R (programming language)

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R is an open source programming language and software environment for statistical computing and graphics that is supported by the R Foundation for Statistical Computing.[6] The R language is widely used among statisticians and data miners for developing statistical software[7] and data analysis.[8] Polls, surveys of data miners, and studies of scholarly literature databases show that R's popularity has increased substantially in recent years.[9]

R is a GNU package.[10] The source code for the R software environment is written primarily in C, Fortran, and R.[11] R is freely available under the GNU General Public License, and pre-compiled binary versions are provided for various operating systems. While R has a command line interface, there are several graphical front-ends available.[12]

R language	
Paradigms	Multi-paradigm: Array, object-oriented, imperative, functional, procedural, reflective
Designed by	Ross Ihaka and Robert Gentleman
Developer	R Core Team[1]
First appeared	August 1993[2]
Stable release	3.4.0 (You Stupid Darkness)[3] / April 21, 2017
Typing discipline	Dynamic
License	GNU GPL v2[4]
Filename extensions	.r, .R, .RData, .rds, .rda
Website	www.r-project.org
Influenced by	
Common Lisp · S · Scheme[2] · XLispStat	
Influenced	
Julia[5]	
R Programming at Wikibooks	

Contents

History

R is an implementation of the S programming language combined with lexical scoping semantics inspired by Scheme.[13] S was created by John Chambers while at Bell Labs. There are some important differences, but much of the code written for S runs unaltered.[14]

R was created by Ross Ihaka and Robert Gentleman[15] at the University of Auckland, New Zealand, and is currently developed by the *R Development Core Team*, of which Chambers is a member. R is named partly after the first names of the first two R authors and partly as a play on the name of S.[16] The project was conceived in 1992, with an initial version released in 1995 and a stable beta version in 2000.[17][18][19]

Statistical features

R and its libraries implement a wide variety of statistical and graphical techniques, including linear and nonlinear modeling, classical statistical tests, time-series analysis, classification, clustering, and others. R is easily extensible through functions and extensions, and the R community is noted for its active contributions in terms of packages. Many of R's standard functions are written in R itself, which makes it easy for users to follow the algorithmic choices made. For computationally intensive tasks, C, C++, and Fortran code can be linked and called at run time. Advanced users can write C, C++,[20] Java,[21] .NET[22] or Python code to manipulate R objects directly.[23] R is highly extensible through the use of user-submitted packages for specific functions or specific areas of study. Due to its S heritage, R has stronger object-oriented programming facilities than most statistical computing languages. Extending R is also eased by its lexical scoping rules.[24]

Another strength of R is static graphics, which can produce publication-quality graphs, including mathematical symbols. Dynamic and interactive graphics are available through additional packages.[25]

R has Rd, its own LaTeX-like documentation format, which is used to supply comprehensive documentation, both on-line in a number of formats and in hard copy.[26]

Programming features

R is an interpreted language; users typically access it through a command-line interpreter. If a user types `2+2` at the R command prompt and presses enter, the computer replies with 4, as shown below:

```
> 2+2
[1] 4
```

This calculation is interpreted as the sum of two single-element vectors, resulting in a single-element vector. The prefix `[1]` indicates that the list of elements following it on the same line starts with the *first* element of the vector (a feature that is useful when the output extends over multiple lines).

Like other similar languages such as APL and MATLAB, R supports matrix arithmetic. R's data structures include vectors, matrices, arrays, data frames (similar to tables in a relational database) and lists.[27] R's extensible object system includes objects for (among others): regression models, time-series and geo-spatial coordinates. The scalar data type was never a data structure of R.[28] Instead, a scalar is represented as a vector with length one.[29]

R supports procedural programming with functions and, for some functions, object-oriented programming with generic functions. A generic function acts differently depending on the classes of arguments passed to it. In other words, the generic function dispatches the function (method) specific to that class of object. For example, R has a generic `print` function that can print almost every class of object in R with a simple `print(objectname)` syntax.[30]

Although used mainly by statisticians and other practitioners requiring an environment for statistical computation and software development, R can also operate as a general matrix calculation toolbox – with performance benchmarks comparable to GNU Octave or MATLAB.[31] Arrays are stored in column-major order.[32]

Packages

The capabilities of R are extended through user-created *packages*, which allow specialized statistical techniques, graphical devices (such as the ggplot2 package developed by Hadley Wickham), import/export capabilities, reporting tools (knitr, Sweave), etc. These packages are developed primarily in R, and sometimes in Java, C, C++, and Fortran.

