ELE 503

Advanced Computer Programming and Statistics

Week#2: Introduction to Statistics and the Law of Large Numbers

By Kingsley E. Erhabor

Week 02.

Introduction to Statistics and the Law of Large Numbers

Introduction to Statistics in Engineering

Basic Statistical Concept

- Mean, Median, Mode, Variance and Standard Deviation

Statistical Distributions

Normal, Binomial and Poisson Distribution

Law of Large Numbers

Applications in Engineering

C# Programming for Statistical Simulations

Real-World Engineering Data Sets

Data Visualization Techniques

Q&A

Closing Take away

Part 1:

Introduction to Statistics in Engineering

Learning Objectives

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- **Understand** basic statistical concepts relevant to engineering
- **Identify** different types of statistical distributions
- **Apply** the Law of Large Numbers in experiments and simulations
- **Utilize** C# for statistical simulations and data visualization.

Importance of Statistics in Engineering

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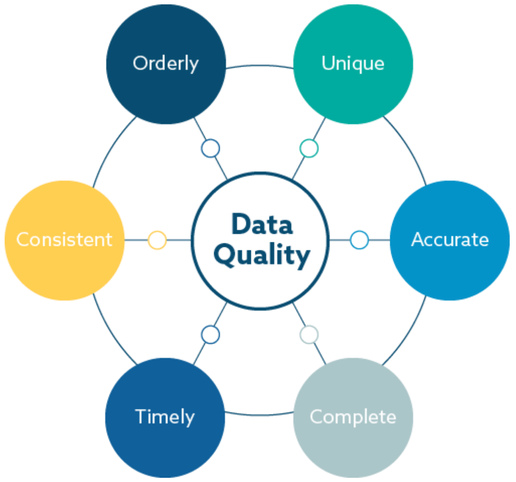
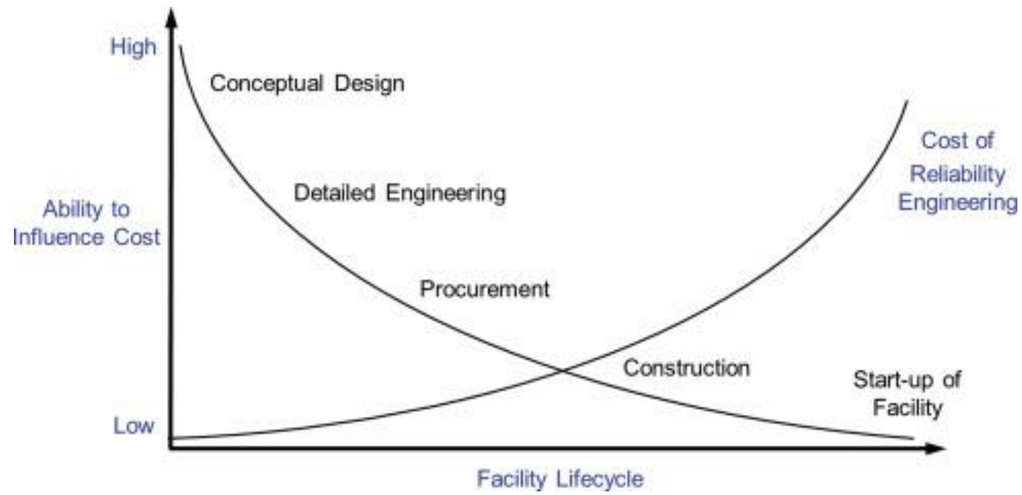


- **Data Analysis:** Critical for interpreting experimental results.
- **Quality Control:** Ensures products meet specified standards.
- **Reliability Engineering:** Predicts product lifespan and failure rates.
- **Decision Making:** Informed choices based on data-driven insights



Applications of Statistics in Engineering

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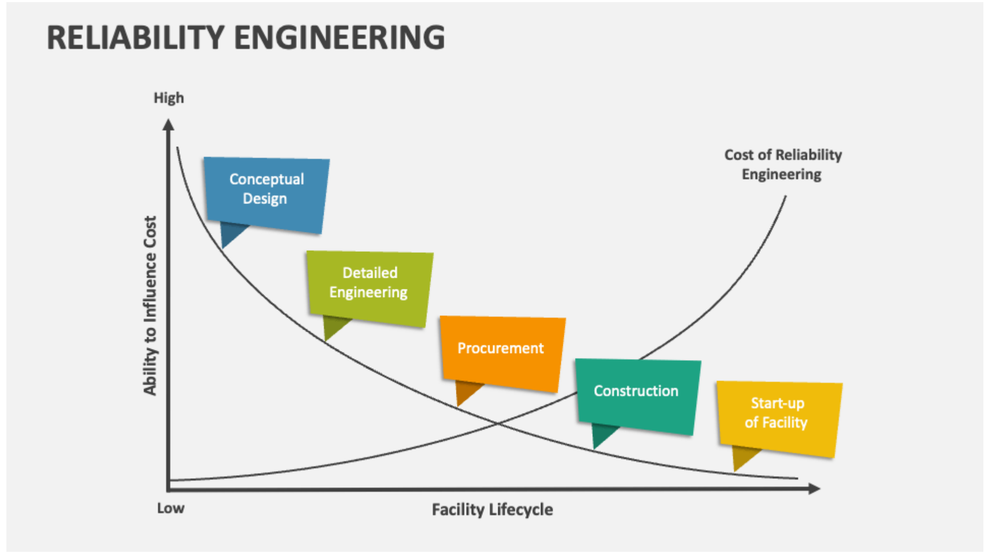
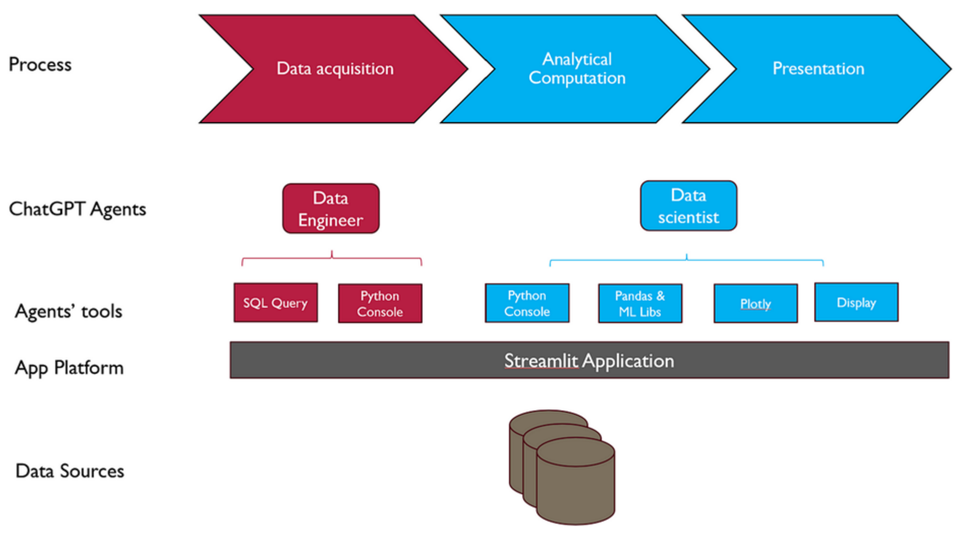
- **Design Optimization:** Enhancing performance and efficiency.
- **Risk Assessment:** Identifying and mitigating potential failures.
- **Process Improvement:** Streamlining manufacturing and operational processes.
- **Simulation Modeling:** Predicting system behaviors under various conditions





