

Visualizing and Analyzing Time Series Data

Lecture 4 – Data Visualization Course

Dr. Muhammad Sajjad

R.A: Imran Nawar



Overview

- Introduction to Time Series Data
- Types of Time Series Data
- Characteristics of Time Series Data
- Importance of Time Series Data Visualization
- **Basic Time Series Data Visualization Techniques**
 - Line Plot
 - Bar Chart
 - Area Chart
 - Stacked Area Chart
 - Moving Averages and Smoothing (are techniques often visualized with line plots.)
- **Advanced Time Series Analysis**
 - Trend Analysis
 - Seasonal Decomposition
 - Stationarity and Differencing
- **Time Series Forecasting**
 - Forecasting
 - Key Components of Time Series Forecasting
 - Popular Forecasting Models
- Applications of Time Series Data Analysis.
- **Case Study:** Forecasting Stock Prices with LSTM
- **Coding:** Visualizing and Analyzing Time Series Data.

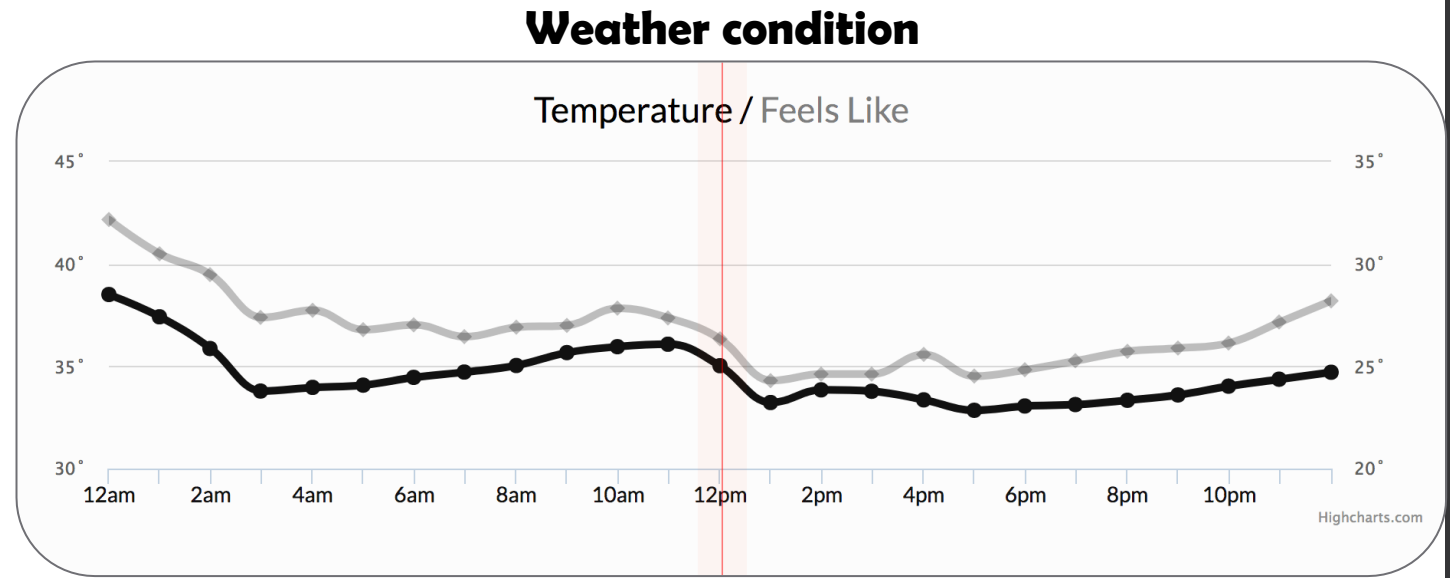
Introduction to Time Series Data

Time Series Data:

- Time series data is information that is collected at regular, consistent intervals over time.
- **Examples:**
 - Temperature measured every two hours
 - Daily stock prices
 - Weekly sales data
- This data type helps us observe trends, patterns, and correlations across time, providing deeper insights into various processes.

Why Time Series Data Matters:

- By analyzing and visualizing time series data, we can identify trends, spot anomalies, and uncover patterns that guide better decision-making and predictions.
- Time series data is widely used in fields like economics, weather forecasting, finance, and more.



Types of Time Series Data

Based on Time Intervals

1. Regular (Equally Spaced):

Data points are collected at consistent, fixed intervals (e.g., daily, monthly, quarterly).

- **Example:** Daily stock prices, monthly sales.

2. Irregular (Unequally Spaced):

Data points are collected at inconsistent intervals, often triggered by specific events.

- **Example:** Earthquake occurrences, sensor measurements triggered by events.

Based on Number of Variables:

1. Univariate Time Series:

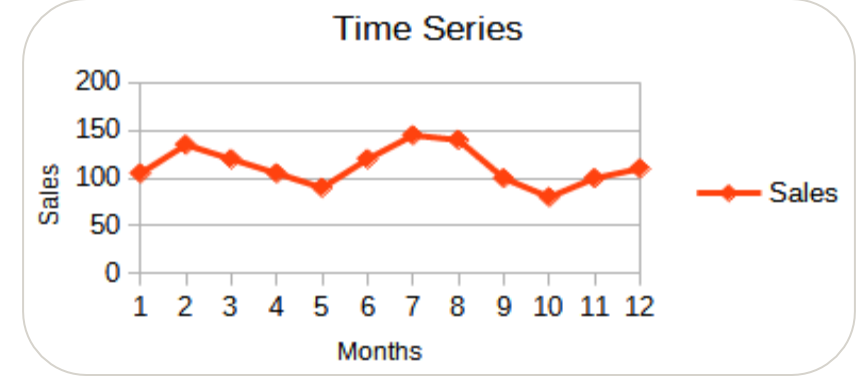
A single variable is measured and recorded over time.

- **Example:** Daily temperature recordings.

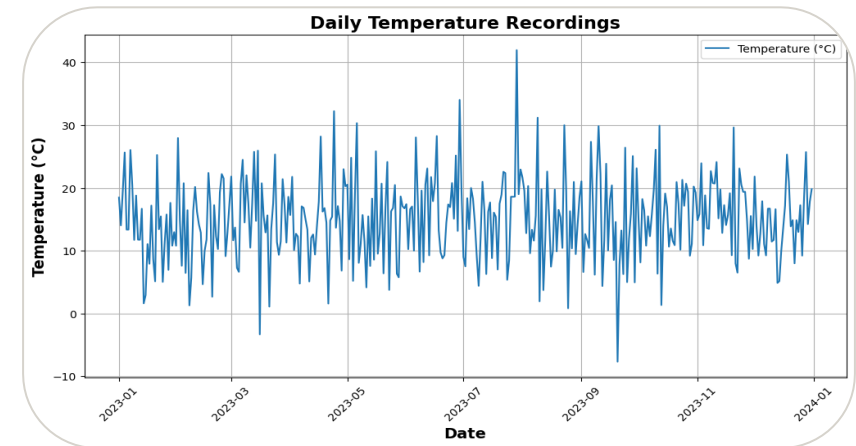
2. Multivariate Time Series:

Multiple variables are measured and recorded over time.

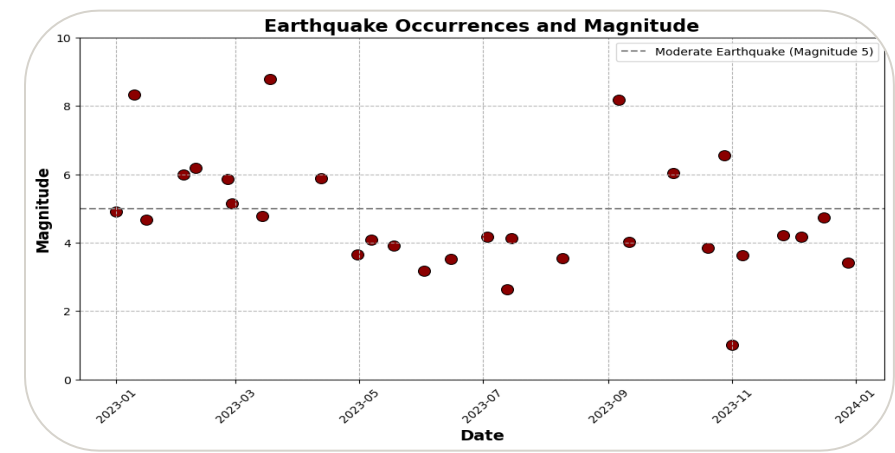
- **Example:** Simultaneous readings of temperature, humidity, and pressure.



