Cartesian (Rectangular) Configuration:

This is the simplest configuration with all three prismatic joints, as shown in Fig. It is constructed by three perpendicular slides, giving only linear motions along the three principal axes. There is an upper and lower limit for movement of each link. Consequently, the endpoint of the arm is capable of operating in a cuboidal space, called workspace.

The workspace represents the portion of space around the base of the manipulator that can be accessed by the arm endpoint. The shape and size of the workspace depends on the arm configuration, structure, degrees of freedom, size of links, and design of joints. The physical space that can be swept by a manipulator (with wrist and end-effector) may be more or less than the arm endpoint workspace. The volume of the space swept is called work volume; the surface of the workspace describes the work envelope.



A 3-DOF Cartesian arm configuration and its workspace

The workspace of Cartesian configuration is cuboidal and is shown in Fig.

Rectangular coordinates robots have following advantages:

- They can obtain large envelopes because travelling along the x, axis the volume region can be increased easily.
- Their linear movement allows for simple controls.
- They have high degree of mechanical rigidity, accuracy, and repeatability due to their structure.
- They can carry heavy loads because the weight-lifting capacity does not vary at different locations within the work envelop.
- Three linear axes.
- Easy to visualize.
- Rigid structure.

- Easy to program offline.
- Linear axis makes for easy mechanical stops.

Rectangular coordinates robots have following disadvantages:

- They make maintenance more difficult for some models with overhead drive mechanisms and control equipment.
- Access to the volume region by overhead crane or other material handling equipment may be impaired by the robot supporting structure.
- Their movement is limited to one direction at a time.
- Can reach in front of itself.
- Requires large floor space for size of work envelope.
- Axes hard to seal.

(ii) Cylindrical Configuration:

The cylindrical configuration pictured in Fig. uses two perpendicular prismatic joints, and a revolute joint. The difference from the Cartesian one is that one of the prismatic joint is replaced with a revolute joint. One typical construction is with the first joint as revolute. The rotary joint may either have the column rotating or a block revolving around a stationary vertical cylindrical column. The vertical column carries a slide that can be moved up or down along the column. The horizontal link is attached to the slide such that it can move linearly, in or out, with respect to the column. This results in a RPP configuration. The arm endpoint is, thus, capable of sweeping a cylindrical space. To be precise, the workspace is a hollow cylinder as shown in Fig. Usually a full 360° rotation of the vertical column is not permitted due to mechanical restrictions imposed by actuators and transmission elements.

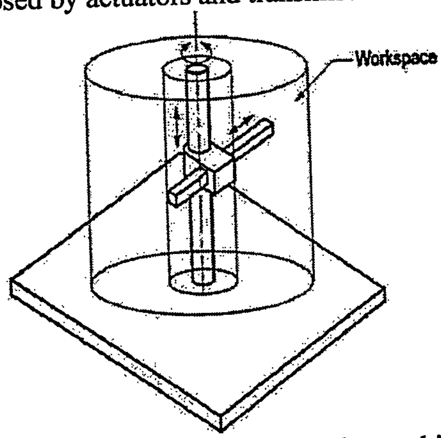


Fig. A 3-DOF cylindrical arm configuration and its workspace

Many other joint arrangements with two prismatic and one rotary joint are possible for cylindrical configuration, for example, a PP configuration. Note that all combinations of I R and 2P are not useful configurations as they may not give suitable workspace and some may only sweep a plane. Such configurations are called non-robotic configurations. It is left for the reader to visualize as to which joint combinations are robotic arm configurations.

The cylindrical configuration offers good mechanical stiffness and the wrist positioning accuracy decreases as the horizontal stroke increases. It is suitable to access narrow horizontal cavities and, hence, is useful for machine-loading operations.

Some advantages of cylindrical coordinate robots are:

- Their vertical structure conserves floor space.

- Their deep horizontal reach is useful for far-reaching operations.
- Their capacity is capable of carrying large payloads.
- Two linear axes, one rotating axis.
- Can reach all around itself.
- Reach and height axes rigid.
- Rotation axis easy to seal.

Some disadvantages of cylindrical coordinate robots are:

- Their overall mechanical rigidity is lower than that of the rectilinear robot because their rotary axis must overcome the inertia.
- Their repeatability and accuracy are also lower in the direction of rotary movement.
- Their configuration requires a more sophisticated control system than the rectangular robot.
- Cannot reach above itself.
- Base rotation axis is less rigid than a linear axis.
- Linear axis is hard to seal.
- Won't reach around the obstacles.
- Horizontal motion is circular.

(iii) Polar (Spherical) Configuration:

The polar configuration is illustrated in Fig. It consists of a telescopic link (prismatic joint) that can be raised or lowered about a horizontal revolute joint. These two links are mounted on a rotating base. This arrangement of joints, known as RRP configuration, gives the capability of moving the arm end-point within a partial spherical shell space as work volume, as shown in Fig.

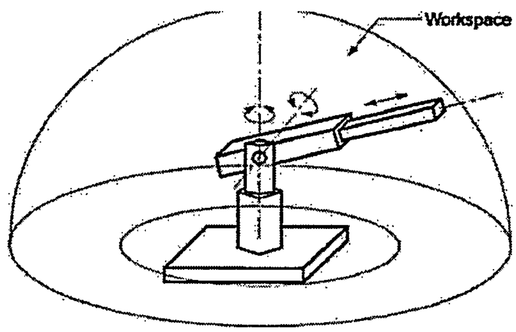


Fig. A 3-DOF polar arm configuration and its workspace

This configuration allows manipulation of objects on the floor because its shoulder joint allows its end-effector to go below the base. Its mechanical stiffness is lower than Cartesian and cylindrical configurations and the wrist positioning accuracy decreases with the increasing radial stroke. The construction is more complex. Polar arms are mainly employed for industrial applications such as machining, spray painting and so on. Alternate polar configuration can be obtained with other joint arrangements such as RPR, but PRR will not give a spherical work volume.

The advantages and disadvantages listed for cylindrical-coordinate robots can also be applied to spherical, with the following exceptions: Cylindrical is more vertical in structure where as spherical yields a low and long machine size to provide the horizontal reach, also their vertical movement is limited.

Advantages:

- One linear axis, two rotating axes.
- Long horizontal reach.

Disadvantages:

- Can't reach around obstacles.
- Generally has short vertical reach.

(iv) Articulated (Revolute or Jointed-arm) Configuration:

The articulated arm is the type that best simulates a human arm and a manipulator with this type of an arm is often referred as an anthropomorphic manipulator. It consists of two straight links, corresponding to the human "forearm" and "upper arm" with two rotary joints corresponding to the "elbow" and "shoulder" joints. These two links are mounted on a vertical rotary table corresponding to the human waist joint. Fig illustrates the joint-link arrangement for the articulated arm.

This configuration (RRR) is also called revolute because three revolute joints are employed. The work volume of this configuration is spherical shaped, and with proper sizing of links and design of joints, the arm endpoint can sweep a full spherical space. The arm endpoint can reach the base point and below the base, as shown in Fig. This anthropomorphic structure is the most dexterous one, because all the joints are revolute, and the positioning accuracy varies with arm endpoint location in the workspace. The range of industrial applications of this arm is wide.

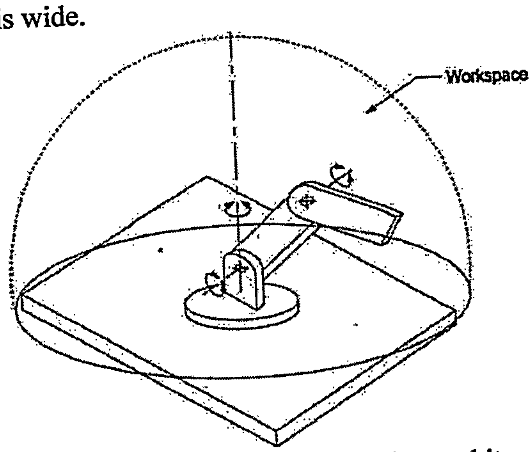


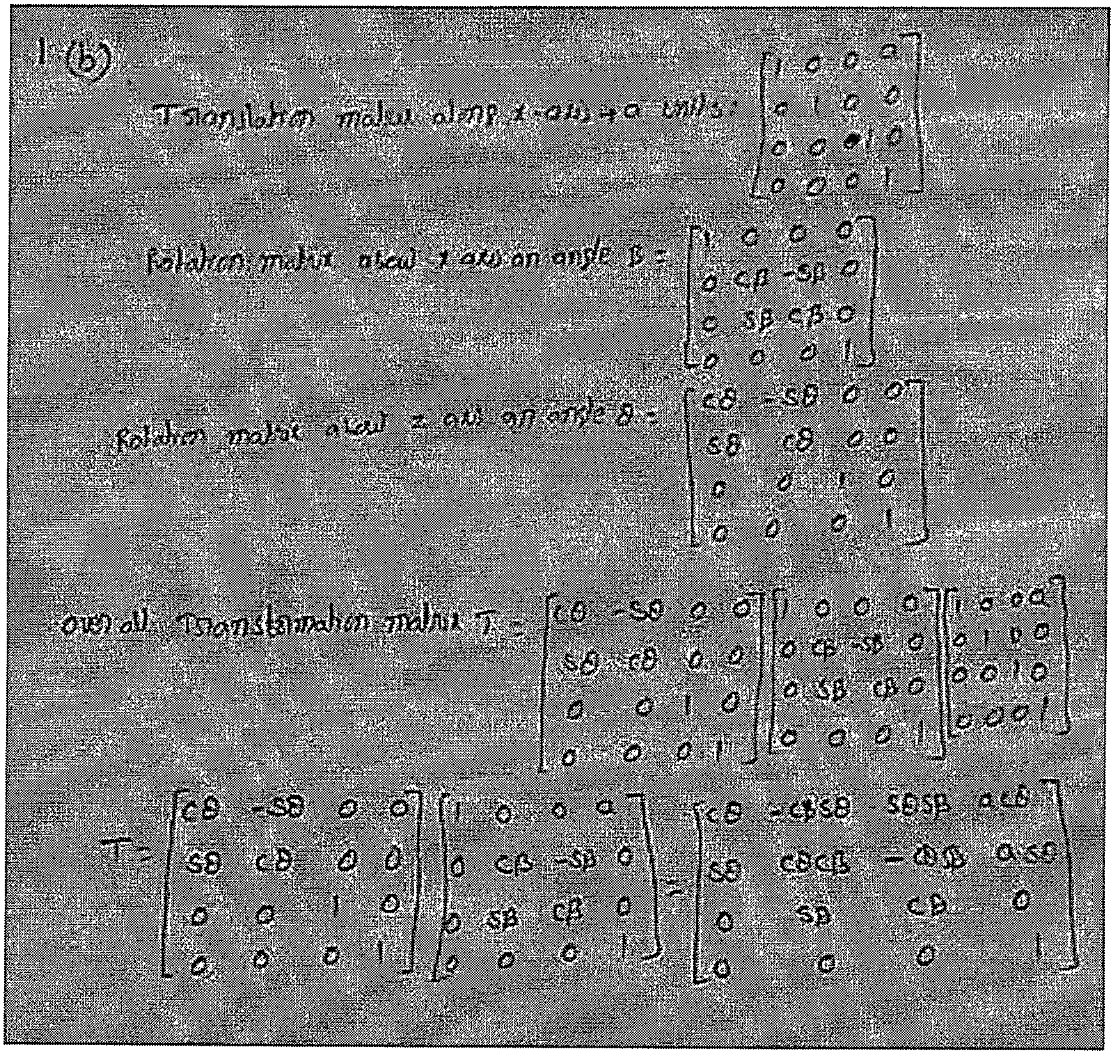
Fig. A 3-DOF articulated arm configuration and its workspace

Advantages of jointed arm coordinated robot:

- Three rotating axes.
- Can reach above or below obstacles.
- Largest work area for least floor space.

Disadvantages of jointed arm coordinated robot:

- Two or four ways to reach a point.
- Most complex manipulator.



1 (b)

Translation matrix along x-axis [illegible] a units: $\begin{bmatrix}1&0&0&a\\0&1&0&0\\0&0&1&0\\0&0&0&1\end{bmatrix}$

Rotation matrix about x axis an angle β = $\begin{bmatrix}1&0&0&0\\0&c\beta&-s\beta&0\\0&s\beta&c\beta&0\\0&0&0&1\end{bmatrix}$

Rotation matrix about z axis an angle θ = $\begin{bmatrix}c\theta&-s\theta&0&0\\s\theta&c\theta&0&0\\0&0&1&0\\0&0&0&1\end{bmatrix}$

Overall Transformation matrix T = $\begin{bmatrix}c\theta&-s\theta&0&0\\s\theta&c\theta&0&0\\0&0&1&0\\0&0&0&1\end{bmatrix}\begin{bmatrix}1&0&0&0\\0&c\beta&-s\beta&0\\0&s\beta&c\beta&0\\0&0&0&1\end{bmatrix}\begin{bmatrix}1&0&0&a\\0&1&0&0\\0&0&1&0\\0&0&0&1\end{bmatrix}$

$$T=\begin{bmatrix}c\theta&-s\theta&0&0\\s\theta&c\theta&0&0\\0&0&1&0\\0&0&0&1\end{bmatrix}\begin{bmatrix}1&0&0&a\\0&c\beta&-s\beta&0\\0&s\beta&c\beta&0\\0&0&0&1\end{bmatrix}=\begin{bmatrix}c\theta&-c\beta s\theta&s\theta s\beta&ac\theta\\s\theta&c\theta c\beta&-c\theta s\beta&as\theta\\0&s\beta&c\beta&0\\0&0&0&1\end{bmatrix}$$

2.(a)

(i) USES OF SENSORS IN ROBOTICS

One of the important applications of sensor technology in automated manufacturing operations is safety or hazard monitoring which concerns the protection of human workers who work in the vicinity of the robot or other equipment.

The second major use of sensor technology in robotics is to implement interlocks in work cell control. Interlocks are used to coordinate the sequence of activities of the different pieces of equipment in the work cell. In the execution of the robot program, there are certain elements of the work cycle whose completion must be verified before proceeding with the next element in the cycle. Sensors, often very simple devices, are utilized to provide this kind of verification.

The third category is quality control. Sensors can be used to determine a variety of part quality characteristics. Traditionally, quality control has been performed using manual inspection techniques on a statistical sampling basis. The use of sensors permits the inspection operation to be performed automatically on a 100 percent basis, in which every part is inspected. The limitation on the use of automatic inspection is that the sensor system can only inspect for a limited range of part characteristics and defects. For example, a sensor probe designed to measure part length cannot detect flaws in the part surface. Many applications of automated inspection are accomplished without the use of robotics.

The fourth major use of sensors in robotics is to determine the positions and other information about various objects in the work cell (e.g., work parts, fixtures, people, equipment, etc.). In addition to positional data about a particular object, other information required to properly execute the work cycle might include the object's orientation, color, size, and other characteristics. Reasons why this kind of data would need to be determined during the program execution include:

- Work part identification.
- Random position and orientation of parts in the work cell.
- Accuracy requirements in a given application exceed the inherent capabilities of the robot.

Feedback information is required to improve the accuracy of the robot's positioning.

TYPES OF SENSORS

Sensors can be divided into two basic classes. The first, called internal state sensors, consists of devices used to measure position, velocity, or acceleration of robot joints and/or the end effector. The following devices fall into this class:

Potentiometers ("pots")
Synchros
Resolvers
Linear inductive scales
Differential transformers (i.e., LVDTs and RVDTs)
Optical interrupters
Optical encoders (absolute and incremental)
Tachometers
Accelerometers

The second class, called external state sensors, is used to monitor the robot's geometric and/or dynamic relation to its task, environment, or the objects that it is handling.
Such devices can be of either the visual or non-visual variety.

ii.Difference Between Internal and External Environments

Definition

Internal environment: It is the extracellular fluid (literally, fluid outside the cells) environment surrounding each cell.

External environment:
It is the air surrounding the living organism.

Stability

Internal environment:
There is more stability in case of the internal environment. The reason for this is because living beings cannot endure extreme changes to aspects like water accessibility and temperature. If these aspects change too extremely, the biochemical reactions that take place within living cells that are requisite for maintaining life will be interrupted. This will cause death of the living organism.

External environment:

The external environment of a living organism is unstable.

Examples

Internal environment: The concentration of Carbon dioxide (CO2), oxygen (O2) and water (H2O) around cells/organs/ tissues inside the body of a living organism.

External environment: Bacteria, changes in light, sound, temperature, heat, and chemical and mechanical contact

2.(b)

CHARACTERISTICS OF ACTUATING SYSTEMS

1. Weight, Power-to-weight Ratio, Operating pressure

1) **Stepper motors are generally heavier than servomotors for the same power.**

2) **The high the voltage of electric motors, the better power-to-weight ratio.**

3) **Pneumatic systems delivers the lowest power-to-weight ratio .**

4) **Hydraulic systems have the ,highest power-to-weight ratio . In these systems, the weight is actually composed of two portions. One is the hydraulic actuators, and the other is the hydraulic power unit (pump, cylinders, rams, reservoirs, filter, and electric motor). If the power unit must also move with the robot, the total power-to-weight ratio will be much less.**

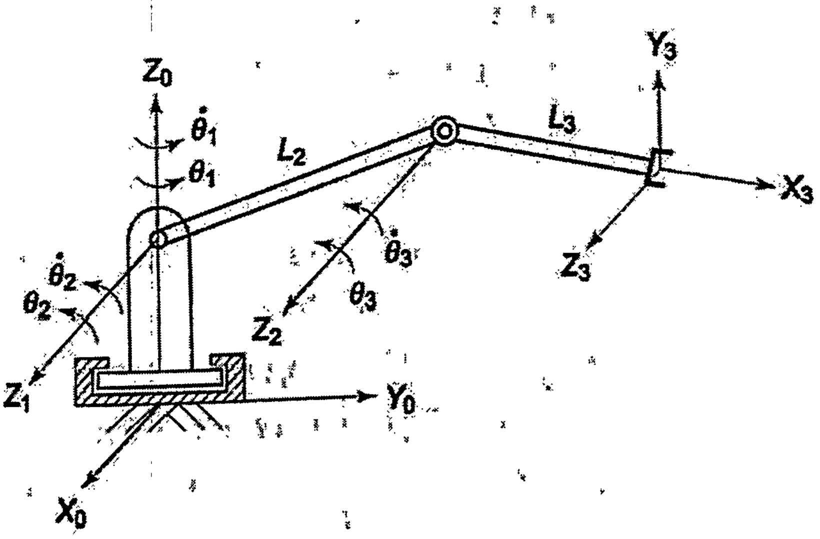
2. Stiffness versus compliance

1) Stiffness is the resistance of a material against deformation. The stiffer the system, the larger the load that is needed to deform it. Conversely, the more compliant the system the easier it deforms under the load.
2) Stiffness is directly related to the modulus of elasticity of the material. Hydraulic systems are very stiff and non-compliant while pneumatic systems are easily compressed and thus are compliant.
3) Stiff systems have a more rapid response to changing loads and pressures and are more accurate.
4) Although stiffness causes a more responsive and more accurate systems, it also creates a danger if all things are not always perfect.

Compare Hydraulic, Electric and Pneumatic Actuators:

Hydraulic	Electric	Pneumatic
- May leak. Not fit for clean room application	+Can be spark-free. Good for explosive environment.	+Complaint systems.
-Requires pump, reservoir, motor, hoses etc.	-Low stiffness	-Noisy systems.
-Can be expensive and noisy, requires maintenance.	-Needs reduction gears, increased backlash, cost, weight, etc.	- Require air pressure, filter, etc.
-Viscosity of oil changes with temperature	-Motor needs braking device when not powered. Otherwise, the arm will fail.	-Difficult to control their linear position
-Very susceptible to dirt and other foreign material in oil	-	-Deform under load constantly
-Low compliance	-	-Very low stiffness. Inaccurate response.
-High torque, High pressure, large inertia on the actuator.	-	-Lowest power to weight ratio

3.(a) Jacobian of articulated arm



Each column of Jacobian matrix is computed separately and all the columns are combined to form the total Jacobian matrix. The joint displacements

θ_1, θ_2, and θ_3 and joint velocities $\dot{\theta}_1$, $\dot{\theta}_2$, and $\dot{\theta}_3$ are shown in the figure and the transformation matrices are given in Eqs. (3.19)–(3.22).

The Jacobian matrix column J_1 for joint 1, which is a rotary joint, is determined as follows:

From Eq. (5.59), the joint axis vector P_0 (P_{i-1} for $i = 1$) is

$$P_0 = {}^0R_0\,\hat{u} \tag{5.99}$$

The transformation matrix ${}^0T_0$ and rotation matrix ${}^0R_0$ are the identity matrices. Thus,

$$P_0 = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix} \tag{5.100}$$

The end-effector position vector (for $i = 1$ and $n = 3$) is determined from Eq. (5.63).

$${}^0P_3 = {}^0T_n O_n - {}^0T_0 O_n$$

or

$${}^0P_3 = {}^0T_3 \begin{bmatrix} 0 \\ 0 \\ 0 \\ 1 \end{bmatrix} - {}^0T_0 \begin{bmatrix} 0 \\ 0 \\ 0 \\ 1 \end{bmatrix}$$

Substituting ${}^0T_3$ from Eq. (3.22), in above equation gives

$${}^0P_3 = \begin{bmatrix} C_1C_{23} & -C_1S_{23} & S_1 & C_1(L_3C_{23} + L_2C_2) \\ S_1C_{23} & -S_1S_{23} & -C_1 & S_1(L_3C_{23} + L_2C_2) \\ S_{23} & C_{23} & 0 & L_3S_{23} + L_2S_2 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 0 \\ 0 \\ 0 \\ 1 \end{bmatrix} - \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 0 \\ 0 \\ 0 \\ 1 \end{bmatrix}$$

or

$${}^0P_3 = \begin{bmatrix} C_1(L_3C_{23} + L_2C_2) \\ S_1(L_3C_{23} + L_2C_2) \\ L_3S_{23} + L_2S_2 \\ 0 \end{bmatrix} \tag{5.101}$$

The first column of Jacobian, J_1, is computed by substituting Eq. (5.100) and Eq. (5.101) in Eq. (5.64), for revolute joint. Thus,

$$J_1 = \begin{bmatrix} \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix} \times \begin{bmatrix} C_1(L_3C_{23} + L_2C_2) \\ S_1(L_3C_{23} + L_2C_2) \\ L_3S_{23} + L_2S_2 \end{bmatrix} \\ \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix} \end{bmatrix} = \begin{bmatrix} -S_1(L_3C_{23} + L_2C_2) \\ C_1(L_3C_{23} + L_2C_2) \\ 0 \\ 0 \\ 0 \\ 1 \end{bmatrix} \tag{5.102}$$

By following the similar steps for joint 2 and joint 3, J_2 and J_3 are obtained as

$$J_2 = \begin{bmatrix} -C_1(L_3S_{23} + L_2S_2) \\ -S_1(L_3S_{23} + L_2S_2) \\ L_3C_{23} + L_2C_2 \\ S_1 \\ -C_1 \\ 0 \end{bmatrix} \tag{5.103}$$

and

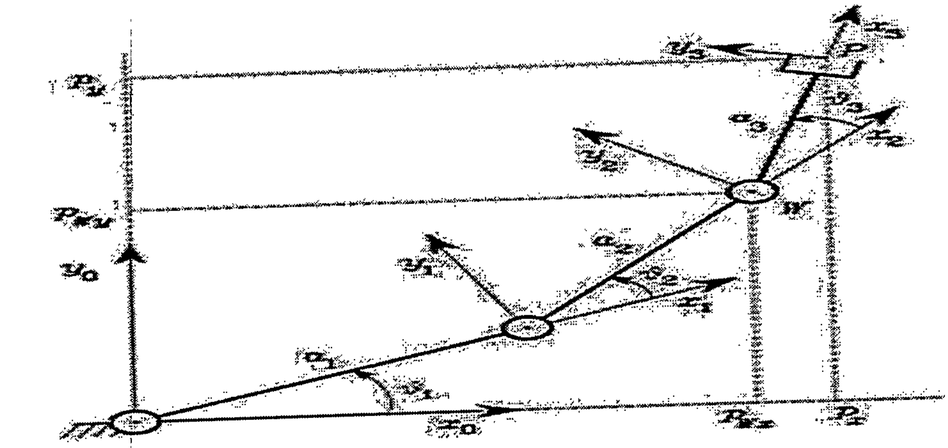
$$J_3 = \begin{bmatrix} -L_3C_1S_{23} \\ -L_3S_1S_{23} \\ L_3C_{23} \\ S_1 \\ -C_1 \\ 0 \end{bmatrix} \tag{5.104}$$

Combining the three columns, the total Jacobian matrix for the articulated arm is

$$J = \begin{bmatrix} -S_1(L_3C_{23} + L_2C_2) & -C_1(L_3S_{23} + L_2S_2) & -L_3C_1S_{23} \\ C_1(L_3C_{23} + L_2C_2) & -S_1(L_3S_{23} + L_2S_2) & -L_3S_1S_{23} \\ 0 & L_3C_{23} + L_2C_2 & L_3C_{23} \\ 0 & S_1 & S_1 \\ 0 & -C_1 & -C_1 \\ 1 & 0 & 0 \end{bmatrix} \tag{5.105}$$

3.(b)

Solution of three-link planar arm



Algebraic solution

$$\phi = \vartheta_1 + \vartheta_2 + \vartheta_3$$

$$p_{Wx} = p_x - a_3c_\phi = a_1c_1 + a_2c_{12}$$

$$p_{Wy} = p_y - a_3s_\phi = a_1s_1 + a_2s_{12}$$

$$c_2 = \frac{p_{Wx}^2 + p_{Wy}^2 - a_1^2 - a_2^2}{2a_1a_2}$$

$$s_2 = \pm\sqrt{1 - c_2^2}$$

$$\vartheta_2 = \text{Atan2}(s_2, c_2)$$

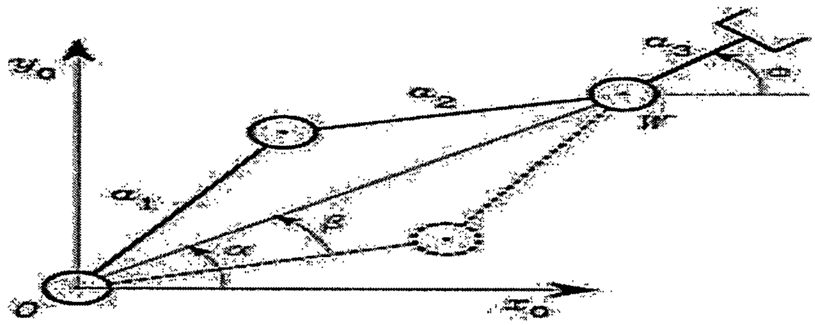
$$s_1 = \frac{(a_1 + a_2c_2)p_{Wy} - a_2s_2p_{Wx}}{p_{Wx}^2 + p_{Wy}^2}$$

$$c_1 = \frac{(a_1 + a_2c_2)p_{Wx} + a_2s_2p_{Wy}}{p_{Wy}^2 + p_{Wy}^2}$$

$$\vartheta_1 = \text{Atan2}(s_1, c_1)$$

$$\vartheta_3 = \phi - \vartheta_1 - \vartheta_2$$

Geometric solution



$$c_2 = \frac{p_{Wx}^2 + p_{Wy}^2 - a_1^2 - a_2^2}{2a_1a_2}$$

$$\vartheta_2 = \cos^{-1}(c_2)$$

$$\alpha = \text{Atan2}(p_{Wy}, p_{Wx})$$

$$c_\beta\sqrt{p_{Wx}^2 + p_{Wy}^2} = a_1 + a_2c_2$$

$$\beta = \cos^{-1}\left(\frac{p_{Wx}^2 + p_{Wy}^2 + a_1^2 - a_2^2}{2a_1\sqrt{p_{Wx}^2 + p_{Wy}^2}}\right)$$

$$\vartheta_1 = \alpha \pm \beta$$

4.(a)

The dynamics of a simple manipulator is worked out to illustrate the Lagrange-Euler formulation and to clarify the problems involved in the dynamic modeling. A planar, 2-DOF manipulator with both rotary joints, as shown in Fig. 6.1, is considered and its dynamic model is obtained using direct geometric approach before discussing the general formulation. For the manipulator, coordinate frames {0} and {1}, joint variables θ_1 and θ_2, link lengths L_1 and L_2, and mass of links m_1 and m_2, respectively, are shown in the figure. The mass of each link is assumed to be a point mass located at the center of mass of each link and links are assumed to be slender members. The linear and angular velocities are v_1, v_2, $\dot{\theta}_1$ and $\dot{\theta}_2$, respectively.

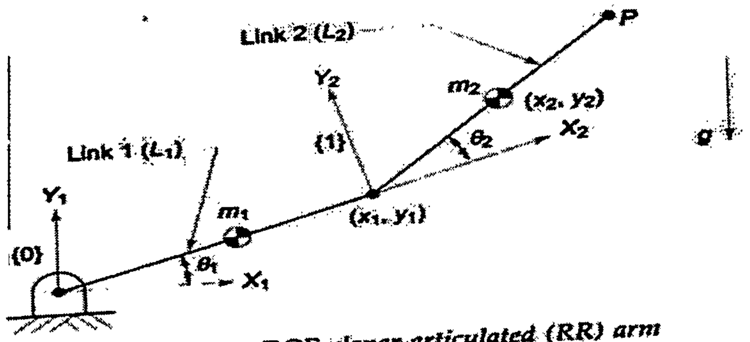


Fig. 6.1 *A 2-DOF planar articulated (RR) arm*

The Lagrangian requires kinetic and potential energies of the manipulator. The kinetic energy of a rigid body (a link), can be expressed as:

$$\mathcal{K} = \frac{1}{2} m v^2 + \frac{1}{2} I \omega^2 \quad (6.3)$$

where v is the linear velocity , ω is the angular velocity, m is the mass, and I is the moment of inertia of the rigid body at its center of mass.

