This document contains my notes on Steve Brunton's Control Bootcamp video series. Each section corresponds to the video of the same title.

Contents

1 Overview

- **Passive controls** attempt to control a system passively, i.e. they are built into the system and don't vary based on observations of the system.
- **Active controls** attempt to control a system actively, i.e. they change their behaviour based on observations of the system.
- **Open-loop controllers** don't observe the output of the system — their inputs are predetermined. One downside of this approach is that you may unnecessarily input energy into the system when it already has the desired output.
- **Closed-loop controllers** observe the output of the system to determine their inputs. They have several benefits over open-loop controllers:
  - They handle uncertainty in the system, e.g. if you don't always know how the system will respond, or if your model isn't completely accurate.
  - They handle disturbances in the system, e.g. if someone pushes a self-balancing inverted pendulum. It may not be possible to account for these in the model.
  - They can be more energy efficient than open-loop controllers, i.e. they don't have the downside mentioned above.
- The mathematical model used in this course is a state-space based system of linear differential equations

  $$\dot{\mathbf{X}} = \mathbf{A}\mathbf{X}$$

  where $\mathbf{X}$ is the **state vector** — a vector containing all the system's values of interest — and $\dot{\mathbf{X}}$ are their rates of change at a time t.
- The solution to the above equation is

  $$\mathbf{X}(t) = e^{\mathbf{A}t}\mathbf{X}(0)$$

  and the eigenvalues of $\mathbf{A}$ can be used to determine the stability of the system, e.g. if they all have negative real components the system is stable.

- Control is introduced to the system by modifying the equation to

$$\dot{\mathbf{X}} = \mathbf{AX} + \mathbf{BU}$$

  where $\mathbf{B}$ is a coefficient matrix and $\mathbf{U}$ is the input to the system.

- If we make the input to the system

$$\mathbf{U} = -\mathbf{KX}$$

  then

$$\begin{aligned}\dot{\mathbf{X}} &= \mathbf{AX} - \mathbf{BKX} \\ &= (\mathbf{A} - \mathbf{BK})\mathbf{X}\end{aligned}$$

  and now it is the eigenvalues of $\mathbf{A} - \mathbf{BK}$ that determine the stability of the system, i.e. we can make an unstable system stable by appropriate choice of inputs.