Synthetic data representing daily temperature trends over time



Synthetic data representing earthquake occurrences and corresponding magnitudes over time.



Characteristics of Time Series Data:

1. Sequential Nature

- Data points are ordered chronologically, with each observation associated with a specific time.
- The sequence is crucial for analysis, as the order affects how patterns are interpreted.

2. Timestamp

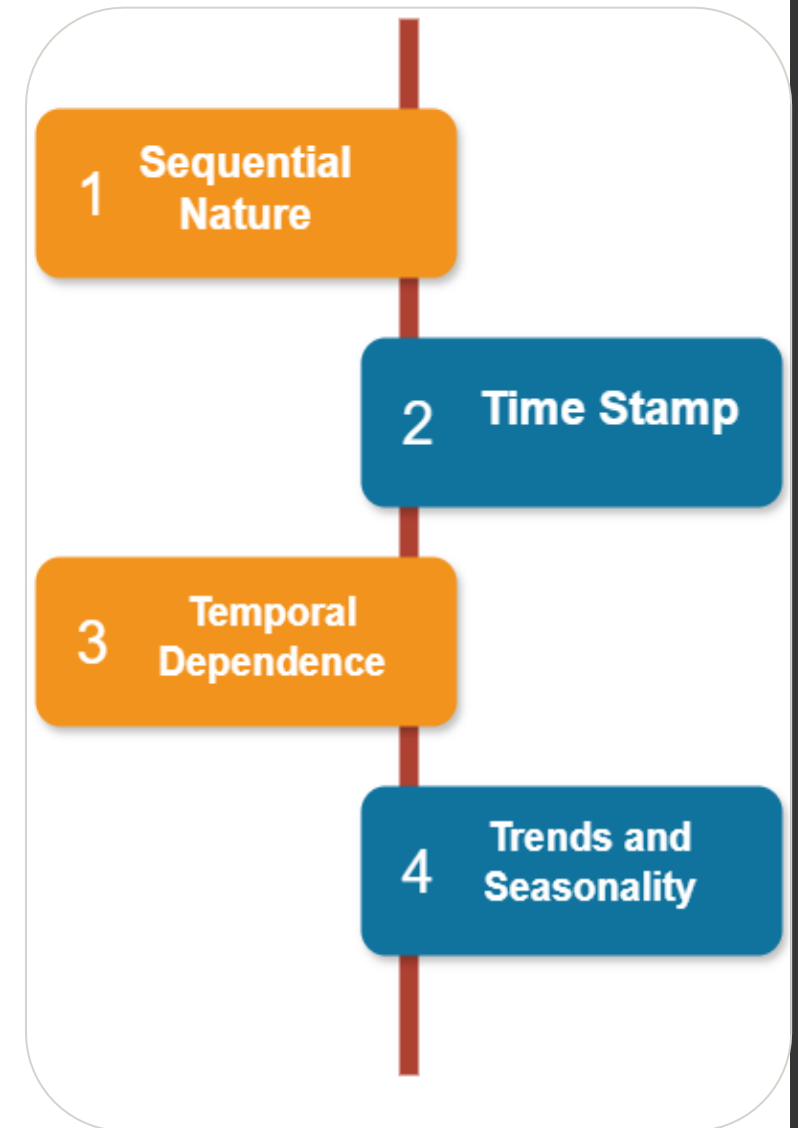
- Each record comes with a timestamp that marks the exact time of the observation.
- Timestamps serve as indices for analysis and computation.

3. Temporal Dependence

- The current value often depends on past values, indicating a relationship over time.
- **Autocorrelation:** The correlation between a variable and its past values is a key feature of time series data.

4. Trend and Seasonality

- **Trends:** A long-term upward or downward movement in the data.
- **Seasonality:** Regular patterns that repeat over fixed time periods, such as daily, monthly, or yearly cycles.



Importance of Time Series Data Visualization

Why Visualize Time Series Data?

- **Understanding Patterns:**

- Identifies trends, seasonal effects, and anomalies
- Reveal hidden patterns and cyclical behaviors over time.

- **Effective Communication:**

- Simplifies complex temporal information, making insights accessible to stakeholders.
- Enhances decision-making by providing clear visual representations.

- **Forecasting Potential:**

- Helps predict future outcomes by showcasing historical patterns.

- **Analyzing Underlying Causes:**

- Helps organizations pinpoint reasons behind trends or recurring events, facilitating deeper insights into data-driven decisions.



Basic Time Series Data Visualization Techniques

- Time series data can be effectively visualized using various techniques to reveal trends, patterns, and changes over time.
- Temporal visualizations help in analyzing data across a time axis, uncovering key insights such as seasonality or trends.

Key Visualization Techniques:

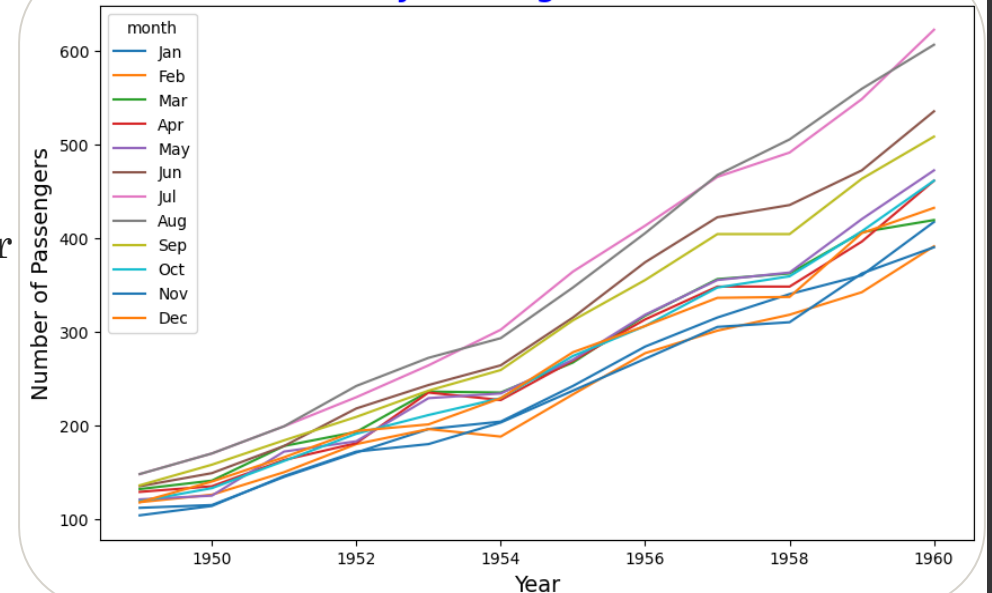
1. Line Plot:

- A fundamental and most common visualization for time series data.
- Show trends over time.
- **Axes:**
 - **X-axis:** Represents time.
 - **Y-axis:** Represents the variable of interest.
- **Use Case:** Perfect for showing how a variable changes over time.
- **Key Features:**
 - Easy to understand
 - Useful for identifying **trends** and **patterns**.
 - Can display multiple lines for comparing variables.
- **Example:** Monthly number of passengers over the years.

