Lecture 2: Data Structures in R

STAT598z: Intro. to computing for statistics

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The R programming language

From the manual,

- R is a system for statistical computation and graphics
- R provides a programming language, high level graphics,interfaces to other languages and debugging facilities

It is possible to go far using R interactively

However, we will also study the language with the goals of

- writing good software
- allowing easy reproducibility of our analyses

‘Everything in R is an object’

An object consists of a symbol (name) and a value

- The function class() returns the object’s class
- Useful for object-oriented programming E.g. Polymorphism lets the same function (print, plot) do different things to different objects

Also relevant: typeof(), mode() and storage.mode()

R types

typeof() gives the type or internal storage mode of an object

Common types include:

- **atomic vectors** “logical”, “integer”, “double”, “complex”, “character”, “raw”
- “list”: Various useful data-structures
- “closure”: Functions
- “symbol”: Variable names
- **Miscellaneous**: Various internal and advanced types

Atomic vectors

Informally, often just called ’vectors’

Contiguous collections of objects of the same type

Common types include: “logical”, “integer”, “double”, “complex”, “character”, “raw”

R has no scalars, just vectors of length 1

Creating length one vectors

```
In [2]: age <- 15  # Length 1 vector
```

```
In [3]: name <- 'Bob'
```

```
In [5]: old_enough <- age >= 18  #old_enough <- FALSE
```

```
In [6]: print(name)
```

```
[1] "Bob"
```

```
In [7]: old_enough
```

FALSE

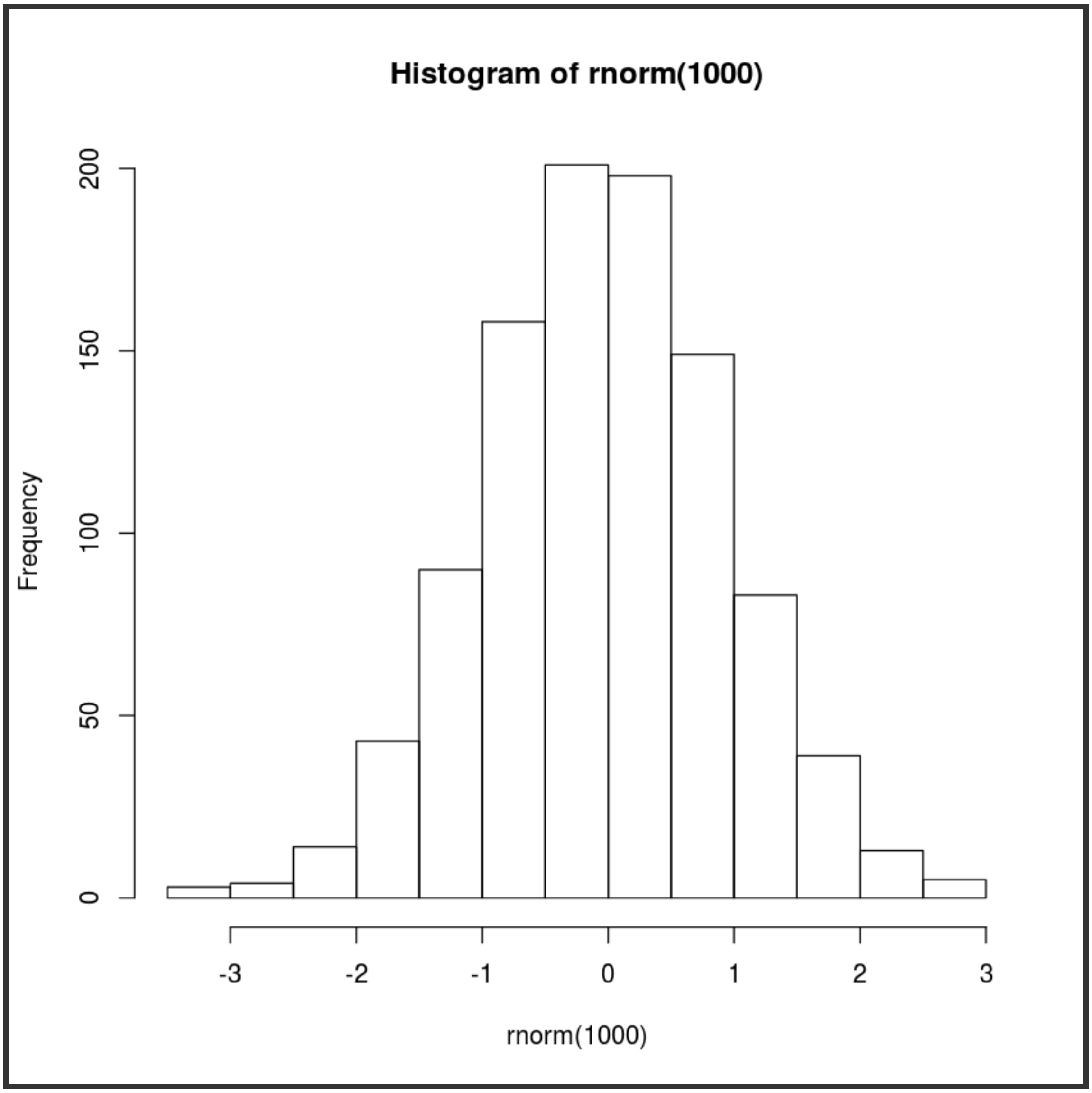
Comments:

