> The vector type is really the heart of R. It's hard to imagine R code, or even an interactive R session, that doesn't involve vectors.
>
> — Norman Matloff (Matloff, 2011)

Data Science for Operational Researchers using R

02 – Atomic Vectors

https://github.com/JimDuggan/Data-Science-for-OR

(1) Atomic Vectors

- A one-dimensional data structure that allows you to store one or more values.
- Created using the combine function c()
- Assignment using ← operator (convention in R)
- Four main types
  - logical
  - integer
  - numeric/double
  - character

```
# Create a logical vector
x_logi <- c(TRUE, T, FALSE, TRUE, F)
x_logi
#> [1]  TRUE  TRUE FALSE  TRUE FALSE

typeof(x_logi)
#> [1] "logical"

str(x_logi)
#>  logi [1:5] TRUE TRUE FALSE TRUE FALSE

is.logical(x_logi)
#> [1] TRUE
```

Other types

```r
# Create a double vector
x_dbl<- c(1.2, 3.4, 7.2, 11.1, 12.7)

x_dbl
#> [1]  1.2  3.4  7.2 11.1 12.7

typeof(x_dbl)
#> [1] "double"

str(x_dbl)
#>  num [1:5] 1.2 3.4 7.2 11.1 12.7

is.double(x_dbl)
#> [1] TRUE
```

```r
# Create a character vector
x_chr<- c("One","Two","Three","Four","Five")

x_chr
#> [1] "One"   "Two"   "Three" "Four"  "Five"

typeof(x_chr)
#> [1] "character"

str(x_chr)
#>  chr [1:5] "One" "Two" "Three" "Four" "Five"
```

Combining Vectors

```
# Create vector 1
v1 <- c(1,2,3)
# Create vector 2
v2 <- c(4,5,6)

# Append for vector 3
v3 <- c(v1, v2)
v3
#> [1] 1 2 3 4 5 6

# Append for vector 4
v4 <- c(v2, v1)
v4
#> [1] 4 5 6 1 2 3
```

Creating large vectors

- Colon operator :
- seq() function
- rep() function
- vector() function

```
x <- 1:10

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

typeof(x)
#> [1] "integer"
length(x)
#> [1] 10
```

```
x0 <- seq(1,10)
x0
#>  [1]  1  2  3  4  5  6  7  8  9 10

x1 <- seq(from=1, to=10)
x1
#>  [1]  1  2  3  4  5  6  7  8  9 10

x2 <- seq(from=1, to=10,by=.5)
x2
#>  [1]  1.0  1.5  2.0  2.5  3.0  3.5  4.0  4.5  5.0  5.5  6.0  6.5  7.0
#> [14]  7.5  8.0  8.5  9.0  9.5 10.0
```

vector() function

```
y1 <- vector("logical",   length = 3)
y1
#> [1] FALSE FALSE FALSE

y2 <- vector("integer",   length = 3)
y2
#> [1] 0 0 0

y3 <- vector("double",   length = 3)
y3
#> [1] 0 0 0

y4 <- vector("character", length = 3)
y4
#> [1] "" "" ""
```

Atomic vectors always contain data of the same type.

This is enforced by R using a process known as coercion.

Coercion

	logical	integer	double	character
logical	logical	integer	double	character
integer	integer	integer	double	character
double	double	double	double	character
character	character	character	character	character

```
# Create a vector with integer and double combined
ex3 <- c(1L,2L, 3L, 4.1)
ex3
#> [1] 1.0 2.0 3.0 4.1
typeof(ex3)
#> [1] "double"
```

```
# Create a vector with logical, integer, double and character
# combined
ex4 <- c(TRUE,1L,2.0, "Hello")
ex4
#> [1] "TRUE"  "1"     "2"     "Hello"
typeof(ex4)
#> [1] "character"
```

Naming vector elements (useful)

```
# Create a double vector with named elements
x_dbl<- c(a=1.2, b=3.4, c=7.2, d=11.1, e=12.7)

x_dbl
#>    a    b    c    d    e
#>  1.2  3.4  7.2 11.1 12.7

summary(x_dbl)
#>    Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
#>    1.20    3.40    7.20    7.12   11.10   12.70
```

```
# Show our previously defined vector x_logi
x_logi
#> [1]  TRUE  TRUE FALSE  TRUE FALSE

# Allocal names to each vector element
names(x_logi) <- c("f","g","h","i","j")
x_logi
#>     f     g     h     i     j
#>  TRUE  TRUE FALSE  TRUE FALSE
```

Missing Values

- When analysing data, it is common that there will be missing values
- A sensor (thermometer) might break down on any given day, and so an hourly temperature recording could be missed
- Logical constant NA is used in R to record a missing value ("Not Available")