Graph of stock prices of Tesla



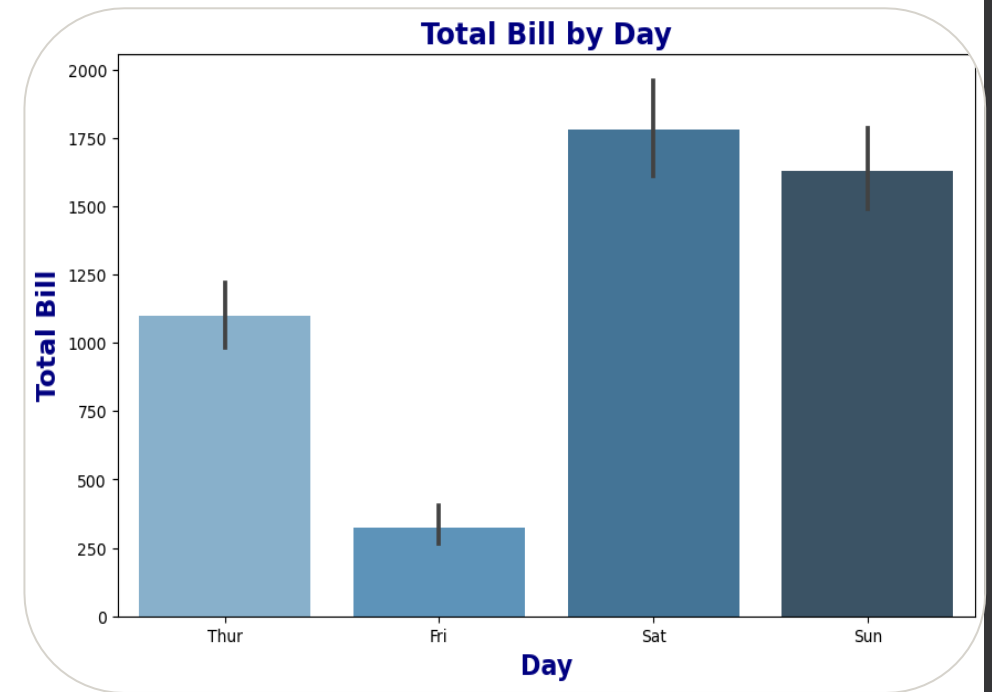
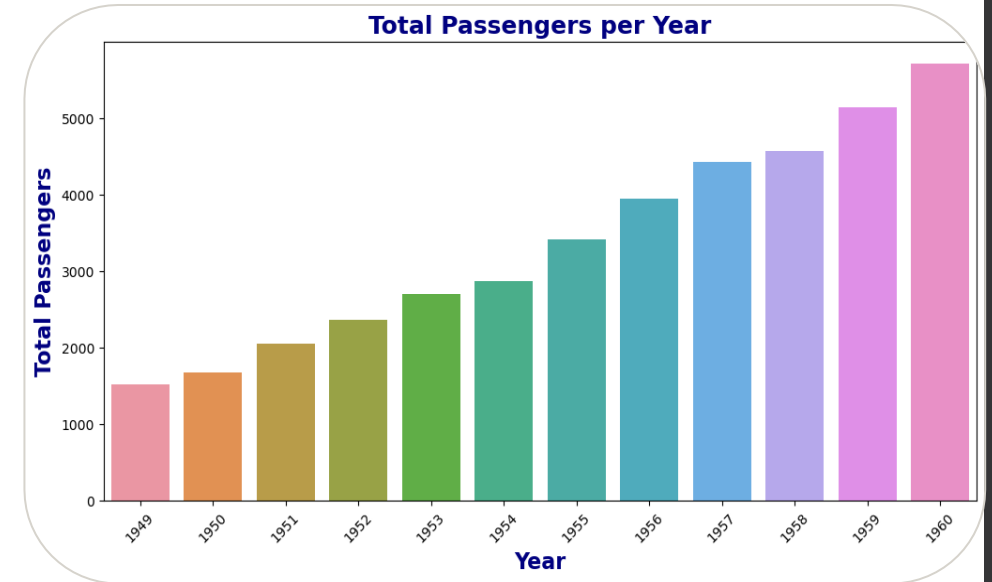
Monthly Passengers Over Years



Basic Time Series Data Visualization Techniques

2. Bar Chart:

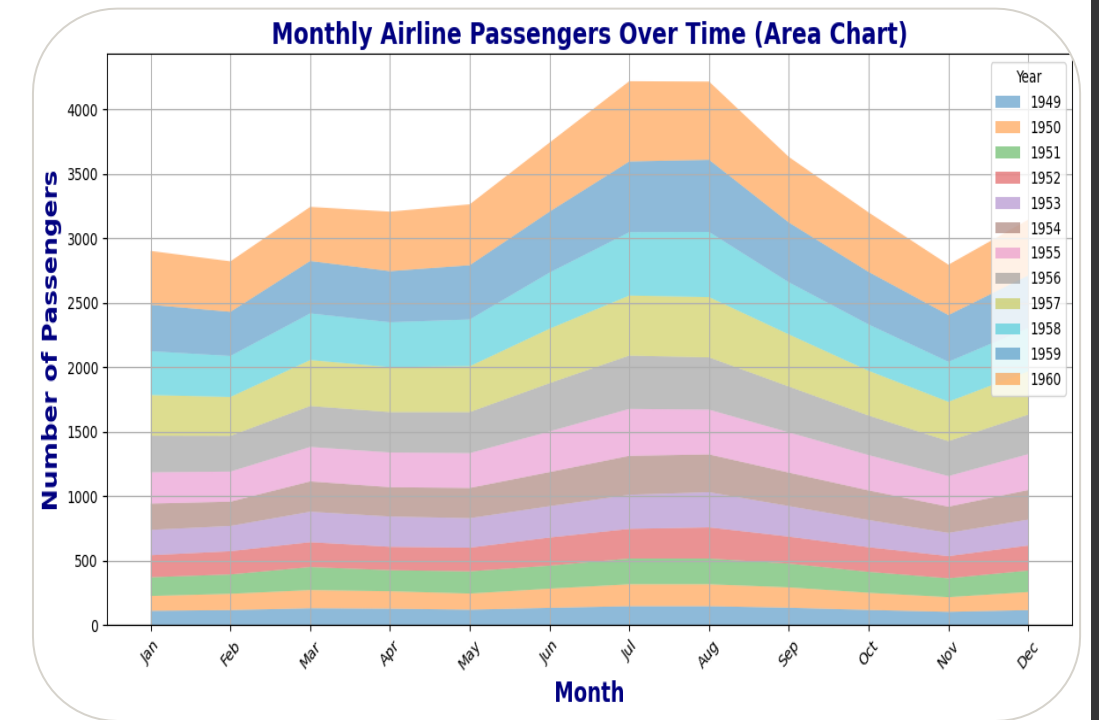
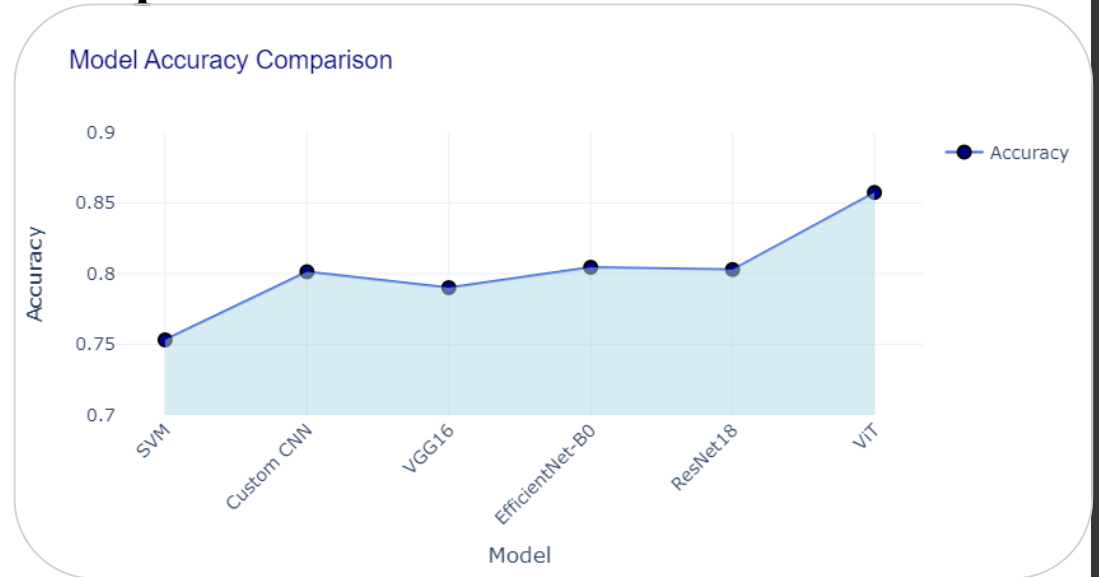
- Represents data as **horizontal or vertical bars**.
- **Axes**
 - **X-axis:** Time periods
 - **Y-axis:** Variable values
- **Key Features:**
 - Bar height/length proportional to variable value.
 - Supports grouped or stacked bars for multiple variables.
 - Best for comparing discrete time intervals.
- **Advantages:**
 - Easy to compare values across time periods
 - Effective for displaying multiple variables
 - Clear representation of discrete data.
- **Use Case:**
 - Ideal for comparing **discrete time intervals** (e.g., yearly revenue comparisons).
- **Example:**
 - Showing total bill amounts across different days of the week.



