## Week 7: Develop a process to account for the random effects in the model

### I. Qualitative & Quantitative Justification

Qualitative Justification: Assumption and justification that the system shows LTI behavior by overlaying plots, visual inspection etc. (week 6 Studio).

Quantitative Justification: Quantitative justification is the most effective way to make a point. Further Validation of the assumption by determining the difference or error between the overlaid plots. Some ways to quantify the results are given below.

1. Extracting the error from the superimposed graphs, measuring its magnitude, and determining whether it is negligible in comparison to the original signal's amplitude.

2. Calculating the error between the overlaid plots using methods such as Mean Average Error or Root Mean Squared Error.

### II. Application

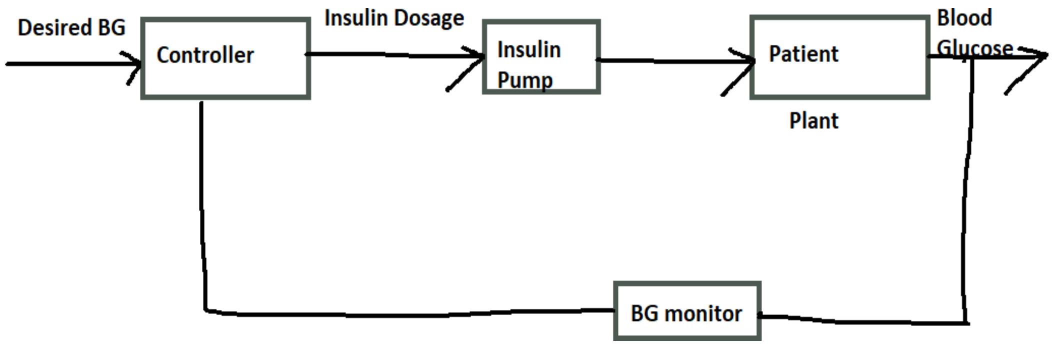
When choosing your application, consider these questions:

a. Are you able to explicitly model the dynamics of the system? If yes, start again.
b. What state (variable) are you trying to control? How do you measure this state?
c. Why do you want to control this state? What are the issues if this state remains uncontrolled? What impacts are there if/when you control this unknown system?
d. How can you control the state i.e., what is the control input?

An example is that your application will attempt to model natural phenomena i.e., something we cannot readily use mathematical modeling, physics, chemistry etc. to model.

**Example: Automatic Insulin administration into a diabetic patient for controlling Blood Glucose Level**

In this instance, the system, or plant, is patient. Blood glucose level is the output. Using continuous glucose monitoring equipment, the output is fed back into the system. The insulin dosage (input to the system) is specified by the controller, which also computes the difference between the desired and actual glucose levels. An insulin pump will be used to introduce insulin into the system. A closed-loop schematic of the application is given below.




## III. Noise and Filtering

Noise refers to unwanted signals that can affect the performance of the system. It is evident that our Blackbox systems are noisy. The systems we utilize are MATLAB simulated systems, not real physical systems, therefore noise is added to the system to emulate the noise found in real engineering systems. Either Gaussian noise, White noise, or White Gaussian Noise could be the noise affecting the system.

- How to identify the noise
  - Extract the noise from the signal.
  - Determine the Noise Mean.
  - Verify whether the noise follows a normal distribution.

Noise can be

1. Internal: Generated from sources inside the system
   - White Noise: A continuous time white noise process w(t), $t \in R$ is a random process which has the property that $E(w) = 0$. White noise is encountered in practice almost everywhere in engineering. Luckily, in most situations the noise is small, and observations can be reduced without having to worry about removing it. In other applications, the noise is so strong that it is imperative to remove the noise to accurately process the data. Another property of white noise is that it has constant power distribution across all frequencies.
   - Gaussian Noise: Random process found in engineering systems. The noise is characterized by a normal distribution with all frequencies present
2. External: Generated from sources outside the system such as mechanical vibrations, environmental factors.

## a) Denoising Methods

Filtering techniques are commonly employed to reduce noise by attenuating undesired frequency components from a signal.

A high pass filter or a low pass filter are two examples of these filtering techniques. High-pass filters allow high-frequency signals to pass through while blocking low-frequency ones. High frequency signals are blocked by a low pass filter while low frequency signals are passed through.

To remove noise from the system, you can also utilize the built-in functions in MATLAB. Different filters have different applications, and there is not one filter that will work well for every signal. It is up to you to know the system, and define what type of disturbance the signal has, to properly construct a filter which eliminates the disturbance.

## b) Methods to evaluate the filter's efficacy

1. Filtering techniques should not change the original signal's amplitude and phase.
2. The filter should work well for different frequencies of sine waves.
3. Use one of the filtered signals as the basis signal and use techniques like RMSE to compare the filtered signals to the base signal.