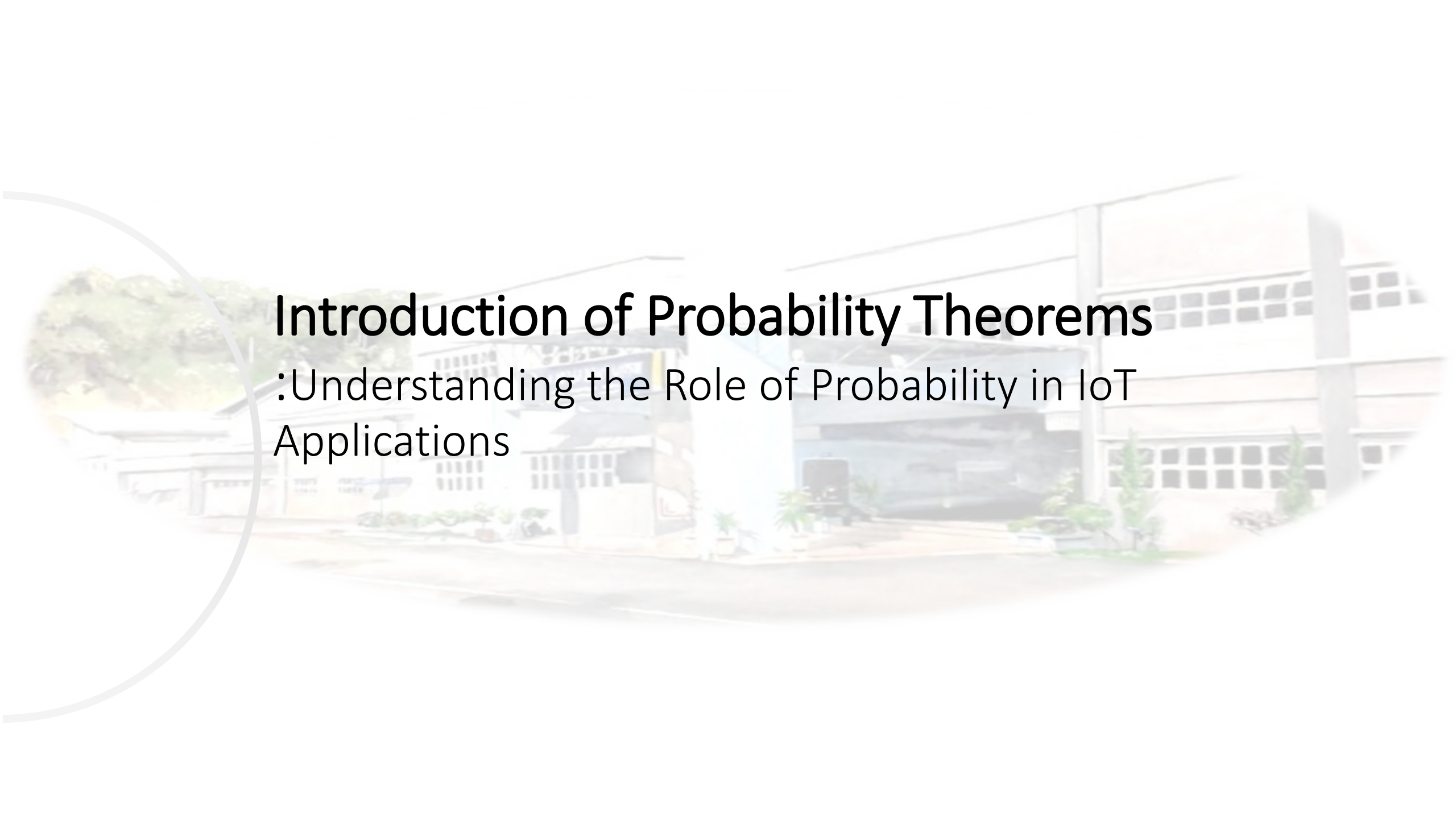
EMJ47703 : IoT and Data Analytics
Ch7 : Probability Theorems in IoT Data_Analytics

Lecturer: Ir. Dr. Huzein Fahmi b. Hawari
Office: Block Meka3B, Level 2, Room #: 40
Email: huzein@unimap.edu.my

In this chapter, we will :

1. **Explain fundamental probability theorems** and their role in data analytics.

