Introduction to R*

Lecture 4: Heterogeneous vectors (Lists & Dataframes) and IO

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Contents

In the first part of this section, two kinds[1] of **heterogeneous** vectors will be discussed:

- lists
- data frames (& tibbles)

Input-output (IO) in R forms the subject of the latter part.

1 R Lists

A `list` is a heterogeneous vector that **may** contain one or more **components**.
The components can be **heterogeneous** objects (atomic types, functions, lists[2], ...).

Under the hood, the list is implemented as a vector of pointers to its top-level components.
The list's length equals the number of top-level components.

1.1 Creation of a list

An R list can be created in several ways:

- using the **list()** function (most common)
- via the **vector()** function
- via a cast using the **as.list()** function

1.1.1 Examples

- use of the **list()** function

```
# Creating an empty list
x1 <- list()
str(x1)
```

```
 list()
```

```
cat(sprintf("  typeof(x1):%s   class(x1):%s   length(x1):%d\n",
               typeof(x1), class(x1), length(x1)))
```

```
  typeof(x1):list   class(x1):list   length(x1):0
```

```
# A more 'complicated' version
x2 <- list(1:10, c("hello","world"),
           3+4i, matrix(data=1:6,nrow=2,ncol=3,byrow=TRUE))
str(x2)
```

```
List of 4
 $ : int [1:10] 1 2 3 4 5 6 7 8 9 10
 $ : chr [1:2] "hello" "world"
```

[1] R also has the pairlist. This topic will not be discussed in this section. People interested in this subject, should have a look at R-internals.
[2] Due to this feature, they are also called `recursive` vectors.

```
 $ : cplx 3+4i
 $ : int [1:2, 1:3] 1 4 2 5 3 6
```

```
cat(sprintf("  typeof(x2):%s   class(x2):%s   length(x2):%d\n",
               typeof(x2), class(x2), length(x2)))
```

```
  typeof(x2):list   class(x2):list   length(x2):4
```

```
# Using existing names
x3 <- list(x=1, y=2, str1="hello", str2="world", vec=1:5)
str(x3)
```

```
List of 5
 $ x   : num 1
 $ y   : num 2
 $ str1: chr "hello"
 $ str2: chr "world"
 $ vec : int [1:5] 1 2 3 4 5
```

```
# Applying name to list
x4 <- list(matrix(data=1:4,nrow=2,ncol=2), c(T,F,T,T), "hello")
names(x4) <- c("mymat","mybool","mystr")
str(x4)
```

```
List of 3
 $ mymat : int [1:2, 1:2] 1 2 3 4
 $ mybool: logi [1:4] TRUE FALSE TRUE TRUE
 $ mystr : chr "hello"
```

- use **vector()** function:

  Allows to create/allocate an empty vector of a certain length.

```
# Allocate a vector of length 5
x5 <- vector(mode="list", length=5)
str(x5)
```

```
List of 5
 $ : NULL
 $ : NULL
 $ : NULL
 $ : NULL
 $ : NULL
```

- using the **as.list()** function

```
x6 <- as.list(matrix(5:10,nrow=2))
str(x6)
```

```
List of 6
```

```
$ : int 5
$ : int 6
$ : int 7
$ : int 8
$ : int 9
$ : int 10
```

Note: The 'inverse' operation is **unlist()**

```
x7 <- unlist(x6)
str(x7)
```

```
 int [1:6] 5 6 7 8 9 10
```

1.2 Accessor operators [ ], [[ ]], $ in R.

1.2.1 General statements

The operator [[i]] selects **only one component** (in cases of lists) or **only one element** in case of homogeneous vectors.

The operator [ ] allows to select **one or more components** (in the case of lists) or **one or more elements** in the case of homogeneous vectors.

The **$** operator can **only** be used for **generic/recursive vectors**.
If you use the **$** operator to other objects you will obtain an **error**.
The **$** operator can **only** be followed by a string or a non-computable index.

1.2.2 Homogenous vectors

In praxi, for homogeneous vectors there is not much difference between [[ ]] and [ ] **except** that [[ ]] does **NOT** allow to select more than **one** element.

Note: The operator [[ ]] can be used as a tool of defensive programming.

