R : Past and Future History

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The R Language and Environment

- R is a computer language and run-time environment which can be used to carry out statistical (or other quantitative) computations.
- The base part of R comes with a wide range of standard statistical and graphical analyses built in, including:
  - nonparametric statistics
  - parametric statistical modelling
  - multivariate analysis
  - smoothing and nonparametric fitting
  - time series analysis
- There are a large number of user-developed extension *packages* which provide an even richer set of capabilities.

Licensing

- R is free software released under the Free Software Foundation's General Public License (see `wwww.fsf.org`).
- This means that R is free of any restrictions on how it can be disseminated.
- In particular, versions of R can be obtained without charge and can be redistributed to others.
- The license prevents the creation of encumbered derived works (i.e. commercial versions).

Uptake

- Because of its license, it is very hard to determine what the installed base of R might be.
- The R development group has confined itself to estimates of the form: "somewhere in excess of 50,000."
- A recent New York Times article presented the estimates: one million (Intel Capital) and two million (Revolution computing).

The R Language

- R is an expression-based language.
  - Users type language *expressions* at the R prompt.
  - These expressions are *evaluated* by the R *interpreter*..
  - The computed values of the expressions are printed.
- R is extensible.
  - Users can implement new functionality in the form of *functions*.
  - Developers can implement new *packages* of functionality that extends the base system.

An Example

Read a data set into R (from a network URL).

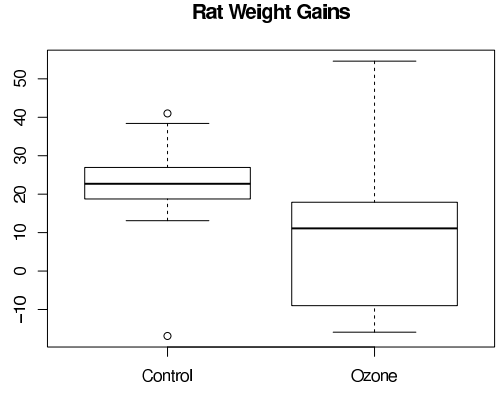
```
> url = paste("http://www.stat.auckland.ac.nz",
              "~ihaka/data",
              "rats.csv", sep = "/")
> rats = read.csv(url)
```

Examine the basic stucture of the data.

```
> summary(rats)
   WeightGain          Group
 Min.   :-16.90   Control:23
 1st Qu.: 10.10   Ozone  :22
 Median : 18.30
 Mean   : 16.83
 3rd Qu.: 26.00
 Max.   : 54.60
```

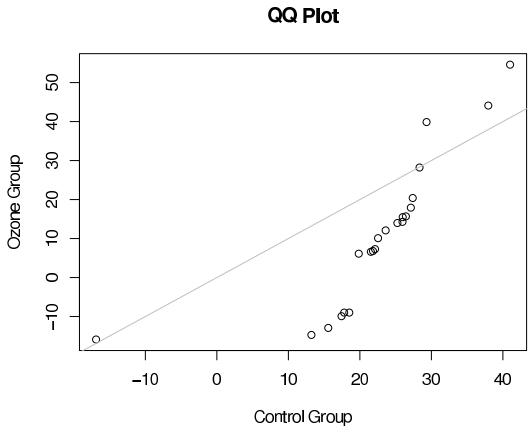
Example (Continued)

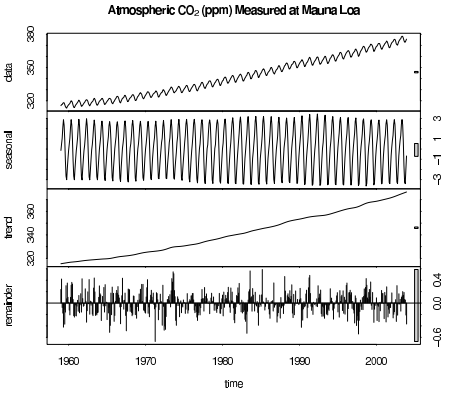
```
> with(rats, tapply(WeightGain, Group, mean))
 Control    Ozone
22.40435 11.00909


> with(rats, summary(aov(WeightGain ~ Group)))
            Df  Sum Sq Mean Sq F value  Pr(>F)
Group        1  1460.1  1460.1  6.1872 0.01682
Residuals   43 10147.5   236.0

> boxplot(WeightGain ~ Group, data = rats,
          main = "Rat Weight Gains")
```

