Introduction to Object-Oriented Programming and S3 System in R (https://github.com/ravichas/OOP-S3-in-R)

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Preliminary information about object types in R

Let us create a logical object, x, and ask for its class.

```
(x <- TRUE) # logical

## [1] TRUE

print(class(x))

## [1] "logical"
```

Let us create a list, also called x, and ask for its class.

```
(x <- list(nums = 1:10,
           chars = c("one","two","three"),
           ints = c(1L,2L,3L)
           ))

## $nums
##  [1]  1  2  3  4  5  6  7  8  9 10
##
## $chars
## [1] "one"   "two"   "three"
##
## $ints
## [1] 1 2 3

print(class(x))

## [1] "list"
```

BMI is a data.frame with four variables, Gender, Height, Weight and Age. We will also R to print BMI's class.

```
(BMI <-     data.frame(
   Gender = c("Male", "Male","Female"),
   Height = c(153.1, 173.6, 165.0),
   Weight = c(81,93, 78),
      Age = c(42,38,26)
))
```

```
##   Gender Height Weight Age
## 1   Male  153.1     81  42
## 2   Male  173.6     93  38
## 3 Female  165.0     78  26

print(class(BMI))

## [1] "data.frame"
```

Hands-on 1

One of the important concept of OOP is functions can respond in different ways depending on the input object type. To explain this concept, let us create the following objects:

- Numeric vector of 10 random numbers
- Categorical vector of length 6
- A linear model object

First, let us create a numerical vector with 10 elements.

```
set.seed(111)
(x_num <- rnorm(10) )

##  [1]  0.2352 -0.3307 -0.3116 -2.3023 -0.1709  0.1403 -1.4974 -1.0102
##  [9] -0.9485 -0.4940
```

Next, we build a categorical vector with 6 elements.

```
(x_fac <- factor(c("A", "B", "A", "C", "A", "B")))

## [1] A B A C A B
## Levels: A B C
```

Finally, a linear model object.

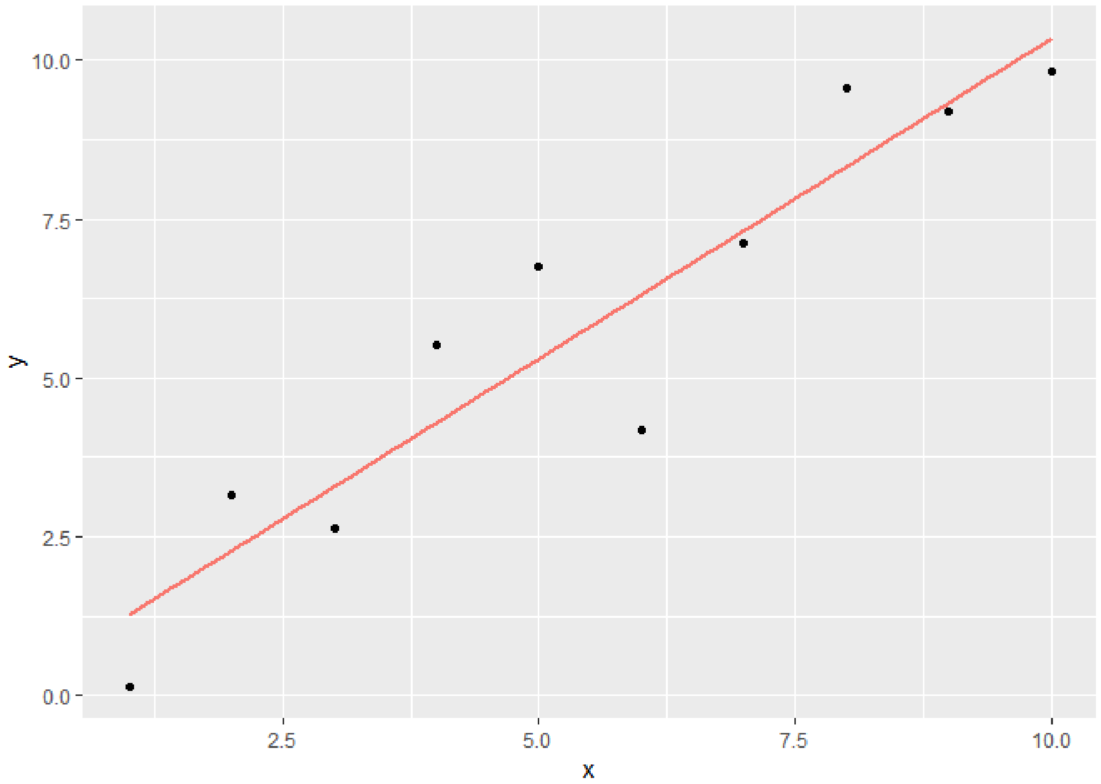
```
set.seed(123)  # set seed
(x <- 1:10)

##  [1]  1  2  3  4  5  6  7  8  9 10

(y <- jitter(x, amount = 2))

##  [1] 0.1503 3.1532 2.6359 5.5321 6.7619 4.1822 7.1124 9.5697 9.2057 9.8265

data.frame(x, y) %>% ggplot(aes(x, y)) +
  geom_point() +
  geom_smooth(aes(col = "red"), method = "lm", se = FALSE) +
  theme(legend.position="none")
```



```
#build a model
model <- lm(y ~ x)
```