Thus, the kinetic energy for the link 1 with the linear velocity $v_1 = \frac{1}{2} L_1 \dot{\theta}_1$, angular velocity $\omega_1 = \dot{\theta}_1$, moment of inertia $I_1 = \frac{1}{12} m_1 L_1^2$, and mass m_1 is

$$\mathcal{K}_1 = \frac{1}{2} m_1 v_1^2 + \frac{1}{2} I_1 \omega_1^2 = \frac{1}{8} m_1 L_1^2 \dot{\theta}_1^2 + \frac{1}{24} m_1 L_1^2 \dot{\theta}_1^2 = \frac{1}{6} m_1 L_1^2 \dot{\theta}_1^2 \quad (6.4)$$

and its potential energy is

$$\mathcal{P}_1 = \frac{1}{2} m_1 g L_1 \sin\theta_1 \quad (6.5)$$

where g is the magnitude of acceleration due to gravity in the negative y-axis direction.

For the second link, link 2, the Cartesian position coordinates (x_2, y_2) of the center of mass of link are:

$$
\begin{aligned}
x_2 &= L_1 \cos \theta_1 + \frac{1}{2} L_2 \cos (\theta_1 + \theta_2) \\
y_2 &= L_1 \sin \theta_1 + \frac{1}{2} L_2 \sin (\theta_1 + \theta_2)
\end{aligned}
\qquad (6.6)
$$

Differentiating Eq. (6.6) gives the components of velocity of link 2 as

$$
\begin{aligned}
\dot{x}_2 &= -L_1 \sin \theta_1 \dot{\theta}_1 - \frac{1}{2} L_2 \sin (\theta_1 + \theta_2)(\dot{\theta}_1 + \dot{\theta}_2) \\
\dot{y}_2 &= L_1 \cos \theta_1 \dot{\theta}_1 + \frac{1}{2} L_2 \cos (\theta_1 + \theta_2)(\dot{\theta}_1 + \dot{\theta}_2)
\end{aligned}
\qquad (6.7)
$$

From these components, the square of the magnitude of velocity of the end of link 2 is

$$v_2^2 = \dot{x}_2^2 + \dot{y}_2^2$$

or

$$
\begin{aligned}
v_2^2 = {} & L_1^2 S_1^2 \dot{\theta}_1^2 + \frac{1}{4} L_2^2 S_{12}^2 (\dot{\theta}_1 + \dot{\theta}_2)^2 + L_1 L_2 S_1 S_{12} (\dot{\theta}_1^2 + \dot{\theta}_1 \dot{\theta}_2) \\
& + L_1^2 C_1^2 \dot{\theta}_1^2 + \frac{1}{4} L_2^2 C_{12}^2 (\dot{\theta}_1 + \dot{\theta}_2)^2 + L_1 L_2 C_1 C_{12} (\dot{\theta}_1^2 + \dot{\theta}_1 \dot{\theta}_2)
\end{aligned}
$$

Simplifying

$$v_2^2 = L_1^2 \dot{\theta}_1^2 + \frac{1}{4} L_2^2 (\dot{\theta}_1 + \dot{\theta}_2)^2 + L_1 L_2 C_2 (\dot{\theta}_1^2 + \dot{\theta}_1 \dot{\theta}_2) \qquad (6.8)$$

where $C_i = \cos \theta_i$, $S_i = \sin \theta_i$, $C_{12} = \cos (\theta_1 + \theta_2)$ and $S_{12} = \sin (\theta_1 + \theta_2)$.

Thus, the kinetic energy of link 2 with $\omega_2 = \dot{\theta}_1 + \dot{\theta}_2$ and $I_2 = \frac{1}{12} m_2 L_2^2$ is

$$
\begin{aligned}
\mathcal{K}_2 &= \frac{1}{2} m_2 v_2^2 + \frac{1}{2} I_2 \omega_2^2 \\
&= \frac{1}{2} m_2 [L_1^2 \dot{\theta}_1^2 + \frac{1}{4} L_2^2 (\dot{\theta}_1 + \dot{\theta}_2)^2 + L_1 L_2 C_2 (\dot{\theta}_1^2 + \dot{\theta}_1 \dot{\theta}_2)] \\
&\qquad + \frac{1}{24} m_2 L_2^2 (\dot{\theta}_1 + \dot{\theta}_2)^2 \qquad (6.9) \\
&= \frac{1}{2} m_2 L_1^2 \dot{\theta}_1^2 + \frac{1}{6} m_2 L_2^2 \left(\dot{\theta}_1^2 + \dot{\theta}_1^2 + 2\dot{\theta}_1 \dot{\theta}_2\right) + \frac{1}{2} m_2 L_1 L_2 C_2 (\dot{\theta}_1^2 + \dot{\theta}_1 \dot{\theta}_2)
\end{aligned}
$$

The potential energy of link 2, from Eq. (6.6), is

$$\mathcal{P}_2 = m_2 g L_1 S_1 + \frac{1}{2} m_2 g L_2 S_{12} \qquad (6.10)$$

The Lagrangian $\mathcal{L} = \mathcal{K} - \mathcal{P} = \mathcal{K}_1 + \mathcal{K}_2 - \mathcal{P}_1 - \mathcal{P}_2$ is obtained from Eqs. (6.4), (6.5), (6.9), and (6.10). Rearranging and simplifying, the Lagrangian is

$$\mathcal{L} = \frac{1}{2}\left(\frac{1}{3}m_1 + m_2\right)L_1^2\dot{\theta}_1^2 + \frac{1}{6}m_2L_2^2(\dot{\theta}_1{}^2 + \dot{\theta}_2{}^2 + 2\dot{\theta}_1\dot{\theta}_2) + \frac{1}{2}m_2L_1L_2C_2(\dot{\theta}_1^2 + \dot{\theta}_1\dot{\theta}_2) - \left(\frac{1}{2}m_1 + m_2\right)gL_1S_1 - \frac{1}{2}m_2gL_2S_{12} \tag{6.11}$$

The Lagrange-Euler formulation for link 1, Eq. (6.2), gives the torque τ_1 at joint 1 as

$$\tau_1 = \frac{d}{dt}\left(\frac{\partial \mathcal{L}}{\partial \dot{\theta}_1}\right) - \frac{\partial \mathcal{L}}{\partial \theta_1} \tag{6.12}$$

The Lagrangian in Eq. (6.11) is differentiated wrt θ_1 and $\dot{\theta}_1$ to give

$$\frac{\partial \mathcal{L}}{\partial \theta_1} = -\left(\frac{1}{2}m_1 + m_2\right)g\,L_1C_1 - \frac{1}{2}m_2gL_2C_{12} \tag{6.13}$$

and

$$\frac{\partial \mathcal{L}}{\partial \dot{\theta}_1} = \left(\frac{1}{3}m_1 + m_2\right)L_1^2\dot{\theta}_1 + \frac{1}{3}m_2L_2^2(\dot{\theta}_1 + \dot{\theta}_2) + \frac{1}{3}m_2L_1L_2C_2(2\dot{\theta}_1 + \dot{\theta}_2) \tag{6.14}$$

Differentiating Eq. (6.14) wrt time

$$\frac{d}{dt}\left(\frac{\partial \mathcal{L}}{\partial \dot{\theta}_1}\right) = \left[\left(\frac{1}{3}m_1 + m_2\right)L_1^2 + \frac{1}{3}m_2L_2^2 + m_2L_1L_2C_2\right]\ddot{\theta}_1 + m_2\left[\frac{1}{3}L_2^2 + \frac{1}{2}L_1L_2C_2\right]\ddot{\theta}_2 - m_2L_1L_2S_2\dot{\theta}_1\dot{\theta}_2 - \frac{1}{2}m_2L_1L_2S_2\dot{\theta}_2^2 \tag{6.15}$$

Substituting the results of Eqs. (6.13) and (6.15) into Eq. (6.12), the torque at joint 1 is obtained as

$$\tau_1 = \left[\left(\frac{1}{3}m_1 + m_2\right)L_1^2 + \frac{1}{3}m_2L_2^2 + m_2L_1L_2C_2\right]\ddot{\theta}_1 + m_2\left[\frac{1}{3}L_2^2 + \frac{1}{2}L_1L_2C_2\right]\ddot{\theta}_2 - m_2L_1L_2S_2\dot{\theta}_1\dot{\theta}_2 - \frac{1}{2}m_2L_1L_2S_2\dot{\theta}_2^2 + \left(\frac{1}{2}m_1 + m_2\right)g\,L_1C_1 + \frac{1}{2}m_2g\,L_2C_{12} \tag{6.16}$$

Similarly, the derivatives of Lagrangian, Eq. (6.11), for joint 2 are

$$\frac{\partial \mathcal{L}}{\partial \theta_2} = -\frac{1}{2}m_2L_1L_2S_2(\dot{\theta}_1^2 + \dot{\theta}_1\dot{\theta}_2) - \frac{1}{2}m_2gL_2C_{12} \tag{6.17}$$

and

$$\frac{\partial \mathcal{L}}{\partial \dot{\theta}_2} = \frac{1}{3}m_2L_2^2(\dot{\theta}_1 + \dot{\theta}_2) + \frac{1}{2}m_2L_1L_2C_2\dot{\theta}_1 \tag{6.18}$$

and

$$\frac{d}{dt}\left(\frac{\partial \mathcal{L}}{\partial \dot{\theta}_2}\right) = \left[\frac{1}{3}m_2L_2^2 + \frac{1}{2}m_2L_1L_2C_2\right]\ddot{\theta}_1 + \frac{1}{3}m_2L_2^2\ddot{\theta}_2 - \frac{1}{2}m_2L_1L_2S_2\dot{\theta}_1\dot{\theta}_2 \tag{6.19}$$

Again from Eq (6.12),

$$\tau_2 = m_2\left[\frac{1}{3}L_2^2 + \frac{1}{2}L_1L_2C_2\right]\ddot{\theta}_1 + \frac{1}{3}m_2L_2^2\ddot{\theta}_2$$
$$+ \frac{1}{2}m_2L_1L_2S_2\dot{\theta}_1^2 + \frac{1}{2}m_2gL_2C_{12} \qquad (6.20)$$

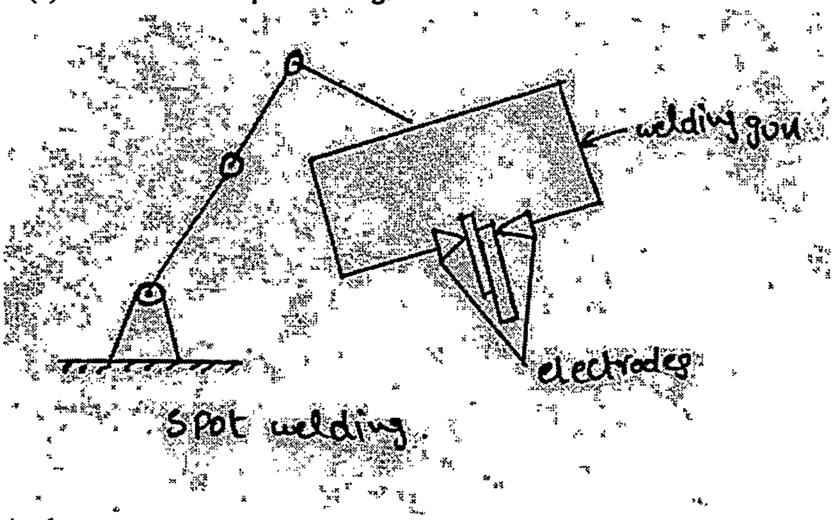
Equations (6.16) and (6.20) are the EOM (dynamic model) of the 2-link planar manipulator. Because both the joints are revolute, the generalized torques τ_1 and τ_2 represent the actual joint torques.

Torque equation, Eqs. (6.16) and (6.20) can be written in the generalized form, which will be described in Section 6.4, as

$$\tau_1 = M_{11}\ddot{\theta}_1 + M_{12}\ddot{\theta}_2 + H_1 + G_1$$
$$\tau_2 = M_{21}\ddot{\theta}_1 + M_{22}\ddot{\theta}_2 + H_2 + G_2 \qquad (6.21)$$

4.(b) Newton- Eulers Formulation:

5.(a) I. Robotics in **Spot welding:**



As the term suggests, spot welding is a process in which two sheet metal parts are fused together at localized points by passing a large electric current through the parts where the weld is to be made. The fusion is accomplished at relatively low voltage levels by using two copper (or copper alloy) electrodes to squeeze the parts together at the contact points and apply the current to the weld area. The electric current results in sufficient heat in the contact area to fuse the two metal parts, hence producing the weld.

Spot welding has traditionally been performed manually by either of two methods. The first method uses a spot-welding machine in which the parts are inserted between the pair of electrodes that are maintained in a fixed position. This method is normally used for relatively small, parts that can be easily handled.

The second method involves manipulating a portable spot-welding gun into position relative to the parts. This would be used for larger work such as automobile bodies. The word "portable" is perhaps an exaggeration. The welding gun consists of the pair of electrodes and a frame to open and close the electrodes. In addition, large electrical cables are used to deliver the current to the electrodes from a control panel located near the workstation. The welding gun with cables attached is quite heavy and can easily exceed 100 lb in weight.

Capabilities and features of robot in spot welding:-

i. The robot must be relatively large.

ii. It must be sufficient payload capacity.

iii. The work volume must be adequate for the size of the product.

iv. It should have increase number of DOF

v. The controller memory must have enough capacity to accomplish the many positioning steps required for the spot welding.

vi. The robot must be able to switch from one program holding sequence to another as the model change.

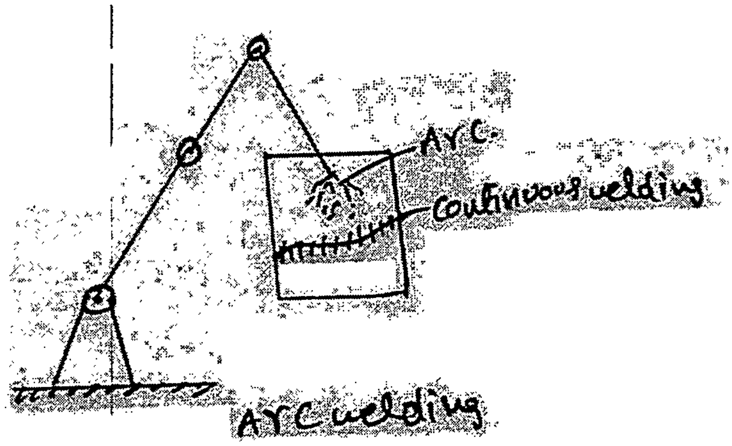
Benefits of robot in spot welding:

i. Improved production quality

ii. Operator safety

iii. Better control over the production.

Continuous arc welding:



Arc welding is a continuous welding process as opposed to spot welding which might be called a discontinuous process. Continuous arc welding is used to make long welded joints in which an airtight seal is often required between the two pieces of metal being joined. The process uses an electrode in the form of a rod or wire of metal to supply the high electric current needed for establishing the arc. Currents are typically 100 to 300A at voltages of 10 to 30 V. The arc between the welding rod and the metal parts to be joined produces temperatures that are sufficiently high to form a pool of molten metal to fuse the two pieces together. The electrode can also be used to contribute to the molten pool, depending on the type of welding process. The high temperatures created in arc welding and the resulting molten metals are inherently dangerous. The high electrical current used to create the arc is also unsafe; Sparks and smoke are generated during the process and these are a potential threat to the operator.

Features of the Welding Robot:

i. Work volume and degrees of freedom: The robot's work volume must be large enough for the sizes of the parts to be welded.

ii. Motion control system: Continuous-path control is required for are welding. The robot must be capable of a smooth continuous motion in order to maintain uniformity of the welding seam.

iii. Precision of motion: The accuracy and repeatability of the robot determines to a large extent the quality of the welding job.

iv. Interface with other systems: The robot must be provided with sufficient input/output and control capabilities to work with the other equipment in the cell.

v. Programming: Programming the robot for continuous arc welding must be considered carefully.

Advantages and Benefits of Robot Arc Welding:

A robot arc-welding cell for batch production has the potential for achieving a number of advantages over a similar manual operation. These advantages include the following:

1. Higher productivity
2. Improved safety and quality-of-work life
3. Greater quality of product
4. Process rationalization.

II. **GENERAL CONSIDERATIONS IN ROBOT MATERIAL HANDLING:-**

In planning an application in which the robot will be used to transfer parts, load a machine, or other similar operation, there are several considerations that must be reviewed.

1.Part positioning and orientation: In most parts-handling applications the parts must be presented tothe robot in a known position and orientation.

2.Gripper design: Special end effectors must be designed for the robot to grasp and hold the workpartduring the handling operation

3.Minimum distances moved: The material-handling application should be planned so as to minimizethe distances that the parts must be moved.

4.Robot work volume: The cell layout must be designed with proper consideration given to the robot'scapability to reach the required extreme locations in the cell and still allow room to maneuver the gripper.

5.Robot weight capacity: There is an obvious limitation on the material handling operation that theload capacity of the robot must not be exceeded. A robot with sufficient weight-carrying capacity must be specified for the application.

6.Accuracy and repeatability: Some applications require the materials to be handled with very highprecision. Other applications are less demanding in this respect.

7.Robot configuration, degrees of freedom, and control: Many parts transfer operations are simpleenough that they can be accomplished by a robot with two to four joints of motion. Machine-loading applications often require more degrees of freedom. Palletizing operations, and picking parts from a moving conveyor are examples where the control requirements are more demanding

8.Machine utilization problems: It is important for the application to effectively utilize all pieces ofequipment in the cell. In a machine loading/unloading operation, it is common for the robot to be idle while the machine is working, and the machine to be idle while the robot is working.

5.(b) I. **MACHINE LOADING AND UNLOADING OF ROBOT:-**

These applications are material-handling operations in which the robot is us to service a production machine by transferring parts to and/or from the machine. There are three cases that tit into this application category:

Machine load/unload: The robot loads a raw workpart into the process and unloads a finished part. A machining operation is an example of this case.
Machine loading: The robot must load the raw workpart or materials into if machine but the part is ejected from the machine by some other means a press working operation the robot may be programmed to load metal blanks into the press but the finished parts are allowed to drop out of the press by gravity.
Machine unloading: The machine produces finished parts from raw material that are loaded directly into the machine without robot assistance. The robot unloads the part from the machine. Examples in this category include die casting and plastic modeling applications.

Robots have been successfully applied to accomplish the loading and/or unloading function in the following production operations:

1. Die casting
2. Plastic molding
3. Forging and related operations
4. Machining operations
5. Stamping press operations

1. Die casting:
Die casting is a manufacturing process in which molten metal is forced into the cavity of a mold under high pressure. The mold is called a die (hence the name, die casting). The process is used to cast metal parts with sufficient accuracy so that subsequent finishing operations are usually not required. Common metals used for die-casted parts include alloys of zinc, tin, lead, aluminum, magnesium, and copper.
The die consists of two halves that are opened and closed by a die casting machine. During operation the die is closed and molten metal is injected into the cavity by a pump. To ensure that the cavity is filled, enough molten metal is forced into the die that it overflows the cavity and creates "flash" in the space between the die halves. When the metal has solidified, the die is opened and the cast part is ejected, usually by pins which push the part away from the mold cavity. When the part is removed fromthe machine, it is often quenched (to cool the part) in a water bath. The flash that is created during the casting process must be removed subsequently by a trimming operation which cuts around the periphery of the part. Thus, the typical die-casting production cycle consists of casting, removing the part from the machine, quenching, and trimming.
The production rates in the die-casting process range from about 100 up to 700 openings of the die per hour, depending on type of machine, the metal being cast, and the design of the part. The die-casting process represents a relatively straightforward application for industrial robots.

2. Plastic Molding:
Plastic molding is a batch-volume or high-volume manufacturing process used to make plastic parts to final shape and size. The term plastic molding covers a number of processes, including compression molding, injection molding, thermoforming, blow molding, and extrusion. Injection molding is the most important commercially, and is the process in this group for which robots are most often used. The injection-molding operation is quite similar to die casting except for the differences in materials being processed. A thermoplastic material is introduced into the process in the form of small pellets or granules from a storage hopper. It is heated in a heating chamber to 200 to 300 C to transform it into semifluid (plastic) state and injected into the mold cavity under high pressure. The plastic travels from the heating chamber into the part cavity through a sprue-and-runner network that is designed into the mold. If too much plastic is injected into the mold Hash is created where the two halves of the mold come

together. If too little material is injected into the unacceptable. When the plastic material has hardened sufficiently the mold opens and the part(s) are removed from the mold.

5.(b). II.

Assembly operations:

The term assembly is defined here to mean the fitting together of two or more discrete parts to form a new subassembly. The assembly operations are,

1. Parts presentation methods
2. Assembly tasks
3. Assembly cell designs.

1. Parts presentation methods:

In order for a robot to perform an assembly task, the part that is to be assembled must be presented to the robot. There are several ways to accomplish this presentation function, involving various levels of structure in the workplace:

i) Parts located within a specific area (parts not positioned or oriented)
ii) Parts located at a known position (parts not oriented)
iii) Parts located in a known position and orientation.

i) Parts located within a specific area (parts not positioned or oriented):
In this case, the robot is required to use some form of sensory input to guide it to the part location and to pick up the part.

ii) Parts located at a known position (parts not oriented):
In the second case, the robot would know where to go to get the part, but would then have to solve the orientation problem. This might require the robot to perform an additional handling operation to orient the part.

iii) Parts located in a known position and orientation:
The third way of presenting the part to the robot (known position and orientation) is the most common method currently used, and is in fact the method used in automatic assembly that precedes the advent of robotics.

There are a number of methods for presenting parts in a known position and orientation, they are

i. Bowl feeders
ii. Magazine feeders
iii. Trays and pallets

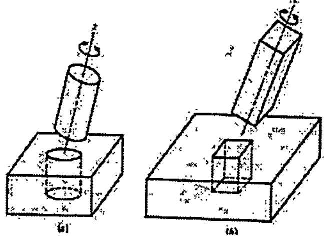
2. Assembly tasks:

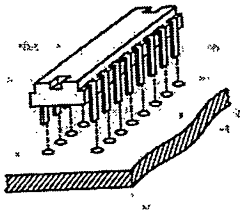
Assembly operations can be divided into two basic categories:

i. parts mating and
ii. parts joining.

i) parts mating :

In parts mating, two (or more) parts are brought into contact with each other.
The variety of parts mating operations include the following assembly situations:





I. Peg-in-hole. This operation involves the insertion of one part (the peg) into another part (the hole). It represents the most common assembly task.

II. Hole-on-peg. This is a variation of the peg-in-hole task. Similar problems exist in defining the degrees of freedom needed to execute the mating of the two parts. A typical example of the hole-on-peg task would be the placement of a bearing or gear onto a shaft.

III. Multiple peg-in-hole. This is another variation on case 1 except that one.

ii) parts joining:

In parts joining, two (or more) parts are mated and then additional steps are taken to ensure that the parts will maintain their relation- ship with each other.

The possible joining operations include the following:

I. Fastening screws

II. Retainers

III. Press fits

IV. Snap fits

V. Welding and related joining methods

VI. Adhesives

VII. Crimpling

VIII. Sewing.

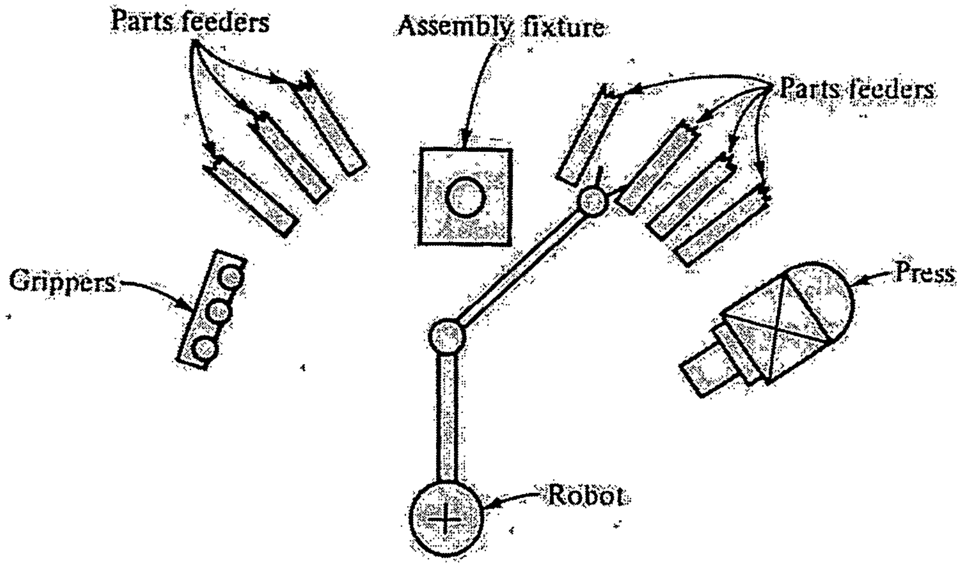
ASSEMBLY SYSTEM CONFIGURATIUNS:

There are two basic configurations of assembly systems, a single workstation, and a series of workstations (an assembly line). Combinations of these two basic types are also possible.

Single-Workstation Assembly:

In this configuration all of the parts which are required to complete the desired assembly are presented to the operator or robot at a single workstation. All of the parts mating and joining tasks for the assembly are accomplished at the single workstation. In manual assembly, this configuration is generally used for low-volume products (e.g., custom-engineered machinery). In robotic assembly, the conditions

warranting the use of this configuration are different from those for manual assembly. A single-station robotic assembly system would typically be used for low- and medium-volume work in which there were a limited number of assembly tasks and parts to be handled. This means that the product is of low to medium complexity. The features and problems of this configuration are illustrated by means of an example.



Single station robotic workcell

Narasaraopeta Engineering College (Autonomous)

NEC Kotappakonda Road, Yellamanda (P.O), Narasaraopet- 522601, Guntur District, AP

Subject Code: R16CC41OE14

IV B.Tech I Semester Regular& Supple Examinations, January-2022

ROBOTICS (OPEN ELECTIVE-III)

(ME)

Time: 3 hours Max Marks: 60

Question Paper Consists of Part-A and Part-B.

Answering the question in Part-A is Compulsory & Four Questions should be answered from Part-B

All questions carry equal marks of 12

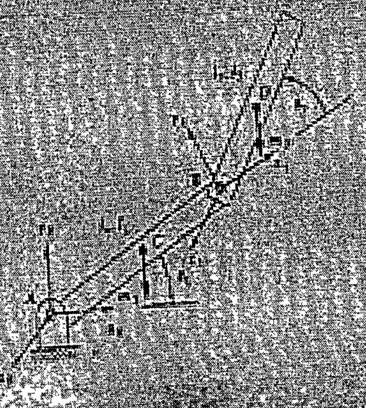
PART-A

1. (a) What are Requirements and challenges of end effectors? [K1,CO1,2M]
   (b) List the limitations of potentiometer? [K1,CO2,2M]
   (c) Write about robot application for welding. [K1,CO3,2M]
   (d) What is D-H notation explain in brief? [K1,CO4,2M]
   (e) Describe the Jacobian matrix? [K2,CO5,2M]
   (f) Illustrate and explain Skew motion. [K2,CO6,2M]

PART-B

4 X 12 = 48

2. a) What are the different types of automation? Explain them with examples. [K1,CO1,6M]
   b) Describe the classification of robots by control system. [K2,CO1,6M]
3. a) Differentiate between stepper motor and D.C. motor drives for a robot. [K2,CO2,6M]
   b) Write about velocity sensors. [K1,CO2,6M]
4. a) Define material transfer application? Explain about simple pick and operation with neat sketch. [K2,CO3,6M]
   b) State characteristics of work which promote application of robots. Discuss robot application for assembly and inspection. [K1,CO3,6M]
5. a) Explain the homogeneous transformation as applicable to rotation? [K2,CO4,6M]
   b) Derive the forward kinematics matrix for an articulated robot arm (RRR) using D-H convention? [K3,CO4,6M]
6. Using Lagrangian method, derive the equations of motion for the two degree of freedom robot arm, shown in figure, the center of mass for each link is at the center of link. The moments of inertia are I1 and I2. [K3,CO5,12M]



7. a) Discuss different features of Trajectory planning in Robots & their significance. [K3,CO6,6M]
   b) [illegible] language structure with the help of block diagram. [K3,CO6,6M]

***

Part-A

1.(a)

Requirements of Gripper

- Capability to grasp, lift & release
- Sensing capability of part
- Minimum/optimum Weight
- Simple design, Accuracy & cost effective
- Capability to work under at high speed
- Self protective using sensors like PROXIMITY sensors
- Suitability for industrial application like repetitive operation, functional rigidity.

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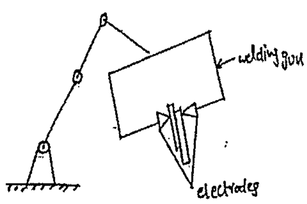
(b) Limitations of Potentiometer

1. It is slow in operation.
2. It has low accuracy.
3. It has limited bandwidth.
4. If you use a linear potentiometer, you should apply a large force to move the sliding contact.
5. There is a possibility of friction and wear due to the sliding of the wiper across the resistive element.

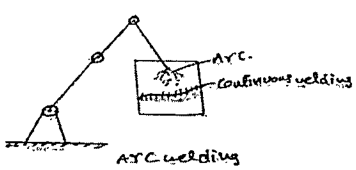
(c) Spot welding:

As the term suggests, spot welding is a process in which two sheet metal parts are fused together at localized points by passing a large electric current through the parts where the weld is to be made. The fusion is accomplished at relatively low voltage levels by using two copper (or copper alloy) electrodes to squeeze the parts together at the contact points and apply the current to the weld area. The electric current results in sufficient heat in the contact area to fuse the two metal parts, hence producing the weld.



Spot welding.

