my-ebook

Parmeshvar

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Youtube ID

Doing a PhD with me: README.1st

Academic Profile

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3 Bayesian data analysis for cognitive science

3.1 Introduction: What this course is about

This course provides an introduction to Bayesian data analysis using the probabilistic programming language **Stan**.
We will use a front end software package called **brms**.

This course is for:

- Linguistics (MM5, MM6)
- Cognitive Systems
- Cognitive Science

Please see the PULS FAQs to find out how the sign-up system works (in German).

We will be using the software R and RStudio, so make sure you install these on your computer.

Topics to be covered:

1. Basic probability theory, random variable theory (including jointly distributed RVs), probability distributions (including bivariate distributions)
2. Using Bayes' rule for statistical inference
3. An introduction to (generalized) linear models
4. An introduction to hierarchical models
5. Measurement error models
6. Mixture models
7. Model selection and hypothesis testing (Bayes factor and k-fold cross-validation)

3.2 Teaching

Science and statistics is/are one unitary thing; you cannot do one without the other. Towards this end, I teach some (in my opinion) critically important classes that provide a solid statistical foundation for doing research in cognitive science.

Courses offered:

1. Free online course, four weeks (MOOC), enrollments open: Introduction to Bayesian Data Analysis
2. Short (four-hour) tutorial on Bayesian statistics, taught at EMLAR 2022: here
3. Introduction to (frequentist) statistics
4. Introduction to Bayesian data analysis for cognitive science
5. BDA cover

3.3 Lecture notes

Download from here.

3.4 Moodle website

All communications with students in Potsdam will be done through this website.

4 Schedule

Week	Lecture	Main Topic	Sub Topic	Video	PDF Resource
Jan 30 + Feb 4	-	Model Selection & Hypothesis Testing	-	-	HW 13
Week 2	1	Descriptive Statistics	Central Tendency	Link	Week 2.pdf
	2	Descriptive Statistics	Measure of Variability	Link	Week 2.pdf
	3	Descriptive Statistics	Describing Data	Link	Week 2.pdf
	4	Probability	-	Link	Week 2.pdf
	5	Distribution	-	Link	Week 2.pdf
Week 3	1	Probability	Z Table (Normal Distribution)	Link	Week 3.pdf
	2	Divergence	Measuring Divergence	Link	Week 3.pdf
	3	Inferential Statistics	Sample and Population	Link	Week 3.pdf
	4	Model Fit	-	Link	Week 3.pdf
	5	Hypothesis Testing	Hypothesis and Error	Link	Week 3.pdf
Week 4	1	Statistical Terms	Terms of Statistics	Link	Week 4.pdf
	2	Hypothesis Testing	T-Test	Link	Week 4.pdf
	3	Hypothesis Testing	T-Test in Detail	Link	Week 4.pdf
	4	ANOVA	ANOVA	Link	Week 4.pdf
Week 5	1	ANOVA	Example of ANOVA	Link	Week 5.pdf
	2	ANOVA	Types of ANOVA	Link	Week 5.pdf
	3	Correlation	Introduction to Correlation	Link	Week 5.pdf
	4	Regression	Regression	Link	Week 5.pdf
	5	Regression	Regression	Link	Week 5.pdf
Week 6	1	Regression	R Script for Regression	Link	Week 6.pdf
	2	Chi-Square	Chi Square	Link	Week 6.pdf

Week	Lecture	Main Topic	Sub Topic	Video	PDF Resource
	3	Chi-Square	Chi Square Test	Link	Week 6.pdf
	4	Logistic Regression	Logistic Function	Link	Week 6.pdf
	5	Distribution	-	Link	Week 6.pdf
Week 7	1	Time Series	Intro to Time Series	Link	Week 7.pdf
	2	Probability	Conditional Probability	Link	Week 7.pdf
	3	Additional Concepts	-	Link	Week 7.pdf
	4	Distribution	-	Link	Week 7.pdf
	5	Poisson Distribution	-	Link	Week 7.pdf
Week 8	1	Libraries & Documentation	Effect Size and Packages	Link	Week 8.pdf
	2	Software Comparison	RStudio vs RKward	Link	Week 8.pdf
	3	Visualization	Flexplot	Link	Week 8.pdf
	4	Programming in R	Functions	Link	Week 8.pdf
	5	R Tools	R Shiny and R Markdown	Link	Week 8.pdf

5 Introduction to Statistics

6 Chapter 1: Welcome and Course Overview

This course offers an introduction to statistics through the RKWard graphical interface of R. Aimed at learners from diverse backgrounds, the course emphasizes practical application over theory. You don't need a strong background in math or computing—just an eagerness to learn.

Pre-Requisites:

- Curiosity
- Basic awareness of numbers
- No fear of statistics or software

> "Aapko darne ki zarurat nahi hai… simple understanding aapko statistics ki data ki aage milegi."

7 Chapter 2: Agenda and Orientation

Key Themes:

- Difference between Mathematics and Statistics
- Nature, Meaning, and Role of Statistics
- Uses, Limitations, and Common Fallacies

Aspect	Mathematics	Statistics
Nature	Abstract, theoretical	Applied, data-centric
Focus	Concepts, theorems, proofs	Tools, interpretation, decision-making
Tools	Logical reasoning, algebra	Hypothesis testing, regression, probability
Application	General structures	Real-world problems

8 Chapter 3: Meaning and Nature of Statistics

Definition:
Statistics is the science of collecting, analyzing, interpreting, and presenting data for decision-making.

Core Concepts:

- Population & Sample
- Parameter & Statistic
- Data classification and tabulation

Purpose:

- Describe and explain phenomena
- Interpret and predict outcomes
- Facilitate scientific and social inquiry

9 Chapter 4: Applications and Uses

Main Uses:

- Summarizing observed data
- Drawing representative samples
- Analyzing relationships and trends
- Supporting decision-making in fields like marketing, psychology, education, and public health

Important Concepts:

- Data summarization
- Prediction based on patterns
- Comparison across groups
- Scientific objectivity

10 Chapter 5: Limitations and Misuse

Limitations:

- Cannot analyze qualitative phenomena
- Not designed for individuals
- Results aren't exact
- Misinterpretation leads to incorrect conclusions

Misuse Includes:

- Small or biased samples
- Misleading graphs
- Invalid comparisons

> "Statistics is not a substitute for common sense or understanding the context."

Fallacies Stem From:

- Poor data collection
- Mislabeling variables
- Improper classification or selection

11 Chapter 6: Paper-Based vs. Software-Based Statistics

Traditional exams test pen-paper knowledge, but software-based tools like RKWard make analysis:

- Faster
- Collaborative
- Easier to store and access
- Essential for modern data-centric fields like AI and machine learning

Understanding both paper and digital approaches ensures comprehensive learning.