A core set of packages is included with the installation of R, with more than 10,500 additional packages (as of April 2017) available at the Comprehensive R Archive Network (CRAN),[33] Bioconductor, Omegahat,[34] GitHub, and other repositories.[35]

The "Task Views" page (subject list) on the CRAN website[36] lists a wide range of tasks (in fields such as Finance, Genetics, High Performance Computing, Machine Learning, Medical Imaging, Social Sciences and Spatial Statistics) to which R has been applied and for which packages are available. R has also been identified by the FDA as suitable for interpreting data from clinical research.[37]

Other R package resources include Crantastic, a community site for rating and reviewing all CRAN packages, and R-Forge, a central platform for the collaborative development of R packages, R-related software, and projects. R-Forge also hosts many unpublished beta packages, and development versions of CRAN packages.[38][39]

The Bioconductor project provides R packages for the analysis of genomic data, such as Affymetrix and cDNA microarray object-oriented data-handling and analysis tools, and has started to provide tools for analysis of data from next-generation high-throughput sequencing methods.[40]

Milestones

A list of changes in R releases is maintained in various "news" files at CRAN.[41] Some highlights are listed below for several major releases.

Release	Date	Description
0.16		This is the last alpha version developed primarily by Ihaka and Gentleman. Much of the basic functionality from the "White Book" (see S history) was implemented. The mailing lists commenced on April 1, 1997.
0.49	1997-04-23	This is the oldest source release which is currently available on CRAN.[42] CRAN is started on this date, with 3 mirrors that initially hosted 12 packages.[43] Alpha versions of R for Microsoft Windows and the classic Mac OS are made available shortly after this version.
0.60	1997-12-05	R becomes an official part of the GNU Project. The code is hosted and maintained on CVS.
0.65.1	1999-10-07	First versions of update.packages and install.packages functions for downloading and installing packages from CRAN.[44]
1.0	2000-02-29	Considered by its developers stable enough for production use.[45]
1.4	2001-12-19	S4 methods are introduced and the first version for Mac OS X is made available soon after.
2.0	2004-10-04	Introduced lazy loading, which enables fast loading of data with minimal expense of system memory.
2.1	2005-04-18	Support for UTF-8 encoding, and the beginnings of internationalization and localization for different languages.
2.11	2010-04-22	Support for Windows 64 bit systems.
2.13	2011-04-14	Adding a new compiler function that allows speeding up functions by converting them to byte-code.
2.14	2011-10-31	Added mandatory namespaces for packages. Added a new parallel package.
2.15	2012-03-30	New load balancing functions. Improved serialization speed for long vectors.
3.0	2013-04-03	Support for numeric index values 2^{31} and larger on 64 bit systems.

Interfaces

The most commonly used graphical integrated development environment for R is RStudio. A similar development interface is R Tools for Visual Studio.

Interfaces with more of a point-and-click approach include Rattle GUI, R Commander, and RKWard.

Some of the more common editors with varying levels of support for R include: Eclipse,[46] Emacs (Emacs Speaks Statistics), Kate,[47] LyX.[48] Notepad++,[49] WinEdt,[50] Tinn-R.[51]

R functionality is accessible from several scripting languages such as Python,[52] Perl,[53] Ruby,[54] F#[55] and Julia.[56]

Implementations

The main R implementation is written in R, C, and Fortran, and there are several other implementations aimed at improving speed or increasing extensibility. A closely related implementation is pqR (pretty quick R) by Radford M. Neal with improved memory management and support for automatic multithreading. Renjin and FastR are Java implementations of R for use in a Java Virtual Machine. CXXR, rho, and Riposte[57] are implementations of R in C++. Renjin, Riposte, and pqR attempt to improve performance by using multiple

processor cores and some form of deferred evaluation.[58] Most of these alternative implementations are experimental and incomplete, with relatively few users, compared to the main implementation maintained by the R Development Core Team.

TIBCO built a runtime engine called TERR, which is part of Spotfire.[59]

useR! conferences

The official annual gathering of R users is called "useR!".[60]

The first such event was useR! 2004 in May 2004, Vienna, Austria.[61] After skipping 2005, the useR conference has been held annually, usually alternating between locations in Europe and North America.[62]

Subsequent conferences have included:[60]

- useR! 2006, Vienna, Austria
- useR! 2007, Ames, Iowa, USA
- useR! 2008, Dortmund, Germany
- useR! 2009, Rennes, France
- useR! 2010, Gaithersburg, Maryland, USA
- useR! 2011, Coventry, United Kingdom
- useR! 2012, Nashville, Tennessee, USA
- useR! 2013, Albacete, Spain
- useR! 2014, Los Angeles, USA
- useR! 2015, Aalborg, Denmark
- useR! 2016, Stanford, California, USA
- useR! 2017, Brussels, Belgium

R Journal

The R Journal is the open access, refereed journal of the R project for statistical computing. It features short to medium length articles on the use, and development of R, including packages, programming tips, CRAN news, and foundation news.

