MTHE 393 Project

Winter 2025

Engineering Design

- Engineering design is a process of making informed decisions to creatively devise products, systems, components, or processes to meet specified goals based on engineering analysis and judgement. The process is often characterized as complex, open-ended, iterative, and multidisciplinary. Solutions incorporate natural sciences, mathematics, and engineering science, using systematic and current best practices to satisfy defined objectives within identified requirements, criteria and constraints. Constraints to be considered may include (but are not limited to):health and safety, sustainability, environmental, ethical, security, economic, aesthetics and human factors, feasibility and compliance with regulatory aspects, along with universal design issues such as societal, cultural and diversification facets.

Graduate Attributes

- Design
- Engineering Tools
- Individual and Team work
- Communication
- Professionalism
- Impact on Society and environment
- Lifelong learning
- Economics and Ethics
- Investigation

Project Goal

Determine a ***linear, time-invariant state-space*** (or transfer function) that models an ***unknown*** dynamic system and ***design*** a ***feedback controller*** to meet prescribed ***performance specifications***.

The unknown system can be referred to as a Black Box.

Unknown Dynamics

MTHE 393 design project

Two problems need to be addressed and woven into a narrative:

1. **Application Problem**

   Identify some applications for a controller and chose one to explore in depth.

2. **Technical Problem**

   Design a controller for your black box that meets a certain performance criteria.

The critical assumption

It will be assumed that the dynamics of your black box match the plant from your application.

Write your project assuming this!
Do not treat the problems as separate things. Weave them together.

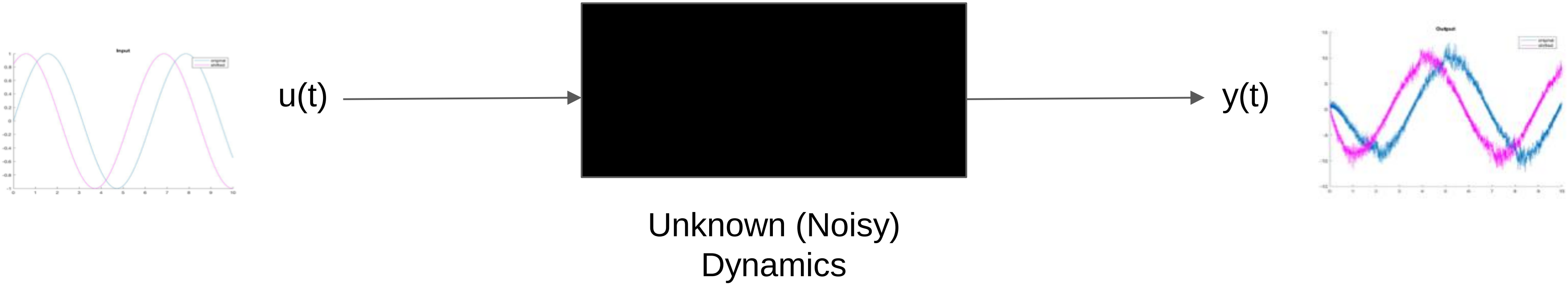
Assumption Validation

To apply these assume we need our system to exhibit Linear & Time-Invariant behaviour.

As the dynamics are “unknown” we cannot *prove* this, but we can assume and *justify* that this assumption is valid.

- Linearity
- Time-Invariance
- Quantitative Justification

Filtering



De-noise (Filtering)

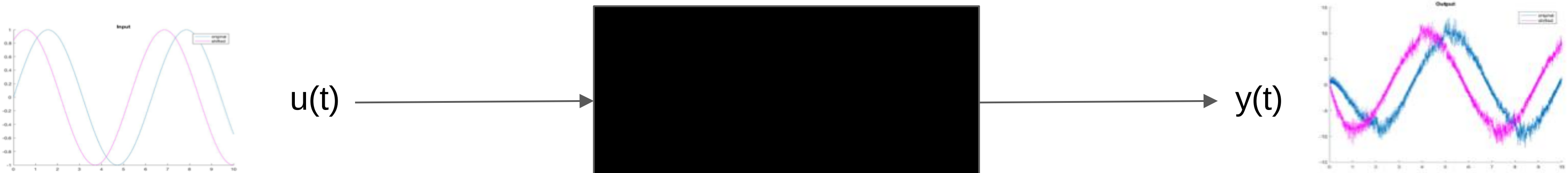
Design filter to account for the noise.