2. **Apply probability concepts** to analyze uncertainty, patterns, and predictions in data-driven systems.

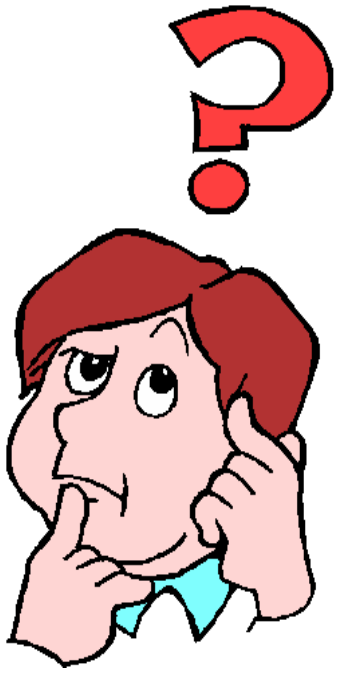


Introduction of Probability Theorems

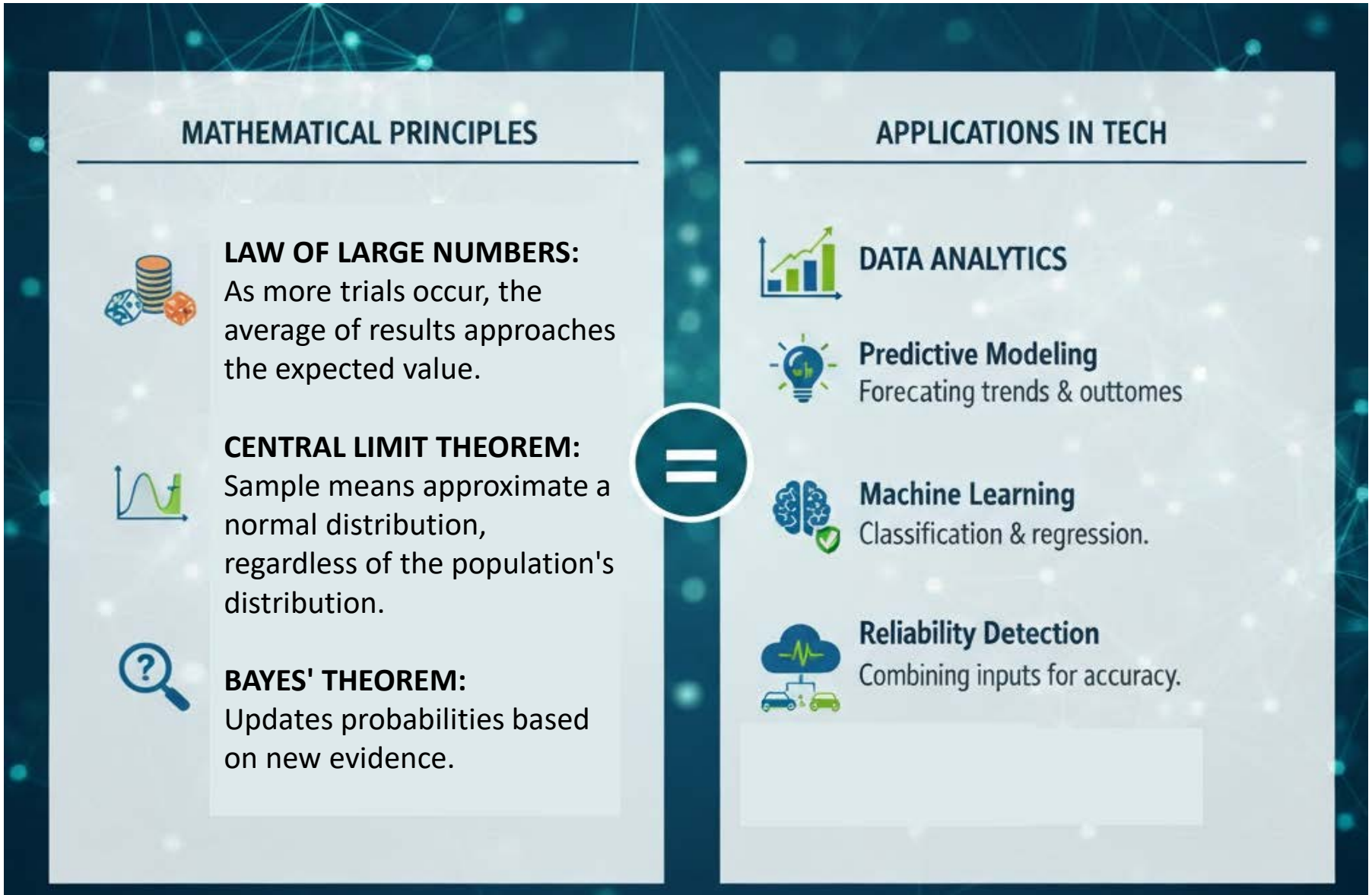
:Understanding the Role of Probability in IoT Applications

