CT5102: Programming for Data Analytics

Lecture 9: The S3 Object System

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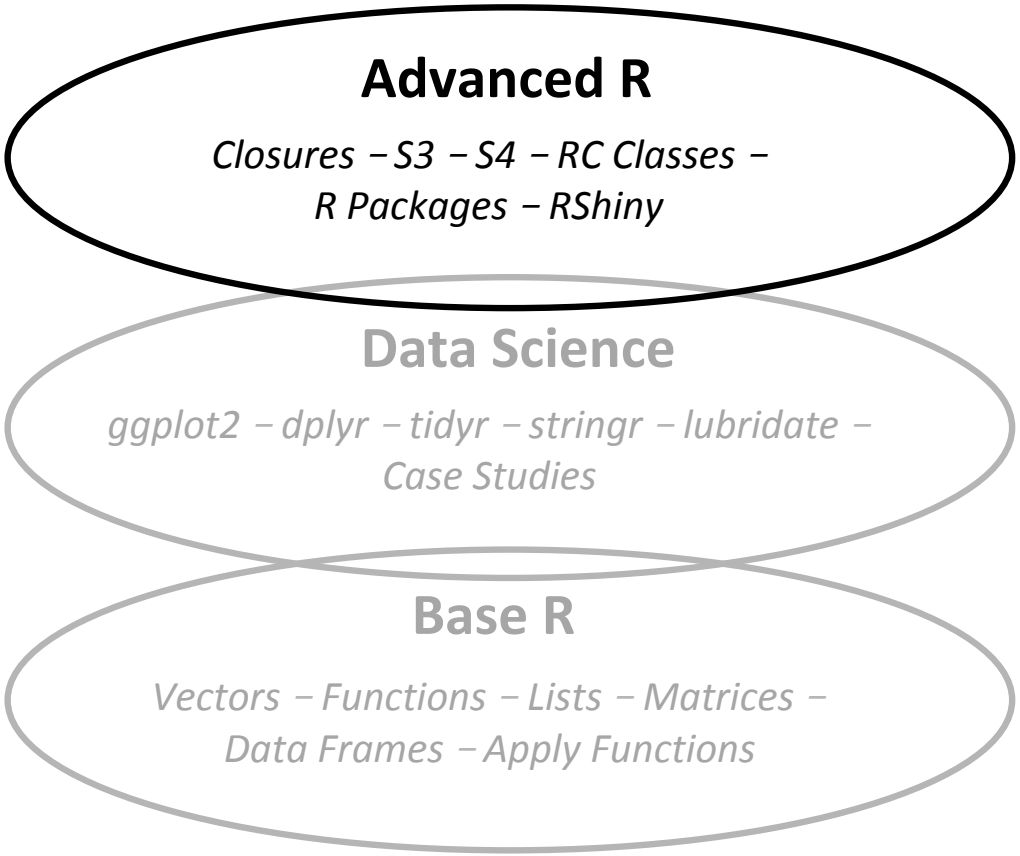
Overview

- Attributes
- S3 Classes
- Inheritance
- Infix Functions



(1) Attributes

- All objects can have arbitrary additional attributes, used to store meta-data about the object
- Attributes can be thought of as a named list (with unique names)
- Attributes can be accessed:
  - Individually with **attr()**
  - All at once with **attributes()**

Example

```
> y<- 1:10
>
> attr(y,"Attribute1") <- "This is a vector"
> attr(y,"Time") <- Sys.time()
>
> str(y)
 atomic [1:10] 1 2 3 4 5 6 7 8 9 10
 - attr(*, "Attribute1")= chr "This is a vector"
 - attr(*, "Time")= POSIXct[1:1], format: "2016-09-30 08:56:19"
```

structure() function

- The structure function returns a new object with modified attributes

```
> y<-structure(1:10,Att1="This is a vector", Att2=Sys.time())
>
> str(y)
 atomic [1:10] 1 2 3 4 5 6 7 8 9 10
 - attr(*, "Att1")= chr "This is a vector"
 - attr(*, "Att2")= POSIXct[1:1], format: "2016-09-30 09:00:00"
```

Properties of attributes

- By default, most attributes are lost when subsetting a vector

```
>
> attributes(y)
$Att1
[1] "This is a vector"

$Att2
[1] "2016-09-30 09:47:59 BST"

>
> attributes(y[1])
NULL
```

Attributes not lost during operations...

