Problem Set 1

COM SCI 188: Intro to Robotics Winter 2026

Question:	1	2	3	4	5	Total
Points:	12	16	20	18	34	100

1. **Definition of Robots.**

   (a) (4 points) The term "robot" is derived from the Czech word "robota" which was introduced in what context?

   A. A patent for the first industrial automaton

   B. A science-fiction story by Isaac Asimov

   C. An early technical paper from the National Science Foundation

   D. A 1920 play titled 'R.U.R.' by Karel Čapek

   (b) (4 points) Which of the following scenarios best describes a machine that fails to meet the full definition of a robot (Sense-Plan-Act)?

   A. A robotic arm using a camera to locate a part, calculating the inverse kinematics to reach it, and then grasping it.

   B. A self-driving car detecting an obstacle, computing a new trajectory to avoid it, and steering around it.

   C. A Braitenberg vehicle (e.g., a "fearful" robot) where the light sensors are directly wired to the motors, causing immediate movement away from light.

   D. A vacuum robot mapping a room, determining which areas have not been cleaned, and navigating to those spots.

   (c) (4 points) What is the central idea behind Moravec's paradox?

   A. The processing power of computers will double approximately every two years, leading to exponential growth in robotic intelligence.

   B. A robot must obey all orders given by humans, except where such orders would conflict with the protection of human life.

   C. The more human-like a robot appears, the more unsettling it becomes to humans.

   D. Tasks that are difficult for humans (like logic and math) are easy for computers, but tasks easy for humans (like perception and mobility) are very difficult for computers.

2. **Sensor Types.**

(a) (4 points) Which of the following is an active, exteroceptive sensor?

A. A thermometer measuring internal motor temperature

B. A bumper switch detecting a wall impact

C. A LIDAR scanner mapping a room

D. A GPS receiver determining position

(b) (4 points) A standard digital camera recording video of a robot's environment is best described as:

A. Active, Exteroceptive

B. Passive, Exteroceptive

C. Active, Proprioceptive

D. Passive, Proprioceptive

(c) (4 points) Why might an active Infrared (IR) proximity sensor fail to detect an object when used outdoors on a bright, sunny day?

A. The wind interferes with the IR beam.

B. The speed of light changes in outdoor humidity.

C. The sun emits high levels of infrared radiation that can overwhelm or saturate the sensor.

D. IR sensors only work in total darkness.

(d) (4 points) You are using wheel encoders to track your robot's position (odometry). What happens to your position estimate if the robot's wheels spin on a slippery floor without the robot actually moving?

A. The robot correctly identifies that it has not moved.

B. The robot's position estimate remains unchanged.

C. The robot incorrectly believes it has moved forward.

D. The encoders automatically recalibrate to zero.

3. **Motor & Gears.**

(a) (4 points) In a robotic system, what is the primary distinction between an actuator and an effector?

A. An actuator is the mechanism that generates motion (e.g., a motor), while an effector is the component that uses this motion to affect the environment (e.g., a wheel).

B. They are interchangeable terms for any moving part of a robot.

C. An actuator is the physical tool that contacts the environment, while the effector is the motor that drives it.

D. An actuator is used for locomotion, while an effector is used for manipulation.

(b) (4 points) For a standard brushed DC motor, what is the relationship between the electrical inputs (voltage, current) and the mechanical outputs (speed, torque)?

A. Speed and torque are both directly proportional to voltage.

B. Speed is proportional to current, and torque is proportional to voltage.

C. Speed is proportional to voltage, and torque is proportional to current.

D. Speed and torque are inversely proportional to each other, regardless of electrical input.

(c) (4 points) Why is gearing essential when using standard DC motors for most robotic applications like lifting an object?

A. To reverse the direction of the motor's rotation.

B. To decrease both the speed and the torque for more precise control.

C. To decrease the motor's high speed and increase its low torque.

D. To increase the motor's high speed and increase its low torque.

(d) (4 points) If a motor's output shaft is connected to an input gear of radius 'r' which drives an output gear of radius '2r', what is the effect on the final output torque and speed?

A. Both torque and speed are halved.

B. Torque is doubled, and speed is halved.

C. Torque is halved, and speed is doubled.

D. Both torque and speed are doubled.

(e) (4 points) What is the key feature that distinguishes a servo motor from a standard DC motor?

A. Servo motors operate on AC power instead of DC power.

B. Servo motors are always brushless for higher efficiency.

C. Servo motors include a built-in controller and position sensor for precise angular control.

D. Servo motors do not require gearing and directly drive the load.

4. **Degrees of Freedom.**

(a) (4 points) How many DoF does a rigid body, such as an airplane, have when moving freely in 3D space?

A. 3, representing its position coordinates (x,y,z).

B. 6, with 3 for position and 3 for orientation.

C. 3, representing its orientation angles (pitch, yaw, roll).

D. 2, representing its movement on a 2D plane.

(b) (4 points) A robot is said to be redundant if:

A. It has more than 6 DoF

B. It lacks sufficient DoF for the task

C. It has more DoF than required to complete the task

D. It has exactly the number of DoF needed for 3D pose control

(c) (4 points) Which term describes the set of all possible positions a robot's end-effector can reach?