12 Chapter 7: Introduction to Variables and Spreadsheets

Variables:

- Store information (e.g., `x = 5`)
- Have unique names
- Can be manipulated with commands (e.g., `x = x + 2`)

Spreadsheets:

- Represent tabular data (rows = observations, columns = variables)
- Familiar formats: Excel, Google Sheets
- Essential in statistical packages

13 Chapter 8: R and GUI Interfaces

Why R?:

- Free and open-source
- Strong community support
- High flexibility
- Powerful graphics and data manipulation capabilities

GUI Tools in R:

- RKWard *(used in this course)*
- R Commander
- Rattle
- R AnalyticFlow

Basic Terms:

- **Console**: Type commands & view outputs
- **Working Directory**: File storage location
- **Package**: Predefined or custom functions
- **Script**: Collection of reusable commands
- **Workspace**: All current variables/functions

14 Chapter 9: Importing Data and Understanding Data Types

Using RKWard:

- Import CSV files using GUI
- Data appears in alphabetical order in workspace
- Each header = variable name

Data Structures:

- Data Frames (most commonly used)
- Matrices
- Vectors
- Lists

Command Line vs GUI:

- Both achieve the same results
- GUI is user-friendly, command line is customizable

```
mean(my_csv.data$JP_01)  # Calculates the mean of variable JP_01
```

15 Chapter 10: Statistical Data Types

Statistical Type	Description	R Equivalent
Nominal	Names, labels (e.g., Male/Female)	String
Ordinal	Order/rank (e.g., 1st, 2nd)	Factor
Interval	Ordered + meaningful intervals (e.g., tax slabs)	Numeric
Ratio	Includes absolute zero (e.g., weight)	Numeric

Others in R:

- Logical (TRUE/FALSE)
- Integer, Complex

  Remember: Not all numbers mean quantity. Shirt numbers (like #18) are nominal, not mathematical.

16 Chapter 11: Data Preparation in RKWard

- Data must be properly **typed** (e.g., "1" as number vs "1" as label)
- Check alignment: Left = character, Right = number
- **Labels** help collaborators understand variables
- Example: `Gender = 1` (Male), `0` (Female)
- Must distinguish between numeric calculations and categorical identifiers

Best Practices:

- Define each variable with meaning
- Validate data types
- Store and share workspace for reproducibility

17 Chapter 12: Visualizing Data with Plots in RKWard

Data visualization is essential to reveal patterns, trends, and distributions. RKWard offers multiple graphical tools:

17.1 1. Histogram

- Depicts the distribution of a single variable
- Can include frequency, relative frequency, and cumulative frequency
- Best for understanding where most data points lie

17.2 2. Pie Chart

- Represents categorical data as slices of a circle
- Best when visualizing proportions

17.3 3. Scatter Plot

- Plots two variables to examine relationships
- X-axis: Independent variable
- Y-axis: Dependent variable
- Useful in exploring associations or potential causality

17.4 4. Box Plot

- Shows data distribution via quartiles
- Median, interquartile range (IQR), and outliers are clearly indicated

- Useful for comparing multiple variables

17.5 5. Density Plot

- Smoothed version of a histogram
- Better suited for continuous data with decimal variation

Key Tips:

- `JP_01` was frequently used as an example variable
- RKWard allows saving and exporting plots easily
- GUI menus guide the user through plot creation

  Always choose the plot type that best matches your data and goal: frequency, relationship, or comparison.

18 Chapter 13: Summary

This eBook provided a foundation for understanding and applying statistics using the RKWard GUI tool in R. It covered essential concepts from what statistics is, to importing and handling data, understanding types of variables and their measurement levels, and visualizing data using a variety of plots.

Learners were introduced to:

- Basic statistical principles
- Software versus paper-based understanding
- Variable types and spreadsheet usage
- Command line and GUI-based tools
- Data visualization through histogram, pie, scatter, box, and density plots

The course emphasized **conceptual clarity**, **practical tools**, and the **power of visualization**. It prepares learners to interpret, analyze, and present data meaningfully in academic or real-world contexts.

19 References

1. Mohanty, B., & Misra, S. (2020). *Statistics for Behavioral and Social Sciences*. PHI Learning.

2. Pandya, D., et al. (2019). *Statistical Analysis in Simple Steps Using R*. Wiley.

3. Field, A., Miles, J., & Field, Z. (2012). *Discovering Statistics Using R*. SAGE Publications.

4. Harris, J. (2021). *Statistics with R: Solving Problems Using Real-World Data*. Pearson.

5. RKWard Project: https://rkward.kde.org

20 Next Steps

Upcoming lectures will cover:

- Graph creation
- Data visualization tools
- Advanced statistical operations in GUI

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22 Introduction

Welcome to the "Basic Statistics Using GUI-R (RK Ward)" course, led by Dr. Harsh Pradhan at the Institute of Management Studies, Banaras Hindu University. This course takes an integrated approach to statistical analysis, bridging theory with practical skills through the R programming language and its GUI, RKWard.

22.1 Objectives of the Course

- Understand fundamental concepts related to statistics.
- Gain proficiency in using R and RKWard for statistical analysis.
- Learn to visualize data effectively.
- Apply statistical methodologies to real-world datasets.

23 Overview of R and RKWard

23.1 R Programming Language

R is a versatile, open-source language specifically designed for statistical analysis and data visualization. It provides an extensive suite of statistical procedures, making it a cornerstone for statisticians and data scientists.

Key Features of R:

- Extensive Libraries: R hosts thousands of packages that support numerous statistical models such as linear regression, time series, and more.
- Customizable Graphics: The base graphics capabilities, along with packages like `ggplot2`, allow users to create a variety of complex visualizations with relative ease.
- Data Manipulation Tools: Packages like `dplyr` and `tidyr` provide robust tools for data cleaning and transformation.

23.2 Understanding RKWard

RKWard serves as a user-friendly interface that simplifies interactions with R, allowing users—especially those less familiar with programming—to utilize its powerful capabilities without a steep learning curve.

Features of RKWard Include:

- Graphical User Interface: Navigation through menus rather than command lines enhances accessibility.
- Built-in Documentation: Context-sensitive help facilitates learning and troubleshooting.
- Integration with R: Commands executed via the GUI can be viewed and modified, providing a dual-learning experience.

24 Understanding Variables

24.1 Types of Variables

Variables are the building blocks of statistical analysis, representing the characteristics or properties of the data.

24.1.1 Qualitative Variables (Categorical Variables)

- **Nominal Variables:** These variables categorize data without an inherent order. For example, types of fruits (apple, orange) are nominal.
- **Ordinal Variables:** These represent ordered categories. For instance, a customer satisfaction survey may be rated as poor, fair, good, or excellent.

24.1.2 Quantitative Variables

- **Discrete Variables:** These variables take on countable values, such as the number of students in a class.
- **Continuous Variables:** These can take any value within a given range, such as height and weight.

24.2 Importance of Defining Variables

Properly understanding and defining variables is crucial for:

- Selecting appropriate statistical tests.
- Ensuring accurate data interpretation.
- Structuring datasets to facilitate analysis.

