Sommario

P1 – Problem n.1

P1 - Problem n. 1

In 2-DOF helicopter, a coupled 2input-2output system can be achieved due to coupling between the pitch and yaw motor torques. The linear 2-DOF helicopter state-space matrices are:

$$A = \begin{bmatrix} 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & -\dfrac{B_P}{J_P + mL^2} & 0 \\ 0 & 0 & 0 & -\dfrac{B_Y}{J_Y + mL^2} \end{bmatrix}; \; B = \begin{bmatrix} 0 & 0 \\ 0 & 0 \\ \dfrac{K_{PP}}{J_P + mL^2} & \dfrac{K_{PY}}{J_P + mL^2} \\ \dfrac{K_{YP}}{J_Y + mL^2} & \dfrac{K_{YY}}{J_Y + mL^2} \end{bmatrix}; C = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \end{bmatrix}; D = \begin{bmatrix} 0 & 0 \\ 0 & 0 \end{bmatrix}$$

where $\theta(t)$ is the pitch angle and $\psi(t)$ is the yaw angle. u_P and u_Y are the control signals applied to pitch and yaw motors, respectively. The amounts of parameters used in this formula are written in the table below.

Name	Description	Value
K_{PP}	Pitch torque	0.204 Nm/V
K_{YY}	Yaw torque	0.072 Nm/V
K_{PY}	Yaw on pitch torque	0.0068 Nm/V
K_{YP}	Pitch on yaw torque	0.0219 Nm/V
J_P	Total pitch moment of inertia	0.0384 kg/m^2
J_Y	Total yaw moment of inertia	0.0432 kg/m^2
B_P	Pitch viscous damping	0.800 NN
B_Y	Yaw viscous damping	0.318 NN
m	Total moving mass	1.3872 kg
L	Centre of mass length from pitch axis	0.186 m
u_P	Pitch axis voltage	V
u_Y	Yaw axis voltage	V
x_1	Pitch angle	rad
x_2	Yaw angle	rad

P1A - Domande

P1 - Question A

Examine the open loop plant response by applying an impulse and step respectively.

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P1A - What can be said about the stability of the system? *
(1 Point)

- The system is unstable
- The system is stable
- The system is marginally stable
- None of these.
- I don't know, I don't answer

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P1A - Are the two outputs strongly correlated? *
(1 Point)

- The outputs are strongly related to both inputs
- The outputs are related to both inputs but not strongly
- The outputs are not related
- None of these.
- I don't know, I don't answer

P1B – Domande

P1 - Question B

Both the inertial sensors that allow us to detect the helicopter angle and the motor piloting drivers work at a maximum frequency of 10Hz. The settling time required is 0.8s. Compatibly with the design constraints,

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P1B - What should be the value of Ts? *
(1 Point)

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P1B - What should be the value of Hp? *
(1 Point)

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P1B - What should be the value of Hc? *
(1 Point)

P1C – Domande

P1 - Question C

Initialize the MPC controller with the found parameters. Define the names of the inputs, outputs and related units. Consider that at time t=0, the system reference is yref = [0 1]' and run a simulation lasting 10s. Observe the simulation results.

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P1C - What can be said about the simulation results? *
(2 Points)

P1D – Domande

P1 - Question D

While designing the control system, you read the datasheet of the motors and you notice that their maximum voltage is ± 12V. In addition, it is specified that to avoid current peaks during starting and braking, the controller must drive the motors using acceleration and deceleration ramps. The minimum rise and fall time required by both ramps to go from 0V to 12V is 4 seconds. Constrain the system accordingly.

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P1D - What happens to the system response? Did the constraints work? (select all the true answers) *
(1 Point)

- ☐ The response of the system has improved.
- ☐ The system response has deteriorated.
- ☐ The constraints did not affect the system.
- ☐ The constraints affected the system
- ☐ None of these.
- ☐ I don't know, I don't answer

P1E – Domande

P1E - Question E

As a design specification for your control system, you are required to eliminate (or at least minimize) overshoots and undershoots.

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P1E - Which parameters do you need to tune? *
(1 Point)

- Prediction Horizon
- Output Weights
- Input Weights
- Input Constraints
- Output Constraints
- Input Rate Weights
- Control Horizon
- None of these.
- I don't know, I don't answer

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P1E - Tune the identified parameters (the minimum necessary) and comment on the results obtained (compare the new tuning with the one identified in question D). *
(2 Points)

P1F – Domande

P1 - Question F

In addition to the previous requests, at the time $t = 5s$ a reference for the pitch angle equal to 25 ° is set.

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P1F - How does the outputs behave with this new reference? *
(1 Point)

- The outputs start to oscillate.
- The outputs diverge from their references.
- The outputs settle properly without oscillations.
- The output settles quickly despite some oscillations.
- None of these.
- I don't know, I don't answer.

P1G – Domande

P1 - Question G

Apply a Gaussian disturbance of 0.01rad amplitude at time $t = 0s$ to the output $y2$ of the system.

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P1G - How does the system behave in the presence of this disturbance? What can be said about the results obtained? *
(1 Point)

- ○ The output appears noisy and the disturbance decreases the settling time.
- ○ The output appears noisy and the disturbance increases the settling time.
- ○ The output appears noisy and the disturbance does not affect performance.
- ○ The output appears noisy and the disturbance does affect performance.
- ○ None of these.
- ○ I don't know, I don't answer.