Comparison with SAS, SPSS, and Stata

The general consensus is that R compares well with other popular statistical packages, such as SAS, SPSS, and Stata.[63] In a comparison of all basic features for a statistical software R is heads up with the best of statistical software.

In January 2009, the *New York Times* ran an article about R gaining acceptance among data analysts and presenting a potential threat for the market share occupied by commercial statistical packages, such as SAS.[64]

Unlike many other statistical software like SAS, SPSS, Stata, MATLAB and Mathematica, R is available to users at no charge and uses free software license.

Commercial support for R

While R is an open-source project supported by the community developing it, some companies strive to provide commercial support and/or extensions for their customers. This section gives some examples of such companies.

In 2007 Richard Schultz, Martin Schultz, Steve Weston and Kirk Mettler founded Revolution Analytics to provide commercial support for Revolution R, their distribution of R, which also includes components developed by the company. Major additional components include: ParallelR, the R Productivity Environment IDE, RevoScaleR (for big data analysis), RevoDeployR, web services framework, and the ability for reading and writing data in the SAS file format.[65] Revolution Analytics also offer a distribution of R designed to comply with established IQ/OQ/PQ criteria which enables clients in the pharmaceutical sector to validate their installation of REvolution R.[66] In 2015, Microsoft Corporation completed the acquisition of Revolution Analytics.[67]

In October 2011 Oracle announced the *Big Data Appliance*, which integrates R, Apache Hadoop, Oracle Linux, and a NoSQL database with Exadata hardware.[68] As of 2012, Oracle R Enterprise[69] became one of two components of the "Oracle Advanced Analytics Option"[70] (alongside Oracle Data Mining).

IBM offers support for in-Hadoop execution of R,[71] and provides a programming model for massively parallel in-database analytics in R.[72]

Other major commercial software systems supporting connections to or integration with R include: JMP,[73] Mathematica,[74] MATLAB,[75] Pentaho,[76] Spotfire,[77] SPSS,[78] Statistica,[79] Platform Symphony,[80] SAS,[81] Tableau Software,[82] Esri ArcGis,[83] Dundas[84] and Statgraphics.[85]

Tibco offers a runtime-version R as a part of Spotfire.[86]

Notable uses

FiveThirtyEight, a political prognosticator, used R to model the chances of the 2008 presidential election, 2010 midterm elections, 2012 presidential election, 2014 midterm elections, and 2016 presidential elections.

Further, R is used by both the Democratic National Committee and the Republican National Committee in order to identify potential voters, and manage efforts to get more people to vote. These were used by Hillary Clinton and Donald Trump, through the companies Cambridge Analytica and Ada.

Examples

Basic syntax

The following examples illustrate the basic syntax of the language and use of the command-line interface.

In R, the widely preferred[87] assignment operator is an arrow made from two characters <-, although = can be used instead.[88]

```
> x <- c(1,2,3,4,5,6)    # Create ordered collection (vector)
> y <- x^2               # Square the elements of x
> print(y)               # print (vector) y
[1]  1  4  9 16 25 36
> mean(y)                # Calculate average (arithmetic mean) of (vector) y; result is scalar
[1] 15.16667
> var(y)                 # Calculate sample variance
[1] 178.9667
> lm_1 <- lm(y ~ x)      # Fit a linear regression model "y = f(x)" or "y = B0 + (B1 * x)"
                         # store the results as lm_1
> print(lm_1)            # Print the model from the (linear model object) lm_1

Call:
lm(formula = y ~ x)

Coefficients:
(Intercept)              x
     -9.333          7.000
```

```
> summary(lm_1)              # Compute and print statistics for the fit
                             # of the (linear model object) lm_1

Call:
lm(formula = y ~ x)

Residuals:
1       2       3       4       5       6
3.3333 -0.6667 -2.6667 -2.6667 -0.6667  3.3333

Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept)  -9.3333     2.8441  -3.282 0.030453 *
x             7.0000     0.7303   9.585 0.000662 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 3.055 on 4 degrees of freedom
Multiple R-squared: 0.9583, Adjusted R-squared: 0.9478
F-statistic: 91.88 on 1 and 4 DF,  p-value: 0.000662

> par(mfrow=c(2, 2))         # Request 2x2 plot layout
> plot(lm_1)                 # Diagnostic plot of regression model
```