Basic Statistical Concepts?

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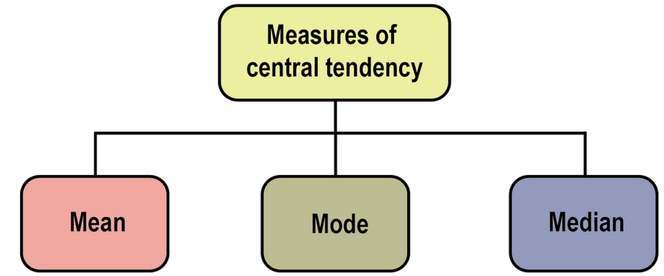
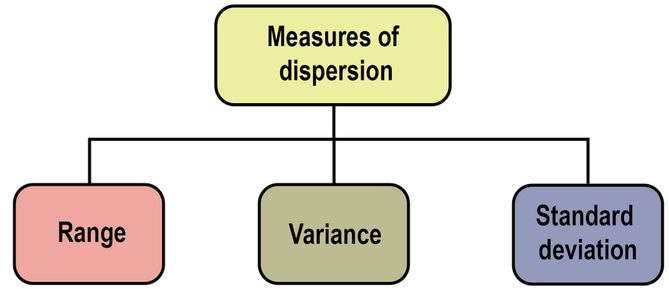
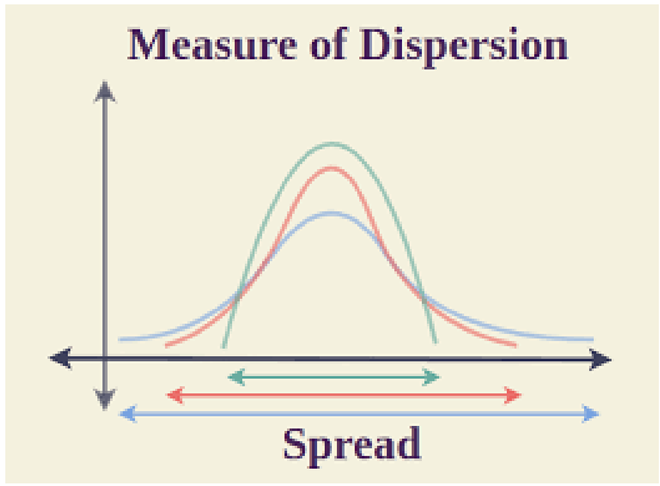
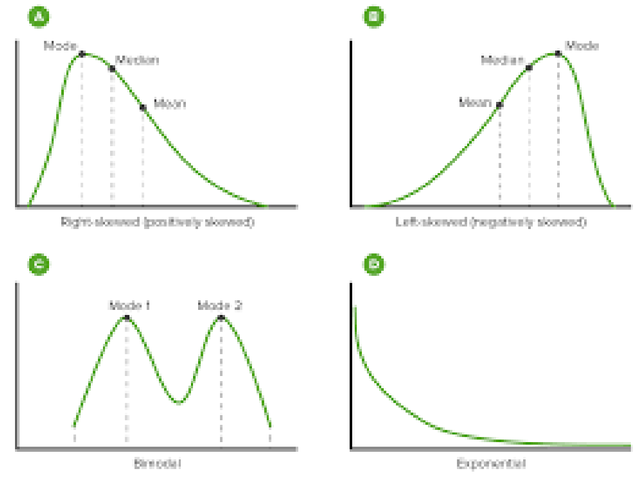




- **Central Tendency:** Mean, Median, Mode
- **Dispersion:** Variance, Standard Deviation
- **Probability:** Fundamental for understanding distributions
- **Correlation and Regression:** Relationships between variables





Mean, Median, and Mode

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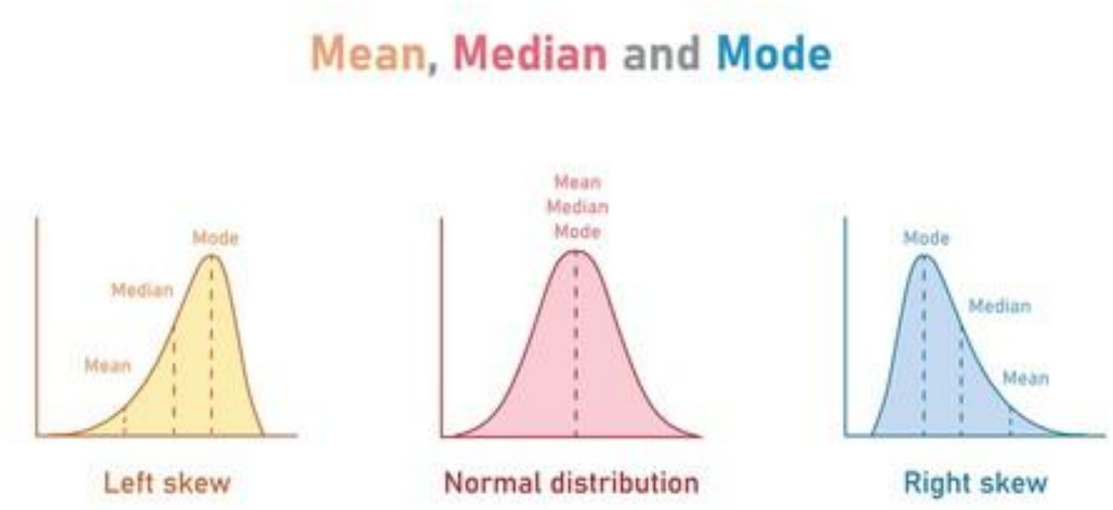
- **Mean:** Average value of a dataset.
- **Median:** Middle value when data is ordered.
- **Mode:** Most frequently occurring value.
- **Illustration:** Example dataset showing mean, median, and mode