Behavior of summary function on different class of objects

```
x_num

##  [1]  0.2352 -0.3307 -0.3116 -2.3023 -0.1709  0.1403 -1.4974 -1.0102
##  [9] -0.9485 -0.4940

summary(x_num)

##    Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
##  -2.302  -0.995  -0.412  -0.669  -0.206   0.235

x_fac

## [1] A B A C A B
## Levels: A B C

summary(x_fac)

## A B C
## 3 2 1
```

Finally, a linear model variable.

```
model
```

```
## 
## Call:
## lm(formula = y ~ x)
## 
## Coefficients:
## (Intercept)            x  
##        0.27         1.01
```

```
summary(model)
```

```
## 
## Call:
## lm(formula = y ~ x)
## 
## Residuals:
##     Min      1Q  Median      3Q     Max 
## -2.135 -0.624 -0.173  1.140  1.453 
## 
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)    
## (Intercept)    0.270      0.854    0.32     0.76    
## x              1.008      0.138    7.32  8.2e-05 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## 
## Residual standard error: 1.25 on 8 degrees of freedom
## Multiple R-squared:  0.87,   Adjusted R-squared:  0.854 
## F-statistic: 53.6 on 1 and 8 DF,  p-value: 8.22e-05
```

How does R distinguish types of variables?

what command(s) can be used for this task?

Let us create an integer matrix

```
# matrix
(int_mat <- matrix(1L:12L, nrow = 4, ncol = 3 )) # column major
```

```
##      [,1] [,2] [,3]
## [1,]    1    5    9
## [2,]    2    6   10
## [3,]    3    7   11
## [4,]    4    8   12
```

Let us determine the variable class

```
class(int_mat) # obj is a matrix
```

```
## [1] "matrix"
```

What type of elements the matrix has?

```
typeof(int_mat) # int matrix; content of the matrix

## [1] "integer"
```

Let us this time create a matrix of floats and ask the same questions

```
(float_mat <- matrix(rnorm(12), nrow = 4, ncol = 3))

##            [,1]    [,2]    [,3]
## [1,]  1.7151 -0.4457  0.1107
## [2,]  0.4609  1.2241 -0.5558
## [3,] -1.2651  0.3598  1.7869
## [4,] -0.6869  0.4008  0.4979

class(float_mat) # matrix

## [1] "matrix"

typeof(float_mat) # double; type of var that makes up matrix

## [1] "double"

# c code; in C floating point #s are double
```

Hands-on 2:

