

A PRACTICAL HISTORY OF R (WHERE THINGS CAME FROM)

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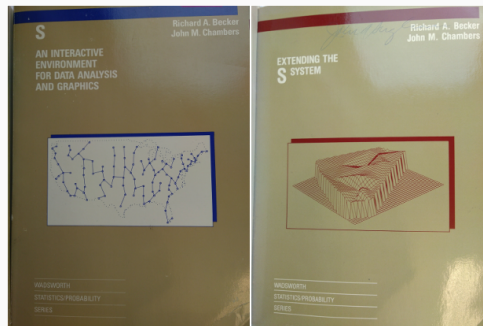
- Not infrequently, we wonder why choices such as `stringsAsFactors=TRUE` or `drop=TRUE` were made.
- Understanding the original uses of S and R (in the 1980s and 1990s), and seeing how these uses affected the development of R lets us appreciate the robustness of R's ecosystem.
- This keynote uses readings of the R sources and other information to explore R's history. The topics to be touched on include the “colour” books (brown, blue, white, green), interlinkages to SICP (Scheme) and LispStat
- We'll also touch on the lives of R-core, the mailing lists and CRAN, and Ancients and Moderns (see [Exploring the CRAN social network](#)).

History of R and its data structures

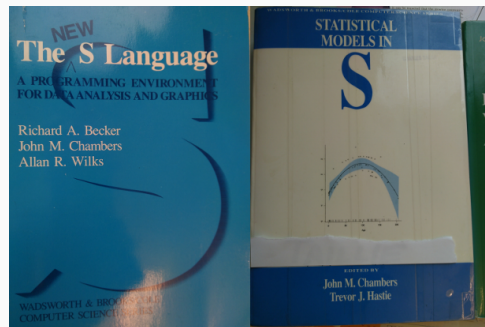
- [Rasmus Bååth](#) has a useful blog piece on R's antecedents in the S language
- Something similar is present in the second chapter of (Chambers, 2016), from the viewpoint of one of those responsible for the development of the S language
- In addition to S, we need to take [SICP and Scheme](#) into account (Abelson and Sussman, 1996, second edition), as described by Ihaka and Gentleman (1996) and Wickham (2014)
- Finally, LispStat and its creators have played and continue to play a major role in developing R (Tierney, 1990, 1996, 2005)

Becker and Chambers (1984): {S}: An Interactive Environment for Data Analysis and Graphics, A.K.A. the Brown Book

Becker and Chambers (1985): Extending the {S} System

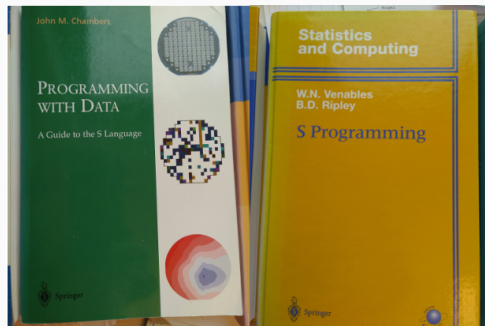


Becker et al. (1988): The New S Language: A Programming Environment for Data Analysis and Graphics, A.K.A. the Blue Book.
Chambers and Hastie (1992): Statistical Models in S edited by John M. Chambers and Trevor J. Hastie (1992), A.K.A. the White Book.



Chambers (1998): Programming with Data: A Guide to the S Language, A.K.A. the Green Book.

Venables and Ripley (2000): S Programming



- The S2 system was described in the Brown Book, S3 in the Blue Book and completed in the White Book, finally S4 in the Green Book
- The big advance from S2 to S3 was that users could write functions; that data.frame objects were defined; that formula objects were defined; and that S3 classes and method dispatch appeared
- S4 brought connections and formal S4 classes, the latter seen in R in the **methods** package (still controversial)
- S-PLUS was/is the commercial implementation of S and its releases drove S3 and S4 changes

- S was a Bell Labs innovation, like Unix, C, C++, and many interpreted languages (like AWK); many of these share key understandings
- Now owned by Nokia, previously Alcatel-Lucent, Lucent, and AT&T
- Why would a telecoms major (AT&T) pay for fundamental research in computer science and data analysis (not to sell or market other products better)?
- Some Green Book examples are for quality control of telecoms components