25 Data Types and Spreadsheet Concepts

25.1 Statistical Data Types

Data types are foundational for statistical analysis as they define what kind of arithmetic operations can be performed on the data.

Data Type	Description	Example
Nominal	Categorical data without order	Blood types (A, B, AB, O)
Ordinal	Categorical data with a defined order	Customer satisfaction (poor, fair, good)
Interval	Numerical data with meaningful differences	Temperature in Celsius
Ratio	Numerical data with an absolute zero	Weight, height

25.2 Spreadsheet Basics

Spreadsheets provide a structured format for data entry, where rows represent instances (e.g., individuals, items) and columns represent variables (e.g., age, gender).

Key Functions of Spreadsheets:

- Data Organization: Data is easily sorted and filtered.
- Formulas and Functions: Built-in functions allow for quick calculation and data manipulation.
- Visualization Integration: Charts and tables can visually represent data.

26 Importing Data in RKWard

26.1 Data Preparation

Before importing data into RKWard, ensure that your dataset meets standards such as:

- Properly labeled columns.
- Consistent data types.
- Absence of unnecessary formatting or symbols.

26.2 Step-by-Step Import Process

Steps to import data into RKWard:

1. Open RKWard and access the main interface.
2. Go to the “Data” tab and select “Import Data”.
3. Choose the file type such as CSV or Excel.
4. Browse to locate your file.
5. Specify data types for each column during import and ensure the first row contains headers.
6. Review the imported data in the workspace to confirm it’s properly loaded.

27 Basic Statistical Practices

27.1 Descriptive Statistics

Descriptive statistics help summarize and organize data in a meaningful way.

27.1.1 Central Tendency Measures

- **Mean:** Average of the dataset.
- **Median:** Middle value when data is ordered.
- **Mode:** Most frequent value in the dataset.

Measure	Formula	Description
Mean	$\bar{x} = \frac{\sum_{i=1}^{n} x_i}{n}$	Average value
Median	(Sorted data, middle item)	Middle value in ordered dataset
Mode	Value that appears most frequently	Most common value

27.1.2 Dispersion Measures

- **Range:** Difference between the maximum and minimum values.
- **Variance:** Measurement of the spread of data points.
- **Standard Deviation:** Square root of variance, providing a measure of the average distance from the mean.

Measure	Formula	Description
Range	$Range = Max - Min$	Spread of dataset
Variance	$Var(X) = \frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n-1}$	Spread of data relative to mean
Standard Deviation	$SD(X) = \sqrt{Var(X)}$	Average distance from mean

27.2 Inferential Statistics

Inferential statistics allow us to make predictions or inferences about a population based on a sample.

- **Hypothesis Testing:** A method to test assumptions regarding population parameters using sample data.
- **Confidence Intervals:** Define a range of values derived from sample statistics that likely encompass the true population parameter.

27.3 Practical R Commands and Functions

Understanding and utilizing R functions is crucial for effective data analysis. Some key functions include:

- `mean()`: Calculates the average.
- `sd()`: Computes standard deviation.
- `t.test()`: Performs a t-test for hypothesis testing.

28 Visualizing Data with Graphs

28.1 Significance of Data Visualization

Visualization enhances comprehension by allowing researchers to observe patterns, trends, and anomalies effectively.

28.2 Types of Graphs

Variety in graph types caters to different data presentation needs:

Graph Type	Use Case
Bar Graph	Comparing categorical data
Histogram	Displaying distribution of continuous data
Box Plot	Summarizing data distributions and spotting outliers
Scatter Plot	Investigating relationships between two quantitative variables

28.3 Implementing Visualization in RKWard

Students will learn how to create visualizations within RKWard by following these steps:

1. Navigate to the graph creation menu.
2. Select the desired type of graph.
3. Customize visual elements such as titles, colors, and axes.
4. Generate and export the graph for use in reports.

29 Practical Applications of Statistics

29.1 Case Studies in Various Fields

Statistics plays a pivotal role in diverse disciplines:

Field	Application
Healthcare	Analyzing medical test results, outcomes of treatments, and patient demographics
Business	Applied for market analyses, customer satisfaction studies, and financial forecasting
Social Sciences	Employed in surveys to understand populations, opinions, and behavioral patterns

29.2 Utilizing Statistical Methods for Decision Making

- Use statistical evidence to guide business strategies.
- Make informed policy decisions based on empirical data.
- Report findings clearly for transparency and comprehension.

30 Summary

The "Basic Statistics Using GUI-R (RK Ward)" course equips learners with the foundational and practical skills needed for statistical analysis using R. Students will understand theoretical concepts, grasp practical applications, and use RKWard effectively to analyze real-world data.

30.1 Key Takeaways

- Proficiency in defining and using variables and data types.
- Capability to import and manipulate data in RKWard.
- Understanding of basic statistical practices and their applications.
- Skill in visualizing data for effective communication of results.

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32 Introduction

32.1 Purpose of the eBook

This eBook aims to provide a comprehensive understanding of basic statistics, focusing on the essential principles necessary for data analysis.

32.2 Importance of Statistics

Statistics is critical in interpreting data efficiently and effectively across disciplines.

33 Basic Concepts of Statistics

33.1 Overview of Statistics

Statistics is the discipline that deals with the collection, analysis, interpretation, and presentation of data.

33.2 Types of Data

- **Qualitative Data**: Represents categories or labels without numeric value (e.g., gender, religion).
- **Quantitative Data**:
  - **Discrete Data**: Countable values (e.g., number of students).
  - **Continuous Data**: Measurable values (e.g., height, weight).

33.3 Descriptive vs. Inferential Statistics

- **Descriptive Statistics**: Summarizes or describes the characteristics of a dataset.
- **Inferential Statistics**: Makes predictions or inferences about a population based on a sample.

34 Measures of Central Tendency

34.1 Definition and Importance

Measures of central tendency describe the center point or typical value of a dataset.

34.2 The Mean

The mean is the arithmetic average of a dataset.

34.2.1 Example

Consider the data: 2, 3, 5, 7, 11
Mean = $\frac{2+3+5+7+11}{5} = \frac{28}{5} = 5.6$

34.3 The Median

The median is the middle value in an ordered dataset.

34.3.1 Example

Consider the data: 3, 5, 1, 7, 9
Ordered: 1, 3, 5, 7, 9 $\rightarrow$ Median = 5

34.4 The Mode

The mode is the value that appears most frequently in a dataset.

34.4.1 Example

Data: 2, 4, 4, 5, 5, 5, 7, 8
Mode = 5

34.5 Comparison of Measures

Measure	Description	Strengths	Limitations
Mean	Average of all data points	Utilizes all data	Sensitive to outliers
Median	Middle value	Robust to outliers	Ignores extreme values
Mode	Most frequent value	Useful for categorical data	May not exist or be unique

35 Measures of Variability

35.1 Definition and Importance

Measures of variability indicate the spread or dispersion within a dataset.

35.2 Range

The range is the difference between the maximum and minimum values.

