

Design your Control Systems with Python, Why Not?

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Control Systems Field

A **Control System** is an interconnection of components forming a system configuration that will provide a desired system response.

There are five main elements of control system, these elements are

- Sensor
- Actuator
- Plant
- Reference Signal
- Controller



Figure 1. Real World Applications of Control Systems

Control system is a vast field. It has a bunch of applications on the real-life, for instance, the aircraft flight control systems, the rocket vertical landing systems, and the other astonishing stuff.

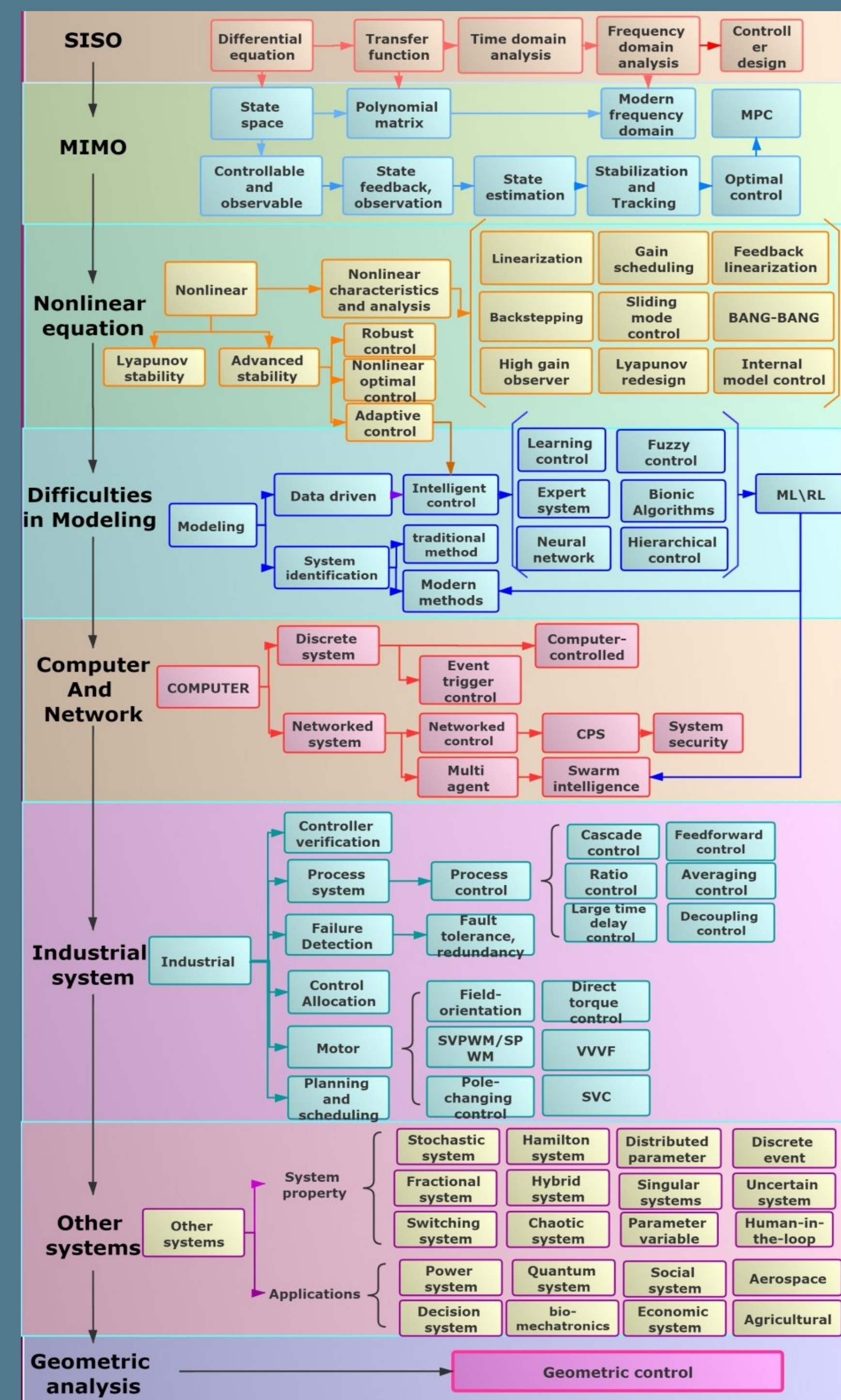


Figure 2. The Map of Control Systems Field [1]