- **Names**, a character vector giving each element a name. ***names(x)***
- **Dimensions**, used to turn vectors into matrices and arrays. ***dim(x)***
- **Class**, used to implement the S3 object system. ***class(x)***

```
>
> x<-1:2
>
> names(x)<-c("a","b")
>
> str(x)
 Named int [1:2] 1 2
 - attr(*, "names")= chr [1:2] "a" "b"
>
> str(x[1])
 Named int 1
 - attr(*, "names")= chr "a"
```

dim() example

```
> a<-1:6
>
> a
[1] 1 2 3 4 5 6
>
> attributes(a)
NULL
>
> dim(a)<-c(2,3)
>
> a
     [,1] [,2] [,3]
[1,]    1    3    5
[2,]    2    4    6
>
> attributes(a)
$dim
[1] 2 3

>
> attributes(a[1,])
NULL
>
> attributes(a[1,,drop=F])
$dim
[1] 1 3
```

Declaring a matrix

```
>
> a <- matrix(1:6, ncol=3, nrow=2)
>
> a
     [,1] [,2] [,3]
[1,]    1    3    5
[2,]    2    4    6
>
> dim(a)
[1] 2 3
```

Challenge 9.1

- For the vector **1:100**, convert this to a **10 x 10 matrix** using the attr() function

(2) S3 System

- Most OO languages
  - implement message-passing OO
  - Object determines which function to call
  - **canvas.drawRect("blue")**
- S3
  - Implements generic-function OO
  - A special type of function called a **generic function** decides which method to call (i.e. method dispatch)
  - **drawRect(canvas, "blue")**
  - S3 is a very casual system, it has no formal definition of classes

S3 Information

- The only OO system used in the base and stats packages, and the most commonly used in CRAN packages
- "S3 in informal an ad-hoc, but has a certain elegance in its minimalism" (Wickham 2015)

```
>
> library(pryr)
>
> typeof(mtcars)
[1] "list"
>
> class(mtcars)
[1] "data.frame"
>
> otype(mtcars)
[1] "S3"
```

Methods in S3

- In S3, methods belong to functions, called **generic functions**
- S3 methods to not belong to objects or classes
- To determine if a function is an S3 generic, inspect the source code for a call to **UseMethod()**
- UseMethod() – Figures out the correct method to call, the process of **method dispatch**
- Method names tend to be **generic.class()**

mean() function example

```
> mean
function (x, ...)
UseMethod("mean")
<bytecode: 0x1060f14d8>
<environment: namespace:base>
>
>
> ftype(mean)
[1] "s3"      "generic"
```

See all methods belonging to a generic

```
>
> methods("mean")
[1] mean.Date     mean.default  mean.difftime mean.POSIXct  mean.POSIXlt
see '?methods' for accessing help and source code
>
```

List all generics that have a method for a given class

```
> methods(class="data.frame")
 [1] [             [[            [[<-          [<-           $             $<-           aggregate
 [8] anyDuplicated as.data.frame as.list       as.matrix     by            cbind         coerce
[15] dim           dimnames      dimnames<-    drop.levels   droplevels    duplicated    edit
[22] format        formula       head          initialize    is.na         isUnknown     left
[29] mapLevels     mapLevels<-   Math          merge         na.exclude    na.omit       NAToUnknown
[36] nobs          Ops           plot          print         prompt        rbind         right
[43] row.names     row.names<-   rowsum        show          slotsFromS3   split         split<-
[50] stack         str           subset        summary       Summary       t             tail
[57] transform     trim          unique        unknownToNA   unstack       within
```

Defining classes and creating objects

- S3 objects usually built on top of lists, or atomic vectors with attributes
- Functions can also be S3 objects
- class(x) shows the class of an object

```
> o<-list(a="Test")
>
> str(o)
List of 1
 $ a: chr "Test"
>
> class(o)<-"my_object"
>
> str(o)
List of 1
 $ a: chr "Test"
 - attr(*, "class")= chr "my_object"
>
> class(o)
[1] "my_object"
```

