CS545–Introduction to Robotics

Catalogue of Questions for Midterm

1. (8 Points) You implemented a PD controller for a robot based on sensor reading obtained from position sensors. In the first test run, you notice that there are vibrations and oscillations in one degree-of-freedom. Give at least 4 possible causes for these vibrations, and for each cause how you would try to improve the robot performance.

2. (8 Points) You need to buy a position sensor for a rotary joint in a robot. You are torn between a potentiometer and an optical encoder. Give at least two pros and cons for both the potentiometer and the optical encoder.

3. (4 Points) Give 2 pros and cons for each type of motor: Pneumatic, Hydraulic, and Electric.

4. (8 Points) What are the major 4 conceptual steps in performing a local stability analysis of a robotic system with a given control law?

5. (4 Points) What is the difference between Euler Angle and Fixed Angle coordinate transformations?

6. (2 Points) Give the Laplace Transform of the function $\dot{x} = \sin(x)$.

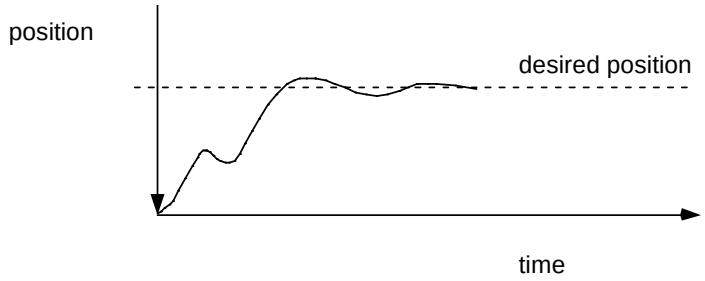
7. (2 Points) In all the examples shown in class, equations of motion of a robot were derived in the framework of rigid-body dynamics. Which major assumptions are made when applying the rigid body dynamics framework?

8. (4 Points) When you discretize a linear non-time variant continuous system , how would you expect the gains of your PD controller to change? Why? Why do we need to discretize this system?

9. Discretization is need for implementing the controller on a computer, which runs at clock rate; normally, discretized controller require lower gains if the gains for the continuous version were tuned for very high values (2 points for every answer or other reasonable answers)

10. (4 Points) You have a one degree-of-freedom robot that you modeled with the equation $m\ddot{x} + b\dot{x} = u$. You built a simple PD controller to control this system. As a desired trajectory, you simply give the target position to the PD controller without any

other refined trajectory plan (this is called a step-input). In response to the step-input, you get the following position trajectory of the robot:



Judging from this trajectory, do you think that your model matches the real dynamics of the robot? Give reasons (keywords) for your statement.

11. (3 Points) Your colleague has a simple robot that is described by the following equations of motion $m\ddot{x} + kx = u$. He wants to control this robot with a P controller and feedforward commands from an inverse dynamics model. Do you think that this is good choice (yes or no)? Give a reason for your answer. Give a suggestion to improve this controller.

12. (4 Points) Give the generic form of a homogenous transformation matrix in a matrix-partitioned form. Explain the elements in the matrix.

13. (5 Points) The state of a robot is described by its position **x** and its velocity $\dot{x}$. Given a desired trajectory described by $x_d, \dot{x_d}$, write down the PID control law for the feedback motor command **u**. Give keywords for how each of the terms helps.

14. (2 Points) You are designing a mobile robot and must select the range sensors. What are the advantages to laser scanners? When might you opt to use sonar?

15. (5 Points) Sketch a robot control block diagram that uses a compute torque controller, assuming that the state of the robot is given by the position **x** and the velocity $\dot{x}$.

16. (4 Points) What is the equilibrium point of the system $\ddot{x} = \dot{x^2} + 1$.

17. (4 Points) Give the linearized system $x = \dot{x^3} + u^5$ at the point x=0 and u=0.

18. (4 Points) Assume the forward kinematics (direct kinematics) of a robot is given by $\mathbf{x} = \mathbf{f}(\mathbf{q})$, where **x** is a 3D vector of endeffector coordinates, **q** is a vector of generalized joint coordinates, and **f** is a vector valued function. Give the general formula of the Jacobian of the forward kinematics by specifying the formula for each coefficient of the Jacobian matrix.

19. (2 Points) For two 3D vectors $\mathbf{x}=[x1, x2, x3]^T$ and $\mathbf{y}=[y1, y2, y3]^T$, what is the definition of the cross product $\mathbf{x} \times \mathbf{y}$?

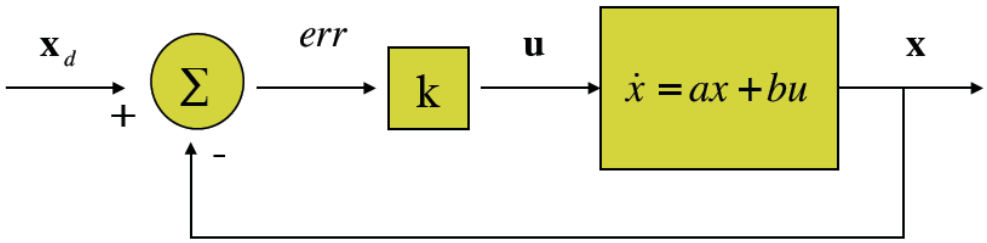
20. (4 points) Provide the block diagram of an open loop controller, where the controller is one box, and the robot is another box, and the robot has the state **x** and the controller outputs the motor command **u**? Give two cases when open loop control can be useful.

21. (4 Points) What is the control law for the motor command **u** for a negative feedback controller using a proportional terms, a derivative term, and an acceleration term? Use **q** as the state variable, and explain all the variables you introduce in your control law.

22. (2 Points) When is an integral control term needed in a control law?

23. (2 Points) For which kind of control systems is frequency analysis most commonly used?

24. (4 Points) Provide the transfer function $\mathbf{x}(s) = H(s)\,\mathbf{x}_d(s)$ of the following 1D system:



25. (2 Points) Why are delays in the state feedback in a control loop problematic? Give at least two reasons.

26. (2 Points) What are the most common methods to overcome the problem of feedback delays in control loops? Give at least two ideas.

27. (4 Points) For Linear Stability Analysis, what is the condition for stability of a continuous time system in terms of the eigenvalues of the system? What is the condition for stability for a discrete time system?

28. (2 Points) What is the difference between Euler Angle and Fixed Angle notation for describing the orientation of a rigid body in 3D space?

29. (4 Points) What is the Denavit-Hartenberg Convention good for? How many parameters are needed to describe the kinematics of a robot in DH convention?

30. (2 Points) What can be problematic when trying to transform task space (operational space) coordinates to joint space coordinates? Give at least two possible problems.

31. (2 Points) You have an optimal encoder with 1000 slots in the encoder disk. What is the resolution you can expect to achieve with this encoder, i.e., for a 360 degree range of motion, what is the smallest movement (as a fraction of a degree) the encoder can recognize?

32. (2 Points) Why are gearboxes with high transmission ratio problematic in robot actuation? Give at least 2 reasons.