<u>Continuous arc welding:</u> Arc welding is a continuous welding process as opposed to spot welding which might be called a discontinuous process. Continuous arc welding is used to make long welded joints in which an airtight seal is often required between the two



Arc welding

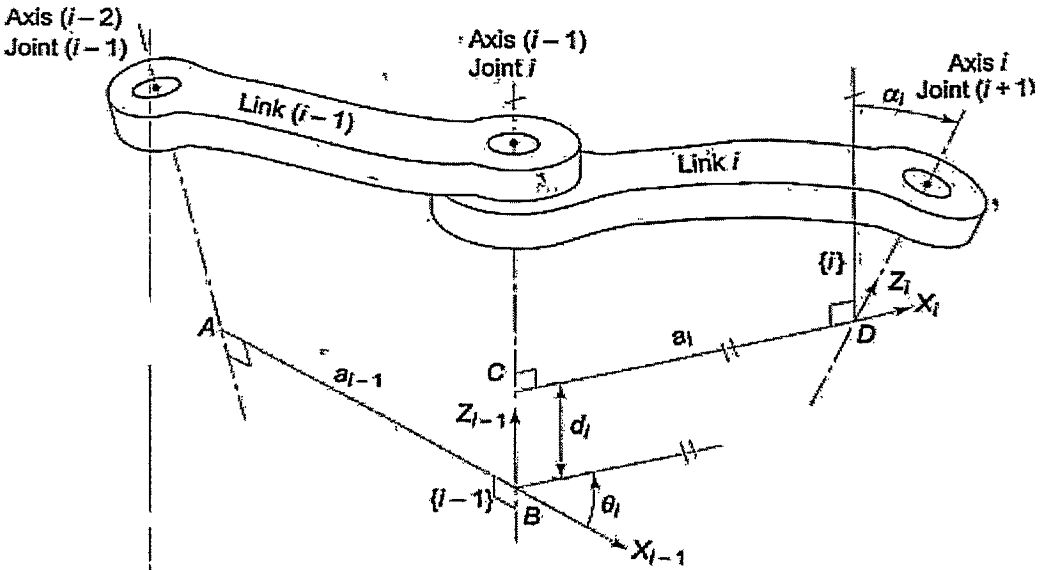
pieces of metal being joined. The process uses an electrode in the form of a rod or wire of metal to supply the high electric current needed for establishing the arc. Currents are typically 100 to 300A at voltages of 10 to 30 V. The arc between the welding rod and the metal parts to be joined produces temperatures that are sufficiently high to form a pool of molten metal to fuse the two pieces together. The electrode can also be used to contribute to the molten pool, depending on the type of welding process.

(d)

DENAVIT-HARTENBERG NOTATION

The definition of a manipulator with four joint-link parameters for each link and a systematic procedure for assigning right-handed orthonormal coordinate frames, one to each link in an open kinematic chain, was proposed by Denavit and Hartenberg (1955) and is known as *Denavit-Hartenberg (DH) notation.* This notation is presented in this section and followed throughout the text.

A frame $\{i\}$ is rigidly attached to distal end of link i and it moves with link i. An n-DOF manipulator will have $(n + 1)$ frames with the frame $\{0\}$ or base frame acting as the reference inertial frame and frame $\{n\}$ being the "*tool frame*".



DH Convention for assigning frames to links and identifying joint-link parameters

(e) Jacobian matrix is a matrix of partial derivatives. Jacobian is the determinant of the jacobian matrix. The matrix will contain all partial derivatives of a vector function. The main use of Jacobian is found in the transformation of coordinates. It deals with the concept of differentiation with coordinate transformation.

$$\begin{bmatrix} \frac{\partial f_1}{\partial x_1} & \frac{\partial f_1}{\partial x_2} & \cdots & \frac{\partial f_1}{\partial x_m} \\ \frac{\partial f_2}{\partial x_1} & \frac{\partial f_2}{\partial x_2} & \cdots & \frac{\partial f_2}{\partial x_m} \\ \frac{\partial f_3}{\partial x_1} & \frac{\partial f_3}{\partial x_2} & \cdots & \frac{\partial f_3}{\partial x_m} \end{bmatrix}$$

(f) Joint interpolated motion is the dominant type of joint motion when moving the robot in forward kinematics. Typically, the robot is commanded to move from the current configuration to a new set of joint values

Part-B

2.(a). Automation of production systems can be classified into three basic types:

1. Fixed automation (Hard Automation)
2. Programmable automation (Soft Automation)
3. Flexible automation.

There are three broad classes of industrial automation: fixed automation, programmable automation, and flexible automation. Fixed automation is used when the volume of production is very high and it is therefore appropriate to design specialized equipment to process the product (or a component of a product) very efficiently and at high production rates. A good example of fixed automation can be found in the automobile industry, where highly integrated transfer lines consisting of several dozen workstations are used to perform machining operations on engine and transmission components.

The economics of fixed automation are such that the cost of the special equipment can be divided over a large number of units, and the resulting unit costs are low relative to alternative methods of production. The risk encountered with fixed automation is this; since the initial investment cost is high, if the volume of production turns out to be lower than anticipated, then the unit costs become greater than anticipated. Another problem with fixed automation is that the equipment is specially designed to produce the one product, and after that product's life cycle is finished, the equipment is likely to become obsolete. For products with short life cycles, the use of fixed automation represents a big gamble.

The typical features of fixed automation are:

- High initial investment for custom-engineered equipment
- High production rates
- Relatively inflexible in accommodating product changes.

Advantages:

1. Low unit cost
2. Automated material handling
3. High production rate.

Disadvantages:

1. High initial Investment
2. Relatively inflexible in accommodating product changes.

Programmable automation is used when the volume of production is relatively low and there are a variety of products to be made. In this case, the production equipment is designed to be adaptable to variations in product configuration. This adaptability feature is accomplished by operating the equipment under the control of a "program" of instructions which has been prepared especially for the given product.

The program is read into the production equipment, and the equipment performs the particular sequence of processing (or assembly) operations to make that product. In terms of economics, the cost of the programmable equipment can be spread over a large number of products even though the products are different. Because of the programming feature, and the resulting adaptability of the equipment, many different and unique products can be made economically in small batches.

The relationship of the first two types of automation, as a function of product variety and production volume, is illustrated in Fig.

Some of the features that characterize programmable automation include:

- High investment in general-purpose equipment
- How production rates relative to fixed automation
- Lower production rates than fixed automation
- Flexible to deal with changes in product configuration
- Most suitable for batch production

Advantages:

1. Flexible to deal with design variations.
2. Suitable for batch production.

Disadvantages:

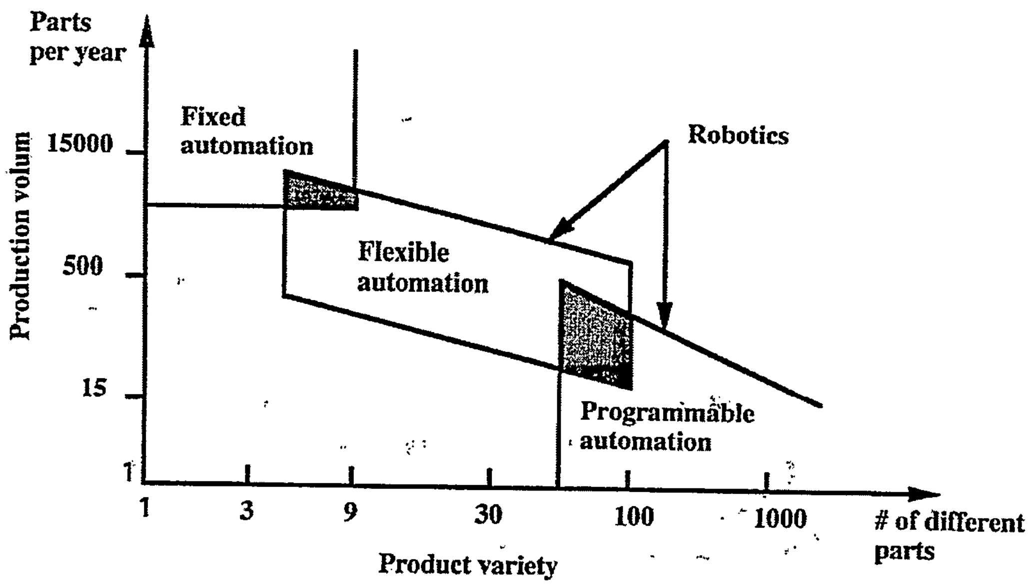
1. High investment in general purpose equipment
2. Lower production rate than fixed automation.

Example: Numerical controlled machine tools, industrial robots and programmable logic controller.

There is a third category between fixed automation and programmable automation, which is called "flexible automation." Other terms used for flexible automation include "flexible manufacturing systems," (or FMS) and "computer-integrated manufacturing systems." The concept of flexible automation has only developed into practice within the past 15 or 20 years.

Experience thus far with this type of automation suggests that it is most suitable for the mid-volume production range, as shown in Fig. As indicated by its position relative to the other two types, flexible systems possess some of the features of both fixed automation and programmable automation. It must be programmed for different product configurations, but the variety of configurations is usually more limited than for programmable automation, which allows a certain amount of integration to occur in the system. Flexible automated systems typically consist of a series of workstations that are interconnected by a materials-handling and storage system. A central computer is used to control the various activities that occur in the system, routing the various parts to the appropriate stations and controlling the programmed operations at the different stations.

Relationship of Fixed Automation, Programmable Automation & Flexible Automation,



One of the features that distinguishes programmable automation from flexible automation is that with programmable automation, the products are made in batches. When one batch is completed, the equipment is reprogrammed to process the next batch. With flexible automation, different products can be made at the same time on the same manufacturing system. This feature allows a level of versatility that is not available in pure programmable automation, as we have defined it. This means that products can be produced on a flexible system in batches if that is desirable, or several different product styles can be mixed on the system. The computational power of the control computer is what makes this versatility possible.

The features of flexible automation can be summarized as follows:

- High investment for a custom-engineered system
- Continuous production of variable mixtures of products
- Medium production rates'
- Flexibility to deal with product design variations.

Advantages:

1. Continuous production of variable mixtures of product.
2. Flexible to deal with product design variation.

Disadvantages:

1. Medium production rate
2. High investment.
3. High 'unit cost relative to fixed automation.

(b) FOUR TYPES OF ROBOT CONTROLS:

Commercially available industrial robots can be classified into four categories according to their control systems. The four categories are:

- Limited-sequence robots or Non-servo control robots
- Playback robots with point-to-point control. or Servo control robots
- Playback robots with continuous path control or Servo control robots

- Intelligent robots

Of the four categories, the limited-sequence robots represent the lowest level of control and the intelligent robots are the most sophisticated.

Limited-sequence robots do not use servo-control to indicate relative positions of the joints. Instead, they are controlled by setting limit switches and/or mechanical stops to establish the endpoints of travel for each of their joints. Establishing the positions and sequence of these stops involves a mechanical setup of the manipulator rather than robot programming in the usual sense of the term. With this method of control, the individual joints can only be moved to their extreme limits of travel. This has the effect of severely limiting the number of distinct points that can be specified in a program for these robots. The sequence in which the motion cycle is played out is defined by a pegboard or stepping switch or other sequencing device. This device, which constitutes the robot controller, signals each of the particular actuators to operate in the proper succession. There is generally no feedback associated with d limited sequence robot to indicate that the desired position has been achieved. Any of the three drive systems can be used with this type of control system; however, pneumatic drive seems to be the type most commonly employed. Applications for this type of robot generally involve simple motions, such as pick-and-place operations.

Playback robots use a more sophisticated control unit in which a series of positions or motions are "taught" to the robot, recorded into memory, and then repeated by the robot under its own control. The term "playback" is descriptive of this general mode of operation. The procedure of teaching and recording into memory is referred to as programming the robot. Playback robots usually have some form of servo-control (e.g., closed loop feedback system) to ensure that the positions achieved by the robot are the positions that have been taught.

Playback robots can be classified into two categories: point-to-point (PTP) robots and continuous-path (CP) robots. Point-to-point robots are capable of performing motion cycles that consist of a series of desired point locations and related actions. The robot is taught each point, and these points are recorded into the robot's control unit. During playback, the robot is controlled to move from one point to another in the proper sequence. Point-to-point robots do not control the path taken by the robot to get from one point to the next. If the programmer wants to exercise a limited amount of control over the path followed, this must be done by programming a series of points along the desired path. Control of the sequence of positions is quite adequate for many kinds of applications, including loading and unloading machines and spot welding.

Continuous-path robots are capable of performing motion cycles in which the path followed by the robot is controlled. This is usually accomplished by making the robot move through a series of closely spaced points which describe the desired path. The individual points are defined by the control unit rather than the programmer: Straight line motion is a common form of continuous-path control for industrial robots. The programmer specifies the starting point and the end point of the path, and the control unit calculates the sequence of individual points that permit the robot to follow a straight line trajectory. Some robots have the capability to follow a smooth, curved path that has been defined by a programmer who manually moves the arm through the desired motion cycle. To achieve continuous-path control to more than a limited extent requires that the controller unit be capable of storing a large number of individual point locations that define the compound curved path. Today this usually involves the use of a digital computer (a microprocessor is typically used as the central processing unit for the computer) as the robot controller. CP control is required for certain types of industrial applications such as spray coating and arc welding.

Intelligent robots constitute a growing class of industrial robot that possesses the capability not only to play back a programmed motion cycle but to also interact with its environment in a way that seems intelligent. Invariably, the controller unit consists of a digital computer or similar devices (e.g., programmable controller). Intelligent robots can alter their programmed cycle in response to conditions that occur in the workplace. They can make logical decisions based on sensor data received from the operation. The robots in this class have the capacity to communicate during the work cycle with humans or computer-based systems. Intelligent robots are usually programmed using an English-like and symbolic language not unlike a computer programming language. Indeed, the kinds of applications that are performed by intelligent robots rely on the use of a high-level language to accomplish the complex and sophisticated activities that can be accomplished by these robots. Typical applications for intelligent robots are assembly tasks and arc-welding operations.

3.(a)

Characteristics	**DC Motors**	**Stepper Motors**
Control characteristics	Simple; no extras needed	Simple; microcontroller needed
Speed Range	Moderate	Low (200-2000 RPMs)
Reliability	Moderate	High
Efficiency	Average	Low
Torque/speed characteristics	High torque at low speeds	Maximum torque at low speeds
Cost	Low	Low

(b)

Tachogenerators

A sensor that converts speed of rotation directly into an electrical signal is called a tachogenerator. It is used to convert angular speed into a directly dependent voltage signal.

Toothed Rotor Variable Reluctance Tachogenerator

This is used to measure angular velocity. This tachogenerator consists of a metallic toothed rotor mounted on the shaft whose speed is to be measured. A magnetic pickup is placed near the toothed rotor and it consists

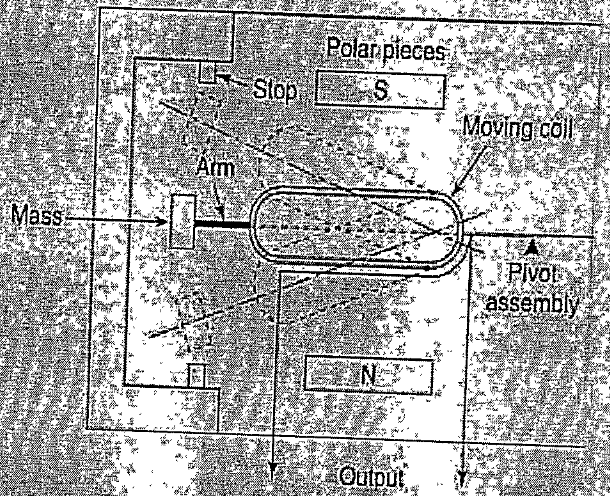


Figure 2.28 | Moving coil type velocity transducer.

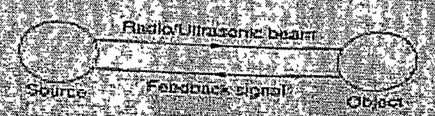


Figure 2.29 | Doppler effect

of housing. The housing contains a small permanent magnet with a coil wound around it, as shown in Figure 2.30.

When the rotor rotates, the reluctance of the air gap between pickup and the toothed rotor changes, the rise in emf is induced in the pickup coil. Finally the output obtained is in the form of pulses and wave shapes. The pulses induced are dependent upon the number of teeth in the rotor and the rotational speed. When the speed is known, the rotational speed is calculated by measuring the frequency pulses.

Suppose the rotor has "n" teeth and number of pulses per second is "p", then the speed of rotation "N" in rps can be calculated as follows:

$$N = \frac{\text{Pulses/second}}{\text{Number of teeth}}$$

$$= \frac{p}{n} \text{ in rps}$$

$$= \frac{p}{n} \times 60 \text{ in rpm}$$

The advantage of toothed rotor variable reluctance tachogenerator is that the information from this device can be easily transmitted and it is easy to calibrate.

AC Tachogenerator

It consists of a rotor which rotates with the rotating shaft and a coil. When the coil rotates in the magnetic field, the emf is induced. The magnet may be in the form of a stationary permanent magnet or an electromagnet. The frequency of this alternating emf is used to measure the angular velocity. The output voltage is rectified and it is measured with a permanent magnet moving coil (PMCC) voltmeter (Figure 2.31).

Figure 2.30 | Toothed rotor tachogenerator

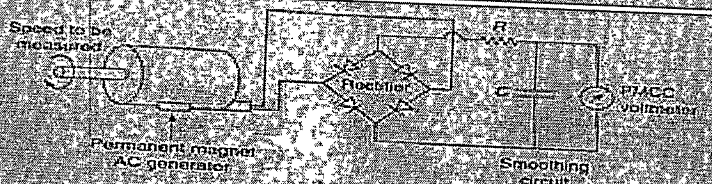


Figure 2.31 | AC tachogenerator

DC Tachogenerators

These use an armature–magnet combination for measuring speed. The armature is connected to the device whose speed is to be measured. As the armature rotates inside the magnetic field, voltage is produced. The polarity of output voltage indicates the direction of rotation. The emf generated is measured with the help of a moving coil voltmeter with a uniform scale calibrated directly in terms of speed (Figure 2.32).

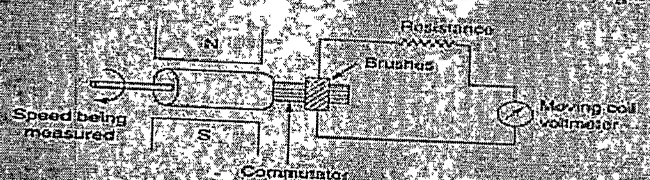


Figure 2.32 | DC Tachogenerator

Advantages of DC Tachogenerator

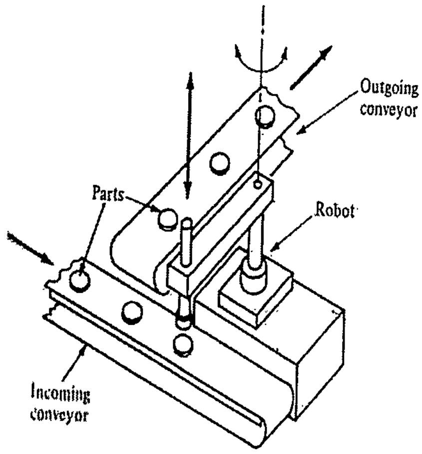
1. Direction of rotation is directly indicated.
2. Conventional-type DC voltmeters are sufficient to use.

4.(a) **MATERIAL TRANSFER APPLICATIONS OF ROBOT:**

Material transfer applications are defined as operations in which the primary objective is to move a part from one location to another location. They are usually considered to be among the most straightforward of robot applications to implement.

Pick-and-Place Operations:

In pick and-place operation, the robot pick up the part at one location and moves it to another location. The part is available to the robot by mechanical feeding device or belt conveyor in a known location and orientation. A simple limit switch is used to stop the component to allow the part to grasp by robot pick up, move with part and position the part at a desired location. The orientation of the part remains unchanged during the travelling. The basic operation are shown in figure. In this case, 2 DOF is involved, one degree of freedom is required to lift the component from pickup point and put it down at the drop-off point and second! DOF is needed to move the part between these two positions. In some cases, a reorientation of the component is accomplished during the move period.



(b) **Assembly operations:**

The term assembly is defined here to mean the fitting together of two or more discrete parts to form a new subassembly. The assembly operations are,

1. Parts presentation methods
2. Assembly tasks
3. Assembly cell designs.

Assembly tasks:

Assembly operations can be divided into two basic categories:

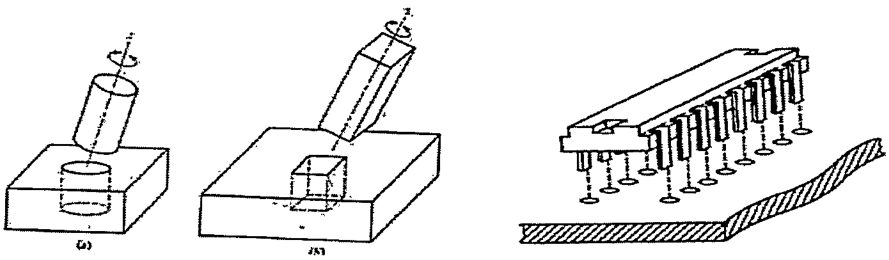
i. parts mating and

ii. parts joining.

i) parts mating :

In parts mating, two (or more) parts are brought into contact with each other.

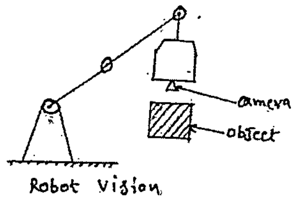
The variety of parts mating operations include the following assembly situations:



1. Peg-in-hole. This operation involves the insertion of one part (the peg) into another part (the hole). It represents the most common assembly task.

Inspection operations:

Inspection is a quality control operation that involves the checking of parts, assemblies, or products for conformance to certain criteria generally specified by the design engineering department. The inspection function is commonly done for incoming raw materials at various stages of the production process, and at the completion of manufacturing prior to shipping the product. Testing is another quality control operation often associated with inspection. The distinction between the two terms is that testing normally involves the functional aspects of the product, such as testing to ensure that the product operates properly, fatigue testing, environmental testing, and similar procedures.



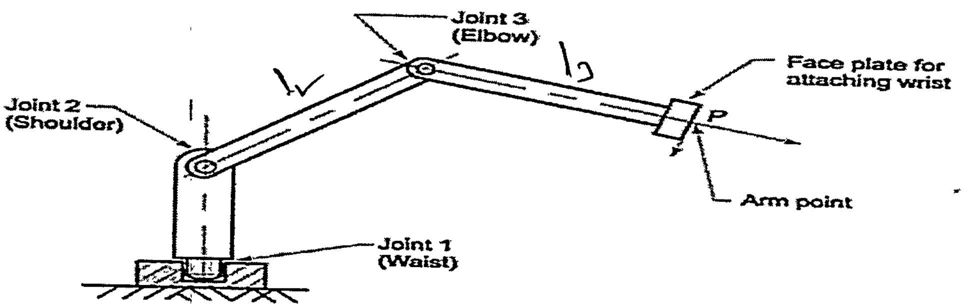
Robotics can be used to accomplish inspection or testing operations for mechanical dimensions and other physical characteristics, and product function and performance. Generally the robot must work with other pieces of equipment in order to perform the operations. Examples include machine vision systems, robot manipulated inspection and/or testing equipment, and robot loading and unloading operation with automatic test equipment. The following subsections will discuss these three categories of robotic inspection systems.

5.(a) Homogeneous Transformation Matrix

$$T = \left[\begin{array}{c|c} \text{Rotation matrix} & \text{Translation vector} \\ (3 \times 3) & (3 \times 1) \\ \hline \text{Perspective} & \text{Scale factor} \\ \text{transformation matrix} & (1 \times 1) \\ (1 \times 3) & \end{array}\right]$$

(b)

An articulated arm is a 3-DOF-manipulator with three revolute joints, that is an RRR arm configuration as shown in Fig. 3.15. The axes of joint 2 and joint 3 are parallel and axis of joint 1 is perpendicular to these two. At the end of the arm, a faceplate is provided to attach the wrist.



A 3-DOF articulated arm with three revolute joints

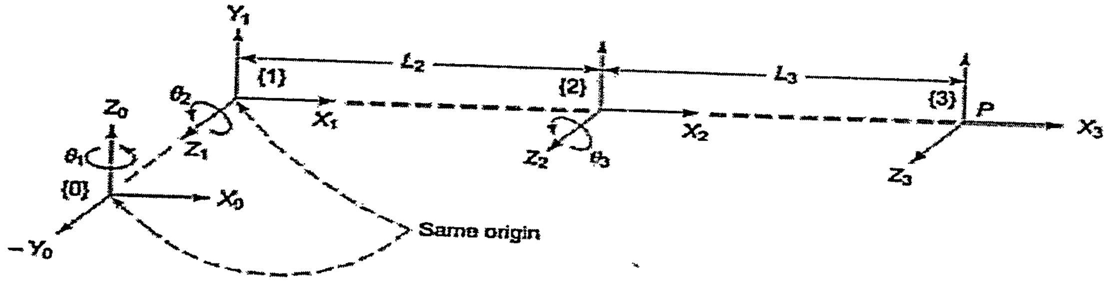


Fig. 3.16 *Frame assignment for articulated arm*

Table 3.3 *Joint-link parameters for articulated arm*

1	0	90°	0	θ_1	θ_1	0	1
2	L_2	0	0	θ_2	θ_2	1	0
3	L_3	0	0	θ_3	θ_3	1	0

$$
{}^0T_1 = {}^0T_1\,{}^1T_2\,{}^2T_3 = \begin{bmatrix} C_1C_{23} & -C_1S_{23} & S_1 & C_1(L_3C_{23}+L_2C_2) \\ S_1C_{23} & -S_1S_{23} & -C_1 & S_1(L_3C_{23}+L_2C_2) \\ S_{23} & C_{23} & 0 & L_3S_{23}+L_2S_2 \\ 0 & 0 & 0 & 1 \end{bmatrix}
$$

where C_{23} and S_{23} refer to $\cos(\theta_2+\theta_3)$ and $\sin(\theta_2+\theta_3)$, respectively.

6.

The dynamics of a simple manipulator is worked out to illustrate the Lagrange-Euler formulation and to clarify the problems involved in the dynamic modeling. A planar, 2-DOF manipulator with both rotary joints, as shown in Fig. 6.1, is considered and its dynamic model is obtained using direct geometric approach before discussing the general formulation. For the manipulator, coordinate frames {0} and {1}, joint variables θ_1 and θ_2, link lengths L_1 and L_2, and mass of links m_1 and m_2, respectively, are shown in the figure. The mass of each link is assumed to be a point mass located at the center of mass of each link and links are assumed to be slender members. The linear and angular velocities are v_1, v_2, $\dot{\theta}_1$ and $\dot{\theta}_2$, respectively.

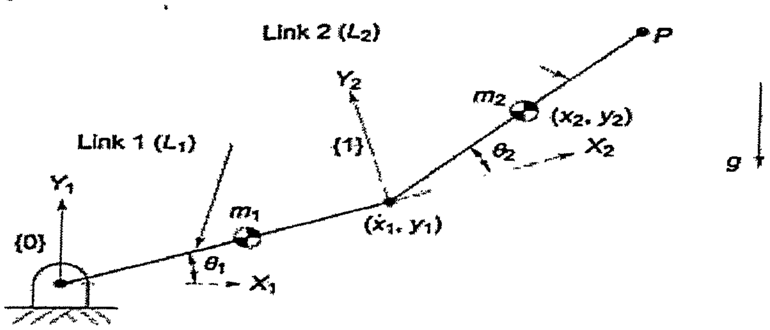


Fig. 6.1 *A 2-DOF planar articulated (RR) arm*

The Lagrangian requires kinetic and potential energies of the manipulator. The kinetic energy of a rigid body (a link), can be expressed as:

$$\mathcal{K} = \frac{1}{2} m v^2 + \frac{1}{2} I \omega^2 \tag{6.3}$$

where v is the linear velocity, ω is the angular velocity, m is the mass, and I is the moment of inertia of the rigid body at its center of mass.

Thus, the kinetic energy for the link 1 with the linear velocity $v_1 = \frac{1}{2} L_1 \dot{\theta}_1$, angular velocity $\omega_1 = \dot{\theta}_1$, moment of inertia $I_1 = \frac{1}{12} m_1 L_1^2$, and mass m_1 is

$$\mathcal{K}_1 = \frac{1}{2} m_1 v_1^2 + \frac{1}{2} I_1 \omega_1^2 = \frac{1}{8} m_1 L_1^2 \dot{\theta}_1^2 + \frac{1}{24} m_1 L_1^2 \dot{\theta}_1^2 = \frac{1}{6} m_1 L_1^2 \dot{\theta}_1^2 \tag{6.4}$$

and its potential energy is

$$\mathcal{P}_1 = \frac{1}{2} m_1 g L_1 \sin \theta_1 \tag{6.5}$$

where g is the magnitude of acceleration due to gravity in the negative y-axis direction.

For the second link, link 2, the Cartesian position coordinates (x_2, y_2) of the center of mass of link are:

$$\begin{aligned} x_2 &= L_1 \cos \theta_1 + \frac{1}{2} L_2 \cos(\theta_1 + \theta_2) \\ y_2 &= L_1 \sin \theta_1 + \frac{1}{2} L_2 \sin(\theta_1 + \theta_2) \end{aligned} \tag{6.6}$$

Differentiating Eq. (6.6) gives the components of velocity of link 2 as

$$\begin{aligned} \dot{x}_2 &= -L_1 \sin \theta_1 \dot{\theta}_1 - \frac{1}{2} L_2 \sin(\theta_1 + \theta_2)(\dot{\theta}_1 + \dot{\theta}_2) \\ \dot{y}_2 &= L_1 \cos \theta_1 \dot{\theta}_1 + \frac{1}{2} L_2 \cos(\theta_1 + \theta_2)(\dot{\theta}_1 + \dot{\theta}_2) \end{aligned} \tag{6.7}$$

From these components, the square of the magnitude of velocity of the end of link 2 is

$$v_2^2 = \dot{x}_2^2 + \dot{y}_2^2$$

or

$$\begin{aligned} v_2^2 = {} & L_1^2 S_1^2 \dot{\theta}_1^2 + \frac{1}{4} L_2^2 S_{12}^2 (\dot{\theta}_1 + \dot{\theta}_2)^2 + L_1 L_2 S_1 S_{12} (\dot{\theta}_1^2 + \dot{\theta}_1 \dot{\theta}_2) \\ & + L_1^2 C_1^2 \dot{\theta}_1^2 + \frac{1}{4} L_2^2 C_{12}^2 (\dot{\theta}_1 + \dot{\theta}_2)^2 + L_1 L_2 C_1 C_{12} (\dot{\theta}_1^2 + \dot{\theta}_1 \dot{\theta}_2) \end{aligned}$$

Simplifying

$$v_2^2 = L_1^2 \dot{\theta}_1^2 + \frac{1}{4} L_2^2 (\dot{\theta}_1 + \dot{\theta}_2)^2 + L_1 L_2 C_2 (\dot{\theta}_1^2 + \dot{\theta}_1 \dot{\theta}_2) \tag{6.8}$$

where $C_i = \cos \theta_i$, $S_i = \sin \theta_i$, $C_{12} = \cos(\theta_1 + \theta_2)$ and $S_{12} = \sin(\theta_1 + \theta_2)$.

