Digital Signal Processing

Lab 2 Introduction

Group Organization

- Pick a Team Lead for each Lab
  - Rotate the Team Lead Role each week
- Team Lead coordinates the group
  - Responsible for lab submission
  - Indicate the Team Lead on the submission
- Collaborate with your group during lab and outside of class

Lab 2 – Statistics in MATLAB

- This lab will explore some of the statistical concepts from Chapter 2
  - Signal statistics
  - Typical Error
  - Central Limit Theorem
- Introduction to Chapter 3
  - Quantization Noise

Typical Error

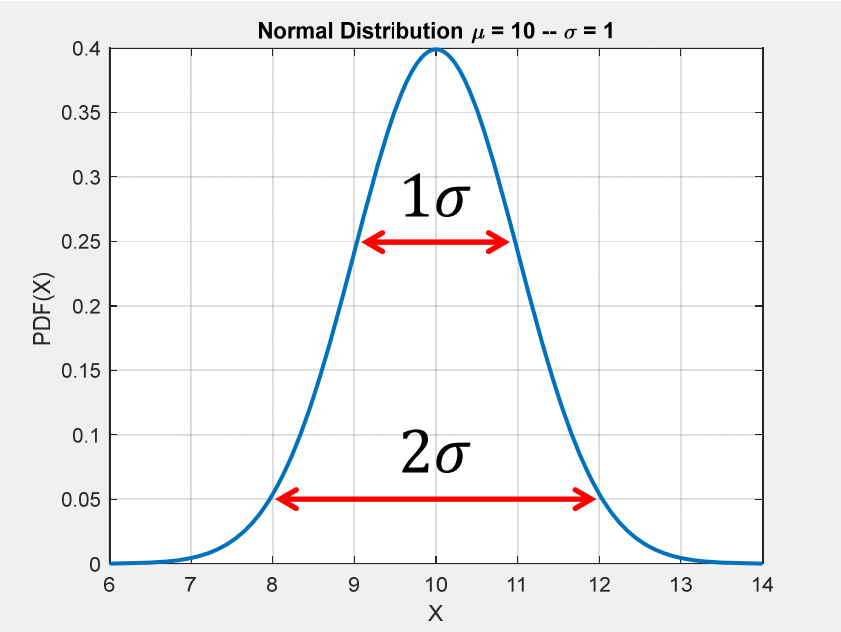
- When we compute an average we are making an estimate of the *true* mean
  - There will be some error in the estimate
  - The "Typical Error" of the estimate is the SD of the estimate

$$Typical\ Error = \sigma_{estimate} = \frac{\sigma_{process}}{\sqrt{N}}$$

- The "typical error" of the estimate decreases by the square root of the number of samples

Typical Error

- What does “typical” mean
  - 68% of the values of the estimate will be within $\pm 1\sigma$ of the true mean



Typical Error of the Estimate

- Example:
  - If I have a signal with a *true* mean $\mu = 6$ and it has noise with a $\sigma = 1$
  - If I estimate the mean of the signal using 9 samples then the typical error of my estimate of the mean is

