

EPFL



Stabilization Control System for Dielectric Elastomer Actuators

Progress Update Presentation

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■ Integrated Actuators Laboratory (LAI)

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Let me introduce myself



NAME

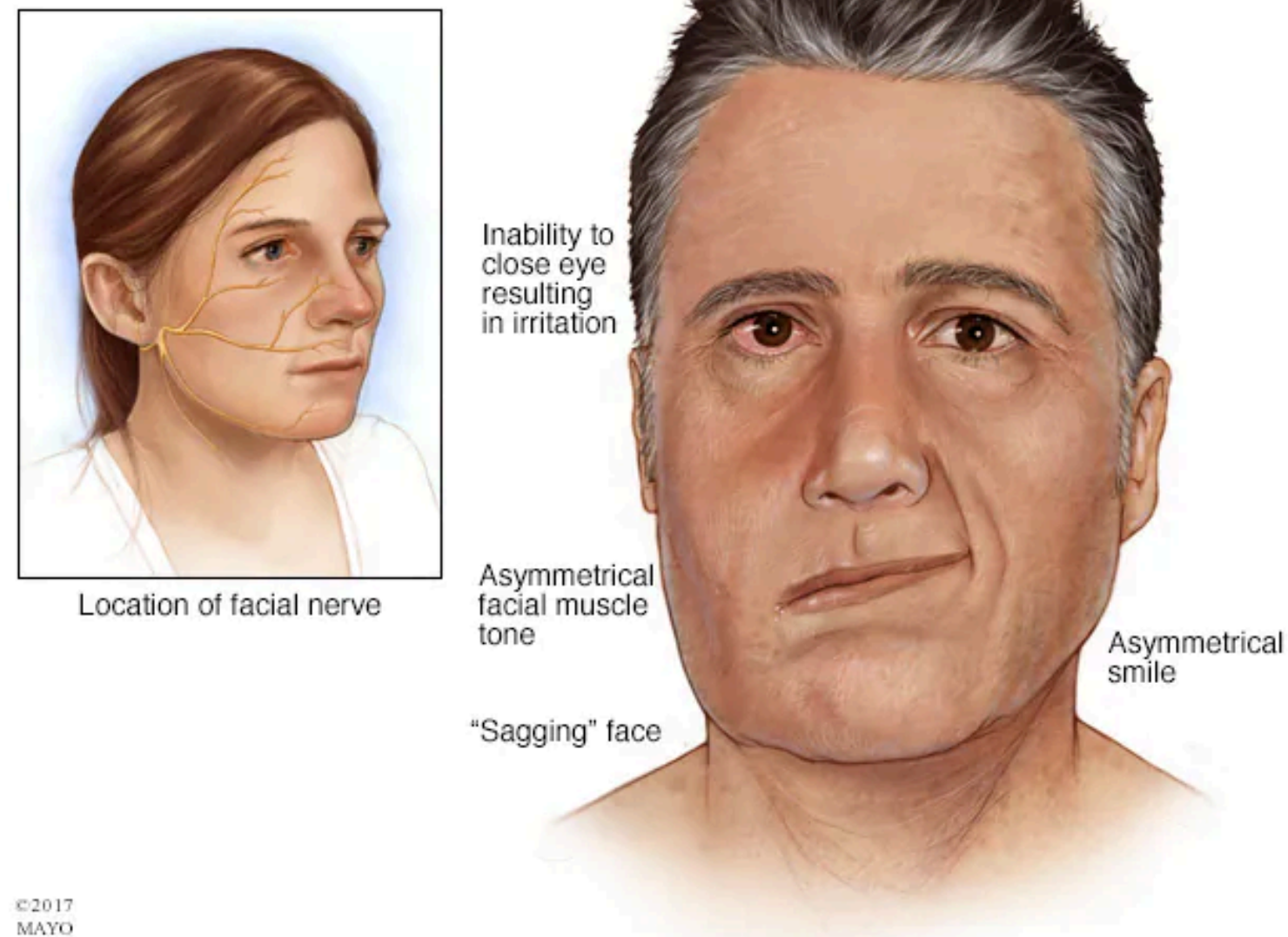
Raki Ben Mustapha

POSITION

2nd year bachelor student in
Microengineering

- my passion is to understand the human body and mind
- I aim to merge tech advancements with healthcare
- I m part of the [Laidlaw Scholars Program](#) which gave me the opportunity to work in your lab

The Challenge

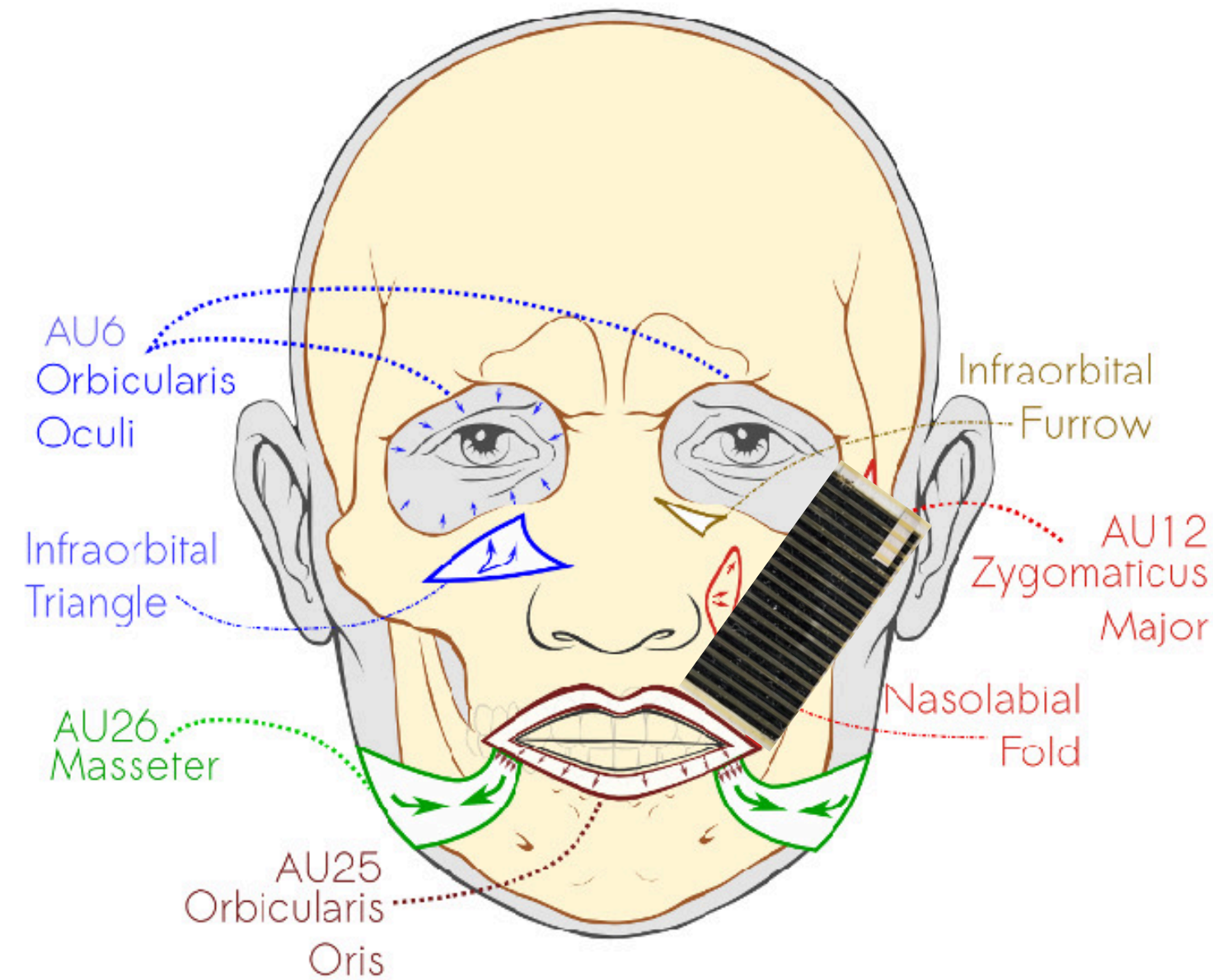


- Facial paralysis is a health condition that affects thousands of people.
- It significantly impacts the ability to express emotions.
- Essential functions like blinking and smiling are impaired.
- One common cause of facial paralysis is Bell's palsy.
- Traditional treatments often fall short in restoring natural movement.