Using structure() function

```
> o<-structure(list(a="test"),class="my_object")
>
> str(o)
List of 1
 $ a: chr "test"
 - attr(*, "class")= chr "my_object"
>
> class(o)
[1] "my_object"
```

Most S3 classes provide a constructor function

```
myobject <- function(x){
  structure(list(a=x), class="my_object")
}

o <- myobject("Test")
```

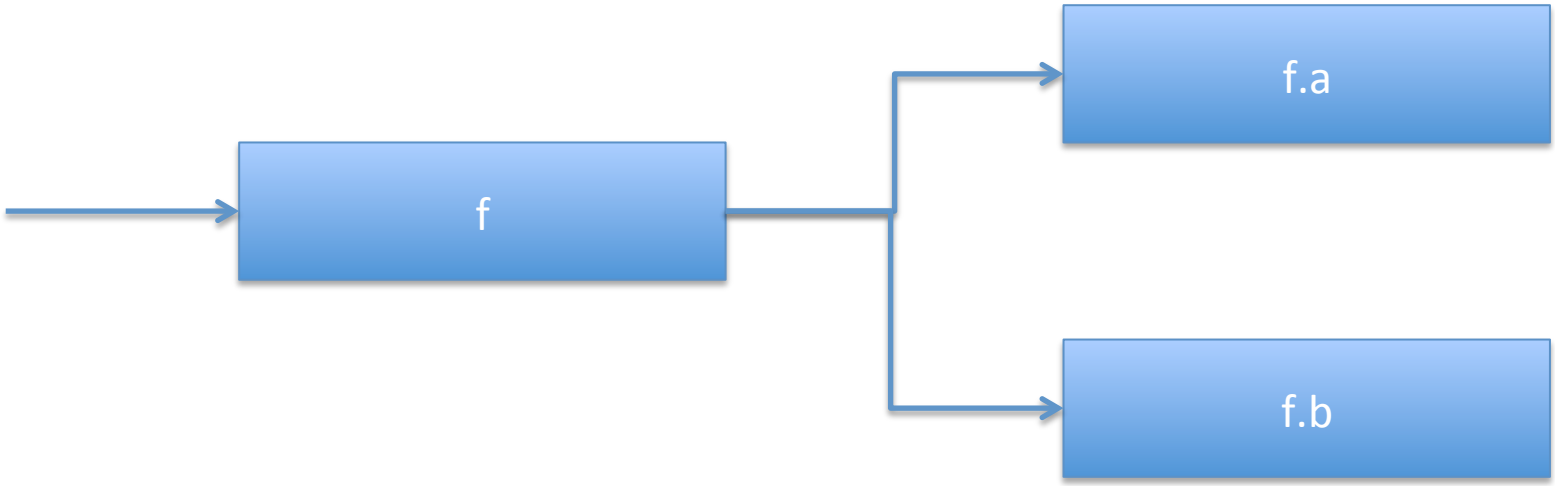
```
> o
$a
[1] "Test"

attr(,"class")
[1] "my_object"
```

Creating new methods and generics

- To add a new generic, create a function that calls **UseMethod()**
- UseMethod takes two arguments
  - The name of the generic function
  - The argument to use for method dispatch
- If the 2nd argument is omitted, it will dispatch on the first argument to the function
- Methods are then added, using a regular function with the name *generic.class*

Overall idea…



Format for specific functions are *[generic function].[class name]*

Example…

```
f <- function(x){
  UseMethod("f")
}

f.a <- function(x){
  print("this is function f.a")
}

f.b <- function(x){
  print("this is function f.b")
}
```

Calling the generic…

```
> x <- structure(list(),class="a")
>
> str(x)
 list()
 - attr(*, "class")= chr "a"
>
> f(x)
[1] "this is function f.a"
```

Default functions…

```
f.default <- function(x){
  print("This is the default function")
}


z<-structure(list(),class="c")

>
> f(z)
[1] "This is the default function"
>
```