Thus, the kinetic energy of link 2 with $\omega_2 = \dot{\theta}_1 + \dot{\theta}_2$ and $I_2 = \frac{1}{12} m_2 L_2^2$ is

$$\mathcal{K}_2 = \frac{1}{2} m_2 v_2^2 + \frac{1}{2} I_2 \omega_2^2$$

$$= \frac{1}{2} m_2 [L_1^2 \dot{\theta}_1^2 + \frac{1}{4} L_2^2 (\dot{\theta}_1 + \dot{\theta}_2)^2 + L_1 L_2 C_2 (\dot{\theta}_1^2 + \dot{\theta}_1 \dot{\theta}_2)]$$

$$+ \frac{1}{24} m_2 L_2^2 (\dot{\theta}_1 + \dot{\theta}_2)^2 \qquad (6.9)$$

$$= \frac{1}{2} m_2 L_1^2 \dot{\theta}_1^2 + \frac{1}{6} m_2 L_2^2 (\dot{\theta}_1^2 + \dot{\theta}_1^2 + 2\dot{\theta}_1 \dot{\theta}_2) + \frac{1}{2} m_2 L_1 L_2 C_2 (\dot{\theta}_1^2 + \dot{\theta}_1 \dot{\theta}_2)$$

The potential energy of link 2, from Eq. (6.6), is

$$\mathcal{P}_2 = m_2 g L_1 S_1 + \frac{1}{2} m_2 g L_2 S_{12} \qquad (6.10)$$

The Lagrangian $\mathcal{L} = \mathcal{K} - \mathcal{P} = \mathcal{K}_1 + \mathcal{K}_2 - \mathcal{P}_1 - \mathcal{P}_2$ is obtained from Eqs. (6.4), (6.5), (6.9), and (6.10). Rearranging and simplifying, the Lagrangian is

$$\mathcal{L} = \frac{1}{2}\left(\frac{1}{3} m_1 + m_2\right) L_1^2 \dot{\theta}_1^2 + \frac{1}{6} m_2 L_2^2 (\dot{\theta}_1{}^2 + \dot{\theta}_2{}^2 + 2\dot{\theta}_1 \dot{\theta}_2) + \frac{1}{2} m_2 L_1 L_2 C_2 (\dot{\theta}_1^2 + \dot{\theta}_1 \dot{\theta}_2) - \left(\frac{1}{2} m_1 + m_2\right) g L_1 S_1 - \frac{1}{2} m_2 g L_2 S_{12} \qquad (6.11)$$

The Lagrange-Euler formulation for link 1, Eq. (6.2), gives the torque τ_1 at joint 1 as

$$\tau_1 = \frac{d}{dt}\left(\frac{\partial \mathcal{L}}{\partial \dot{\theta}_1}\right) - \frac{\partial \mathcal{L}}{\partial \theta_1} \qquad (6.12)$$

The Lagrangian in Eq. (6.11) is differentiated wrt θ_1 and $\dot{\theta}_1$ to give

$$\frac{\partial \mathcal{L}}{\partial \theta_1} = -\left(\frac{1}{2} m_1 + m_2\right) g L_1 C_1 - \frac{1}{2} m_2 g L_2 C_{12} \qquad (6.13)$$

and
$$\frac{\partial \mathcal{L}}{\partial \dot{\theta}_1} = \left(\frac{1}{3} m_1 + m_2\right) L_1^2 \dot{\theta}_1 + \frac{1}{3} m_2 L_2^2 (\dot{\theta}_1 + \dot{\theta}_2)$$

$$+ \frac{1}{2} m_2 L_1 L_2 C_2 (2\dot{\theta}_1 + \dot{\theta}_2) \qquad (6.14)$$

Differentiating Eq. (6.14) wrt time

$$\frac{d}{dt}\left(\frac{\partial \mathcal{L}}{\partial \dot{\theta}_1}\right) = \left[\left(\frac{1}{3} m_1 + m_2\right) L_1^2 + \frac{1}{3} m_2 L_2^2 + m_2 L_1 L_2 C_2\right] \ddot{\theta}_1$$

$$+ m_2 \left[\frac{1}{3} L_2^2 + \frac{1}{2} L_1 L_2 C_2\right] \ddot{\theta}_2 - m_2 L_1 L_2 S_2 \dot{\theta}_1 \dot{\theta}_2 - \frac{1}{2} m_2 L_1 L_2 S_2 \dot{\theta}_2^2 \qquad (6.15)$$

Substituting the results of Eqs. (6.13) and (6.15) into Eq. (6.12), the torque at joint 1 is obtained as

$$\tau_1 = \left[\left(\frac{1}{3}m_1 + m_2\right)L_1^2 + \frac{1}{3}m_2L_2^2 + m_2L_1L_2C_2\right]\ddot{\theta}_1$$
$$+ m_2\left[\frac{1}{3}L_2^2 + \frac{1}{2}L_1L_2C_2\right]\ddot{\theta}_2 - m_2L_1L_2S_2\dot{\theta}_1\dot{\theta}_2 - \frac{1}{2}m_2L_1L_2S_2\dot{\theta}_2^2$$
$$+ \left(\frac{1}{2}m_1 + m_2\right)g\,L_1C_1 + \frac{1}{2}m_2g\,L_2C_{12} \qquad (6.16)$$

Similarly, the derivatives of Lagrangian, Eq. (6.11), for joint 2 are

$$\frac{\partial \mathcal{L}}{\partial \theta_2} = -\frac{1}{2}m_2L_1L_2S_2(\dot{\theta}_1^2 + \dot{\theta}_1\dot{\theta}_2) - \frac{1}{2}m_2gL_2C_{12} \qquad (6.17)$$

and

$$\frac{\partial \mathcal{L}}{\partial \dot{\theta}_2} = \frac{1}{3}m_2L_2^2(\dot{\theta}_1 + \dot{\theta}_2) + \frac{1}{2}m_2L_1L_2C_2\dot{\theta}_1 \qquad (6.18)$$

and

$$\frac{d}{dt}\left(\frac{\partial \mathcal{L}}{\partial \dot{\theta}_2}\right) = \left[\frac{1}{3}m_2L_2^2 + \frac{1}{2}m_2L_1L_2C_2\right]\ddot{\theta}_1 + \frac{1}{3}m_2L_2^2\ddot{\theta}_2 - \frac{1}{2}m_2L_1L_2S_2\dot{\theta}_1\dot{\theta}_2 \qquad (6.19)$$

Again from Eq (6.12),

$$\tau_2 = m_2\left[\frac{1}{3}L_2^2 + \frac{1}{2}L_1L_2C_2\right]\ddot{\theta}_1 + \frac{1}{3}m_2L_2^2\ddot{\theta}_2$$
$$+ \frac{1}{2}m_2L_1L_2S_2\dot{\theta}_1^2 + \frac{1}{2}m_2gL_2C_{12} \qquad (6.20)$$

Equations (6.16) and (6.20) are the EOM (dynamic model) of the 2-link planar manipulator. Because both the joints are revolute, the generalized torques τ_1 and τ_2 represent the actual joint torques.

Torque equation, Eqs. (6.16) and (6.20) can be written in the generalized form, which will be described in Section 6.4, as

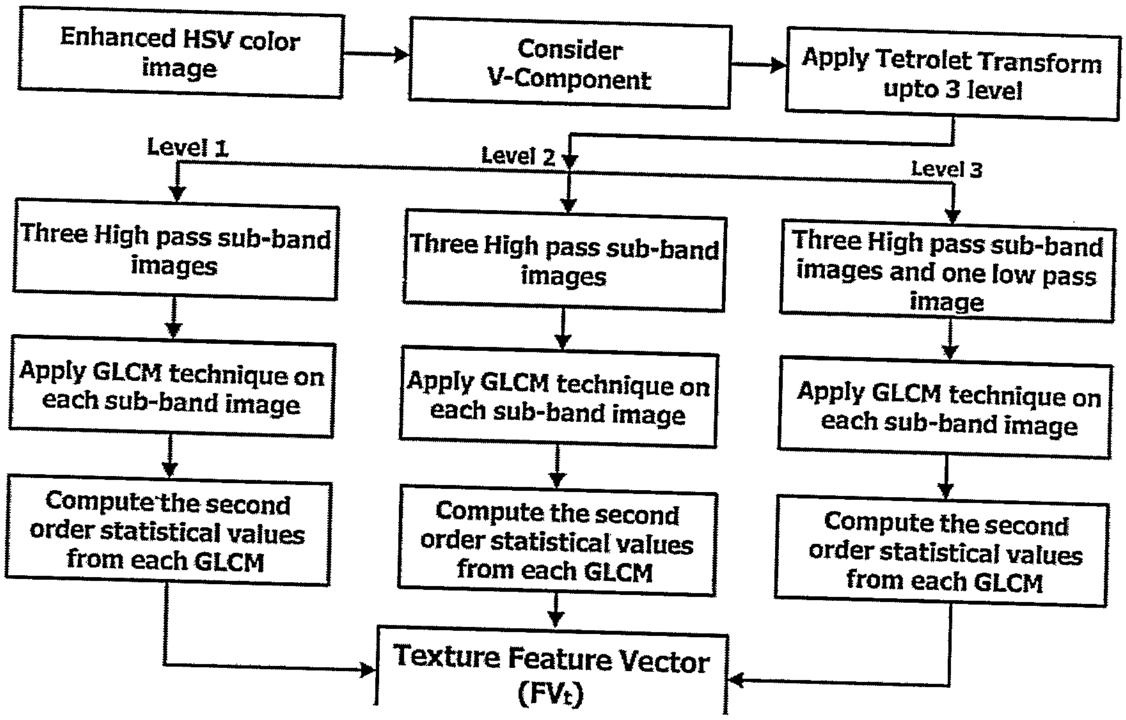
$$\begin{aligned}\tau_1 &= M_{11}\ddot{\theta}_1 + M_{12}\ddot{\theta}_2 + H_1 + G_1\\ \tau_2 &= M_{21}\ddot{\theta}_1 + M_{22}\ddot{\theta}_2 + H_2 + G_2\end{aligned} \qquad (6.21)$$

7.(a) 1.Description of Task

2. Select proper trajectory planning Technique

3. computing tajactory plan

(b)


Enhanced HSV color image
Consider V-Component
Apply Tetrolet Transform upto 3 level
Level 1
Level 2
Level 3
Three High pass sub-band images
Three High pass sub-band images
Three High pass sub-band images and one low pass image
Apply GLCM technique on each sub-band image
Apply GLCM technique on each sub-band image
Apply GLCM technique on each sub-band image
Compute the second order statistical values from each GLCM
Compute the second order statistical values from each GLCM
Compute the second order statistical values from each GLCM
Texture Feature Vector (FV_t)

NARASARAOPETA ENGINEERING COLLEGE (AUTONOMOUS)

Subject Code: R16CC41OE14

Date: 23-03-2021

IV B.TECH I SEMESTER REGULAR, MARCH – 2021

ROBOTICS (OPEN ELECTIVE – III) – – – – KEY

(ME)

Max. Marks: 60

1.

a. **What are the Laws of Robots?**

Ans. Asimov's Three Laws are as follows:

- A robot may not injure a human being or, through inaction, allow a human being to come to harm.
- A robot must obey the orders given it by human beings except where such orders would conflict with the First Law.
- A robot must protect its own existence as long as such protection does not conflict with the First or Second Laws.

b. **What are the major difficulties of using sensors?**

Ans. A servo motor is a type of motor that can rotate with great precision. Normally this type of motor consists of a control circuit that provides feedback on the current position of the motor shaft, this feedback allows the servo motors to rotate with great precision. If you want to rotate an object at some specific angles or distance, then you use a servo motor. It is just made up of a simple motor which runs through a servo mechanism. If motor is powered by a DC power supply then it is called DC servo motor, and if it is AC-powered motor then it is called AC servo motor. For this tutorial, we will be discussing only about the DC servo motor working. Apart from these major classifications, there are many other types of servo motors based on the type of gear arrangement and operating characteristics. A servo motor usually comes with a gear arrangement that allows us to get a very high torque servo motor in small and lightweight packages. Due to these features, they are being used in many applications like toy car, RC helicopters and planes, Robotics, etc

c. **Enumerate robot applications in automotive industry.**

Ans. Robot vision, spot and arc welding, Assembly, Painting, sealing and coating, Machine tending, part transfer, Material Removal, Internal Logistics, etc.

d. **Differentiate Forward and Inverse Kinematics**

Ans.

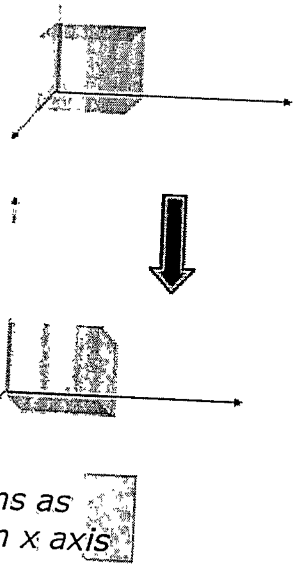
Joint Variables ——> Pose of the End effector of a Robotic Arm = Forward Kinematics

Pose of the End effector of a Robotic Arm ——> Joint Variables = Inverse Kinematics

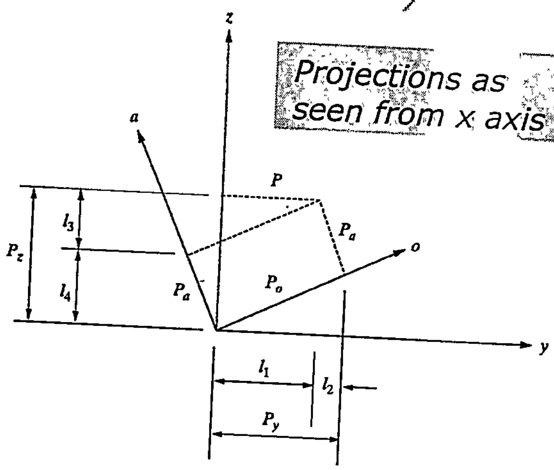
e. Explain the rotation matrix w.r.t. X-Axis with a neat sketch.

➢ 3D ROTATIONS – (ii) Rotation about x-axis
Similarly we can obtain rotation matrix about x-axis

$$[T_{Rx}] = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & \cos\vartheta & \sin\vartheta & 0 \\ 0 & -\sin\vartheta & \cos\vartheta & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$



Ans.



f. List any four Robot programming languages and mention their field of specialization.

Ans. A robot will require a programming language for describing the operations that are to be done. Recently, there are plenty of robot programming languages available. Among them, five robot languages are commonly and basically used. They are:

RAIL: This language was designed by Automatix for arc welding and inspection purposes.

AML: AML (A Manufacturing Language) is a high level language based on sub routine, which is mainly implemented to manage RS / 1 Assembly Robot, End Effectors Active Force Feedback, and Cartesian Arm with hydraulic motors.

VAL: VAL (Variable Assembly Language) Robot Programming Language is adopted mainly for Unimation Robots for program, managing and monitoring of robot and its components with simple syntax.

AL: Second generation, High Level Code. This language has got the capability to control two Stanford Scheinman and two PUMA 600 arms simultaneously.
RPL: This language has got the capability to control two Stanford Scheinman and two PUMA 600 arms simultaneously.

2.

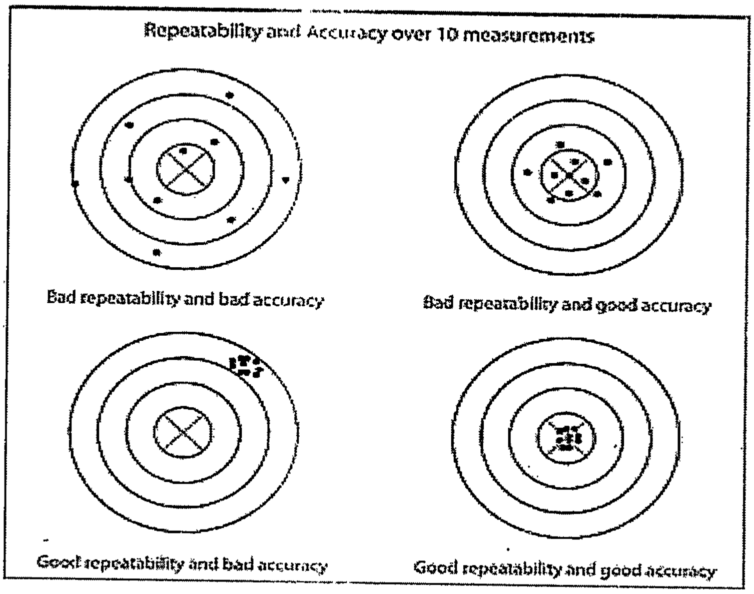
a. What is the importance of automation in Industry? Explain.

Ans. Importance of automation in Industry:

- Affordable and what is more important – cost less than several standalone solutions;
- Can easily substitute for an additional labor force (which might be needed but is not affordable);
- Eliminate most additional expenses (correspondence delivery, faxing, a significant part of travel expenses, etc.)
- Reduces labour cost about many percent.
- Scheduled work according to time which not expect from labour or employees compared to automatic machine or automation.
- Automation in industry gives you exact number of "real time value".
- Produce high-quality goods for the consumers
- Generates a high RO (Return of Investment) for the investors
- Bring safety to the workplace

b. Discuss importance of accuracy in robotics? Explain Precision of movement

Ans. Accuracy is the difference (i.e. the error) between the requested task and the obtained task (i.e. the task actually achieved by the robot). Accuracy is hitting your target each time.



Accuracy are likely to be important to evaluate: path, position and orientation. Robot accuracy is a measure of how close a robot can attain a known position. It is required for systems where the paths are taught offline or if the process requires changing the robot position dynamically using vision or another means.

Robot accuracy is improved when the work zone is defined as localized as possible. It is important to define where in the robot's work envelope the process will take place. This is called the process work zone. A higher level of accuracy is achievable if the process work zone is defined and the calibration is restricted to this zone. When defining a process work zone, there are three considerations to follow. First, the process work zone needs to include all processes that require accuracy. Second, make the zone only as large as the process requires. Third, limit robot configuration (orientation) changes in the process work zone as much as possible.

Different levels of accuracy require different solutions. The required level of robot accuracy determines the number of options and calibration tools required to achieve that accuracy. The more calibration tools required, the more complex and expensive the solution will be.

The combination of position and orientation with the robot's end-effector is called a pose. Furthermore, the pose accuracy generally will have some effect on the path accuracy, which because of its inherent movement is a dynamic characteristic. The pose accuracy and repeatability of the robot are divided into the two previously mentioned components: position and orientation.

The absolute position accuracy is the ability of the robot to reach a specific programmed position with a minimum of error.

Geometrically, the position accuracy of the robot for a given position can be defined as being the distance between the desired position and the centroid position (centroid is the mean position of all the points in all of the coordinate directions) which is actually achieved after repetitive movements of the end-effector toward the original desired position (see the Figure below).

Precision of movement:

Precision of the robot's movement is another measure of performance. It can be defined in three features: **1. spatial resolution 2. Accuracy 3. Repeatability.**

Spatial resolution: Smallest increment of movement into which the robot can divide its work volume. Spatial resolution depends on two factors:
1. Control resolution
2. Mechanical inaccuracies
Number of Increments=2^n

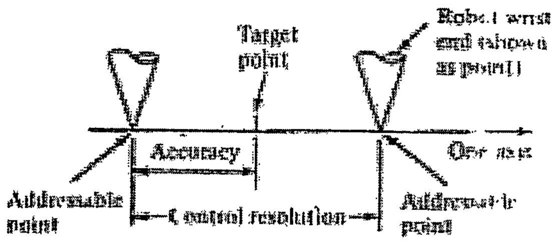
Control resolution: Total motion range divided by the number of increments. To obtain the Control resolution of entire robot, component resolutions for each joint would have to be summed vertically. The total control resolution would depend on the wrist motions as well as the arm and body motions.

Mechanical inaccuracies: Mechanical inaccuracies in the robot's links and joint components and its feedback measurement system constitute the other factor that contributes to spatial resolution.

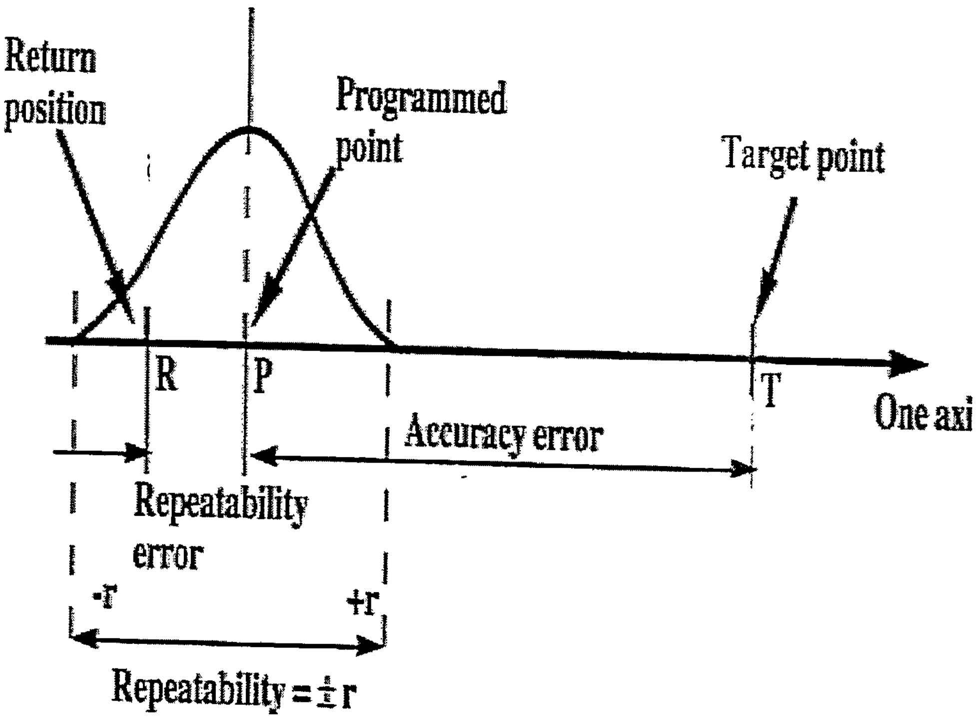
1. Elastic deflection in structural members
2. Gear backlash
3. Stretching of pulley cords
4. Leakage of hydraulic fluids
5. Load handled
6. Speed of arm movement
7. Maintenance

Spatial resolution can be improved by increasing the bit capacity of control memory.

Accuracy: Robot's ability to position its wrist end at a desired target point within the work volume. Robot's accuracy to be one-half of its spatial resolution. Accuracy varies with work volume, worse when target in outer range of its work volume and better when closer to the base. Accuracy is improved if the motion cycle is restricted to a limited work range.



Repeatability: Repeatability is concerned with the robot's ability to position its wrist or an end effectors attached to its wrist at a point in space that had previously been taught to the robot. Repeatability and accuracy refer to two different aspects of the robot precision. Accuracy relates to the robot's capacity to be programmed to achieve a given target point.



3.

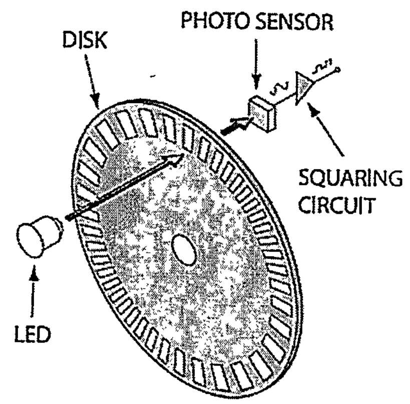
a. **Compare the performance of hydraulic and pneumatic actuators.**
Ans.

	Hydraulics	Pneumatics
Leakage	Contamination	No disadvantages apart from energy loss
Environmental influences	Sensitive in case of temperature fluctuation, risk of fire in case of leakage.	Explosion-proof, insensitive to temperature
Energy storage	Limited, with the help of gases.	Easy
Energy transmission	Up to 100 m, flow rate $v = 2 - 6$ m/s, signal speed up to 1000 m/s.	Up to 1000 m, flow rate $v = 20 - 40$ m/s, signal speed $20 - 40$ m/s.
Operating speed	$v = 0.5$ m/s	$v = 1.5$ m/s
Power supply costs	High	Very high
	1 :	2.5
Linear motion	Simple using cylinders, good speed control, very large forces.	Simple using cylinders, limited forces, speed extremely, load-dependent.
Rotary motion	Simple, high turning moment, low speed.	Simple, inefficient, high speed.
Positioning accuracy	Precision of up to ±1 µm can be achieved depending on expenditure.	Without load change precision of 1/10 mm possible.
Stability	High, since oil is almost incompressible, in addition, the pressure level is considerably higher than for pneumatics.	Low, air is compressible.
Forces	Protected against overload, with high system pressure of up to 600 bar, very large forces can be generated F < 3000 kN.	Protected against overload, forces limited by pneumatic pressure and cylinder diameter F < 30 kN at 6 bar.

b. Explain any one velocity sensor with a neat sketch.

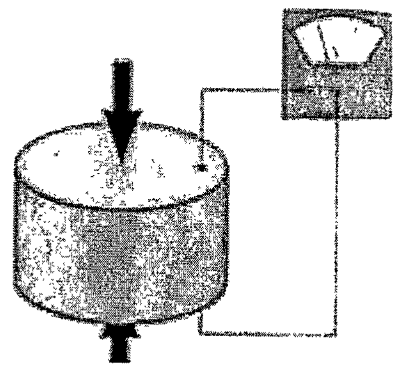
Ans. Different type of velocity sensors are:-- 1)Encoders 2)Tacho-generators 3)Pyroelectic sensors 4)Moving coil type. **Explain any One**

A digital optical encoder is a device that converts motion into a sequence of digital pulses. By counting a single bit or by decoding a set of bits, the pulses can be converted to relative or absolute position measurements. Encoders have both linear and rotary configurations, but the most common type is rotary. Rotary encoders are manufactured in two basic forms: the absolute encoder where a unique digital word corresponds to each rotational position of the shaft, and the incremental encoder, which produces digital pulses as the shaft rotates, allowing measurement of relative position of shaft. Most rotary encoders are composed of a glass or plastic code disk with a photographically deposited radial pattern organized in tracks. As radial lines in each track interrupt the beam between a photo emitter-detector pair, digital pulses are produced.



Tacho-generator: Is used to measure angular velocity Can be of two types: variable reluctance or ac generator The variable reluctance one consist of toothed wheel of ferromagnetic material which is attached to the rotating shaft. As the wheel rotates, the air- gap between the coil and the Ferro-magnet changes. Thus the flux linked by the a pick up coil changes. This result in alternating e.m.f in the coil. If the coil has n teeth and rotates with angular velocity w, then the flux and the induced voltage

Piezoelectric sensors: A piezoelectric sensor is device that uses the piezoelectric effect to measure the changes in velocity converting to electric quantity



Moving COIL Type: velocity transducer/sensor consists of a moving coil suspended in the magnetic field of a Permanent magnet. The velocity is given as the input, which causes the movement of the coil in the magnetic field. This causes an e.m.f to be generated in the coil. This induced e.m.f will be proportional to the input velocity and thus, is a measure of the velocity

c. Describe the suitable type of position sensor with a neat sketch.

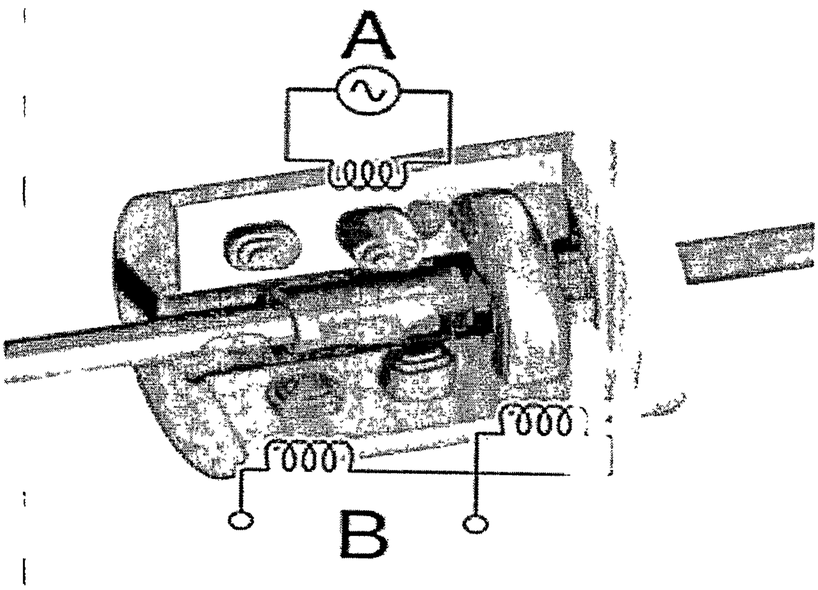
Ans. Position sensors use different sensing principles to sense the displacement of a body. Depending upon the different sensing principles used for position sensors, they can be classified as follows:

1. Resistance-based or Potentiometric Position sensors
2. Capacitive position sensors
3. Linear Voltage Differential Transformers
4. Magnetostrictive Linear Position Sensor
5. Eddy Current based position Sensor
6. Hall Effect based Magnetic Position Sensors
7. Fiber-Optic Position Sensor
8. Optical Position Sensors **Explain any one among these sensors for sample LVDT given below.**

LINEAR VOLTAGE DIFFERENTIAL TRANSFORMER

Linear Variable Differential Transformer commonly known by its acronym, LVDT is an electromechanical transducer which converts rectilinear motion of an object into a corresponding electrical signal. It is used for measuring movements ranging from microns upto several inches.

LVDT consists of a primary winding and a pair secondary windings. Primary winding is sandwiched between the secondary windings. Secondary windings are symmetrically spaced about the primary and are identically wound. The coils are wound on a hollow form of glass reinforced polymer and then secured in a cylindrical stainless steel housing. The windings form the stationary part of the sensor.
The moving element of an LVDT is called the core made of highly permeable magnetic material; the core moves freely axially in the coil's hollow bore. The core is mechanically coupled to the object whose displacement is to be measured.



Graphical Image Showing Insides of a Typical Linear Voltage Differential Transformer

When the primary winding of LVDT is energized by alternating current of suitable amplitude and frequency, AC voltage is induced in the secondary. The output of the LVDT is the differential voltage between the two secondary windings; the differential voltage varies with the position of the core. Often, differential AC output voltage is converted into DC voltage for use in measurement systems.