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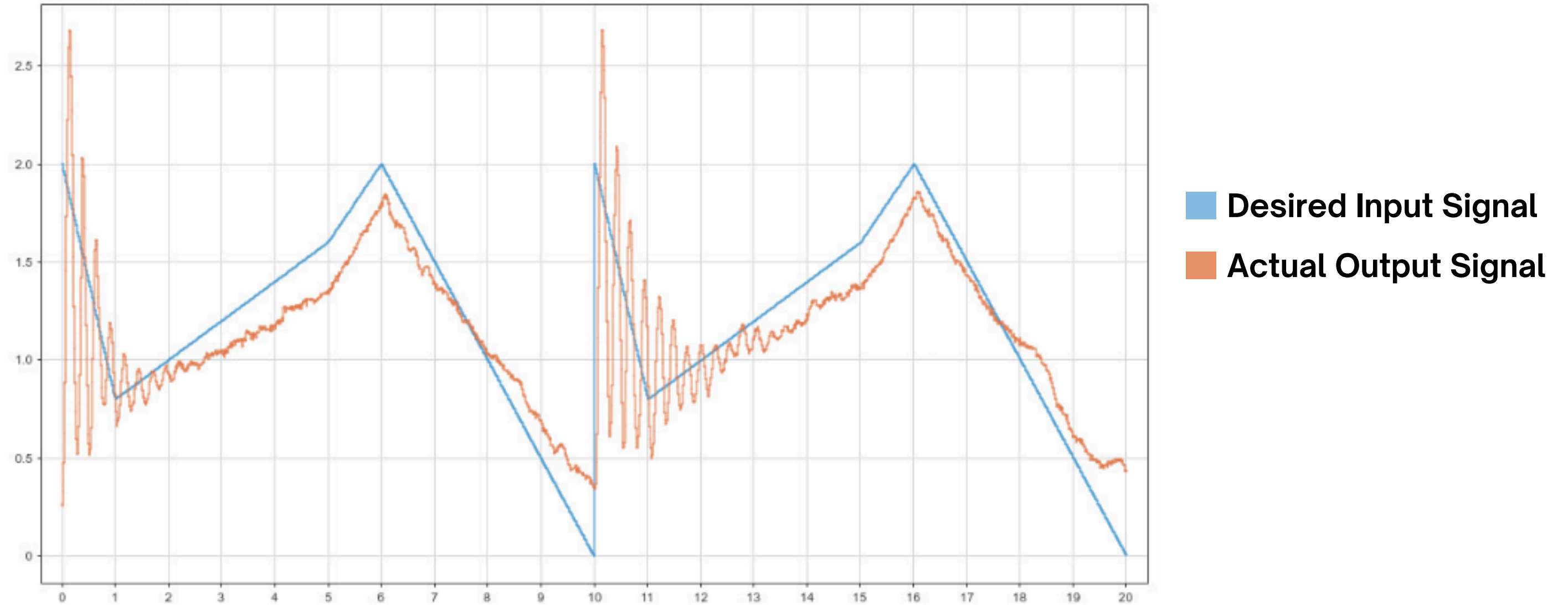
The Solution



- **D**ielectric **E**lastomer **A**ctuators
- flexible materials can mimic the natural movement of muscles, making them ideal for facial reanimation.
- However, controlling these actuators precisely to achieve smooth, lifelike movements is a complex challenge.

This is where my work comes in

My Role



Graph Title: Comparison of Desired Input Signal and Actual Output Response

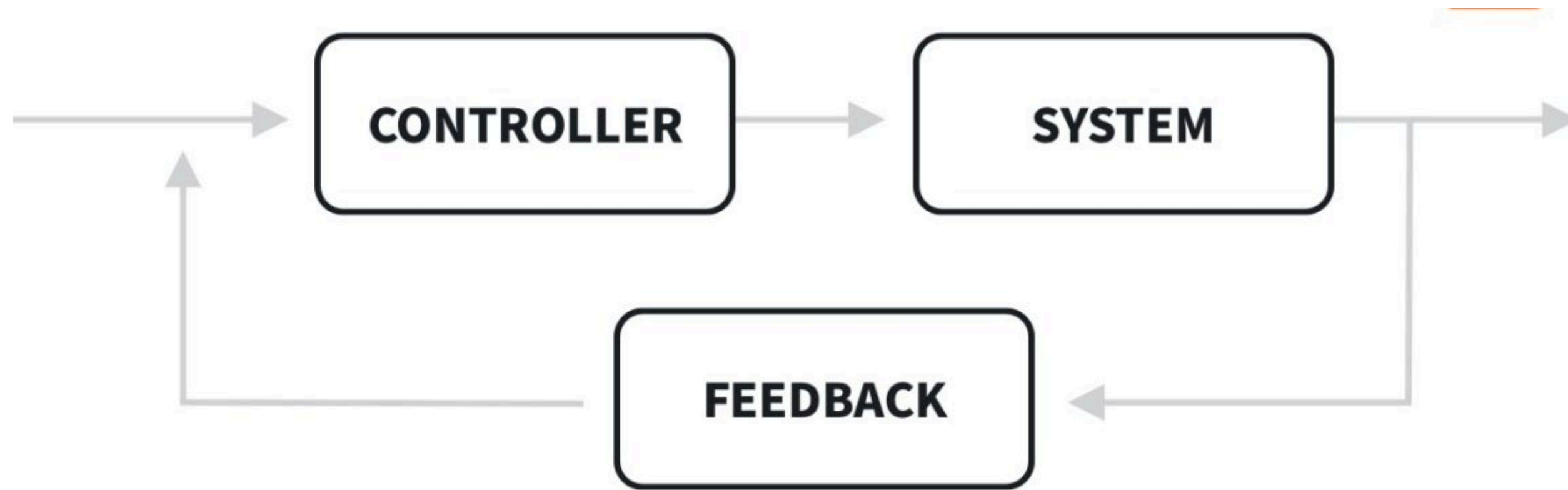
the output response follows the general trend of the input but with a lot of deviations, oscillations, and delays.

these errors may impact the precise and accurate control of the DEAs

My Role

developing and refining **a control system** to minimize these deviations,
ensuring that the output response matches more closely the input
commands

What is a control system ?

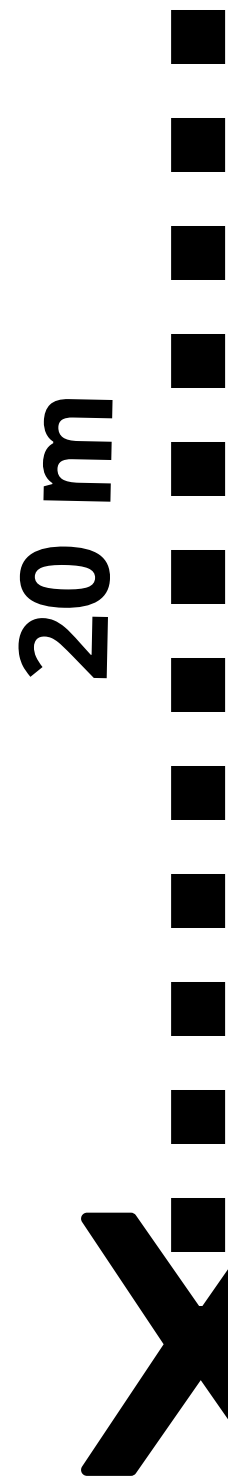
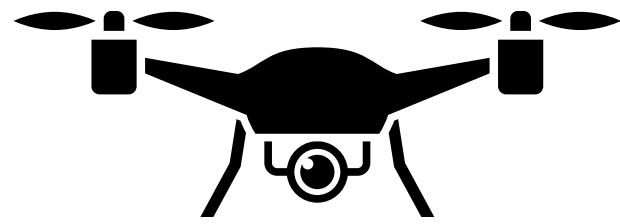


A control system is a set of mechanisms that regulates the behavior of a device to achieve a desired output

One of the most known control systems is : **PID control**

Which i will be using in my project

What is a control system ?



To better understand, consider a drone that is commanded to rise to an altitude of 20 meters.

Due to initial errors or disturbances, the drone might only reach 19 meters.

Sensors detect this error and provide feedback to the control system.

The controller processes this feedback and instructs the actuators to adjust the drone's motors, making it rise by an additional meter.

This process occurs iteratively in a closed loop until the drone accurately reaches the desired 20-meter altitude.

