Introduction to Object-Oriented Programming and S3 System in R

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Preliminary information about object types in R

Let us create a logical object, x.

```
(x <- TRUE) # logical
```

```
## [1] TRUE
```

```
print(class(x))
```

```
## [1] "logical"
```

Let us create a list, also called x.

```
( 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.

```
(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.

```
( x_num <- rnorm(10) )
```

```
##  [1]  0.167221 -1.080480 -1.443743  0.346096 -0.653390 -0.470769 -0.981555
##  [8]  0.003727 -0.552327 -0.253259
```

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 variable.

```
# setting seed

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

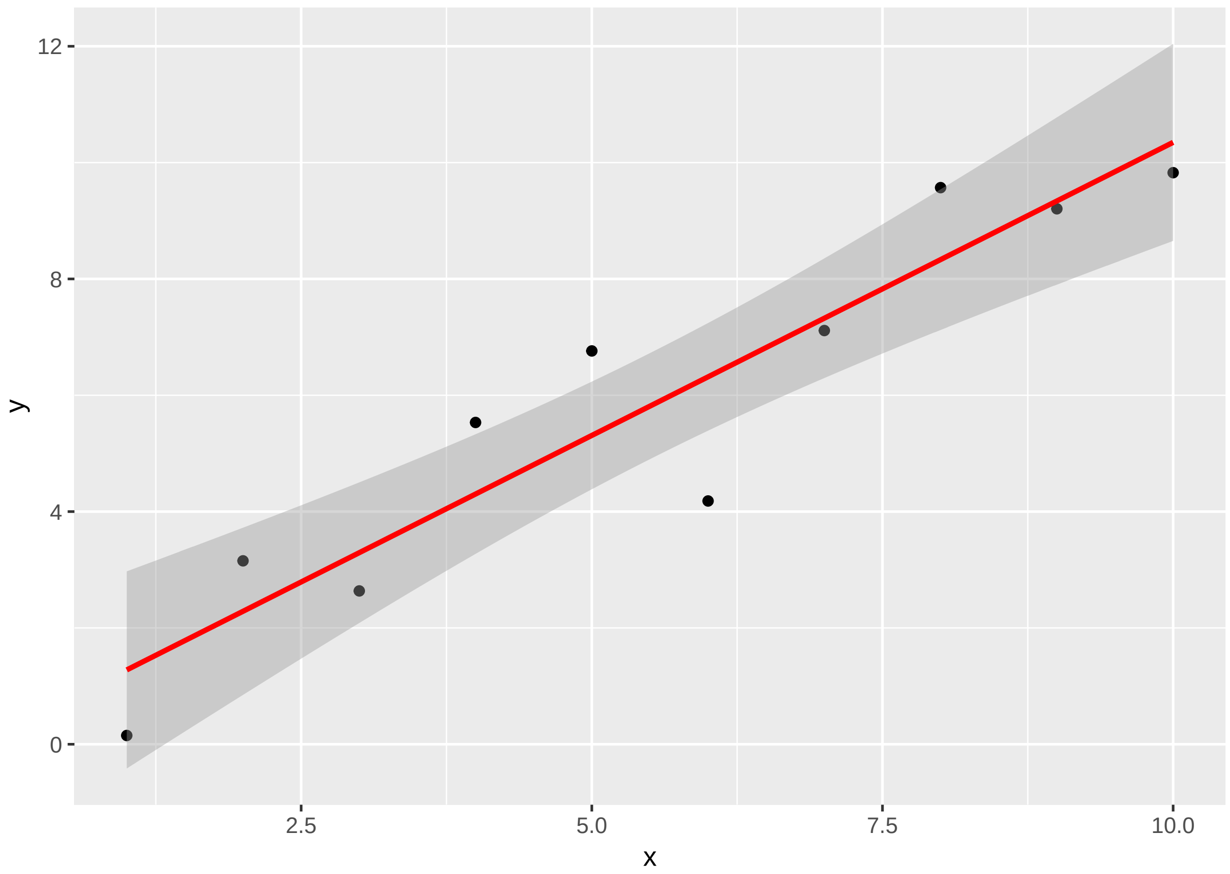
```
##  [1]  1  2  3  4  5  6  7  8  9 10
```

