Introduction to R

Nishant Gopalakrishnan, Martin Morgan

Fred Hutchinson Cancer Research Center

19-21 January, 2011
Getting Started

Atomic Data structures
   Creating vectors
   Subsetting vectors
   Factors

Matrices and arrays

Lists, data frames, and environments
   Lists
   Data frames
   Environments

Control flow
   apply

Functions

Visualizing data
Getting help in R

- `help` and `?: help("data.frame") or ? data.frame`
- `help.search("slice"), apropos("mean")`
- `browseVignettes("Biobase")`
- `RSiteSearch (requires internet connection)`
- `R/Bioconductor mailing lists (sessionInfo())`
Data structures in R

R has a rich set of self-describing data structures.

- **vector** - array of the same type
- **factor** - categorical
- **matrix** (2-dimensional), **array** (n-dimensional)
- **list** - can contain objects of different types
- **data.frame** - table-like
- **environment** - hash table
- **class** - arbitrary record type
- **function**
Creating vectors

There are two symbols that can be used for assignment: <- and =.

> v <- 123
[1] 123

> s <- "a string"
[1] "a string"

> t <- TRUE
[1] TRUE

> letters # 'letters' is a built-in variable

[1] "a" "b" "c" "d" "e" "f" "g" "h" "i"
[10] "j" "k" "l" "m" "n" "o" "p" "q" "r"
[19] "s" "t" "u" "v" "w" "x" "y" "z"

> length(letters) # 'length' is a function
[1] 26
Functions for Creating vectors

- `c` - concatenate
- `:` - integer sequence, `seq` - general sequence
- `rep` - repetitive patterns
- `vector` - vector of given length with default value

```
> seq(1, 3)
[1] 1 2 3

> 1:3
[1] 1 2 3

> rep(1:2, 3)
[1] 1 2 1 2 1 2

> vector(mode="character", length=5)
[1] "" "" "" "" """
Naming vectors

The elements of a vector can be named

- at creation time
- using names, dimnames, rownames, colnames

```r
> x <- c(a=0, b=2)
> x

a b
0 2

> names(x) <- c("Australia", "Brazil")
> x

Australia       Brazil
            0       2
```
Subsetting

- Subsetting is indicated by [],.
- Note that [ is actually a function (try get("["). \(x[2, 3]\) is equivalent to "\[\](x, 2, 3). Its behavior can be customized for particular classes of objects.
- The number of indices supplied to [ must be either the dimension of \(x\) or 1.
Subsetting with positive indices

- A subscript consisting of a vector of positive integer values is taken to indicate a set of indices to be extracted.
  ```
  > x <- 1:10
  > x[2]
  [1] 2
  > x[1:3]
  [1] 1 2 3
  ```

- A subscript which is larger than the length of the vector being subset produces an NA in the returned value.
  ```
  > x[9:11]
  [1] 9 10 NA
  ```
Subsetting with positive indices (continued)

- Subscripts which are zero are ignored and produce no corresponding values in the result.
  
  ```r
  > x[0:1]
  [1] 1
  > x[c(0, 0, 0)]
  integer(0)
  ```

- Subscripts which are `NA` produce an `NA` in the result.
  
  ```r
  > x[c(10, 2, NA)]
  [1] 10 2 NA
  ```
Assignments with positive indices

- Subset expressions can appear on the left side of an assignment. In this case the given subset is assigned the values on the right (recycling the values if necessary).

```r
> x[2] <- 200
> x[8:10] <- 10
> x

[1]  1  200  3  4  5  6  7 10 10
[10] 10
```

- If a zero or `NA` occurs as a subscript in this situation, it is ignored.
Subsetting with negative indices

- A subscript consisting of a vector of negative integer values is taken to indicate the indices which are not to be extracted.
  > `x[-(1:3)]`
  
  [1]  4  5  6  7  10  10  10

- Subscripts which are zero are ignored and produce no corresponding values in the result.

- `NA` subscripts are not allowed.

- Positive and negative subscripts cannot be mixed.
Assignments with negative indices

- Negative subscripts can appear on the left side of an assignment. In this case the given subset is assigned the values on the right (recycling the values if necessary).
  
  ```
  > x = 1:10
  > x[-(8:10)] = 10
  > x
  
  [1] 10 10 10 10 10 10 10 8 9 10
  ```

- Zero subscripts are ignored.

- `NA` subscripts are not permitted.
Subsetting by Logical Predicates

- Vector subsets can also be specified by a logical vector of TRUEs and FALSEs.