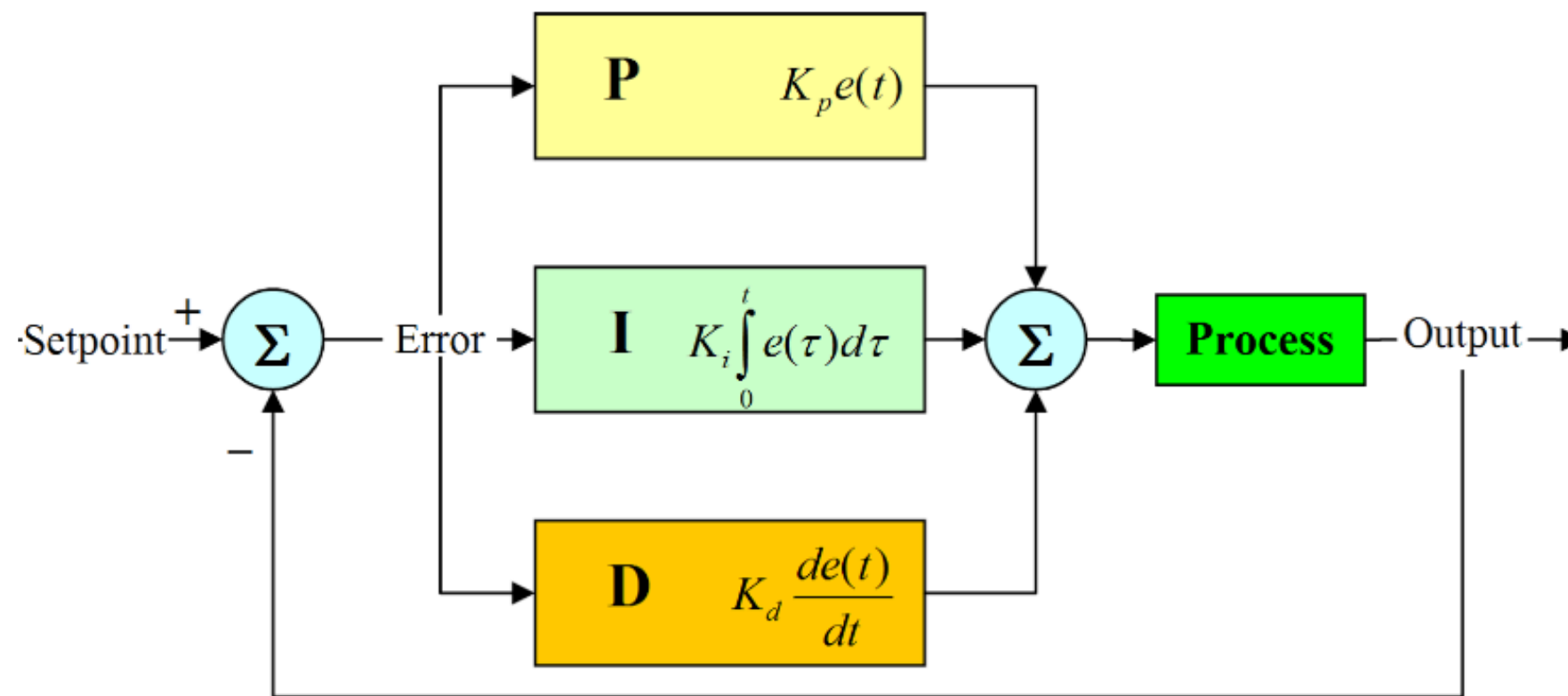
The efficiency of the control system determines how quickly and stably the device can reach and maintain the target output. A better control system minimizes the time and oscillations to reach the desired command.

Pid Control

Proportional

Integral

Derivative



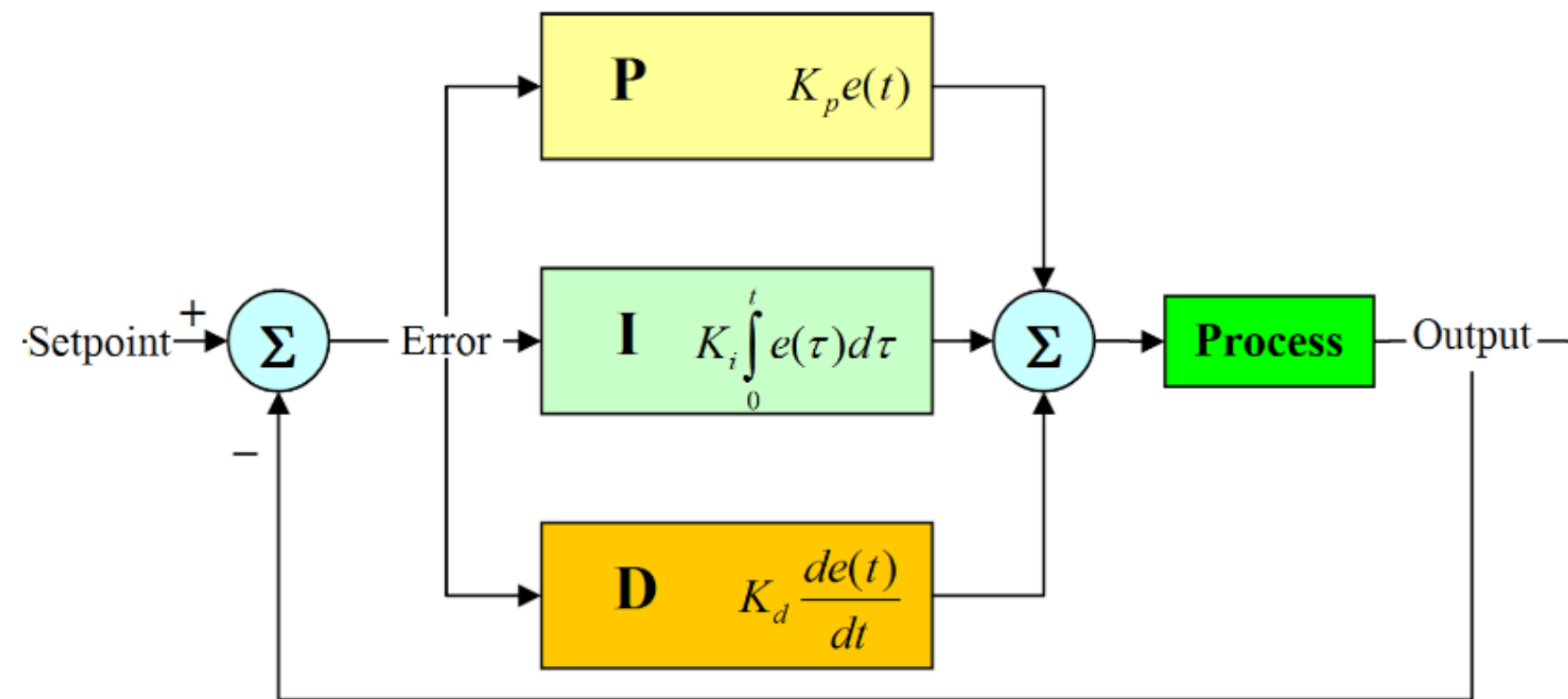
Each one of these three components deals with a specific type of error.
Let's understand how they work.

Pid Control

P

responds to the current error between the desired setpoint and the measured output.