```
(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
```

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

data.frame(x, y) %>% ggplot(aes(x, y)) +
  geom_point() +
  geom_smooth(method = "lm", col = "red")
```



Behavior of summary function on different class of objects

```
x_num
```

```
##  [1]  0.167221 -1.080480 -1.443743  0.346096 -0.653390 -0.470769 -0.981555
##  [8]  0.003727 -0.552327 -0.253259
```

```
summary(x_num)
```

```
##    Min. 1st Qu.  Median    Mean 3rd Qu.    Max. 
## -1.4437 -0.8995 -0.5115 -0.4918 -0.0605  0.3461
```

```
x_fac
```

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

```
summary(x_fac)
```

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

```
model
```

```
## 
## Call:  glm(formula = y ~ x)
## 
```

```
## Coefficients:
## (Intercept)            x
##        0.27         1.01
##
## Degrees of Freedom: 9 Total (i.e. Null);  8 Residual
## Null Deviance:       96.3
## Residual Deviance: 12.5  AIC: 36.6
```

```
summary(model)
```

```
##
## Call:
## glm(formula = y ~ x)
##
## Deviance 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
##
## (Dispersion parameter for gaussian family taken to be 1.563)
##
##     Null deviance: 96.293  on 9  degrees of freedom
## Residual deviance: 12.505  on 8  degrees of freedom
## AIC: 36.61
##
## Number of Fisher Scoring iterations: 2
```

How does R distinguish types of variables?

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

```
# matrix
(int_mat <- matrix(1:12, 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
```

```
# determine the variable
class(int_mat) # obj is a matrix
```

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

```
# what type of matrix (elements are of what type)
typeof(int_mat) # int matrix; content of the matrix
```

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

```
(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:

- How does R distinguish types of variables?
- Introduction to S3-systems
- Interrogation of objects to see whether they are S3 objects

```
int_mat
```

```
##      [,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 & R6: 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]  0.167221 -1.080480 -1.443743  0.346096 -0.653390 -0.470769 -0.981555
##  [8]  0.003727 -0.552327 -0.253259
```

```
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]  0.167221 -1.080480 -1.443743  0.346096 -0.653390 -0.470769 -0.981555
##  [8]  0.003727 -0.552327 -0.253259
## 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 & R6: 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.

```
string <- "Hello World!"
print(string)
```

```
## [1] "Hello World!"
```

```
# Let us look at the function
print
```

```
## function (x, ...)
## UseMethod("print")
## <bytecode: 0x00000000189e9dc8>
## <environment: namespace:base>
```

```
x_Date <- Sys.Date() # "2019-03-26"
class(x_Date) # "Date"
```

```
## [1] "Date"
```

```r
print(x_Date) # "2019-03-26"
```

```
## [1] "2019-05-02"
```

```r
print.Date(x_Date) # "2019-03-26"
```

```
## [1] "2019-05-02"
```

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.

```r
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.

```r
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
```

```r
.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
```

As we saw, print function (just a simple 1 line function) > print function (x, . . .) UseMethod(“print”) <bytecode: 0x000000000a237408> # memory, important, ignore for now <environment: namespace:base> # environment, important, but ignore for now print function calls UseMethod(“print”)

```
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
```

```
print
```

```
## function (x, ...)
## UseMethod("print")
## <bytecode: 0x00000000189e9dc8>
## <environment: namespace:base>
```

```
( 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"
```

```
# get the first name from the vector
# create generic function
GetFirst <- function(obj) {
  UseMethod("GetFirst",obj)
  }
class(GetFirst)
```

```
## [1] "function"
```

```
# 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")
class(human)
```

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

```r
who_am_i(human)
```

```
## I am a Mammal

## I am a Eukaryote

## I am a simple character!
```