EENG307: Application Example #1*

Lecture 22

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Contents

1 The Big Picture: Evaluating an Application for Control Design

Let's take a step back to think about control design a bit more holistically for a specific example. As control engineers, we're interested in being able to model a system mathematically (so that we can analyze it to design a controller) and to incorporate specifications into our designs, both of which we have done for a number of examples this semester. However, we might also want to think in a more "big picture" manner, especially to question the assumptions we are given. We might ask such questions as:

- For whom are we creating a design? There might be an obvious client, but are there other stakeholders that might not yet be considered? Are there people, communities, environments, or flora/fauna that might be impacted if the project succeeds...or if it fails? Are there things we can do as control engineers to minimize any negative impacts?
- How is the "problem" we are trying to solve currently defined? Are there other ways we could think about it, and how would that impact our designs?
- What do we need to model in order to create a design? How do we know when a model is "good enough"?
- Given our model, what kinds of issues do we anticipate?
- How will we measure success?
- and more.

This "article" is a bit unusual as it is more of a scaffold for class discussion than an article itself.

2 Motion Modeling and Control for a Solar Array using Simulink

Begin by opening the video by the Mathworks at https://www.youtube.com/watch?v=bE179wgm164. This 11-min video illustrates the process of modeling, designing, and evaluating a controller for a solar panel consisting

of a motor with rotating element that tracks the sun across the sky. It is produced as a teaching tool for Simulink but can illustrate many of the concepts we are working on in this class.

2.1 Motivation and Overview

Watch the first 1:30 minutes of the video and answer these questions:

1. What reason is given for needing an active control system? In other words, what is the problem that we are trying to solve?

   solar panels fixed in place – don't produce as much elec. as if they rotated

2. What are the three main steps listed for the process that will be illustrated?

   model
   design
   test

3. In what domain (time or frequency) is the physical system initially modeled? Can you see any similarities to the DC motor or rotating mechanical systems models we have built in this class?

   time, e.g.
   $$\frac{d^2\theta}{dt^2} = \frac{1}{J}\left(T - k_d \frac{d\theta}{dt}\right)$$
   $$s^2\theta(s) = \frac{1}{J}\left(T(s) - k_d s \theta(s)\right)$$
   $$\frac{\theta(s)}{T(s)} = \frac{1}{Js^2 + k_d s}$$
   damping term

2.2 Panel Model Creation

Since this is a Simulink tutorial video, it should come as no surprise that Simulink is used to build the model. Watch the next 4:45 minutes of the video (until time 6:15) and answer these questions:

4. What do you notice about building the model from the time-domain equations (from the "Motivation and Overview" part of this application example) vs. by first deriving your transfer function and implementing that in Simulink directly like we have previously done?

   uses integrator, gain, & summing blocks only
   (see separate sheets)

5. Given that the Simulink model consists of integrators, gains, and a summing junction (square version), could you use block diagram techniques to derive the transfer function for the panel equation of motion from torque to angular position theta?

   yes! see separate sheet

6. Given your understanding of stability and what you observe in the video, which of the following two systems would you expect to be BIBO stable and which not? Why?

   - System with torque as input and angular position (theta) as output

   not BIBO stable (can tell from one example of a bounded input & unbounded output)

- System with torque as input and angular velocity (theta_dot) as output

$$\text{BIBO stable:} \left(\frac{1}{Js^2 + bs}\right)(s) = \frac{1}{Js + b}$$

(need T.F. to prove)

7. Do you notice any new Simulink elements or techniques that might be helpful (beyond what your team has been using for the project thus far)? If so, make a note of them so you don't forget.

2.3 Control Design

The creation of the motor model is summarized very quickly, and then the video gets into control design concepts. Watch the next 4:10 minutes of the video (until time 10:25) and answer these questions:

8. Before designing the controller, what test(s) do they show to check if their plant system (motor + panel) is configured correctly?

Panel spins when voltage applied to motor

9. How is the reference ("sun position") initially modeled (i.e., what kind of signal is used)?

step

10. What kind of controller is used? What is the reason given for eliminating one of the P, I, or D terms?

PI — don't need to respond to quick changes

11. The video shows some actual sun data used as a reference. If you didn't have that data, what kind of reference ("sun position") would better represent the actual movement of the sun, compared to the initial kind of signal selected? What system **Type** would you expect to need to track this kind of signal with zero steady-state error?

roughly a ramp (time ~9:30)

12. Is the controller's performance deemed suitable? What reasons are given for why or why not?

yes: "pretty good" — no rationale!

3

2.4 Summary

In the last minute of the video, some additional tools and information are mentioned. For example, we sometimes use/teach Simscape in this class, which allows us to obtain models for physical systems without first needing to derive the equations. Feel free to check these out if they seem interesting!

Now that we've finished the video, let's go back to the initial "big picture" questions and discuss:

13. For whom was the video creating a design? Are there other stakeholders that might not yet be considered? Are there people, communities, environments, or flora/fauna that might be impacted if the project succeeds...or if it fails? Are there things we can do as control engineers to minimize any negative impacts?