Present error

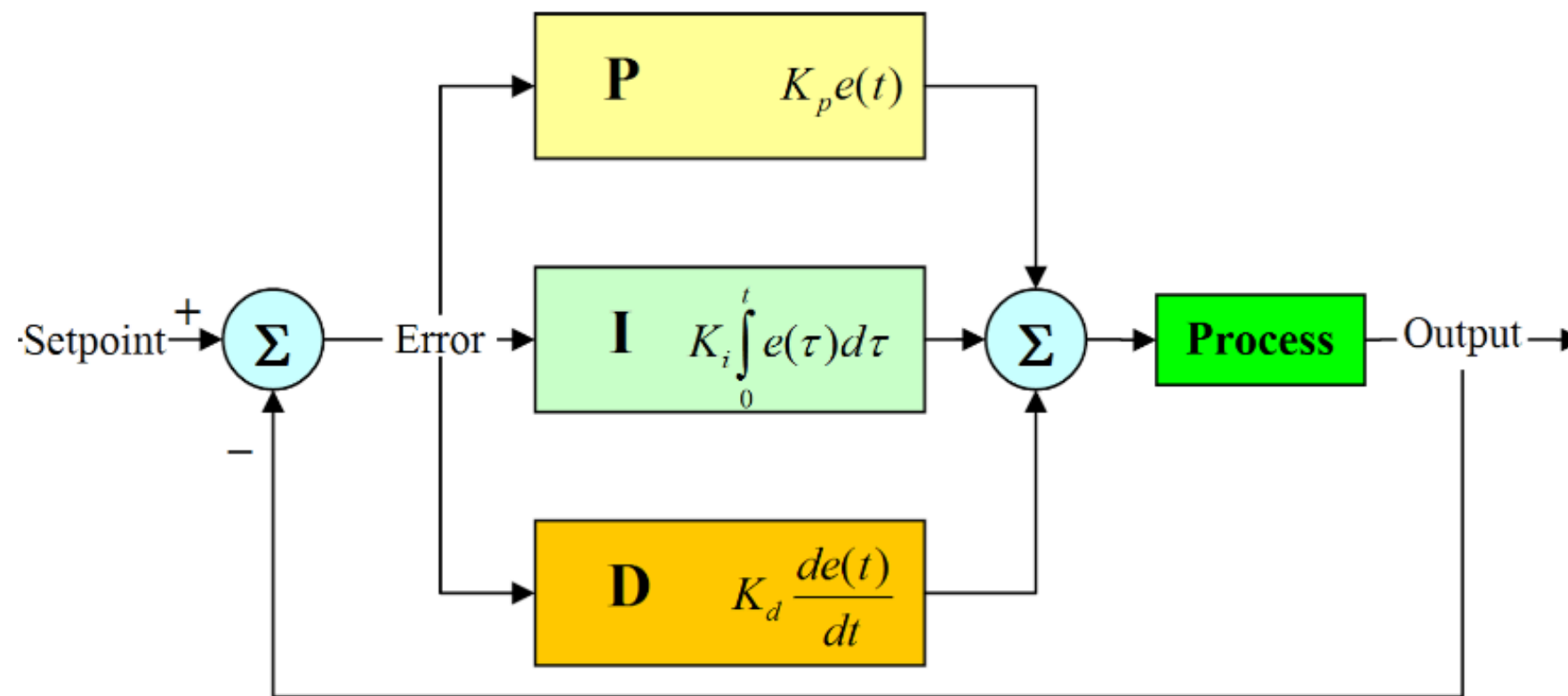


Pid Control

Integral

Integral control addresses accumulated past errors over time

Past error

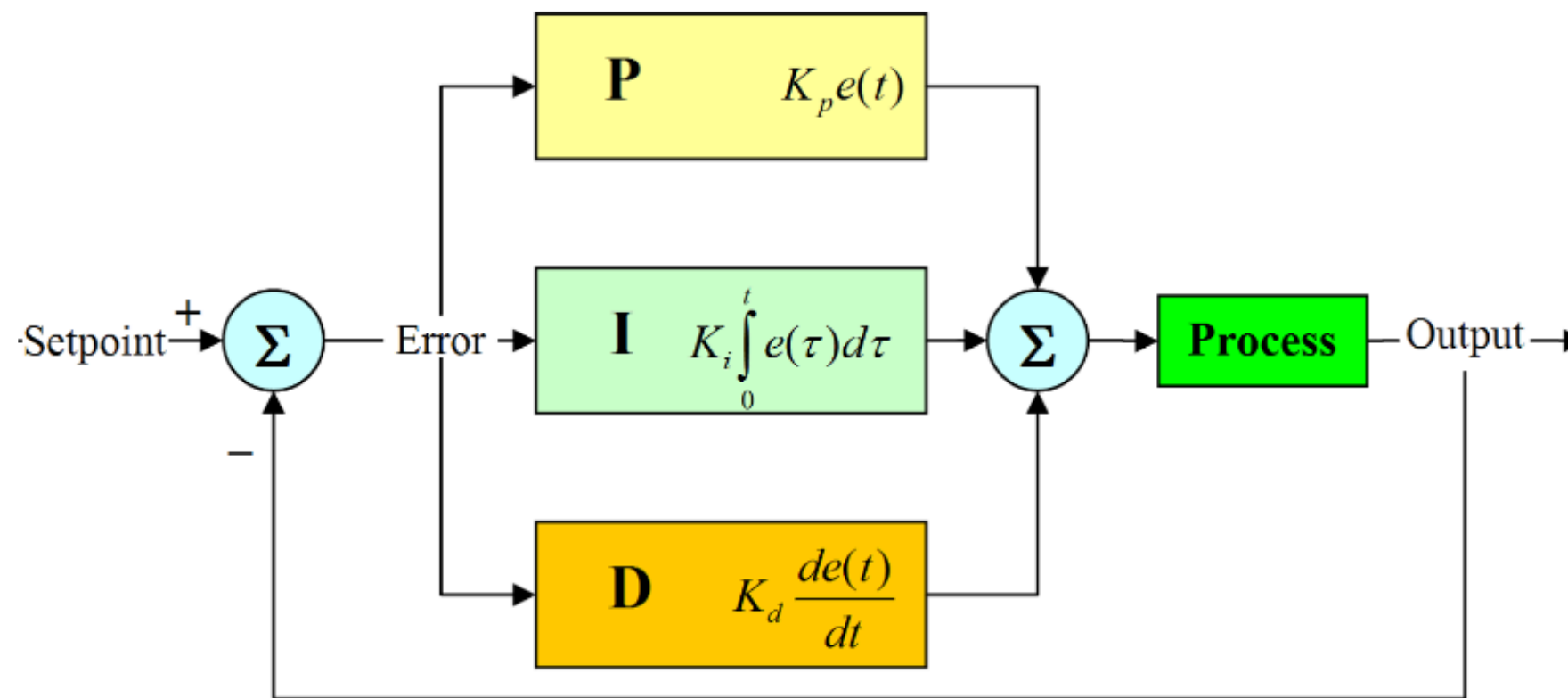


Pid Control

Derivative

predicts future error based on its current rate of change and adjusts the actuator output accordingly

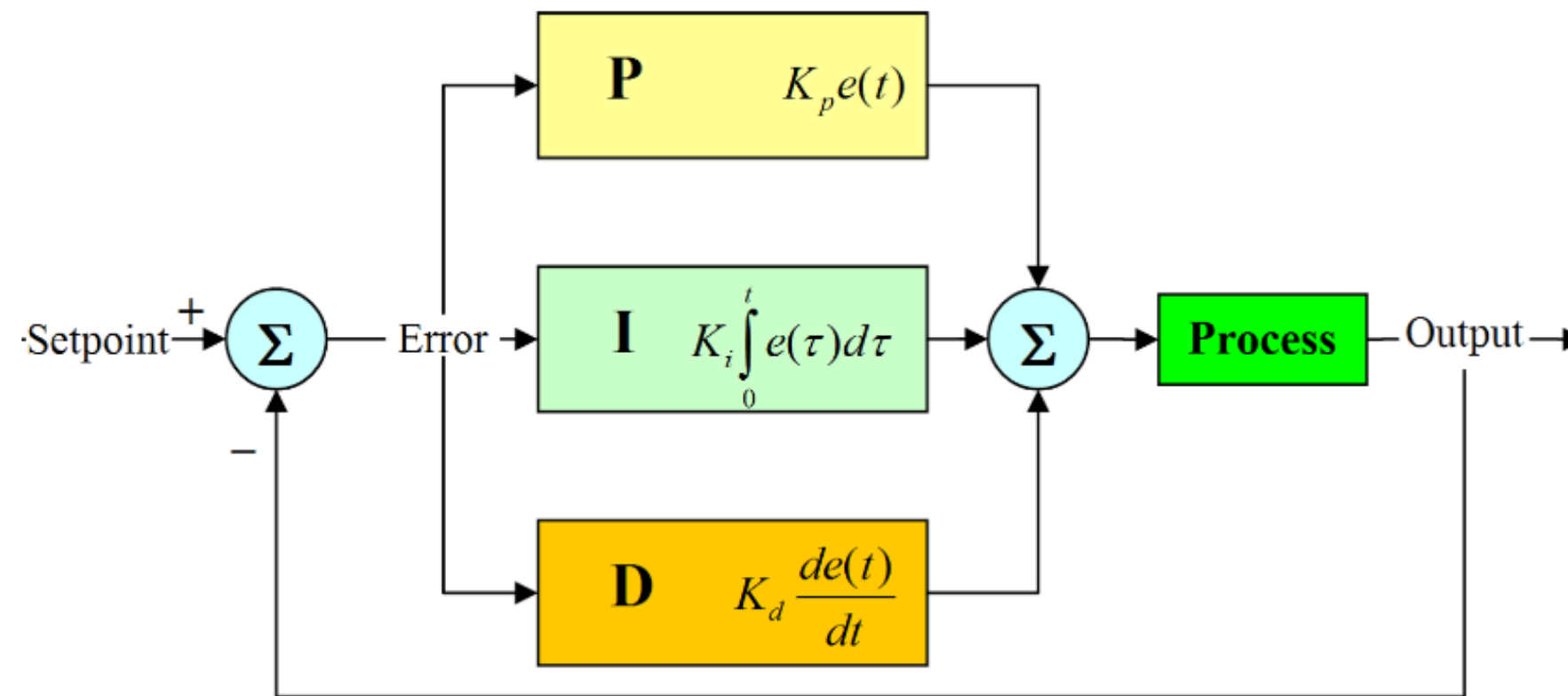
Futur error



Pid Control

Each component is multiplied by a coefficient to enhance its impact on the overall control system.