Introduction to Probability Theorems

- Probability theorems are mathematical principles that help in understanding and predicting the likelihood of events. They are foundational in data analytics and IoT applications.

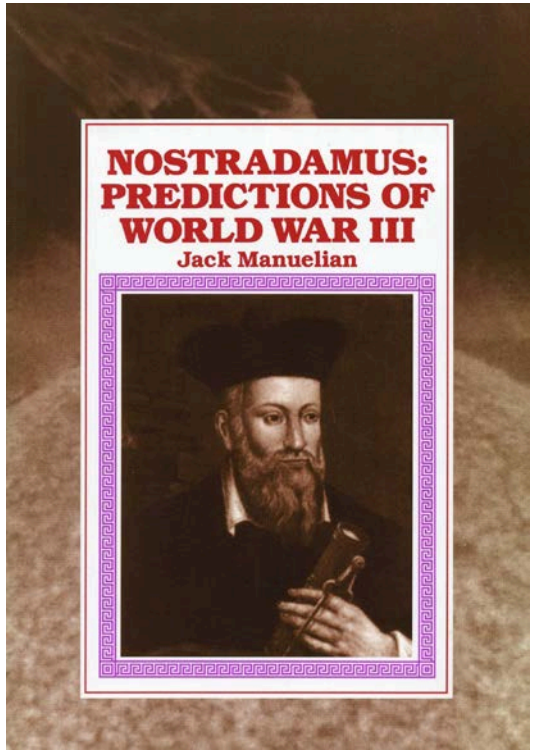


Introduction to Probability Theorems



Importance of Probability in Data Analytics

- Probability is the measure of the likelihood of an event occurring. In data analytics, it is used to make predictions, identify patterns, and support decision-making processes.

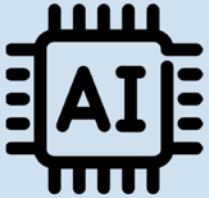


Overview of IoT and Data Analytics

- The Internet of Things (IoT) involves interconnected devices that collect and exchange data. Data analytics in IoT helps in processing this data to derive actionable insights.

Role of Probability in IoT Data Analytics

- Probability plays a crucial role in IoT data analytics by enabling predictive modeling, anomaly detection, and decision-making under uncertainty. (Risk Management)

Classical Risk Assessment and Management	Cooperative Risk Management	Business Risk Management	Comprehensive Risk Management	AI Technology in Risk Management
				
1900–1979	1980–1999	2000–2010	2011–2020	2021–AI Era
1900				Our days
Specializing in insurance coverage, finance, and operations with a responsive approach to risk management.	Integrated risk management into the process of strategic planning, taking into account functioning, ethical, and strategic concerns.	The strategy was comprehensive, including new threats such as cyber risk, and placed particular emphasis on the role of corporate culture in risk management.	The wider implications of risks include the integration of risk management with business tasks such as environmental responsibility, administration, and regulation.	AI technologies are proven to be invaluable in quickly identifying and controlling dangers. AI response planning becomes critical for minimizing business disruptions during crises, particularly in the realm of cybersecurity.