Variance and Standard Deviation

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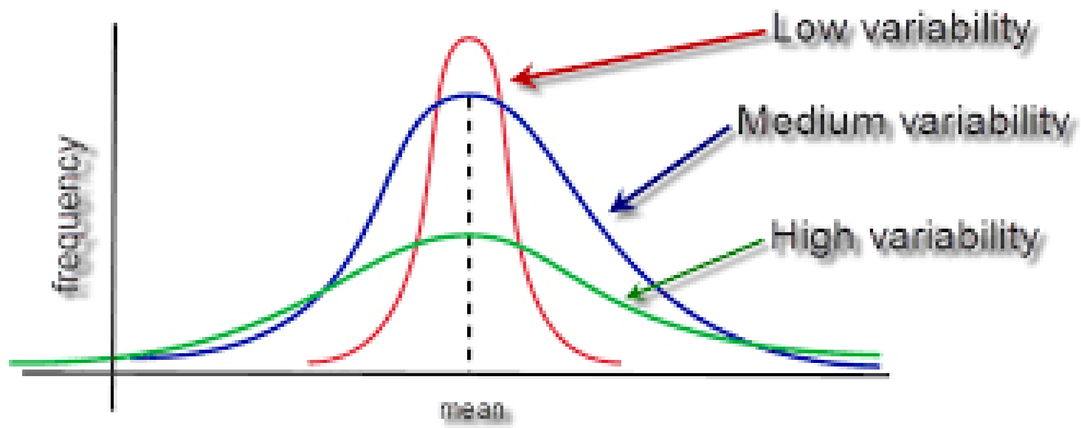
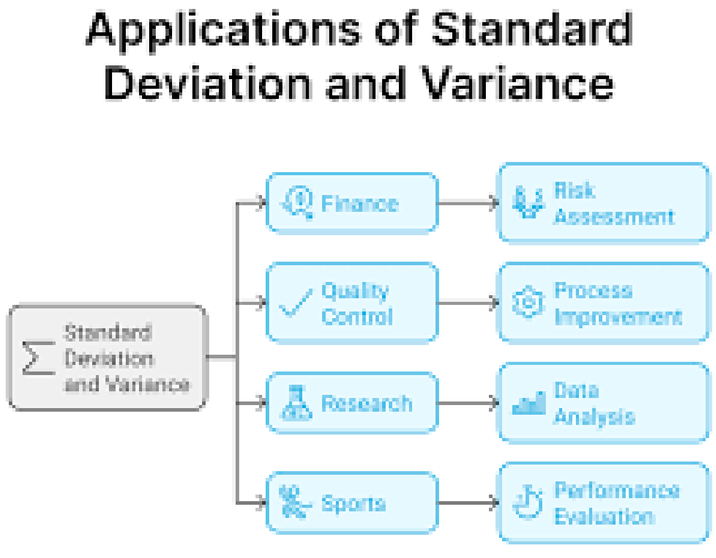
- **Variance (σ2 -sigma^2):** Measure of data dispersion.
- **Standard Deviation (σ\sigmaσ):** Square root of variance.
- **Formula:**

$$\sigma^2 = \frac{1}{n}\sum_{i=1}^{n}(x_i - \mu)^2$$

- **Interpretation:** Higher values indicate more spread-out data.





Part 2:

Statistical Distributions

Normal Distribution

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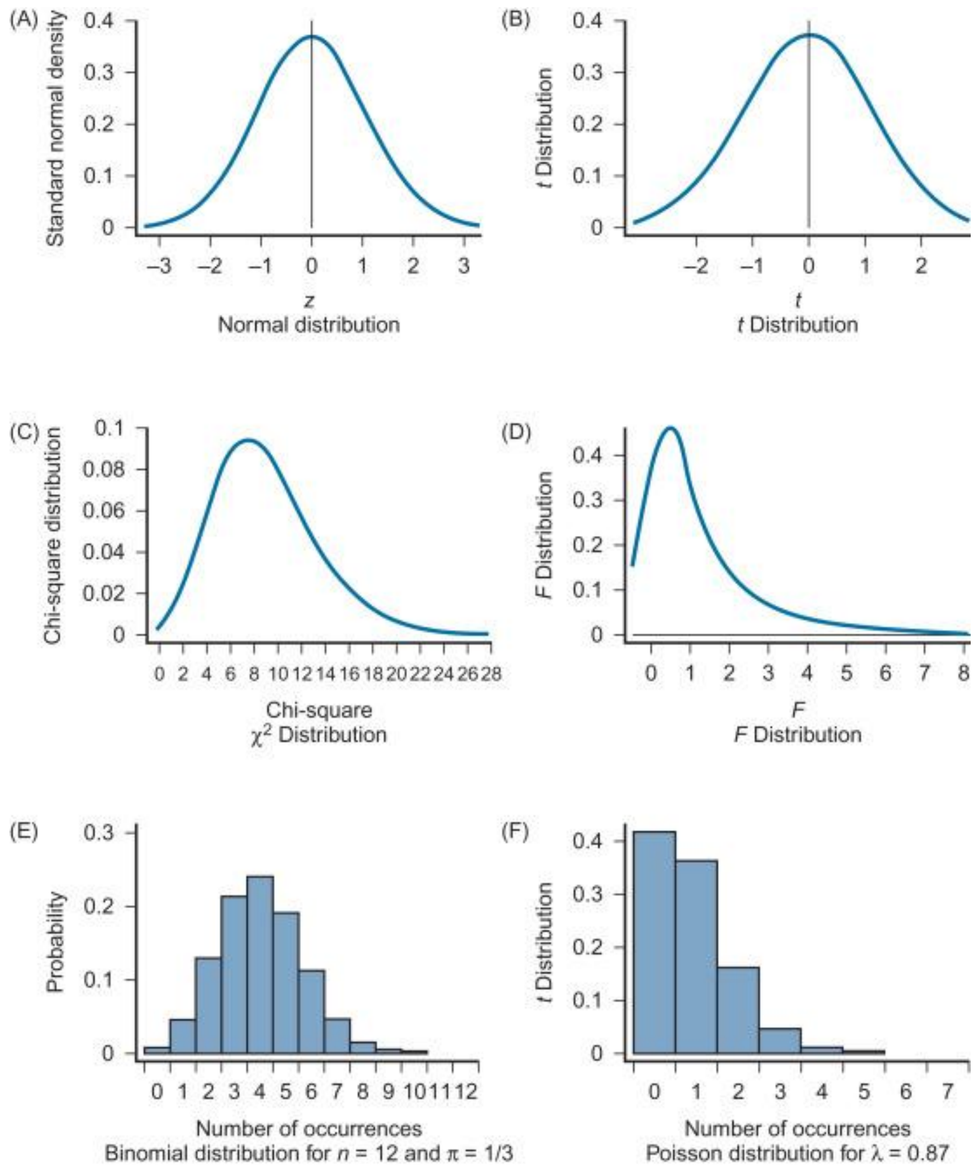
- **Characteristics:**
  - Bell-shaped curve
  - Symmetrical around the mean
  - Defined by mean (μ\muμ) and standard deviation (σ\sigmaσ)

- **Probability Density Function (PDF):**

$$f(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{(x-\mu)^2}{2\sigma^2}}$$

- **Applications:** Measurement errors, natural phenomena.