K_P K_I K_D



My mission was to tune the PID controller by selecting the optimal coefficients to achieve the best stability and the fastest response time.

PID TUNING

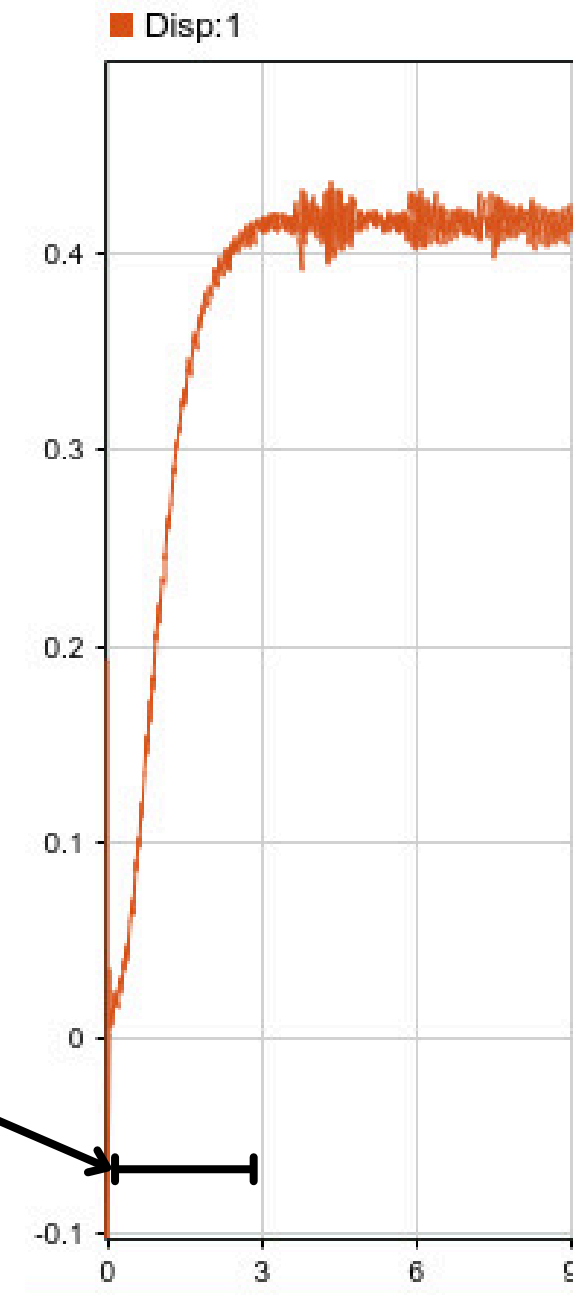
Matlab involves tuning tools that can help you achieve the best output. it can autotune your PID control using the transfer function that you have of your system .

$$G_{iso} = \frac{0.005391s^2 + 32.5s + 3.11e^4}{s^4 + 6.031s^3 + 5778s^2 + 9038s + 5.985e^5}$$

Autotune limits

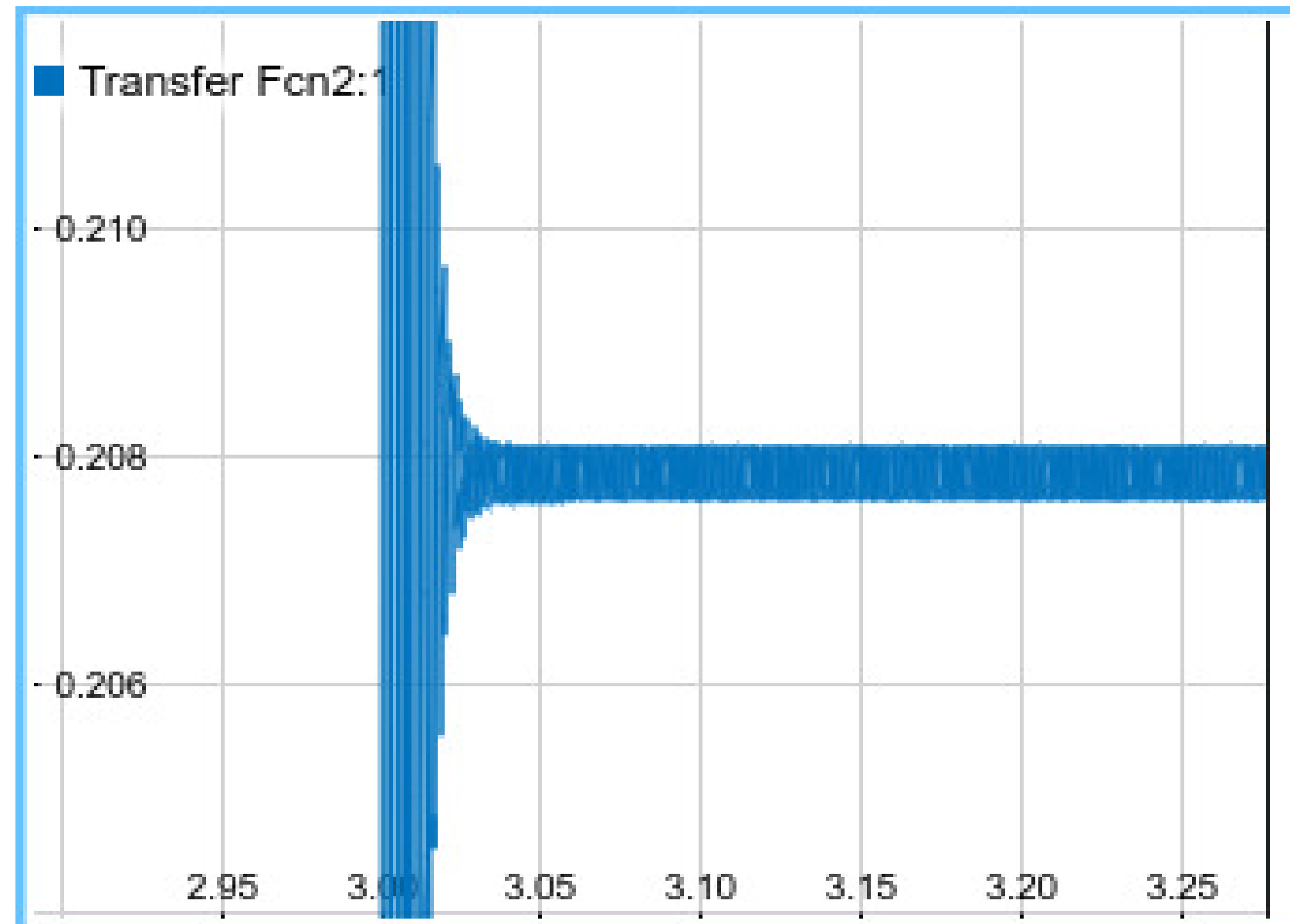
The MATLAB autotune tool had several limitations, and the best response time I was able to achieve with it was 3 seconds.