Matlab in Thingspeak

https://www.youtube.com/watch?v=y5PoByl4LgA&t=166s

https://www.youtube.com/watch?v=7B5OALGzTK0

Key Probability Theorems Used in IoT

- 1. Bayes' Theorem
- 2. Law of Large Numbers
- 3. Conditional Probability

Bayes' Theorem: Concept and Formula

- Bayes' Theorem describes the probability of an event based on prior knowledge of conditions that might be related to the event.

Bayes Theorem Formula

$$P(A|B) = \frac{P(B|A)*P(A)}{P(B)}$$

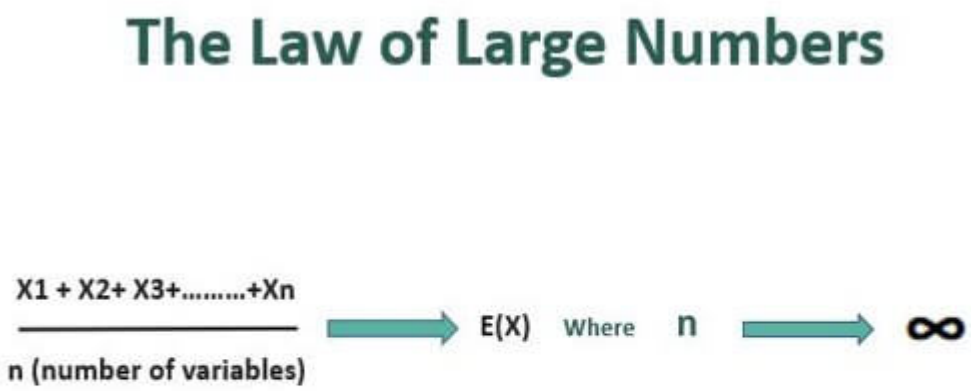
Application of Bayes' Theorem in IoT (Example in ThingSpeak)

- Bayes' Theorem can be used in ThingSpeak to predict sensor failures by analyzing historical data and current readings to calculate the probability of failure.

https://www.youtube.com/watch?v=y5PoByl4LgA&t=166s

Law of Large Numbers: Concept and Formula

- The Law of Large Numbers states that as the size of a sample increases, the sample mean will get closer to the population mean.
- Formula: $\lim(n \to \infty)\ (1/n)\ \Sigma\ Xi = \mu$