Essential Python Library

There are four main library for designing control systems using Python

- Python Control Systems Library
- NumPy
- SciPy
- Matplotlib

Python as an Alternative Language

The reason why we can use Python as an alternative language for control systems design

- It is free and open-source, so we legally can use that without paying for software license
- Possessing all of the basics function for control systems design
- Support MATLAB like control systems design function
- Python is a powerful and agile programming language
- Having large communities

Designing the Control Systems

In this poster, the DC Motor system is used to design its speed control system.

The aim of designing the speed control system for a DC Motor system is to control or regulate the DC Motor Speed to go to the desired speed.

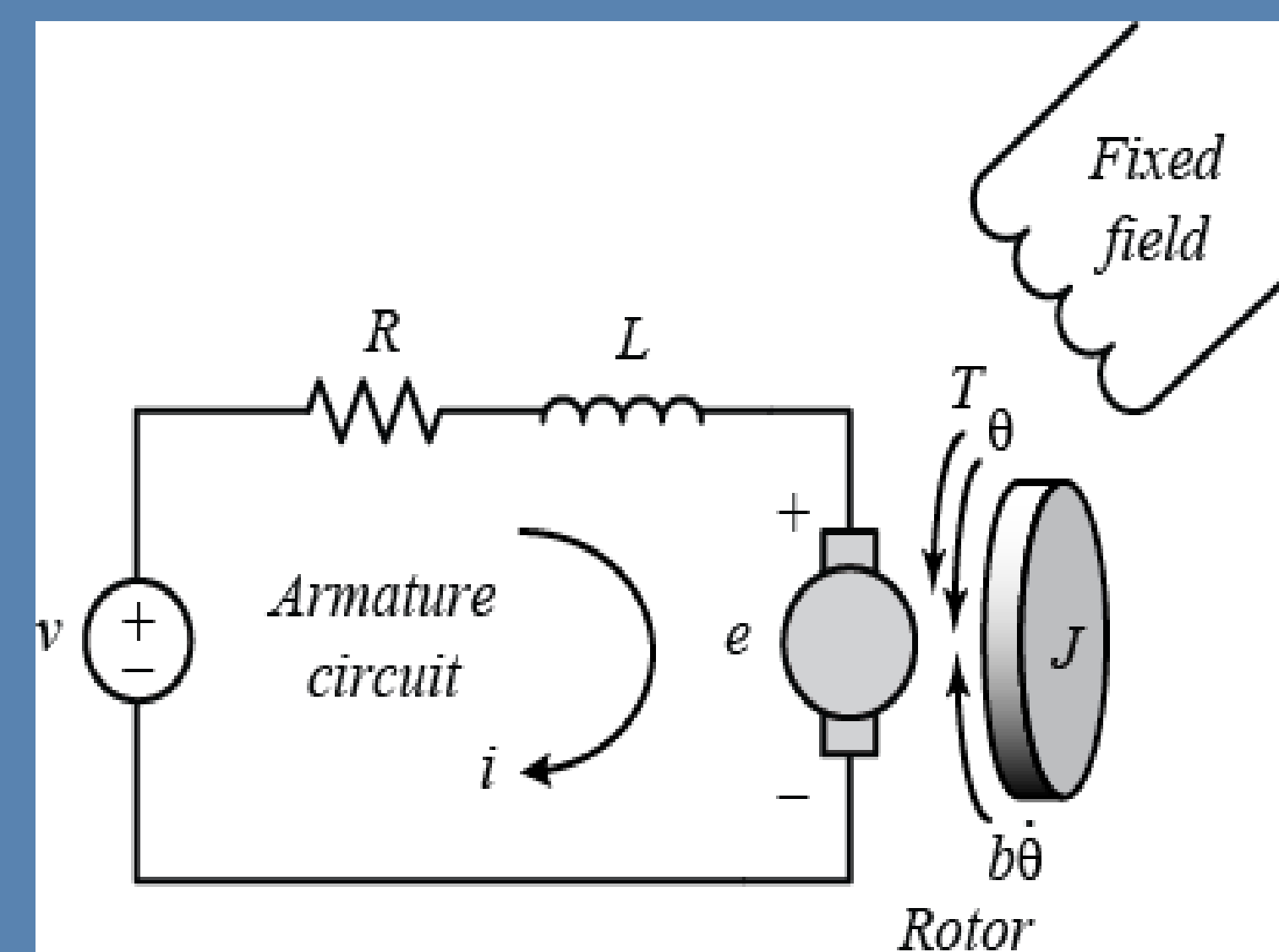


Figure 3. DC Motor System [2]

The control input for this system is the voltage applied to DC Motor. Thus, by changing or varying the voltage, the Motor will be rotating clockwise or counterclockwise.

The DC Motor system characteristics used in this poster are continuous, linear, and stable in nature because it is linear and stable so it will be more straightforward to control.

System Parameters

The DC Motor parameters values are shown in Table I

Parameters Name	Values
Moment Inertia of The Rotor (J)	0.08 kg.m ²
Motor Viscous Friction Constant (b)	0.05 B.m.s
Electromotive Force Constant (Ke)	0.01 V/rad/s
Motor Torque Constant (Kt)	0.01 B.m/Ampere
Electric Resistance (R)	0.5 Ohm
Electric Inductance (L)	0.5 H

Table I. DC Motor System Parameters

After the systems modeled using the law of physics (with $K_e = K_t = K$), the Transfer Function of the system can be denoted as,

$$M(s) = \frac{K}{(Js+b)(Ls+R)+K^2}$$

So, by plugging the values of each parameters then the system Transfer Function obtained as follows,

$$M(s) = \frac{0.01}{0.04s^2 + 0.065s + 0.0251}$$

Systems Analysis

It is important to know and analyzed well the system before we design the controller or control system, because with knowing more the characteristics of the system, the easier we design the control system is.

First, the poles of the DC motor system are analyzed pole-zero map as shown in Figure 4.

