# Time Series Forecasting

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# Objective

- Understand the importance of forecasting and its impact on the effectiveness of the supply chain and overall performance of an organization
- Learn various components of time-series data such as trend, seasonality, cyclical components and random components
- Learn different techniques such as moving average, exponential smoothing methods
- Learn practical challenges associated with forecasting models using case studies

# Introduction to Forecasting

- Forecasting is one of the most important and frequently addressed problems in analytics
- Inaccurate forecasting can have significant impact on both top line and bottom line of an organization
- Example: Non-availability of a product in the market can result in customer dissatisfaction, whereas, too much inventory can erode the organization's profit.
- Thus, it becomes necessary to forecast the demand for a product and service as accurately as possible

# Introduction to Forecasting

- Every organization prepares long-range and short-range planning for the organization
- Forecasting demand for product and service is an important input for both long-range and short-range planning

# Forecasting Methodologies

- There are many different time series techniques
- It is usually impossible to know which technique will be best for a particular data set
- It is customary to try out several different techniques and select the one that seems to work best
- To be effective time series modeler, you need to keep several time series techniques in your “tool box”
- Simple ideas
  - Moving averages
  - AR
- Complex statistical concepts
  - Box-Jenkins methodology

# Time Series Data

- Time series data is a sequence of observations collected from a process with **equally** spaced time periods
- Examples:
  - Daily closing stock prices
  - Daily data on sales
  - Monthly inventory
  - Daily customers
  - Monthly unemployment rates
  - GDP

# Time Series Data

- Why do we study time series analysis?
  - Time series are analyzed to understand the past and to predict the future, enabling managers or policy makers to make properly informed decisions.
  - Time series analysis quantifies the main features in data and the random variation.
  - These reasons, combined with improved computing power, have made time series methods widely applicable in government, industry, and commerce.

# Typical Time Series

$$\hat{y}_{t+1} = f(y_t, y_{t-1}, y_{t-2} \dots) + g(x_t, x_{t-1}, x_{t-2} \dots)$$