_ long response time (3s)



Autotune limits

Trying to minimize the time response, i find myself with a non stable response

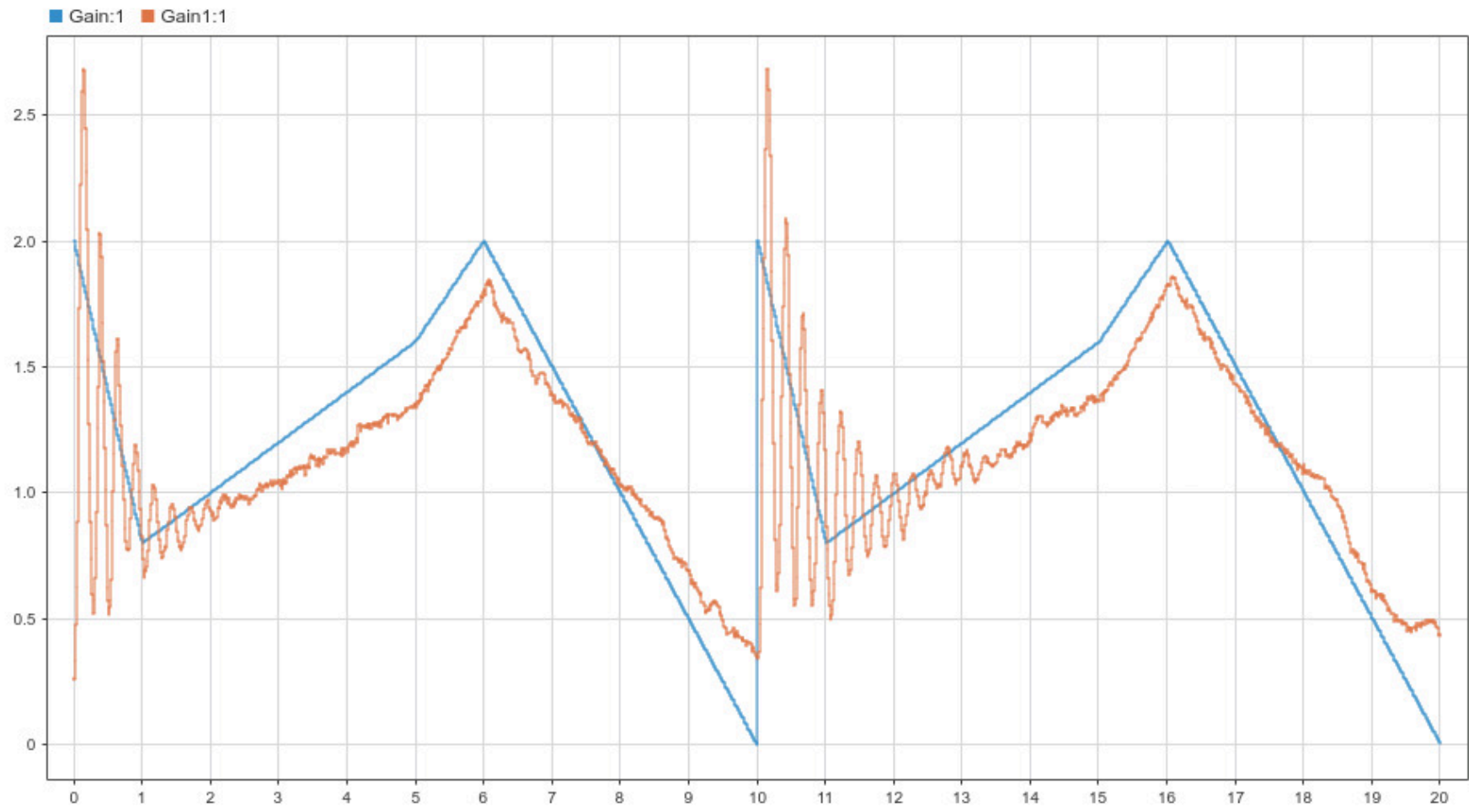


Solution: Manual tuning

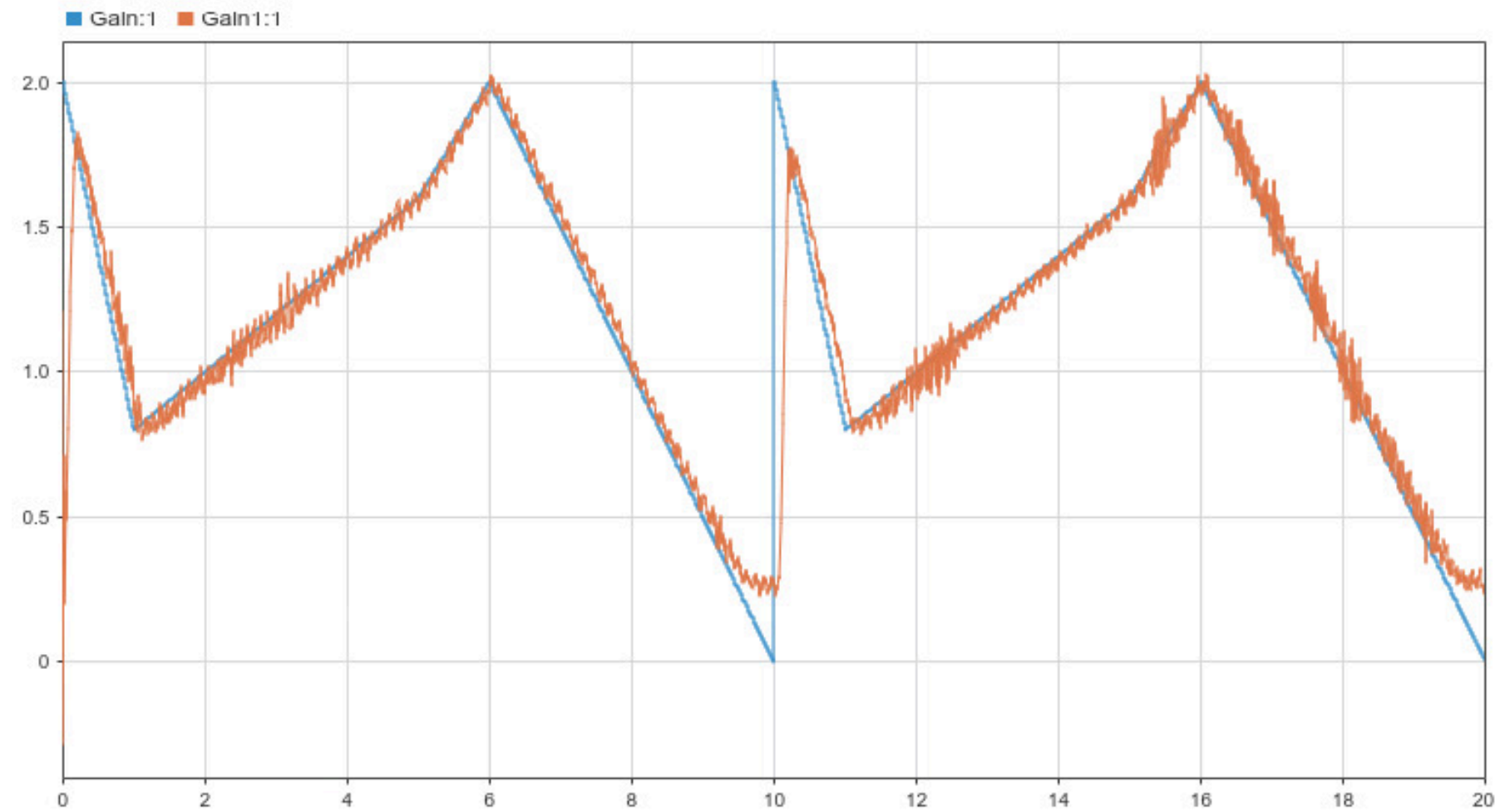
I found myself needing to balance the trade-off between :