35.2.1 Example

Data: 4, 8, 2, 10, 6
Range = 10 - 2 = 8

35.3 Variance

Variance is the average of the squared deviations from the mean.

35.3.1 Example

Data: 2, 4, 4, 4, 5, 5, 7
Mean = 4.43 (approx.)
Variance = $\frac{\sum(x_i-\bar{x})^2}{n-1}$

35.4 Standard Deviation

Standard deviation is the square root of the variance.

35.5 Interquartile Range (IQR)

The IQR measures the middle 50% of the data between Q1 and Q3.

35.5.1 Example

Data: 1, 2, 3, 4, 5, 6, 7, 8, 9
Q1 = 3, Q3 = 7
IQR = 7 - 3 = 4

36 Probability Fundamentals

36.1 Introduction to Probability

Probability measures the likelihood of occurrence of an event.

36.2 Types of Events

- **Independent Events**: One event does not affect another.
- **Dependent Events**: One event influences the outcome of another.
- **Mutually Exclusive Events**: Events that cannot happen at the same time.

36.3 Basic Probability Rules

1. **Addition Rule**: This rule applies when you're calculating the probability of event A **or** event B occurring.
$$P(A \cup B) = P(A) + P(B) - P(A \cap B)$$

2. **Multiplication Rule**: This rule applies when you're calculating the probability of event A **and** event B both occurring (for independent events).
$$P(A \cap B) = P(A) \times P(B)$$

36.4 Introduction to Probability Distributions

36.4.1 Normal Distribution

- Symmetric about the mean.
- Bell-shaped curve.
- Properties: Mean = Median = Mode.

37 Detailed Transcripts

37.1 Transcript from Lec06

Key Discussion Points: - Effects of outliers on the mean. - Properties of the mean.

37.2 Transcript from Lec07

Key Discussion Points: - Concepts of range, variance, and standard deviation.

37.3 Transcript from Lec08

Key Discussion Points: - Explanation of the Z score. - Galton board demonstration.

37.4 Transcript from Lec09

Key Discussion Points: - Introduction to probability distributions. - Basic probability concepts and terms.

38 Summary of Week 2 Content

- Measures of central tendency.
- Measures of variability.
- Basic probability and events.
- Introduction to distributions.

39 Tables and Visualizations

39.1 Frequency Distribution Example

Value	Frequency
1	4
2	6
3	3
4	2
5	1

39.2 Interquartile Range Example

Position	Value
1	12
2	30
3	45
4	57
5	70

$$\text{IQR} = 57 - 30 = 27$$

39.3 Box Plot Visualization

A box plot visualizes:

- Minimum
- First Quartile ($Q1$)
- Median
- Third Quartile ($Q3$)
- Maximum

40 References

41 Appendices

- Additional exercises
- Data sets for practice
- Online resources and guides on RKWard

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43 Introduction

43.1 Importance of Statistics

Statistics is a powerful tool used across various disciplines, from economics and social sciences to natural sciences and engineering. It enables researchers to analyze data, draw conclusions, and make predictions about populations based on sample observations. Understanding statistical principles is essential for anyone involved in empirical research, data science, and decision-making processes.

43.2 Overview of Topics

This eBook will delve deeply into core concepts such as populations and samples, hypotheses and errors, various statistical models, the normal distribution, and essential statistical techniques in R using the GUI-R interface. Each chapter will provide detailed explanations, examples, and practical applications to enhance understanding.

44 Understanding Populations and Samples

44.1 Definition of Population

In statistics, a population is defined as the entire set of individuals, items, or events of interest. For instance, if a researcher aims to study the average height of adults in the United States, the population would include every adult residing in the country.

44.2 Definition of Sample

A sample is a subset of the population selected for analysis. It is crucial that this sample adequately represents the population to ensure that the conclusions drawn are applicable. For example, selecting individuals from various demographic backgrounds when studying a health-related issue ensures a more accurate reflection of the population.

44.3 Importance in Research

The primary reason for studying a sample rather than the entire population is practicality. Conducting a census can be time-consuming and costly. Hence, researchers select samples that allow them to infer insights about the population efficiently.

44.4 Relationship Between Population and Sample

The relationship between population and sample is crucial, as a well-chosen sample can provide valid insights into the population characteristics. Understanding this relationship helps researchers avoid common pitfalls, such as bias in sampling, which can lead to inaccurate conclusions.

45 Hypotheses and Errors

45.1 Understanding Hypotheses

A hypothesis is an educated guess or a statement about the relationship between two or more variables that can be tested through research. For example, one might hypothesize that "students who study more than three hours a day will score higher on exams."

45.2 Crafting Null and Alternative Hypotheses

1. **Null Hypothesis (H_0)**: A statement suggesting that there is no effect or difference.

$$H_0 : \mu_1 = \mu_2$$

2. **Alternative Hypothesis (H_a)**: A statement indicating the presence of an effect or difference.

$$H_a : \mu_1 \neq \mu_2$$

45.3 Types of Errors

- **Type I Error** (α): Occurs when a true null hypothesis is incorrectly rejected.
- **Type II Error** (β): Occurs when a false null hypothesis is incorrectly accepted.

45.4 Significance Level

The significance level (often set at 0.05) helps researchers determine the threshold for rejecting the null hypothesis. If the probability of obtaining the observed data under the null hypothesis is less than the significance level, the null hypothesis can be rejected.

46 Inferential Statistics

46.1 Introduction to Inferential Statistics

Inferential statistics allow researchers to draw conclusions about populations based on sample data. It involves estimating population parameters, testing hypotheses, and making predictions.

46.2 Sampling Techniques in Detail

46.2.1 Simple Random Sampling

Each member of the population has an equal chance of being selected.

46.2.2 Stratified Sampling

The population is divided into subgroups (strata) and samples are drawn proportionally from each stratum.

46.2.3 Systematic Sampling

Every nth member of the population is selected after a random start.

46.2.4 Cluster Sampling

Entire clusters are randomly selected for analysis.

46.3 Estimating Population Parameters

Researchers estimate parameters like the population mean or proportion using sample data and quantify uncertainty through confidence intervals.

46.4 Central Limit Theorem

The Central Limit Theorem (CLT) states that, for sufficiently large samples ($n > 30$), the sampling distribution of the sample mean approximates a normal distribution regardless of the population's distribution.

47 Model Fit

47.1 Definition and Importance of Model Fit

Model fit refers to how well a statistical model represents the data it is based upon. A good model fit enables accurate predictions and reliable conclusions.

47.2 Statistical Models Explained

47.2.1 Linear Regression

Used to predict a dependent variable using one or more independent variables.

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + ... + \epsilon$$

47.2.2 Logistic Regression

Used when the outcome variable is binary (e.g., yes/no, pass/fail).

47.2.3 Multiple Regression

An extension of linear regression that includes more than one predictor.

47.3 Evaluating Model Fit

47.3.1 R-squared

$$R^2 = 1 - \frac{SS_{res}}{SS_{tot}}$$

Indicates the proportion of variance explained by the model.

