

R PROGRAMMING



Dr. Prashanth M.C

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A Practical and Applied Approach



Dr. Prashanth M.C



MAJESTIC TECHNOLOGY SOLUTIONS (P) LTD.

2026

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By Dr. Prashanth M.C

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Published by:

Magestic Technology Solutions (P) Ltd.

#35-46, Kuttiappan Street, Kellys,

Chennai - 600 010. Tamil Nadu, India.

Website: www.magesticts.com

Email: magesh@magesticts.com | martina@magesticts.com

Editorial Contacts:

Prof. Dr. S. Magesh, Chief Editor – 9790911374

Mrs. Esther Faith Martina, Senior Editor – 9962578190

Title:	R PROGRAMMING
Author:	Dr. Prashanth M.C
ISBN:	978-93-92090-45-5
DOI:	https://www.doi.org/10.47716/978-93-92090-45-5
Edition:	First Edition, 2026
Format:	Single-component retail product (Book)
Language:	English
Price:	Rs. 400/-

Printed in India by the Publisher.

Preface

The R programming language has become one of the most powerful and widely used tools for statistical computing, data analysis, and visualization. With the increasing importance of data-driven decision making in fields such as business, research, healthcare, and technology, learning R has become essential for students and professionals alike. This book has been prepared to provide a comprehensive understanding of R programming, covering fundamental concepts, statistical techniques, graphical representation, and practical applications.

This project report is designed especially for students to help them understand the practical implementation of R programming through examples, case studies, and sample programs. The book includes various built-in functions, datasets, statistical methods, and visualization techniques that are essential for real-world data analysis. Each chapter is structured in a simple and systematic manner to make learning easy and effective.

I hope this book will serve as a valuable resource for students, researchers, and beginners who wish to learn and apply R programming in their academic and professional careers.

Dr. Prashanth M.C

Foreword

In today's data-driven world, the importance of statistical tools and programming languages cannot be overstated. R programming has emerged as one of the leading tools for statistical analysis, data visualization, and research. This project report provides a clear and practical introduction to R programming and its applications.

The author has presented the concepts in a simple and organized manner, supported by examples, case studies, and graphical representations. This book will be highly useful for students and beginners who wish to learn R programming and apply it in their academic and research work.

I appreciate the effort taken by the author in preparing this valuable project report and wish him success in future endeavors.

Editor's Note

This book has been carefully reviewed and organized to present the concepts of R programming in a clear and structured manner. The objective of this project is to help students understand statistical computing and data analysis using R.

Special attention has been given to include sample programs, case studies, built-in datasets, and appendices for reference. The content has been arranged to make it easy for students to learn both the theoretical and practical aspects of R programming.

I hope this book will serve as a useful learning resource.

About the Author



Dr. Prashanth M.C is an experienced academician and researcher with over a decade of expertise in Computer Science. Currently a temporary faculty member at Bengaluru City University, he holds an MSc and PhD in Computer Science, along with a KSET qualification. His research has been published in leading Scopus-indexed journals, such as Springer, highlighting his academic excellence. Dr. Prashanth M.C is also the holder of an Indian patent.

He has presented at several international and national conferences and actively participates in Faculty Development Programs to continuously enhance his skills. With a strong commitment to knowledge-sharing, Dr. Prashanth M.C mentors students, authors research papers, and contributes to the growth of the academic community. His dedication to both teaching and innovation makes him a key figure in the field of Computer Science.

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Introduction to R Programming

1.1 Introduction to Statistical Computing

Statistical computing is the discipline that integrates statistical analysis with computational techniques to collect, manage, analyze, and interpret data using computers. It involves the use of specialized software, programming languages, and algorithms to perform statistical operations efficiently and accurately. In the modern era of data-driven decision-making, statistical computing has become an essential tool for researchers, analysts, businesses, and policymakers.

Traditionally, statistical analysis was performed manually using paper, calculators, and mathematical tables. While this approach was suitable for small datasets, it became inefficient and error-prone when dealing with large and complex data. The development of computers revolutionized statistics by enabling rapid computation, storage, and analysis of vast amounts of data. Statistical computing allows users to perform complex calculations within seconds, which would otherwise take hours or even days manually.

Statistical computing encompasses a wide range of activities, including data entry, data cleaning, data transformation, statistical modeling, visualization, and interpretation. These activities help users to identify patterns, relationships, and trends in data. For example, a business analyst may use statistical computing to analyze customer purchasing behavior, while a healthcare researcher may use it to study the effectiveness of a medical treatment.

