The R language and why you should be using it

Roger Barlow
Huddersfield University

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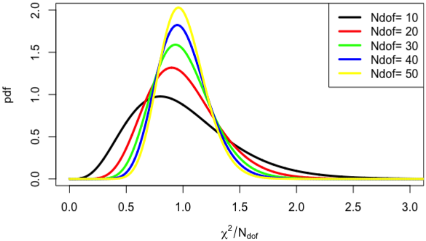
Reasons for learning R

1. It's the definitive language for serious statistics
2. It's very easy to learn. Gentle learning curve: you can do useful stuff straight away
3. It provides really neat and easy plots for your talks and publications




```
Ndof <- seq(10,50,10)
colours <- c("black","red","green","blue","yellow")
plot(0,0,type='n',xlim=c(0,3),ylim=c(0,2),ylab="pdf",xlab=expression(chi^2/N[dof]
xx  <- seq(0,300,.01)
for(n in  Ndof) lines(xx/n,n*dchisq(xx,n),lwd=3,col=colours[n/10])
legend('topright',col=colours,legend=paste("Ndof=",Ndof),lwd=3)
```

4. It's a beautiful language enabling you to write really elegant code

Download in seconds

From `r-project.org` for R or `rstudio.com` for the Rstudio IDE.

R - key facts

- R is the freeware version of the statistics language S
- It's an interpreted language - hence user-friendly
- Incorporates nice features of earlier languages: Algol, APL, LISP etc
- Only four types: `numeric, logical, character, complex` . (`complex` is rare.) All numbers are stored as doubles.
- Very weakly typed. No need to declare variables before use.
- R is a rich language: the same thing can often be done is several ways. Sometimes they are equivalent, sometimes not.
- Run programs (also known as scripts) through `source("`*filename*`")` or use R-studio
- Statements terminated by newline (unless incomplete) or semicolon
- Everything is a vector
- Easy to use basic functions are generally extended through optional arguments
- Comprehensive online help through `help(`*topic*`)` and user manual

A first R session

What you type is shown in blue

It has the usual operators

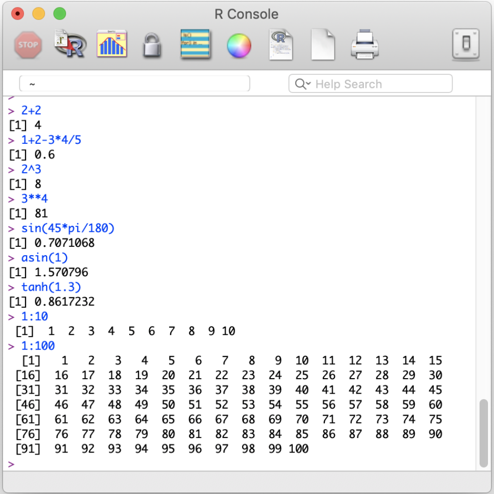
including exponentiation, which can be ** or ^

It has the usual functions

and some less usual ones

The : operator generates a vector

The meaning of the square brackets is revealed.
Everything is a vector



Doing things with vectors

The `seq` (sequence) function generalises the : operator

You can specify the increment or the length

The `rep` (repeat) function is also handy

The `c` function - for combine. concatenate or column-vector - is used all the time

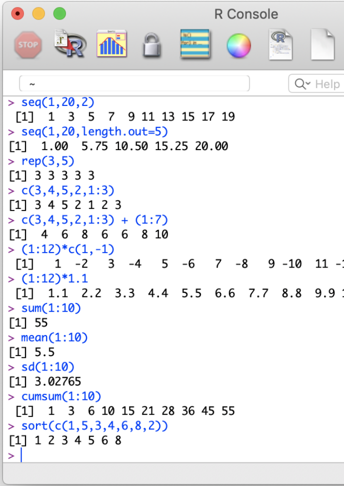
Operations between two vectors take place element by element

If the vectors are not the same length, the shorter one is it recycled

Operations with a single number are a special case of this

The functions `sum`, `mean` and `sd` operate on vectors to give a number

Other useful functions like `cumsum` and `sort` . Also `max,min,range,length...`



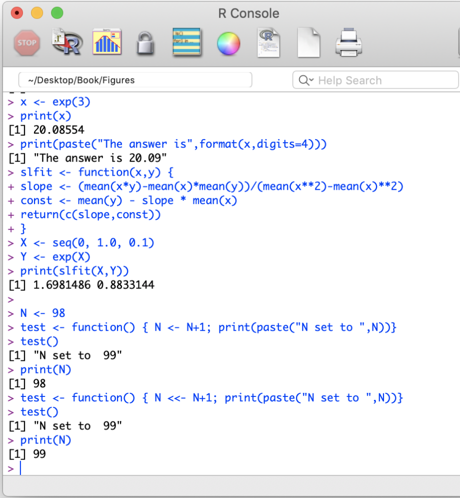
Variables and functions

from a calculator to a computer

The assignment operator is `<-`
(`=` works but `<-` is preferable)