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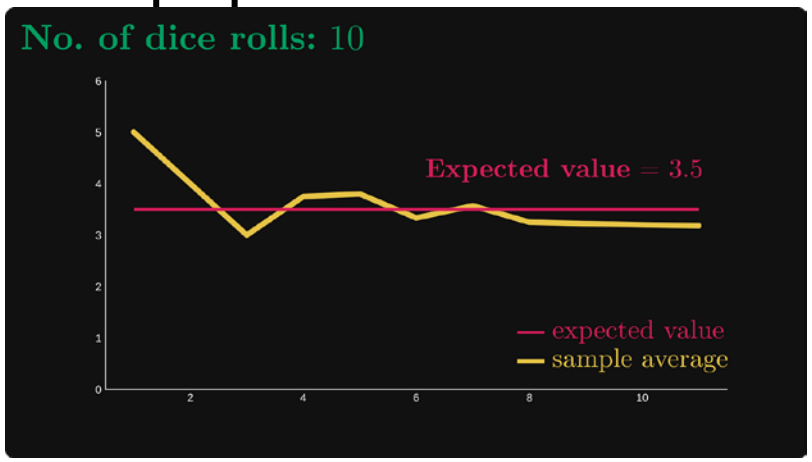
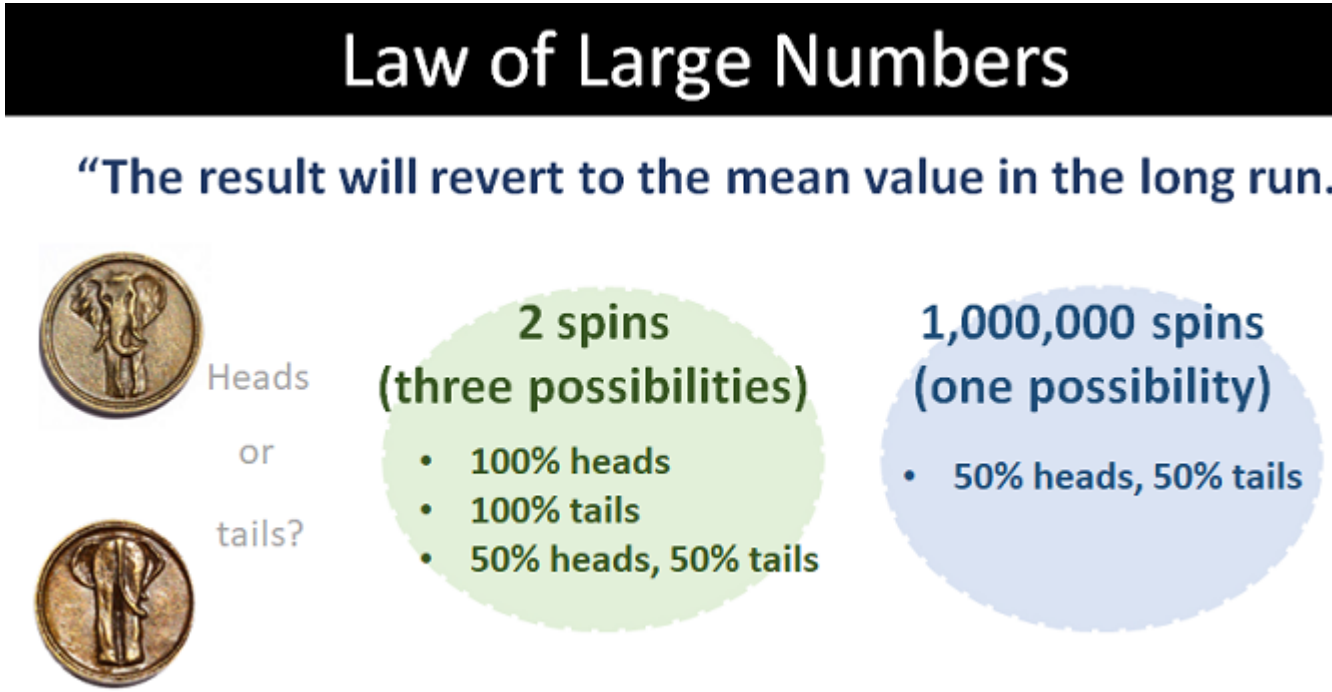
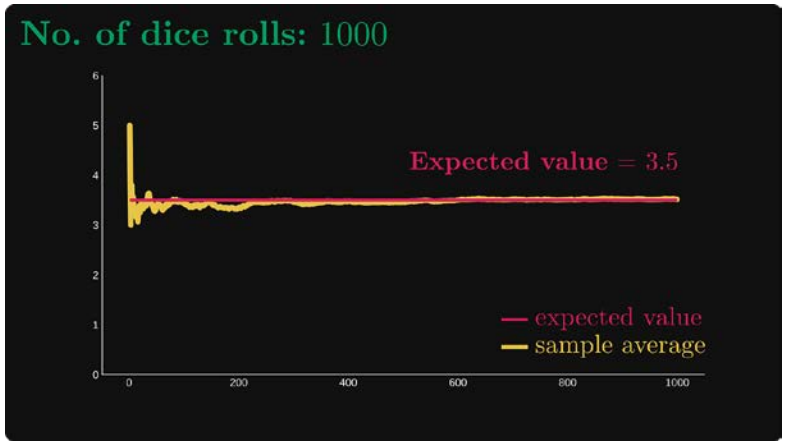






Application of Law of Large Numbers in IoT (Example in MATLAB)

- In MATLAB, the Law of Large Numbers can be applied to analyze large datasets from IoT devices, such as temperature sensors, to estimate the average temperature over time.