When primary winding is excited, the voltage induced in the secondary depends upon the coupling of the magnetic flux by the core to the secondary windings. When the core is at the centre, equal flux is coupled to the two secondary windings and hence, the differential voltage output is zero. However, when the core is at off-centre, unequal flux is induced in the secondary windings and the amount of flux in the two windings and hence the differential voltage between the two wingings depend upon the position of the core.

LVDTs offer various advantages like Friction-Free Operation, very high resolution, unlimited mechanical life, high reliability, no cross sensitivity, environmentally rugged, and so on.

For measuring angular motions, a variant of LVDT, i.e, Rotary Voltage Differential Transformer is used. RVDT is exactly similar to LVDT in terms of operation; difference is in their construction.

4.

a. Discuss the role of robots in spot welding.

Ans. Robot spot welding:

Automatic welding imposes specific demands on resistance welding equipment. Often, equipment must be specially designed and welding procedures developed to meet robot welding requirements.

The spot welding robot is the most imortant component of a robotized spotwelding installation. Welding robots are available in various sizes, rated by payload capacity and reach. Robots are also classified by the number of axes. A spot welding gun applies approriate pressure and current to the sheets to be welded. There are different types of welding guns, used for different applications, available. An automatic *weld-timer* initiates and times the duration of current.
During the resistance welding process the welding electrodes are exposed to severe heat and pressure. In time, these factors begin to deform (mushroom) the electrodes. To restore the shape of the electrodes, an automatic *tip-dresser* is used.
One problem when welding with robots is that the cables and hoses used for current and air etc. tend to limit the capacity of movement of the robot wrist. A solution to this problem is the swivel, which permits passage of compressed air, cooling water, electric current and signals within a single rotating unit.
The swivel unit also enables off-line programming as all cables and hoses can be routed along defined paths of the robot arm.
A robot can repeatedly move the welding gun to each weld location and position it perpendicular to the weld seam. It can also replay programmed welding schedules. A manual welding operator is less likely to perform as well because of the weight of the gun and monotony of the task. Spot welding robots should have six or more axes of motion and be capable of approaching points in the work envelope from any angle. This permits the robot to be flexible in positioning a welding gun to weld an assembly. Some movements that are awkward for an operator, such as positioning the welding gun upside down, are easily performed by a robot.

b. How robots are used in material handling applications.

Ans. Material Handling Applications Robots are mainly used in three types of applications: material handling; processing operations; and assembly and inspection. In material handling, robots move parts between various locations by means of a gripper type end effector. Material handling activity can be sub divided into material transfer and machine loading and/or unloading.

Material transfer: Main purpose is to pick up parts at one location and place them at a new location. Part reorientation may be accomplished during the transfer. The most basic application is a pick-and-place procedure, by a low-technology robot (often pneumatic), using only up to 4 joints.

More complex is palletizing, where robots retrieve objects from one location, and deposit them on a pallet in a specific area of the pallet, thus the deposit location is slightly different for each object transferred. The robot must be able to compute the correct deposit location via powered lead- through method, or by dimensional analysis.

Other applications of material transfer include de-palletizing, stacking, and insertion operations.

Machine loading and/or unloading: Primary aim is to transfer parts into or out-of a production machine. There are three classes to consider:

- machine loading – where the robot loads the machine

- machine unloading, where the robot unloads the machine
- machine loading and unloading—where the robot performs both actions

Used in die casting, plastic molding, metal machining operations, forging, working, and heat-treating operations.

c. What are future applications of robots?

Ans. Robotics will continue to transform manufacturing in numerous ways, but there are 6 trends in robotic automation that will play a key role in the near future.

1. Adoption of Industrial Internet of Things (IIoT) Technology
2. Industrial Cybersecurity as a Priority
3. Big Data Analysis Becomes a Competitive Differentiator
4. Open Automation Architectures Will Be Implemented
5. Virtual Solutions Will Invade Physical Processes
6. Collaborative Robots Will Continue to Grow in Popularity, etc.

Robotic automation has been a revolutionary technology in the manufacturing sector, but it's still poised to transform the industry over the next couple of years. The six trends above will be some of the most impactful advances in robotic automation in the future.

7.

d. Trajectory planning steps :

Trajectory planning is a subset of the overall problem that is navigation or motion planning. The typical hierarchy of motion planning is as follows:

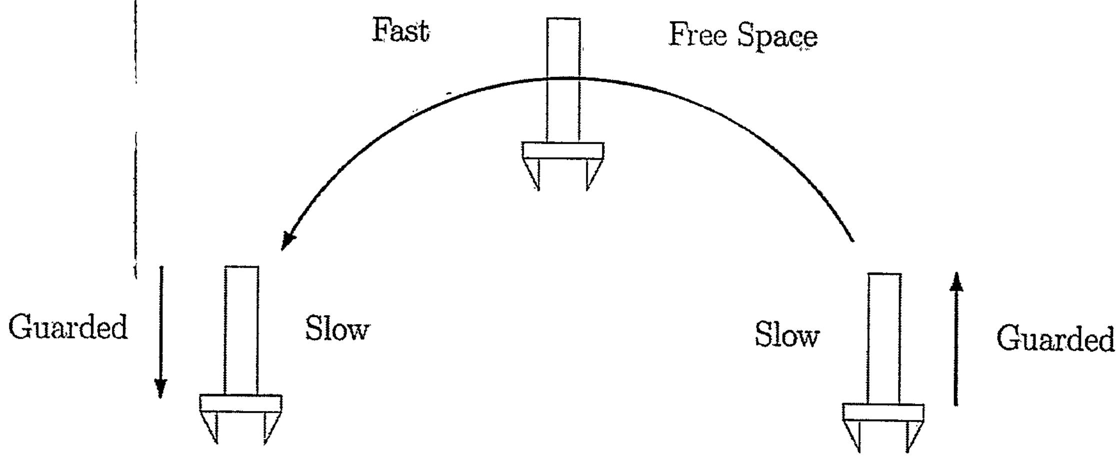
- Task planning – Designing a set of high-level goals, such as "go pick up the object in front of you".
- Path planning – Generating a feasible path from a start point to a goal point. A path usually consists of a set of connected waypoints.
- Trajectory planning – Generating a time schedule for how to follow a path given constraints such as position, velocity, and acceleration.
- Trajectory following – Once the entire trajectory is planned, there needs to be a control system that can execute the trajectory in a sufficiently accurate manner.

We make specifications on:

- Velocity of a motion;
- Acceleration of a motion;
- jerk of a motion; etc

The following path planning strategies exist:

- path constrained (signed path) off-line or on-line path planning with collision avoidance
- position controlled motion with on-line obstacle identification and collision avoidance (without path constraints, i.e. path signs)
- path constrained off-line path planning or on-line pass through the signed path (collisions are possible)
- position controlled motion without obstacle identification (collisions are possible)



b. Explain briefly off-line programming and its advantages.

Off-line Programming:

• Programs can be developed without needing to use the robot
• The sequence of operations and robot movements can be optimized or easily improved
• Previously developed and tested procedures and subroutines can be used
• External sensor data can be incorporated, though this typically makes the programs more complicated, and so more difficult to modify and maintain
• Existing CAD data can be incorporated-the dimensions of parts and the geometric relationships between them, for example.
• Programs can be tested and evaluated using simulation techniques, though this can never remove the need to do final testing of the program using the real robot
• Programs can more easily be maintained and modified
• Programs can more be easily properly documented and commented.

Advantages of Offline Programming

- Reduces downtime required for robot programming. Programs are developed offline, so the robot only has to be halted while the new program is being downloaded and tested.
- Can be quite intuitive, especially if the robot can be moved around in a 3D CAD environment with drag and drop techniques.
- Easy to test many different approaches to the same problem, which would be inefficient for online programming methods.

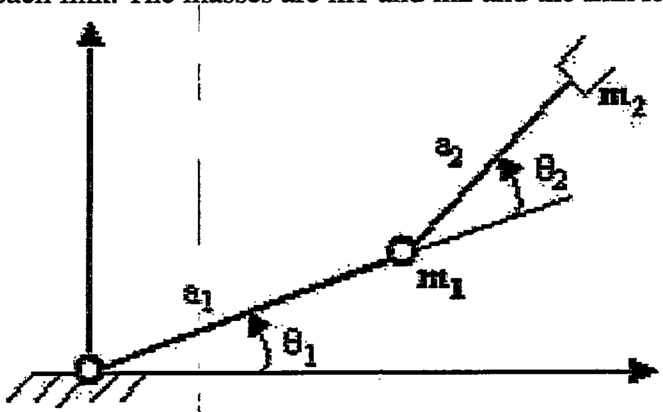
NARASARAOPETA ENGINEERING COLLEGE
(AUTONOMOUS)

IV B.Tech II Semester Regular Examinations, April-2023

Sub Code: 19BME8PE04 **ROBOTICS AND APPLICATIONS**

Time: 3 hours (ME) Max. Marks: 60

Note: Answer All **FIVE** Questions.
All Questions Carry Equal Marks (5 X 12 = 60M)

Q.No		Questions	KL	CO	M
		Unit-I			
1	a	Sketch and explain the four basic robot configurations classified according to the coordinate system.	K2	CO1	12M
		OR			
	b	Determine the transformation matrix T that represents a translation of 'a' units along x-axis, followed by a rotation of β about x-axis and followed by a rotation of Θ about z-axis.	K3	CO1	12M
		Unit-II			
2	a	i) What are the uses of sensor in robotics? Explain the types of sensors used in robotics?	K4	CO2	6M
		ii) Distinguish between External and internal sensors with applications	K4	CO2	6M
		OR			
	b	Discuss the performance characteristics of actuators. Compare electrical, pneumatic & hydraulic actuators for their characteristics	K3	CO2	12M
		Unit-III			
3	a	Determine the manipulator jacobian matrix and singularities for the 3-DOF articulated arm.	K4	CO3	12M
		OR			
	b	Derive the Inverse kinematics of the 3-DOF manipulator by considering an example	K4	CO3	12M
		Unit-IV			
4	a	Determine the dynamic equations for the two-link manipulator shown in Figure 1, using Lagrange-Euler formulation. Assume that the whole mass of the link can be considered as a point mass located at the outermost end of each link. The masses are m1 and m2 and the link lengths are a_1 and a_2.  Figure1	K4	CO4	12M
		OR			
	b	Explain about Newton – Euler formulations by considering an example	K4	CO4	12M

5	Unit-V				
	a	i) Explain the applications of Robot in spot and continuous arc welding	K4	CO5	6M
		ii) What are general considerations in Robot material handling?	K4	CO5	6M
	OR				
	b	i) In which type of production, robots are preferred for loading and unloading function? Explain.	K4	CO5	6M
		ii) Explain use of robot in assembly operation	K4	CO5	6M

KL: Blooms Taxonomy Knowledge Level CO: Course Outcome M:Marks

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Narasaraopeta Engineering College (Autonomous)
Kotappakonda Road, Yellamanda (P.O), Narasaraopet- 522601, Guntur District, AP.

Subject Code: R16CC41OE14

IV B.Tech I Semester Regular & Supple Examinations, November-2022

ROBOTICS (OPEN ELECTIVE-III)

(ME)

Time: 3 hours **Max Marks: 60**

Question Paper Consists of **Part-A** and **Part-B.**
Answering the question in **Part-A** is Compulsory & Four Questions should be answered from Part-B
All questions carry equal marks of 12.

PART-A

1. (a) Write the laws of Robot.
   (b) What do you mean by encoder?
   (c) Mention the applications of Robots in Manufacturing.
   (d) List the various D-H parameters.
   (e) Define Jacobian.
   (f) Differentiate Trajectory planning and path planning.

[2+2+2+2+2+2]

PART-B

4 X 12 = 48

2. Explain the different types robots based on configuration with neat sketches.

3. Discuss the various Actuators used in Robotics with neat sketches.

4. Explain the various future applications of Robots in detail.

5. (a) Explain Homogeneous transformations as applicable to rotation and translation.
   (b) Differentiate Forward and Reverse Kinematics in detail.

6. Derive Euler and Newton forward for a Manipulator.

7. Explain the different types of Robot Programming in detail.

***

Narasaraopeta Engineering College (Autonomous)
Kotappakonda Road, Yellamanda (P.O), Narasaraopet- 522601, Guntur District, AP.

ME

Subject Code: R16CC41OE14

IV B.Tech I Semester Adv. Supplementary Examinations, Feb-2020

ROBOTICS (OPEN ELECTIVE-III)

(ME)

Time: 3 hours | Max Marks: 60

Question Paper Consists of **Part-A** and **Part-B.**

Answering the question in **Part-A** is Compulsory & Four Questions should be answered from Part-B

All questions carry equal marks of 12.

PART-A

1. (a) **Define** work volume of the Robot. Sketch the work volume of a cylindrical robot.
   (b) **Mention** the advantages of brushless DC motors.
   (c) **List out** the applications of Robots in manufacturing domain.
   (d) **Recall** the transformation matrix when a point rotates by an angle of Θ about Y axis.
   (e) **State** the importance of Jacobian matrix in Robotics.
   (f) **What** are the different steps in trajectory planning?

[2+2+2+2+2+2]

PART-B

4 X 12 = 48

2. (a) Illustrate the different types of automation with examples.
   (b) Classify robots based on coordinate system. List out applications for each classification.

3. (a) Explain the working principle of DC motor and list out its advantages and disadvantages.
   (b) Outline the working principle of potentiometer. State its usage in Robots.

4. (a) Justify the role of robots in the automation. Also comment on the challenges faced in incorporating robots.
   (b) Paraphrase the application of Robots in assembly and inspection.

5. Derive the Forward and inverse kinematic equations of a 2R link system.

6. Formulate the Lagrangian model for analysing the dynamics of any one Robot configuration.

7. (a) Define trajectory planning. Write about various methods of trajectory planning.
   (b) Outline the teach pendant method of Robot programming. List out the advantages.

***

Narasaraopeta Engineering College (Autonomous)

Kotappakonda Road, Yellamanda (P.O), Narasaraopet- 522601, Guntur District, AP.

Subject Code: R16CC410E14

IV B.Tech I Semester (Regular/supple) Examinations, (Month, Year)

ROBOTICS

(ME)

Time: 3 hours **Max Marks: 60**

Question Paper Consists of **Part-A** and **Part-B.**

Answering the question in **Part-A** is Compulsory & Four Questions should be answered from Part-B

All questions carry equal marks of 12.

PART-A

1. (a) What are the types of End effectors?
   (b) Explain about Hydraulic actuators.
   (c) Explain in brief about spray painting application in robots.
   (d) What is D-H notation explain in brief?
   (e) What is meant by Jacobian?
   (f) What are the software packages available for robot programming?

[2+2+2+2+2+2]

PART-B

4 X 12 = 48

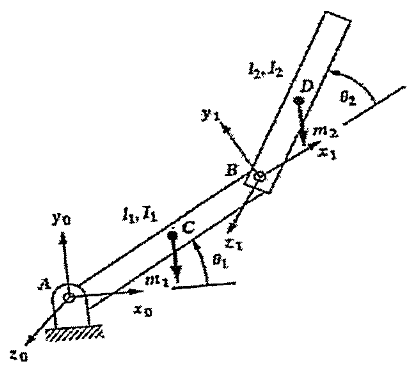
2. (a) What are the basic components of Robot? Explain them briefly with sketch?
   (b) Explain the importance of Robotics in Automation.

3. Explain mechanical grippers and their linkage mechanisms with neat sketches.

4. (a) Explain use of robot in assembly operation.
   (b) Explain application of robot in robot continuous arc welding.

5. (a) What is the role of D-H notation? Explain their importance in solving Forward Kinematics.
   (b) Write homogenous transformation matrices for rotation in 3D.

6. Using Lagrangian method , derive the equations of motion for the two degree of freedom robot arm, shown in figure, the center of mass for each link is at the center of link. The moments of inertia are I_1 and I_2



7. (a) Explain the steps involved in Trajectory planning.
   (b) Discuss the SPEED control commands of Robot languages.

Narasaraopeta Engineering College (Autonomous)
NEC Kotappakonda Road, Yellamanda (P.O), Narasaraopet- 522601, Guntur District, AP.

Subject Code: R16CC410E14

IV B.Tech I Semester (Regular/supple) Examinations, (Month, Year)

ROBOTICS

(ME)

Time: 3 hours **Max Marks: 60**

Question Paper Consists of **Part-A** and **Part-B.**
Answering the question in **Part-A** is Compulsory & Four Questions should be answered from Part-B
All questions carry equal marks of 12.

PART-A

1. (a) **Differentiate** flexible automation and fixed automation.
   (b) **What** do you mean by velocity sensor?
   (c) **Discuss** robot application for welding and machine loading.
   (d) **Differentiate** forward and inverse kinematics.
   (e) **What** is Lagrange – Euler formulations? What are its applications?
   (f) **List** out different robot programming languages.

[2+2+2+2+2+2]

PART-B

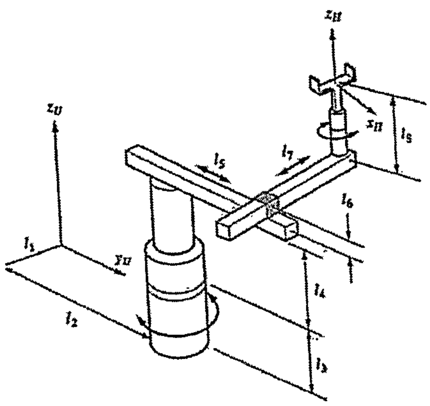
4 X 12 = 48

2. **How** do you specify a robot? Is robotics automation? **Discuss** the different Classification systems of robots.

3. (a) **Compare** stepper motor and D.C. motor drives for a robot.
   (b) **What** are the functions of sensors? **How** do you sense the positional accuracy of a robot? **Describe** the suitable type of sensor used to measure the position.

4. (a) **State** characteristics of work which promote application of robots. **Discuss** robot application for assembly and inspection.
   (b) **What** are the desirable features of a robot for successful machine tool load/unload applications?

5. For the four degree of freedom robot depicted in figure:
   i) Assign appropriate frames for D-H representation.
   ii) Fill out the parameter table containing θ,d,a,α
   iii) write an equation in terms of A matrices that show how $^{U}T_{H}$ can be calculated.



6. **Explain** about Newton – Euler formulations by considering an example.

7. **What** are the common types of motion that a robot manipulator can make in travelling from point to point? **Explain** in detail.

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Code No: RT32034 **R13** **SET - 2**

III B. Tech II Semester Regular/Supplementary Examinations, April - 2017

ROBOTICS

(Mechanical Engineering)

Time: 3 hours Maximum Marks: 70

Note: 1. Question Paper consists of two parts (**Part-A** and **Part-B**)
2. Answering the question in **Part-A** is compulsory
3. Answer any **THREE** Questions from **Part-B**

*****

PART –A

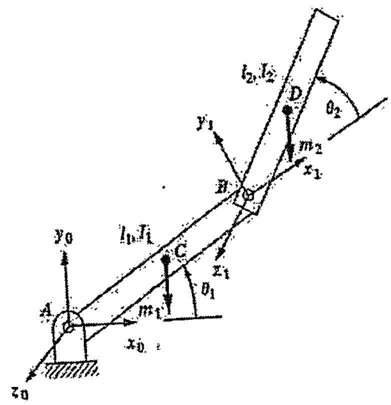
1 a) How do you classify robots by coordinate system? [4M]
b) What are common types of arms? [4M]
c) What is D-H notation explain in brief? [4M]
d) What is the purpose of Differential transformation? [4M]
e) Illustrate and explain joint integrated motion. [3M]
f) What is potentiometer? [3M]

PART -B

2 a) Explain the importance of Robotics in Automation. [8M]
b) Explain about the controllers in detail. [8M]

3 a) Explain about homogeneous Transformations in Robotics kinematics. [8M]
b) Discuss briefly about path control and path generation. [8M]

4 Using Lagrangian method , derive the equations of motion for the two degree of freedom robot arm, shown in figure, the center of mass for each link is at the center of link. The moments of inertia are I_1 and I_2 [16M]



5 a) Explain about importance of Robot Programming lead through programming. [8M]
b) Write about Textual Robot languages programming as a path in space. [8M]

6 What are the types of actuators explain with neat sketch? 16M

7 a) What are general considerations in Robot material handling? [8M]
b) Explain in detail about safety sensors and safety Monitoring. [8M]

*****

Code No: RT32034 | R13 | SET - 3

III B. Tech II Semester Regular/Supplementary Examinations, April- 2017

ROBOTICS

(Mechanical Engineering)

Time: 3 hours | Maximum Marks: 70

Note: 1. Question Paper consists of two parts (**Part-A** and **Part-B**)
2. Answering the question in **Part-A** is compulsory
3. Answer any **THREE** Questions from **Part-B**

*****

PART –A

1 a) Mention some future applications of robots. [4M]
b) What are Requirements and challenges of end effectors? [4M]
c) Differentiate between joint coordinates and world coordinates? [4M]
d) What is Newton – Euler formulations? What are its applications? [4M]
e) Illustrate and explain straight line motion. [3M]
f) Explain about Hydraulic actuators. [3M]

PART -B

2 a) How do you specify a robot? Is robotics automation? Discuss the different classification systems of robots. [8M]
b) Define the terms 'Robot' and 'Robotics'. Discuss the role of robots in engineering [8M]

3 3 Describe about D-H Transformation for a forward Kinematics problems of planar 3 dot manipulator. 16M

4 Draw the block diagram that corresponds to the spring-mass-damper system represented by equations 16M

$$M\frac{d^2y}{dt^2}+K_d\frac{dy}{dt}+K_d=K_sX$$

$$Ms^2Y(s)+ K_dSY(S)+ K_sY(s)= K_sX(s)$$

5 a) Discuss the textural robot language structure with the help of block diagram. [8M]
b) Discuss the relative merits and demerits of different textual robot languages. [8M]

6 How do you classify Tactile sensor? Explain them briefly with neat sketch. 16M

7 a) Define material transfer application? Explain about simple pick and operation with neat sketch. [8M]
b) List out some applications of robot? [8M]

*****

Code No: RT32034 **R13** SET - 1

III B. Tech II Semester Supplementary Examinations, April/May -2019

ROBOTICS

(Mechanical Engineering)

Time: 3 hours Max. Marks: 70

Note: 1. Question Paper consists of two parts (**Part-A** and **Part-B)**
2. Answering the question in **Part-A** is compulsory
3. Answer any **THREE** Questions from **Part-B**

*****

PART –A

1	a)	What is fixed Automation?	[3M]
	b)	What are the disadvantages of hydraulic grippers?	[4M]
	c)	Find the composite rotation matrix representing, a rotation of θ about w-axis.	[4M]
	d)	Differentiate between path planning and trajectory planning.	[4M]
	e)	What is robot software?	[3M]
	f)	Discuss the working principle of Range sensors.	[4M]

PART -B

2	a)	Discuss the anatomy of Robot and explain the important parts of a robot with a neat sketch.	[8M]
	b)	What is the future scope of Robotics? Explain.	[8M]
3	a)	How is a robot end effector specified? Expln.	[8M]
	b)	Explain the special requirements exist for the motors of the mechanical arm.	[8M]
4	a)	Find the D-H matrix for R-R manipulators.	[8M]
	b)	Determine the revolution matrix for a rotation of 45^0 about y-axis followed by a rotation of 120^0 about z-axis, and a final rotation of 90^0 about x-axis.	[8M]
5		Find the manipulated Jacobian matrix(J) of cylindrical robot.	[16M]
6	a)	Define the following commands: (i) WAIT (ii) SIGNAL (iii) DELAY	[8M]
	b)	Explain the functioning of the following textual robot language commands: (i) DMOVE (ii) REACT (iii) CLOSE 40mm	[8M]
7	a)	What are the uses of sensors in robot? Give examples and explain any one.	[8M]
	b)	Explain the applications of robots in continuous arc welding & spray painting.	[8M]

*****

Code No: RT32034 **R13** SET - 1

III B. Tech II Semester Supplementary Examinations, November -2018

ROBOTICS

(Mechanical Engineering)

Time: 3 hours Max. Marks: 70

Note: 1. Question Paper consists of two parts (**Part-A** and **Part-B**)
2. Answering the question in **Part-A** is compulsory
3. Answer any **THREE** Questions from **Part-B**

*****

PART –A

1	a)	Discuss the role of robots in engineering.	[3M]
	b)	Define degree of freedom.	[3M]
	c)	Explain briefly about Eular angles.	[4M]
	d)	What are the challenges of end effectors?	[4M]
	e)	Explain why path planning is required for a robotic system.	[4M]
	f)	Discuss the working principle of Acoustic sensors.	[4M]

PART -B

2	a)	Describe the functions of the robot.	[8M]
	b)	With the help of line diagram explain basic components of a Robot system.	[8M]
3	a)	What are the requirements and challenges of end effectors?	[8M]
	b)	What is meant by Joint gripper? Explain.	[8M]
4	a)	Explain the following i) Euler angles ii) RPY representation	[8M]
	b)	Derive the Inverse kinematics of the 3-DOF manipulator by considering an example.	[8M]
5	a)	Derive the Denavit and Hartenberg 4×4 transformation matrix.	[8M]
	b)	Define and explain a geometric Jacobian.	[8M]
6	a)	Explain the various capabilities and limitations of the robot languages.	[8M]
	b)	Discuss the following categories of program instructions in VAL robot programming: i) Robot configuration control ii) Motion control	[8M]
7	a)	Explain the operation of optical encoder used in robot as a feedback device.	[8M]
	b)	What are essential characteristics of a spot welding manipulator?	[8M]

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Code No: RT32034 **R13** **SET - 1**

III B. Tech II Semester Regular/Supplementary Examinations, April - 2017

ROBOTICS

(Mechanical Engineering)

Time: 3 hours Maximum Marks: 70

Note: 1. Question Paper consists of two parts (**Part-A** and **Part-B**)
2. Answering the question in **Part-A** is compulsory
3. Answer any **THREE** Questions from **Part-B**

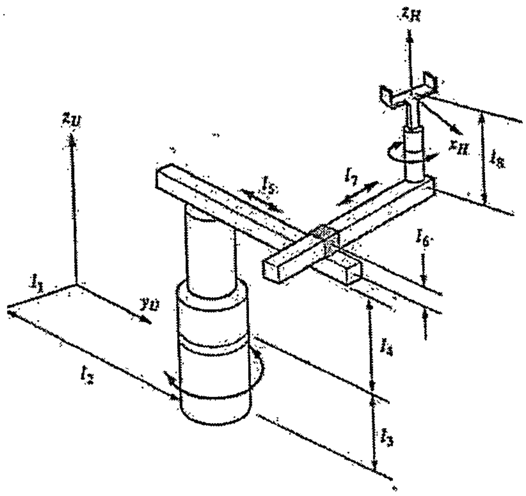
*****

PART –A

1	a)	What is Automation in robotics?	[4M]
	b)	What are degrees of freedom?	[4M]
	c)	What is Forward Kinematics Explain?	[4M]
	d)	What is meant by Jacobian?	[4M]
	e)	Illustrate and explain Skew motion.	[3M]
	f)	Explain in brief about spray painting application in robots.	[3M]

PART -B

2	a)	Explain about Robot anatomy in detail with neat sketch.	[8M]
	b)	What are the future applications of robots?	[8M]
3		For the four degree of freedom robot depicted in figure: i) Assign appropriate frames for D-H representation. ii) Fill out the parameter table containing θ,d,a,α iii) write an equation in terms of A matrices that show how $^{U}T_{H}$ can be calculated	16M]



4		Explain about Newton – Euler formulations by considering an example.	[16M]
5	a)	Explain about programmable logic controller.	[8M]
	b)	Write a brief notes on PLC programming terminals.	[8M]
6	a)	What are the uses of sensor in robotics? What are the types of sensors used in robotics?	[8M]
	b)	Explain about Force sensors with neat sketch.	[8M]
7		Explain about welding operations of robot with neat sketch.	[16M]

*****

Code No: R32032 **R10** **Set No: 1**

III B.Tech. II Semester Regular/Supplementary Examinations, May/June -2014

ROBOTICS

(Mechanical Engineering)

Time: 3 Hours **Max Marks: 75**

Answer any FIVE Questions
All Questions carry equal marks

*****

1. a) Explain the three classes of Automation.
   b) Why robots are to be applied in industries?

2. a) What is work envelope? Show the work envelope of
   i) SCARA robot **ii**) Cartesian robot **iii**) articulated robot **iv**) Cylindrical robot
   b) What is the difference between standard servo and feed forward servo?

3. For the point $P_{xyz}=(8,3,6)^T$ perform following operations
   a). Rotate 60° about the Y-axis followed by translation of 4 units along x-axis?
   b). Rotate 30° about the Z-axis followed by rotation of 60° about X-axis?
   c). Translate 10 units along Z-axis followed by rotation of 45° along Z-axis?

4. Write the steps involved in deriving forward kinematics for any manipulator based on D-H convection?

5. What are singular configurations? Determine Jacobin, singularities and joint velocities for a 3-DOF spherical wrist?

6. Write briefly about Robot programming, languages and software packages?

7. a) Differentiate stepper motor and D.C motor drives of a robot?
   b) Explain the position sensors used in robotics?

8. a). What are the requirements of the robot for spray-coating applications?
   b). Discuss the robotic Inspection system.

*****

Code No: R32032 **R10** **Set No: 2**

III B.Tech. II Semester Regular/Supplementary Examinations, May/June -2014

ROBOTICS

(Mechanical Engineering)

Time: 3 Hours **Max Marks: 75**

Answer any FIVE Questions

All Questions carry equal marks

*****

1. a) Write the present and future applications of robots used in industries.
   b) Write the main characteristics of robot application in industry.

2. a) Explain the architecture of the following robots
   i) jointed arm robot ii) Cartesian robot iii) cylindrical robot iv) spherical robot
   b) With the help of line diagram show basic components of a robot connected to a system?

3. a) Obtain the homogeneous transformation matrix that represents a rotation of 'α' degrees about the current X-axis followed by a translation of 'b' units along the current X-axis, followed by a translation 'd' units along the current Z-axis, followed by a rotation of 'θ' degrees about the current Z-axis?
   b) Explain about equivalent axis & angle representation?

4. Derive the forward kinematics matrix for a SCARA robot arm without wrist?

5. Derive the jacobian matrix and find the linear and angular velocities of the end effector for a planar RR manipulator?