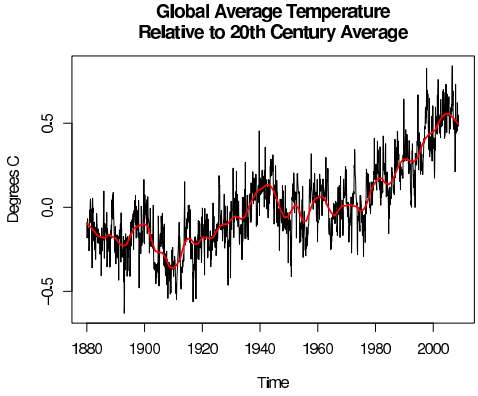


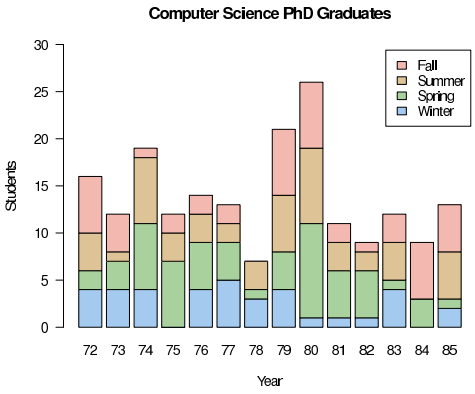
Example Continued

```
> with(rats,
       qqplot(WeightGain[Group == "Control"],
              WeightGain[Group == "Ozone"],
              main = "QQ Plot",
              xlab = "Control Group",
              ylab = "Ozone Group"))

> abline(0, 1, col = "gray")
```





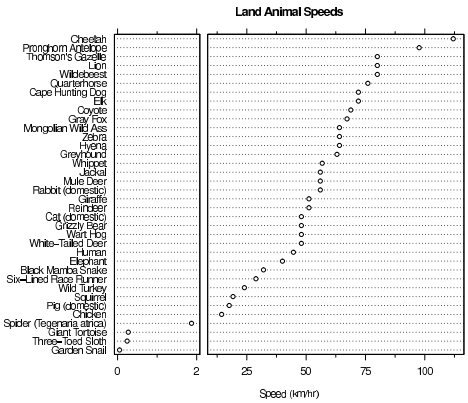


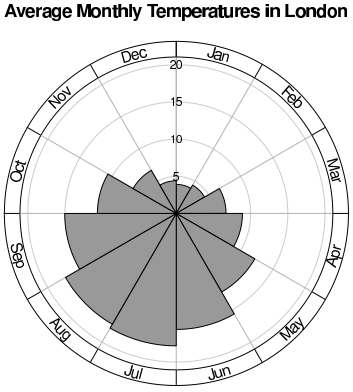


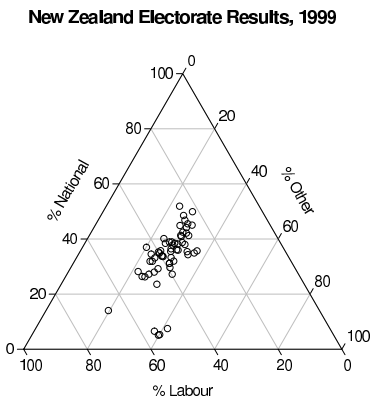
Extensibility

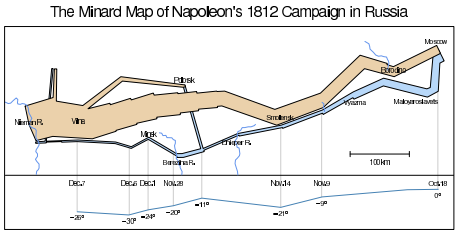
Define a square root function using Newton's method.

```
> root =
      function(x) {
          rold = 0
          rnew = 1
          while(any(rnew != rold)) {
              rold = rnew
              rnew = 0.5 * (rnew + x/rnew)
          }
          rnew
      }

> root(1:4)
[1] 1.000000 1.414214 1.732051 2.000000
```









Early History - 1990

- Ross Ihaka joins the Department of Statistics at the University of Auckland.
- Robert Gentleman spends sabbatical from the University of Waterloo.
- During a chance encounter in the corridor, the following exchange takes place:

  Gentleman: "Let's write some software."
  Ihaka: "Sure, that sounds like fun."

- The initial goal is to build a testbed for trying out ideas and to publish a paper or two.

The Initial Language

```
> (set x (seq 10))
(1 2 3 4 5 6 7 8 9 10)

> (sum x)
55

> (set factorial (lambda (x)
  (if (< x 1)
      1
      (* x (factorial (- x 1))))))
<closure>

> (factorial 5)
120
```

Early History - 1992

- Robert Gentleman joins the department at Auckland.
- A decision is made to develop enough of a language to teach introductory statistics courses at Auckland.
  - It is decided to adopt the syntax of the S language developed at Bell Laboratories.
  - As a joke, the name "R" is coined for the language (standing for Robert and Ross).