47.3.2 Adjusted R-squared

Adjusts R^2 based on the number of predictors in the model.

47.3.3 AIC and BIC

Model selection metrics that penalize overly complex models to avoid overfitting.

48 Understanding Normal Distribution and Z-tables

48.1 Characteristics of Normal Distribution

- Symmetrical bell-shaped curve
- Mean = Median = Mode
- 68%-95%-99.7% rule applies

48.2 Practical Application of Z-tables

Z-scores help determine how far a data point is from the mean in terms of standard deviations.

$$Z = \frac{(X - \mu)}{\sigma}$$

48.2.1 Application Examples

Example 1
Average height = 70 inches, SD = 3, height = 74 inches:

$$Z = \frac{74 - 70}{3} = 1.33$$

This corresponds to roughly 90.82% in the z-table.

49 Descriptive Statistics

49.1 Summary Measures

49.1.1 Mean

$$\text{Mean} = \frac{\sum X}{N}$$

49.1.2 Median

The middle value in a sorted dataset.

49.1.3 Mode

The most frequently occurring value.

49.1.4 Variance

$$\sigma^2 = \frac{\sum (X - \mu)^2}{N}$$

49.1.5 Standard Deviation

$$\sigma = \sqrt{\sigma^2}$$

49.2 Measures of Shape

49.2.1 Skewness

Indicates asymmetry.

49.2.2 Kurtosis

Measures peakness. Normal = 3.

49.3 Data Visualization Techniques

- **Histograms**: Show distribution of data
- **Box Plots**: Summarize quartiles and outliers
- **Scatter Plots**: Show relationships between two variables

50 Conclusion and Future Directions

This eBook explored key statistical concepts, from foundational definitions to hypothesis testing, model evaluation, and inferential techniques. It also highlighted the importance of visualization and data literacy in research and analytics. Future directions include diving into machine learning, predictive modeling, and advanced analytics in R.

51 References

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53 Introduction

This eBook serves as a comprehensive guide to understanding basic statistics, focusing particularly on concepts pertinent to the use of GUI-R (RK Ward). It combines theoretical knowledge with practical applications, allowing readers to engage with statistical analysis effectively.

54 Course Overview

54.1 Course Name

Basic Statistics using GUI-R (RKWard)

54.2 Instructor Profile

Dr. Harsh Pradhan is an Assistant Professor at the Institute of Management Studies, Banaras Hindu University. He specializes in statistical methods and data analysis techniques. For a complete overview of his work, refer to his BHU Faculty Profile.

54.3 Learning Objectives

- Understand and apply fundamental statistical concepts.
- Perform T-tests and ANOVA using real data.
- Calculate and interpret confidence intervals.
- Utilize GUI-R for statistical analysis effectively.

55 Fundamental Statistical Concepts

55.1 Descriptive Statistics

Descriptive statistics summarize and describe the features of a dataset.

55.1.1 Measures of Central Tendency

- **Mean**: Average value calculated by summing observations and dividing by the number of observations.
- **Median**: The middle value when the data is ordered. If there is an even number of observations, it is the average of the two middle values.
- **Mode**: The most frequently occurring value in a dataset.

55.1.1.1 Example Calculation

Given the data set: `[4, 8, 6, 5, 3]`

- **Mean**: $(4 + 8 + 6 + 5 + 3)/5 = 5.2$
- **Median**: Ordered data [3, 4, 5, 6, 8], median is 5.
- **Mode**: No mode (all values are unique).

55.1.2 Measures of Dispersion

- **Range**: The difference between the maximum and minimum values in a dataset.
- **Variance**: The average of the squared differences from the Mean.
- **Standard Deviation (SD)**: The square root of variance, showing how much variation exists from the mean.

55.1.2.1 Example Table of Measures

Statistic	Value
Mean	5.2
Median	5
Mode	N/A
Range	5
Variance	3.52
SD	1.88

55.2 Inferential Statistics

Inferential statistics involves making predictions or inferences about a population based on a sample of data.

55.2.1 Hypothesis Testing

- **Null Hypothesis (H)**: A statement asserting there is no effect or difference.
- **Alternative Hypothesis (H)**: A statement indicating the presence of an effect or difference.

55.2.2 Confidence Intervals

A confidence interval (CI) provides a range of values likely to contain the population parameter (e.g., mean) with a certain level of confidence (usually 95%).

Formula:

$$CI = \bar{x} \pm Z \times \frac{s}{\sqrt{n}}$$

Where: - $\bar{x}$ = sample mean
- Z = Z-score for the desired confidence level
- s = standard deviation of the sample
- n = sample size

55.2.3 Types of Errors

- **Type I Error**: Rejecting the null hypothesis when it is true (false positive).
- **Type II Error**: Failing to reject the null hypothesis when it is false (false negative).

56 The Student T-Test

56.1 Introduction to T-Test

The T-test is a hypothesis test used to determine if there is a significant difference between the means of two groups.

56.2 Types of T-Tests

- **Independent T-Test**: Compares means of two independent groups.
- **Paired T-Test**: Compares means of two related groups.
- **One-sample T-Test**: Tests the mean from a single group against a known mean.

56.3 Performing T-Tests

56.3.1 Step-by-Step Process

1. **State the Hypotheses**:
   - H : $\mu_1 = \mu_2$
   - H : $\mu_1 \neq \mu_2$
2. **Calculate the T-statistic**:
$$t = \frac{\bar{x_1} - \bar{x_2}}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$$
3. **Degrees of Freedom**:
$$df = n_1 + n_2 - 2$$
4. **Find the P-value** from statistical tables or software.
5. **Make a Decision**: If p < 0.05, reject H .

56.4 Assumptions of the T-Test

- Normal distribution.
- Independent groups (for independent T-tests).
- Equal variances.

56.5 Example: Independent T-Test

Group	Mean	SD	n
Group A	78	10	30
Group B	85	12	30

Calculation:

$$t = \frac{78 - 85}{\sqrt{\frac{10^2}{30} + \frac{12^2}{30}}} \approx -2.53$$

56.6 T-Test in GUI-R

- Open GUI-R and import your dataset.
- Select 'T-Test' from the menu.
- Define groups.
- Run the test and interpret the output.

57 Analysis of Variance (ANOVA)

57.1 Introduction

ANOVA compares means among 3+ groups to determine if at least one is different.

57.2 One-Way ANOVA

Involves one independent variable.

57.2.1 Steps:

1. **Hypotheses**:
   - H : All group means equal.
   - H : At least one group mean is different.
2. **Calculate F-statistic**:

$$F = \frac{MS_{Between}}{MS_{Within}}$$

3. **Degrees of Freedom**:
   - $df_{Between} = k - 1$
   - $df_{Within} = N - k$

57.3 Example Table

Group	Mean	Variance	n
Group 1	5.5	1.5	30
Group 2	7.1	2.0	30
Group 3	6.8	1.8	30

57.3.1 Summary Table

Source	SS	df	MS	F
Between Groups	42.4	2	21.2	5.24
Within Groups	122.7	87	1.41	
Total	165.1	89		

57.4 ANOVA in GUI-R

- Import data.
- Choose ANOVA.
- Define variables.
- Run and interpret.