- S-PLUS was quickly adopted for teaching and research, and with S3, provided extensibility in the form of libraries
- Most links have died by now, but see this [FAQ](#) for a flavour - there was a lively community of applied statisticians during the 1990s
- Academics like Ross Ihaka and Robert Gentleman found S-PLUS constraining (platform, price, data structures)
- ... so we get to R

R did not always look like an alternative implementation of the S language. It started as a small Scheme-like interpreter (loosely based on work by Sam Kamin [4] and David Betz [2]). This provided a platform for experimentation and extension. The following dialog shows a very early version of the R interpreter at work.

```
> (define square (lambda (x) (* x x)))
square
> (define v 10)
v
> (square v)
100
```

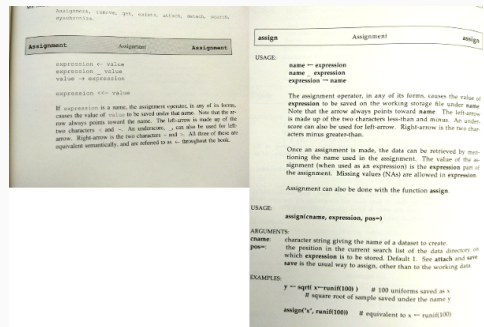
The S-like appearance of R was added incrementally. We initially moved to an S-like syntax for our experiments because, although we were both familiar with Lisp syntax, we didn't feel that it was really suitable for expressing statistical computations. This choice of syntax set us on a path towards compatibility with S. Once initiated, the move towards compatibility with S was irresistible. This was partly because we wanted to see just how far we could push it and partly because it gave us access to code resources and developers.

(JSM talk)

- Luke Tierney was in R core in 1997, and has continued to exert clear influence over development
- Because R uses a Scheme engine, similar to Lisp, under the hood, his insight into issues like the garbage collector, namespaces, byte-compilation, serialization, parallelization, and now **ALTREP** has been crucial ([see also the proposal by Luke Tierney, Gabe Becker and Tomas Kalibera](#))
- Many of these issues involve the defensive copy on possible change policy involved in lazy evaluation, which may lead to multiple redundant copies of data being present in memory
- Luke Tierney and Brian Ripley have fought hard to let R load fast, something that is crucial to ease the use of R on multicore systems or inside databases

Vintage R

Why was `underscore_separated` not a permitted naming convention in R earlier (see [Bååth \(2012\)](#))? `_` was not a permitted character in names until it had lost its left assign role, the same as `<-`, in 1.9.0 in 2004. (Brown Book p. 256, Blue Book p. 387)



Why is the **factor** storage mode still so central? **stringsAsFactors = TRUE** was the legacy **as.is = FALSE**; analysis of categorical variables was more important, and **factor** only needed to store **nlevels()** strings (White Book p. 55-56, 567)

If this is on a file named "auto1" it can be read in and turned into a data frame by a simple call to `read.table()`.

```
> somedata <- read.table("auto1")
> dim(somedata)
[1] 10  5
> dinnames(somedata)
[[1]]:
 [1] "Acura.Integra.4"      "Audi.100.5"          "BMW.325i.6"
 [4] "Chevrolet.Lumina.4"   "Ford.Festiva.4"       "Mazda.929.V6"
 [7] "Mazda.MX.5.Miata"     "Nissan.300ZX.V6"      "Oldsmobile.Calais.4"
[10] "Toyota.Cressida.6"

[[2]]:
 [1] "Price"      "Country"      "Reliability"  "Mileage"      "Type"
```

Let's look at this example in a little more detail to see what is going on. The file contained fields separated by "white space", one or more blanks or tabs. The first line of the file contained five fields, meant to be the names for the variables; the remaining lines had six fields, the first being the row label and the rest the data for this observation. Some of the fields are numeric; others are character strings. The character strings will be turned into factor variables, as we can see by the following:

56

CHAPTER 3. DATA FOR MODELS

```
> sapply(somedata, data.class)
      Price Country Reliability  Mileage    Type
"numeric" "factor" "numeric"  "numeric" "factor"
```

USE QUESTIONS: drop

drop = TRUE for array-like objects;
since matrices are vectors with a **dim**
attribute, choosing (part of) a row or
column made **dim** redundant (Blue
Book p. 128, White Book p. 64)

creates a matrix with two rows, since the specified names occur among the row dimnames for the matrix. As with vector subscripts, it is possible to replicate rows and/or columns in subscripting matrices. In fact, this is a powerful technique (see the exercises below).