Challenge 9.2

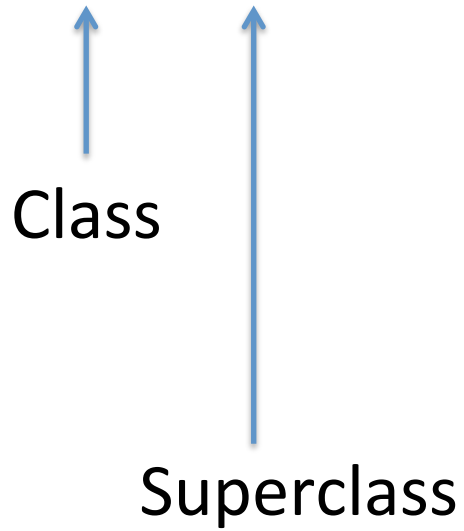
- Find a way to "override" the print function for a vector object so that it prints a summary of the vector when it is called (using the summary() function).

```
> print
function (x, ...)
UseMethod("print")
<bytecode: 0x1063940d8>
<environment: namespace:base>
>
```

(3) Inheritance

- The idea of inheritance is to form new classes of specialised versions of existing ones.

```
> z<-structure(list(),class=c("b","a"))
>
> z
list()
attr(,"class")
[1] "b" "a"
```



S3 Inheritance:
(1) Define two generic functions

```
f<-function(x){
  UseMethod("f")
}

g <-function(x){
  UseMethod("g")
}
```

S3 Inheritance:
(2) Create methods for class a and b

```
f.a<-function(x){
  print("function f.a")
}

f.b<-function(x){
  print("function f.b")
}

g.a<-function(x){
  print("function g.a")
}
```

S3 Inheritance:
(3) Create object of b, inherit from a

```
>
> z<-structure(list(),class=c("b","a"))
>
> class(z)
[1] "b" "a"
>
> f(z)
[1] "function f.b"
>
> g(z)
[1] "function g.a"
```

Challenge 9.3

- Write a new class called “df1” which inherits from “data.frame”
- Create a print function for “df1” which displays the current time, before calling the standard print methods for a data.frame class
- Test the results as follows with the mtcars data frame

```
>
> d[1:2,]
[1] "2016-10-02 16:10:40 BST"
               mpg cyl disp  hp drat    wt  qsec vs am gear carb
Mazda RX4       21   6  160 110  3.9 2.620 16.46  0  1    4    4
Mazda RX4 Wag   21   6  160 110  3.9 2.875 17.02  0  1    4    4
```

(4) Infix Functions

- Chambers (2008):
  - *Everything that exists is an object.*
  - *Everything that happens is a function call*

- **Operators are also functions**

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

Infix Functions

- Most functions in R are “prefix” operators: the name of the function comes before the arguments
- You can also create infix functions where the function name comes in between its arguments
- All user-defined infix functions must start and end with %. R comes with the following infix functions predefined: **%%**, **%*%**, **%/%**, **%in%**, **%o%**, **%x%**

Example

```
`%+%` <- function(s1, s2){
  paste(s1,s2,sep=" ")
}
```

```
>
> "CT5102" %+% "Programming for Data Analytics"
[1] "CT5102 Programming for Data Analytics"
```

Base operators can be used by S3 classes

```
> methods("[")
 [1] [,nonStructure-method    [.acf*
 [3] [.AsIs                   [.bibentry*
 [5] [.check_details_changes* [.data.frame
 [7] [.Date                   [.difftime
 [9] [.Dlist                  [.DLLInfoList
[11] [.factor                 [.formula*
[13] [.getAnywhere*           [.hexmode
[15] [.listof                 [.noquote
[17] [.numeric_version        [.octmode
[19] [.pdf_doc*               [.person*
[21] [.POSIXct                [.POSIXlt
[23] [.raster*                [.roman*
[25] [.simple.list            [.table
[27] [.terms*                 [.ts*
[29] [.tskernel*              [.warnings
see '?methods' for accessing help and source code
```

```
> methods("[<-")
[1] [<-,data.frame-method [<-.data.frame
[3] [<-.Date              [<-.factor
[5] [<-.numeric_version   [<-.POSIXct
[7] [<-.POSIXlt           [<-.raster*
[9] [<-.ts*
see '?methods' for accessing help and source code
```