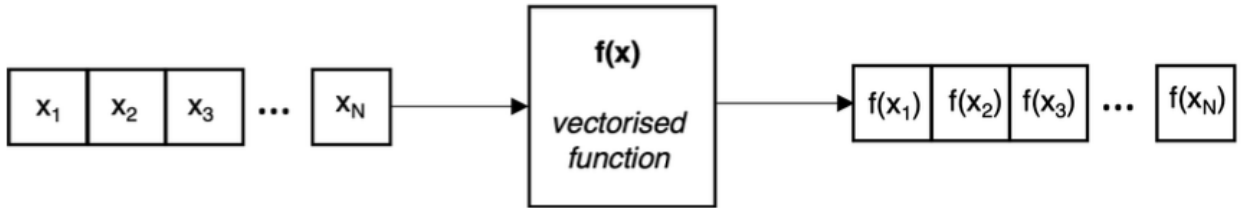
```
# define a vector v
v <- 1:10
v
#>  [1]  1  2  3  4  5  6  7  8  9 10

# Simulate a missing value by setting the final value to NA
v[10] <- NA
v
#>  [1]  1  2  3  4  5  6  7  8  9 NA

# Notice how summary() deals with the NA value
summary(v)
#>    Min. 1st Qu.  Median    Mean 3rd Qu.    Max.    NA's
#>       1       3       5       5       7       9       1

# Notice what happens when we try to get the maximum value of v
max(v)
#> [1] NA
```

Detecting NAs

```
v
#>  [1]  1  2  3  4  5  6  7  8  9 NA
# Look for missing values in the vector v
is.na(v)
#>  [1] FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE FALSE  TRUE
```

```
v
#>  [1]  1  2  3  4  5  6  7  8  9 NA
max(v, na.rm = TRUE)
#> [1] 9
```

Vectorisation



- Vectorisation is a powerful feature of R that where a function can operate on all the elements of an atomic vector, and return all the results in new atomic vector, of the same size.
- In these scenarios, vectorisation removes the requirement to write loop structures that would iterate over the entire vector, and so leads to a simplified data analysis process.

```
# Set the random number seed to 100
set.seed(100)
# Create a sample of 5 numbers from 1-10.
v <- sample(1:10,5)
v
#> [1] 10  7  6  3  1
length(v)
#> [1] 5
typeof(v)
#> [1] "integer"

# Call the vectorised function sqrt (square root)
rv <- sqrt(v)
rv
#> [1] 3.162 2.646 2.449 1.732 1.000
length(rv)
#> [1] 5
typeof(rv)
#> [1] "double"
```

R Operators (Support vectorization)

R Arithmetic Operator	Description
+	Addition
-	Subtraction
*	Multiplication
/	Division
%/%	Integer division
** or ^	Exponentiation
%%	Modulus

```r
# Define two sample vectors, v1 and v2
v1 <- c(10, 20, 30)
v1
#> [1] 10 20 30
v2 <- c(2, 4, 3)
v2
#> [1] 2 4 3

# Adding two vectors together
v1 + v2
#> [1] 12 24 33
# Vector subtraction
v1 - v2
#> [1]  8 16 27
```

R Relational Operators (Support Vectoristion)

R Relational Operator	Description
<	Less than
<=	Less than or equal to
>	Greater than
>=	Greater than or equal to
==	Equal to
!=	Not equal to

```
# Setup a test vector
v5 <- c(5,1,4,2,6,8)
v5
#> [1] 5 1 4 2 6 8

# Test for all six relational operators
v5 < 4
#> [1] FALSE  TRUE FALSE  TRUE FALSE FALSE
v5 <= 4
#> [1] FALSE  TRUE  TRUE  TRUE FALSE FALSE
v5 > 4
#> [1]  TRUE FALSE FALSE FALSE  TRUE  TRUE
v5 >= 4
#> [1]  TRUE FALSE  TRUE FALSE  TRUE  TRUE
v5 == 4
#> [1] FALSE FALSE  TRUE FALSE FALSE FALSE
v5 != 4
#> [1]  TRUE  TRUE FALSE  TRUE  TRUE  TRUE
```

Logical Operators

R Logical Operator	Description
!	Logical NOT: Converts TRUE to FALSE, or FALSE to TRUE
&	Logical AND: TRUE if all relational expressions are TRUE, otherwise FALSE
|	Logical OR: TRUE if any relational expression is TRUE, otherwise FALSE

```
# Setup a test vector, in this case, a sequence of random numbers
set.seed(200)
v  <- sample(1:20, 10, replace = T)
v
#>  [1]  6 18 15  8 12 18 12 20  8  4

# Use logical AND to see which values are in the range 10-14
v >= 10 & v <= 14
#>  [1] FALSE FALSE FALSE FALSE  TRUE FALSE  TRUE FALSE FALSE FALSE

# Use logical OR to see which values are lower than 5 or greater than 17
v < 5 | v > 17
#>  [1] FALSE  TRUE FALSE FALSE FALSE  TRUE FALSE  TRUE FALSE  TRUE

# Use logical NOT to see which values are not even (using the remainder o
!(v %% 2 == 0)
#>  [1] FALSE FALSE  TRUE FALSE FALSE FALSE FALSE FALSE FALSE FALSE
```

ifelse(test_condition, true_value, false_value)