If the matrices resulting from subscribing end up with one row or one column, there is a choice to make. S can retain the matrix properties or it can drop one dimension to produce a vector. By default, S drops these redundant, or "dead," dimensions.

```
> n <- matrix(1:12, 3, 4)
> n[, 2]
[1] 4 5 6
```

In most cases of interactive computing, that is the right choice since it tends to reduce complexity—why have a 1-column matrix when a vector will do. However, when you are writing functions, you may need to rely on a subscripted matrix remaining a matrix. In this case, add `drop=F` to the subscripts:

```
ml, which, drop=FALSE)
```

This ensures that no dimensions will be dropped, and allows you to avoid surprises when one or the other subscript happens to leave only one element.

Exercises

Data frames can be treated as matrices in calls to most of the basic functions treating arrays: subsets and elements, `dim()`, `dimnames()`, and functions based on those. If `x` is a data frame, then

```
x[i,:]; x[:,j]; x[i,j]
dim(x); dimensions(x)
nrow(x); ncol(x)
```

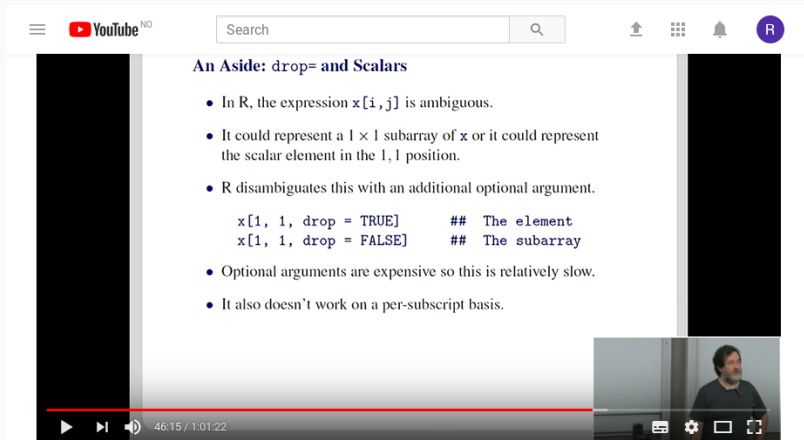
produce results corresponding intuitively to their behavior on matrices. For example, `x[,1]` produces a new data frame by using 1 to index the rows of `x`. The indexing by 1 can use numeric, logical, or character values. Similarly, `x[,j]` indexes on the columns (the variables) and `x[i,j]` on both. When a single column is selected, the result is by default the variable, not a data frame containing one variable. This action can be suppressed by including the argument `drop=F`, following the rules applied to arrays ([§ 8](#), page 128). For example, if `stats` was some statistic computed for each of the variables in `market.frame`, the expression

```
series.frame[.state > cutoff , drop=Y]
```

ensures that the extracted object is still a data frame, even if it has only one column. A single row by default remains a data frame—there is no generally useful object corresponding to rows of a data frame. If you really want to, however, you can cause the single row to be dropped to a list by including the argument `drop=F`.

BUT SCALARS ARE ALSO VECTORS ...

Treating scalars as vectors is not efficient:



The image shows a YouTube video player interface. At the top, there is a search bar with the text "Search" and a magnifying glass icon. To the right of the search bar are icons for upload, grid, notifications, and a user profile icon labeled "R". Below the search bar, the video content is displayed. The title of the video is "An Aside: drop= and Scalars". The video content includes a list of bullet points and two lines of R code. The first bullet point states that in R, the expression `x[i, j]` is ambiguous. The second bullet point explains that it could represent a 1×1 subarray of `x` or the scalar element at the $1, 1$ position. The third bullet point notes that R disambiguates this with an additional optional argument. The code examples show `x[1, 1, drop = TRUE]` for the element and `x[1, 1, drop = FALSE]` for the subarray. The fourth bullet point mentions that optional arguments are expensive, making this relatively slow. The fifth bullet point states that this approach doesn't work on a per-subscript basis. At the bottom of the video player, there is a progress bar showing 46:15 / 1:01:22, and a small inset video of the speaker.