```r
> x = 1:10
> x > 5

[1] FALSE FALSE FALSE FALSE FALSE TRUE
[7] TRUE TRUE TRUE TRUE
```

```
> x[x > 5]

[1] 6 7 8 9 10
```

- NA values used as logical subscripts produce NA values in the output.

- The subscript vector can be shorter than the vector being subsetted. The subscripts are recycled in this case.

- The subscript vector can be longer than the vector being subsetted. Values selected beyond the end of the vector produce NAs.
Subsetting by name

- If a vector has named elements, it is possible to extract subsets by specifying the names of the desired elements.
  
  ```r
  > x <- c(a=1, b=2, c=3)
  > x[c("c", "a", "foo")]
  c  a <NA>
  3  1   NA
  >
  ```

- If several elements have the same name, only the first of them will be returned.

- Specifying a non-existent name produces an `NA` in the result.
Vectorized arithmetic

- Most arithmetic operations in the R language are vectorized. That means that the operation is applied element-wise.
  \[
  1:3 + 10:12
  \]
  \[
  [1] 11 13 15
  \]

- When one operand is shorter than the other, the short operand is recycled until it is the same length as the longer operand.
  \[
  1 + 1:5
  \]
  \[
  [1] 2 3 4 5 6
  \]
  \[
  paste(1:5, "A", sep="")
  \]
  \[
  [1] "1A" "2A" "3A" "4A" "5A"
  \]

- Many operations which need to have explicit loops in other languages do not need them with R. You should vectorize any functions you write.
Factors

- A special type of vector with grouping information about its components
- A vector with its components grouped with distinct levels
- ```R
  > col <- c("red", "green", "red", "yellow", "red")
  > factor(col)
  [1] red  green red yellow red
  Levels: green red yellow
```
Matrices and $n$-Dimensional Arrays

- Can be created using matrix and array.
- Are represented as a vector with a dimension attribute.
- Left most index is fastest (like Fortran or Matlab)
Matrix examples

```r
> x <- matrix(1:10, nrow=2)
> dim(x)
[1] 2 5
> x
[1,]  1  3  5  7  9
[2,]  2  4  6  8 10
> as.vector(x)
 [1]  1  2  3  4  5  6  7  8  9 10
```
Naming dimensions of matrix

```r
> x <- matrix(c(4, 8, 5, 6, 4, 2, 1, 5, 7), nrow=3)
> dimnames(x) <- list(
+   year = c("2005", "2006", "2007"),
+   "mode of transport" = c("plane", "bus", "boat"))
> x

mode of transport
year     plane bus boat
 2005     4   6   1
 2006     8   4   5
 2007     5   2   7
```
When subsetting a matrix, missing subscripts are treated as if all elements are named; so \( \mathbf{x}[1,] \) corresponds to the first row and \( \mathbf{x}[,3] \) to the third column.

For arrays, the treatment is similar, for example \( \mathbf{y}[1,1] \).

These can also be used for assignment, \( \mathbf{x}[1,] = 20 \).
Subsetting arrays

- Rectangular subsets of arrays obey similar rules to those which apply to vectors.
- One point to note is that arrays can also be treated as vectors. This can be quite useful.

```r
> x = matrix(1:9, ncol=3)
> x[ x > 6 ]
[1]  7  8  9
> x[row(x) > col(x)] = 0
> x
     [,1] [,2] [,3]
[1,]    1    4    7
[2,]    0    5    8
[3,]    0    0    9
```
Lists

A list is an ordered set of elements that can be arbitrary $R$ objects (vectors, other lists, functions, ...). In contrast to atomic vectors, which are homogeneous, lists can be heterogeneous.

```r
> lst = list(a=1:3, b = "ciao", c = sqrt)
> lst

$a
[1] 1 2 3

$b
[1] "ciao"

$c
function (x) .Primitive("sqrt")
> lst$c(81)
[1] 9
```
Subsetting and lists

- Lists are useful as containers for grouping related things together (many R functions return lists as their values).
- Because lists are a recursive structure it is useful to have two ways of extracting subsets.
- Subsetting with \([\ ]\) produces a sub-list of the original list.
- \([ [ \ ] ]\) subsetting extracts a single element from a list.
Subsetting and lists

- Lists are useful as containers for grouping related things together (many R functions return lists as their values).
- Because lists are a recursive structure it is useful to have two ways of extracting subsets.
- The [ ] form of subsetting produces a sub-list of the list being subsetted.
- The [[ ]] form of subsetting can be used to extract a single element from a list.
Subsetting lists

- Using the [ ] operator to extract a sublist.
  > lst[1]
  $a$
  [1] 1 2 3

- Using the [[ ]] operator to extract a list element.
  > lst[[1]]
  [1] 1 2 3

- As with vectors, indexing using logical expressions and names is also possible.
Subsetting by name

- The dollar operator provides a short-hand way of accessing list elements by name. This operator is different from all other operators in R, it does not evaluate its second operand (the string).

\[
\text{lst}\$a
\]

[1] 1 2 3

\[
\text{lst}[\text{"a"}]
\]

[1] 1 2 3

- For $ partial matching is used, for [[ it is not by default, but can be turned on.
Data frames

- Data frames are used to hold a spreadsheet-like table. In a data.frame, the observations are the rows and the covariates are the columns.
- Data frames can be treated like matrices and be indexed with two subscripts. The first subscript refers to the observation, the second to the variable.
- Data frames are lists, and list subsetting can be used on them.
Create a data frame