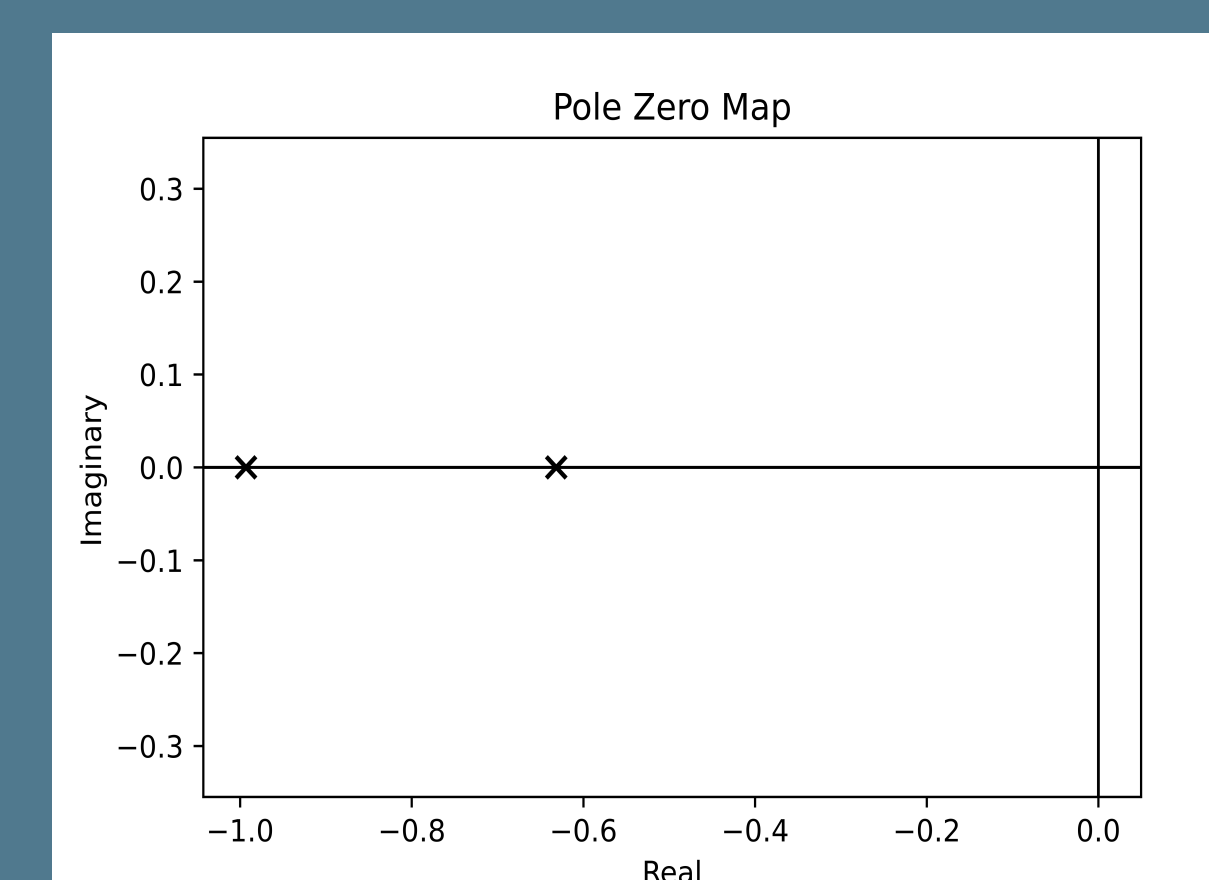


Figure 4. System Pole Zero Map

From the pole-zero map above, we can know that the system is stable because the poles are located in the left half-plane (-0.99 and -0.63) of S-Plane.

Controlling The Systems

Before we implement and design the controller to the DC Motor, we ought to know the