An Aside: drop= and Scalars

- In R, the expression `x[i, j]` is ambiguous.
- It could represent a 1×1 subarray of `x` or it could represent the scalar element in the $1, 1$ position.
- R disambiguates this with an additional optional argument.

```
x[1, 1, drop = TRUE]    ## The element
x[1, 1, drop = FALSE]   ## The subarray
```

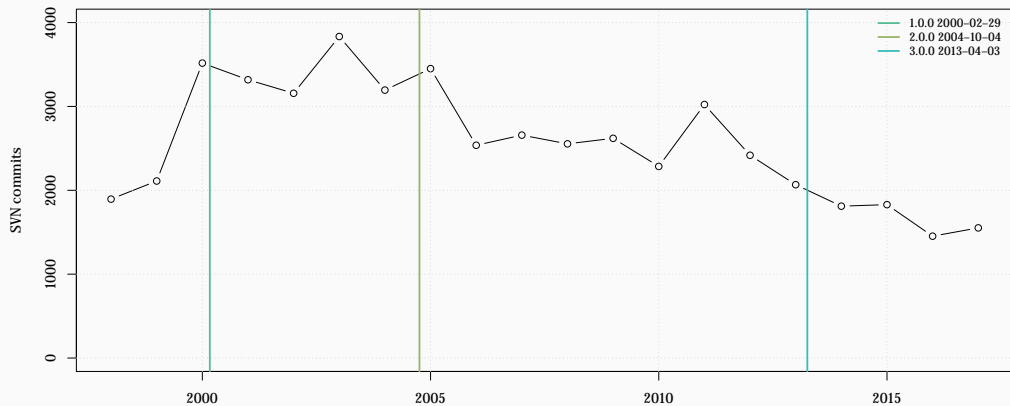
- Optional arguments are expensive so this is relatively slow.
- It also doesn't work on a per-subscript basis.

- An R-0.49 source tarball is available from CRAN
- Diffs for Fedora 27 (gcc 7.3.1) include setting compilers and `-fPIC` in `config.site`, putting `./` before `config.site` in `configure`, and three corrections in `src/unix`: in `dataentry.h` add `#include <X11/Xfuncproto.h>` and comment out `NeedFunctionPrototypes`; in `rotated.c` comment out `/*static*/ double round`; in `system.c` comment out `__setfpucw` twice; BLAS must be provided externally
- Not (yet) working: prototypes are missing in the `eda` and `mva` packages so the shared objects fail to build
- R-0.49 video

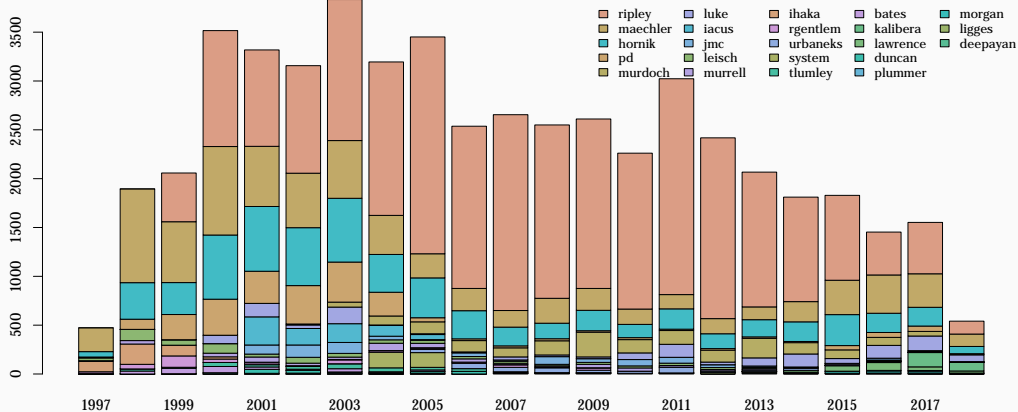
R SVN logs

- The command: `svn log --xml --verbose -r 6:74688 https://svn.r-project.org/R/trunk > trunk_verbose_log1.xml` provides a rich data source
- Each log entry has a revision number, author and timestamp, message and paths to files indicating the action undertaken for each file
- The XML version is somewhat easier to untangle than the plain-text version
- I haven't tried possible similar approaches to Winston Chang's [github r-source repo](#)