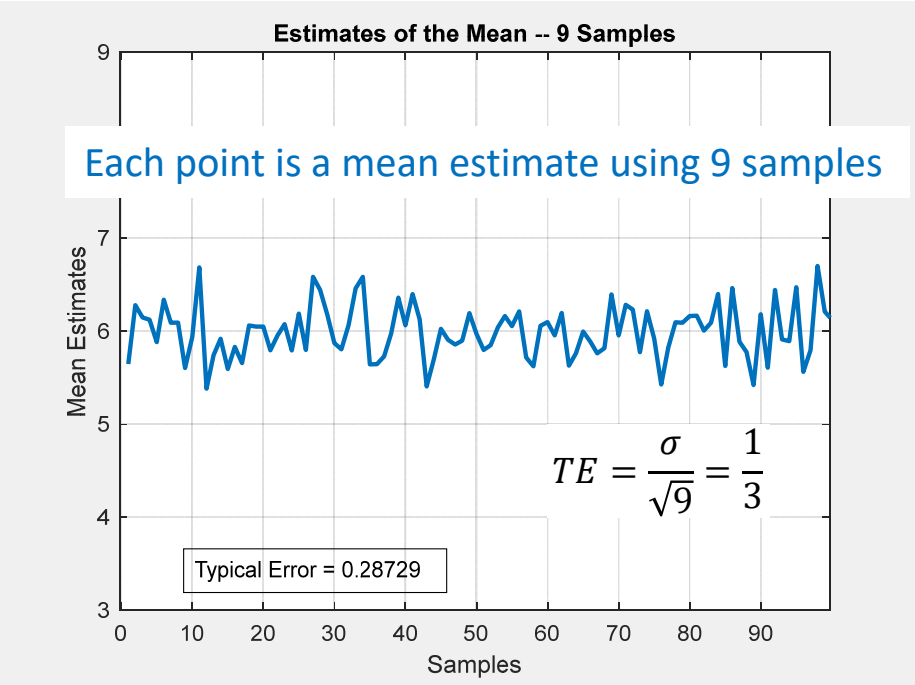
$$Typical\ Error = \sigma_{estimate} = \frac{\sigma}{\sqrt{N}} = \frac{1}{\sqrt{9}} = .333$$

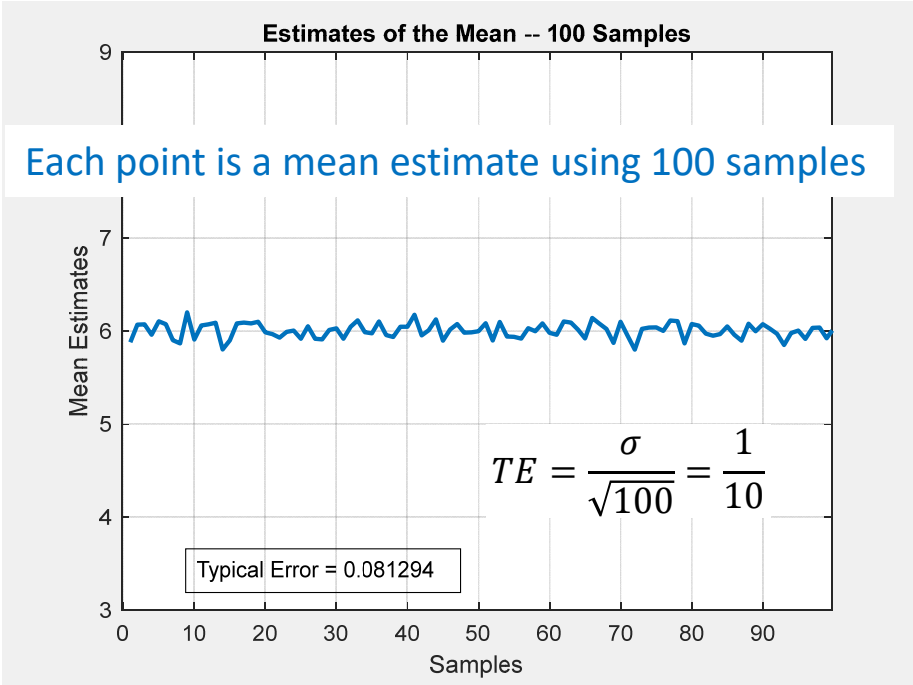
  - If I increase the number of samples that I use to estimate the mean to 100 then the typical error of my estimate of the mean is

$$Typical\ Error = \sigma_{estimate} = \frac{\sigma}{\sqrt{N}} = \frac{1}{\sqrt{100}} = .10$$