58 Confidence Intervals

58.1 Concept

Shows likely range for population parameter.

58.2 Formula

$$CI = \bar{x} \pm Z \cdot \frac{s}{\sqrt{n}}$$

58.3 Example

Sample Mean = 100, SD = 15, n = 30, Z = 1.96

$$CI = 100 \pm 1.96 \times \frac{15}{\sqrt{30}} \approx [98.04, 101.96]$$

59 Practical Applications in GUI-R

59.1 GUI-R Overview

GUI-based interface for R statistical computing.

59.2 Workflow

1. Import Data (CSV/Excel).
2. Choose Statistical Test.
3. Run & Analyze Results.
4. Export or visualize.

59.3 Case Studies

- **T-Test**: Compare test scores from two teaching methods.
- **ANOVA**: Evaluate effect of 3 different drugs on recovery rate.

60 Conclusion

Mastering statistics and GUI-R helps researchers interpret and communicate data insights. T-tests, ANOVA, and confidence intervals are foundational tools, and GUI-R provides an accessible environment for applying them.

61 References

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62.1 1. Overview of Relationship Testing

Understanding and quantifying the relationships in data is paramount in statistics. Methods like correlation and regression provide researchers with invaluable tools for analyzing interactions between variables.

Correlation focuses on measuring the degree of linear association between two continuous variables. Conversely, **regression analysis** extends this concept by allowing the prediction of one variable based on the known values of another or multiple independent variables. Researchers often utilize these methodologies not only within academic settings but also across industries including healthcare, finance, and social sciences, where such analyses guide decision-making processes.

In cases where the variables in question are categorical, statisticians rely on tests such as the **Chi-Square** test. The Chi-Square test assesses if distributions of categorical variables differ from one another, which is essential when determining relationships in categorical datasets. Thus, relationship testing via these methodologies allows for comprehensive data analysis and interpretation, which in turn aids in developing conclusions and recommendations.

62.2 2. Lecture 24 – Introduction to Correlation

In this section, a detailed exploration of correlation begins.

62.2.1 2.1 Covariance and Its Importance

Covariance is a foundational statistic representing how two variables change together. If both variables tend to increase together, the covariance is positive. If one increases while the other decreases, the covariance is negative. However, covariance is not standardized, making it challenging to interpret across different datasets. For example, if height and weight are analyzed, a covariance of 30 might indicate a certain relationship between the two variables, but without context, it is difficult to ascertain the strength of that connection.

The formal mathematical representation of covariance between variables X and Y is given by:

$$Cov(X,Y) = \frac{1}{n-1}\sum_{i=1}^{n}(X_i - \bar{X})(Y_i - \bar{Y})$$

Where n is the number of data points, X_i and Y_i are the individual sample points of X and Y, and $\bar{X}$ and $\bar{Y}$ are the means of X and Y, respectively.

62.2.2 2.2 Correlation Coefficients Explained

Correlation transforms the covariance into a standardized metric, the correlation coefficient, which ranges between –1 to +1:

- A correlation of +1 indicates a perfect positive linear relationship.
- A correlation of -1 indicates a perfect negative linear relationship.
- A correlation of 0 indicates no linear relationship.

The most commonly used correlation coefficient is **Pearson's Correlation (r)**, suitable for continuous variables that are normally distributed:

$$r = \frac{Cov(X, Y)}{SD(X) \cdot SD(Y)}$$

Where $SD(X)$ and $SD(Y)$ are the standard deviations of X and Y.

Other coefficients, such as **Spearman's Rank Correlation** and **Kendall's Tau**, are used for ordinal data or when assumptions of normality are violated. Spearman's correlation assesses monotonic relationships, which allows for discovering relationships that aren't necessarily linear.

62.2.3 2.3 Practical Examples Using RKWard

Before running the following R code examples, we define a sample dataset:

```
mydata <- data.frame(
  Height = c(150, 160, 170, 180, 190),
  Weight = c(50, 60, 70, 80, 90)
)
```

Utilizing RKWard, the process of correlating variables becomes straightforward. For instance, researchers often analyze anthropometric measurements such as height and weight. By entering the appropriate data into RKWard and generating a correlation analysis, researchers can obtain:

- **Covariance**: 2.57 (units: $m \cdot kg$).
- **Correlation**: 0.71, suggesting a strong positive relationship.

Steps to perform correlation in RKWard include:

1. Input the dataset.

2. Utilize the correlation function, such as:

   ::: {.cell}

   ```
   cor(mydata$Height, mydata$Weight)
   ```

   ::: {.cell-output .cell-output-stdout}

   ```
   [1] 1
   ```

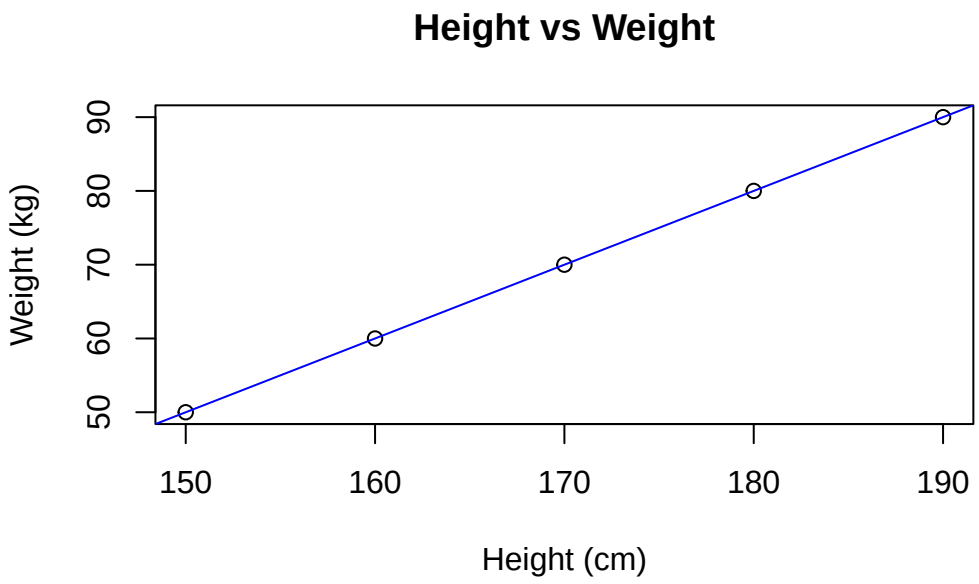
::: :::

3. Interpret the computed correlation coefficient.

62.2.4 2.4 Visualizing Correlation Using Graphs

Visualizations play an essential role in understanding correlations. Scatter plots allow one to visually assess relationships between variables. In RKWard, users can generate scatter plots using the following code:

```
plot(mydata$Height, mydata$Weight, main="Height vs Weight", xlab="Height (cm)", ylab="Weight (
abline(lm(Weight ~ Height, data=mydata), col="blue")
```



This scatter plot displays individual data points and the fitted regression line, helping to illustrate how height correlates with weight visually. By adding a regression line, one can further investigate if the relationship appears linear and the strength of that association.