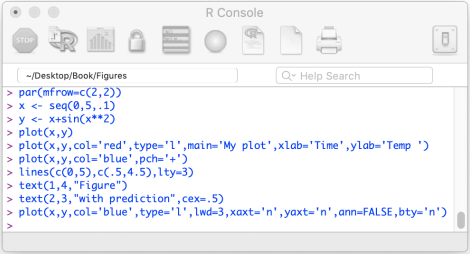
For printing results, `paste` is vital. It inserts spaces - use `paste0` if you don't want them
Use `format` to tidy the output

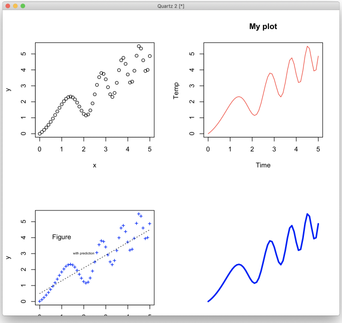
Functions are easy to define.
You can only return one thing - but that can be a vector
They have read access to higher scope variables but write only to local copies except with the 'super-assign' double-headed arrow `<<-`



Plots

`plot(x,y).` gets you started
Then you can add options





Use `lines` `points` `text` `legend` and `polygon` to add to an existing plot
Options apply only to that function call.
To make them stick use `par`
`par` also used for multiframes

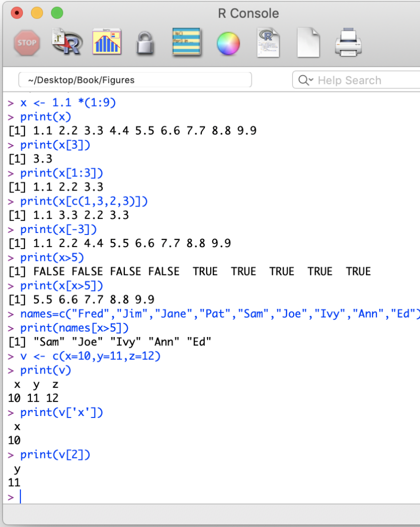
Use square brackets. The index is a number (and starts at 1)

But the index can also be a vector (as everything is a vector)

If the index is negative, it means ‘everything except’

Or the index can be logical.

Or the index can be character



Program Control

Part 1: How to use them

The usual looping and branching commands are provided.
{ parentheses } define blocks

```
for (i in 1:10) {
stuff
}

error=100 ; count=0
while (error>1E-5 & count<100) {
error <- iteratefit(data)
count <- count+1
}
if (x>99) {
stuff
} else {
more stuff
}
```

Program Control

part 2: How to avoid them

You have 100 values in x and you need to find the averages for the positive and negative values. A C++ program could be

```
int np=nm=0;
double sp=sm=0;
for(int i=0;i<100;i++){
    if (x[i]>0) {sp+= x[i]; np++;}
    if (x[i]<0) {sm+= x[i]; nm++;}
    }
cout<<" average of positive values "<<sp/np<<" and of
negative values "<<sm/nm<<endl;
```

The R version is just

```
print (paste( " average of positive values", mean(x[x>0]),
"and of negative values ",mean(x[x<0])))
```

If you find yourself using an `if` statement in R, maybe think again.
If you find yourself using a `for` loop in R, definitely think again.

From vectors to matrices

Vector: a block of elements, all of the same type.

It has a length `length(v)`

An array is a vector which *also* has a dimension `dim(v)`.
Can be read or written.
(Product of dimensions must equal length)

Omitting index gives all values (slicing)

Function `matrix` also available

```
> x <- 1:12
> print(x)
 [1]  1  2  3  4  5  6  7  8  9 10 11 12
> length(x)
[1] 12
> dim(x)
NULL
> dim(x)=c(3,4)
> print(x)
     [,1] [,2] [,3] [,4]
[1,]    1    4    7   10
[2,]    2    5    8   11
[3,]    3    6    9   12
> print(x[3,4])
[1] 12
> print(x[3,])
[1]  3  6  9 12
> dim(x)=c(2,6)
> print(x)
     [,1] [,2] [,3] [,4] [,5] [,6]
[1,]    1    3    5    7    9   11
[2,]    2    4    6    8   10   12
> dim(x)=c(2,3,2)
> print(x)
, , 1

     [,1] [,2] [,3]
[1,]    1    3    5
[2,]    2    4    6

, , 2

     [,1] [,2] [,3]
[1,]    7    9   11
[2,]    8   10   12

> y <- matrix(1:12,3,4)
> print(y)
     [,1] [,2] [,3] [,4]
[1,]    1    4    7   10
[2,]    2    5    8   11
[3,]    3    6    9   12
```