Structure of a function

The ease of function creation by the user is one of the strengths of using R. Objects remain local to the function, which can be returned as any data type.[89] Below is an example of the structure of a function:

```
functionname <- function(arg1, arg2, ... ){ # declare name of function and function arguments
  statements                                 # declare statements
  return(object)                             # declare object data type
}
```

```
sumofsquares <- function(x){  # a user-created function
  return(sum(x^2))            # return the sum of squares of the elements of vector x
}
```

```
> sumofsquares(1:3)
[1] 14
```

Mandelbrot set

Short R code calculating Mandelbrot set through the first 20 iterations of equation $z = z^2 + c$ plotted for different complex constants c. This example demonstrates:

- use of community-developed external libraries (called packages), in this case caTools package
- handling of complex numbers
- multidimensional arrays of numbers used as basic data type, see variables C, Z and X.

```
install.packages("caTools")   # install external package
library(caTools)              # external package providing write.gif function
jet.colors <- colorRampPalette(c("#00007F", "blue", "#007FFF", "cyan", "#7FFF7F",
                                  "yellow", "#FF7F00", "red", "#7F0000"))
dx <- 400                     # define width
dy <- 400                     # define height
C <- complex( real=rep(seq(-2.2, 1.0, length.out=dx), each=dy ),
              imag=rep(seq(-1.2, 1.2, length.out=dy), dx ) )
C <- matrix(C,dy,dx)          # reshape as square matrix of complex numbers
Z <- 0                        # initialize Z to zero
X <- array(0, c(dy,dx,20))    # initialize output 3D array
for (k in 1:20) {             # loop with 20 iterations
  Z <- Z^2+C                  # the central difference equation
  X[,,k] <- exp(-abs(Z))      # capture results
}
write.gif(X, "Mandelbrot.gif", col=jet.colors, delay=900)
```
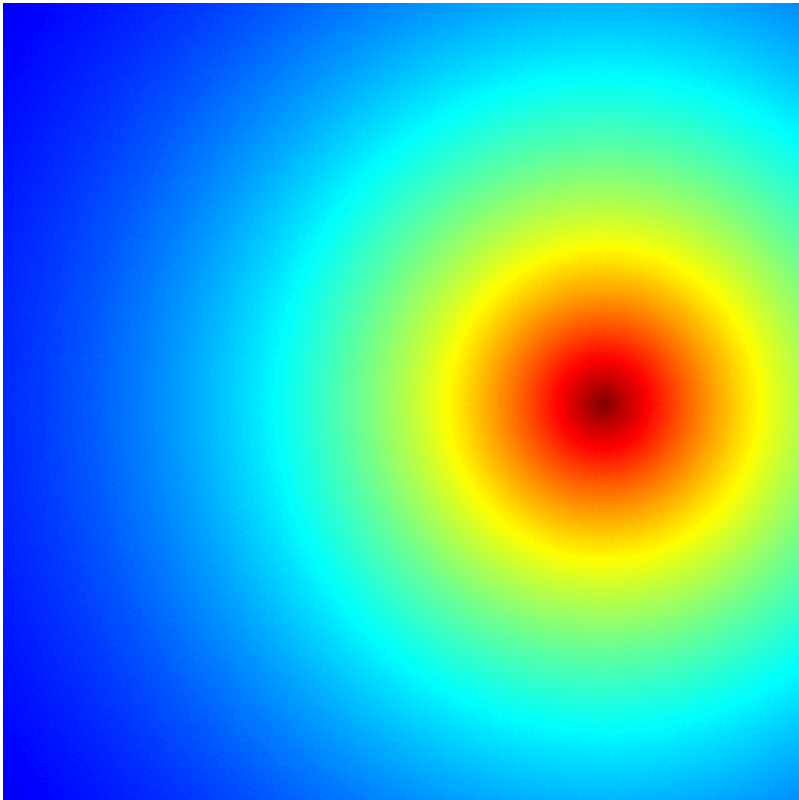

See also

- Comparison of numerical analysis software
- Comparison of statistical packages
- List of numerical analysis software

- List of statistical packages
- Programming with Big Data in R (pbdR)[90]
- Rmetrics

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External links

- Official website of the R project
- An Introduction to R
- R books, has extensive list (with brief comments) of R-related books
- R-bloggers, a daily news site about R, with 10,000+ articles, tutorials and case-studies, contributed by over 450 R bloggers.
- The R Graphical Manual, a collection of R graphics from all R packages, and an index to all functions in all R packages
- R seek, a custom frontend to Google search engine, to assist in finding results related to the R language
- R Graph Gallery

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│ Numerical analysis software for Windows │ Programming languages created in 1993
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