COMMITTS 1998-2017



COMMITTS BY AUTHOR AND YEAR BETWEEN R6 AND R74688



```
## <logentry revision="6">
##   <author>ihaka</author>
##   <date>1997-09-18T04:41:25.000000Z</date>
##   <paths>
##     <path action="M" prop-mods="false" text-mods="true" kind="file">/trunk/src/library/base/R/lm</path>
##   </paths>
##   <msg>New predict.lm from Peter Dalgaard</msg>
## </logentry>

## <logentry revision="74688">
##   <author>ripley</author>
##   <date>2018-05-03T11:11:00.501520Z</date>
##   <paths>
##     <path text-mods="true" kind="file" action="M" prop-mods="false">/trunk/src/library/tools/R/utls.R</path>
##   </paths>
##   <msg>TexLive 2018 may produce logs not in the current encoding</msg>
## </logentry>
```

COMMIT MESSAGES BY NUMBER OF FILES AFFECTED, YEAR AND REVISION

```
## 2015 68948 2150 use https
## 2012 59039 1727 use preferred form of 'R Core Team'
## 2011 56186 1260 Revert r56184 and r56185
## 2011 56184 1249 Remove redundant \alias entries from man pages
## 2007 42333 1223 add copyright/licence header, remove CVS-style $Id fields
## 2012 61433 620 remove trailing spaces
## 2012 60146 602 add copyright statements
## 2007 42338 559 add licence statements
## 2012 59780 524 update, including bug-reporting address
## 2003 27444 497 splitting base
```


| | | | | | | | |
|----|-------|------------|------|------|--------------|-------|-----------|
| ## | | | | | | | |
| ## | tools | FAQ | m4 | etc | configure.ac | share | configure |
| ## | 396 | 467 | 579 | 601 | 693 | 1085 | 1319 |
| ## | BUGS | date-stamp | po | NEWS | tests | doc | src |
| ## | 1485 | 2531 | 3762 | 5842 | 11445 | 11484 | 97067 |

EPOCH FILE COMMITS IN TRUNK/SRC

```
##
## windows graphics      gnome macintosh      appl      unix      nmath      scripts      extra      modules
##      74      79      217      611      796      1524      1764      1966      2315      2358
## include gnuwin32      main      library
##      3528      9140      15011      57563
```

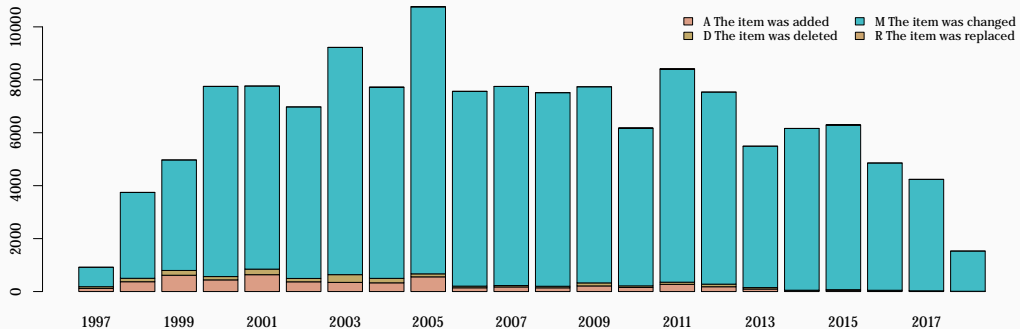
EPOCH FILE COMMITS IN TRUNK/SRC/LIBRARY

```
##
##      mle Recommended      stepfun Makefile.in      lqs      eda      compiler
##      65      94      109      130      135      158      234
##      profile      stats4 translations      nls      datasets      modreg      mva
##      247      261      296      319      333      402      462
##      splines      ctest      tcltk      ts      parallel      grid      graphics
##      464      549      865      900      1096      1931      2158
##      grDevices      methods      utils      stats      tools      base
##      3695      3982      5397      6840      7028      19331
```