Basic Time Series Data Visualization Techniques

3. Area Chart

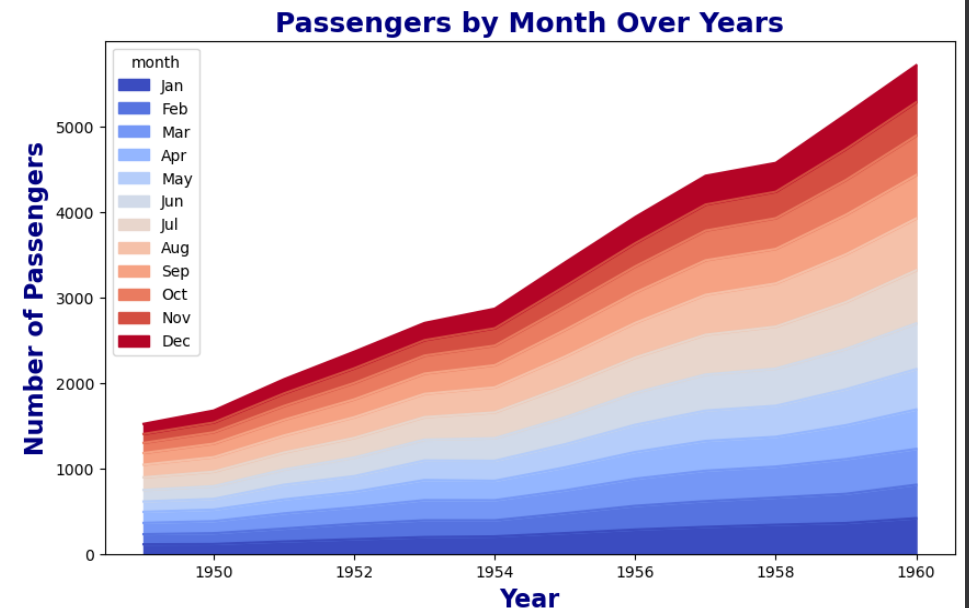
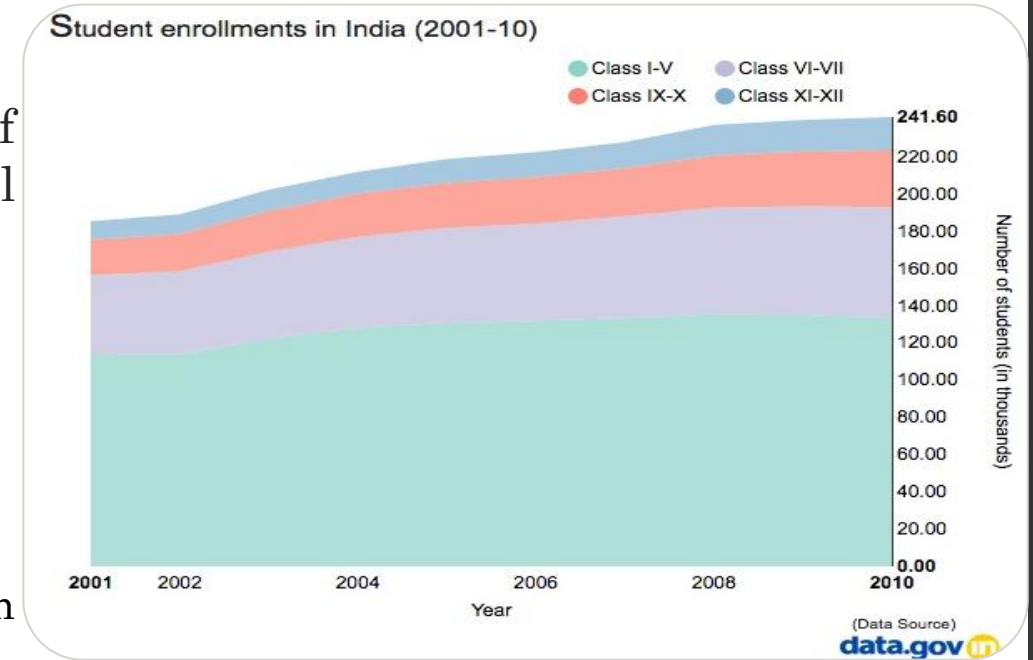
- Area chart extend line plots by filling the area beneath the line to show trends over time.
- **Axes:**
 - **X-axis:** Time
 - **Y-axis:** Variable values
- **Key Features:**
 - Can represent one or more variables.
 - The area under the line(s) is filled, making it easier to see the magnitude of values over time.
 - Best for visualizing distributions or magnitude changes over time.
- **Use Case:**
 - Shows cumulative totals or proportions over time.
- **Example:** Yearly sales growth of different products.



Basic Time Series Data Visualization Techniques

4. Stacked Area Chart

- Stacked area charts allow for the comparison of multiple variables, showing both individual contributions and cumulative totals over times.
- Axes:**
 - X-axis:** Time
 - Y-axis:** Stacked variable values
- Key Features:**
 - Requires two or more variables.
 - Areas are stacked to show each variable's contribution to the total.
 - Best for comparing multiple variables over time.
- Use Case:**
 - Comparing market share or other proportion-based data over time.
- Example:** Market share of different smartphone brands over the past decade.



Basic Time Series Data Visualization Techniques

Moving Averages and Smoothing

- Moving Averages are a type of smoothing techniques used to reduce noise and reveal the underlying trends in time series data.
- Smoothing in general refers to techniques that reduce short-term fluctuations in data, making long-term trends easier to see.

- **Key Types:**

1. **Simple Moving Average (SMA):**

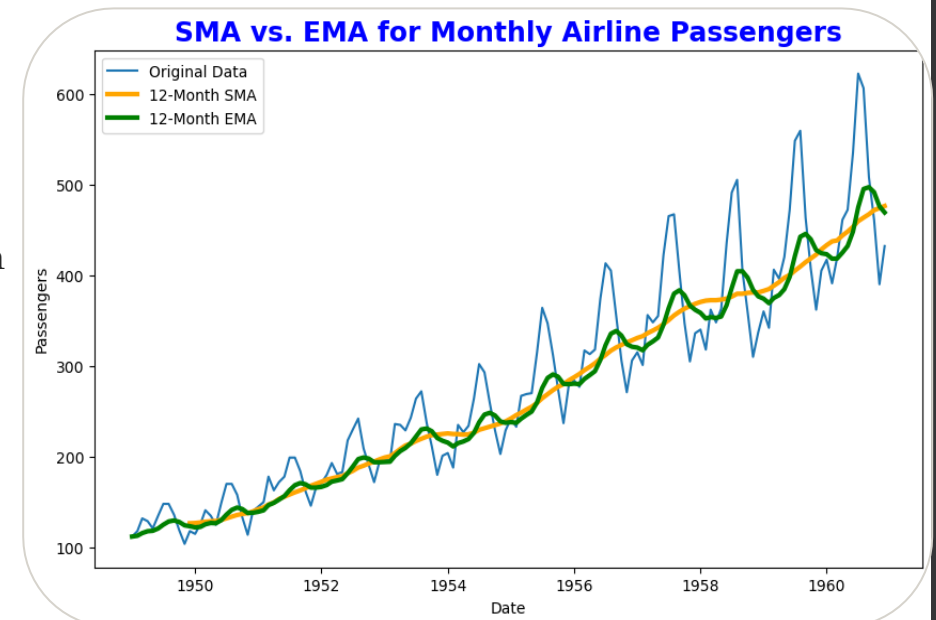
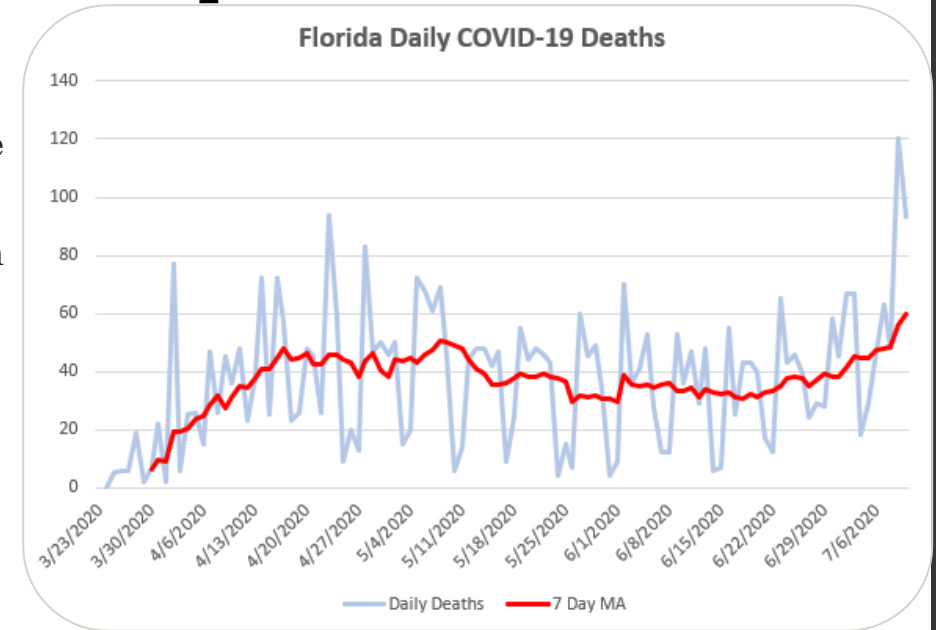
- Averages data over a specific window.
- Equal weight for each data point.
- Best for long-term trend visualization.
- **Use Case:** Identifying long-term trends in stable time series data.