Interrogation of objects to see whether they are S3 objects

```
(int_mat <- matrix(1L:12L, nrow = 4, ncol = 3 )) # column major

##      [,1] [,2] [,3]
## [1,]    1    5    9
## [2,]    2    6   10
## [3,]    3    7   11
## [4,]    4    8   12

sloop::otype(int_mat) # package::command(object)

## [1] "base"

head(mtcars)

##                    mpg cyl disp  hp drat    wt  qsec vs am gear carb
## Mazda RX4         21.0   6  160 110 3.90 2.620 16.46  0  1    4    4
## Mazda RX4 Wag     21.0   6  160 110 3.90 2.875 17.02  0  1    4    4
## Datsun 710        22.8   4  108  93 3.85 2.320 18.61  1  1    4    1
## Hornet 4 Drive    21.4   6  258 110 3.08 3.215 19.44  1  0    3    1
## Hornet Sportabout 18.7   8  360 175 3.15 3.440 17.02  0  0    3    2
## Valiant           18.1   6  225 105 2.76 3.460 20.22  1  0    3    1

sloop::otype(mtcars)

## [1] "S3"
```

S3: How to assign classes?

- Can I override the class?
  - Yes
- And as expected, it wont break the functionality
- Can I woverride the type?
  - No

```
x_num

##  [1]  0.2352 -0.3307 -0.3116 -2.3023 -0.1709  0.1403 -1.4974 -1.0102
##  [9] -0.9485 -0.4940

class(x_num)

## [1] "numeric"

typeof(x_num)

## [1] "double"

class(x_num) <- "random-numbers"
class(x_num)

## [1] "random-numbers"

# the class that we have added has become an attribute
x_num

##  [1]  0.2352 -0.3307 -0.3116 -2.3023 -0.1709  0.1403 -1.4974 -1.0102
##  [9] -0.9485 -0.4940
## attr(,"class")
## [1] "random-numbers"

# we cannot override typeof
typeof(x_num)

## [1] "double"

is.numeric(x_num) # no matter what the class says

## [1] TRUE
```

S3: Function overloading

S3 exists so that we dont have to write many many functions to take care of different data types.

How does it work?

- S3 splits a function into generic and method functions.
- Methods named generic.class (Ex. print.Date)

Example of generic functions are print, summary etc.

```
(x_Date <- Sys.Date()) # "YYYY-MM-DD"

## [1] "2019-05-05"

class(x_Date) # "Date"

## [1] "Date"

print(x_Date) # "YYYY-MM-DD"

## [1] "2019-05-05"

# is same as calling print.Date
print.Date(x_Date)

## [1] "2019-05-05"

# Let us explore the print function
print

## function (x, ...)
## UseMethod("print")
## <bytecode: 0x00000000150e08b8>
## <environment: namespace:base>
```

print function is just a simple one line function. You can ignore the last two lines that shows the memory location and the object environment. After determining the class of the object, generic print function calls via UseMethod("print") to provide the final output.

What methods exist for a generic function?

- For example, for the **generic function** what methods are available
- generic.class1, generic.class2, generic.class3

Exmaple. print (generic), print.data.frame, print.Date etc.

```
head(methods(print)) # too many methods

## [1] "print.acf"      "print.AES"      "print.all_vars" "print.anova"
## [5] "print.any_vars" "print.aov"
```

What methods are available for a given class of an object?

- The methods could be coming from different generic classes. For example, generic1.class, generic2.class etc.
- Note this methods call for this case will return both S3 and s4 objects.

```
# gives both S3 and S4
methods(class = "lm") # or methods(class=lm)

##  [1] add1           alias          anova          case.names
##  [5] coerce         confint        cooks.distance deviance
##  [9] dfbeta         dfbetas        drop1          dummy.coef
## [13] effects        extractAIC     family         formula       
## [17] fortify        hatvalues      influence      initialize    
## [21] kappa          labels         logLik         model.frame   
## [25] model.matrix   nobs           plot           predict       
## [29] print          proj           qr             residuals     
## [33] rstandard      rstudent       show           simulate      
## [37] slotsFromS3    summary        variable.names vcov          
## see '?methods' for accessing help and source code

# of them which ones are S3
.S3methods(class = "lm")

##  [1] add1           alias          anova          case.names    
##  [5] confint        cooks.distance deviance       dfbeta        
##  [9] dfbetas        drop1          dummy.coef     effects       
## [13] extractAIC     family         formula        fortify       
## [17] hatvalues      influence      kappa          labels        
## [21] logLik         model.frame    model.matrix   nobs          
## [25] plot           predict        print          proj          
## [29] qr             residuals      rstandard      rstudent      
## [33] simulate       summary        variable.names vcov          
## see '?methods' for accessing help and source code
```