6. a) What is path planning? Explain the need for path planning?
   b) A single cubic trajectory is given by $\theta(t) = 8+10t+45t^2+35t^3$ and is used over the time interval from t =1 to t = 2. What are the initial and final velocities and accelerations?

7. a) Explain the encoders used in robots.
   b) Explain about stepper motors.

8. a) What are the general considerations in selecting a robot for material handling?
   b) Explain the use of robots in inspection of parts.

*****

Code No: R32032 **R10** **Set No: 4**

III B.Tech. II Semester Regular/Supplementary Examinations, May/June -2014

ROBOTICS

(Mechanical Engineering)

Time: 3 Hours **Max Marks: 75**

Answer any FIVE Questions

All Questions carry equal marks

*****

1. a) Give comparison of CAD/CAM and robotics.
   b) Classify robots based on the co-ordinate system and control system with neat diagram.

2. a) Sketch and explain general linkage mechanisms for mechanical grippers.
   b) Give comparison of electric, hydraulic and pneumatic types of locomotion devices.

3. a) Explain Roll-Pitch-Yaw (RPY) transformation with an example?
   b) For the point $P_{xyz} = (0,5,2)^T$ perform following operations i) Rotate 30° about the Y-axis followed by translation of 4 units along z-axis? ii) Translate 6 units along Z-axis followed by rotation of 60° along y-axis?

4. Derive the forward kinematics equation using the D-H convention for the three link planar revolute jointed manipulator (RRR)?

5. What is dynamic modeling? Distinguish the advantages and disadvantages between Euler-Lagrange and Newton-Euler formulation?

6. a) An articulated robot (RRR) is to move all three axes so that the first joint is rotated through 45°, the second joint is rotated through 60° and the third joint is rotated through 45°. Maximum speed of any rotational joints is 15 °/s. Ignore effects of acceleration and deceleration.
   i) Determine the time required to move each joint if skew motion is used?
   ii) Determine the time required to move the arm to the desired position and the rotational velocities of each joint, if joint interpolation motion is used?
   b) Differentiate between path planning and trajectory planning?

7. Explain about robot actuators and feedback components.

8. a) What are the different types of robotic programming techniques? Explain.
   b) Describe material handling operations.

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Code No: R32032 **R10** **Set No: 3**

III B.Tech. II Semester Regular/Supplementary Examinations, May/June -2014

ROBOTICS

(Mechanical Engineering)

Time: 3 Hours **Max Marks: 75**

Answer any FIVE Questions

All Questions carry equal marks

*****

1. a) What are the Laws of Robotics? What are the Thumb Rules on the decision of a robot usage?
   b) Discuss about various special purpose robots?

2. a) Explain the terms resolution, payload, repeatability, degrees of freedom and accuracy of a manipulator.
   b) Explain various types of joints used in robots. What are the design considerations of gripper selection?

3. a) Explain the homogeneous transformation as applicable to rotation?
   b) If a point (8i+5j+6k) is translated 4 units along Y-axis and then rotated 30° about X-axis, obtain the co-ordinates after transformation?

4. Derive the forward kinematics matrix for an articulated robot arm (3-axis) using D-H convention?

5. What is Jacobian? Find the jacobian matrix for 2-link planar RP manipulator and also find its singularities?

6. Derive the expression for the joint torques of a two link planar revolute jointed robotic manipulator using Lagrange-Euler formulation?

7. a) Explain the working principle of pneumatic and hydraulic actuators?
   b) Write a brief notes on feed back components?

8. Describe the applications of robots for the following cases.
   a). Material handling
   b). Continuous arc welding
   c). Loading and unloading

*****

Code No: M0324 **R07** **Set No.1**

IV B.Tech. I Semester Regular Examinations, November, 2011

ROBOTICS

(Mechanical Engineering)

Time: 3 Hours **Max Marks: 80**

Answer any FIVE Questions
All Questions carry equal marks
****

1. a) Give the classification of robots based on [6]
 (i) Coordinate system (ii) control system.
 b) Explain the applications of robots in modern industry. [5]
 c) Explain about flexible automation. [5]

2. a) What are of the advantages and disadvantages of the following grippers? [8]
 (i) Magnetic grippers (ii) Vacuum cups
 b) What the major components of a robot? Explain their main functions. [8]

3. a) What are properties of a rotation matrix? [8]
 b) A coordinate frame {B} is located initially coincident with a coordinate frame {A}. If the frame {B}is rotated through 30 degrees about Z_B and 60 degrees about current Y_B, find the rotation matrix that will describe a vector of frame {B} in frame {A}. [8]

4. a) Represent D-H parameters on a link of robot manipulator and determine them for a two-link planar arm. [8]
 b) Solve the inverse kinematics problem of a three link planar arm. [8]

5. Explain Newton-Euler formulation for a robot arm. [16]

6. a) What are the advantages and disadvantages of trajectory planning in joint – variable space? [5]
 b) A single link rotary robot is required to move from $\theta(0) = 30^0$ to $\theta(2) = 100^0$ in 2 seconds. The joint velocity and acceleration are both zero at the initial and final positions. Determine the coefficients of a quadratic polynomial that accomplishes the motion. [6]
 c) What are different approaches for collision – free path planning? [5]

Code No: M0324 **R07** **Set No.2**

IV B.Tech. I Semester Regular Examinations, November, 2011

ROBOTICS

(Mechanical Engineering)

Time: 3 Hours **Max Marks: 80**

Answer any FIVE Questions
All Questions carry equal marks
****

1. a) Define an industrial robot. [4]
   b) Define workspace of a robot. Explain the classification of robots based on workspace. [6]
   c) Differentiate between fixed and flexible automation. [6]

2. a) Mention the applications of the following types of grippers [8]
   (i) Vacuum cups (ii) Magnetic grippers (iii) Adhesive grippers (iv) Scoops
   b) What are advantages and disadvantages of the following robot drive systems?
   (i) Hydraulic drive systems (ii) pneumatic drive systems [8]

3. a) Show that a rotation matrix is an orthogonal matrix. [6]
   b) Find the transformation matrices for the following operations on the point $2\hat{i} - 5\hat{j} + 4\hat{k}$.
   i) Rotate 60° about x-axis and then translate 4 units along y-axis.
   ii) Translate -6 units along y-axis and rotate 30° about x-axis. [10]

4. Solve the direct kinematics problem of the manipulator shown in Fig.1. [16]

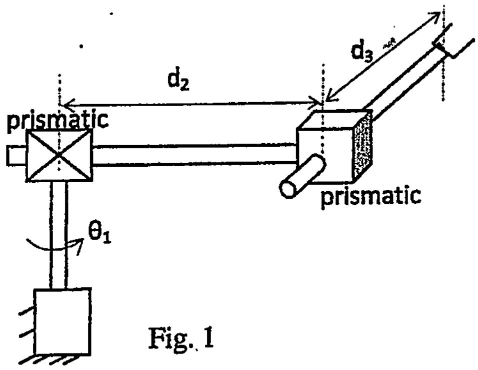

Fig. 1

Code No: M0324 **R07** **Set No.3**

IV B.Tech. I Semester Regular Examinations, November, 2011

ROBOTICS

(Mechanical Engineering)

Time: 3 Hours **Max Marks: 80**

Answer any FIVE Questions
All Questions carry equal marks
****

1. a) What is automation? Explain different types of automation? [10]
   b) Give the applications of robots. [6]

2. a) What is an end effector? Explain different types of grippers. [10]
   b) Differentiate between pneumatic and hydraulic drive systems [6]

3. a) State and prove the properties of a rotation matrix. [8]
   b) A coordinate frame B is initially coincident with coordinate frame A. The frame B is then rotated about the vector $0.707\hat{i} + 0.707\hat{j}$, defined in frame A and Passing through a point (1, 2, 3), through an angle 60 degrees. Give description of the frame B with respect to A. [8]

4. For the link SCARA manipulator shown in Fig. 1, assign the link frames and find the transformation matrix from the end effector to the base. [16]

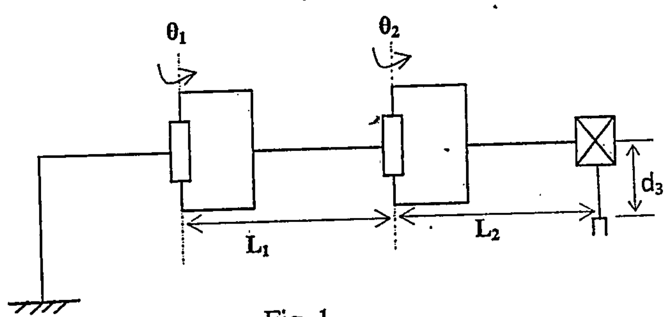

Fig. 1

Code No: M0324 **R07** **Set No.4**

IV B.Tech. I Semester Regular Examinations, November, 2011

ROBOTICS

(Mechanical Engineering)

Time: 3 Hours Max Marks: 80

Answer any FIVE Questions
All Questions carry equal marks
****

1. a) What is the role of an industrial robot in automation? Explain about programmable automation. [10]
   b) What are the basic components of an industrial robot? [6]

2. a) Explain the classification of mechanical grippers according to the type of actuators for finger movement. [8]
   b) Represent the following robot arms with the help line diagrams. [8]
   (i) Spherical arm (ii) anthropomorphic arm (iii) SCARA (iv) PUMA

3. a) A mobile body reference frame OABC is rotated 60^0 about OZ axis of the fixed base reference frame OXYZ. If $P_{xyz} = [-1,2,4]^T$ and $Q_{xyz} = [2, -3, 3]^T$ are the coordinates with respect to OXYZ frame, determine coordinates of P and Q with respect to the OABC frame. [8]
   b) A moving frame, initially coincident with fixed frame, is rotated through an angle α about x-axis, then rotated about current y axis of the moving frame through an angle β and then rotated by an angle γ about the current z axis. Find the transformation matrix between final position of the moving frame and the fixed frame. [8]

4. A spatial PRP manipulator is shown in Fig. 1. Assign the link frames and obtain the D-H parameters. Write direct kinematic equations. The joint variables are d_1, θ_2 and d_3. [16]

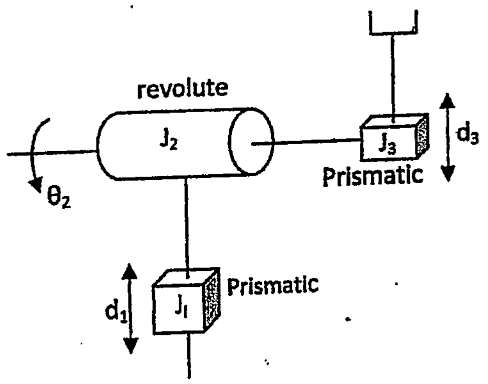

Fig. 1

Code No: M0324 **R07** **Set No. 1**

IV B.Tech. I Semester Supplementary Examinations, February/March, 2012

ROBOTICS

(Mechanical Engineering)

Time: 3 Hours **Max Marks: 80**

Answer any FIVE Questions
All Questions carry equal marks
****

1. (a) What is meant by automation? Explain any type of automation.
   (b) What are different configurations of an industrial robot? Explain them briefly. [8+8]

2. (a) Describe about the basic components of a robot. [8]
   (b) List the advantages and disadvantages of electric drive system compared to hydraulic drive system used in robots. [8]

3. (a) List the properties of rotation matrices. [8]
   (b) A mobile body reference frame OABC is rotated 30^0 about OY axis of the fixed base reference frame OXYZ. If $P_{xyz} = [2,-3,4]^T$ and $Q_{xyz} = [1, 8, -3]^T$ are the coordinates with respect to OXYZ frame, determine coordinates of P and Q with respect to the OABC frame. [8]

4. Find the direct kinematics equation of the four-link closed chain planar arm shown in Fig. 1. The two links connected by the prismatic joint are orthogonal to each other.[16]

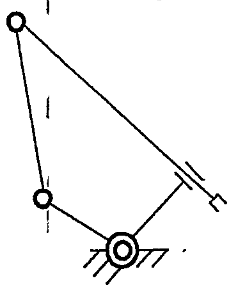

Fig.1

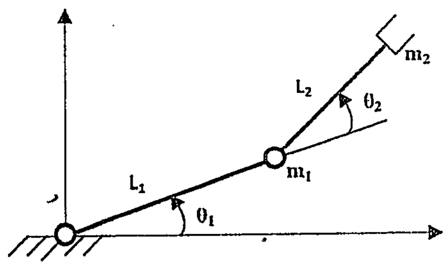

Fig. 2

5. Determine the dynamic equations for the two-link manipulator shown in Fig. 2. Assume that whole mass of the link can be considered as a point mass located at the outermost end of each link. The masses are m_1 and m_2 and the link lengths are L_1 and L_2. [16]

Code No: M0324 **R07** **Set No. 2**

IV B.Tech. I Semester Supplementary Examinations, February/March, 2012

ROBOTICS

(Mechanical Engineering)

Time: 3 Hours Max Marks: 80

Answer any FIVE Questions
All Questions carry equal marks

****

1. (a) Define the term "industrial automation". Explain different types of industrial automation. [10]
   (b) What are the present day applications of robot? [6]

2. (a) What is the function of gripper used in robots? What are the considerations to be made in the selection and design of grippers? [8]
   (b) Give the line diagrams of (i) Articulated robot (ii) SCARA. [8]

3. (a) A coordinate frame {B} is located initially coincident with a coordinate frame {A}. If the frame {B} is rotated through 60 degrees about Z_B and 30 degrees about current X_B, find the rotation matrix that will describe a vector of frame {B} in frame {A}. [8]
   (b) Find the transformation matrices for the following operations on the point $3\hat{i} - 5\hat{j} + 4\hat{k}$.
      i) Rotate 30° about Y-axis and then translate -3 units along Z-axis.
      ii) Translate -4 units along x-axis and rotate 45° about y-axis. [8]

4. Determine the forward kinematic solution for the parallelogram arm shown in Fig.1

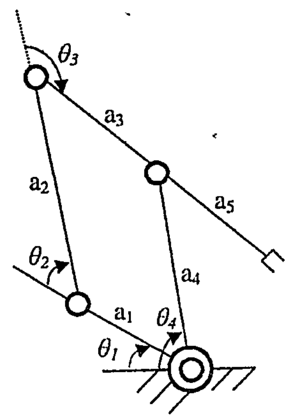

Fig. 1

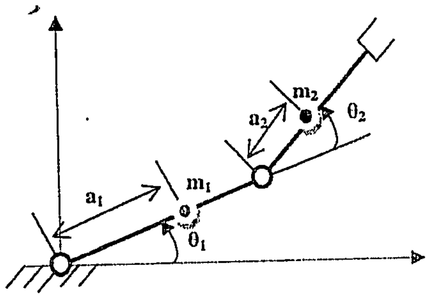

Fig. 2

Code No: M0324 **R07** **Set No. 3**

IV B.Tech. I Semester Supplementary Examinations, February/March, 2012

ROBOTICS

(Mechanical Engineering)

Time: 3 Hours **Max Marks: 80**

Answer any FIVE Questions
All Questions carry equal marks
****

1. (a) Give classification of robots based on control system. [6]
   (b) Explain the following
   i) Programmable automation ii) Flexible automation [10]

2. (a) Explain the classification of mechanical grippers according to the type of actuators for finger movement. [8]
   (b) Differentiate between pneumatic and hydraulic drive systems [8]

3. (a) If $a_{xyz} = [2,1,2]^T$, $b_{xyz} = [6,-2,3]^T$, are the co-ordinates of two points with respect to the reference frame OXYZ, determine the corresponding points with respect to the rotated $OX_1Y_1Z_1$ mobile frame if it has been rotated 30^0 about the OY axis. [8]
   (b) Obtain the rotation matrix corresponding to the set of Euler angles with respect to fixed XZY axes. [8]

4. (a) Show and explain the D-H parameters for i^{th} link in a manipulator. Obtain the transformation matrix from frame i to frame i-1 attached to the ends of i^{th} link in a manipulator in terms of the D-H parameters. [8]
   (b) Obtain the D-H parameters for the manipulator shown in Fig. 1. [8]

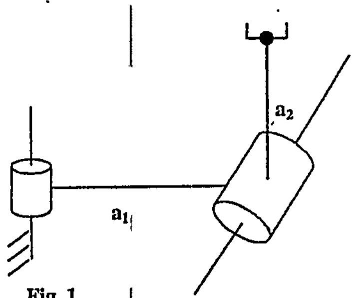

Fig. 1

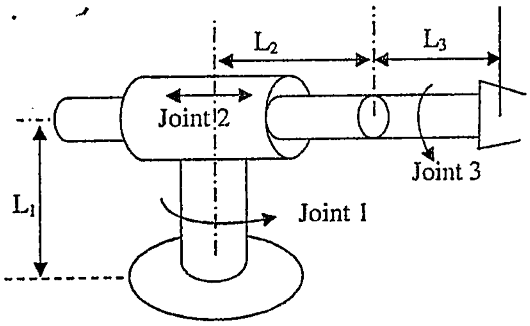

Fig. 2

Code No: M0324 **R07** **Set No. 4**

IV B.Tech. I Semester Supplementary Examinations, February/March, 2012

ROBOTICS

(Mechanical Engineering)

Time: 3 Hours **Max Marks: 80**

Answer any FIVE Questions

All Questions carry equal marks

****

1. (a) Write the Asimov's laws of robotics. [4]
   (b) Differentiate between fixed automation and programmable automation automation. [6]
   (c) Explain about playback robots. [6]

2. (a) Describe about vacuum grippers and Magnetic grippers. [8]
   (b) Give line diagram of a polar coordinate robot and show the associated degrees of freedom and work volume. [8]

3. (a) Find the transformation matrices for the following operations on the point $2\hat{i} + 5\hat{j} - 6\hat{k}$.
      i) Rotate 45° about y-axis and then translate -6 units along x-axis.
      ii) Translate 7 units along x-axis and rotate 60° about z-axis.
      iii) Translate 3 units along z-axis and rotate 30° about y-axis. [9]
   (b) State and prove the properties of a rotation matrix. [7]

4. Determine D-H parameters for a three link planar arm shown in Fig.1. Obtain the forward kinematic solution. [16]

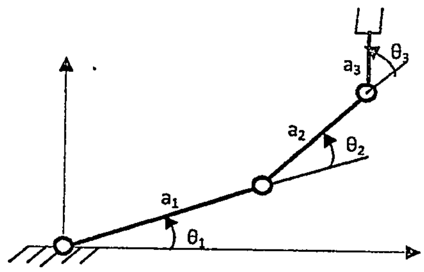

Fig. 1

Code No: M0324/R07

Set No. 1

IV B.Tech I Semester Supplementary Examinations, March 2013

ROBOTICS

(Mechanical Engineering)

Time: 3 hours

Max Marks: 80

Answer any FIVE Questions

All Questions carry equal marks

*****

1. (a) Give and explain the classification of robots by coordinate system with sketches.
   (b) Give and explain the classification of robots by control method. [8+8]

2. (a) A part weighing 8lb is to be held by a gripper using friction against two opposing fingers. The coefficient of friction between the fingers and the part surface is estimated to be 0.3. The orientation of the gripper will be such that the weight of the part will be applied in a direction parallel to the contacting finger surfaces. A fast work cycle is anticipated so that the 'g' factor to be used in force calculations should be 3.0 Compute the required gripper forçe for the specifications given.
   (b) A vacuum gripper is to be designed to handle flat plate glass in an automobile wind shield plant. Each plate weighs 28lb. A single section cup will be used and the diameter of the suction cup is 60in. Determine the negative pressure required (compared to atmospheric pressure of 14.7 lb/sq.in) to lift each plate. Use a safety factor of 1.5 in your computation. [8+8]

3. Discuss the two coordinate systems used in the kinematic analysis of robotic arm with a suitable sketches. [16]

4. (a) Derive rotation in y-z plane and the z-x plane using the geometric approach.
   (b) Derive the rotation formula using vector techniques. [8+8]

5. For a planar RP manipulator, derive the Jacobian matrix and find the linear velocity and angular velocity of the end effector. [16]

6. (a) Using WAIT, SIGNAL and DELAY commands write a program for the press unloading task.
   (b) Using the 8 $\times$ 8 grid of a robot with one rotational axis and one linear axis, show the path taken by the robot if it is directed to move between point (2, 2) and point (7, 5) in the grid using joint interpolation. [8+8]

7. (a) Explain the principles of stepper motor operation.
   (b) What is the resolution of an absolute optical encoder that has six tracks? [8+8]

8. (a) Explain the Robotic parallel Assembly systems.
   (b) Explain the product designing for Robotic assembly. [8

*****

Code No: M0324/R07

Set No. 2

IV B.Tech I Semester Supplementary Examinations, March 2013

ROBOTICS

(Mechanical Engineering)

Time: 3 hours

Max Marks: 80

Answer any FIVE Questions

All Questions carry equal marks

*****

1. (a) What is precision of movement of a robot? Explain the terms special resolution, accuracy and repeatability?
   (b) A robot with single degree of freedom has one sliding joint with a full range of 1.0m. The robot's control memory has a 12-bit storage capacity. Determine the control resolution for this axis of motion. [8+8]
2. (a) Explain the basic definition and operation of mechanical grippers.
   (b) Explain the vacuum cups of grippers. [8+8]
3. Explain Yaw-Pitch-Roll (YPR) transformation with an example. [16]
4. (a) Explain about the forward kinematics.
   (b) Explain about the inverse kinematics. [8+8]
5. Determine Jacobian, Singularties and Joint velocities for a 3 DOF planar area with the revolute joints. [16]
6. (a) Explain the End Effector commands of Robot languages.
   (b) Discuss the Robot program synthesis. [8+8]
7. A dc tachometer is to be used as the velocity feedback device on a certain twisting joint. The joint actuator is capable of driving the joint at a maximum velocity of 0.75 rad/sec and the tachometer constant is 8 V/rad/sec.
   (a) What is the maximum output voltage that can be generated by the device, if the tachometer is geared with the joint so that it rotates with twice the angular velocity of the joint?
   (b) If the joint rotates at a speed of 25^0/sec, determine the output voltage of dc tachometer. [8+8]
8. (a) Discuss the robotic inspection in loading and unloading.
   (b) What characteristics an arc - welding robotic system must have? Explain. [8+8]

*****

Code No: M0324/R07

Set No. 3

IV B.Tech I Semester Supplementary Examinations, March 2013

ROBOTICS

(Mechanical Engineering)

Time: 3 hours

Max Marks: 80

Answer any FIVE Questions

All Questions carry equal marks

*****

1. Sketch any Four of the following robots indicating the joints and degrees of freedom:
   (a) Polar robot
   (b) Cylindrical robot
   (c) Cartesian robot
   (d) SCARA robot
   (e) Gantry robot
   (f) Jointed arm robot. [4+4+4+4]

2. (a) What does the term compliance mean? Explain.
   (b) Describe the two methods used to achieve compliance. [8+8]

3. Consider the forward transformation of the two-joint manipulator shown in figure 3. Given that the length of joint 1, L1=12in, the length of joint 2, L2=10in., the angle $\theta 1=30^0$ and the angle $\theta 2=45^0$, compute the coordinate position (x and y coordinates) for the end-of-the-arm Pw. [16]

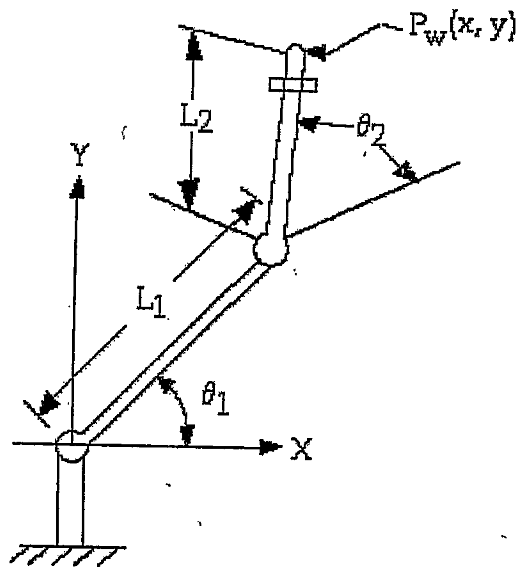

Figure 3

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4. A jointed -arm Robot of configuration VVR is to move all three axes so that the three joints move at different rotational velocities. The first joint moves at 10^0/s, the second joint moves at 25^0/s, and the third joint moves at 30^0/s.
   (a) Determine the time required to move each joint if skew motion is used.
   (b) Determine the time required to move the arm to the new position and the velocity of each joint, if joint-interpolated motion is used. [8+8]

5. Using Lagrange - Euler formulation, derive the expression for the joint Torques or forces of a planar PR Robotic manipulator. [16]

6. (a) Using WAIT, SIGNAL and DELAY commands write a program for the press unloading task.
   (b) Using the 8 × 8 grid of a robot with one rotational axis and one linear axis, show the path taken by the robot if it is directed to move between point (2, 2) and point (7, 5) in the grid using joint interpolation. [8+8]

7. A stepper motor is to be used to actuate one joint of a robot arm in a light duty pick - and - place application. The step angle of the motor is 10^0. For each pulse received from the pulse train source, the motor rotates through a distance of one step angle.
   (a) What is the resolution of the stepper motor ?
   (b) Relate this value to the definitions of control resolution, spatial resolution and accuracy. [4+12]

8. (a) What are the capabilities and features of Robots in spot welding? Explain.
   (b) Discuss the problems for robots in arc welding. [8+8]

*****

Code No: M0324/R07

Set No. 4

IV B.Tech I Semester Supplementary Examinations, March 2013

ROBOTICS

(Mechanical Engineering)

Time: 3 hours

Max Marks: 80

Answer any FIVE Questions

All Questions carry equal marks

*****

1. (a) What is precision of movement of a robot? Explain the terms special resolution, accuracy and repeatability?

   (b) A robot with single degree of freedom has one sliding joint with a full range of 1.0m. The robot's control memory has a 12-bit storage capacity. Determine the control resolution for this axis of motion. [8+8]

2. (a) Explain the basic definition and operation of mechanical grippers.

   (b) Explain the vacuum cups of grippers. [8+8]

3. Discuss the two coordinate systems used in the kinematic analysis of robotic arm with a suitable sketches. [16]

4. Write and explain the arm matrix of SCARA robot. [16]

5. For a planar RP manipulator, derive the Jacobian matrix and find the linear velocity and angular velocity of the end effector. [16]

6. (a) What are the features and capabilities of the second generation languages? Explain.

   (b) Discuss the motion level languages. [10+6]

7. (a) Make a list of internal sensors used in robotic manipulators. Give brief description of their working and uses.

   (b) What is the velocity of the piston and the force generated by the piston in a pneumatic actuator if the fluid pressure is 0.5 Mpa inside the cylinder, the piston is 40 mm in diameter, and the flow rate is 2 cm^3/sec. [8+8]

8. (a) Explain the Robotic parallel Assembly systems.

