ECEn 774
Final Exam, Winter 2016
Due by 11:59PM April 20

Name:

The exam is open book, open notes, open computer. Computer simulations can be in Matlab, Python, or any programming language of choice.

For each problem turn in handwritten derivations and proofs, final computer simulation plots, and computer code.

Problem 1	________	/ 20
Problem 2	________	/ 20
Problem 3	________	/ 20
Problem 4	________	/ 20
Problem 5	________	/ 20
Total	________	/ 100

I certify that the solutions to this exam represents my own work, and that I did not consult with any other individual about the problems on the exam.

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Signature

All of the problems on this exam will be concerned with a simplified model of the forward motion of an underwater vehicle. Let the forward position of the vehicle be denoted by $p(t)$ and the forward velocity denoted by $v(t)$. The equations of motion are given by

$$\begin{aligned}\dot{p} &= v + v_c \\ m\dot{v} &= -\mu_1 v\,|v| - \mu_2 v\,|v|^3 + \alpha T,\end{aligned}$$

where m is the mass of the vehicle, μ_1 and μ_2 are drag coefficients, α is the trottle effectiveness coefficient, T is the trust, and v_c is the velocity of the current.

For the purposes of simulation, assume that the true parameters of the system are $m = 10\ kg$, $\mu_1 = 25\ kg/m$, $\mu_2 = 15\ kgs^2/m^3$, and $\alpha = 0.8$. The maximum thrust is $T_{\max} = 50\ N$. For all problems assume that $\dot{p}_r(t) = \ddot{p}_r(t) = 0$.

1. **(20 pts)** Using LaSalle's invariance principle, show that PD control stabilizes the system around a reference trajectory $p_r(t)$. For this problem, assume that the velocity of the current is zero. Implement the PD controller in simulation and show tracking results when $p_r(t)$ is a series of step inputs. Modify the parameters known to the controller to assess the robustness of the controller.

2. **(20 pts)** Assume that the velocity of the current v_c is non-zero but that it is known to the controller. Use backstepping to design a controller that guarantees that the tracking error goes to zero in the presence of v_c. Implement the resulting controller in simulation and show tracking results when $p_r(t)$ is a series of step inputs. Assume that the system parameters are all known. Modify the parameters known to the controller to assess the robustness of the controller.

3. **(20 pts)** Again assume that the velocity of the current v_c is non-zero but known, and that the system parameters are all known. Select a change of variables and a feedback linearizing controller that results in a linear system in the transformed variables. Select a linear stabilizing controller to stabilize the tracking error. Implement the resulting controller in simulation and show tracking results when $p_r(t)$ is a series of step inputs. Modify the parameters known to the controller to assess the robustness of the controller.

4. **(20 pts)** Design a sliding mode controller that drives the tracking error to zero. Use the sliding mode $s = \dot{e} + k_s e$ where $e = p - p_r$. In this case we assume that the parameters are not precisely known. Assume that the only knowledge of m, μ_1, μ_2, α, and v_c, is that $5 \leq m \leq 20$, $0 < \mu_1 \leq 50$, $0 < \mu_2 \leq 30$, $0 < \alpha \leq 1$, and $-1 \leq v_c \leq 1$. Implement the resulting controller in simulation and show tracking results when $p_r(t)$ is a series of step inputs. Modify the system parameters to assess the robustness of the controller.

5. **(20 pts)** Derive an adaptive controller that guarantees asymptotic tracking by first linearizing the system and augmenting the state with an integrator. Use LQR or pole placement to design the linear baseline controller, and then add an adaptive element using a reference model with an observer-like modification. Implement the resulting controller in simulation and show tracking results when $p_r(t)$ is a series of step inputs. Modify the parameters known to the controller to assess the robustness of the controller.