Is the object/function generic or method?

```
pryr::is_s3_generic("print") # TRUE

## [1] TRUE

pryr::is_s3_method("print") # FALSE

## [1] FALSE

pryr::is_s3_method("print.Date") # TRUE

## [1] TRUE
```

Let us define our object.

```
(people <- c("Frank Blanchard",
             "Andrea Gnuschke",
             "Max Cole",
             "Maryellen Hackett",
             "Victoria Brun",
             "Jonathan Summers",
             "Christopher Worthington",
             "Samuel Lopez",
             "Richard Frederickson",
             "Chris Hu") )

##  [1] "Frank Blanchard"         "Andrea Gnuschke"        
##  [3] "Max Cole"                "Maryellen Hackett"      
##  [5] "Victoria Brun"           "Jonathan Summers"       
##  [7] "Christopher Worthington" "Samuel Lopez"
##  [9] "Richard Frederickson"    "Chris Hu"

class(people)

## [1] "character"

(class(people) <- "InsiteGroup")

## [1] "InsiteGroup"
```

Suppose, we want to write an S3 function that gets the first name from the **InsiteGroup** object.

```
GetFirst <- function(obj) {
  UseMethod("GetFirst",obj)
  }

# create methods function
GetFirst.InsiteGroup <- function(obj) {
  return(obj[1])
 }

 # create default function
GetFirst.default <- function(obj) {
  cat("This is a generic class\n")
   # do something
  }

 GetFirst(people)

## [1] "Frank Blanchard"
```

If no suitable methods can be found for a generic, then an error is thrown. For example, at the moment, get_n_elements() only has 2 methods available. If you pass a data.frame/matrix to get_n_elements() instead, you'll see an error. One could use generic.default to deal with all the missing class of objects.

Can variables have more than one class?

```
 human <- "laugh"

# less specific to more specific; final default class,character
 class(human) <- c("mammalia","eukaryota","character")

# create a generic method for who_am_i
who_am_i <- function(x, ...) {
   UseMethod("who_am_i")
  }

# create mammalia method for who_am_i
```

```
who_am_i.mammalia <- function(x, ...) {
   # usually, we will carry out some useful procedure here!
   message("I am a Mammal") # write a message
  }

# create eukarota method for who_am_i
who_am_i.eukaryota <- function(x, ...) {
   message("I am a Eukaryote") # write a message
  }

# finally one for character method
who_am_i.character <- function(x, ...) {
   message("I am a simple character!") # write a message
  }

# call human to see all the 3 messages are displayed
 class(human)

## [1] "mammalia"  "eukaryota" "character"

 who_am_i(human)

## I am a Mammal
```

Advanced example

```
 human <- "laugh"

# less specific to more specific; final default class,character
 class(human) <- c("mammalia","eukaryota","character")

# create a generic method for who_am_i
who_am_i <- function(x, ...) {
   UseMethod("who_am_i")
  }

# create mammalia method for who_am_i
who_am_i.mammalia <- function(x, ...) {
   # let us write a message
   message("I am a Mammal")
   NextMethod("x")
  }

# create eukarota method for who_am_i
who_am_i.eukaryota <- function(x, ...) {
   # let us write a message
   message("I am a Eukaryote")
   NextMethod("x")
  }

# finally one for character method
```

```
who_am_i.character <- function(x, ...) {
# let us write a message
   message("I am a simple character!")
   # since this is the last, no NextMethod
  }

# call human to see all the 3 messages are displayed
 class(human)

## [1] "mammalia"  "eukaryota" "character"

 who_am_i(human)

## I am a Mammal

## I am a Eukaryote

## I am a simple character!
```