One of the fundamental functions of statistical computing is descriptive analysis. Descriptive statistics summarize and describe the main characteristics of a dataset. Common descriptive measures include:

- Mean (average value)
- Median (middle value)
- Mode (most frequent value)
- Standard deviation (measure of variation)
- Range (difference between maximum and minimum values)

1. Introduction to R Programming

These measures help in understanding the overall distribution and variability of data.

Another important function is inferential analysis. Inferential statistics involve making predictions or drawing conclusions about a population based on a sample. For example, a researcher may analyze a sample of voters to predict the outcome of an election. Inferential statistical techniques include hypothesis testing, regression analysis, correlation analysis, and confidence intervals.

Statistical computing also supports data visualization, which is the graphical representation of data using charts, graphs, and plots. Visualization makes it easier to understand complex data and communicate results effectively. Common graphical representations include:

- Bar charts
- Line graphs
- Pie charts
- Histograms
- Scatter plots

Visualization plays a crucial role in identifying trends, patterns, and outliers.

Modern statistical computing relies heavily on specialized software and programming languages. Some of the commonly used statistical computing tools include:

- R Programming Language
- Python
- SPSS (Statistical Package for Social Sciences)
- SAS (Statistical Analysis System)
- Stata

Among these tools, R has gained significant popularity due to its flexibility, open-source nature, and extensive statistical capabilities.

Statistical computing is widely used in various fields and industries. In business, it is used for sales forecasting, market research, and customer analysis. In healthcare, it is used for clinical trials, disease prediction, and patient data analysis. In economics, it helps in analyzing economic trends and making policy decisions. In engineering, it is used for quality control and process optimization. In social sciences, statistical computing helps in survey analysis and behavioral research.

Another important aspect of statistical computing is reproducibility. Reproducibility means that the same analysis can be repeated and verified by others using the same data and

methods. Programming languages such as R allow users to write scripts that document each step of the analysis process, ensuring transparency and reliability.

Statistical computing also plays a key role in the emerging field of data science. Data science combines statistics, programming, and domain knowledge to extract meaningful insights from data. Statistical computing forms the foundation of data science by providing tools for data analysis, modeling, and visualization.

In summary, statistical computing is the use of computers and software to perform statistical analysis and data processing. It improves the efficiency, accuracy, and reliability of data analysis. With the rapid growth of data in modern times, statistical computing has become an essential skill for students, researchers, and professionals across various disciplines. R programming language is one of the most powerful and widely used tools for statistical computing, and it provides the foundation for learning data analysis and data science.

1.2 Evolution of R Programming

The R programming language is one of the most important tools for statistical computing and data analysis used today. Its development is closely linked to the evolution of statistical computing and the need for flexible, powerful, and accessible tools for data analysis. Understanding the evolution of R helps users appreciate its design, capabilities, and widespread adoption in research and industry.

1.2.1 Origin in the S Programming Language

The origins of R can be traced back to the S programming language, which was developed in the 1970s at Bell Laboratories (now part of AT&T) by John Chambers and his colleagues. The primary objective of developing S was to create a programming environment specifically designed for statistical analysis and graphical visualization.

Before the development of S, statisticians relied mainly on general-purpose programming languages such as FORTRAN and C. These languages were powerful but not specifically designed for statistical work, making data analysis more difficult and time-consuming. The S language introduced a more user-friendly and interactive environment, allowing statisticians to perform data analysis more efficiently.

S quickly became popular in academic and research institutions. Later, a commercial version of S known as S-PLUS was developed by Statistical Sciences, Inc., and it was widely used for statistical analysis.

The success of the S language laid the foundation for the development of R.

1.2.2 Development of R Programming Language

In the early 1990s, Ross Ihaka and Robert Gentleman, who were statisticians at the University of Auckland in New Zealand, recognized the need for a free and open-source statistical computing environment similar to S-PLUS. At that time, most statistical software was commercial and expensive, limiting access for students and researchers.

To address this issue, they began developing R as an open-source implementation inspired by the S programming language. The name "R" was chosen partly because it is the first letter of the names Ross and Robert, and also as a reference to the S language.

The development of R started in 1992, and the initial version was released to the public in 1995. This marked the beginning of a new era in statistical computing, as users now had access to a powerful and free statistical tool.