```r
> df <-
+   data.frame(type=rep(c("case", "control"), c(2, 3)),
+                time=rexp(5))
> df
type  time
1 case 3.5281914
2 case 0.3684031
3 control 0.4300495
4 control 0.6170052
5 control 0.3854129
> df$time
[1] 3.5281914 0.3684031 0.4300495 0.6170052 0.3854129
```
Update row and column names

> names(df)
[1] "type" "time"
> rn <- paste("id", 1:5, sep="")
> rownames(df) <- rn
> df[1:2, ]

   type  time
id1 case 3.5281914
id2 case 0.3684031
Environments

- Environments are list-like, but have *pass-by-reference* semantics.
- There is no concept of ordering in an environment. All objects are stored and retrieved by **name**.

```r
> e1 = new.env()
> e1[["a"]]<-1:3
> assign("b", "ciao", e1)
> ls(e1)

[1] "a" "b"
```

- Names must match exactly (for lists, partial matching is used for the $ operator).

Accessing elements in an environment

- Access to elements in environments can be through, get, assign, mget.

```r
> mget(c("a", "b"), e1)

$a
[1] 1 2 3

$b
[1] "ciao"
```

- You can also use the dollar operator and the `[[ ]]` operator, with character arguments only. No partial matching is done.

```r
> e1$a
[1] 1 2 3

> e1[['b']]
[1] "ciao"
```
Assigning values to lists and environments

- Items in lists and environments can be (re)placed in much the same way as items in vectors are replaced.

```r
> lst[[1]] = list(2,3)
> lst[[1]]

[[1]]
[1] 2

[[2]]
[1] 3

> e1$b = 1:10
> e1$b

[1] 1 2 3 4 5 6 7 8 9 10
```
R has a standard set of control flow functions:

- Looping: `for`, `while` and `repeat`.
- Conditional evaluation: `if`, `switch`.
The ‘apply’ family of functions

- A natural programming construct in R is to *apply* the same function to elements of a list, of a vector, rows of a matrix, or elements of an environment.
- The members of this family of functions are different with regard to the data structures they work on and how the answers are dealt with.
- Some examples, *apply*, *sapply*, *lapply*, *mapply*, *eapply*. 
apply applies a function over the margins of an array.

For example,

- `apply(x, 2, mean)` computes the column means of a matrix `x`, while
- `apply(x, 1, median)` computes the row medians.
apply is often more convenient than a for loop.

```r
> a = matrix(runif(1e6), ncol=10)
> ## 'apply'
> s1 = apply(a, 1, sum)
> ## 'for', pre-allocating for efficiency
> s2 = numeric(nrow(a))
> for(i in 1:nrow(a))
+   s2[i] = sum(a[i,])
> ## purpose-built function (much faster!)
> s3 = rowSums(a)
```
Writing functions

- Writing R functions provides a means of adding new functionality to the language.
- Functions that a user writes have the same status as those which are provided with R.
- Reading the functions provided with the R system is a good way to learn how to write functions.
Here is a function that computes the square of its argument.

```r
> square = function(x)
+ { 
+   x * x 
+ }
> square(10)
[1] 100
```

Because the function body is vectorized, so is this new function.

```r
> square(1:4)
[1]  1  4  9 16
```
Composition of functions

Once a function is defined, it is possible to call it from other functions.

```r
> sumsq = function(x) sum(square(x))
> sumsq(1:10)
[1] 385
```
Returning values

- Any single R object can be returned as the value of a function; including a function.
- If you want to return more than one object, you should put them in a list (usually with names), or an S4 object (discussed later), and return that.
- The value returned by a function is either the value of the last statement executed, or the value of an explicit call to `return`.
- `return` takes a single argument, and can be called from any where in a function.
Visualizing data in R

Basic plots

- plot: x-y plotting
- boxplot: box-whisker plot
- hist: histogram
- barplot: bar plot
Basic scatter plot

```r
> df <- data.frame("y" = 1:10, "x" = rnorm(10))
> plot(df$x, df$y, col = "red")
```
Trellis graphics

Lattice package

- xyplot: scatter plot
- bwplot: box-whisker plot
- histogram: histogram
- densityplot: kernel density plot
Lattice plots

> xyplot( y ~ x | c, data, groups = g)

- lattice function
- formula
  - primary variables
  - conditioning variable
- grouping variable
- data
Reading/writing data from/to files

- `read.delim("file")`, `read.table("file")`
- `write.table`, `write`
- `load`, `save`
Packages

- In R the primary mechanism for distributing software is via packages.
- The most reliable way to install Bioconductor packages (and their dependencies) is to use biocLite.
  ```r
  > source("http://bioconductor.org/biocLite.R")
  > biocLite("Biobase")
  ```
- During an R session, use library to load a package in order to obtain access to its functionality.
  ```r
  > library(Biobase)
  ```
Selected references

- *Lattice: Multivariate Data Visualization with R* by D. Sarkar.

Course resource