a) Determine the noise affecting the Black Box system

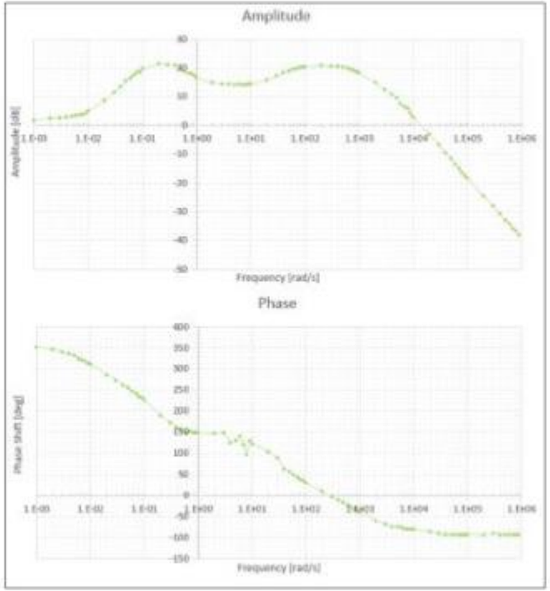
b) Comparison of alternative filtering methods

c) Quantitative Justification of the chosen filter.

Bode Plot

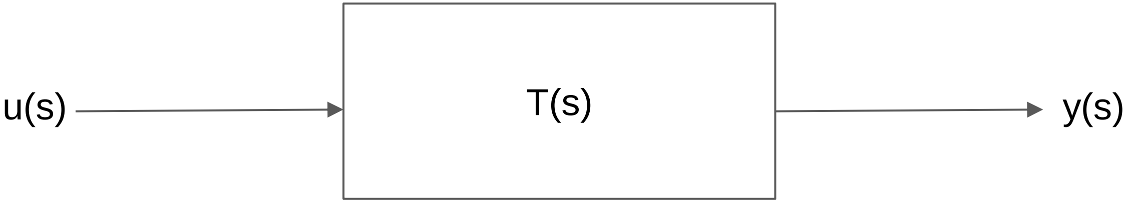


Unknown (Noisy)
Dynamics

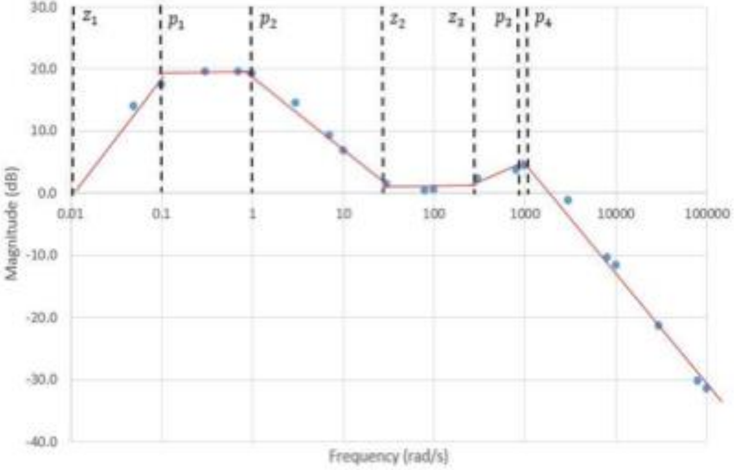


- Find the magnitude and phase response
- Frequency range of ~10^(-4) to ~10^(4).