1.2.3 Formation of the R Core Team

As R gained popularity, a group of experts and developers formed the R Core Team in 1997. This team took responsibility for maintaining, improving, and updating the R language. The R Core Team continues to play a vital role in the development and stability of R.

In 2000, R version 1.0.0 was officially released. This was a significant milestone, as it represented a stable and mature version of the software suitable for widespread use.

1.2.4 Establishment of the R Foundation

In 2003, the R Foundation for Statistical Computing was established to support the development and promotion of R. The foundation provides organizational support, manages resources, and ensures the continued growth of the R ecosystem.

The R Foundation also oversees the Comprehensive R Archive Network (CRAN), which is a repository of R software, packages, and documentation. CRAN allows users to download R and thousands of additional packages developed by contributors worldwide.

1.2.5 Growth and Global Adoption

Since its official release, R has experienced rapid growth and global adoption. Several factors contributed to its popularity:

- First, R is open-source and free, making it accessible to students, researchers, and organizations.
- Second, R provides powerful statistical and graphical capabilities, making it suitable for complex data analysis.
- Third, R supports the development of packages, allowing users to extend its functionality.

- Fourth, R has a strong and active global community that continuously contributes to its development.

As a result, thousands of packages have been developed for R, covering areas such as machine learning, data visualization, bioinformatics, finance, and artificial intelligence.

1.2.6 R in Modern Data Science

In recent years, R has become one of the most widely used programming languages in data science, analytics, and research. It is extensively used in:

- Academic research
- Business analytics
- Healthcare analytics
- Financial modeling
- Machine learning
- Artificial intelligence

Many universities include R programming in their curriculum, and many organizations use R for data-driven decision-making.

The development of powerful packages such as ggplot2, dplyr, tidyr, and caret has further strengthened R's position as a leading data analysis tool.

1.2.7 Key Milestones in the Evolution of R

Table 1.1. - Major Milestones in the Development of R

Year	Milestone
1970s	Development of S language at Bell Laboratories
1992	Development of R started
1995	First version of R released
1997	Formation of R Core Team
2000	Release of R version 1.0.0
2003	Establishment of R Foundation
Present	R widely used in data science and research

1.2.8 Importance of Open-Source Nature

One of the most important reasons for the success of R is its open-source nature. Being open-source means that the source code is freely available and can be modified by users. This has allowed developers worldwide to contribute to its improvement.

The open-source model has resulted in continuous innovation, rapid development, and widespread adoption.

1.2.9 Summary of Evolution

The R programming language evolved from the S language and was developed to provide a free and powerful statistical computing environment. Since its release in 1995, R has grown significantly and has become one of the most important tools for data analysis and research.

Its continuous development by the R Core Team and support from the R Foundation have ensured its reliability and success. Today, R is widely recognized as a standard tool for statistical computing and data science.

1.3 Features and Advantages of R

R programming language has gained worldwide recognition as one of the most powerful tools for statistical computing and data analysis. Its design specifically focuses on providing a flexible and comprehensive environment for data handling, statistical modeling, and graphical representation. The popularity of R among statisticians, researchers, data scientists, and business analysts is largely due to its wide range of features and practical advantages. These features enable users to perform simple as well as complex data analysis efficiently and accurately.

One of the most important features of R is that it is open-source and freely available. Unlike many statistical software packages that require expensive licenses, R can be downloaded and used without any cost. Being open-source also means that its source code is accessible to developers and researchers, allowing them to modify and improve the software. This has resulted in continuous development and innovation, making R a constantly evolving and improving programming language. The free availability of R has made it especially popular in academic institutions and research organizations.

Another major strength of R is its comprehensive statistical analysis capability. R provides built-in functions for performing a wide variety of statistical techniques, ranging from basic descriptive statistics to advanced modeling and machine learning methods. Users can calculate measures such as mean, median, variance, and standard deviation, and can also perform complex analyses such as regression, correlation, hypothesis testing, and time-series analysis. This makes R a complete statistical computing environment suitable for both beginners and advanced users.

R is also well known for its powerful data visualization capabilities. Data visualization is essential for understanding patterns, trends, and relationships in data, and R provides extensive graphical tools for this purpose. Users can create a variety of graphs, including bar charts, line graphs, histograms, pie charts, and scatter plots. In addition to basic graphics, R supports advanced visualization through specialized packages such as `ggplot2`, which allows users to create high-quality and professional graphical outputs. These graphical outputs are widely used in research publications, reports, and presentations.