P1H – Domande

P1 - Question H

Generate the controller script. Realize in Simulink the system-controller model used considering as reference yref = [0 0.5236]'. Look at the outputs through two scopes.

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P1H - Upload your main script calling it NAME_SURNAME_P1_MAIN.docx(1 Point)

To save the script in docx format:
click on the editor tab
click on the arrow at the bottom on save
click on save as.

In the window on "Salva come:" select "All files (. *)"*
In "Nome file:" write the name of your file in the format specified above.

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P1H - Upload your controller script calling it NAME_SURNAME_P1_CONTROLLER.docx(1 Point)

To save the script in docx format:
click on the editor tab
click on the arrow at the bottom on save
click on save as.

In the window on "Salva come:" select "All files (. *)"*
In "Nome file:" write the name of your file in the format specified above.

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P1H - Upload your Simulink model calling it NAME_SURNAME_P1_SIMULINK.docx(1 Point)

To save the model in docx format:
Close Matlab and Simulink
Rename your Simulink file by changing its extension

P2 – Problem n.2

P2 - Problem n.2

A drug taken orally is ingested at a $r(t)$ rate. The mass of the drug in the gastrointestinal tract is indicated by $m1(t)$ and in the bloodstream by $m2(t)$.
The rate of change of drug mass in the gastrointestinal tract is equal to the rate at which the drug is ingested minus the rate at which the drug enters the bloodstream, a rate that is considered proportional to the mass present (constant of proportionality $k1$).
The rate of change of mass in the blood stream is proportional to the amount from the gastrointestinal tract minus the rate at which mass is lost by metabolism, which is proportional to the mass in the blood (proportionality constant $k2$). Consider k1=0.1, k2=0.9. The mass of the drug is measured in mg.

IMPORTANT: The controller's goal is only to control the mass of the drug in the bloodstream.

P2A - Domande

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P2A - Develop a state space representation for the considered plant model. The system has a dynamics whose magnitude is in days. Consider $Ts = 1$, $Hp = 6$, $Hc = 6$. Write the code used. *
(1 Point)

P2B – Domande

P2 - Question B

Obviously it is not possible to have negative mass values of the drug taken, the drug in the gastrointestinal tract and the drug in the bloodstream. The drug package insert tells us that it is not possible to take more than 2 mg of the drug every day. The daily dose increase cannot exceed 0.5mg.

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P2B - Which parameters do you need to tune? (select all the true answers) *
(1 Point)

- ☐ Prediction Horizon
- ☐ Output Weights
- ☐ Input Weights
- ☐ Input Constraints
- ☐ Output Constraints
- ☐ Input Rate Constraints
- ☐ Input Rate Weights
- ☐ Control Horizon
- ☐ None of these.
- ☐ I don't know, I don't answer

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P2B - Write the code used *
(1 Point)

P2C – Domande

P2 - Question C

Taking the drug and changing its dosage have no cost.

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P2C - Which parameters do you need to tune? (select all the true answers) *
(1 Point)

- [ ] Prediction Horizon
- [ ] Output Weights
- [ ] Input Weights
- [ ] Input Constraints
- [ ] Output Constraints
- [ ] Input Rate Constraints
- [ ] Input Rate Weights
- [ ] Control Horizon
- [ ] None of these.
- [ ] I don't know, I don't answer

P2D – Domande

P2 - Question D

P2D - Carry out a simulation lasting 30 days considering $yref$ = [1 1]'. Graphically represent the evolution of the system input and outputs.

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P2D - Write the code used *
(1 Point)

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P2D - After how many days is there a drug mass spike in the gastrointestinal tract? *
(1 Point)

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P2D - After how many days does the mass of the drug in the bloodstream settle at 99%? *
(1 Point)

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P2D - Load the matlab scripts(1 Point)

To save the script in docx format:
click on the editor tab
click on the arrow at the bottom on save
click on save as.

In the window on "Salva come:" select "All files (. *)"*
In "Nome file:" write the name of your file in the format specified above.

P3 – Problem n. 3 - Domande

P3 - Given the discrete-time system S (A, B, C, D) described in Figure

$$\begin{cases} x_1(k+1) = u(k) \\ x_2(k+1) = x_1(k) \end{cases}$$

$$y(k) = \begin{bmatrix} x_1(k) \\ x_2(k) \end{bmatrix}$$

With the reference:

$$r(k) = \begin{bmatrix} 1(k) \\ 1(k) \end{bmatrix} \qquad 1(k) = 1 \ \forall k$$

Cost function:

$$V(k) = \sum_{i=H_W}^{H_P} [r(k+1) - x(k+1)]^T \begin{bmatrix} 1 & 0 \\ 0 & 2 \end{bmatrix} [r(k+1) - x(k+1)]$$

$$H_P = 2 \qquad H_W = 2$$

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P3 - Question 1: Compute the cost function V(k) *
(2 Points)

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P3- Question 2: Compute u(k) *
(2 Points)

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P3 - Question 3: Compute u(k) when r(k)= [2 2]' for any k *
(2 Points)