- test_condition is a logical vector, or an operation that yields a logical vector, such as a logical operator
- true_value is the new vector value if the condition is true
- false_value is the new vector value if the condition is false

```
# Create a vector of numbers from 1 to 10
v <- 1:10
v
#>  [1]  1  2  3  4  5  6  7  8  9 10

# Calculate the mean
m_v <- mean(v)
m_v
#> [1] 5.5

# Create a new vector des_v based on a condition, and using ifelse()
des_v <- ifelse(v > m_v, "GT", "LE")
des_v
#>  [1] "LE" "LE" "LE" "LE" "LE" "GT" "GT" "GT" "GT" "GT"
```

Challenge 2.1

Generate a random sample of 20 temperatures (assume integer values in the range -5 to 30) using the `sample()` function (`set.seed(99)`). Assume that temperatures less than 4 are cold, temperatures greater that 25 are hot, and all others are medium, use the `ifelse()` function to generate the following vector. Note that an `ifelse()` call can be nested within another `ifelse()` call.

```
# The temperature data set
temp
#>  [1] 27 16 29 28 26  7 14 30 25 -2  3 12 18 24 16 14 26  8 -2  8

# The descriptions for each temperature generated by ifelse() call
des
#>  [1] "Hot"    "Medium" "Hot"    "Hot"    "Hot"    "Medium" "Medium"
#>  [8] "Hot"    "Medium" "Cold"   "Cold"   "Medium" "Medium" "Medium"
#> [15] "Medium" "Medium" "Hot"    "Medium" "Cold"   "Medium"
```

Subsetting

> R's subsetting operators are fast and powerful. Mastering them allows you to succinctly perform complex operations in a way that few other languages can match.
>
> — Hadley Wickham (Wickham, 2019)

- Subsetting operations allow you to process data stored in atomic vectors, and R provides a range of flexible approaches that can be used to subset data
- There are 4 ways:
  - Positive integer
  - Negative integer
  - Logical vectors
  - Named elements

```
# set the seed
set.seed(111)
```

```
# Generate the count data, assume a Poisson distribution
customers <- rpois(n = 10, lambda = 100)
# Name each successive element to be the day number
names(customers) <- paste0("D",1:10)
customers
#>  D1  D2  D3  D4  D5  D6  D7  D8  D9 D10
#> 102  96  97  98 101  85  98 118 102  94
```

Positive integers

```
# Get the customer from day 1
customers[1]
#>  D1
#> 102
# Get the customers from day 1 through to day 5
customers[1:5]
#>  D1  D2  D3  D4  D5
#> 102  96  97  98 101
# Use c() to get the customers from day 1 and the final day
customers[c(1,length(customers))]
#>  D1 D10
#> 102  94
# Note, with c(), any duplicates will be returned
customers[c(1:3,3,3)]
#>  D1  D2  D3  D3  D3
#> 102  96  97  97  97
```

Negative integers (exclusion)

```
# Exclude the first day's observation
customers[-1]
#>  D2  D3  D4  D5  D6  D7  D8  D9 D10
#>  96  97  98 101  85  98 118 102  94
# Exclude the first and last day
customers[-c(1,length(customers))]
#>  D2  D3  D4  D5  D6  D7  D8  D9
#>  96  97  98 101  85  98 118 102
# Exclude all values except the first and last day
customers[-(2:(length(customers)-1))]
#>  D1 D10
#> 102  94
```

Logical vectors (1)

```
# Create a logical vector based on a relation expression
lv <- customers > 100
lv
#>    D1    D2    D3    D4    D5    D6    D7    D8    D9   D10
#>  TRUE FALSE FALSE FALSE  TRUE FALSE FALSE  TRUE  TRUE FALSE
```

```
# Filter the original vector based on the logical vector
customers[lv]
#>  D1  D5  D8  D9
#> 102 101 118 102
```

Logical vectors (2)

```
# Subset the vector to only show values great than 100
customers[customers > 100]
#>  D1  D5  D8  D9
#> 102 101 118 102
```

```
# Subset every second element from the vector
customers[c(TRUE,FALSE)]
#>  D1  D3  D5  D7  D9
#> 102  97 101  98 102
```

Named elements

```
customers
#>  D1  D2  D3  D4  D5  D6  D7  D8  D9 D10
#> 102  96  97  98 101  85  98 118 102  94
```

```
# Show the value from day 10
customers["D10"]
#> D10
#>  94
```

```
# Extract the first and last elements
customers[c("D1","D10")]
#>  D1 D10
#> 102  94
```

Challenge 2.2

- set.seed(100) to ensure everyone gets the same result
- Use sample() to draw 1000 random numbers that represent a dice throw (dice 1)
- Use sample() to draw another 1000 random numbers that represent a second dice throw (dice 2)
- Add the outcomes together to simulate the throw of two dice
- Use atomic vector subsetting to find the total number equal to 7
- See how useful the function table() when applied to the sum of outcomes.