2. **Exponential Moving Average (EMA):**

- More weight given to recent data points.
- Reacts more quickly to changes.
- Useful for identifying short-term changes while retaining a focus on trends.
- **Use Case:** Detecting recent trends or shift in volatile data.

➤ **Purpose:**

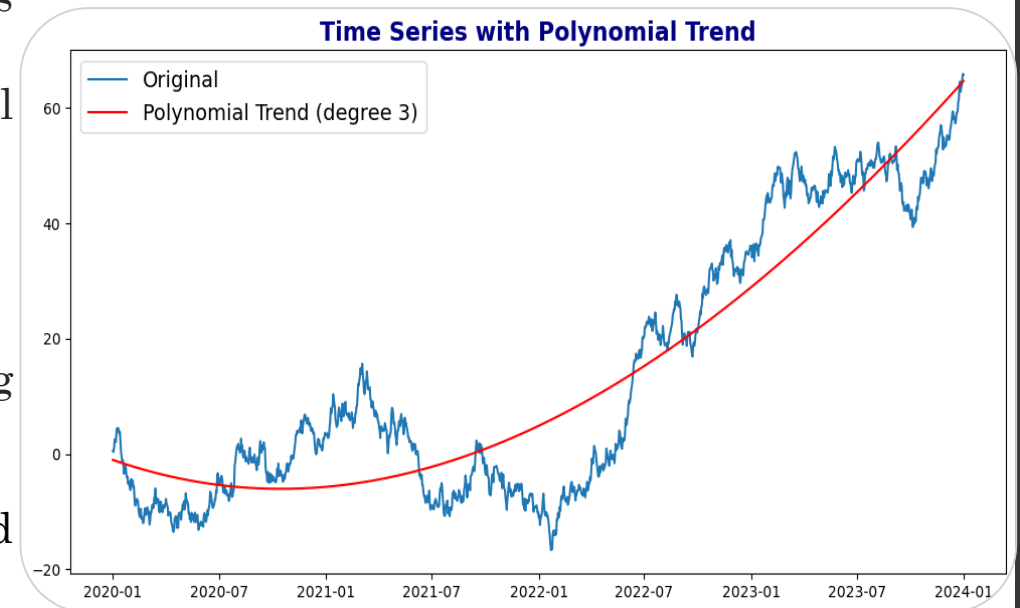
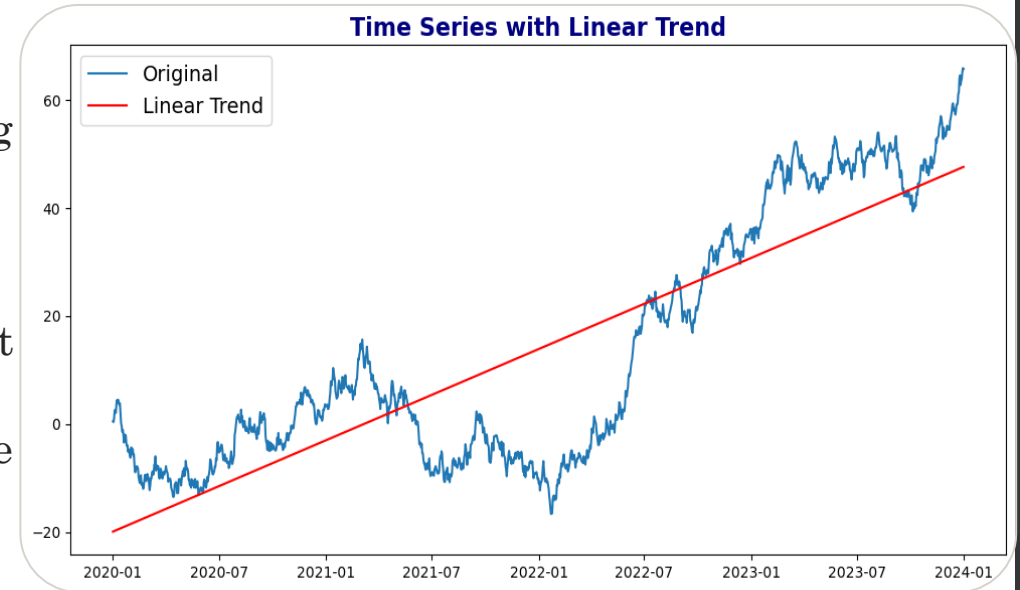
- To reduce noise and make underlying trends more visible.
- Facilitate better decision-making based on trend analysis.



Advanced Time Series Analysis

Trend Analysis

- Identifies the long-term direction of a time series, focusing on overall patterns.
- **Types:**
 - **Linear Trend:** A straight line indicating a consistent rise or fall.
 - **Polynomial Trend:** A curved line representing more complex movements.
- **Methods:**
 - **Decomposition:** Breaking time series into components (trend, seasonal, residual).
 - **Regression Analysis:** Fitting linear or polynomial models to data.
- **Use Cases:**
 - **Linear Trend:** Economic growth, population trends.
 - **Polynomial Trend:** Sales growth with fluctuating patterns.
- **Example:** Using linear regression to identify an upward trend in annual revenue.



Advanced Time Series Analysis

Seasonal Decomposition

➤ Breaks down time series into three parts.

- **Trend:** Long-term direction (upward, downward, or flat).
- **Seasonal:** Repeating patterns (e.g., monthly or yearly cycles).
- **Residual:** The remaining noise or irregular variations after removing trend and seasonality.

• Techniques:

- **Additive:** Time series is expressed as the sum of its components.

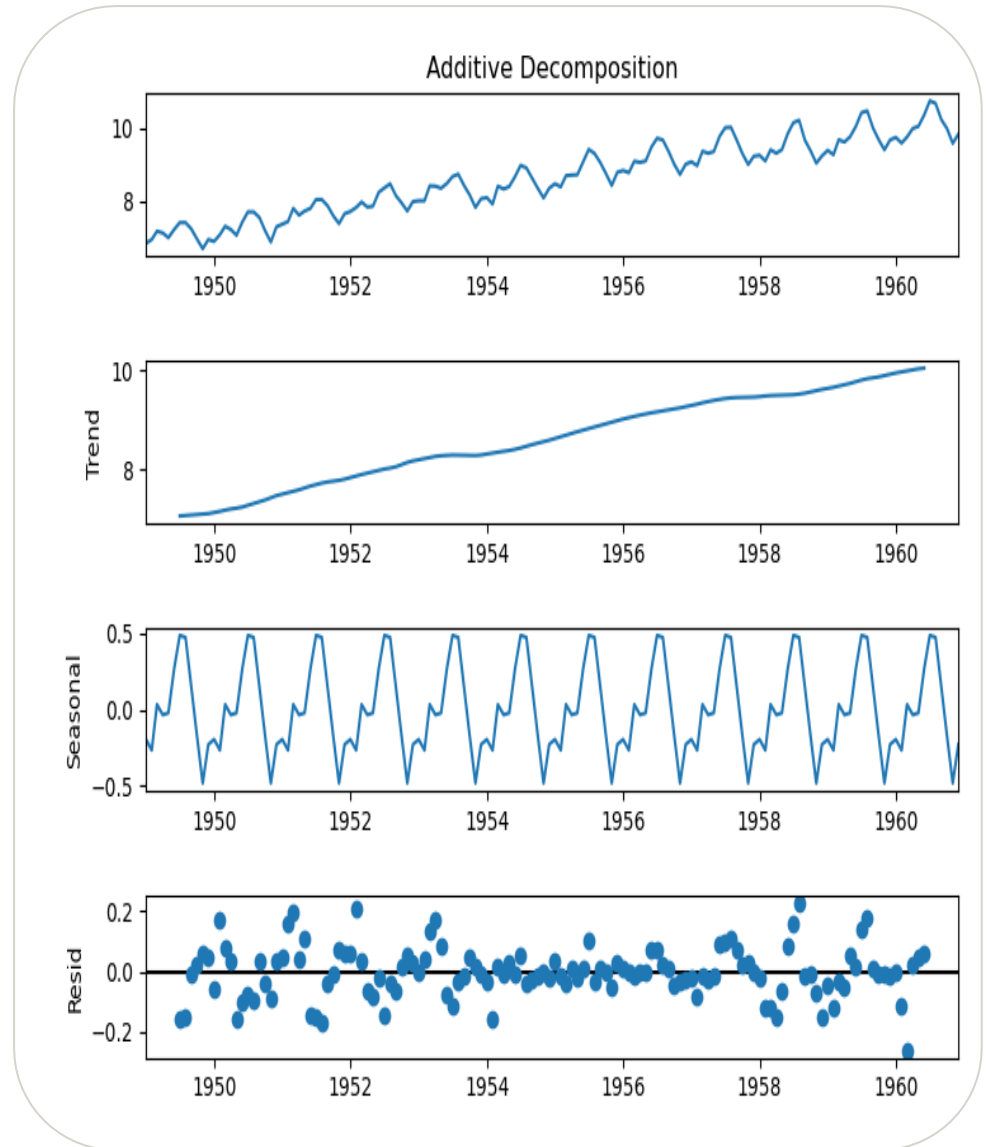
$$\text{Series} = \text{Trend} + \text{Seasonal} + \text{Residual}$$