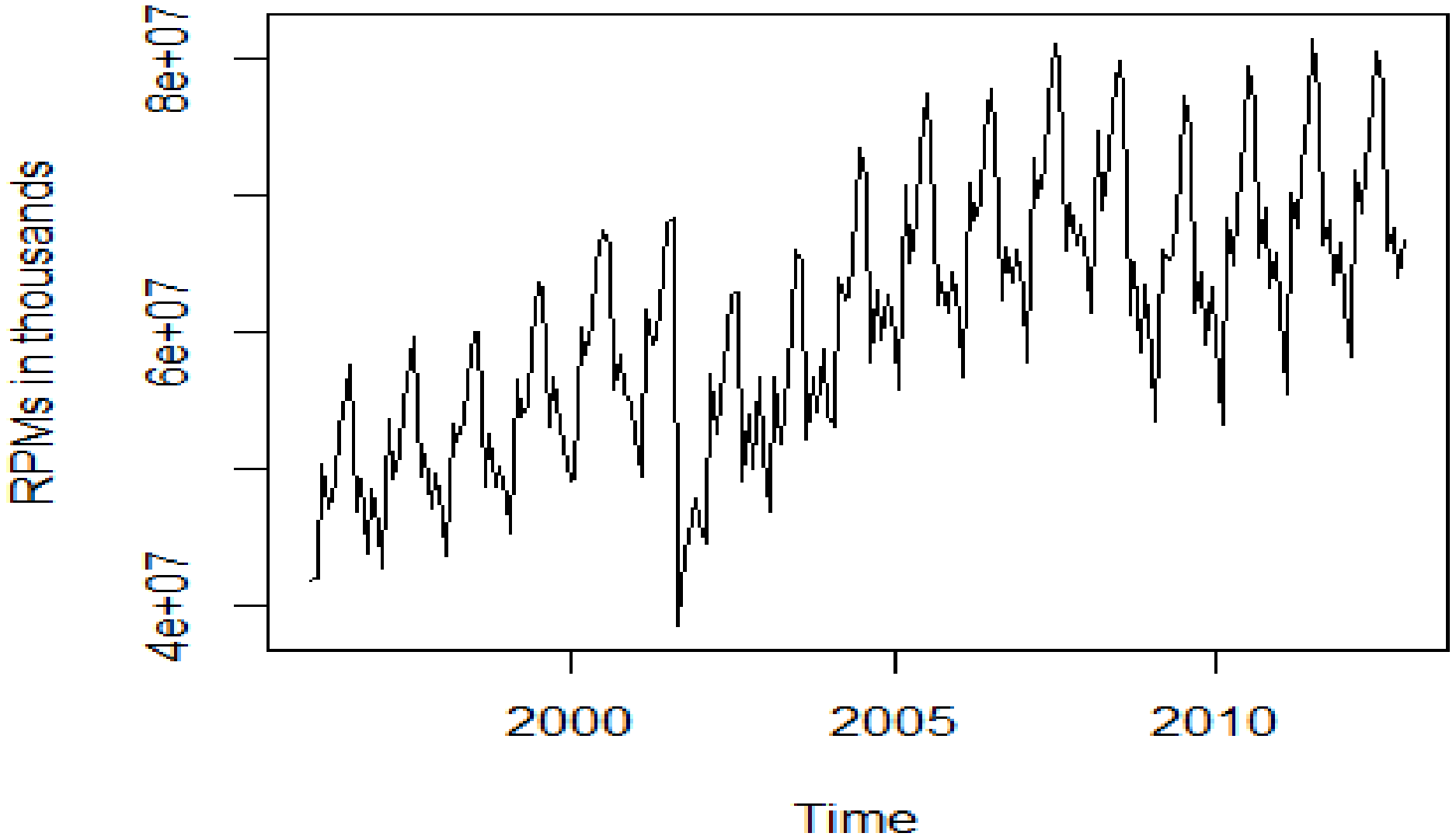
*f* and g can be linear or nonlinear

# Time Series Data: Components

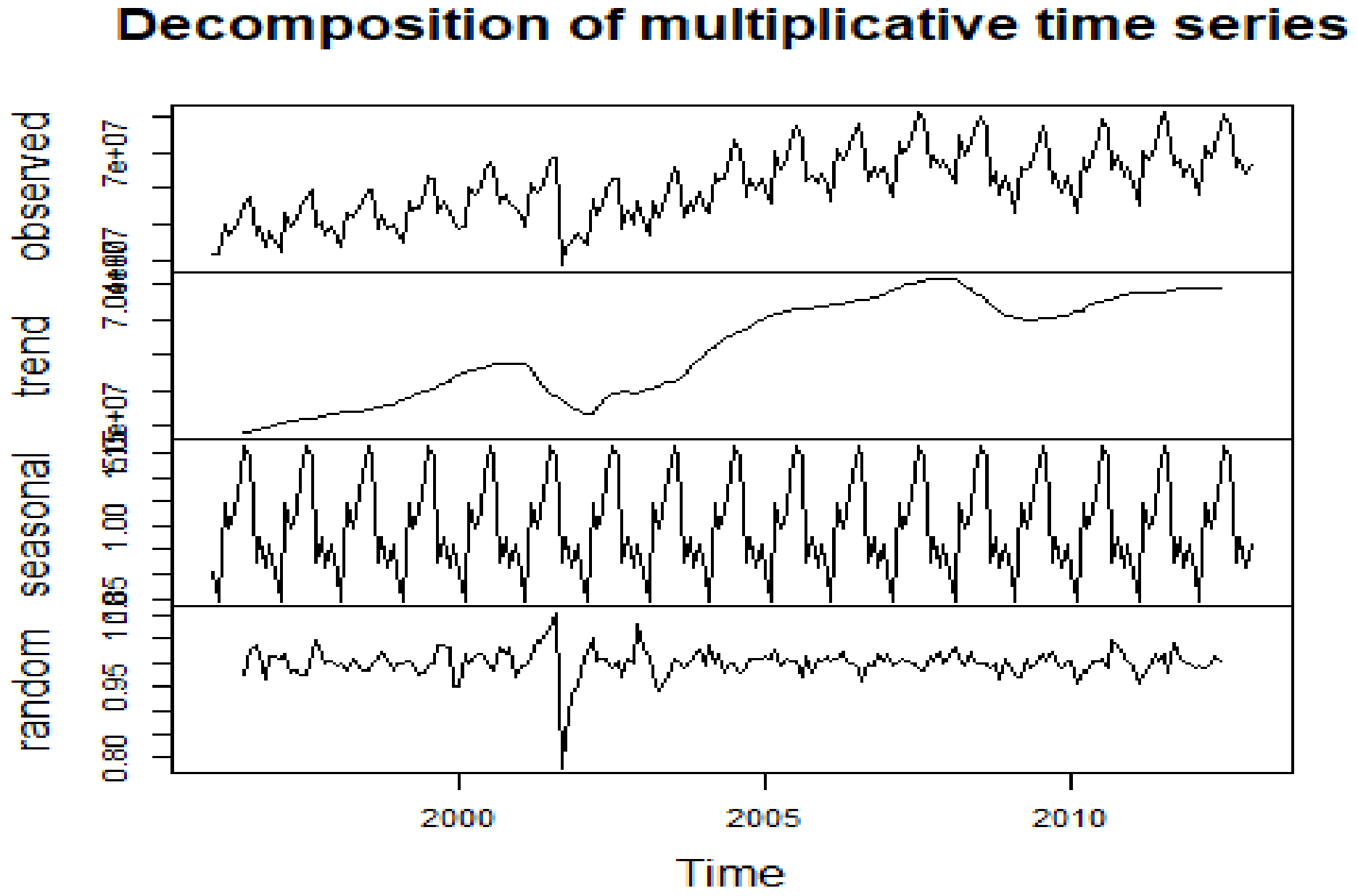
- **Trend**
  - Gradual long term movement(up or down). Easiest to detect
    - Eg: Population growth in India
- **Seasonality**
  - Results from events that are periodic and recurrent in nature. An up-and-down repetitive movement within a trend occurring periodically.
    - Eg: Sales in festive seasons
- **Cyclical Patterns**
  - Results from events recurrent but not periodic in nature. An up-and-down repetitive movement in demand repeats itself over a long period of time
    - Eg: Recession in US economy
- **Random component / Irregular component**
  - Disturbances or residual variation that remain after all the other behaviors have been accounted for. Erratic movements that are not predictable because they do not follow a pattern
    - Eg: Earthquake

