

Scenario 1: Agricultural Drone for Crop Monitoring

A team of researchers is developing an autonomous quadrotor drone to monitor large agricultural fields for crop health. The drone needs to fly over wide areas, avoid sudden obstacles (like birds or trees), and collect high-resolution multispectral imagery for processing on-board or offline. It should be power-efficient and capable of functioning with minimal user intervention in areas with poor connectivity.

Questions:

- a) Which control paradigm (deliberative, reactive, or hybrid) is most appropriate for this drone and why?
- b) What kind of processor should be chosen to balance computational demand and energy efficiency for on-board image processing and flight control? Justify your answer.
- c) Which sensor would be more suitable for detecting small, high-speed aerial obstacles — LiDAR or camera? Explain your reasoning.

Answers:

- a) A hybrid paradigm is most suitable. Deliberative control is useful for planned coverage of large areas, while reactive components allow the drone to avoid sudden obstacles like birds or branches in real-time.
- b) A low-power edge processor like the NVIDIA Jetson Nano is appropriate. These provide sufficient processing for image analysis and sensor fusion without consuming excessive energy, preserving battery life for flight.
- c) A camera is more appropriate. It offers fast visual feedback, wide field of view, and is well-suited for detecting small, fast-moving objects, whereas LiDAR can miss small or rapidly changing obstacles at distance.

Scenario 2: Autonomous Warehouse Robot

An e-commerce company is deploying autonomous mobile robots (AMRs) to move packages across a warehouse. These robots must follow optimal paths, adapt to dynamic layouts, avoid human workers and forklifts, and communicate with a central server for job scheduling. Speed and safety are critical, as the environment is highly dynamic.

Questions:

- a) Which robotic control paradigm is best suited to meet the demands of safety, efficiency, and centralized coordination? Explain your choice.
- b) Considering the need for both connectivity and fast local decisions, what type of processor should the robot have? Support your answer.
- c) For human and forklift detection in narrow aisles, should the robot use ultrasonic sensors, depth cameras, or thermal sensors? Justify your selection.

Answers:

- a) A hybrid control paradigm is ideal. Deliberative planning helps with route optimization and job scheduling, while reactive control ensures safety by handling sudden changes like people or forklifts entering the robot's path.
- b) Jetson Nano is ideal. It enables fast local decision-making (for obstacle avoidance and safety) while also supporting communication with a central server for coordinated task allocation.
- c) Depth cameras are most suitable. They provide accurate spatial perception and work well in structured indoor environments with good lighting. Ultrasonic sensors are too coarse, and thermal sensors don't provide sufficient spatial detail for safe navigation in tight spaces.

Scenario 3: Underwater Inspection Robot

A robotic submarine is being developed to inspect offshore oil pipelines and underwater structures. It must navigate murky water, avoid underwater rocks, identify structural cracks using cameras or sonar, and operate autonomously without GPS. Real-time onboard decision-making is necessary due to limited communication with surface operators.

Questions:

- a) What robotic control paradigm would be most effective for this mission, given the harsh and communication-limited environment?
- b) Which processor architecture would best support low-latency autonomy and visual-sonar data fusion under constrained power and thermal budgets? Explain your reasoning.
- c) In low-visibility underwater conditions, which sensor is more appropriate for structure detection —camera or sonar? Defend your answer.

Answers:

- a) A reactive control paradigm is most effective. Because communication with the surface is limited and the environment is unstructured, the robot must make fast local decisions without depending on high-level planning or external commands.
- b) A multi-core embedded processor like Jetson nano is suitable. These processors provide sufficient compute for fusing sonar and camera data while remaining efficient in power-constrained underwater scenarios.
- c) Sonar is more appropriate in this case. The camera relies on clear visual conditions, which are often not present underwater. Sonar can operate reliably in murky or dark conditions and detect structures based on acoustic reflections.

Scenario 4: Pick-and-Place Robot in Electronics Manufacturing

You are designing a 4-DOF desktop pick-and-place robot for assembling small electronic components like microchips and resistors. The robot must operate quickly and accurately in a cleanroom environment, handling delicate parts with minimal vibration. It needs to be compact, lightweight, and cost-effective for mass deployment.