Binomial Distribution

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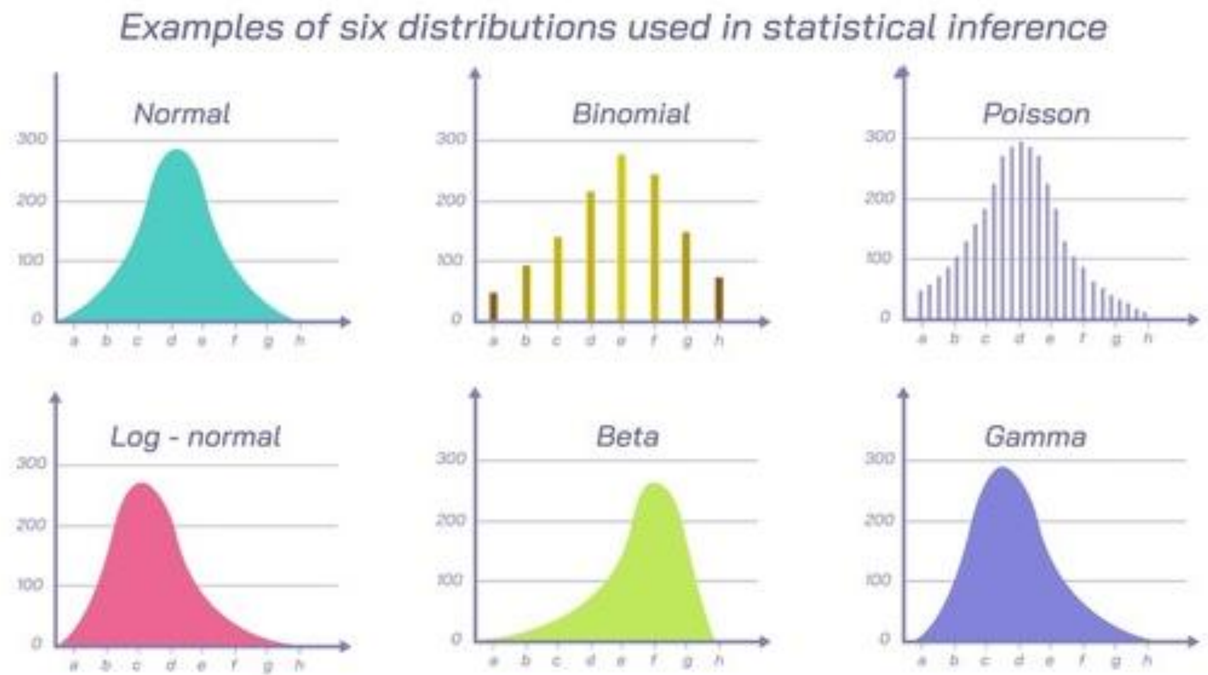
- **Characteristics:**
  - Discrete distribution
  - Number of successes in fixed trials
  - Parameters: nnn (trials), ppp (success probability)

- **Probability Mass Function (PMF):**

$$P(X = k) = \binom{n}{k} p^k (1-p)^{n-k}$$

- **Applications:** Quality control, reliability testing



Poisson Distribution

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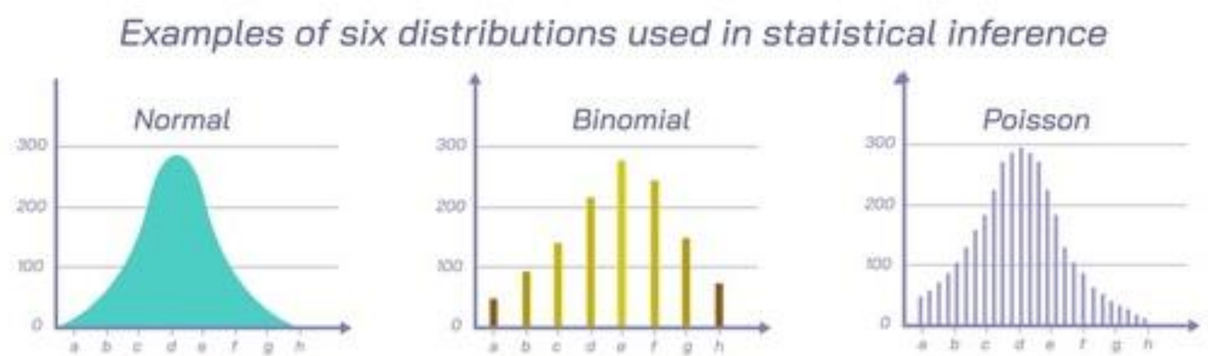
- **Characteristics:**
  - Discrete distribution
  - Number of events in a fixed interval
  - Parameter: λ\lambdaλ (rate)



- **Probability Mass Function (PMF):**

$$P(X = k) = \frac{\lambda^k e^{-\lambda}}{k!}$$

- **Applications:** Modeling rare events, traffic flow analysis.

Part 3:
Law of Large Numbers

Law of Large Numbers (LLN

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- **Definition:** As sample size increases, sample mean approaches population mean.

- **Formal Statement:**

$$\lim_{n \to \infty} \bar{X}_n = \mu$$

- **Types:**
  - Weak Law: Convergence in probability.
  - Strong Law: Almost sure convergence.

- **Importance:** Justifies use of sample averages in experiments.