EPOCH FILE COMMITS IN TRUNK/SRC/LIBRARY/BASE

```
##
##      Makefile DESCRIPTION.in      makebasedb.R      Makefile.win      basel loader.R      demo
##          8          10          11          18          32          61
##      data      Makefile.in          inst          po          R          man
##          66          75          270          497          6719      11557
```

FILES BY YEAR AND COMMIT ACTION



CRAN and BioConductor packages

- Once S3 permitted extension by writing functions, and packaging functions in libraries, S and R ceased to be monolithic
- In R, a library is where packages are kept, distinguishing between base and recommended packages distributed with R, and contributed packages
- Contributed packages can be installed from CRAN (infrastructure built on CPAN and CTAN for Perl and Tex), Bioconductor, other package repositories, and other sources such as github
- With over 12000 contributed packages, CRAN is central to the R community, but is stressed by dependency issues (CRAN is not run by R core)

- Andrie de Vries [Finding clusters of CRAN packages using igraph](#) looked at CRAN package clusters from a page rank graph
- We are over three years further on now, so updating may be informative
- However, this is only CRAN, and there is the big BioConductor repository to consider too
- Adding in the BioConductor (S4, curated) repo does alter the optics, as you'll see, over and above the cluster dominated by **Rcpp**

| | | | | | | | |
|----|---------------|--------------|--------------|---------------|---------------|------------|-----------|
| ## | Rcpp | MASS | ggplot2 | AnnotationDbi | Matrix | dplyr | plyr |
| ## | 0.022904 | 0.012068 | 0.011862 | 0.011165 | 0.006948 | 0.006738 | 0.005348 |
| ## | mvtnorm | Biobase | survival | stringr | data.table | lattice | igraph |
| ## | 0.005125 | 0.005062 | 0.005036 | 0.004683 | 0.004207 | 0.004105 | 0.003996 |
| ## | RcppArmadillo | httr | magrittr | jsonlite | IRanges | reshape2 | S4Vectors |
| ## | 0.003946 | 0.003917 | 0.003904 | 0.003813 | 0.003668 | 0.003524 | 0.003481 |
| ## | foreach | sp | RColorBrewer | shiny | GenomicRanges | Biostrings | tidyr |
| ## | 0.003305 | 0.003274 | 0.003100 | 0.002987 | 0.002739 | 0.002574 | 0.002486 |
| ## | tibble | BiocGenerics | | | | | |
| ## | 0.002474 | 0.002443 | | | | | |



A word cloud of R packages. The largest word is 'MASS'. Other prominent words include 'ggplot2', 'survival', 'plyr', 'igraph', 'Matrix', 'data.table', 'reshape2', 'lattice', 'RColorBrewer', 'nlme', 'gridExtra', 'doParallel', 'foreach', 'raster', 'coda', 'zoo', 'scales', 'mvtnorm', and 'sp'.

MASS
plyr
igraph
nlme
RColorBrewer
gridExtra
survival
doParallel
raster
coda
zoo
scales
foreach
reshape2
lattice
ggplot2^{sp}
mvtnorm
Matrix
data.table



A word cloud of R packages. The largest word is 'stringr'. Other prominent words include 'jsonlite', 'dplyr', 'tibble', 'Rcurl', 'XML', 'shiny', 'magrittr', 'tidyr', 'lubridate', 'httr', 'purrr', 'assertthat', 'rlang', 'readr', 'xml2', 'knitr', 'tidyr', 'R6', and 'digest'.

tibble
purrr
jsonlite
Rcurl
XML
assertthat
shiny
magrittr
tidyr
lubridate
httr
dplyr
readr
rlang
xml2
knitr
tidyr
R6
digest

CRAN/BIOCONDUCTOR TOP SIX PAGE RANK CLUSTERS

reshape2
mvtnorm
igraph
nlme gridExtra
zoo coda
data.table
raster
scales
SPLattice
plyr
survival
doParallel
MASS
ggplot2
Matrix
RColorBrewer
foreach

dplyr
RCurTubRState
tidy
stringr
magrittr
XML
shiny
tibble
jsonlite
digest

BiocGenerics
IRanges
S4Vectors
Biostrings
GenomicRanges
SummarizedExperiment
Biobase