Questions:

- a) Which transmission system is most appropriate — Belt, Gear, or Chain? Justify your answer.
- b) Which actuator type should be used — Electric, Pneumatic, or Hydraulic? Explain your choice.
- c) Which motor type is best — DC, Servo, or Stepper? Support your answer.

Answers:

- a) **Belt transmission** is appropriate due to its lightweight, low-noise operation and suitability for high-speed, low-load applications. It also reduces vibration, which is important when handling delicate components.
- b) **Electric actuators** are suitable because they provide clean and precise control required in cleanroom environments and allow for easy integration into small robotic arms.
- c) **Stepper motors** are cost-effective and precise for open-loop control. They offer good positional accuracy at low cost, which is sufficient for short-range desktop pick-and-place tasks.

Scenario 5: Heavy-Duty Construction Robot

You're building a heavy-duty robotic manipulator for handling large concrete panels and steel frames at a construction site. The robot must operate outdoors in harsh weather, lift heavy payloads exceeding 100 kg, and perform tasks like drilling or positioning beams. The environment includes vibrations, dust, and large temperature variations.

Questions:

- a) Which transmission system (Gear, Belt, Chain) is best suited for this rugged use-case? Why?
- b) Which actuator type (Hydraulic, Pneumatic, or Electric) is most appropriate? Justify your answer.
- c) Which motor type (Servo, DC, Stepper) would be most robust for this application? Justify.

Answers:

- a) **Chain transmission** is best for outdoor and heavy-duty use due to its durability, shock resistance, and ability to transmit high torque in dirty, rugged conditions without slipping.
- b) **Hydraulic actuators** are most suitable due to their high power-to-weight ratio and ability to generate the large forces needed to lift heavy objects reliably in outdoor environments.
- c) **Servo motors** are preferred because they offer closed-loop feedback and high torque control, which is essential for safety and precision in moving heavy materials under variable load conditions.

Scenario 6: Robotic Arm for Food Packaging Line

You're designing a 5-DOF robotic arm for an automated food packaging line that picks up baked goods (e.g., cookies, pastries) and places them into boxes at high speed. The robot must be hygienic, fast, and operate continuously with minimal downtime. The payload is light (~1 kg), but speed and precision are critical. The environment is clean but slightly humid due to food processing.

Questions:

- a) Which transmission system (Gear, Belt, Chain) is best suited for fast and clean food handling? Explain.
- b) Which actuator type (Electric, Pneumatic, Hydraulic) is ideal for this application? Justify your answer.
- c) Which motor (DC, Stepper, Servo) would you choose for this robot and why?

Answers:

- a) **Belt transmission** is suitable because it is quiet, clean, and fast — perfect for environments requiring minimal contamination and rapid repetitive movements. It also minimizes vibration when handling light loads like food items.
- b) **Electric actuators** are best due to their cleanliness, reliability, and precise control. Pneumatics could be fast but are harder to control precisely, and hydraulic systems are unsuitable due to hygiene and maintenance concerns.
- c) **Servo motors** are ideal for their speed, precise control, and ability to maintain accuracy during fast motion cycles. Their closed-loop feedback ensures consistent placement of delicate food items.

Scenario 7: Robotic Firefighting Arm

A disaster-response team is developing a mobile robotic arm mounted on a tracked robot to assist in firefighting operations. The arm needs to remove debris, operate tools, or hold hoses in high-heat environments. It should handle payloads up to 30 kg, operate in water and smoke, and resist mechanical shock from debris or impacts.