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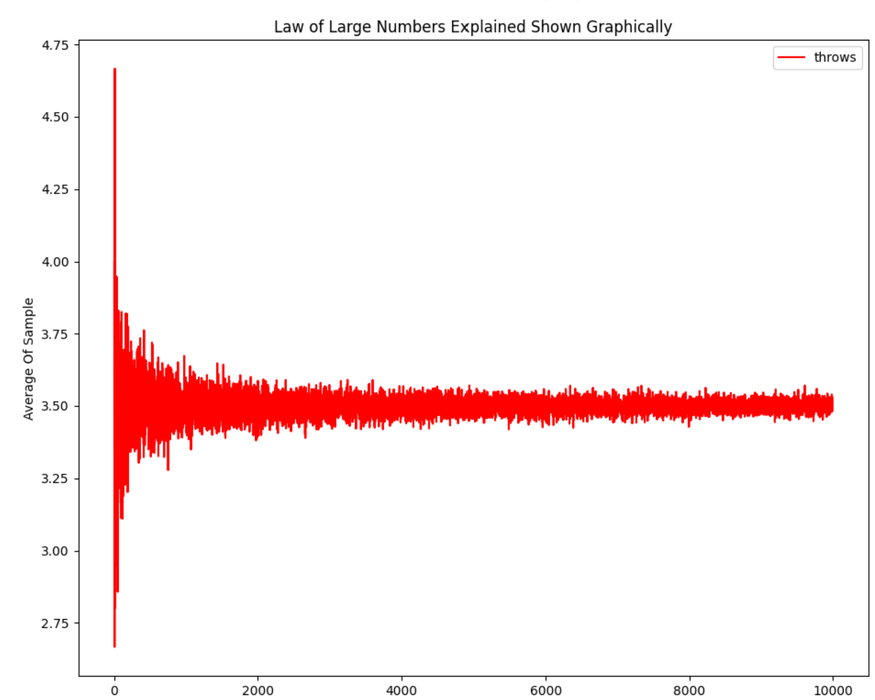

Applications of LLN in Engineering

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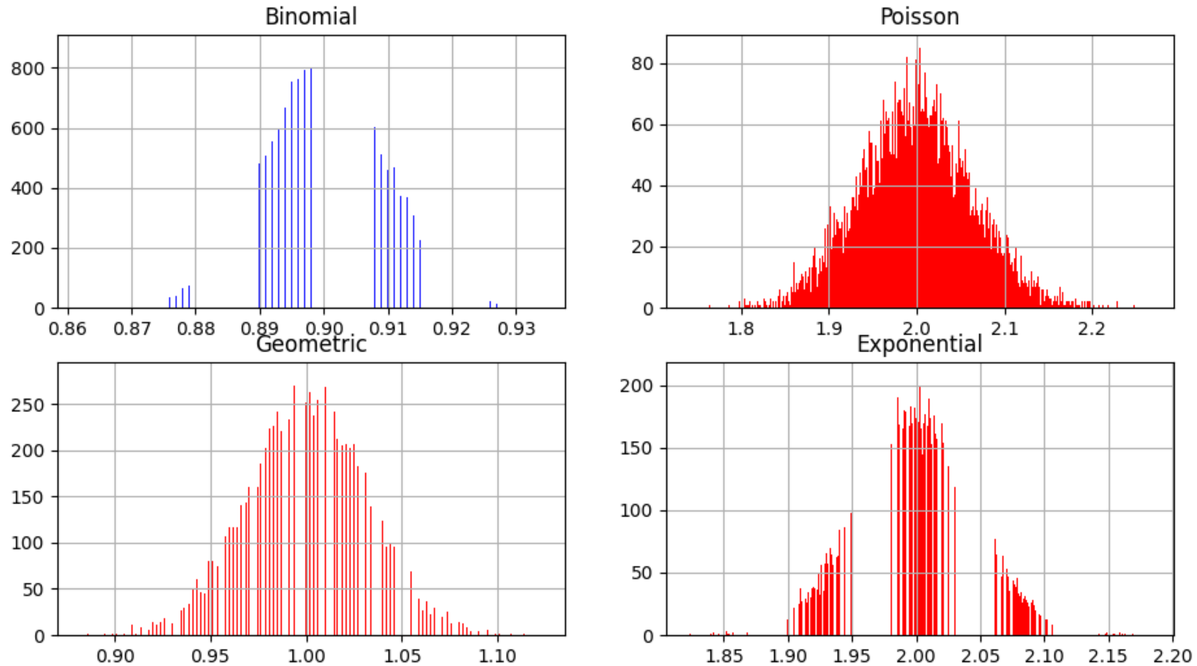
- **Experimental Design:** Ensuring accurate estimations.
- **Simulation Reliability:** Predicting system behaviors.
- **Quality Assurance:** Consistent product quality over large batches.
- **Predictive Modeling:** Enhancing forecast accuracy.



Part 4:

C# Programming for Statistical Simulations

Introduction to C# for Statistical Simulations

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- **Why C#?**
  - Object-oriented programming for modularity.
  - Robust libraries for data handling and visualization.
  - Integration with engineering tools.

- **Key Libraries:**
  - OxyPlot for visualization
  - LINQ for data manipulation

Simulating Statistical Distributions in C#

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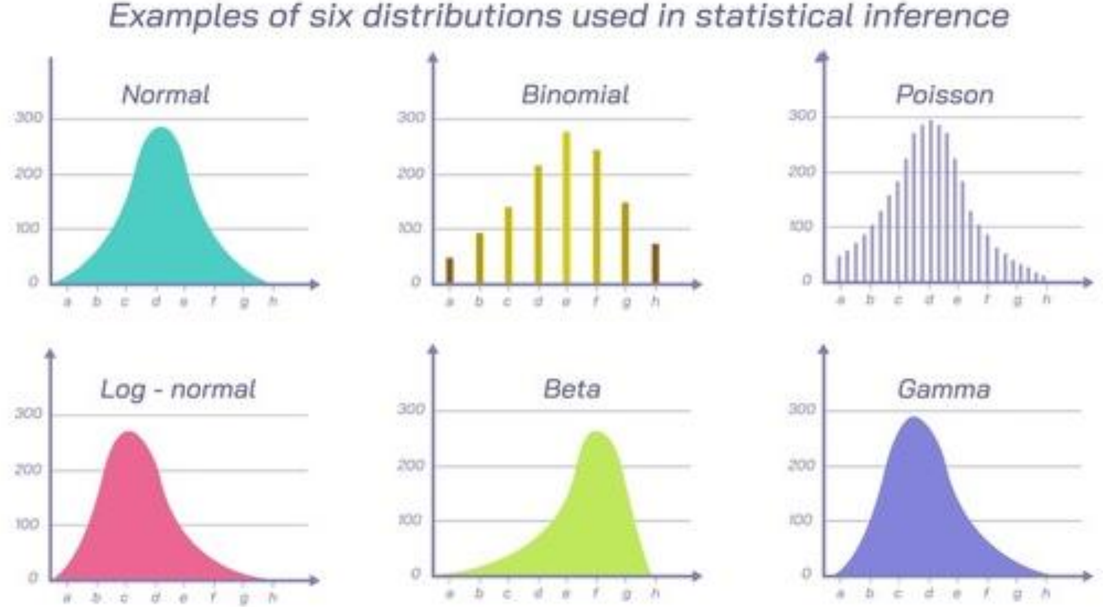
- **Normal Distribution:** Box-Muller Transform
- **Binomial Distribution:** Bernoulli Trials
- **Poisson Distribution:** Event Counting
- **LLN Demonstration:** Sample mean convergence