Early History - 1994

- An initial version of the language is complete.
- We have begun discussing what we are doing with colleagues overseas.
- A number of these colleagues encourage us to release the language as "free software."
- A little thought convinces us that there are limited prospects for the software as a commerical product.
- We adopt the free software foundation GPL as our license and begin to make releases via the internet.

Early History - 1996

- By 1996 we were becoming victims of our own success.
- We were being supplied with a continual stream of bug reports and suggestions for improvement.
- Maintaining the mailing list was becoming problematic.
- It was beginning to be clear that the project was getting close to the limit of what two of us could handle.

The original R developers plotting world domination.

R Becomes A GNU Project

```
From:  Richard Stallman <rms@gnu.ai.mit.edu>
To:  ihaka@stat.auckland.ac.nz
cc:  rms@gnu.ai.mit.edu
Subject:  Re:  Seen on your wishlist
Date:  Tue, 16 Sep 1997 21:56:06 -0400

   So [explicitly], yes we would like R to be
   considered as a GNU program.

I hereby dub R GNU software!
```

1997 - The Watershed Year

- The mailing list turned out to be very successful and our user base increased enormously (to nearly 100!).
- The list was so successful that was split into the present `r-help` and `r-devel` lists.
- Kurt Hornik and Fritz Leisch established the CRAN archive at TU Vienna as a repository for user contributions.
- We became so deluged with patches and requests for enhancements that we decided to open up the development process by giving a selected "core" of developers direct access to the CVS archive.

A Free Software Project

- Since we opened up the project, it has gone ahead in leaps and bounds.
- On February 29, 2000, the software was deemed fully featured enough and stable enough for the 1.0 release to take place.
- There are now nearly 20 core developers maintaining and extending the language interpreter and its basic functionality.
- The group includes a number of well-known researchers in Statistical Computing.
- The software now has a regular six-monthly release cycle and will shortly see the release of version 2.10

The intense software development effort leading up to R version 1.

Current Status

- The *R Project* is an international collaboration of researchers in statistical computing.
- The formal structure for the project is provided by the *R Foundation*, a non-profit foundation based in Vienna.
- Development is carried out by the roughly 20 members of the "R Core Team."
- Releases of the R environment are made through the CRAN (comprehensive R archive network) twice per year.
- The software continues to be released under a "free software" license.

Current Status

- There are some 50 books which have been published (or are in preparation) dealing with R and its applications.
- Springer has a book series dedicated to R (currently there are 20 titles in the series).
- The "R Newsletter" is about to be relaunched as the "R Journal."
- There are over 1700 extension *packages* which have been contributed to CRAN.

Limitations

- R is a useful piece of software, but it does have limitations.
- Two major complaints are:
  - "It's too slow for my analysis."
  - "It can't handle my multigigabyte data set."
- Help is on the way for the first of these problems.
- The second issue is fundamental.

Why Speed Can be Improved

- Multicore machines are becoming commonplace, soon they will be ubiquitous.
- Within a year or two this should provide an order of magnitude improvement for many statistical problems.
- The improvement is possible because many of R's computations are vectorised and it is possible to partition them and assign the subproblems to separate processors.

Why Size is a Problem

The following example shows a simple computation which extracts the diagonal from an $n \times p$ matrix `x`.

```
x[row(x) == col(x)]
```

This essentially says to return those elements of `x` where the row index is equal to the column index.

The calculation requires the following objects be created:

- An $n \times p$ matrix of row indices.
- An $n \times p$ matrix of column indices.
- An $n \times p$ matrix of logicals from comparing row and column indices.

The data storage required is 4 times that of the original matrix.

Scalar Computations

The computation of a matrix diagonal can be done in a scalar fashion.

```
k = min(n, p)
d = numeric(d)
for(i in 1:k)
    d[i] = x[i, i]
```

The problem with this is that R is optimised for vector and array computations and the computation above can run very slowly.

Compilation

- Computational performance can often be improved by the process of *compilation*.
- Compilation is the process of replacing references to values by name in program by references to their location.
- The example

```
silly =
    function(x) {
        if (x > 0) y = 1
        y
    }
```

  demonstrates that compilation is not a viable option for R.

A New Language?

- Because of the performance and resource consumption problems with R, a new language is needed.
- Initial work indicates that it is possible to build a language which will perform two orders of magnitude faster than R for scalar computations and use significantly less memory than R for tasks such as model fitting.
- At the moment progress is slow because there are just three people working part-time on the project (Ihaka, Duncan Temple Lang and Brendan McArdle).
- Progress is slow because the research is unsupported.