# Components of Time Series

Revenue Passenger Miles
Jan 1996 to Dec 2012 ( 17 years)



# Trend, Seasonality and Randomness



# Forecasting Techniques

- Different forecasting techniques developed based on different logics
- Simple techniques such as moving average and exponential smoothing predict the future value of a time-series data as a function of the past observations
- Regression based models such as auto-regressive(AR), moving average(MA), auto-regressive and moving-average(ARMA), auto-regressive integrated moving average(ARIMA), and ARIMA with X (ARMAX) use more sophisticated regression models to forecast the future value of a time-series data
- Important: Using complex mathematical models do not guarantee more accurate forecast
- Simple moving average technique may outperform complex ARIMA models in few cases

# Forecasting Accuracy

- Different forecasting techniques such as moving average, exponential smoothing, and ARIMA will be used for forecasting before selecting the best model
- The model selection may depend on the chosen forecasting accuracy measure
- Frequently used forecasting accuracy measures:
  - Mean absolute error
  - Mean absolute percentage error
  - Mean squared error
  - Root mean square error

# Forecasting Accuracy

- Let $Y_t$ is the actual value of $Y$ at time $t$ and $F_t$ is the corresponding forecasted value
- Assume that there are $n$ (for example $n = 100$ ) observations in total
  - Mean absolute error(MAE)

$$MAE = \frac{1}{n}\sum_{t=1}^{n} |Y_t - F_t|$$

    - MAE is the average absolute error and should be calculated on the test data set
  - Mean absolute percentage error(MAPE)

$$MAPE = \frac{1}{n}\sum_{t=1}^{n} \frac{|Y_t - F_t|}{Y_t} \times 100\%$$

    - MAPE is one of the popular forecasting accuracy measures used by practioners since it expresses the average error in percentage terms and is easy to interpret
    - Since MAPE is dimensionless it can be used for comparing different models with varying scales

# Forecasting Accuracy

- Mean squared error(MSE)

$$MSE = \frac{1}{n}\sum_{t=1}^{n}(Y_t - F_t)^2$$

  - Lower MSE implies better prediction
  - However, it depends on the range of the time-series data
- Root mean square error(RMSE)

$$\text{RMS}E = \sqrt{(\frac{1}{n}\sum_{t=1}^{n}(Y_t - F_t)^2)}$$

  - RMSE and MAPE two most popular accuracy measures of forecasting
  - RMSE is the standard deviation of errors or residuals

- Example: In 2006, Netflix, the movie portal, announced a competition with a prize money worth one million dollars to predict the rating on a 5-point scale likely to be given by a customer for a movie. The participants were given a target RMSE of 0.8572 to qualify for the prize ( source: https://en.wikipedia.org/wiki/Netflix_Prize )

# Thanks