1.2.2.1 Examples

```
a <- seq(from=1,to=30,by=3)
a
```

```
 [1]  1  4  7 10 13 16 19 22 25 28
```

```
# Extraction of ONE element
cat(sprintf(" a[[2]] : %d\n", a[[2]]))
```

```
 a[[2]] : 4
```

```
cat(sprintf(" a[2]   : %d\n", a[2]))
```

```
 a[2]   : 4
```

```
# Extraction of MORE than 1 element using [[]] => ERROR
a[[c(2,3)]]
```

```
Error in a[[c(2, 3)]]: attempt to select more than one element in vectorIndex
```

but:

```
# Extraction of MORE than 1 element using [] => OK
a[c(2,3)]
```

```
[1] 4 7
```

1.2.3 Heterogeneous vectors (i.e. lists and derived classes)

We stated earlier that the operator [[ ]] allows to select **only one** component.
It also means that this operator selects **the component as is**.
If this one component is a matrix it selects a matrix, if it were a list it will be a list, etc.

The operator [ ] allows to select more than **one** component.
Therefore, in order to return potentially heterogeneous components it **always**
returns a `list` even if only one component were to be returned.

1.2.3.1 Examples

```
str(x2)
```

```
List of 4
 $ : int [1:10] 1 2 3 4 5 6 7 8 9 10
 $ : chr [1:2] "hello" "world"
 $ : cplx 3+4i
 $ : int [1:2, 1:3] 1 4 2 5 3 6
```

```
# Selection using [[]]
x24 <- x2[[4]]
x24
```

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

```
class(x24)
```

```
[1] "matrix" "array"
```

```
typeof(x24)
```

```
[1] "integer"
```

```
length(x24)
```

```
[1] 6
```

```
# Selection using []
x24 <- x2[4]
x24
```

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

```
class(x24)
```

```
[1] "list"
```

```
typeof(x24)
```

```
[1] "list"
```

```
length(x24)
```

```
[1] 1
```

```
# Select third el. of the FIRST component
x13 <- x2[[1]][3]
x13
```

```
[1] 3
```

which is the same as:

```
v1 <- x2[[1]]
v1[3]
```

```
[1] 3
```

Heterogeneous vectors are also known as **recursive/generic** vectors,
as can be seen in the following example:

```
# A more advanced 'recursive' example
v <- list(v1=1:4,
          lst1=list(a=3, b=2, c=list(x=5,y=7, v2=seq(from=7,to=12))))
```

```
# Extracting the component as a homogeneous vector
v[[2]][[3]][[3]]
```

```
[1]  7  8  9 10 11 12
```

```
class(v[[2]][[3]][[3]])
```

```
[1] "integer"
```

```
# Extracting as a list
v[[2]][[3]][3]
```

```
$v2
[1]  7  8  9 10 11 12
```

```
class(v[[2]][[3]][3])
```

```
[1] "list"
```

We can extract the same data using names if available:

```
v$lst1$c$v2
```

```
[1]  7  8  9 10 11 12
```

```
# List of function objects
lstfunc <- list(cube=function(x){x**3},
                quartic=function(x){x**4})
lstfunc$cube(5)
```

```
[1] 125
```

```
lstfunc$quartic(5)
```

```
[1] 625
```

1.3 Modifying lists

- **Removal/deletion** of components: set them to **NULL**.
  The components will be **automatically** re-indexed.

```
mylst1 <- list(a=1:10, b=seq(1,5), matrix(1:10, nrow=2),
               "hello", "world", 1:5 )
str(mylst1)
```

```
List of 6
 $ a: int [1:10] 1 2 3 4 5 6 7 8 9 10
 $ b: int [1:5] 1 2 3 4 5
 $  : int [1:2, 1:5] 1 2 3 4 5 6 7 8 9 10
 $  : chr "hello"
 $  : chr "world"
```

```
 $  : int [1:5] 1 2 3 4 5
```

```
# Removal of the 5th component
mylst1[[5]] <- NULL
str(mylst1)
```

```
List of 5
 $ a: int [1:10] 1 2 3 4 5 6 7 8 9 10
 $ b: int [1:5] 1 2 3 4 5
 $  : int [1:2, 1:5] 1 2 3 4 5 6 7 8 9 10
 $  : chr "hello"
 $  : int [1:5] 1 2 3 4 5
```

- **Appending** an object:

  Assign the object (`obj`) to the list component with index `length(lst)+1`

```
# Creation of a list mylst2
mylst2 <- list( 1:5, 'a' , 'b')
str(mylst2)
```

```
List of 3
 $ : int [1:5] 1 2 3 4 5
 $ : chr "a"
 $ : chr "b"
```

```
# Appending a Boolean vector to the existing list mylst2
mylst2[[length(mylst2)+1]] <- c(T,F,T)
str(mylst2)
```

```
List of 4
 $ : int [1:5] 1 2 3 4 5
 $ : chr "a"
 $ : chr "b"
 $ : logi [1:3] TRUE FALSE TRUE
```