- **Multiplicative:** Time series is expressed as the product of its components.

$$\text{Series} = \text{Trend} * \text{Seasonal} * \text{Residual}$$

• Use Cases:

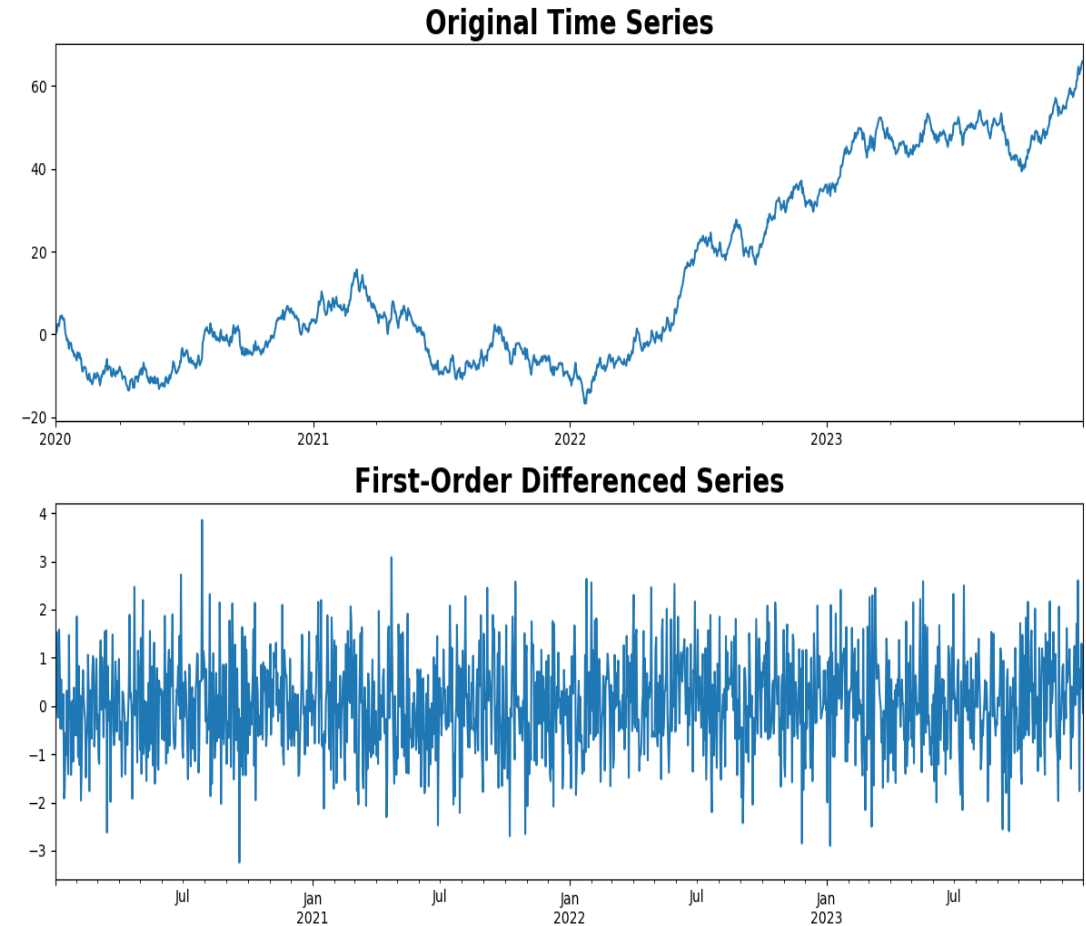
- Helpful for analyzing repeated patterns, such as monthly sales fluctuations or yearly weather changes.



Advanced Time Series Analysis

Stationarity and Differencing

- **Stationarity:**
 - A time series is stationary if its key statistical properties (mean, variance, etc.) do not change over time.
 - **Why it matters:** Many forecasting models assume that data is stationary.
- **Differencing:**
 - A method used to transform a non-stationary time series into a stationary one by subtracting the previous observation from the current one.
 - Helps remove trends or seasonality in the data.
- **Why is this important?**
 - Certain models like ARIMA require the data to be stationary to make reliable predictions.



Time Series Forecasting Models and Techniques (Visualizing the Future)

Forecasting involves predicting future values based on historical data.

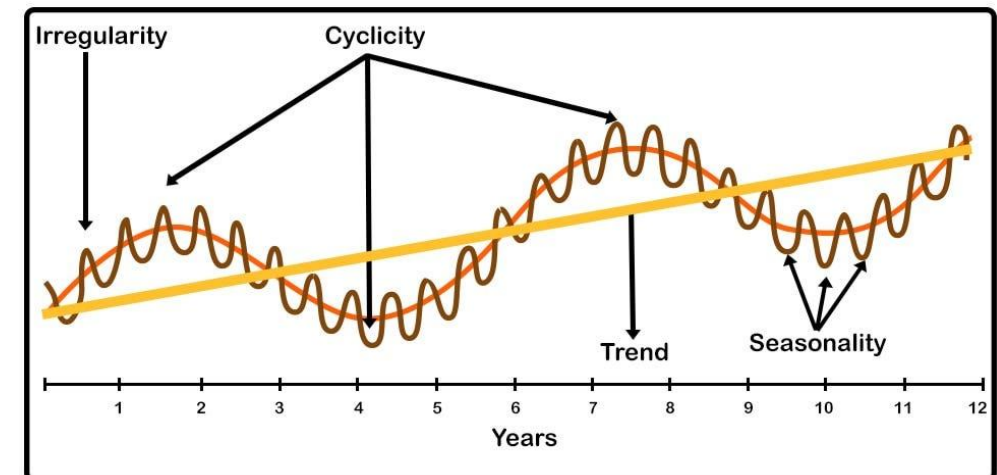
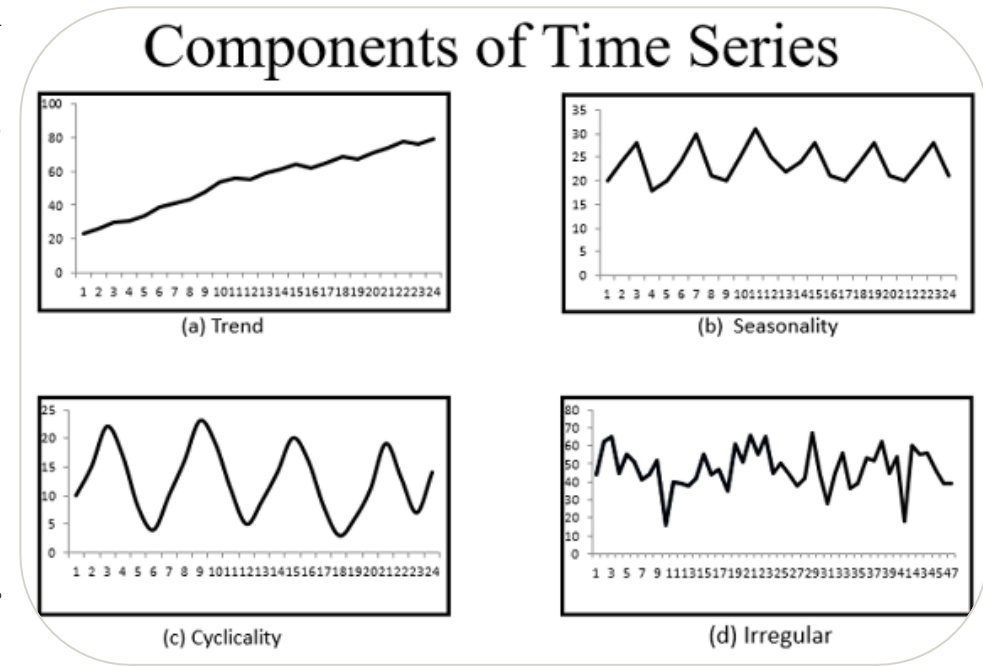
Time series forecasting involves predicting future data points based on previously observed values.