Typical Error of the Estimate

- Compare using 9 samples and 100 samples to compute the mean





The mean estimates are around 6 but have some "typical error" ≈ 0.33

The mean estimates are around 6 but have some "typical error" ≈ 0.1

Digital Signal Processing

The Central Limit Theorem

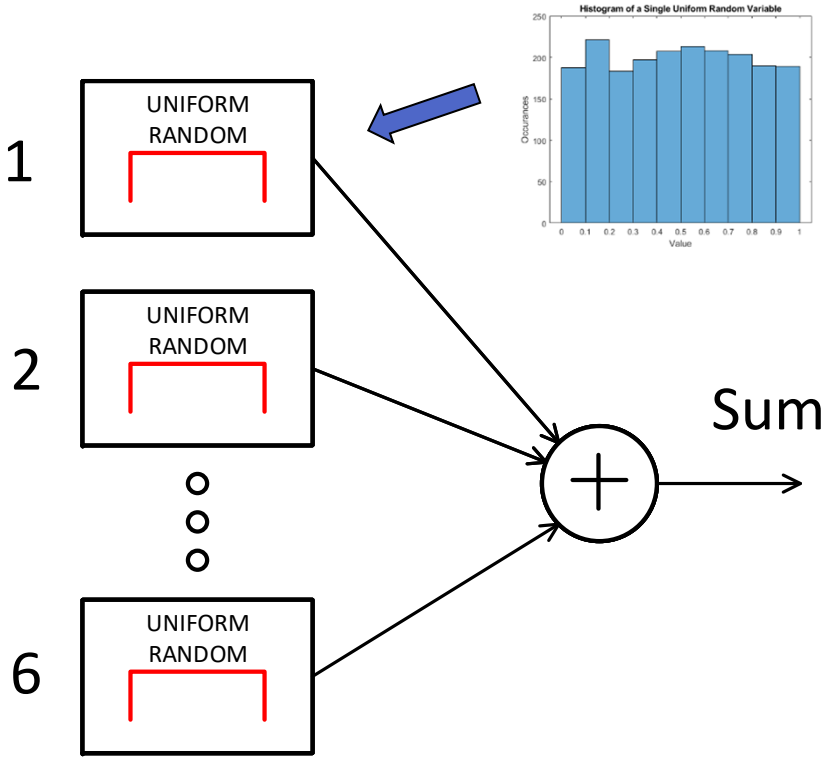
The Central Limit Theorem

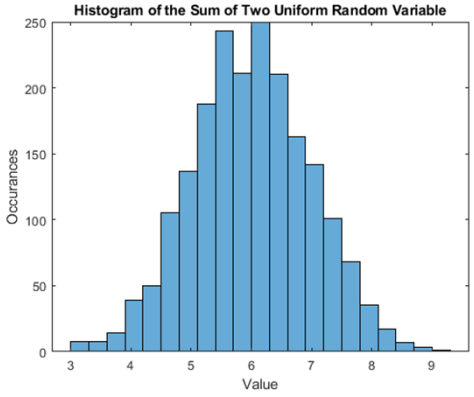
- The sum of random processes becomes normally distributed as more and more of the random numbers are added together.

- True even if the random numbers being added together are from different probability distributions

Central Limit Theorem
MATLAB Example

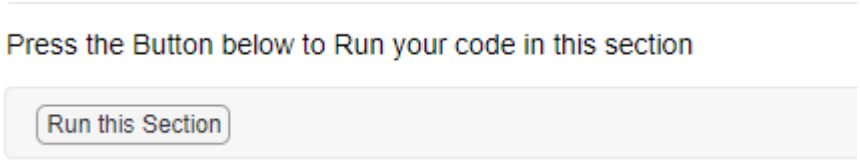
- Generate 6 uniformly distributed random numbers. Add them. What is the distribution of the sum?