Another important feature of R is its extensive package ecosystem. R provides thousands of packages that extend its functionality and allow users to perform specialized tasks. These packages are available through the Comprehensive R Archive Network (CRAN), which is a central repository for R software and extensions. The availability of packages enables users to perform tasks such as data manipulation, machine learning, web application development, and advanced statistical analysis. This flexibility makes R highly adaptable to different application areas.

R is also platform independent, meaning it can run on different operating systems such as Windows, macOS, and Linux. This allows users to work on different computer systems without changing their code. The platform independence of R makes it highly convenient for both individual users and organizations that use multiple operating systems.

Another significant advantage of R is its ability to handle and manage data effectively. R provides various data structures such as vectors, matrices, lists, and data frames, which allow users to organize and manipulate data efficiently. It also supports importing data from various file formats, including CSV files, Excel files, text files, and databases. This makes R highly suitable for working with real-world datasets.

In addition to being a statistical tool, R is also a full-fledged programming language. Users can write programs, define functions, and automate repetitive tasks. This helps in saving time and improving efficiency. Automation also reduces the chances of errors and ensures consistency in data analysis.

R also benefits from a strong and active global community. Thousands of users and developers contribute to its growth by creating packages, writing documentation, and providing support. This large community makes it easier for beginners to learn R and for professionals to find solutions to complex problems.

Another important advantage of R is its ability to support reproducible research. In reproducible research, the entire analysis process is documented in the form of code, allowing others to verify and repeat the analysis. This improves the reliability and transparency of research findings. Reproducibility is particularly important in scientific and academic research.

Due to these features and advantages, R has become one of the most widely used tools in data science, research, finance, healthcare, and business analytics. Its flexibility, powerful

statistical capabilities, and excellent graphical features make it an ideal tool for data analysis and decision-making.

In conclusion, R provides a powerful, flexible, and cost-effective environment for statistical computing and data analysis. Its open-source nature, extensive functionality, strong community support, and advanced visualization capabilities have made it one of the most important programming languages in modern data science and research.

1.4 Applications of R in Data Science and Research

R programming language has become one of the most widely used tools in data science and research due to its powerful statistical capabilities, flexibility, and ability to handle large and complex datasets. It provides a comprehensive environment for data analysis, modeling, and visualization, which are essential components of data science. As organizations and researchers increasingly rely on data to make decisions, R has emerged as a valuable tool for extracting meaningful insights and supporting evidence-based conclusions.

One of the primary applications of R is in data analysis. Data science involves collecting, cleaning, analyzing, and interpreting data, and R provides functions and tools for each of these tasks. Researchers and analysts use R to organize data, perform statistical analysis, and identify patterns and relationships within the data. For example, a company may use R to analyze customer purchase data to understand buying behavior and improve marketing strategies. R enables users to handle both small and large datasets efficiently, making it suitable for real-world data analysis.

R is extensively used in academic research across various disciplines, including social sciences, economics, psychology, biology, and environmental science. Researchers use R to analyze experimental data, test hypotheses, and validate research findings. It provides accurate statistical methods that help researchers draw reliable conclusions from their studies. In addition, R allows researchers to document their analysis through scripts, which ensures transparency and reproducibility. This is particularly important in scientific research, where the validity of results must be verified by others.

Another important application of R is in data visualization, which is a key component of data science. Visualization helps in presenting data in a graphical format, making it easier to understand trends, patterns, and relationships. R provides powerful tools for creating high-quality graphs such as bar charts, histograms, line graphs, and scatter plots. These visualizations are useful for communicating results to decision-makers, researchers, and the general public. Effective visualization helps in simplifying complex data and improving understanding.

R is also widely used in business analytics. Organizations use R to analyze sales data, customer information, and market trends. This analysis helps businesses make informed

decisions, improve performance, and gain a competitive advantage. For example, businesses use R for sales forecasting, customer segmentation, and performance analysis. By analyzing past data, organizations can predict future trends and develop effective strategies.

In the field of healthcare and medical research, R plays a crucial role in analyzing patient data, conducting clinical trials, and studying disease patterns. Medical researchers use R to evaluate the effectiveness of treatments and identify risk factors associated with diseases. Statistical analysis performed using R helps healthcare professionals make informed medical decisions and improve patient care. R is also used in epidemiology to study the spread of diseases and develop preventive measures.