Matrix calculations

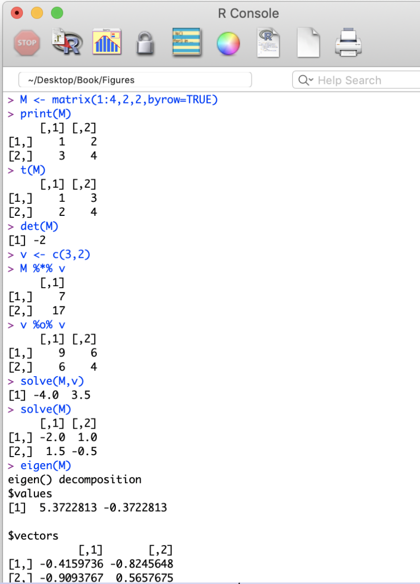
Functions `t` for transpose, `det` for determinant

Operator `%*%` does matrix product

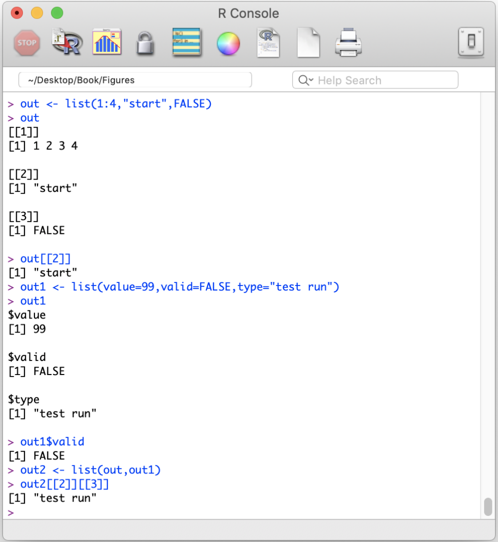
Operator `%o%` does outer (Cartesian) product

`solve(A,b)` for linear equations
Ax=b
`solve(A)` on its own gives inverse

Eigenvector/value analysis comes as standard



Lists



A vector is a block of elements, all of the same type

A list is a block of elements which may be of different types

List indexing by double square brackets

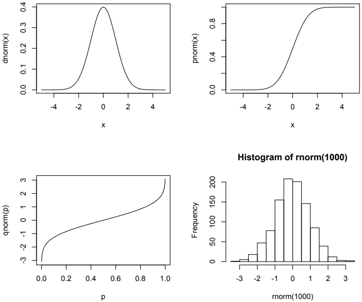
or by name - very useful for function returns

List elements can be lists

Statistics functions and random numbers

Note: this *is* a statistics package so Gaussians are called 'Normal'

`dnorm(x)` gives unit Gaussian $\frac{1}{\sqrt{2\pi}}e^{-x^2/2}$
`dnorm(x,mu,sigma)` gives general Gaussian
`pnorm(x)` gives integrated Gaussian.
`qnorm(p)` gives the inverse. ("How many sigma is 95%?" etc)
`rnorm(n)` generates n random numbers



Same pattern for other functions:

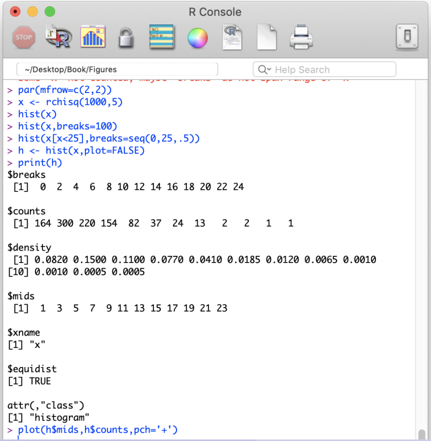
Poisson	`dpois(r,mu)` `ppois(r,mu)` `qpois(p,mu)` `rpois(n,mu)`
Uniform.	`dunif(x)` or `dunif(x,a,b)` `punif(x)` `qunif(p)` `runif(n)`
χ^2	`dchisq(x,N)` `pchisq(x,N)` `qchisq(p,N)` `rchisq(n,N)`.
Binomial	`dbinom(r,N,P)` `pbinom(r,N,P)` `qbinom(p,N,P)` `rbinom(n,N,P)`