Conditional Probability: Concept and Formula

- Conditional Probability is the probability of an event occurring given that another event has already occurred.
- Formula: $P(A|B) = P(A \cap B) / P(B)$

Application of Conditional Probability in IoT

- Conditional Probability can be used in IoT to predict the likelihood of an event, such as a device malfunction, given certain conditions like high temperature or humidity.

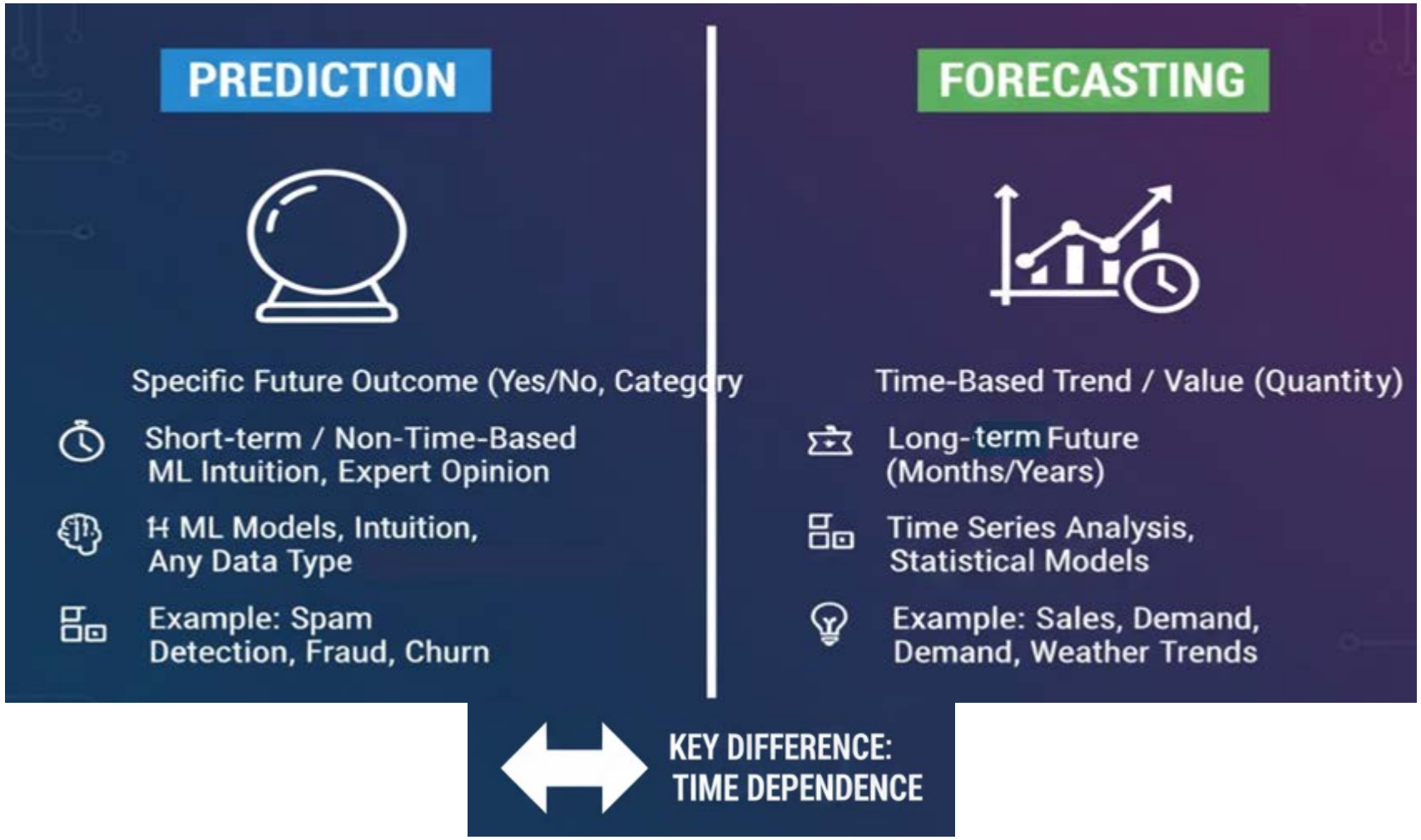
Advantages of Using Probability Theorems in IoT

- 1. Improved decision-making
- 2. Enhanced predictive analytics
- 3. Better anomaly detection
- 4. Efficient resource allocation

Improved Decision-Making with Probability in IoT

- Probability helps in making informed decisions by analyzing the likelihood of various outcomes based on IoT data.