62.3 3. Lecture 25 – Uses and Types of Correlation

In expanding the utility of correlation analysis, we delve into its uses and potential pitfalls.

62.3.1 3.1 Correlation vs. Causation

As previously mentioned, while correlation can indicate a relationship between variables, it does not infer causation. A classic example is the correlation observed between ice cream sales and drowning incidents. Though both variables may increase during summer months, one does not cause the other; rather, a third variable, temperature, influences both.

Researchers must ensure clarity when interpreting data, often utilizing controlled experiments to establish causal links. Notably, techniques such as **Randomized Controlled Trials (RCTs)** are crucial in establishing causation by controlling for confounding factors.

62.3.2 3.2 Practical Applications of Correlation

Correlation is widely utilized across myriad fields:

- **Healthcare**: Researchers may assess relationships between dietary habits and health outcomes. For example, a study of patients' sugar intake and diabetes prevalence may reveal significant correlations, informing dietary recommendations.
- **Market Research**: Businesses frequently utilize correlation to analyze customer behaviors, such as understanding the relationship between advertising spend and sales revenue.
- **Education**: Correlational analyses may explore the connection between study habits and student performance across various subjects, informing educational strategies.

62.3.3 3.3 Correlation in Different Fields

To illustrate the diversity of correlation's applications, here are some field-specific examples:

Field	Example
Psychology	Assessing the relationship between stress levels and academic performance.
Economics	Evaluating the correlation between unemployment rates and inflation.
Sports Analytics	Analyzing the relationship between player statistics and game outcomes.
Environmental Science	Examining the correlation between pollution levels and public health metrics.

In all these instances, correlations can guide further research and interventions designed to enhance outcomes based on insights gathered.

62.4 4. Lecture 26 – Linear Regression and Model Assumptions

The concept of regression analysis is rooted in its power to model and predict outcomes based on independent variables.

62.4.1 4.1 The Linear Model

The primary form of regression is **simple linear regression**, which describes the relationship between a single independent variable (predictor) and a dependent variable:

$$y = mx + c$$

Here, m signifies the slope of the line, indicating the change in y for every one-unit increase in x. The constant c represents the y-intercept, where the line intersects the y-axis.

Example: A researcher finds the regression equation $y = 3x + 2$. This indicates that for every additional hour studied, the test score (y) is expected to increase by 3 points.

62.4.2 4.2 Fitting Models in RKWard

RKWard simplifies the process of conducting regression analysis through intuitive functionalities. The steps include:

1. **Inputting Data**: Users need to ensure datasets are correctly formatted.

2. **Fitting the Model**: Using the `lm()` function in R:

   ::: {.cell}

   ```
   model <- lm(Weight ~ Height, data=mydata)
   ```

   :::

   This fits a linear regression model predicting `Weight` from `Height`.

3. **Analyzing Model Output**: The `summary()` function provides crucial statistics related to fits, such as coefficients and R^2 values:

   ::: {.cell}

   ```
   summary(model)
   ```

   ::: {.cell-output .cell-output-stderr}

   ```
   Warning in summary.lm(model): essentially perfect fit: summary may be
   unreliable
   ```

   :::

   ::: {.cell-output .cell-output-stdout}

```
Call:
lm(formula = Weight ~ Height, data = mydata)

Residuals:
         1          2          3          4          5
 1.270e-14 -1.296e-14 -6.454e-15  9.733e-16  5.736e-15

Coefficients:
              Estimate Std. Error    t value Pr(>|t|)
(Intercept) -1.000e+02  6.265e-14 -1.596e+15   <2e-16 ***
Height       1.000e+00  3.673e-16  2.723e+15   <2e-16 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 1.161e-14 on 3 degrees of freedom
Multiple R-squared:      1, Adjusted R-squared:      1
F-statistic: 7.413e+30 on 1 and 3 DF,  p-value: < 2.2e-16
```

::: :::

4. **Interpreting Coefficients**: The coefficient for `Height` tells you how much `Weight` is expected to change for each one-unit increase in `Height`, holding everything else constant.

62.4.3 4.3 Assessing Model Performance

To assess how well the regression model fits the data, several statistics are gathered during the analysis:

- **Coefficient of Determination (R^2)**: R^2 shows the proportion of variance in the dependent variable that is predictable from the independent variable(s). A higher R^2 value indicates a better fit.
- **F-Ratio**: This statistic tests the overall significance of the regression model. A significant F-ratio indicates that at least one predictor variable has a significant relationship with the dependent variable.
- **P-Values**: Each coefficient in the regression output is accompanied by a p-value. A p-value less than 0.05 typically indicates that the predictor is significantly related to the dependent variable.

The essential fundamentals of regression analysis also include validation of core assumptions:

62.4.4 4.4 Common Pitfalls in Regression Analysis

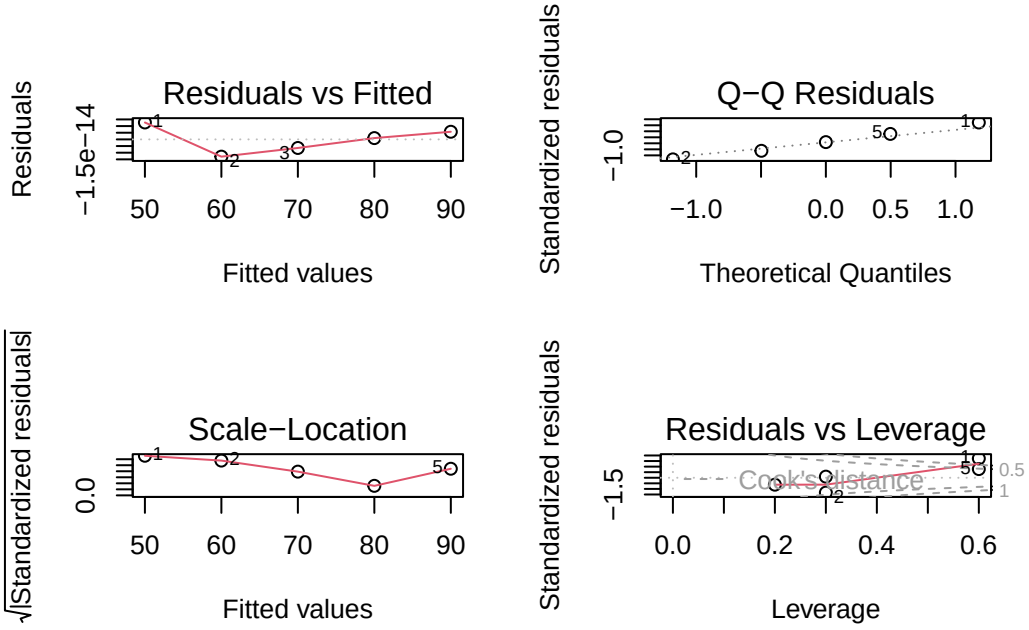
Common pitfalls to avoid in regression analysis include:

- **Overfitting**: Developing a complex model that fits the training data too closely may fail to generalize well on test data. To counter this, simplicity in model choice is often preferred.
- **Multicollinearity**: High correlations among independent variables can distort regression results. Variance Inflation Factor (VIF) assessments help to diagnose multicollinearity issues.