   (b) Explain the product designing for Robotic assembly. [8+8]

*****

Code No: R32032 **R10** **Set No: 1**

III B.Tech. II Semester Regular Examinations, April/May -2013

ROBOTICS

(Mechanical Engineering)

Time: 3 Hours **Max Marks: 75**

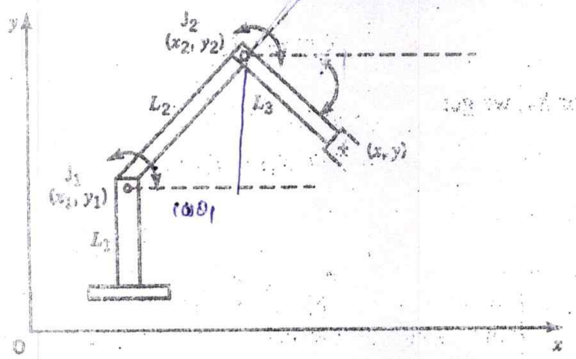
Answer any FIVE Questions

All Questions carry equal marks

*****

1. What do you understand by degree of freedom (DOF)? How many DOFs are required to position an end-effector at any point in 3-D space? Discuss [15]

2. An RR robot has two links of length 0.50 m and 1.0 m, respectively. Assuming that the global coordinate system is defined at joint J_1, determine
(a) The coordinates of the end-effector point if the joint rotations are 45° at both joints as shown in Figure
(b) Joint rotations if the end-effector is located at (1, 4.4, 0.5) [15]



Fig

3. A double acting hydraulic rotary vane or bucket actuator is used for a twist joint in a robot. The outer and inner radius of the vane is 2.5 mm and 0.75 mm respectively. Thickness of the vane is 0.2 mm. The hydraulic power source can generate up to 1000 kg/mm^2 of pressure to delivery to the cylinder at the rate 100 mm^3/min, determine the angular velocity and torque generated by the actuator. Also find the power developed by the hydraulic actuator. [15]

4. Most robots today are programmed by teaching. Why is this type of programming likely to be replaced by preprogramming (off-line programming)? [15]

5. What are the basic rules and procedures followed in the use of robots in assembly? [15]

6. Discuss why recessing the sensor inside the gripper's fingers eliminates the position-ambiguity problem. [15]

7. Determine (a) Jacobian (b) Singularities and (c) Joint velocities for a 3-DOF planar arm with the revolute joints. [15]

8. What is Jacobian matrix? Explain its use in evaluating the velocity of robot.

*****

Code No: R32032 | **R10** | **Set No: 2**

III B.Tech. II Semester Regular Examinations, April/May -2013

ROBOTICS

(Mechanical Engineering)

Time: 3 Hours | **Max Marks: 75**

Answer any FIVE Questions

All Questions carry equal marks

*****

1. Distinguish between servo and non-servo robots. What is the hierarchy of control for servo robots? [15]

2. A point vector is translated in *x, y,* and z directions by a distance of 1, 2, and 1, respectively. Write the transformation matrix for the translation. If the point is (3, 2, 1), determine the position of this point after translation. Afterwards the point vector is rotated about the *x, y,* and z axes by angles of 30°, 45°, and 60°, respectively. Write the transformation matrices for the rotations and also the total transformation matrix from the initial position of (3, 2, 1). Also find the new position of this point. [15]

3. A permanent magnet DC motor is coupled to a load through a gearbox. If the polar moments of inertia of the rotor and load are Jr and J_i , the gearbox has a *N: M* reduction from the motor to the load, the motor has a starting torque Ts and a no-load speed ω_{max}, and the load torque is proportional to its speed $(Ti = k\omega)$,
   (a). What is the maximum acceleration that the motor can produce in the load?
   (b). What is the steady state speed of the motor and the load?
   (c). How long will it take for the system to reach a steady state speed? [15]

4. What are some advantage and disadvantages of teaching-by-building? [15]

5. A vertical hollow cylinder is to be welded to a horizontal hollow cylinder at right angles. The set up is a CO_2 MIG welding interfaced with a robot controller. Describe the robot task and indicate the programming for welding. [15]

6. A new experimental strain gage is mounted on a 0.25 mm diameter steel bar in the axial direction. The gage has a measured resistance of 120 Ω and when the bar is loaded with 500 kg in tension, the gage resistance increases by 0.01 Ω. What is the gage factor of the gage? [15]

7. Compare pneumatic, magnetic and vacuum end effectors. [15]

8. What is a skew symmetric matrix? How this matrix is related to the angular velocity of a link of an n-DOF manipulator. [15]

*****

9:50 to 10:40
10:40 to 11:30
11:30 : 12:20
12:20 : 1:10

Code No: R32032 **R10** **Set No: 3**

III B.Tech. II Semester Regular Examinations, April/May -2013

ROBOTICS

(Mechanical Engineering)

Time: 3 Hours **Max Marks: 75**

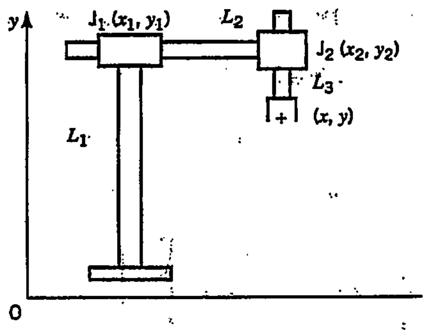
Answer any FIVE Questions

All Questions carry equal marks

*****

1. Bring the relationship between the following the parameters of the robot. [15]
   (a) Resolution (b) Accuracy (c) Repeatability

2. An LL robot has two links of variable length. Assuming that the global coordinate system is defined at joint J_1, determine
   (a) The coordinates of the end-effector point if the variable link lengths are 1 m and 2 m as shown in Figure .
   (b) Variable link lengths if the end-effector is located at (1, 2). [15]



Fig

3. For each of the following applications, what is a good choice for the type of electric motor used? Justify your choice.
   a. Robot arm joint b. Ceiling fan c. Electric trolley
   d. Circular saw e. NC milling machine f. Electric crane
   g. Disk drive head actuator h. Disk drive motor i. Windshield wiper motor
   j. Industrial conveyor motor k. Washing machine l. clothes dryer [15]

4. A robot is to be programmed to unload parts from one pallet and load them onto another pallet. The parts are located on the unload pallet in a 3 by 4 pattern in known fixed positions, 40 mm apart in both directions. The two directions of the pallet are assumed to be parallel to the ex and y world coordinate axes of the robot. The parts are to be placed on the load pallet to the x and y world coordinate axes of the robot. Make a sketch of the workstation setup before you begin programming. [15]

5. If a linear stepper has a pitch of 0.040 mm and micro stepping is used to divide this distance into 400 micro steps (i.e., one micro step moves the motor 0.0001 mm.), what pulse frequency must be applied to the motor to achieve velocities from 0 to 60 mm/s? [15]

6. What is spot welding? Describe briefly the operations involved in robotic spot welding. What are the advantages of robotic welding over manual welding? [15]

7. Explain the suitability of robots in automation and how they will be useful in reducing the manufacturing time. [15]

8. Show that the three differential rotations of δx, δy and δz made in any order about the x-,y-, and z- axes, respectively are equivalent to a differentional rotation of $d\theta$ about axis K. [15]

*****

Code No: R32032 **R10** **Set No: 4**

III B.Tech. II Semester Regular Examinations, April/May -2013

ROBOTICS

(Mechanical Engineering)

Time: 3 Hours **Max Marks: 75**

Answer any FIVE Questions

All Questions carry equal marks

*****

1. What are the basic components of a robotic system? State the main function of each of the components. [15]

2. Two Frames A & B are initially coincident. Frame A is fixed, while Frame B moves according to the following sequence:
i) Rotation about X_A of 30 degrees ii) Rotation about Y_B of 60 degrees
iii) Rotation about Z_A of 90 degrees, and iv) Translation of (1,2,3) along Frame B.
Find the new position and orientation of Frame B in Frame A. (Express this as a homogeneous transformation matrix.) [15]

3. A D.C servo motor is used to actuate speed of a robot joint. It has torque constant of 10mm-kg/A and voltage constant of 12 V/Kr/min (1Kr/min =100r/min) The armature resistance is 2.5 Ω. At a particular moment during the robot cycle, the joint is not moving and a voltage of 25 V is applied to the motor.
(a) Determine a torque of the motor immediately after the voltage is applied.
(b) As the motor accelerates, the effect of back-emf is to reduce the torque determine the back emf and corresponding torque at 250 rpm and 500 rpm.
(c) Sketch a graph between the torque and the speed [15]

4. In a pallet objects protruding 50 mm from the face of the pallet are located in a number of rows and columns. The pallet has 4 rows that are 30 mm apart and 4 columns that are 50 mm apart. The plane of the pallet is assumed to be parallel to the X- Y plane. The rows are parallel to X-axis and the columns are parallel to Y-axis. The objects are to be picked up one after another from the pallet and placed in a location chute. The robot end effector should stop at 70 mm above the pickup point as safe position. Gripper should hold the object at 30 mm from base. Write the program in VAL to pickup the object at left top corner moving towards y axis and then moving to the next columns. What are the basic rules and procedures followed in the use of robots in assembly? [15]

5. A vertical hollow cylinder is to be welded to a horizontal hollow cylinder at right angles. The set up is a CO_2 MIG welding interfaced with a robot controller. Describe the robot task and indicate the programming for welding. [15]

6. A strain gage bridge used in a load cell dissipates energy .Why? Compare the power dissipated in a bridge circuit with equal resistance arms for gages of 350 Ω and 120 Ω when the excitation voltage is 10 V. What strategies can one employ if heating becomes a problem? Do these strategies have any deficiencies? Determine (a) Jacobian (b) Singularities and (c) Joint velocities for a 3-DOF planar arm with the revolute joints. [15]

7. What are the singularities of a manipulator? How are they classified and determined? Explain briefly. [15]

8. Compare pneumatic, magnetic and vacuum end effectors. [15]

*****

Code No: M0324/R07

Set No. 1

IV B.Tech I Semester Regular Examinations, November 2012
ROBOTICS
(Mechanical Engineering)

Time: 3 hours

Max Marks: 80

Answer any FIVE Questions
All Questions carry equal marks
*****

1. (a) Explain about the five types of robot manipulators.
   (b) What factors need to be taken into consideration when selecting a gripper for a particular task? [8+8]

2. (a) A part weighing 8lb is to be held by a gripper using friction against two opposing fingers. The coefficient of friction between the fingers and the part surface is estimated to be 0.3. The orientation of the gripper will be such that the weight of the part will be applied in a direction parallel to the contacting finger surfaces. A fast work cycle is anticipated so that the 'g' factor to be used in force calculations should be 3.0 Compute the required gripper force for the specifications given.
   (b) A vacuum gripper is to be designed to handle flat plate glass in an automobile wind shield plant. Each plate weighs 28lb. A single section cup will be used and the diameter of the suction cup is 60in. Determine the negative pressure required (compared to atmospheric pressure of 14.7 lb/sq.in) to lift each plate. Use a safety factor of 1.5 in your computation. [8+8]

3. (a) What is the rotation matrix for a rotation of 30^0 about OZ axis, followed by a rotation of 60^0 about the OX axis, followed by a rotation of 90^0 about the OY axis?
   (b) Derive the formula for $\sin(\varphi+\theta)$ by expanding symbolically the rotation of φ and θ using the rotation matrix. [8+8]

4. A jointed-arm robot of configuration VVR is to move all three axes so that the first joint is rotated through 50^0, the second joint is rotated through 90^0 and the third joint is rotated through 25^0. Maximum speed of any of these rotational joints is 10^0/s. Ignore effects of acceleration and deceleration.
   (a) Determine the time required to move each joint if skew motion is used.
   (b) Determine the time required to move the arm to the desired position and the rotational velocity of each joint, if joint-interpolated motion is used. [8+8]

5. (a) Discuss about the Jacobians in the force domain.
   (b) Explain the determination of Jacobians with respect to frames attached to different links, when the Jacobian with respect to base frame is given. [8+8]

6. (a) Explain the End Effector commands of Robot languages.
   (b) Discuss the Robot program synthesis. [8+8]

7. A certain dc servometer used to actuate a robot joint has a torque constant of 3 N.m/A and a voltage constant of 15 V/kr/min (1 kr/min = 1000 r/min). The armature resistance is 3Ω. At a particular moment during the robot cycle, the joint is not moving and a voltage of 30 V is applied to the motor.

   (a) Determine the torque of the motor immediately after the voltage is applied.

   (b) Determine the back - emf and the corresponding torque of the motor at 500 and 1000 r/min.

   (c) If there were no resisting torques and no inductance of the armature windings operating to reduce the speed of the motor, determine the maximum theoretical speed of the motor when the input voltage is 30 V. [4+6+6]

8. (a) What are the applications of Robot in pick - and - place operations? Explain.

   (b) Discuss the features and capabilities of robots in spot welding? [8+8]

*****

Code No: M0324/R07

Set No. 2

IV B.Tech I Semester Regular Examinations, November 2012

ROBOTICS

(Mechanical Engineering)

Time: 3 hours

Max Marks: 80

Answer any FIVE Questions

All Questions carry equal marks

*****

1. (a) What is precision of movement of a robot? Explain the terms special resolution, accuracy and repeatability?

   (b) A robot with single degree of freedom has one sliding joint with a full range of 1.0m. The robot's control memory has a 12-bit storage capacity. Determine the control resolution for this axis of motion. [8+8]

2. (a) A part weighing 8lb is to be held by a gripper using friction against two opposing fingers. The coefficient of friction between the fingers and the part surface is estimated to be 0.3. The orientation of the gripper will be such that the weight of the part will be applied in a direction parallel to the contacting finger surfaces. A fast work cycle is anticipated so that the 'g' factor to be used in force calculations should be 3.0 Compute the required gripper force for the specifications given.

   (b) A vacuum gripper is to be designed to handle flat plate glass in an automobile wind shield plant. Each plate weighs 28lb. A single section cup will be used and the diameter of the suction cup is 60in. Determine the negative pressure required (compared to atmospheric pressure of 14.7 lb/sq.in) to lift each plate. Use a safety factor of 1.5 in your computation. [8+8]

3. Draw and explain with an example the Composite rotations algorithm. [16]

4. Consider the Unimation PUMA 200 manipulator. This is a six-axis articulated robot with a roll-pitch-roll type of spherical wrist. Assign link coordinates using the first half of the D-H algorithm. Label the diagram with a's and d's as appropriate. [16]

5. Using Lagrange - Euler formulation, derive the expression for the joint Torques of a planar revolute jointed Robotic manipulator having unequal links. [16]

6. (a) Discuss the minimum time trajectories.

   (b) For a two - segments continuous - acceleration trajectory, the path points are $\theta^s = 10^0$, $\theta^g = 30^0$ and $\theta^m = 22^0$. The duration of two segments are 1.2 second and 1.0 second, respectively. Taking the velocity at via point as 15 deg/s, find the coefficients of the polynomials. [6+10]

7. A stepper stone motor is to be used to drive each of the three linear axes of a cartesian coordinate Robot. The motor output shaft will be connected to a screw thread with a screw pitch of 3 mm. It is desired that the control resolution of each of the axes be 0.6 mm.

(a) To achieve this control resolution, how many step angles are required on the stepper motor?

(b) What is the corresponding step angle?

(c) Determine the pulse rate that will be required to drive a given joint at a velocity of 7.5 cm/sec. [4+4+8]

8. (a) Explain the Robotic parallel Assembly systems.

(b) Explain the product designing for Robotic assembly. [8+8]

*****

Code No: M0324/R07

Set No. 3

IV B.Tech I Semester Regular Examinations, November 2012

ROBOTICS

(Mechanical Engineering)

Time: 3 hours | Max Marks: 80

Answer any FIVE Questions

All Questions carry equal marks

*****

1. (a) What is an end effector? Explain its function.
   (b) Sketch 3 different types of grippers commonly used. [8+8]

2. (a) Explain the basic components of a robotic system.
   (b) Explain the forward and reverse transformation of the 2-degrees of freedom arm [6+10]

3. Consider the forward transformation of the two-joint manipulator shown in figure 3. Given that the length of joint 1, L1=12in, the length of joint 2, L2=10in., the angle $\theta1=30^0$ and the angle $\theta2=45^0$, compute the coordinate position (x and y coordinates) for the end-of-the-arm Pw. [16]

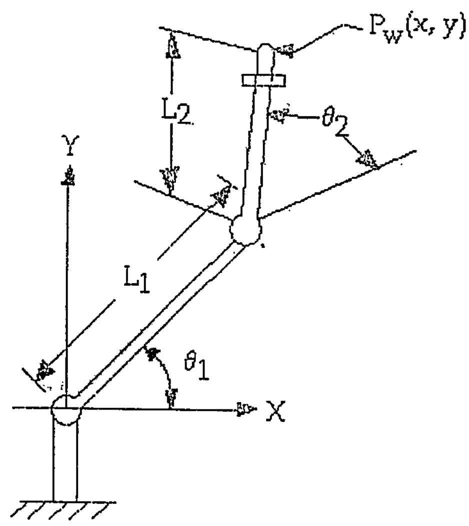


Figure 3

4. A jointed-arm robot of configuration VVR is to move all three axes so that the first joint is rotated through 50^0, the second joint is rotated through 90^0 and the third joint is rotated through 25^0. Maximum speed of any of these rotational joints is 10^0/s. Ignore effects of acceleration and deceleration.
   (a) Determine the time required to move each joint if skew motion is used.

(b) Determine the time required to move the arm to the desired position and the rotational velocity of each joint, if joint-interpolated motion is used. [8+8]

5. Using Norton - Euler forward equations, determine the joint torques or forces of a planar RP robotic Manipulator. [16]

6. (a) Compare the Joint space and Cartesian space trajectory planning.

   (b) The trajectory for a point - to - point motion between two points is divided into three segments and a 4 - 3- 4 trajectory plan is used. Determine the polynomial equations for the three segments. Assume appropriate constraints. [6+10]

7. A certain potentiometer is to be used as the feedback device to indicate position of the output link of a rotational Robot joint. The excitation voltage of the potentiometer equals 15 V and the total wiper travel of the potentiometer is 320^0, the wiper arm is directly connected to the rotational joint so that the given rotation of the joint corresponds to an equal rotation of the wiper arm.

   (a) Determine the voltage constant of the potentiometer.

   (b) The robot joint is actuated to a certain angle, causing the wiper position to be 38^0. Determine the resulting output voltage of the potentiometer.

   (c) In another actuation of the joint , the resulting output voltage of the potentiometer is 3.75 V. Determine the corresponding angular position of the wiper and the output link. [4+6+6]

8. (a) How Robotics can be used to perform inspection operation? Explain.

   (b) Explain the Robot - manipulated inspection or Test equipment. [8+8]

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Code No: M0324/R07 **Set No. 4**

IV B.Tech I Semester Regular Examinations, November 2012

ROBOTICS

(Mechanical Engineering)

Time: 3 hours Max Marks: 80

Answer any FIVE Questions

All Questions carry equal marks

*****

1. (a) What is precision of movement of a robot? Explain the terms special resolution, accuracy and repeatability?

   (b) A robot with single degree of freedom has one sliding joint with a full range of 1.0m. The robot's control memory has a 12-bit storage capacity. Determine the control resolution for this axis of motion. [8+8]

2. (a) A part weighing 8lb is to be held by a gripper using friction against two opposing fingers. The coefficient of friction between the fingers and the part surface is estimated to be 0.3. The orientation of the gripper will be such that the weight of the part will be applied in a direction parallel to the contacting finger surfaces. A fast work cycle is anticipated so that the 'g' factor to be used in force calculations should be 3.0 Compute the required gripper force for the specifications given.

   (b) A vacuum gripper is to be designed to handle flat plate glass in an automobile wind shield plant. Each plate weighs 28lb. A single section cup will be used and the diameter of the suction cup is 60in. Determine the negative pressure required (compared to atmospheric pressure of 14.7 lb/sq.in) to lift each plate. Use a safety factor of 1.5 in your computation. [8+8]

3. Discuss the two coordinate systems used in the kinematic analysis of robotic arm with a suitable sketches. [16]

4. The joints and links of the RR: R manipulator in figure 4, figure 4 have the following values: $\theta_1=45^0$. $\theta_2=45^0$. $\theta 3= -135^0$, L_1=500mm, L_2=400mm and L_3=25mm. Determine the values of x and z in world space coordinates. [16]

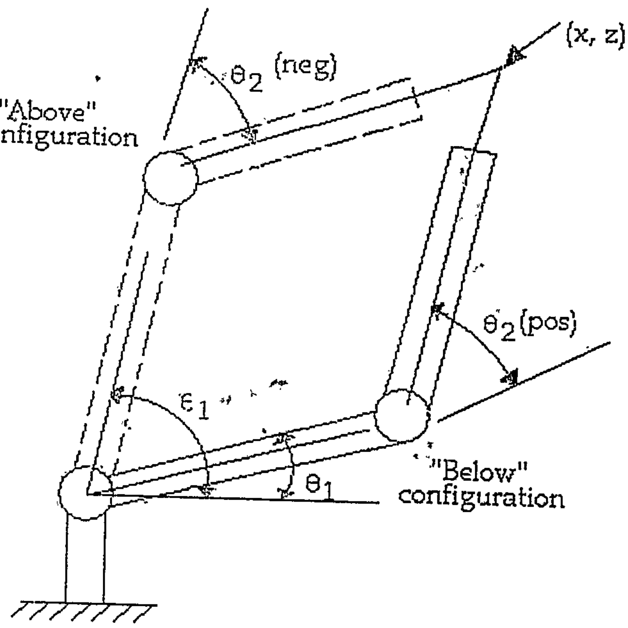

Figure 4

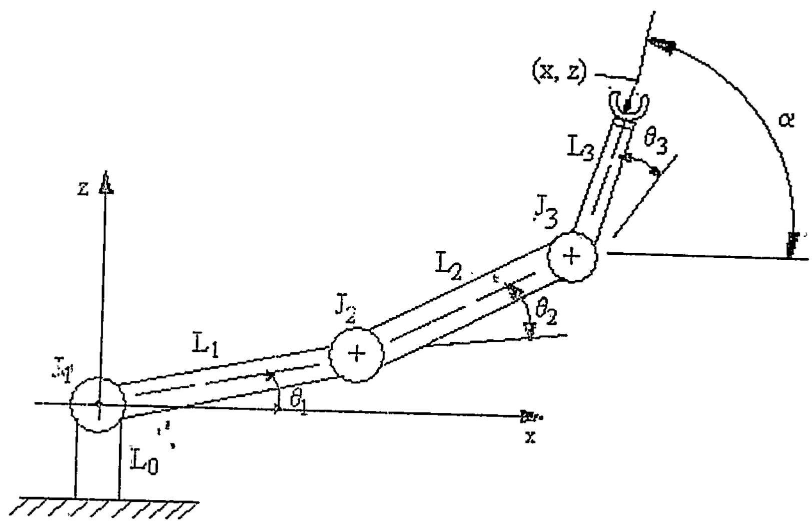

Figure 4

5. Using Norton - Euler forward equations, determine the joint torques or forces of a planar RP robotic Manipulator. [16]

6. (a) What are the features and capabilities of structured programming languages? Explain.

   (b) What are the two basic ingredients of task - object languages? Explain.

(c) What are the problems to be solved before task - object languages? Explain. [8+4+4]

7. A dc tachometer is to be used as the velocity feedback device on a certain twisting joint. The joint actuator is capable of driving the joint at a maximum velocity of 0.75 rad/sec and the tachometer constant is 8 V/rad/sec.

   (a) What is the maximum output voltage that can be generated by the device, if the tachometer is geared with the joint so that it rotates with twice the angular velocity of the joint?

   (b) If the joint rotates at a speed of 25^0/sec, determine the output voltage of dc tachometer. [8+8]

8. (a) What are the general considerations in robot material handling?

   (b) Discuss the robot application in pick - and - place operations. [8+8]

*****

Code No: M0324 **R07** Set No. 1

IV B.Tech. I Semester Supplementary Examinations, February/March, 2012

ROBOTICS

(Mechanical Engineering)

Time: 3 Hours **Max Marks: 80**

Answer any FIVE Questions
All Questions carry equal marks
****

1. (a) What is meant by automation? Explain any type of automation.
   (b) What are different configurations of an industrial robot? Explain them briefly. [8+8]

2. (a) Describe about the basic components of a robot. [8]
   (b) List the advantages and disadvantages of electric drive system compared to hydraulic drive system used in robots. [8]

3. (a) List the properties of rotation matrices. [8]
   (b) A mobile body reference frame OABC is rotated 30^0 about OY axis of the fixed base reference frame OXYZ. If $P_{xyz} = [2,-3,4]^T$ and $Q_{xyz} = [1, 8, -3]^T$ are the coordinates with respect to OXYZ frame, determine coordinates of P and Q with respect to the OABC frame. [8]

4. Find the direct kinematics equation of the four-link closed chain planar arm shown in Fig. 1. The two links connected by the prismatic joint are orthogonal to each other.[16]

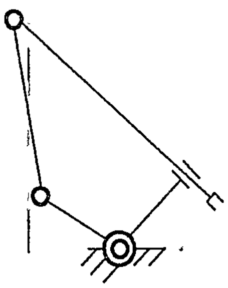

Fig.1

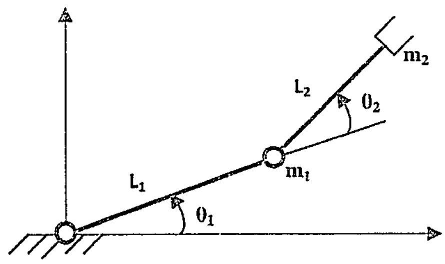

Fig. 2

5. Determine the dynamic equations for the two-link manipulator shown in Fig. 2. Assume that whole mass of the link can be considered as a point mass located at the outermost end of each link. The masses are m_1 and m_2 and the link lengths are L_1 and L_2. [16]

6. (a) What are the different motion types that a robot manipulator can make in traveling from point to point? Explain. [8]
   (b) What are the basic elements of the robot language? Explain. [8]

7. (a) Write short notes on
      (i) Pneumatic actuators (ii) electric motors [8]
   (b) Describe different types of encoders. [8]

8. (a) Discuss the advantages and benefits of robot arc welding. [8]
   (b) Explain the requirements of a robot for spray-coating applications? [8]

Code No: M0324 **R07** **Set No. 2**

IV B.Tech. I Semester Supplementary Examinations, February/March, 2012

ROBOTICS

(Mechanical Engineering)

Time: 3 Hours **Max Marks: 80**

Answer any FIVE Questions
All Questions carry equal marks
****

1. (a) Define the term “industrial automation”. Explain different types of industrial automation. [10]
   (b) What are the present day applications of robot? [6]

2. (a) What is the function of gripper used in robots? What are the considerations to be made in the selection and design of grippers? [8]
   (b) Give the line diagrams of (i) Articulated robot (ii) SCARA. [8]

3. (a) A coordinate frame {B} is located initially coincident with a coordinate frame {A}. If the frame {B}is rotated through 60 degrees about Z_B and 30 degrees about current X_B, find the rotation matrix that will describe a vector of frame {B} in frame {A}. [8]
   (b) Find the transformation matrices for the following operations on the point $3\hat{i} - 5\hat{j} + 4\hat{k}$.
   i) Rotate 30^o about Y-axis and then translate -3 units along Z-axis.
   ii) Translate -4 units along x-axis and rotate 45^o about y-axis. [8]

4. Determine the forward kinematic solution for the parallelogram arm shown in Fig.1

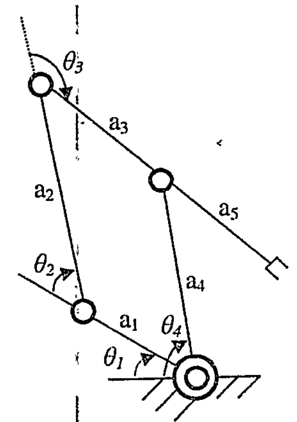

Fig. 1

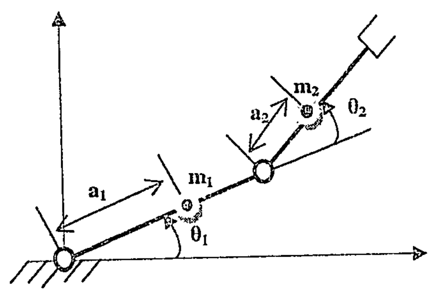

Fig. 2

5. Derive the dynamic equations for the two link manipulator shown in Fig.2. The lengths of the links 1 and 2 are L_1 and L_2 respectively. [16]

6. (a) Given the values for the joint variable: q(0) = 0, q(2) =2 and q(4) =3, compute the two fifth order interpolating polynomials with continuous velocities and accelerations. [10]
   (b) Explain the WAIT, SIGNAL and DELAY commands used in robot programming. [6]

7. (a) Explain about electric servomotors employed in robots. [5]
   (b) What is a resolver? Explain its operating principle. [6]
   (c) Describe about the working of a tachometer. [5]

8. (a) Discuss the considerations to be made while designing for robotic assembly. [8]
   (b) Describe the problems encountered in the use of robots for arc welding applications? [8]

Code No: M0324 **R07** **Set No. 3**

IV B.Tech. I Semester Supplementary Examinations, February/March, 2012

ROBOTICS

(Mechanical Engineering)

Time: 3 Hours **Max Marks: 80**

Answer any FIVE Questions
All Questions carry equal marks
****

1. (a) Give classification of robots based on control system. [6]
   (b) Explain the following
   i) Programmable automation ii) Flexible automation [10]

2. (a) Explain the classification of mechanical grippers according to the type of actuators for finger movement. [8]
   (b) Differentiate between pneumatic and hydraulic drive systems [8]

3. (a) If $a_{xyz} = [2,1,2]^T$, $b_{xyz} = [6,-2,3]^T$, are the co-ordinates of two points with respect to the reference frame OXYZ, determine the corresponding points with respect to the rotated $OX_1Y_1Z_1$ mobile frame if it has been rotated 30^0 about the OY axis. [8]
   (b) Obtain the rotation matrix corresponding to the set of Euler angles with respect to fixed XZY axes. [8]

4. (a) Show and explain the D-H parameters for i^{th} link in a manipulator. Obtain the transformation matrix from frame i to frame i-1 attached to the ends of i^{th} link in a manipulator in terms of the D-H parameters. [8]
   (b) Obtain the D-H parameters for the manipulator shown in Fig. 1. [8]

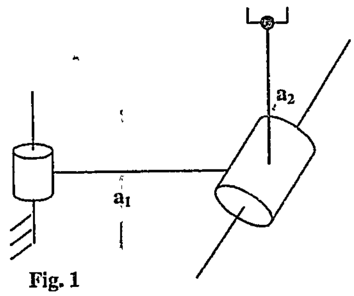

Fig. 1

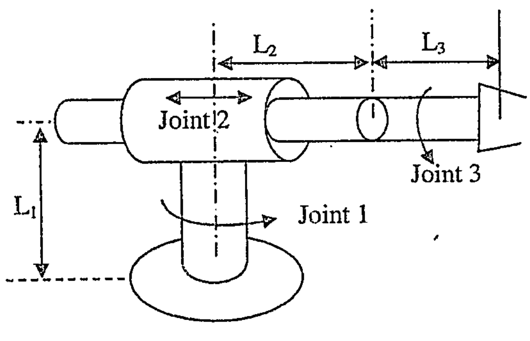

Fig. 2

5. Determine the 3x3 jacobian that calculates linear velocity of the tool tip from the three joint rates for the manipulator shown in Fig. 2. [16]

6. (a) A single cubic trajectory is given by $\theta(t) = 10 + 8t + 50t^2 - 20t^3$ and is used over a time interval from $t = 0$ to $t = 3$ seconds. What are the starting and final positions, velocities and accelerations? [8]
   (b) Explain briefly the characteristics of robot task-level languages. [8]

7. (a) What are different types of encoders? Explain them briefly. [8]
   (b) Discuss about velocity transducers. [8]

8. (a) Explain the robotic arc- sensing systems? [8]
   (b) What are the desirable features of a robot for successful machine tool load/unload application? [8]

Code No: M0324 **R07** **Set No. 4**

IV B.Tech. I Semester Supplementary Examinations, February/March, 2012

ROBOTICS

(Mechanical Engineering)

Time: 3 Hours Max Marks: 80

Answer any FIVE Questions
All Questions carry equal marks

****

1. (a) Write the Asimov's laws of robotics. [4]
   (b) Differentiate between fixed automation and programmable automation automation. [6]
   (c) Explain about playback robots. [6]

2. (a) Describe about vacuum grippers and Magnetic grippers. [8]
   (b) Give line diagram of a polar coordinate robot and show the associated degrees of freedom and work volume. [8]

3. (a) Find the transformation matrices for the following operations on the point $2\hat{i} + 5\hat{j} - 6\hat{k}$.
   i) Rotate 45° about y-axis and then translate -6 units along x-axis.
   ii) Translate 7 units along x-axis and rotate 60° about z-axis.
   iii) Translate 3 units along z-axis and rotate 30° about y-axis. [9]
   (b) State and prove the properties of a rotation matrix. [7]

4. Determine D-H parameters for a three link planar arm shown in Fig.1. Obtain the forward kinematic solution. [16]

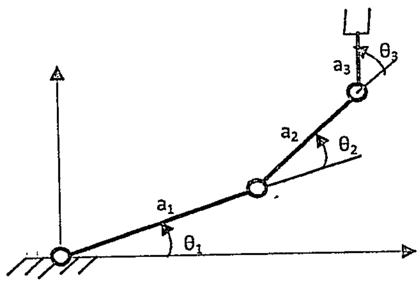

Fig. 1

Code No: M0324 **R07** **Set No. 4**

5. (a) Find the inertia matrix for a right circular cylinder of radius r, height h and total mass M, of uniform density. [6]
   (b) Explain the Newton-Euler formulation for the manipulator dynamics. [10]