Applications:

- **Business:** Sales forecasting
- **Weather:** Temperature and precipitation forecasting
- **Finance:** Stock price prediction.

Key Components of Time Series Forecasting

- **Trend**
 - A Gradual upward or downward shift in the series over time.
 - **Example:** Rising global temperatures over decades
- **Cyclical Fluctuation Analysis**
 - Repeating patterns that are not tied to a fixed period
 - Long-term oscillations unrelated to seasonality.
 - **Example:** Economic boom and bust cycles
- **Seasonality (Seasonal Pattern)**
 - Regular, repeating patterns or cycles in data.
 - **Example:** Retail sales peaking during holidays

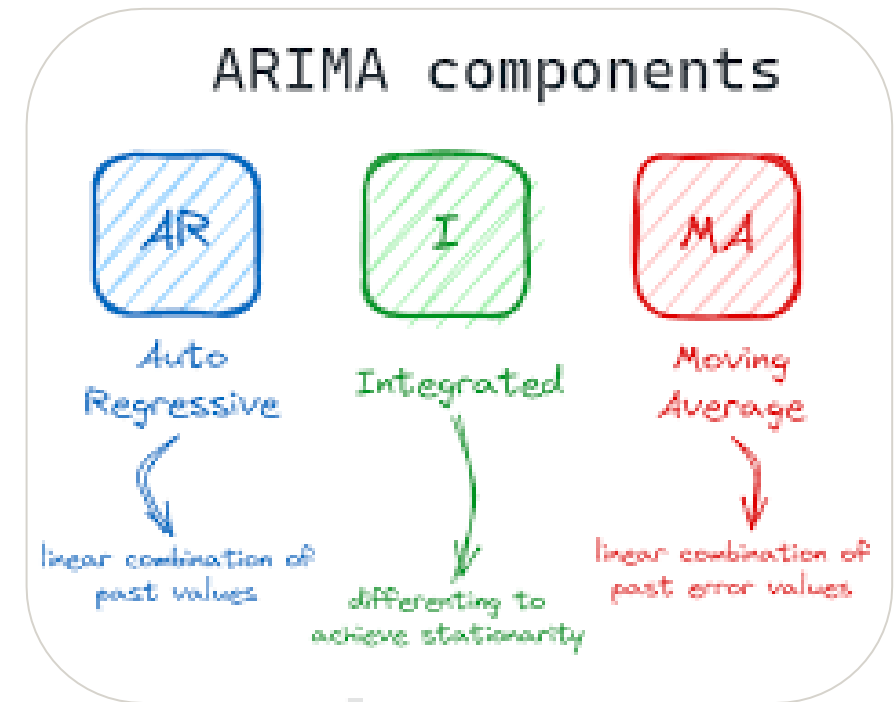


Popular Forecasting Models

Essential forecasting models used in time series analysis.

1. ARIMA (AutoRegressive Integrated Moving Average)

- A popular model for forecasting univariate time series that combines three components.
 - **AutoRegressive (AR)**: Predicts future values using past values.
 - **Integrated (I)**: Differencing the data to make it stationary.
 - **Moving Average (MA)**: Uses past forecast errors in a regression-like model.
- **Use Case**: Best suited for data without strong seasonality.
- **Advantages**:
 - Can handles non-stationary data.
 - Works well for linear relationships.



Popular Forecasting Models

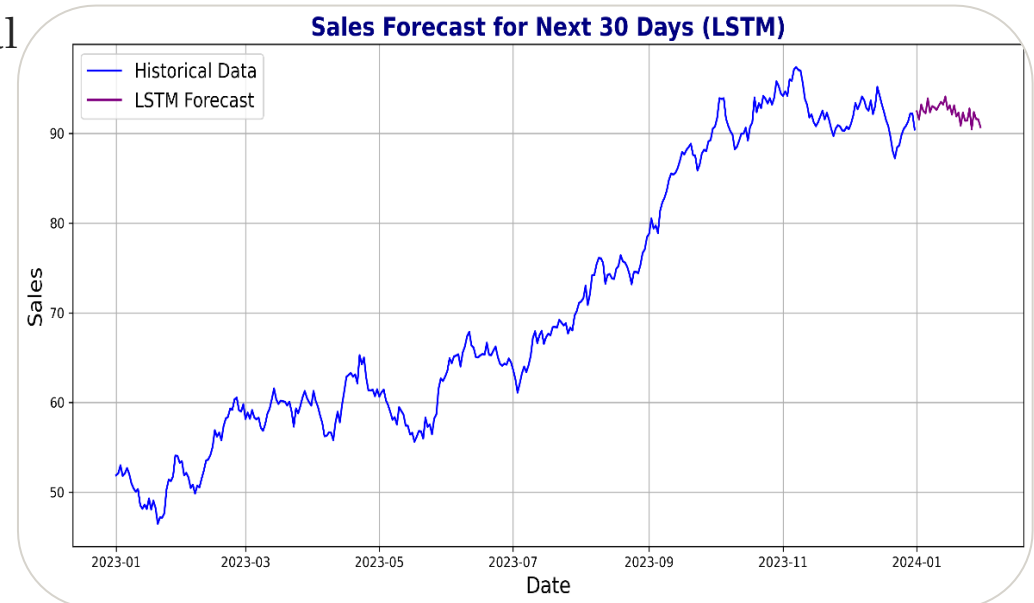
- **Exponential Smoothing (ETS)**

- A forecasting method that applies weighted averages with exponentially decreasing weights.
- **Components:**
 - Error, Trend, Seasonality (hence the term ETS)
- **Use Case:** Effective for data with trend and seasonality.
- **Example:** Forecasting monthly sales figures