Example Slide 1 – Normal Distribution Simulation

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- **Normal Distribution:** Box-Muller Transform

Example Slide 2 – Binomial Distribution Simulation

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- **Binomial Distribution:**

Example Slide 3 – Poisson Distribution Simulation

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- **Poisson Distribution:**

Example Slide 4 – Law of Large Numbers Demonstration

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- **Law of Large Numbers :**

Example Slide 5 – Data Visualization with OxyPlot

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- **Data Visualization :**

Real-World Engineering Data Sets

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- **Sources:**
  - UCI Machine Learning Repository
  - Kaggle Datasets
  - NASA Open Data
  - Industry Collaborations
  - Laboratory Experiments

Examples:

- Structural load measurements
- Signal processing data
- Manufacturing process data

Importance of Data Visualization

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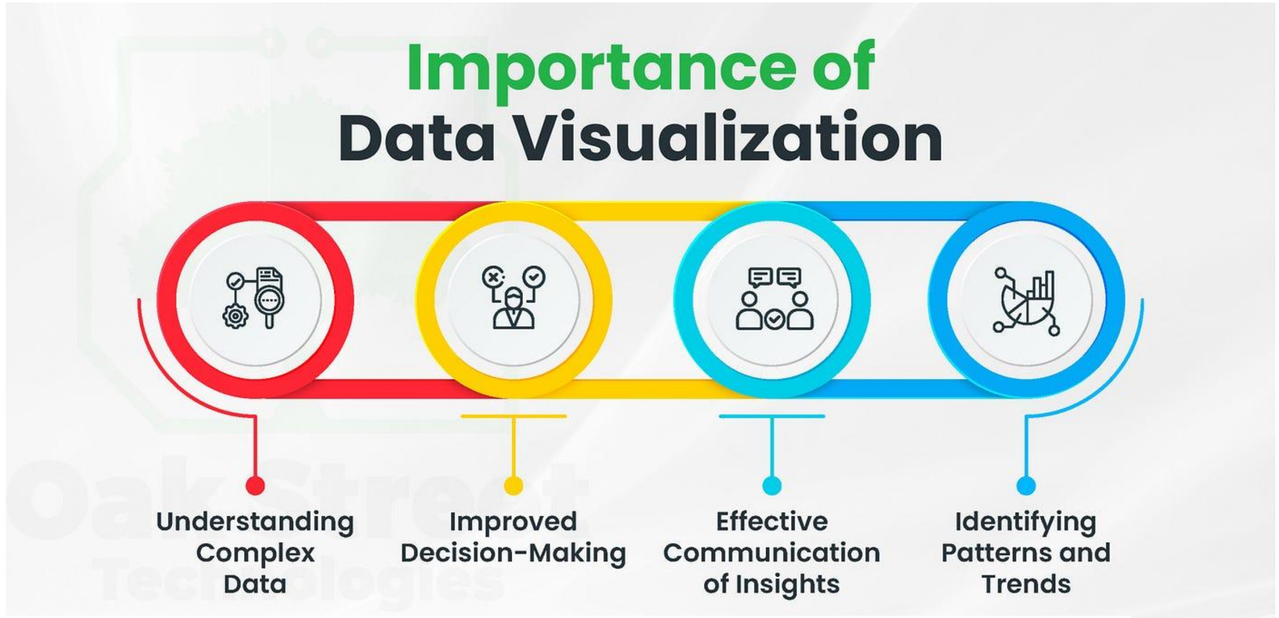
- **Understanding Data Distribution:** Identifying patterns and anomalies.
- **Communication:** Conveying findings effectively to stakeholders.
- **Decision Making:** Facilitating informed choices based on visual insights.
- **Tools:** OxyPlot, LiveCharts, MATLAB, Excel