- good stability
- fast response time

The result with a manual tuning

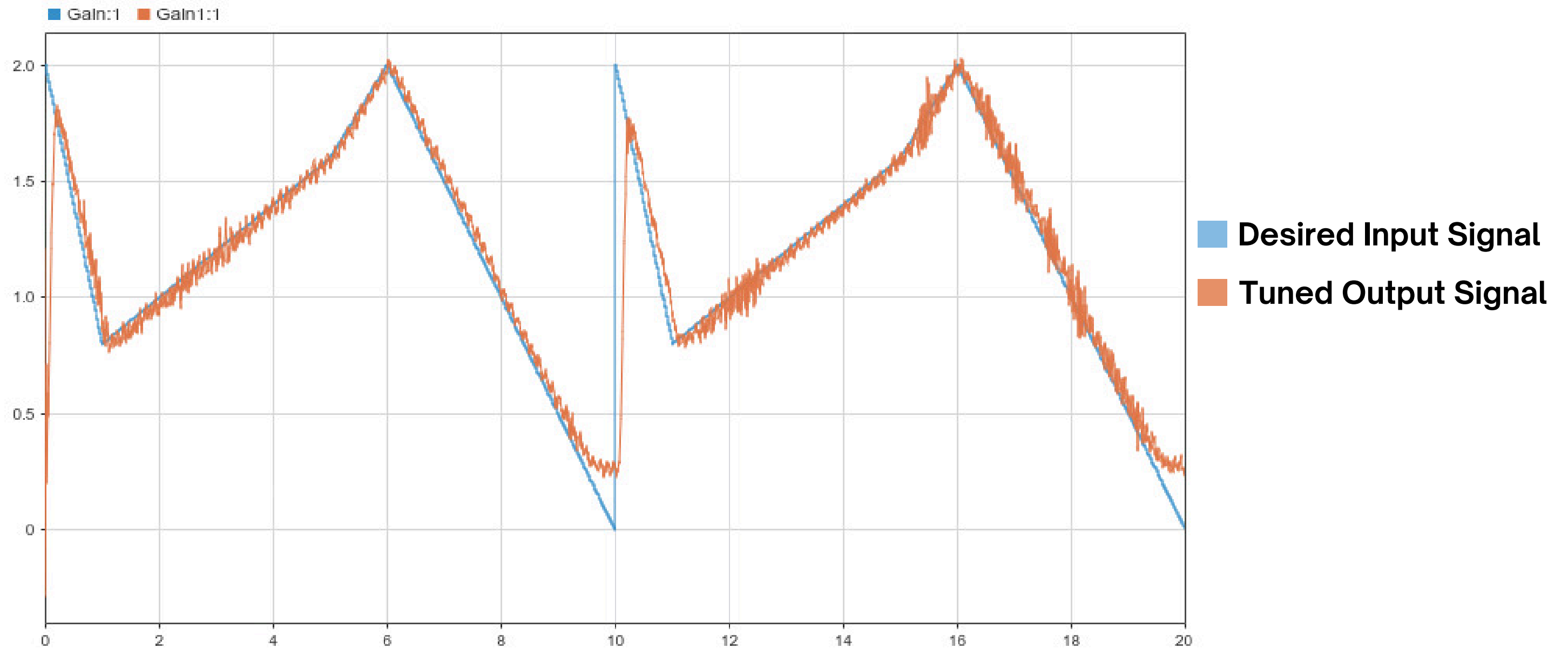


BEFORE



AFTER

The result with a manual tuning



Graph Title: Comparison of Desired Input Signal and Actual Output Response after tuning the PID control

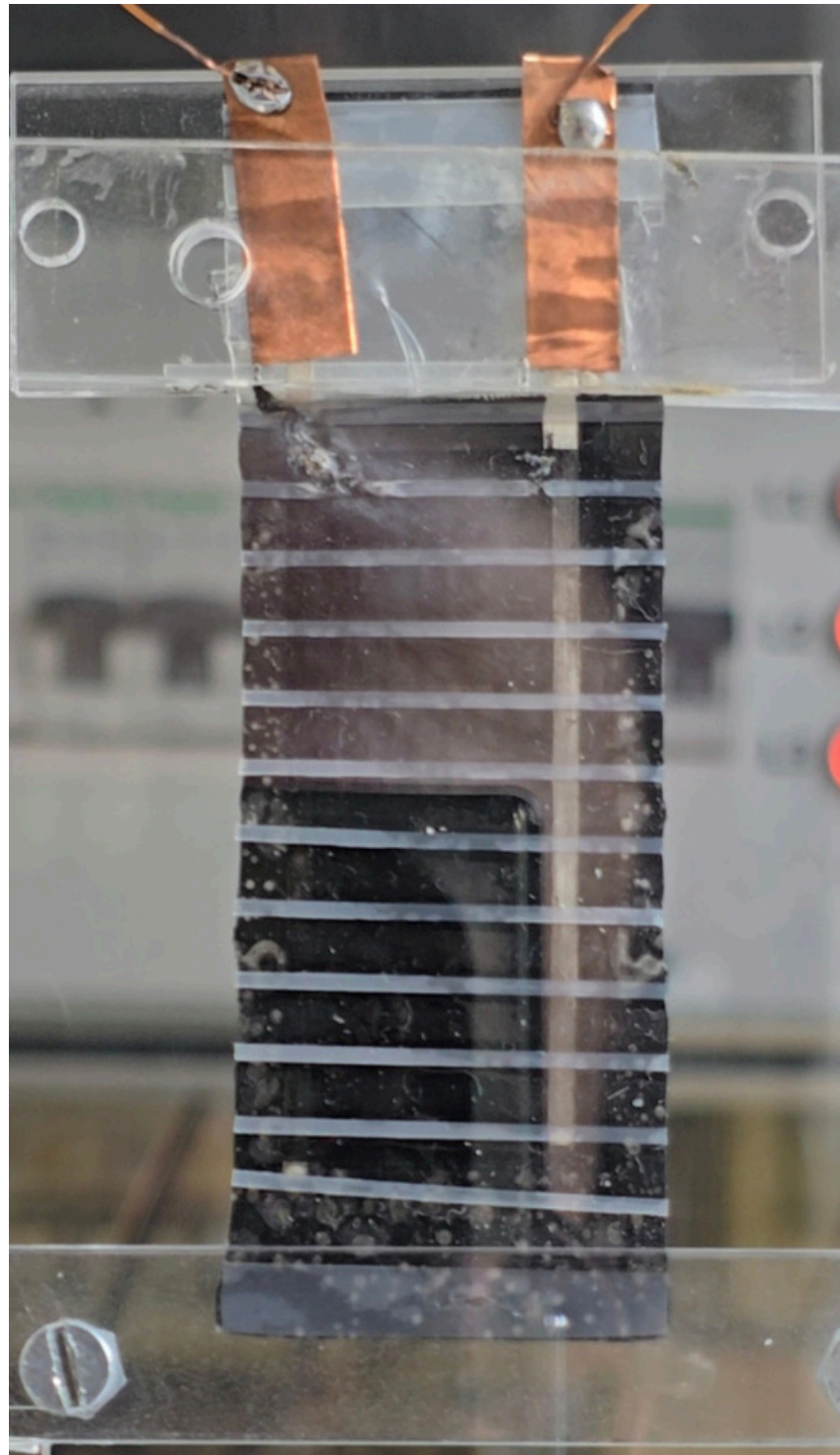
We observe that the output signal is more stable and closely follows the desired signal. The small oscillations are merely noise introduced by the laser sensor.

The response time: 50 ms

My next steps

Although the results were impressive, the control system only functioned while applying a 2 N vertical force, achieved by attaching a 200-gram weight to the DEA.

Additionally, the input signal was not representative of a human muscle signal. My next step was to test the system on a more human-like prototype using a human muscle signal.

