Kinematics, dynamics and control of robots - Homework project 4

Remark: In case you had mistakes in Project 3, you must correct them and update the functions, dynamics matrices, tau, and state equations. **Use the analytic calculation for velocities and accelerations** (using the Jacobian and its time derivative).

Run dynamic simulations of the robot motion from point A to B according to the polynomial velocity profile planned in HW3. The control torques/forces should be determined according to the following control laws:

- Inverse dynamics +PD:
$$\tau = C(q,\dot{q})\dot{q} + G(q) + H\left[\ddot{q}_d - K_p(q - q_d) - K_D(\dot{q} - \dot{q}_d)\right]$$
- PD + gravity compensation:
$$\tau = G(q) - K_p(q - q_d) - K_D(\dot{q} - \dot{q}_d)$$
- PID
- MINMAX trajectory tracking control. Formulate the control law and explicitly detail and explain all calculations.
- Adaptive control (AC). Formulate the control law and explicitly detail and explain all calculations. -**bonus 15 point**

For the first two control laws, the nominal value of the load mass at the gripper is $M = 0.5[kg]$.
For the rest, the load is unknown and bounded by $0 < M < 1[kg]$.

<u>For each control law, complete the following:</u>

1. Choose the control parameters to achieve the following requirements:
   - For an error in the initial position of the tool of 1cm upwards $(+\hat{z}_0)$ from point A, the magnitude tracking error in end effector's position converges to 0.15% of the total path length in less than 1.5 seconds.
   - The tool position converges to the required position with minimal oscillations.
   - The control torques/forces are as small as possible.

   Present the chosen control parameters with a short explanation of how you chose them.
2. Preform the dynamic simulation with the above initial condition for a time of 3 seconds, where after $t = 2[sec]$ the tool should stay at point B at rest.
   Present the following figures:
   - Error in joint values with respect to the planned motion, as a function of time.
   - Norm of the error in tool position $\sqrt{(x - x_d)^2 + (y - y_d)^2 + (z - z_d)^2}$ as a percentage of the total path length, as a function of time.
   - Control torques/forces as functions of time, compared to the planned torques/forces from HW3.
3. Repeat the simulation in section 2, but this time with **no load mass** at the tool.
   Use the same control parameters that you chose in section 2, where the control laws are not “aware” of the change. Explain the results.
4. In conclusion, compare the different control laws and between the closed loop and open loop control. Refer to the following:
   - Complexity of real time calculations.
   - Sensitivity to initial condition error.
   - The size of control parameters and control torques/forces.
   - Robustness – sensitivity to errors in the robot model.

<u>Functions to be submitted</u>: function tau=tau_cont(q,qdot,t,law)

Submission in pairs by 10.10.2024 on the course moodle page.

Good luck!