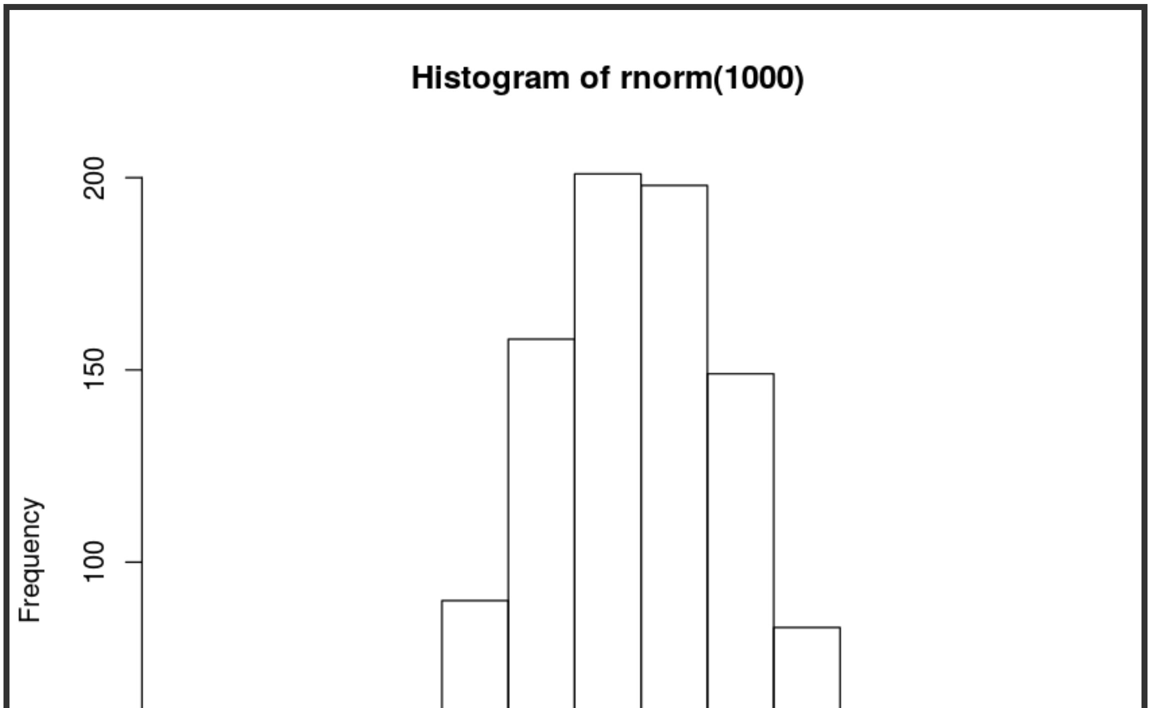
- age, name, and old_enough are variable names
- ‘ <- ’ is the assign operator
- ‘ = ’ usually works but is not recommended

In [10]:
```
16 -> age # Valid, but harder to read
```

In [1]:

```
plot(hist(rnorm(1000)))
```





In [12]:

```
typeof(age) # Note: age is a double
```

```
'double'
```

In [13]:

```
class(age)
```

```
'numeric'
```

In [15]:

```
typeof(name)
```

```
'character'
```

In [16]:

```
class(name)
```

```
'character'
```

In [17]:

```
age <- 19L
typeof(age)
```

```
'integer'
```

General vectors:

The c() function (**concatenate**) creates vectors

```
In [18]: people <- c("Alice", "Bob", 'Carol') # single/double quotes
```

```
In [24]: years <- 1991 : 2000  # Watch out for: years <- 2000:1991
```

```
In [28]: even_years  <- (years %% 2) == 0
```

```
In [23]: class(people)
```

'character'

```
In [27]: typeof(years)
```

'integer'

```
In [30]: is.vector(even_years)
```

'logical'