Financial analysis is another important area where R is widely used. Financial institutions use R to analyze stock market data, evaluate investment performance, and manage financial risks. R provides tools for time-series analysis, which helps analysts study changes in financial data over time. This enables investors and financial analysts to make informed investment decisions and predict market trends.

R is also used in machine learning and predictive modeling, which are essential components of modern data science. Machine learning involves building models that can learn from data and make predictions. R provides various packages and functions that allow users to develop predictive models for classification, regression, and clustering. These models are used in applications such as customer prediction, fraud detection, and recommendation systems.

In addition, R is widely used in environmental and scientific research. Scientists use R to analyze environmental data such as temperature, rainfall, and pollution levels. This analysis helps in understanding environmental changes and developing solutions to environmental problems. R is also used in fields such as agriculture, engineering, and physics for data analysis and modeling.

Another important application of R is in education. Many universities and academic institutions use R to teach statistics, data analysis, and data science. Students learn how to analyze data, create visualizations, and interpret results using R. Its simple syntax and powerful capabilities make it an effective learning tool for students.

Overall, R has become an essential tool in data science and research due to its ability to handle data, perform statistical analysis, and create meaningful visualizations. Its wide range of applications across different fields demonstrates its importance in modern data-driven environments. The ability of R to support accurate analysis, reproducibility, and effective communication of results makes it a valuable tool for researchers, analysts, and organizations.

1.5 Installing R and RStudio

To begin working with R programming, it is necessary to install two important components: the R software and RStudio. The R software provides the core environment for statistical computing and data analysis, while RStudio provides a user-friendly interface that makes it easier to write, execute, and manage R programs. RStudio is an Integrated Development Environment (IDE) designed specifically for R, and it enhances the usability of R by providing additional tools and features. Both R and RStudio are freely available and can be installed on different operating systems such as Windows, macOS, and Linux.

The installation process involves first installing the R software and then installing RStudio. RStudio depends on R to function, so R must be installed before installing RStudio.

1.5.1 Installing R Software

The R software is available through the Comprehensive R Archive Network (CRAN), which is the official repository for R. The following steps explain the installation process.

First, open a web browser such as Google Chrome, Mozilla Firefox, or Microsoft Edge, and visit the official R website by typing the following address in the address bar:

`https://cran.r-project.org`

This website provides access to download R for different operating systems.

When the website opens, the user will see options to download R for various operating systems, including Windows, macOS, and Linux. The user should select the appropriate option based on the operating system installed on their computer. For example, if the computer is running Windows, the user should click on the link labeled “Download R for Windows.”

After selecting the operating system, the user will be directed to a page that contains further instructions and download links. The user should click on the link that says “base,” which refers to the main R installation package. Then, click on the link to download the latest version of R. The file will begin downloading and will be saved on the computer.

Once the download is complete, the user should open the downloaded file. This will launch the R installation wizard. The installation wizard guides the user through the installation process.

The user will first be asked to select a language for installation. After selecting the language, the user should click the “Next” button. The wizard will then display the license agreement. The user should read the license agreement and click “Next” to accept the terms and continue.

Next, the wizard will ask the user to select the destination folder where R will be installed. The default location is usually recommended, and the user can click “Next” to proceed.

The wizard will then display additional options, such as selecting components and startup options. In most cases, the default settings are suitable, and the user can continue by clicking “Next.”



Dr. Prashanth M.C

Dr. Prashanth M.C is an experienced academician and researcher with over a decade of expertise in Computer Science. Currently a temporary faculty member at Bengaluru City University, he holds an MSc and PhD in Computer Science, along with a KSET qualification. His research has been published in leading Scopus-indexed journals, such as Springer, highlighting his academic excellence. Dr. Prashanth M.C is also the holder of an Indian patent. He has presented at several international and national conferences and actively participates in Faculty Development Programs to continuously enhance his skills. With a strong commitment to knowledge-sharing, Dr. Prashanth M.C mentors students, authors research papers, and contributes to the growth of the academic community. His dedication to both teaching and innovation makes him a key figure in the field of Computer Science.

ISBN: 978-93-92090-45-5

DOI: 10.47716/978-93-92090-45-5

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ISBN 978-93-92090-45-5



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