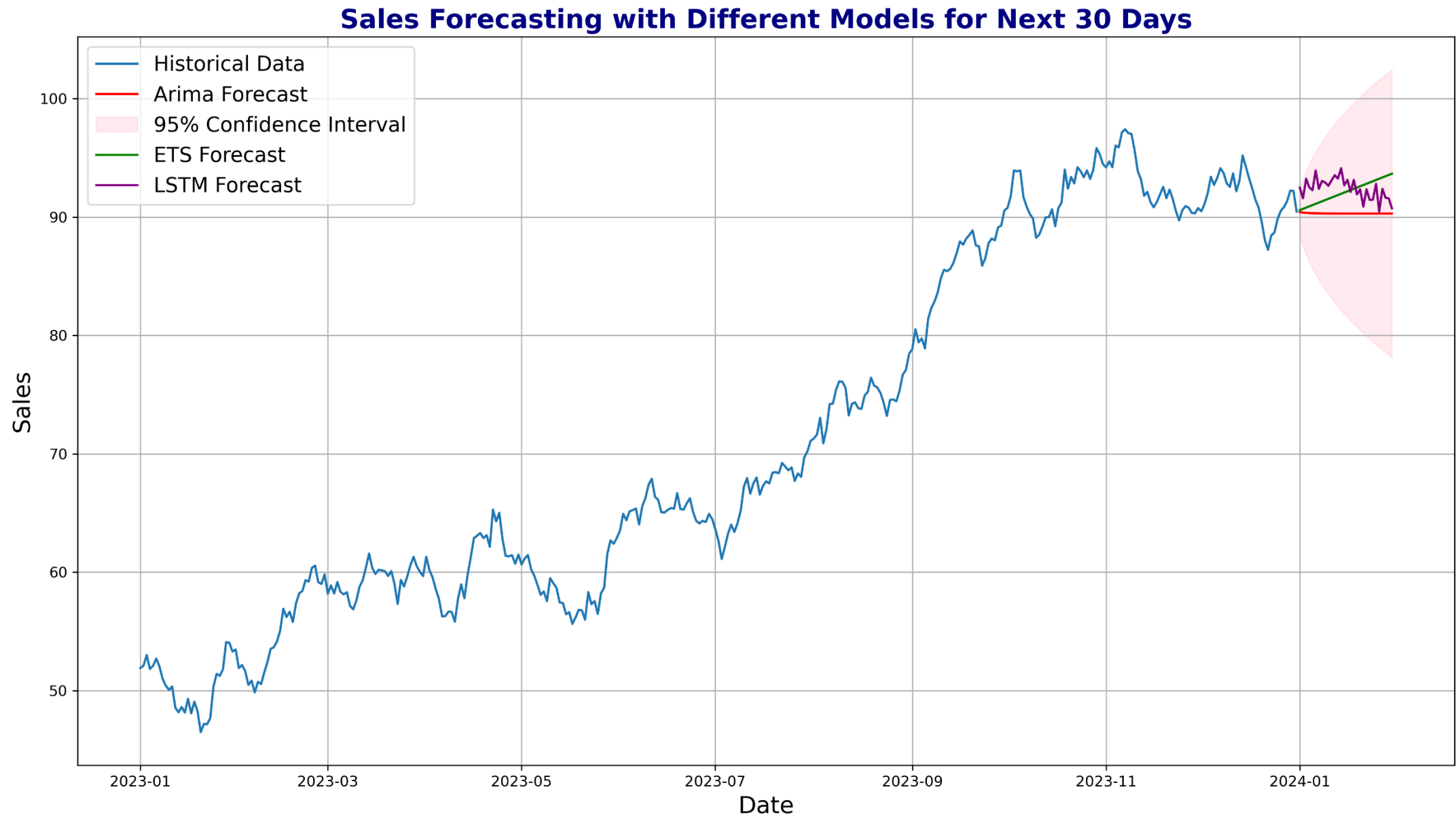


- **LSTM Networks (Long Short-Term Memory)**

- A type of deep learning model that learns from sequential data and remembers long-term patterns.
- **Advantages**
 - Captures complex patterns in time series data.
 - Suitable for large datasets and non-linear relationships.
- **Use Case:** Useful for advanced tasks like stock price prediction or sales forecasting.



Popular Forecasting Models



Applications of Time Series Data Analysis

➤ Finance:

- **Stock Price Movements:** Analyze trends and fluctuations in market prices.
- **Economic Indicators:** Evaluate key economic metrics like GDP, inflation, and employment.
- **Algorithmic Trading:** Utilizing historical data to automate trading strategies.

➤ Healthcare:

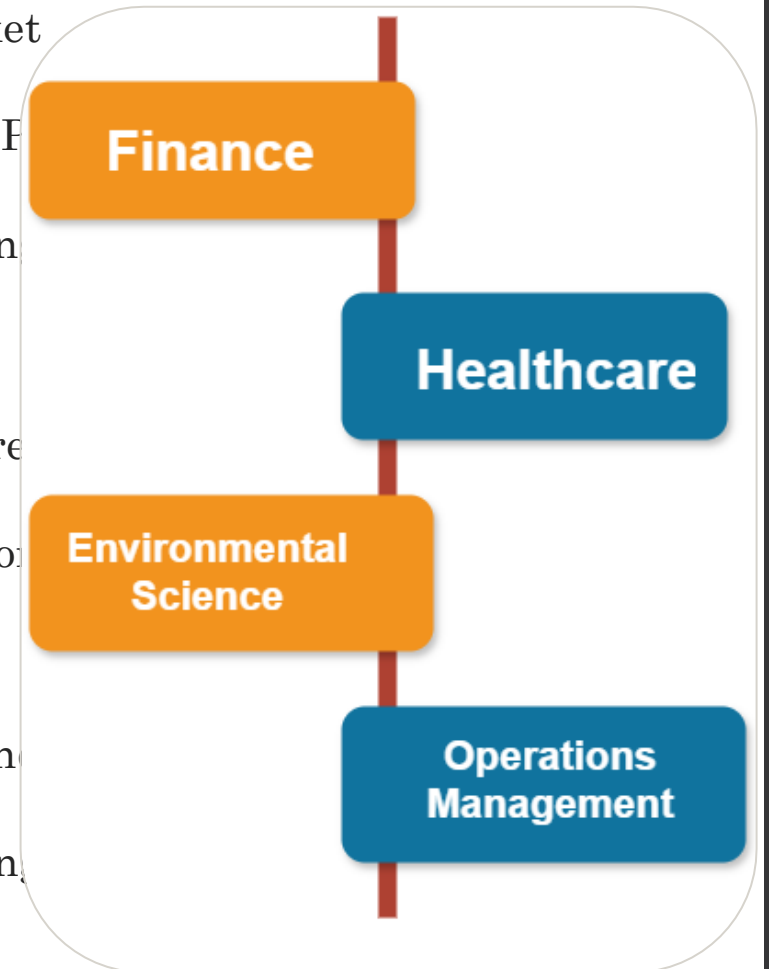
- **Patient Monitoring:** Track vital signs (heart rate, blood pressure) over time for health assessment.
- **Epidemic Forecasting:** Predict the spread of diseases based on historical patterns.

➤ Environmental Science:

- **Climate Change:** Analyze long-term trends in temperature and atmospheric conditions.
- **Weather forecasting:** Predict short-term weather patterns using historical data.

➤ Operations Management:

- **Inventory Control:** Optimize stock levels based on demand patterns.
- **Demand Forecasting:** Anticipate future product demand to improve supply chain efficiency.



Case Study: Forecasting Stock Prices with LSTM

Objective

- To visualize, analyze, and forecast **Apple Inc. (AAPL)** stock prices using Long Short-Term Memory (LSTM) models.

Dataset

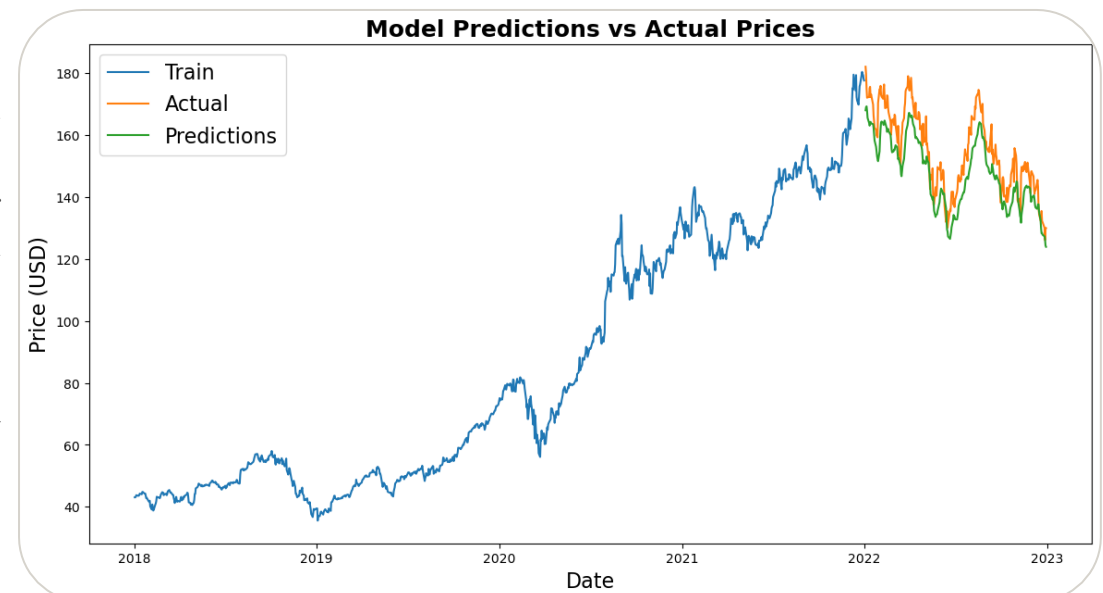
- **Dataset Source:** Yahoo Finance
- **Dataset:** Daily stock prices for Apple Inc. (AAPL) over the last 5 years.

Steps:

1. **Data Preprocessing:** Convert dates, handle missing values, and visualize stock prices with moving averages.
2. **Feature Engineering:** Prepare the data by scaling and creating sequences for LSTM input.
3. **Model Construction:** Build an LSTM model with 2 layers and dropout for regularization.
4. **Training the Model:** Train the model on 80% of the data over 10 epochs.
5. **Testing and Prediction:** Predict future stock prices using the trained LSTM model and compare them to actual prices.

Conclusion:

- This case study showcases how LSTM models can effectively forecast stock prices, offering practical experience in time series forecasting, feature engineering, and model evaluation.



Conclusion and Key Takeaways

• Conclusion

- Visualizing and analyzing time series data is a crucial skill in many fields. By mastering these techniques, you can uncover patterns, make informed predictions, and communicate complex temporal information effectively.

• Key Takeaways:

- **Choose Appropriate Techniques:** Use visualization and analysis techniques based on the nature of the time series data (trend, seasonality, stationarity).
- **Gain Better Insights:** Visualizations reveal hidden patterns and facilitate more informed decision-making.
- **Embrace Advanced Forecasting:** Modern tools, including machine learning and hybrid models, offer more robust and accurate forecasting solutions.
- **Stay Updated:** Keep up with advancements in time series analysis for better predictive performance and practical applications.

- **Next Lecture:** Interactive Data Visualization with Plotly.



Thank You