    Mathworks

    Workers on the roof, birds/wildlife

    Ask questions: what are noise impacts? Does energy gain offset energy required to move panels? etc.

14. Is the application example timely and relevant in our (or your) community? Can you envision this kind of control application benefiting you, whether singular or plural?
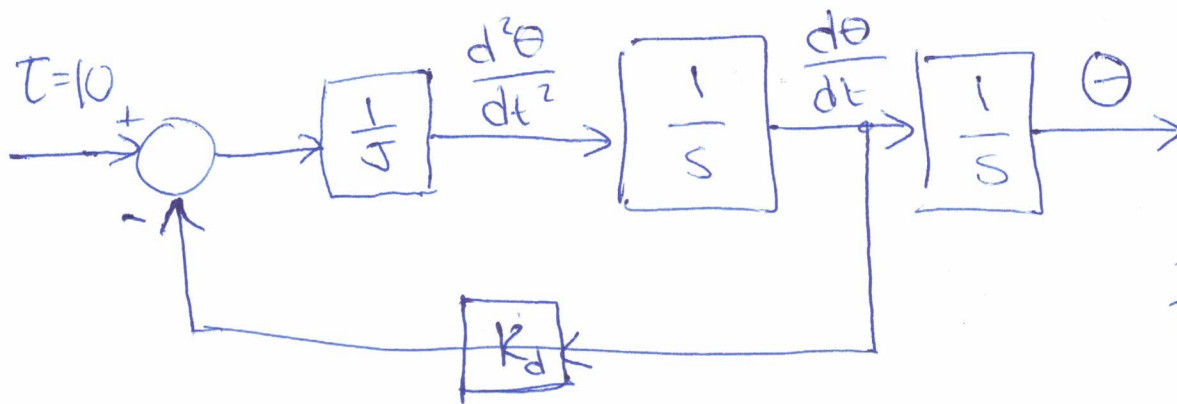
    (skipped due to time)

15. Are there other ways we could think about the problem of tracking the sun to increase energy efficiency, and how would that impact our designs?

    More on cost-benefit analysis, e.g. ~~does~~ ~~cost~~ would the $ be more usefully spent on better insulation or other ways to reduce electricity usage. More tech isn't always the most efficient answer.
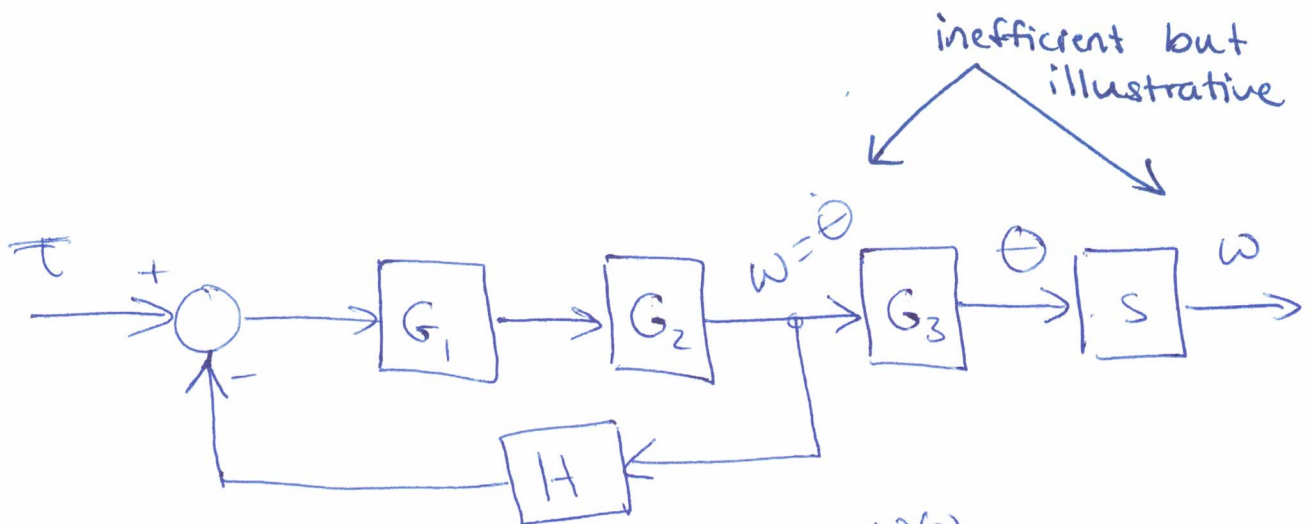
3   Quiz Yourself

Since this article is written as a guided in-class discussion for a solar panel application example, there are no quiz yourself problems.

$\tau = 10$

$$\frac{\theta}{\tau} = \frac{1}{Js^2 + K_d s}$$

draw diagram from eq:

$$\frac{d^2\theta}{dt^2} = \frac{1}{J}\left(\qquad \right) \quad \text{etc.}$$

inefficient but illustrative

$$\frac{\omega(s)}{\theta(s)} = s$$

$$\frac{\omega(s)}{\tau(s)} = \frac{\omega}{\theta} \cdot \frac{\theta}{\tau}$$

$$= s \frac{1}{Js^2 + K_d s}$$

$$= \frac{1}{Js + K_d}$$