Indexing elements of a vector

Use brackets [] to index subelements of a vector

First element of a vector is indexed by 1

In [31]:
```
people[1]    # First element is indexed by 1
```

```
'Alice'
```

In [34]:
```
years[1 : 5] # Index with a subvector of integers
```

```
1991  1992  1993  1994  1995
```

In [35]:
```
years[c(1, 3, length(years))]
```

```
1991  1993  2000
```

Negative numbers exclude elements

```
In [36]: people[-1] # All but the first element
```

'Bob' 'Carol'

```
In [1]: years[c(-1, - length(years))] #All but first and last elementts
```

```
Error in eval(expr, envir, enclos): object 'years' not found
Traceback:
```

```
In [38]: years[ - c(1,length(years))] # Equivalently
```

1992 1993 1994 1995 1996 1997 1998 1999

Index with logical vectors

In [39]:

```
even_years  # Same as print(even_years)
```

```
FALSE  TRUE  FALSE  TRUE  FALSE  TRUE  FALSE  TRUE
FALSE  TRUE
```

In [40]:

```
years[even_years] # Index with a logical vector
```

```
1992  1994  1996  1998  2000
```

Example

Sample 100 Gaussian random variables and find the mean of the positive elements

In [41]:

```r
xx <- rnorm(100, 0, 1) # Sample 100 Gaussians
indx_xx_pos <- (xx > 0) # Is this element positive
```

In [42]:

```r
xx_pos <- xx[indx_xx_pos] # Extract positive elements
```

In [44]:

```r
xx_pos_mean <- mean(xx_pos) # calculate mean
```

```
0.841472158649378
```

More terse:

```
In [ ]:  xx <- rnorm(100, 0, 1) # Sample 100 Gaussians
```

```
In [45]: xx_pos_mean <- mean(xx[xx > 0]) # calc. mean of positives
```

```
In [46]: xx_pos_mean
```

```
0.841472158649378
```

Replacing elements of a vector

Can assign single elements

In [47]:

```
people[1] <- 'Dave'; print(people)
```

```
[1] "Dave"  "Bob"   "Carol"
```

or multiple elements:

In [51]:

```
years[even_years] <- years[even_years] + 1; print(years)
```

```
 [1] 1991 1993 1993 1995 1995 1997 1997 1999 1999 2001
```

or assign multiple elements a single value (more on this when we look at recycling)

In [53]:

```
years[-c(1,length(years))] <- 0; print(years)
```

```
 [1] 1991    0    0    0    0    0    0    0    0 2001
```

How about years <- 0?

Coercion

What if we assign an element a value of the wrong type?

In [54]:

```
vals <- 1 : 3
typeof(vals)
```

'integer'

In [56]:

```
vals[2] <- 'two'; print(vals)
typeof(vals)
```

```
[1] "1"   "two" "3"
```

'character'

R will **coerce** the vector to the most flexible type

In increasing flexibility: logical, integer, double, and character

The c() operator does the same

In [57]:

```
stuff <- c( TRUE , 3L, 3.14, 'pi')
stuff
```

```
'TRUE'  '3'  '3.14'  'pi'
```

In [58]:

```
typeof(stuff)
```

```
'character'
```

Use **lists** if you really wanted a heterogeneous collection

More on the c() operator

Atomic vectors are always flat, even for nested c() operators

Example from Advanced R, Hadley Wickham:

```
In [59]: c(1, c(2, c(3, 4)))
```

```
1  2  3  4
```

A vector of vectors is still just a vector

Use lists/matrices/arrays if you want nested structure

What if we assign to an element outside the vector?

```
In [60]: years[length(years) + 1] <- 2015
```

```
In [61]: length(years); years
```

```
11

    1991  0  0  0  0  0  0  0  0  2001  2015
```

We have increased the vector length by 1

In general, this is an inefficient way to go about things

Much more efficient is to first allocate the entire vector

In [65]:

```
vals <- 1 : 3
typeof(vals)
```

'integer'

In [66]:

```
vals[6] <- 6L
```

In [68]:

```
print(vals)
```

```
[1]  1  2  3 NA NA  6
```

Also get NAs if we access elements outside the range of the vector

NA (Not available)

NA is a length 1 constant to handle missing values

Different from NaN (not a number), which results from e.g. dividing 0 by 0

NA can be coerced into any of the earlier data types

A useful command is is.na()

Vector operations and recycling

Unary transformations to a vectors: mean, sum, power etc

Binary operations are usually elementwise

What if vectors have different lengths?

Recycle: repeat shorter vector till the lengths match

Very convenient, but can allow bugs to remain undetected

R gives a warning if longer length is not multiple of shorter

Recycling

In [ ]:

```
val <- 1 : 6
val + 1
```

In [ ]:

```
val + c(1,2)
```