- **Homoscedasticity**: The assumption that residuals have constant variance across values of the independent variable must be checked. Various graphical plots can identify deviations from this assumption.
- **Normality of Residuals**: The normality of residuals can be evaluated using a QQ plot or the Shapiro-Wilk test, ensuring that the data meet the normality requirement before proceeding with interpretations.

Visualizing the fitted model along with residual plots, such as:

```
par(mfrow=c(2,2))
plot(model)
```



allows one to assess these assumptions logically and adjust the approach as needed.

62.5 5. Lecture 27 – Advanced Regression & Diagnostic Tests

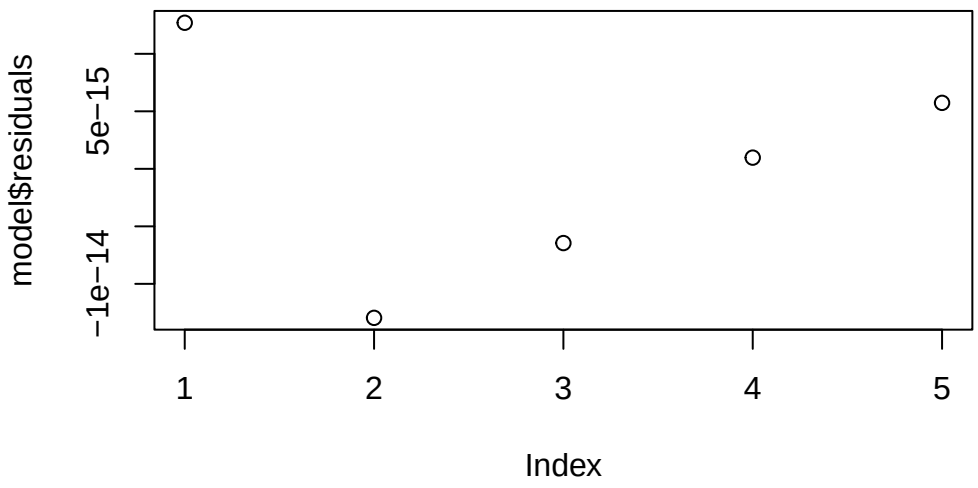
In advanced regression analyses, there lies a wealth of diagnostic tests and methodologies to identify the robustness of the model trained.

62.5.1 5.1 Exploring Residuals

Residuals, the differences between observed and predicted values, are vital to understanding model performance. Analyzing these residuals helps identify patterns or systematic errors in the model's predictions.

The ideal residual plot should show no discernible pattern, confirming the appropriateness of linear regression. These residuals can be plotted using:

```r
plot(model$residuals)
```



62.5.2 5.2 Common Diagnostic Tests

To validate linear regression assumptions, several tests are essential:

- **Durbin-Watson Test**: Tests for autocorrelation within residuals. The null hypothesis states there is no autocorrelation. A value close to 2 is desirable.
- **Breusch-Pagan Test**: This test assesses the homoscedasticity of residuals.
- **NCV Test**: This is a graphical or statistical method to evaluate non-constant variance in errors.

Each of these tests provides critical insights into whether a linear regression model can be relied upon or if adjustments are necessary.

62.5.3 5.3 Advanced Topics in Regression Analysis

Beyond the foundational elements discussed, advanced regression topics include:

- **Multiple Regression**: An extension of simple linear regression where multiple independent variables are considered. The regression equation takes the form:

$$y = b_0 + b_1 x_1 + b_2 x_2 + \cdots + b_n x_n + \epsilon$$

- **Interaction Terms**: Inclusion of interaction terms in regression models can capture the combined effect of two or more predictors. This is essential in deeper analysis when relationships are not purely linear.

- **Polynomial Regression**: When data exhibit a non-linear relationship, polynomial regression may be used to model these patterns adequately.

62.6 6. Concepts from Week 5 & 6 Slides

62.6.1 6.1 Week 5: ANOVA and Its Variants

The insights from ANOVA significantly complement correlation and regression analyses.

ANOVA Types:

- **One-Way ANOVA**: Ideal for comparing means across three or more groups. It tests the hypothesis that at least one group mean is significantly different from the others. The F-value computed in ANOVA is compared against a critical value from F-distribution tables.

Source	SS	df	MS	F
Between	461.64	3	153.88	8.27
Within	167.42	9	18.60	
Total	629.06	12		

- **Repeated Measures ANOVA**: This test analyzes means when repeated measurements occur for the same subjects, controlling for variability between subjects.

62.6.2 6.2 Week 6: Chi-Square and Non-Parametric Tests

Chi-Square Applications:

- **Goodness of Fit**: Tests if sample data matches the expected distribution.
- **Test of Independence**: Determines if two categorical variables are related or independent.

For instance, a Chi-Square test might explore whether gender relates to the choice of academic major, providing insight into educational trends within populations.

Non-Parametric Equivalents:

These tests come into play when data does not meet the normality assumption necessary for traditional parametric tests. Key non-parametric tests include:

Test	Description
Mann–Whitney	Tests differences between two independent groups.
Kruskal–Wallis	An extension of the Mann-Whitney test for three or more groups.
Wilcoxon Signed-Rank	Compares two related samples.

Logistic Regression: As trends in data become more complex, predicting outcomes between two categories is frequently required. For example, in financial sectors, logistic regression may predict default rates based on categorical input variables:

$$p = \frac{1}{1 + e^{-(a+bx)}}$$

where p is the probability of the outcome, determined by the independent variables included.

62.7 7. Summary

Ultimately, understanding how to quantify and interpret the relationships between variables through correlation, regression, and Chi-Square tests is fundamental for robust statistical analysis.

Concept	Description
Correlation	Measures association (e.g., Pearson, Spearman, Kendall)
Regression	Predicts a dependent variable from one or more independent variables
Chi-Square	Tests associations between categorical variables
Model Assumptions	Include normality, linearity, homoscedasticity, independence
Diagnostic Tools	Residual plots, QQ plots, Durbin-Watson, NCV test

62.8 Example Data for R Code Chunks

Before running the following R code examples, we define a sample dataset:

```r
mydata <- data.frame(
  Height = c(150, 160, 170, 180, 190),
  Weight = c(50, 60, 70, 80, 90)
)
```