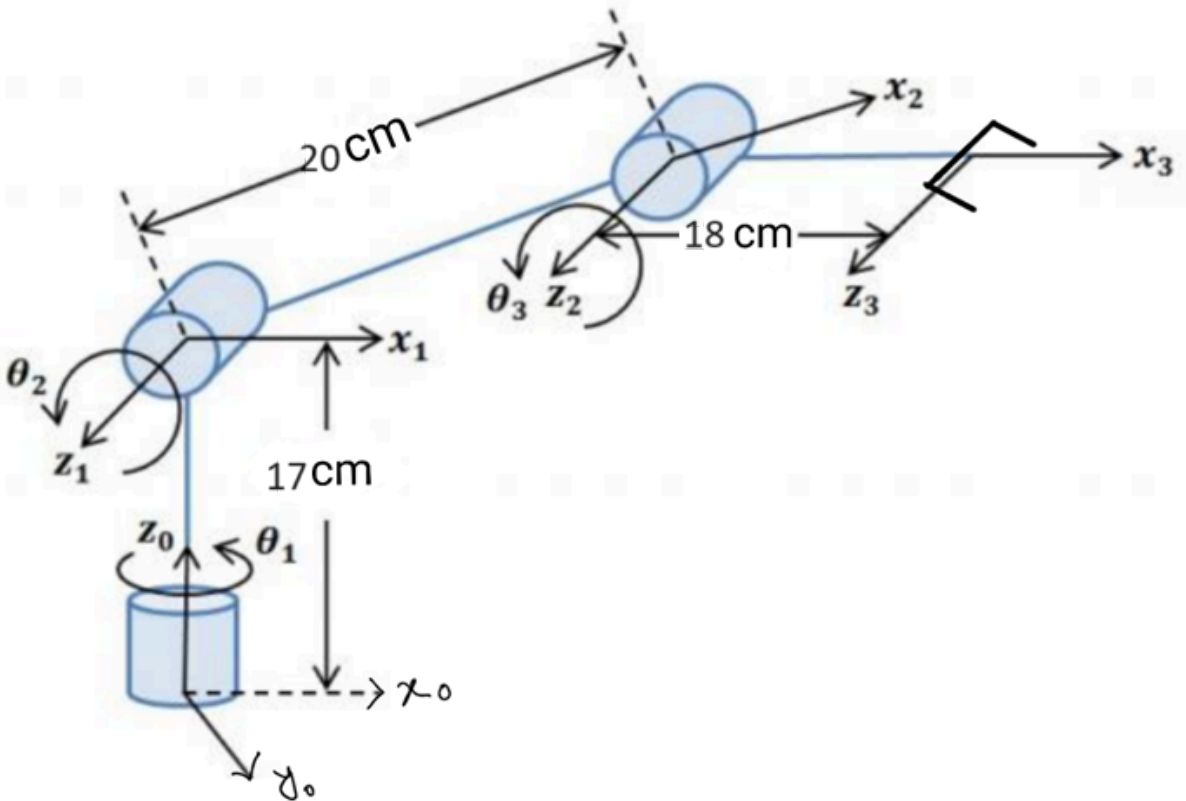
Questions:

- a) What transmission system (Gear, Belt, Chain) is most reliable in high-temperature, high-impact situations? Explain.
- b) Which actuator type (Hydraulic, Pneumatic, Electric) would perform best in these firefighting conditions? Why?
- c) What kind of motor (DC, Servo, Stepper) would you recommend for durability and performance?

Answers:

- a) **Chain transmission** is the most durable in high-impact and high-temperature environments. It can handle mechanical stress and dirt better than gears or belts and doesn't slip under sudden shocks.
- b) **Hydraulic actuators** are preferred due to their ability to provide high force even under harsh conditions, including heat, water exposure, and vibration. They are also more resistant to impact and external force.
- c) **Servo motors** are recommended due to their precise control and robustness. For tasks like tool manipulation or hose control, closed-loop accuracy is necessary despite the rough environment.

Practice: This type of manipulator's forward and inverse kinematics properly.



- To drop the object you have to move the waist for 60° , shoulder for 70° , and elbow for 58° . Calculate the coordinates (x, y, z) where the object will be dropped after the movements?
- If the object is placed in the coordinates 25,15,30 (x, y, z) . What should be the angle of waist, shoulder and elbow to pick that object?