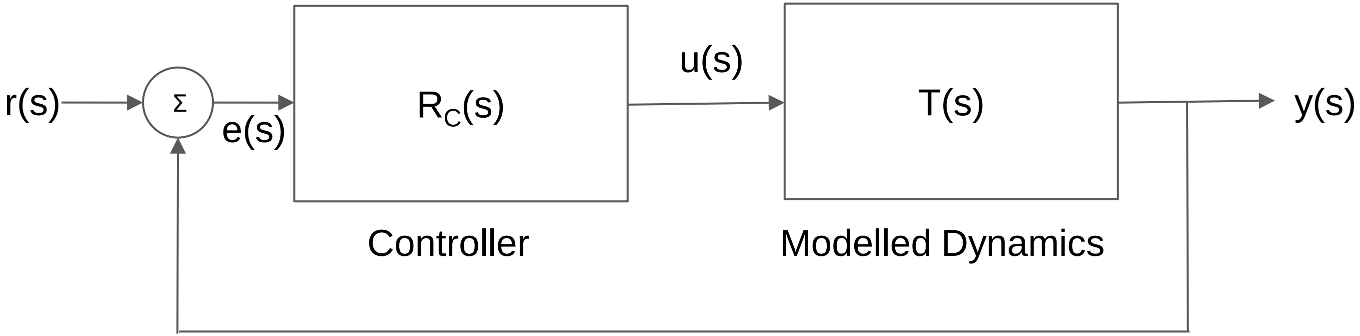
Heuristic Transfer Function



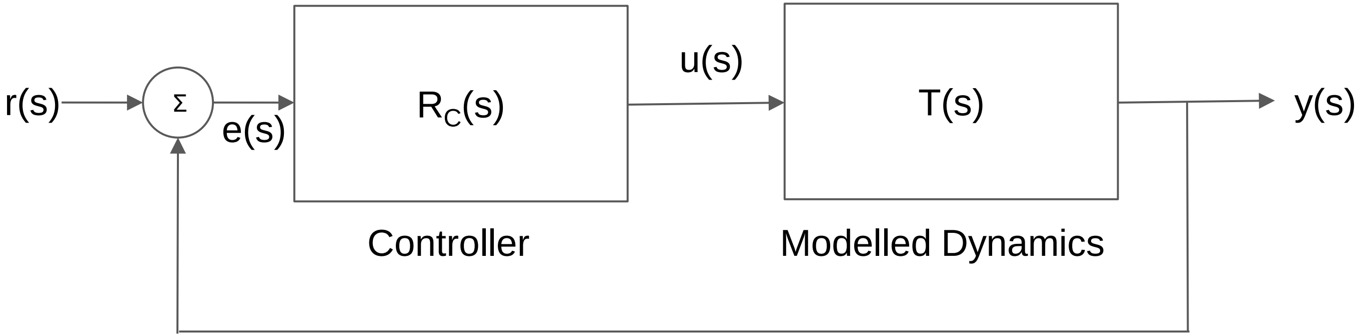
Modelled Dynamics



- Find the position of Zeroes and Poles from Bode Plot
- Determine Heuristic Transfer Function
- Compare open loop step response