Tips for Lab 2

- Run your code incrementally in each section
  - Press the RUN box at the bottom of each section



Tips for Lab 2

- To see intermediate results of equations don't put a ; at the end of the command line

- To hide the output to keep things neat use the ; at the end
  - You may want to display just the end result

```
%  This command will show its output

a = 5
```

```
a = 5
```

```
%  This command will not display output

b = 10;
```

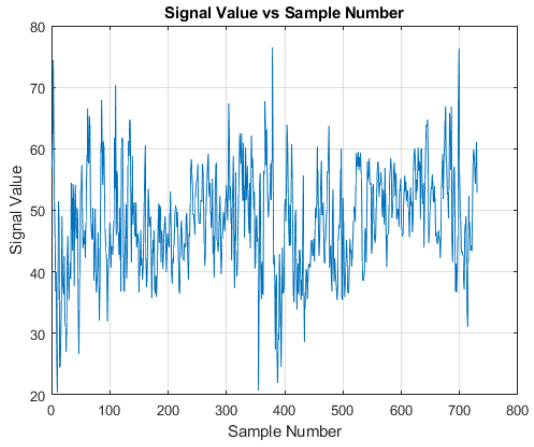
Tips for Lab 2

- Title all your plots! Label all Axes
  - Use descriptive text!

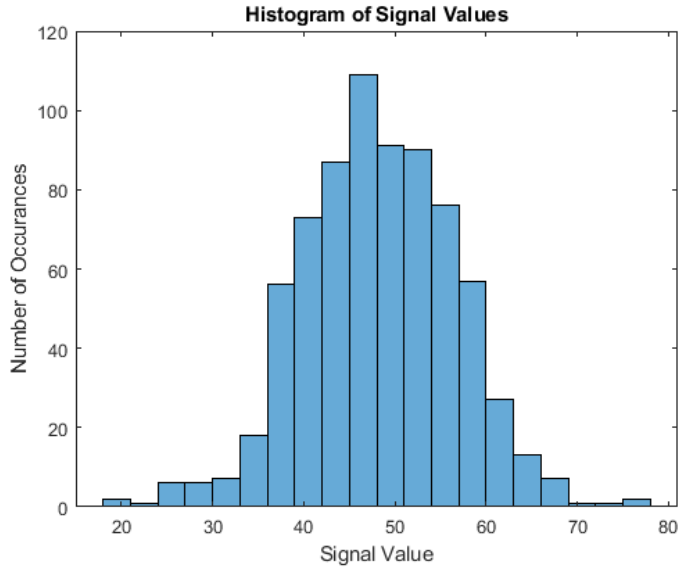
```
figure
plot( sample, signal, 'LineWidth',1 )


%  Solution -- Place your code to label the axes and title the graph

title('Signal Value vs Sample Number')
xlabel('Sample Number')
ylabel('Signal Value')
grid on
```




```
histogram(signal)
title('Histogram of Signal Values')
xlabel('Signal Value')
ylabel('Number of Occurances')
```



Column and Row Notation

- Assume a MATLAB matrix A with m rows and n columns

- A complete MATLAB Column A(: ,colNumber)
- A complete MATLAB ROW A(rowNumber, :)

$$\mathrm{A}=\begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix}$$

$$A(:,2) = \begin{bmatrix} a_{12} \\ a_{22} \\ a_{32} \end{bmatrix}$$

$$A(3,:) = \begin{bmatrix} a_{31} & a_{32} & a_{33} \end{bmatrix}$$

Summing Across Dimensions

- sum(A, 1) sums across the first dimension, sums up the value in each column (default)

- sum(A, 2) sums across the second dimension, sums up the value in each row

```
>> A = rand(5,3)

A =

    0.6020    0.4505    0.8258
    0.2630    0.0838    0.5383
    0.6541    0.2290    0.9961
    0.6892    0.9133    0.0782
    0.7482    0.1524    0.4427
```

5X3 Matrix

```
>> sum(A,1)

ans =

    2.9564    1.8291    2.8811
```

Sums up each column

```
>> sum(A,2)

ans =

    1.8783
    0.8851
    1.8792
    1.6807
    1.3432
```

Sums up each row

Lab 2 Submission Requirements

- Submit your completed MATLAB Live Script file (.mlx) and an export of the file as a PDF Document
  - It may work better to export to a Word file first then save as a PDF file.
  - Make sure that you have run the entire script before exporting to PDF
  - Double check your PDF output before you submit to myCourses
- Submit a brief work breakdown document describing the roles of each team member this lab