Data Visualization: From Numbers to Narratives in Minutes

Histograms in Data Analysis

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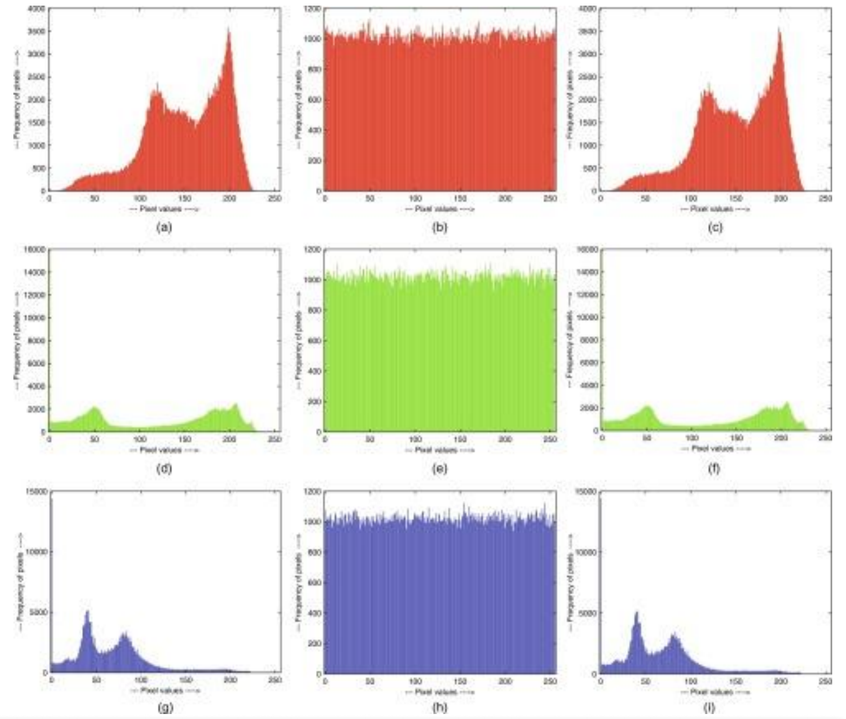
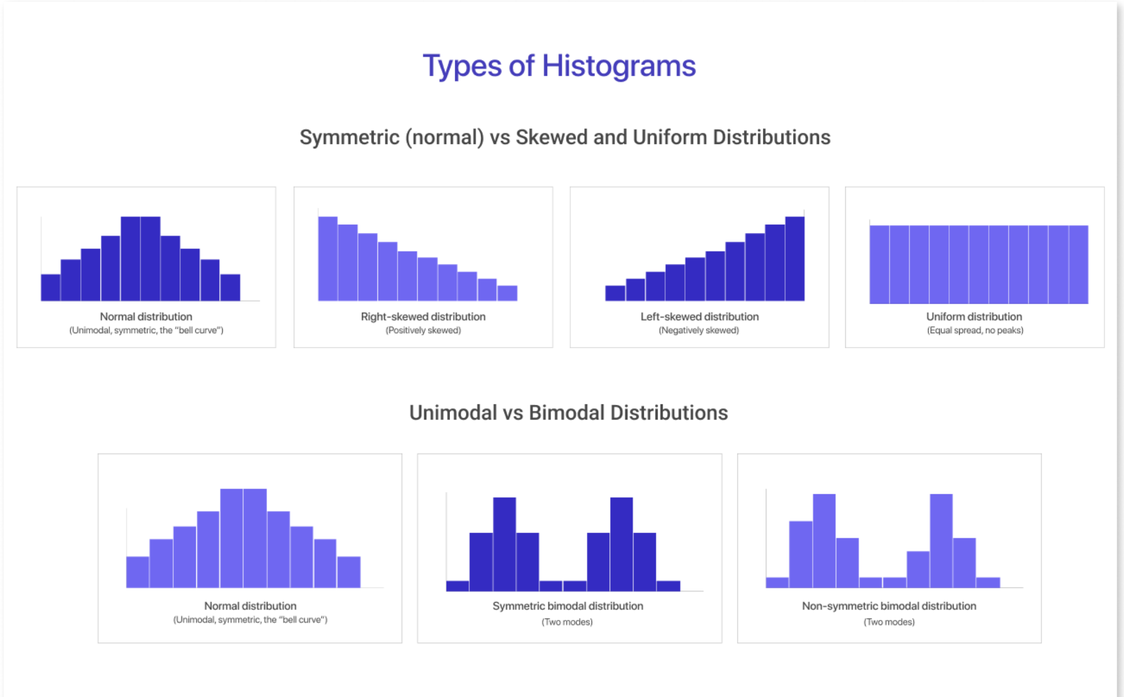
- **Purpose:** Visual representation of data distribution.
- **Construction:**
  - Divide data into bins.
  - Count observations in each bin.
- **Interpretation:** Shape, spread, central tendency.
- **C# Implementation:** Using OxyPlot or LiveCharts.





Probability Density Functions (PDFs)

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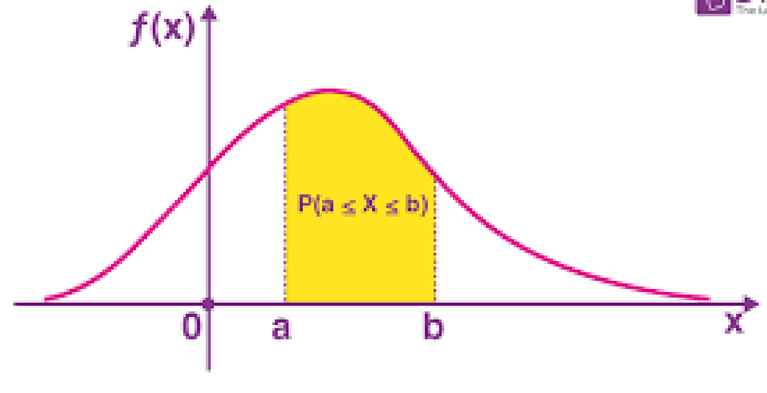
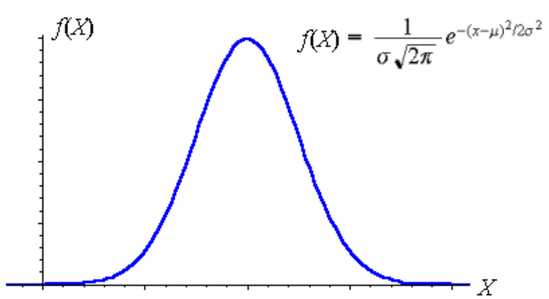
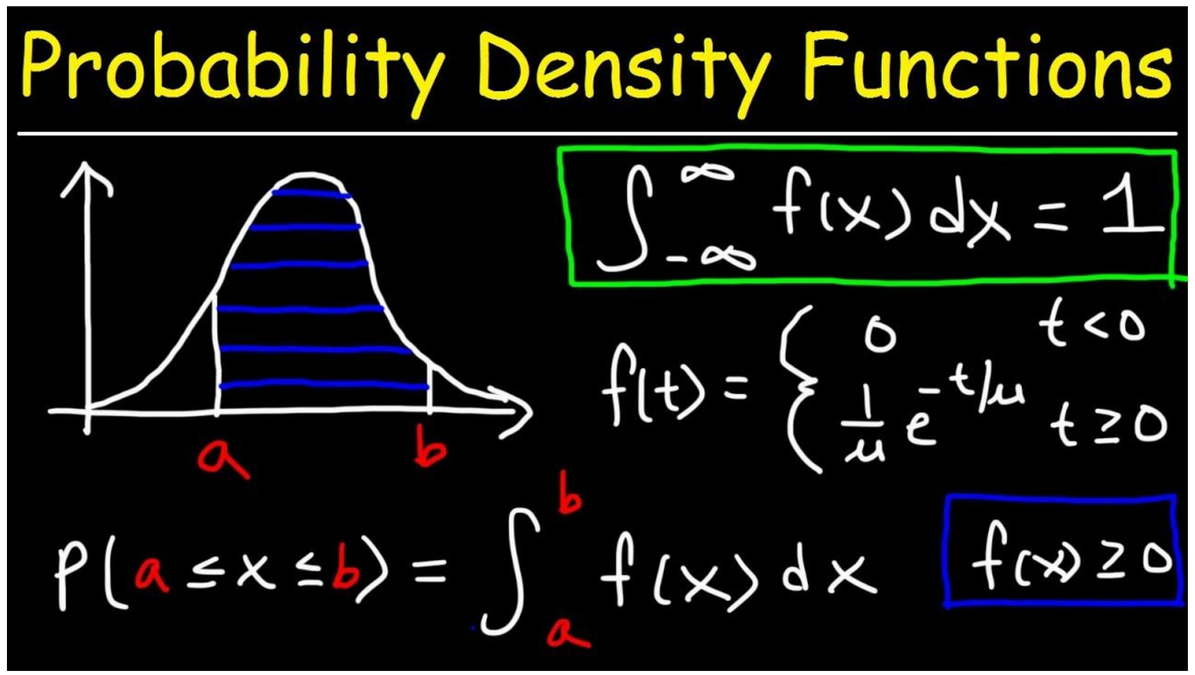


- **Purpose:** Represents the likelihood of a continuous random variable.