block diagram of the DC Motor Speed Control System as shown in Figure 5,

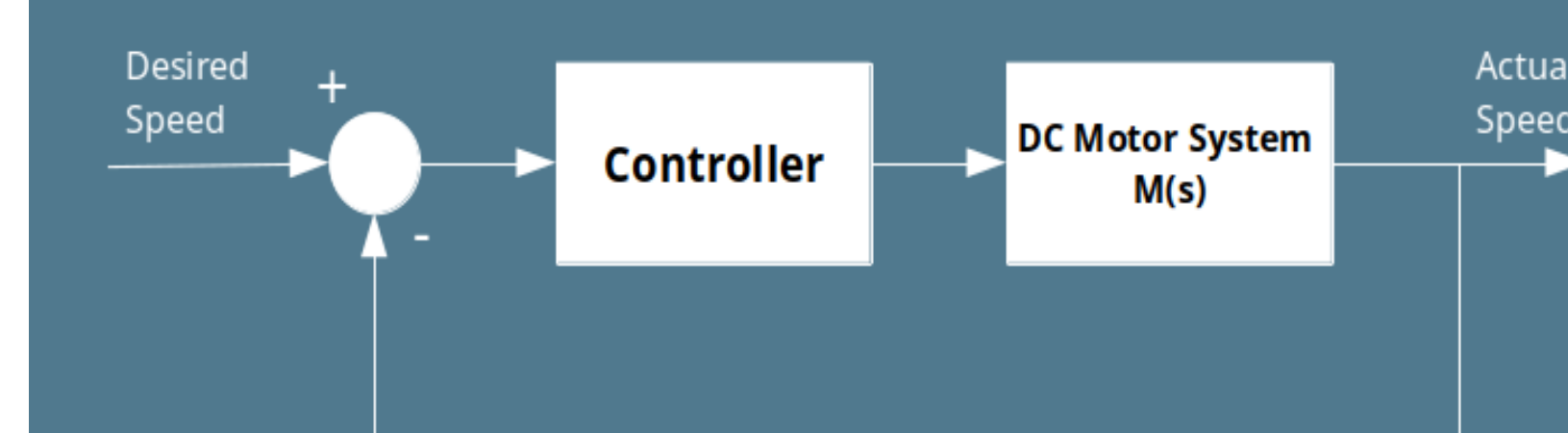


Figure 5. DC Motor Speed Control Block Diagram

After that, the next step is to design the controller, in this case, three different types of the commonly used and straightforward controller were applied, they are,

