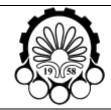
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In the name of god

Advanced RoboticsHomework Assignment #7



1) Classify the following robot tasks as motion control, force control, hybrid motion-force control, impedance control, or some combination. justify your answer:

- a) Tightening a screw with a screwdriver
- b) Pushing a box along the floor
- c) Pouring a glass of water
- d) Shaking hands with a human
- e) Throwing a baseball to hit a target
- f) Shoveling snow
- g) Digging a hole
- h) Giving a back massage
- i) Vacuuming the floor
- j) Carrying a tray of glasses

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- 2) express natural and artificial constraints that achieve the following tasks:
- a) opening a cabinet door
- b) turning a screw that advances linearly a distance p for every revelation
- c) drawing a circle on a chalkboard with a piece of chalk

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3) Aside from joint angels and angular velocities, if we have access to joint angular accelerations, we can accomplish impedance control without having force sensor. Construct the appropriate control law. Draw a block diagram of the control system.

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4) For a system with dynamic equation shown below:

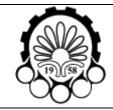
$$\frac{ml^2}{2}\ddot{x} + c\dot{x} + m \lg \sin(x) = u$$

Design an inverse Dynamic controller where c & 1 are known , but m is unknown And then determine steady state error .

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5) Remember passivity based method, one term is changed and control law is determined as below:

$$\begin{aligned} \tau &= \hat{M} \ddot{q}_r + \hat{C} \dot{q}_r + \hat{G} + K \operatorname{sgn}(r) \\ r &= \Delta e + \dot{e} \\ \dot{q}_r &= \Delta e + \dot{q}_d \\ K &= \operatorname{diag}\left[k_1, k_2, ..., k_i\right] \quad k_i > \mid 0 \end{aligned}$$

Use a suitable Lyapunov function and proof that the error reach the surface:

$$r = \Lambda e + \dot{e}$$

In addition once on the surface, q(t) will goes to $q_d(t)$ exponentially fast (which implies that r=0 is reached in a finite time. In addition, once in sliding mode, e converges exponentially fast to zero)

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6) Remember passivity based method

Use similar process and design an Adaptive control for robot dynamic equations when control input is changed to below form, when M-C-G are constant but unknown:

$$\tau = K_p \tilde{q} + K_v \dot{\tilde{q}} + M(q) \left[\ddot{q}_d + \Lambda \dot{\tilde{q}} \right] + C(q, \dot{q}) \left[\dot{q}_d + \Lambda \tilde{q} \right] + g(q),$$

Hint: use this Lyapunov function candidate:

$$V(t, \tilde{q}, \dot{\tilde{q}}, \tilde{\theta}) = \frac{1}{2} \left[\dot{\tilde{q}} + \Lambda \tilde{q} \right]^T M(q, \theta) \left[\dot{\tilde{q}} + \Lambda \tilde{q} \right] + \tilde{q}^T K_p \tilde{q} + \frac{1}{2} \tilde{\theta}^T \Gamma^{-1} \tilde{\theta}.$$