If you set the index to a number which is **larger** than `length(lst) +1`
all the new intermittent components will be set to `NULL`.
You can get rid of these additional `NULL` values by subsequently deleting them.

```
# Insert a component at an index > length(mylst2)+1
# -> we will get some additional NULL values.
mylst2[[7]] <- "value"
str(mylst2)
```

```
List of 7
 $ : int [1:5] 1 2 3 4 5
 $ : chr "a"
 $ : chr "b"
```

```
 $ : logi [1:3] TRUE FALSE TRUE
 $ : NULL
 $ : NULL
 $ : chr "value"
```

```
# Delete the NULL values! Start from the end!
mylst2[[6]] <- NULL
mylst2[[5]] <- NULL
str(mylst2)
```

```
List of 5
 $ : int [1:5] 1 2 3 4 5
 $ : chr "a"
 $ : chr "b"
 $ : logi [1:3] TRUE FALSE TRUE
 $ : chr "value"
```

- **Insertion** of a component

  Create a new vector with the 'left' components, the new component and the 'right' components.

```
str(mylst2)
```

```
List of 5
 $ : int [1:5] 1 2 3 4 5
 $ : chr "a"
 $ : chr "b"
 $ : logi [1:3] TRUE FALSE TRUE
 $ : chr "value"
```

```
# Add new component at index 4
newlst2 <- c(mylst2[1:3], "NEW", mylst2[4:length(mylst2)])
str(newlst2)
```

```
List of 6
 $ : int [1:5] 1 2 3 4 5
 $ : chr "a"
 $ : chr "b"
 $ : chr "NEW"
 $ : logi [1:3] TRUE FALSE TRUE
 $ : chr "value"
```

1.4 Functions: return multiple objects

If a function needs to return **multiple objects** a list **must** be used.

1.4.1 Example

```
func01 <- function(n)
{
   x <- n*(n+1)/2
   y <- cbind(1:n,(1:n)^2)
   return(list('x'=x,'y'=y))
}
n <- 8
res <- func01(n)
```

```
res$x
```

```
[1] 36
```

```
res$y
```

```
     [,1] [,2]
[1,]    1    1
[2,]    2    4
[3,]    3    9
[4,]    4   16
[5,]    5   25
[6,]    6   36
[7,]    7   49
[8,]    8   64
```

1.5 Exercises

- Let's consider the following list:

```
lstex1 <- list(
               list(
                    seq(from=4,to=40,by=5),
                    "hello world",
                    list(
                         matrix(100:119,nrow=5),
                         "bye",
                         c(7,13,17),
                         list(451,-1,-17)
                        )
                   )
              )
```

  Extract the following data from `mylistex1`:

  - the elements 7 13 as a vector.
  - the second column of `matrix(100:119,nrow=5)` as a matrix.
  - -1 as a scalar.
  - -1 as a list.
  - **all** numerical values into a vector. (Hint:**unlist()**)

- Create the following list:

```
lstex2 <- list(1:10,
               matrix(seq(from=1,to=20), nrow=4),
               5+3i,
               list('a','d','b'),
               "UoU",
               c(T,F,T,T,T),
               "Hello"
              )
```

  Perform some operations (deletions, insertions, modifications)
  such that `lstex2` takes on the following form:

```
lstex2 <- list( matrix(seq(from=1,to=20), nrow=4),
               "Hello UoU",
               list('a','b','c','d'),
               c(T,F,T,T,T)
              )
```

2 R Dataframes

A `date frame` is a `list` with three `attributes`:

- **names** : component names
- **row.names** : row names
- **class**: **data.frame**

From the above we can infer that the number of rows is the **same** for each component. The components of a data frame are either vectors, factors,numerical matrices, lists or other data frames.

2.1 Examples

2.2 Creating a data frame

- read.table
- data.frame

2.3 attach and detach

3 Input-Output (IO)

3.1 Functionality in `Base R`

3.2 Other options:

- library `readr`
  - supports a lot of formats (csv, tcsv, delim, ...)
  - allows column specification
  - faster than `Base R`'s read/write operations
  - uses a `tibble` instead of a `data frame`.
  - for more info: `R for Data Science` - Chapter 11.Data import
- library `data.table`
  - very fast IO: optimal for large read (**fread()**) and write (**fwrite()**) operations
  - memory efficient
  - low-level parallelism (use of multiple CPU threads)