BM2000 Control Systems

PID Controller Design

Instructions

1. The deadline of submission of your codes is March 23rd, 18:00.
2. The in-person evaluation of all the submissions will take place on the same day at 18:00.
3. The mode of submission will be announced on March 19th.

In critical care units, intravenous infusion pumps are used to deliver drugs that regulate physiological variables such as blood pressure, sedation level, or glucose concentration. A common example is automated delivery of anesthetic drugs (e.g., *propofol*) where the objective is to maintain a desired depth of anesthesia during surgery. Modern systems attempt to implement closed-loop control, where a physiological signal is measured by a sensor (e.g., EEG-based BIS index). For a given physiological signal, a controller determines the drug infusion rate. Once infused, the drug dynamics inside the body affect the measured physiological variable. If $u(t)$ is the drug infusion rate and $c(t)$ is the drug concenttaion in the target tissue (brain), then these two are related by

$$\dot{c}(t) = \frac{1}{\tau_1}\left(u(t) - c(t)\right) \tag{1}$$

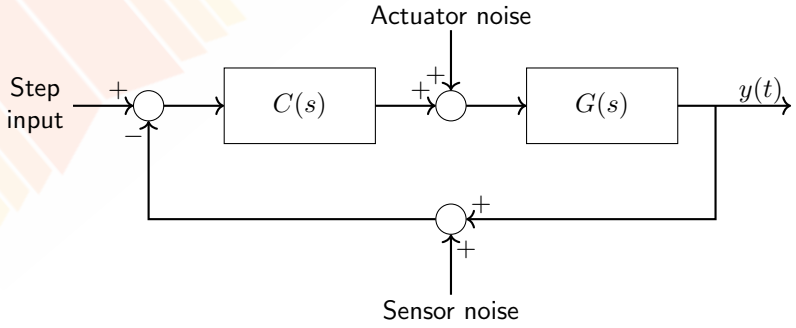
This equation takes into account the effect of drug circulation and its diffusion in the tissue. Once the drug reaches the target organ (brain), its effect depends on processes such as drug binding to the receptor, neurotransmitter modulation, and cellular signaling, etc., to give rise to the biological effect $y(t)$ that is measured by the sensors. This relation is also assumed to follow a first order kinetics given by

$$\dot{y}(t) = \frac{1}{\tau_2}\left(c(t) - y(t)\right). \tag{2}$$

In addition to this, two sources of uncertainty are also present in the system

1. *Actuator noise*: Infusion pumps exhibit fluctuations in delivered drug rate due to mechanical imperfections.
2. *Sensor noise*: Physiological sensors (e.g., EEG electrodes) introduce measurement noise.

The system can be effectively represented as



In this project, you will design a PID controller to regulate a simplified biomedical system while accounting for these noise sources, along with the following performance requirements

- The system is to be designed to work with step inputs.
- The steady-state error should be as small as possible.
- The maximum overshoot should not exceed 5%.
- The settling time should not be more than 2 minutes.