- PID (Proportional Integral Derivative) Controller
- State-Feedback Controller
- LQR (Linear Quadratic Regulator) Controller

All of the control algorithms were implemented and simulated using Python Control Systems Library. The state-feedback and LQR require the state-space form of the system. Due to that, we should convert the Transfer Function to State Space form using the tf2ss() function.

The gain of the PID controller, poles for the state-feedback controller, and LQR controller weight were chosen arbitrarily (the detail of the gain and the other controller parameters can be seen on the provided notebook). The implemented controllers were simulated on several reference input signal.

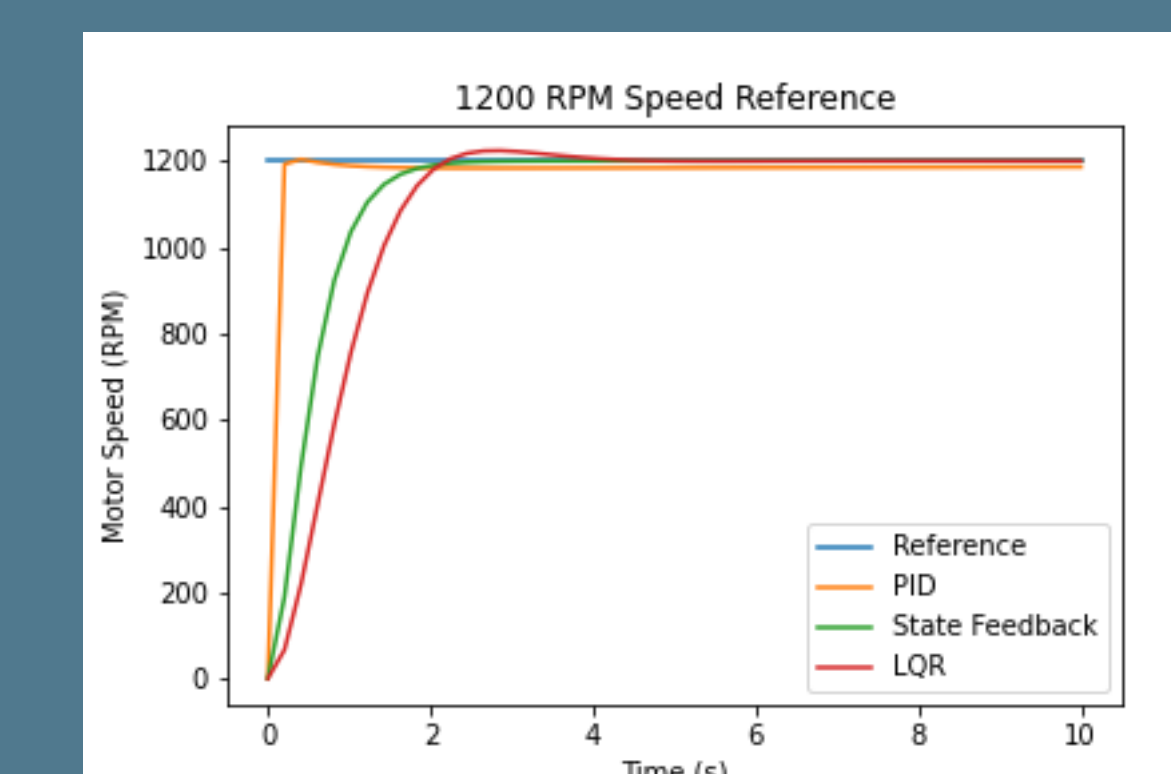


Figure 6. Step Signal 1200 RPM Reference

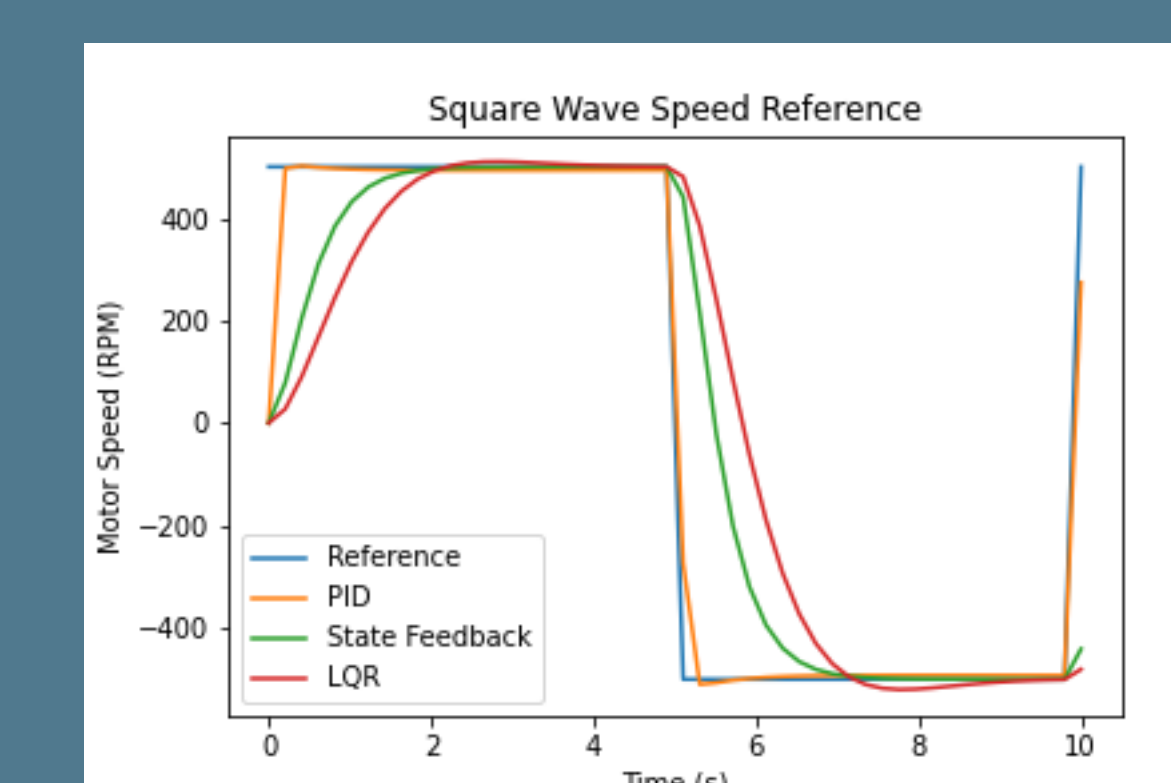


Figure 7. Square Wave Reference Signal

The DC Motor Speed is successfully followed the desired reference signal.

Verdict

In conclusion, the Python programming language can be used for designing the control systems with a free and open-source environment.

Additionally, with those advantages, then Python as well can be used as a powerful alternative for every student, lecturer, and researcher across the world in the control systems field.

References

- [1] "System control on Twitter: 'After a month of addition and modification, the Structure chart of control theory was finally completed. Thank you all for your guidance and suggestions @CSSIEEE@IFAC_Control@SpringerControl@MemmesControlhttps://t.co/fXrKCRqaTM'/Twitter,"Twitter.https://twitter.com/Lugh562007/status/1271641079599644672 (accessed Jul. 14, 2020).
- [2] "Control Tutorials for MATLAB and Simulink - Motor Speed: System Modeling." <http://ctms.engin.umich.edu/CTMS/index.phpexample=MotorSpeed§ion=SystemModeling> (accessed Jul. 14, 2020).

Acknowledgements




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More Full Explanation

Checkout the complete explanation and the code which I used to implement and design this control system in the notebook/repository I have made in the link below,

- <https://bit.ly/39fomit>

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