10-01-2017

MECE401 Final

Q1) The control structure for angular velocity control of a joint of a robot is given below.



In this control scheme C(s) is the controller transfer function, H(s) is the joint mechanical transfer function, Text is the external disturbance torque acting on the joint, T is the applied torque to the joint, wd is the desired angular velocity set point for the joint, wo is the observed angular velocity of the joint and ‘e’ is the error. The controller and joint mechanical transfer function are given as,

 (PI controller) and

where, Kp and KI are the parameters of the controller and J and B are the moment of inertia and friction coefficient of the joint.

1. Assuming that Text is not available (Text(s) = 0), find the transfer function G1(s) where output is the observed angular velocity and the input is the desired angular velocity of the joint. (20 point)
2. Assuming the closed loop feedback system is critically damped, determine the value of Kp in terms of KI, J and B. (10 point)
3. Show that the steady state error value of the angular velocity of the joint is equal to 0 rad/sec if a unit step input of wd is applied as the input (for unit step input wd, the Laplace domain representation is ) (15 point)

Q2) The structure of a 2 DOF (degree of Freedom) manipulator is given below. The first joint of the manipulator is a revolute joint whereas the second joint is a prismatic joint.



The transformation from the base coordinate frame (x0, y0, zo) to (x1, y1, z1) is

The transformation from the coordinate frame (x0, y0, zo) to (x2, y2, z2) is

1. Find . (5 point)
2. Find the Manipulator Jacobian. (25 point)

Q3) The **force (in Newton)** and **moment (in newton-meter)** vector of a 2 DOF (degree of freedom) manipulator with respect to base coordinate frame is given as,

For this manipulator the Manipulator Jacobian is given as

The first joint of the manipulator is a revolute joint whereas the second joint is a prismatic joint. Find the joint torque value acting on the first joint and joint force value acting on the second joint. (20 point)

Q4) We have a cylindrical bar with density K. The radius of the cylindrical bar is rx and the height is d. This link is aligned over x coordinate frame as shown in the figure below:



Find the pseudo inertia matrix of this link (BONUS question 100 point)

Hint: the small concentric mass of this object is given by dm=Kdxdydz

In order to find the components of the pseudo inertia matrix you have to convert the Cartesian coordinate system to polar coordinate where y=r×cos(θ) and z=r×sin(θ) and x=x. For example to find second mass moments of the body one have to use the equations.

To find the second mass product (cross products) of the body one have to use

ind the mass of the body one have to use the equationthe equations

To find the first moments of the body one have to use the equations

To find the mass of the body one have to use the equation

The pseudo inertia matrix in that case will be equal to