- **Characteristics:**
  - Area under the curve equals 1.
  - Shows distribution shape.

- **Implementation in C#:**
  - Calculate PDF values.
  - Plot using visualization libraries.





Interactive Learning Activities

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- **Data Simulation Exercise:** Write C# programs to simulate statistical distributions.
- **LLN Demonstration:** Implement and observe sample mean convergence.
- **Data Visualization Project:** Create histograms and PDFs using engineering data sets.
- **Group Discussion:** Real-world applications of statistical analysis in engineering.

Summary of Key Concepts

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- **Statistical Measures:** Mean, median, mode, variance, standard deviation.
- **Distributions:** Normal, binomial, Poisson.
- **Law of Large Numbers:** Importance in sample mean convergence.
- **C# Programming:** Tools for simulation and visualization.
- **Data Visualization:** Enhancing understanding through visual aids.

Importance of C# in Statistical Analysis

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- **Versatility:** Suitable for a wide range of engineering applications.
- **Libraries:** Access to powerful tools for data handling and visualization.
- **Integration:** Seamless integration with other engineering software.
- **Efficiency:** Capable of handling large datasets and complex computations.

Q&A Session

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- **Open Floor:** Address any questions or clarifications.

- **Discussion Points:**
  - Challenges faced during simulations.
  - Real-world applications of today's topics.
  - Further exploration of statistical methods.

Homework Assignment

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- **Programming Task:**
  - Implement C# classes for Normal, Binomial, and Poisson distributions.
  - Generate 5 samples for each dataset and calculate sample means and variances
- **LLN Exploration:**
  - Modify LawOfLargeNumbersDemo to plot sample mean vs. sample size.
  - Submit plots demonstrating convergence to expected value.
- **Data Analysis:**
  - Select a real-world engineering data set.
  - Perform statistical analysis to determine its distribution.
  - Create visualizations (histogram and PDF) to support findings.

Closing Remark

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- **Mastering Statistics:** Essential for engineering problem-solving.
- **Programming Skills:** Enhances ability to model and analyze data.
- **Real-World Applications:** Apply concepts to drive engineering innovations.
- **Support:** Utilize lecture hours and resources for assistance.
- **Encouragement:** Stay curious and continue exploring statistical methods

Efosa's Introduction

Engineer | Programmer | Innovator

Technical Authority

Shell Nigeria

Subject Mater Expert (EMEA) for Process Automation & Control (PACO)-Subsea control systems and Subsea Distribution

Containerization 85 %

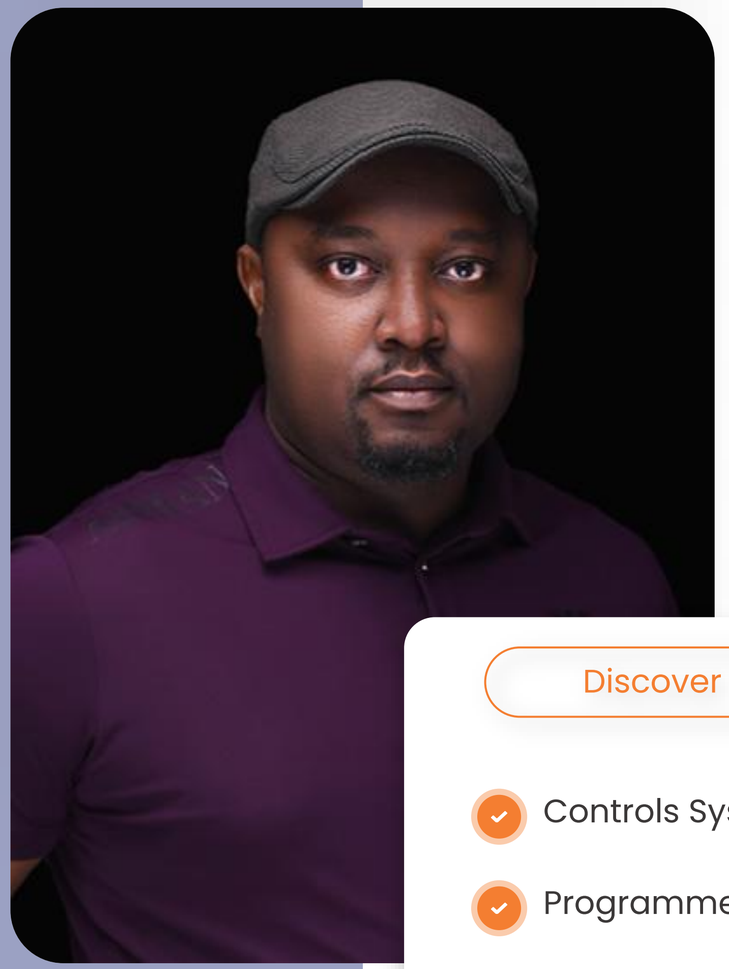
AI & ML 80 %

Renewable Energy 90 %

Innovator, VC

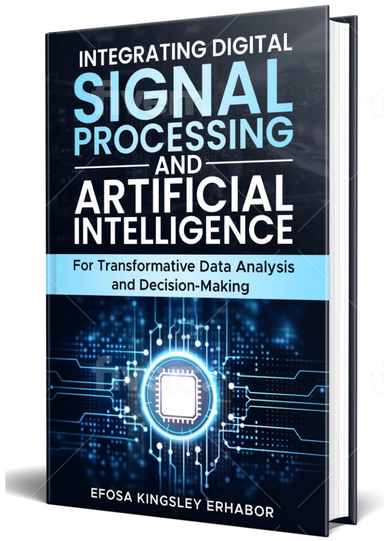
Katharos Technologies

Linux, Devops, AI and Software SME, Innovator and enterprenur



Discover

- Controls System
- Programmer
- Subsea Engineer
- AI and ML



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