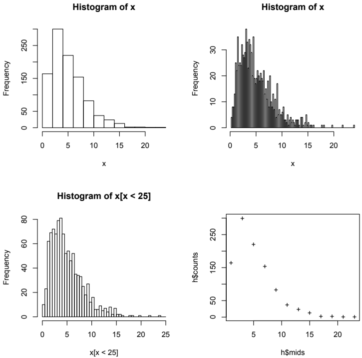
... and so on

Histograms

Just so easy using `hist` !

Override default binning with `breaks`.
Histogram contents available through self-describing list





Histograms

Compare and contrast:

A histogram in R

```
h <- hist(x)
```

A histogram in ROOT

```
#include "TH1F.h"
TH1F* h = new TH1F("h","My title",100,0,1);
for(int_t i=0;i<N;i++) {h->Fill(x[i]);}
h->Draw();
c1->Update();
delete h;
```

Character Strings

Character strings are demarcated by single or double quotes.
`"Hello, world"` or `'Hello, world!'`
Length given by `nchar(string)`
Strings can be tested for equality (unlike C)

Merge by `paste` . Coerces all its arguments into being character strings.
Separate by `strplit("Hello, world"," ")`
Substrings `substr(string, from, to)` may be read or assigned-to
Replacement by `sub(find, replace, string)` and `gsub`
Location using `grep(pattern,string)` - lots of variants

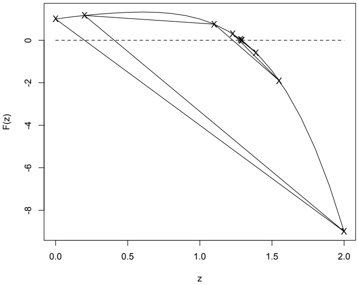
If you're not into `grep` and regular expressions, use the `stringr` package.
`library(stringr)`

Fitting I

Solving an equation

```
F <- function(x){
    return(1+x-x**2+x**3-x**4)}
uniroot(F,c(0,2))
```

$root
[1] 1.290647
$f.root
[1] 8.489406e-06
$iter
[1] 9
$init.it
[1] NA
$estim.prec
[1] 6.103516e-05



Fitting II

Maximising a 1-D function

Take same function `F(x)`

```
optimize(F,c(0,2),maximum=TRUE)
```

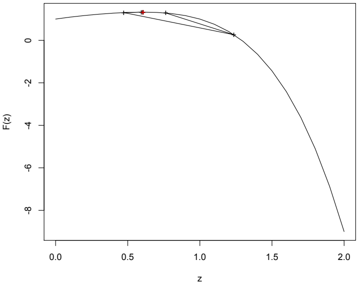
$maximum

[1] 0.6058243

$objective

[1] 1.326447

Takes 10 iterations



Fitting III

Maximising in higher dimensions

Test with famous Rosenbrock function

```
Rosenbrock <- function(x){
return((x[1]-1)**2 +
100*(x[1]**2-x[2])**2)}
```

Minimum at (1,1) but valley sides steep

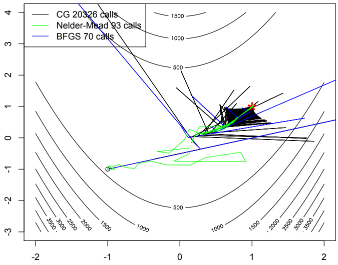
```
optim(c(-1,-1),Rosenbrock)
```

– taking (-1,-1) as the starting value

Default method is Nelder-Mead (like 'SIMPLEX')

Can also try conjugate-gradient `method='CG'` - does worse

and quasi-Newton `method='BFGS'` does better



Other stuff

I havn't had time to talk about

- Data Frames: An array that looks like a lab notebook. Or a spreadsheet. Used a lot, for input and output and packages
- Contour plots: and other 2D graphics
- ggplot: an entirely separate plotting / visualisation package
- Models: used for fitting. You can say things line `z ~ 1 + x + x*y`
- Objects and classes: You can use R for writing OO code, though not quite like Stroustrup
- Web access: Many R functions can read websites etc
- Contributed software: there is lots out there that's not in the core, and it's easy to download and include
- Other features that I havn't learned about yet

Conclusions

R is

- Powerful
- Elegant
- Useful
- User-friendly
- Stuffed with great packages
- Easy-to learn

But don't take my word for it – try it for yourself!