6. (a) What are the characteristics of robot task-level languages? Explain. [8]
   (b) Explain different algorithms for planning collision-free path of a robot. [8]

7. (a) Explain the working of potentiometers. [6]
   (b) Describe the working of hydraulic actuators. [5]
   (c) Explain about construction and working of absolute encoders. [5]

8. (a) Explain how robotics can be applied to inspection automation? [8]
   (b) Explain the general considerations to be made in robot material handling? [8]

NEC NARASARAOPETA ENGINEERING COLLEGE
(AUTONOMOUS)

DEPARTMENT OF MECHANICAL ENGINEERING

CO-POs & CO-PSOs ATTAINMENT

Course Code: C414	Course Name: ROBOTICS	Year/Sem: IV/I

External Examination Assessment

S.No	Q.No	1						2		3		4		5		6	7	
		a	b	c	d	e	f	a	b	a	b	a	b	a	b	a	a	b
	COs	I	II	III	IV	V	VI	I	I	II	II	III	III	IV	IV	V	VI	VI
	MaxMarks	2	2	2	2	2	2	6	6	6	6	6	6	6	6	12	6	6
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4		2	2	1	1	1	1	5	3	4	4	4		3	3	5	2	2
5		1	1	1				4	4			4		4		7		
6		2	2	1	1	1	1	5	3	4	4	4		3	3	5	2	2
7		1	1	1	1	1	1			3		3				7	4	4
8		1	1	1	1	1	1	1	5	5	5	5				8		
9				2	1	1	1	1	1	5	4	4		4	4	6	1	
10		1	1	1				4	4			4		4		7		
11		1	1	1	1	1	1	3	3	3	3	3						
12		1			1		1		4	4		4				5	4	1
13		1	2	1	1	1	1	4	4	4	4	4		4	4	5		
14		2		2			2	3	3		3	3				3	4	4
15		1			1		1		4	4		4				5	4	1
16		1	1	1	1	1	1	3	3	3	3	3						
17		2	2	2	1	1	1	3	2	3	2	4		3	3	5	3	
18		1	1	1	1	1	1	4	4	4	4	4	1	4				
19		1	1	1	1	1	1	3	3	3	3	3						
20		2		2		2		4	4	4						1	4	3
21		1	1	1	1	1	1	4	4	3	3	3	4	4				
22		2			2			4		3	3					6		2
23		1	1	1	1	1	1	3								4		
24		1	2	1	1	1	1	4	4	4	4	4		4	4	5		
25			1	1								4				6	2	
26		1	1	1	1	1	1	5	5			5				8	3	4
27		1	1	1	1	1	1	4	4			4	4			6		
28		1	1			2		4	2		4	5		4	4		3	3
29		1	1	1	1	1	1	4	4			4	4			6		
30		1	1	1	1	1	1	5	5			5				7	3	4
31		1	1			1		4	2		4	5		4	4		3	3
32		1	1			2		4	2		4	5		4	4		3	3
33		1	1	1	1	1	1	5	5			5				8	3	4
34		1	1			1		4	2		4	5		4	4		3	3
35		1	1	1	1	1	1	5	5			5				8	3	4
36		1	1			2		4	2		4	5		4	4		3	3
37		1	1			2		4	2		4	5		4	4		3	3
38		1	1			2		4	2		4	5		4	2		3	3
39		1	1	1	1	1	1	5	5								5	4
40		1	1	1	1	1	1	4	5			5				9	4	4
41		1																
42		1	1			2		4	2		4	5		4	2		3	3
43		1	1			1		4	2		4	5		4	2		3	3

44		1	1	1	1	1	1	5	5							2	5	4
45		1	1	1	1	1	1	5	4								5	4
46		1			1		1		4	4		4				5	4	1
47		1	1			1		4	2		4	5		4	2		3	3
48		1	1			1		4	2		4	5		4	2		3	3
49		1	1			1		4	2		4	5		4	2		3	3
50		1	1	1	1	1	1	4	2		4	5		4	3		3	3
51		1	1			1		4	2		4	3		4	2		3	3
52		1	1			1		3	2		4	3		4	2		3	3
53		1	1			1		2	2		4	5		4	2		2	3
54		1	1	1	1	1	1	4	2		4	5		4	3		3	3
55		1	1	1	1	1	1	4	4	4	4	2						
56		1	1			1		4	2		4	5		4	2		3	3
57		1	1			1		4	2		4	3		3	2		3	3
58		1	1			1		3	2		4	3		3	2		3	3
59		1	1			1		3			4	3		3	2		3	3
60		1	1			1		4	2		4	3		4	2		3	3
61		1	1			1		4	2		4	5	2	4	2		3	3
62		1	1			1		4	2		4	5		4	2	5	3	3
63		1	1			1		4	2		3	3		4	2		3	3
64		1	1	1		1		4	2		4	3		4	2		3	3
65		1	1	1	1	1		4	2		4	3		4	2	2	3	3
66		1	1			1		4	2		4	3		4	2	7	3	3
67		1	1	1	1	1		4	2		4	3		4	2	2	3	3
68		1	1	1	1	1	1	4	4		4					6		
69		1	1	1	1	1	1	4	4				4			8	2	2
70		1	1			1		5	5							8	4	3
71		1	2	1	1			4	4	4	4	4	4	4	4	5		
72		1	1			1		4	2		4	3		4	2	7	3	3
73		1	1			1		4	2		4	3		4	2	6	3	3
74		1	2	1	1			4	4	4	4	4	4	4	4	5		
75		1	1			1		5	5							8	4	3
76		1	1			1		3	2		4	3		4	2	6	3	3
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78		1	1			1		5	5							8	4	3
79		1	1	1	1	1		4	2		4	3		4	2	7	3	3
80		1					1	4									2	
81		1	1			1		3	2		4	3		4	2	6	3	3
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84		1	1	1	1	1	1	4	3		3	3				5		
85		1	1		1	1		5	5							8	4	3
86		1	1			1		5	5							8	4	3
87		1	1			1		5	5							6	4	3
88		1	1	1	1	1	1	4	3		3	3				5		
89		1	1			1		5	5							6	4	3
90		1	1	1	1	1	1	4	3		3	3				5		
91		1	1	1	1	1	1	4	3		3	3				5		
92		1	1	1	1	1	1	4	4	4	4	4	4			6	3	
93		1			2			5			5		3			7	5	5
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95		1	1	1	1	1		5	5							6	4	3
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97		1	1	1	1	1		5	5							6	4	3
98		1	1	1	1	1	1	4	3		3	3				5		
99		1	1	1	1	1	1	4	3		3	3				7		
100		1			2			5			5		3			7	5	5
101		2	1	1	1	1	1	4	4	4	4	5		2	4	6	4	2
102		1	1	1	1	1	1	3	3	3	3	3				7	6	3
103		1			2			5			4		3			7	5	5
104		1			2			5			5		3			7	5	5
105		1			2			4			5		3			6	4	5
106		1	1	1	1	1	1	4	3		3	3				5		
107		1		1		1		3	3	3	3	3	3			5	2	
108		1	1	1	1	1	1	4	3		3	3				5		
109		1		1		1		3	3	3	3	3	3			5	2	
110		1			2			5			5		3			7	5	5
111		1	1	1	1	1	1	4	3		3	3				5	2	
112		1	1	1	1	1	1	4	3		3	3				5	3	1
113		1	1	1	1	1	1	4	3		3	3				8		2
114		1			2			5			4		3			7	5	5
115		1	1	1	1	1	1	4	3		3	3				5		
116		1	1	1	1	1	1	4	3		3	3				5	3	1
117		1	1	1	1	1	1	4	3		3	3				3	3	1
118		1	1	1	1	1	1	2	3		3	3				5	3	1
119		1	1	1	1	1	1	4	3		3	3				5		
120		1	1	1	1	1	1	4	3		3	3				5		
121		2	2		2	2			4		2	5	3	5				
122		1		1	1			4				5				7	3	3
123		1		1	1		1	5	5		5			5	5	3		
124		1		1	1		1	4	4	2	4		2			7	4	4
125		1		1	1		1	4	4	4	4		2			7	4	4
126		1	2		2		2		4			4			4	8	3	3
127		1	1	1	1	1	1	4	3		3	3				5		
128		2				2	1	4	4		5					4	5	5
No. of Students answered		125	104	73	79	104	64	119	113	32	92	96	21	54	50	92	94	87
50% of Max Marks		1	1	1	1	1	1	3	3	3	3	3	3	3	3	6	3	3
No. of Students crossed 50% of Max Marks		125	104	73	79	104	64	115	76	31	90	95	17	52	22	50	82	72
% of Students crossed 50% of Max Marks		100	100	100	100	100	100	97	67	97	98	99	81	96	44	54	87	83
Attainment Level		3	3	3	3	3	3	3	2	3	3	3	3	3	0	1	3	3

No of times Co Attained	3	3	3	3	2	3
Attainment Level	3	3	3	2	2	3
CO	I	II	III	IV	V	VI

Rubrics:

If 50% of the students crossed 50% of the marks: Attainment Level 1
If 60% of the students crossed 50% of the marks: Attainment Level 2
If 70% of the students crossed 50% of the marks:Attainment Level 3

Internal Examination Assessment

S.No	Roll. No	Test	Mid-1						Assignm		Quiz1	Mid-2				Assignm		Quiz 2	CO I	CO II	CO III	CO IV	CO V	CO VI
			a	b	a	b	a	b				a	a	a	b				Max. Marks	Max. Marks	Max. Marks	Max. Marks	Max. Marks	Max. Marks
		COs	I	I	II	II	III	III	I	II		IV	V	VI	VI	IV	V							
		Max. Marks	5	5	5	5	5	5	10	10	10	10	10	5	5	10	10	10	30	30	20	30	30	20
1	18471A0302		5	5	5	5	5	3	10	9	9	10	10	5	4	9	10	6	29	28	17	25	26	15
2	18471A0303		5	4	5	4	5	4	9	8	8	10	10	4	5	9	10	4	26	25	17	23	24	13
3	18471A0304		5	5	5	5	5	5	9	8	10	9	10	5	5	9	10	5	29	28	20	23	25	15
4	18471A0305		4	5	4	5	4	5	7	8	10	10	10	5	5	9	10	4	26	27	19	23	24	14
5	18471A0306		5	5	5	5	5	5	9	9	9	10	8	4	4	10	10	3	28	28	19	23	21	11
6	18471A0307		5	5	5	5	5	5	6	7		8	10	4	4	5	10	4	16	17	10	17	24	12
7	18471A0308		4	5	4	4	5	5	10		9	9	9	4	5	9	10	6	28	17	19	24	25	15
8	18471A0309								9	9	9	10	9	5	5	10	10	9	18	18	9	29	28	19
9	18471A0310		4	4	5	5	5	5	10	10	10	10	10	5	5	9	10	3	28	30	20	22	23	13
10	18471A0311		5	4	5	4	5	4	10	8	10	10	8	5	4	10	10	6	29	27	19	26	24	15
11	18471A0312		4	4	5	5	5	5	9	9	8	10	10	5	5			2	25	27	18	12	12	12
12	18471A0313		5	5	5	5	5	4	8	9	10	9	9	5	5	9	10	4	28	29	19	22	23	14
13	18471A0315		4	5	5	5	5	5	10		10	10	10	5	5	10	10	4	29	20	20	24	24	14
14	18471A0316		4	4	5	5	5	5	10		9	10	10	5	5	10	10	5	27	19	19	25	25	15
15	18471A0317		5	4	5	4	5	4	9		10	10	10	5	5		10	3	28	19	19	13	23	13
16	18471A0318		4	4	5	5	5	5	9	8	9	9	9	4	5	10	9	4	26	27	19	23	22	13
17	18471A0319								9	9	8	10	9	5	5	9	9	3	17	17	8	22	21	13
18	18471A0320		4	4	5	5	5	5	8	7	8	8	8	4	4	9	10	3	24	25	18	20	21	11
19	18471A0321		4	4	4	4	4	4	9	9	8	10	10	5	5	10	10	3	25	25	16	23	23	13
20	18471A0322		4	4	4	4	4	4	8	8	9	10	10	5	5	10	9	3	25	25	17	23	22	13
21	18471A0323								10	8	5	10	10	5	5	10		5	15	13	5	25	15	15
22	18471A0324		5	5	5	5	5	5	8	9	9	10	10	5	5		9	2	27	28	19	12	21	12
23	18471A0325		5	4	5	4	5	4	10	9	5	10	10	5	5		9	5	24	23	14	15	24	15
24	18471A0326		4	4	5	5	5	5	9	9	10	10	10	5	5	10	9	3	27	29	20	23	22	13
25	18471A0327		4	5	4	5	4	5	10	9	10	10	10	5	5	8	10	4	29	28	19	22	24	14
26	18471A0328								10	9	10	10	10	5	5	10	10	6	20	19	10	26	26	16
27	18471A0329		4	4	4	4	4	4		9	8	10	10	5	5		10	5	16	25	16	15	25	15
28	18471A0330		5	5	4	4	4	4	9		8	10	10	5	5	9		2	27	16	16	21	12	12
29	18471A0331		4	3	4		4		1	8	10	10	10	5	5	8	10	3	18	22	14	21	23	13
30	18471A0332		4	4	5	5	5	5	9	8	10	10	10	5	5	10	10	5	27	28	20	25	25	15

31	18471A0333		4	4	5	5	5	5	9	8	9	10	10	5	5	10	9	5	26	27	19	25	24	15
32	18471A0334		5	4	5	4	4	5	10	8	10	10	10	5	5	10	10	6	29	27	19	26	26	16
33	18471A0335		4	5	4	5	4	5	6		10	8	8	4	4	9	8	6	25	19	19	23	22	14
34	18471A0336		4	4	4	4	4	4		9	3	7	7	4	3	8	10	4	11	20	11	19	21	11
35	18471A0337		4	5	4	4	4	4		8		10	10	5	5		8	6	9	16	8	16	24	16
36	18471A0338		4		4		4		6		9	10	10	5	5	10	7	4	19	13	13	24	21	14
37	18471A0339		5	5	5	5	5	5	10		8	10	10	5	5		10	5	28	18	18	15	25	15
38	18471A0340		4	4	4	4	4	4	8		9	10	10	5	5		10	6	25	17	17	16	26	16
39	18471A0341		4	5	4	5	4	5	10	8	10	10	10	5	5	7	10	4	29	27	19	21	24	14
40	18471A0342		4	4	5	5	5	5	10	9	10	10	10	5	5	9	9	5	28	29	20	24	24	15
41	18471A0343		4	5	4	5	4	5	9		8	10	10	5	5	6	10	4	26	17	17	20	24	14
42	18471A0344		5	5	4	4	4	4	9	8	2	10	10	5	5	10	8	4	21	18	10	24	22	14
43	18471A0345		4	4	5	5	5	4	6	8	5	8	8	4	4	10	10	3	19	23	14	21	21	11
44	18471A0346		4	4	4	4	4		10	7	10	10	10	5	5		7	6	28	25	14	16	23	16
45	18471A0347		4	4	2	4	4	4	10	9	10	10	10	5	5	8	10	2	28	25	18	20	22	12
46	18471A0348		4	4	5	5	5	5	9		10	9	9	4	3	8	10	6	27	20	20	23	25	13
47	18471A0349		3	3	3	3	3	3	8	9	6	8	8	4	4	9	10	5	20	21	12	22	23	13
48	18471A0350		3		3	5	4	2	7	9	6	10	10	5	5	10	10	5	16	23	12	25	25	15
49	18471A0351		3		3	3	3	3	9	10	9	10	9	4	5	9	10	4	21	25	15	23	23	13
50	18471A0352		4	5	5	4	5	4	10	10	10	9	9	4	4	10	9	2	29	29	19	21	20	10
51	18471A0353		4	5	4	5	4	5	9	3	10							1	28	22	19	1	1	1
52	18471A0354		5	5	5	5	5	5	9	7	4	10	10	4	4	9	10	4	23	21	14	23	24	12
53	18471A0355		4	5	4	5	4	5		9		7	7	3	4	9	10		9	18	9	16	17	7
54	19475A0301		4	5	4	5	4	5	9		8	7	7	3	4	10	10	4	26	17	17	21	21	11
55	19475A0302		4	5	4	5	4	5	9	5	8	10	10	5	5	8	10	4	26	22	17	22	24	14
56	19475A0304		4	4	4	4	4	4		10	10	10	10	5	5		10	4	18	28	18	14	24	14
57	19475A0305		3	3	3	3	3		10			10	10	5	5	8		4	16	6	3	22	14	14
58	19475A0307		4	4	4	4	4	4	8		10	10	10	5	5	10	10	6	26	18	18	26	26	16
59	19475A0308		4	4	5	5	5	5	10	8	10	10	10	5	5	10	7	6	28	28	20	26	23	16
60	19475A0309		4	4	4	4	4		10	9	9	6	6	3	2	10	10	5	27	26	13	21	21	10
61	19475A0310		4	4	4	4	4	4	10	7	9	10	10	5	5	10		5	27	24	17	25	15	15
62	19475A0311								10		10	8	9	5	4	10		6	20	10	10	24	15	15
63	19475A0312									9	10	7	7	3	3	10		7	10	19	10	24	14	13
64	19475A0313		5	5	5	5	4	4	9	10	9	8	8	3	5	10	6	8	28	29	17	26	22	16
65	19475A0314		5	5	5	5	3	3	8	9	10	7	7	1	4		8	4	28	29	16	11	19	9
66	19475A0315		5	5	5	5	5	4	9		10	9	10	2	5	10	0	3	29	20	19	22	13	10
67	19475A0316		5	3	5	4	5	5	10	6	7	10	9	4	5	10	7	5	25	22	17	25	21	14

68	19475A0317		5	5	4	5	5	5	10		10	8	7	4	4	10		5	30	19	20	23	12	13
69	19475A0318		5	5	4	5	5	5	10		8	7	9	3	5	10	5	4	28	17	18	21	18	12
70	19475A0319		5	5	5	1	5	5	8	9	9	8		5	5	10	0	3	27	24	19	21	3	13
71	19475A0320									10		7	7		5		10	4	0	10	0	11	21	13
72	19475A0321		4	5	5	5	5	4	9	10	10	9	9	5	5	9		5	28	30	19	23	14	15
73	19475A0322		5	5	4	5	4	4	9	10	10	9	3	4	5	10	8	4	29	29	18	23	15	13
74	19475A0323		5	5	5	3	5	5	8	10	1	9	9	3	5		10	3	19	19	11	12	22	11
75	19475A0324		4	5	5	5	5	5	7	10	5	8	9	5	5	10	0	2	21	25	15	20	11	12
76	19475A0325		5	5	5	5	5	4	10		9	9	9	2	4	10	7	7	29	19	18	26	23	13
77	19475A0326		5	5	5	3	5	5	10	10	10	9	9	5	5	10		6	30	28	20	25	15	16
78	19475A0327		5	5	5	4	4	4	9	10	9	8	10	5	5	9	1	4	28	28	17	21	15	14
79	19475A0328		5	5	5	4	5	4	9	10	10	9	9	5	5	10	8	3	29	29	19	22	20	13
80	19475A0329									10		8	8		5	10	5	5	0	10	0	23	18	10
81	19475A0330		5	5	5	5	5	3	10	8	7	9	9	5	5	0	7	5	27	25	15	14	21	15
82	19475A0331		5	5	5	4		4	9	9	10	10	10	5	5	10	0	3	29	28	14	23	13	13
83	19475A0332		5	5		5	5	4	8	10	8	10	10	0	5	10	0	6	26	23	17	26	16	11
84	19475A0333								9	10	7	10	10	5	4		7	3	16	17	7	13	20	12
85	19475A0334		5	5	5	4	5	5	10	10	9	9	7	4	5	10	5	4	29	28	19	23	16	13
86	19475A0335		5	5	5	3	5	4	10	5	10	9	10	4	5	9	0	5	30	23	19	23	15	14
87	19475A0336		4	5	5	4	5	5	9	9	9	8	9	3	5	10		3	27	27	19	21	12	11
88	19475A0337		4	4	5	4	5	5	7	10	8	9	9	4	5	10	8	6	23	27	18	25	23	15
89	19475A0338									10	10	9	9	5	5		9	5	10	20	10	14	23	15
90	19475A0339		5	5	4		5	5	10	10	10	9	9	4	5		10	3	30	24	20	12	22	12
91	19475A0340		4	4	5	4	3	5	10	10	7	7		5	5	10	0	4	25	26	15	21	4	14
92	19475A0341		3	3	5		3		8	10	10	7	9	4	5	10	0	4	24	25	13	21	13	13
93	19475A0342		5	5	5	4	5	4	10	10	10	9	10	4	5	10	0	3	30	29	19	22	13	12
94	19475A0343		5	5	5	4	4	5	10	10	7					2		6	27	26	16	8	6	6
95	19475A0344		4	5	4	4	4	5	9	10	9	9	9	4	4	10	0	3	27	27	18	22	12	11
96	19475A0345		5	5	4	3	5	4	10	6	9	9	9	4	5		10	6	29	22	18	15	25	15
97	19475A0347		4	5	5	4	3	3	9	7		9	9	4	4	10	0	7	18	16	6	26	16	15
98	19475A0348		3	4	5	5	5	3	9	10	10	9	9	4	4	10		4	26	30	18	23	13	12
99	19475A0349		5	5				2	10	10	10	9	8	5	4	2	6	7	30	20	12	18	21	16
100	19475A0350		5	5	5	4	5	5	7			10	8	4	5	10		5	17	9	10	25	13	14
101	19475A0351		3	5	5	1	5	4	8	10	5		9				9	4	21	21	14	4	22	4
102	19475A0352		3	5	4	4	5	5	6	10	8	9	9	5	5		9	5	22	26	18	14	23	15
103	19475A0353		5	5	4	5	5	4	8	10	9	10	10	4	4	10		6	27	28	18	26	16	14
104	19475A0354		4	4	4	4	5	5	7		9	9	9	4	5		7	7	24	17	19	16	23	16

105	19475A0355		4	5	4	4	5	4	8	10	9	9	9	5	5	10	0	7	26	27	18	26	16	17
106	19475A0356		4	4	5	4	5	5	9	10		9	10	5	5		10	6	17	19	10	15	26	16
107	19475A0357		5	4	2		4	4	10	10	10	9	9	4	5	10	0	5	29	22	18	24	14	14
108	19475A0358		5	5	5	4	3		7	10	10	9	10	5	5	10	1	6	27	29	13	25	17	16
109	19475A0359		5	5	5	4	5	4	10	10	10	8	9	4		10	0	5	30	29	19	23	14	9
110	19475A0360		5	5	5	3			7	9	8	9	9	5	5	10	0	3	25	25	8	22	12	13
111	19475A0361		5	5	4	1		1	7	10	9	9	8	5	5	10	0	4	26	24	10	23	12	14
112	19475A0362		5	4			2	4	10	10	10	9	9	4	5		10	5	29	20	16	14	24	14
113	19475A0363		5	5	5	4	4	4	10		8	6	9	5	5	10	0	5	28	17	16	21	14	15
114	19475A0364		5	5	4	4	4	4	10	10	10	8	9	5	5	10	8	2	30	28	18	20	19	12
115	19475A0365		5	5	5	5	5	4	7	9	10	8	9	4	5	10	8	6	27	29	19	24	23	15
116	19475A0366		5	4	5	4	4	4	10		9	9	7	4	5	10	0	6	28	18	17	25	13	15
117	19475A0367		4	5	4	4	5	4	8	10		9	9	4	5	7	10	6	17	18	9	22	25	15
118	19475A0368		4	5	4	4	5	4		9	9	9	8	4	4	9		6	18	26	18	24	14	14
119	19475A0369		4	4	4	3	5	4	9	10	10	9	9	4	5	10	0	3	27	27	19	22	12	12
120	19475A0370		4	5	5				10	10		9	9	4	5	10	9	4	19	15	0	23	22	13
121	19475A0371		4	4	4	4	4	4	10		10	8	6	5	5	7	0	6	28	18	18	21	12	16
122	19475A0372		5	5	4	5	5	4	9	10	10	8	9	4	5		10	5	29	29	19	13	24	14
123	19475A0373		3	4	4	3	2	3		9	7	9	7	3	5	10	10	4	14	23	12	23	21	12
124	19475A0374		4	5	4	4	5	1		9	10	6	9	4	5	10	0	6	19	27	16	22	15	15
125	19475A0376								8	9	8	9	9	5	5	8	5	4	16	17	8	21	18	14
126	19475A0377									9		8	9	3	4		5	3	0	9	0	11	17	10
127	19475A0378		3	3	4	4	3	5		9		9	9	5	5		8	4	6	17	8	13	21	14
128	19475A0379		5	5	5	4	5	4	8	10		9	9	4	5	10		5	18	19	9	24	14	14
50% of maximum marks																			15	15	10	15	15	10
No. of Students crossed 50% of max. marks																			118	120	111	109	99	122
% of students crossed 50% of max. marks																			92	94	87	85	77	95
Attainment Level																			3	3	3	3	3	3

Rubrics:

If 50% of the students crossed 50% of the marks: Attainment Level 1
If 60% of the students crossed 50% of the marks: Attainment Level 2
If 70% of the students crossed 50% of the marks:Attainment Level 3

Course Code: C414	Course Name: ROBOTICS				Year/Sem: IV/I
CO Attainment					
	CO Attainment Level (Internal)	CO Attainment Level (External)	Direct CO Attainment Level (Internal * 30%) + (External * 70%)	Indirect CO Attainment Level	Total CO Attainment Level (Direct CO Attainment * 90% + Indirect CO Attainment * 10%)
C414.1	3	3	3.00	2.49	2.95
C414.2	3	3	3.00	2.53	2.95
C414.3	3	3	3.00	2.49	2.95
C414.4	3	2	2.30	2.47	2.32
C414.5	3	2	2.30	2.36	2.31
C414.6	3	3	3.00	2.41	2.94
C414					2.74

1. Copy the Direct CO Attaiment Level (Internal) and Diect CO Attaiment Level (External) from the previous sheets and then find the Direct CO Attainment Level.
2. Find Direct CO attainment level using the formula:
   CO Attainment Level (Internal) * 30% + CO Attainment Level (External) * 70%
3. Copy Indirect CO Attainment Level.
4. Find the CO attainment level using the formula:
   Direct CO Attainment Level *90% + Indirect CO Attainment Level * 10%

Course Code: C414	Course Name: ROBOTICS	Year/Sem: IV/I

CO-PO & CO-PSO Mapping

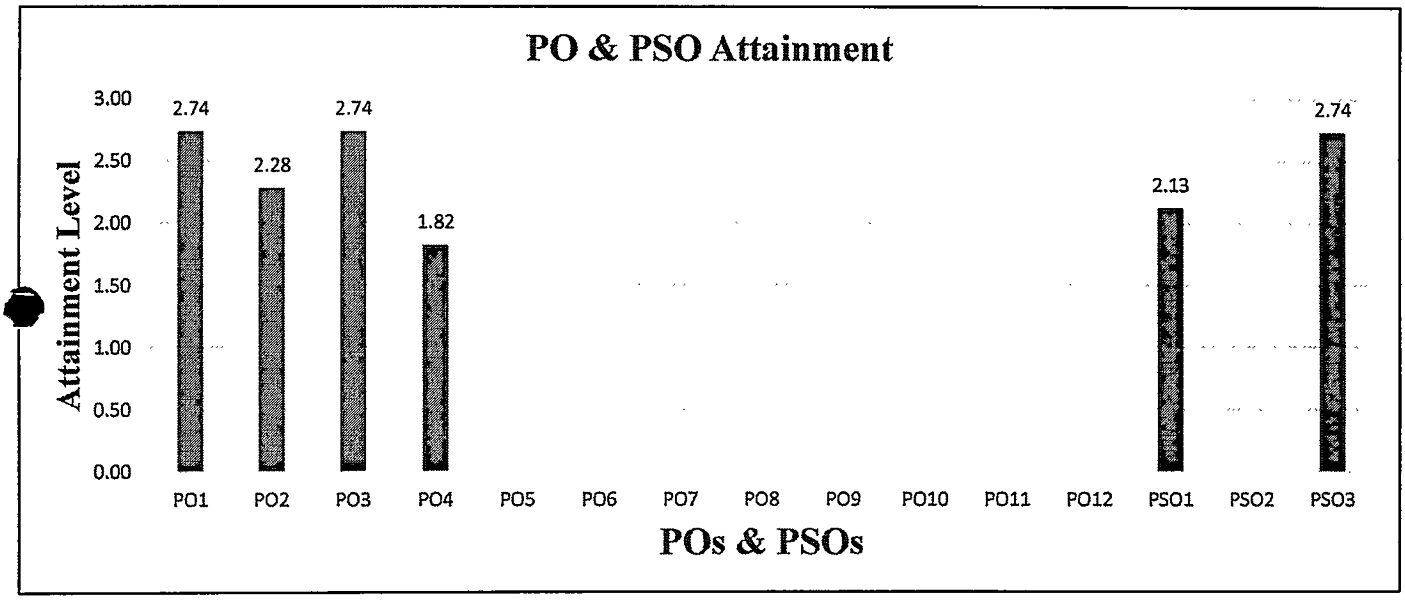
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
C414.1	3	2	-	-	-	-	-	-	-	-	-	-	2	-	-
C414.2	3	2	-	-	-	-	-	-	-	-	-	-	2	-	-
C414.3	3	2	-	-	-	-	-	-	-	-	-	-	3	-	-
C414.4	3	3	3	2	-	-	-	-	-	-	-	-	-	-	3
C414.5	3	3	3	2	-	-	-	-	-	-	-	-	-	-	3
C414.6	3	3	3	2	-	-	-	-	-	-	-	-	-	-	3
C414	3.00	2.50	3.00	2.00	-	-	-	-	-	-	-	-	2.33	-	3.00

Total CO Attainment through Direct & Indirect Assessment

CO Attainment	2.74

PO & PSO Attainment

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
PO Attainment	2.74	2.28	2.74	1.82	-	-	-	-	-	-	-	-	2.13	-	2.74



1. Copy CO - PO matrix and CO attainment matrix from previous pages and find PO attainment.
2. PO attainment is calculated as per the following formula:
POi * Total CO attainment Level / 3 where 'i' ranges from 1 to 12

1. Copy CO - PSO matrix and CO attainment matrix from previous pages and find PSO attainment.
2. PSO attainment is calculated as per the following formula:
PSOi * Total CO attainment Level / 3 where 'i' ranges from 1 to 3