Rcpp
RcppArmadillo

AnnotationDbi

BiocParallel

- Francois Keck explored CRAN package co-authorship in a more recent blog: [Exploring the CRAN social network](#)
- Once again, a little time has passed, so maybe things have shifted
- Thanks to Martin Morgan, I've added listings corresponding in part to `tools::CRAN_package_db()`
- It is refreshing to see that BioConductor is clearly present, and the people implicated are active in upgrading R internals

FIRST 3 PACKAGE AUTHOR CLUSTERS

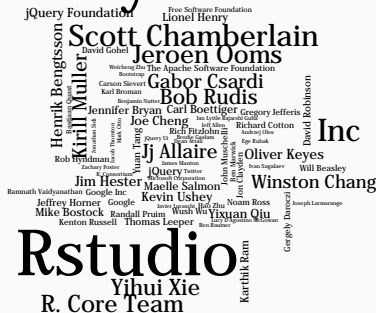
| ## | Name | Package | ## | Name | Package | ## | Name | Package |
|-------|-------------------|---------|-------|-------------------|---------|-------|-------------------------|---------|
| ## 1 | Kurt Hornik | 62 | ## 1 | Rstudio | 110 | ## 1 | Rafael A. Irizarry | 13 |
| ## 2 | Martin Maechler | 52 | ## 2 | Hadley Wickham | 107 | ## 2 | Hector Corrada Bravo | 13 |
| ## 3 | Achim Zeileis | 49 | ## 3 | Inc | 50 | ## 3 | Kasper Daniel Hansen | 12 |
| ## 4 | Dirk Eddelbuettel | 48 | ## 4 | Scott Chamberlain | 49 | ## 4 | John D. Storey | 12 |
| ## 5 | Brian Ripley | 35 | ## 5 | Jeroen Ooms | 40 | ## 5 | Jeffrey T. Leek | 11 |
| ## 6 | Romain Francois | 28 | ## 6 | R. Core Team | 38 | ## 6 | Andrew E. Jaffe | 10 |
| ## 7 | Torsten Hothorn | 28 | ## 7 | Yihui Xie | 36 | ## 7 | Leonardo Collado-Torres | 8 |
| ## 8 | Ben Bolker | 27 | ## 8 | Bob Rudis | 32 | ## 8 | Benilton Carvalho | 6 |
| ## 9 | Douglas Bates | 26 | ## 9 | Jj Allaire | 31 | ## 9 | Rafael Irizarry | 6 |
| ## 10 | Roger Bivand | 25 | ## 10 | Kirill Muller | 31 | ## 10 | Matthew N. McCall | 6 |
| ## 11 | Thomas Lumley | 24 | ## 11 | Gabor Csardi | 30 | ## 11 | W. Evan Johnson | 5 |
| ## 12 | Michael Friendly | 21 | ## 12 | Winston Chang | 27 | ## 12 | Tim Triche | 5 |

Figure 1: extract_ hell

FIRST TWO PACKAGE AUTHOR CLUSTERS



Hadley Wickham



FIRST 6 PACKAGE AUTHOR CLUSTERS

Achim Zeileis
Kurt Hornik
Thomas Lumley
Friedrich Leisch
Roger Bivand
Brian Ripley
Douglas Bates
Martin Maechler
Dirk Eddelbuettel
Romain Francois
Michael Friendly

Jeroen Ooms
Kevin Ushey
Mikolaj Hocky
Carl Beucler
Henrik Bengtsson
Scott Chamberlain
Yihui Xie
J.J. Allaire
Oliver Keyes
Bob Rudis
Gabor Csardi
R Core Team
Hadley Wickham
Rstudio

Martin Morgan
Michael Lawrence

Robert I. Huth
Bob I. Huth
Trey Hastie

Robert I. Huth
Bob I. Huth
Trey Hastie

Robert I. Huth
Bob I. Huth
Trey Hastie

- Many sources in applied statistics with an S-like syntax but Lisp/Scheme-like internals, and sustained tensions between these
- Many different opinions on preferred ways of structuring data and data handling, opening for adaptations to different settings
- More recently larger commercial interest in handling large input long data sets, previously also present; simulations also generate large output data sets; bioinformatics both wide and long
- Differing views of the world in terms of goals and approaches
- Differences provide ecological robustness