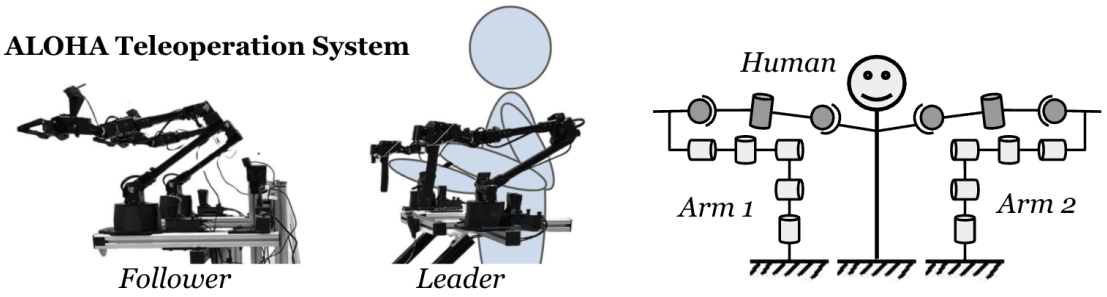
A. Configuration Space

B. Joint Space

C. Action Space

D. Workspace

(d) (6 points) The ALOHA teleoperation system is a "puppeteering" setup where a human demonstrator kinesthetically move a set of leader arms that control the follower arms :



What is the DoF of the system formed by the human and the leader arms? (assume the demonstrator can only move their arms)

Solution:
# bodies = 4 (human arms) + 8 (robot arms) + 2 (hands) + 1 (ground) = 15
# revolute joints = 12
# spherical joints = 4
dof = 6x(15-1) - (12x5 + 4x3) = 12

5. **Rigid Body Motion.**

(a) (4 points) What is the primary function of the Inverse Kinematics (IK) problem?

A. To find the end-effector's position given the robot's joint angles.

B. To find the acceleration of the end-effector based on the forces applied.

C. To find the torques and forces required at each joint to produce a desired motion.

D. To find the required joint angles to place the robot's end-effector at a desired position and orientation.

(b) (4 points) What is the primary motivation for using homogeneous coordinates when representing rigid body transformations?

A. To reduce the size of the matrices needed for calculations.

B. To convert 3D problems into simpler 2D problems.

C. To represent both rotation and translation within a single matrix multiplication.

D. To eliminate the need for trigonometric functions in rotation matrices.

(c) (4 points) Which statement correctly describes the transformation matrix ${}^{A}T_{B}$?

A. It represents the pose of frame A with respect to reference frame B.

B. It transforms the coordinates of a point from frame A to frame B.

C. It describes the geometric motion from frame B to frame A.

D. It represents the pose of frame B in frame A and transforms points from frame B to A.

(d) (4 points) Which is a key property of a valid 3D rotation matrix R?

A. The inverse of the matrix is equal to its transpose ($R^{-1} = R^{T}$).

B. The determinant of the matrix is equal to 0.

C. The inverse of the matrix is equal to the matrix itself ($R^{-1} = R$).

D. The matrix is always symmetric ($R = R^{T}$).

(e) (4 points) In the axis-angle representation of rotation, which is then used to form a quaternion (x,y,z,w), what does the quaternion (0,0,0,1) signify?

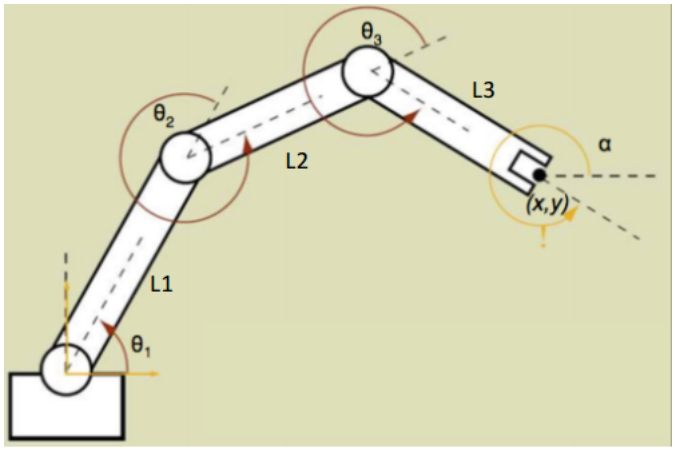
A. An identity rotation (no rotation).

B. A 90-degree rotation about the Y-axis.

C. An invalid or undefined rotation.

D. A 180-degree rotation about the Z-axis.

(f) Consider the planar manipulator robot pictured below. The robot has three DC motors attached at joints. (Note: the robot's end-effector only travels in the plane of the page.)



(g) (4 points) What is the number of DoF of this arm?

Solution: 3 total DOF, 3 DOM (x, y, theta)

(h) (4 points) For a given reachable end-effector position in 2D space, how many inverse kinematic solutions can this robot theoretically have?

Solution: infinitely many (DoF > task space dimension)

(i) (6 points) Given $L_1 = 0.6, L_2 = 0.4, L_3 = 0.3, \theta_1 = 60°, \theta_2 = 330°, \theta_3 = 315°$ Calculate the position (x, y) of the end-effector in the base frame.

Solution:

$$x = L_1 \cos(\theta_1) + L_2 \cos(\theta_1 + \theta_2) + L_3 \cos(\theta_1 + \theta_2 + \theta_3)$$

$$y = L_1 \sin(\theta_1) + L_2 \sin(\theta_1 + \theta_2) + L_3 \sin(\theta_1 + \theta_2 + \theta_3)$$

(x, y) $\approx (0.936,\ 0.642)$