Prediction vs Forecasting



all **forecasts** are a type of prediction, but not all **predictions** are forecasts. Forecasting is a specialized, time-dependent prediction

Prediction vs Forecasting

Examples

- **Prediction:**
  - Classifying an email as "Spam" or "Not Spam."
  - Predicting if a machine will fail in the next 24 hours (a binary outcome).
  - Predicting a customer's lifetime value based on their attributes.
- **Forecasting:**
  - Estimating a company's revenue for the next financial year.
  - Projecting the average monthly temperature for the next season.
  - Forecasting inventory demand for the next six months.
  - In simple terms, all forecasts are a type of prediction, but not all predictions are forecasts. Forecasting is a specialized, time-dependent prediction.

Enhanced Predictive Analytics in IoT

- Predictive analytics in IoT uses probability to forecast future events, such as equipment failures or energy consumption patterns.

Limitations of Probability Theorems in IoT

- 1. Requires large datasets for accuracy
- 2. Computationally intensive
- 3. May not account for all variables
- 4. Dependent on data quality

Challenges in Handling Large IoT Data

- 1. Data storage and management
- 2. Ensuring data quality
- 3. Real-time processing
- 4. Scalability of analytics models

Example: Predictive Maintenance in IoT Using Probability

- Probability can be used to predict equipment failures by analyzing historical maintenance data and current sensor readings.

Example: Anomaly Detection in IoT Using Probability

- Anomaly detection in IoT can be achieved by calculating the probability of data points deviating from the expected range.

Example: Sensor Data Analysis in IoT Using Probability

- Probability is used to analyze sensor data to identify patterns, trends, and anomalies in IoT systems.

Real-World Example : Tesla Autopilot (Automotive Engineering)
Problem:
Cameras, radar, and ultrasonic sensors do not always provide perfect information due to weather, lighting, or sensor noise.

How Probability Is Used:
•**Bayes' Theorem** continuously updates the probability of objects (cars, pedestrians) based on new sensor data.
•**Conditional probability** estimates the likelihood of an obstacle given partial or uncertain inputs.
•**Law of Large Numbers** improves model reliability as millions of driving data points are collected.