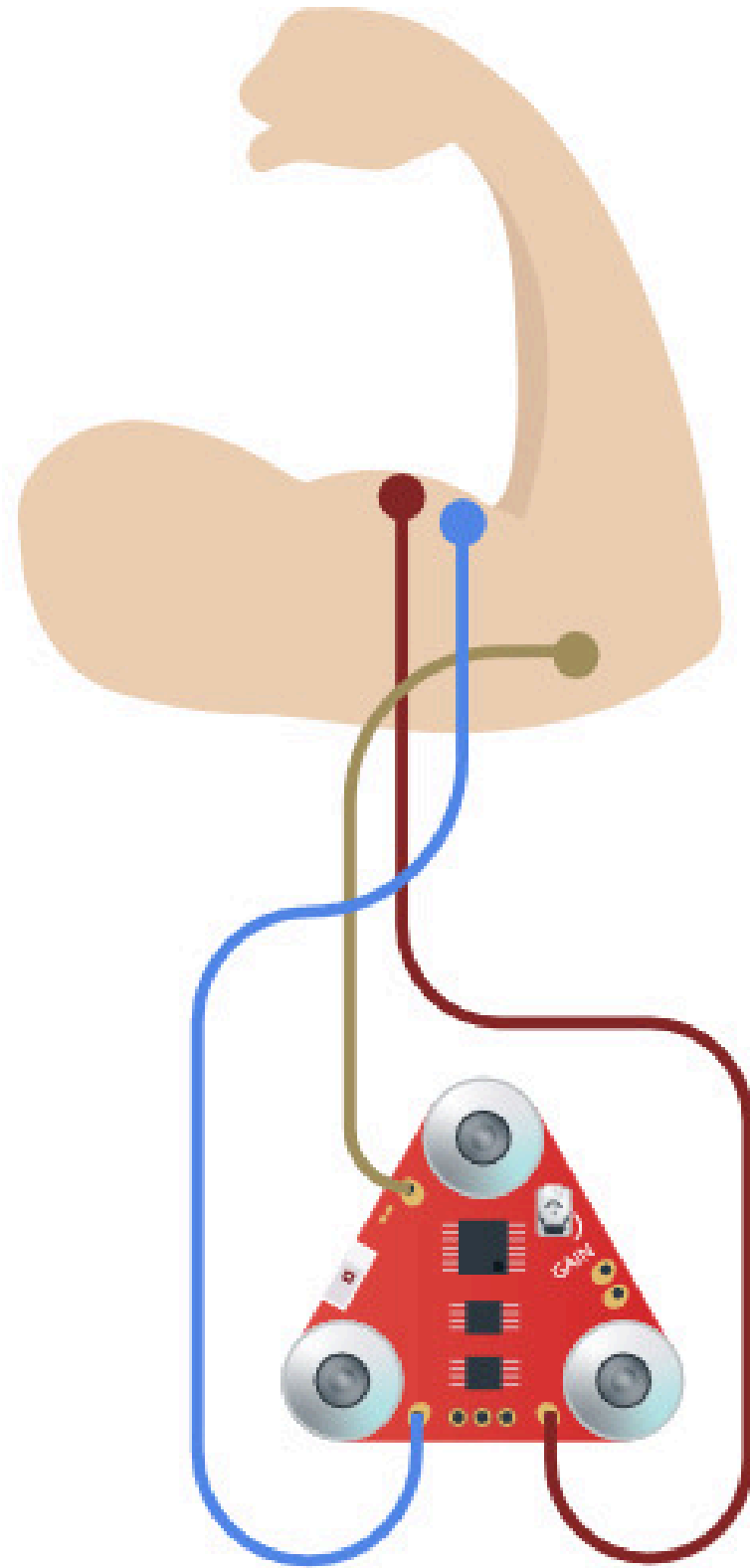


My next steps



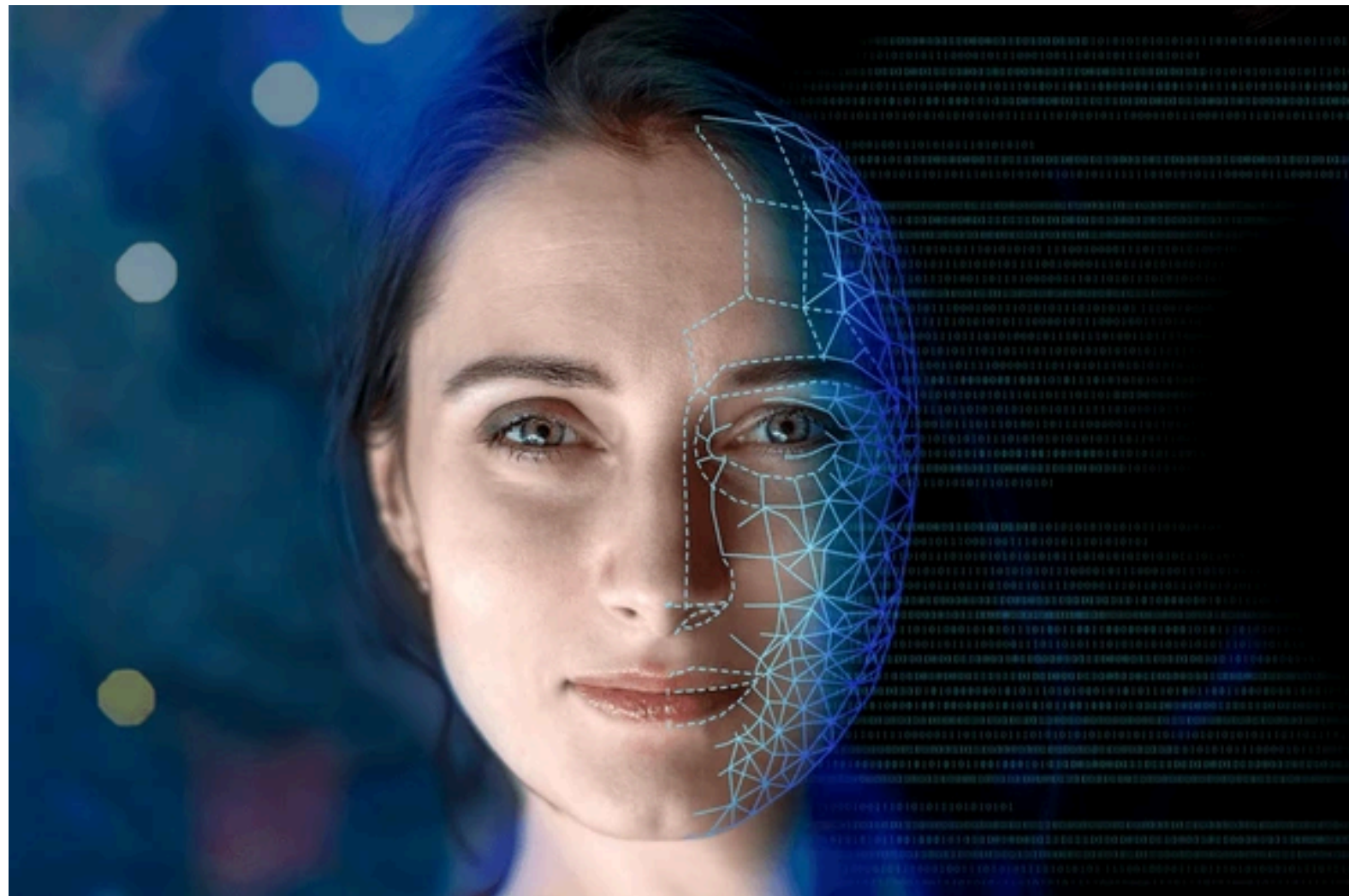
To develop a humanoid prototype, I 3D printed a human skull. then, I attached to it the equivalent of passive muscles to simulate the buccolabial muscles. and I connected one end of the DEA to these passive muscles and the other end to the skull.

My next steps



To ensure realistic muscle movement, I will be utilizing also an EMG sensor to provide authentic human muscle signals.

My next steps

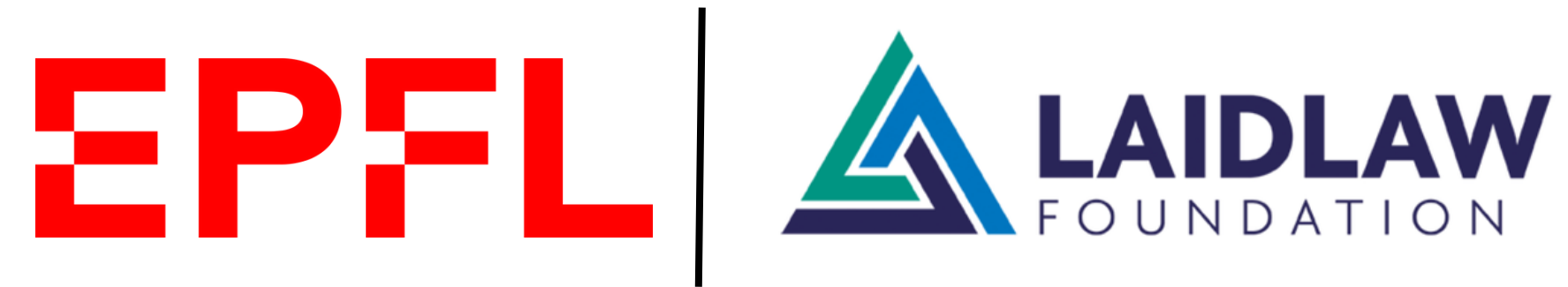


In addition, I aim to create a real-time animation that displays the expected facial movements based on the output signals .

To achieve this , I will be using the matlab 3D animation toolbox

Conclusion

This research has made great strides towards developing a system that can restore natural facial movements for individuals affected by paralysis. By refining the control mechanisms and testing with human-like prototypes, we aim to create solutions that bring back the ability to express emotions and perform essential functions like smiling



Thank you for your attention

"A smile is a curve that sets everything straight." - Phyllis Diller