- Incorporate Controller to Modelled Dynamics with feedback



- Tune Controller to performance specifications

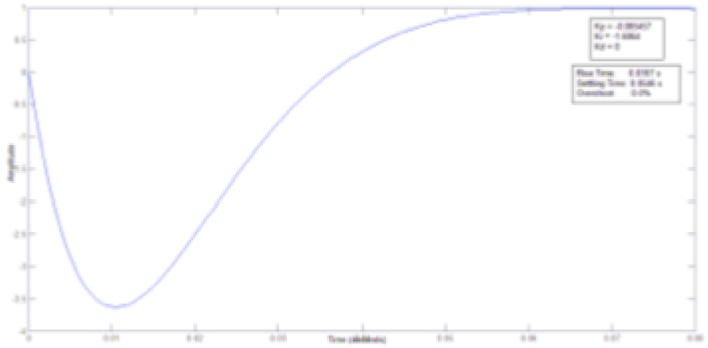
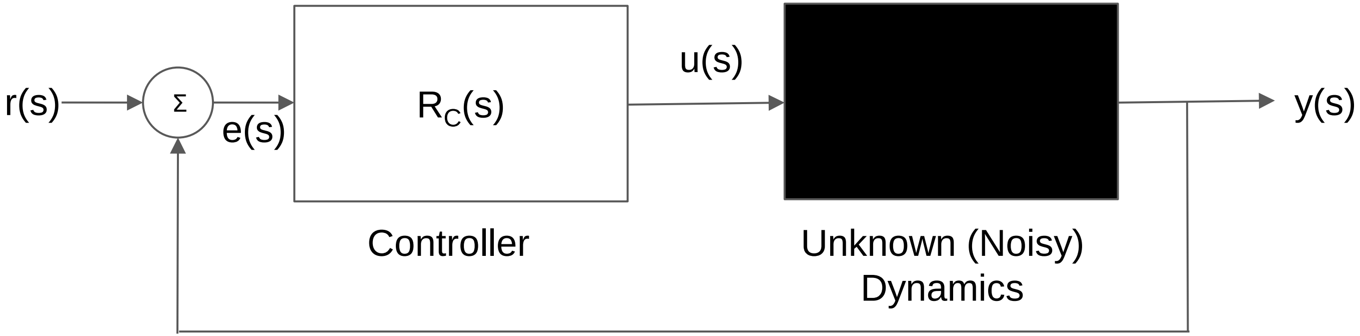
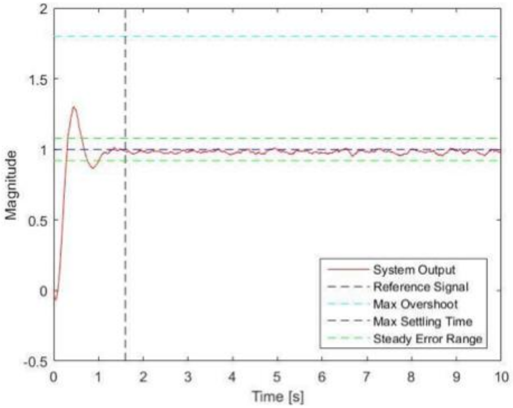


Figure 6: Step response of controlled system with PID controller gain values



Implement (& Fine tune) Controller on Black Box System



- Add Black Box and tune Controller to achieve performance specifications

Application Area

Need to choose an application where the “dynamics” are unknown, but where you need to model them to control some variable the system outputs.

Simple (and off-limit) examples include:

- Cruise Control.
- Insulin regulation in the body.
- Retrofitting buildings in earthquake zones.

Choose two applications (be creative). You will do a high-level TBL, Ethics, Regulatory analysis for both for your interim report and a thorough analysis in your final report -- more on this later.

A few notes:

- Ask questions.
- Any design step, choice, claim, conclusion you make must be justified. This is a ***design*** project, not an exercise in trial-and-error, and therefore you must show a design-making ***process***.
- Quantitative justification is the most effective way to make a point.
- The average final grade for groups whose justifications are subjective and/or qualitative is 10% lower compared to those that do.
- Divide and conquer -- you are a team, and this is a project.
- Do not overthink it.

Project Deliverables

Assessment	Max Length per Assessment*	Weight Per Assessment	# of Assessments	Total Weight
Status Reports	2 pages	2.5%	2	5%
Interim Report	15 pages	15%	1	15%
Group Evaluation	N/A	5%	1	5%
Final Presentation	10 minutes	27.5%	1	27.5%
Final Report	30 pages	27.5%	1	27.5%

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- Summarize your work on the Technical Problem
- Present two possible applications, each with a preliminary TBL
- Identify which application you will pursue further and why?

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Using the application selected at the end of the interim report, write a report/make a presentation about how you designed the control system.

An in-depth TBL is required.

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Submit your To Do List for the project. Alternatively, you may use some sort of project management application and submit the output document in place of the To Do List.

You and your group will discuss your progress on your project with Dr. Yüksel (likely in your tutorial slot).

Questions?