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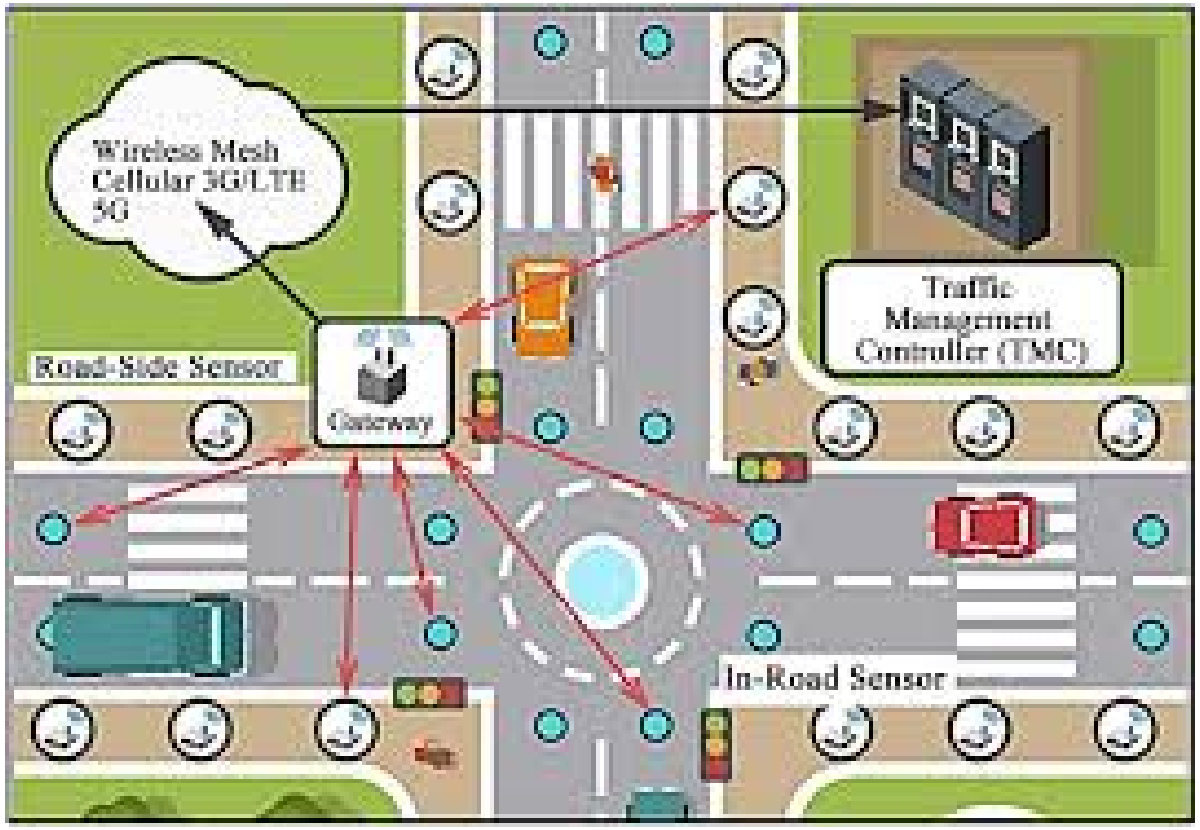
https://www.youtube.com/watch?v=IQJL3htsDyQ&t=642s

Example: Traffic Flow Prediction in IoT Using Probability

- IoT data from traffic sensors can be analyzed using probability to predict traffic flow and optimize routes.



Example: Energy Consumption Forecasting in IoT Using Probability

- Probability is used to forecast energy consumption patterns in IoT-enabled smart grids based on historical data.

Tools for Implementing Probability in IoT (ThingSpeak, MATLAB)

- 1. ThingSpeak: A platform for IoT analytics and visualization
- 2. MATLAB: A tool for advanced data analysis and probability modeling

Comparison of Probability Theorems in IoT Applications

Theorem	Application
• Bayes' Theorem	• Predictive modeling
• Law of Large Numbers	• Estimating averages
• Conditional Probability	• Event likelihood prediction

Future Trends in Probability and IoT Analytics

- 1. Integration with AI and machine learning
- 2. Real-time probability analytics
- 3. Enhanced scalability and efficiency
- 4. Improved data privacy and security

Ethical Considerations in IoT Data Analytics

- 1. Data privacy and security
- 2. Transparency in analytics models
- 3. Avoiding bias in probability calculations
- 4. Ensuring ethical use of insights

References and Further Reading

- 1. Probability and Statistics for Engineers and Scientists by Ronald E. Walpole
- 2. IoT Analytics: Concepts and Applications by John Doe
- 3. MATLAB Documentation: Probability and Statistics Toolbox
- 4. ThingSpeak Documentation: IoT Analytics Platform

What does probability measure?

A. Accuracy of data
B. Likelihood of an event
C. Size of a dataset
D. Speed of computation

Which notation represents conditional probability?

A. $P(A \cap B)$

B. $P(A + B)$

C. $P(A|B)$

D. $P(A - B)$.

Which factor most affects the accuracy of probability-based analysis?

A. Color of sensors
B. Dataset size and quality
C. Programming language
D. User interface

A major limitation of probability methods is that they:

A. Depend on assumptions and data quality
B. Require no data
C. Are always inaccurate
D. Cannot be automated

Summary

In this chapter, we have covered:

- Probability theorems provide a mathematical foundation for analyzing uncertainty in data analytics.
- Key concepts such as Bayes' Theorem, conditional probability, and the Law of Large Numbers support prediction and inference.
- Probability enables informed decision-making, anomaly detection, and predictive analysis.
- Despite limitations such as data dependency and computational cost, probability remains essential in modern analytics.

THANK YOU

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