Week 6: *Vectors*

EMSE 4571: Intro to Programming for Analytics

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Week 6: *Vectors*

1. Making vectors
2. Vector operations
3. Comparing vectors

BREAK

4. Slicing vectors
5. Lists

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We've already been using vectors!

```
x <- 1
x
```

```
#> [1] 1
```

```
is.vector(x)
```

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

```
length(x)
```

```
#> [1] 1
```

The universal vector generator: `c()`

Numeric vectors

```
x <- c(1, 2, 3)
x
```

```
#> [1] 1 2 3
```

Character vectors

```
y <- c('a', 'b', 'c')
y
```

```
#> [1] "a" "b" "c"
```

Logical vectors

```
z <- c(TRUE, FALSE, TRUE)
z
```

```
#> [1]  TRUE FALSE  TRUE
```

Elements in vectors must be the same type

Type hierarchy:

- `character` > `numeric` > `logical`
- `double` > `integer`

Coverts to characters:

```
c(1, "foo", TRUE)
```

```
#> [1] "1"    "foo"  "TRUE"
```

Coverts to numbers:

```
c(7, TRUE, FALSE)
```

```
#> [1] 7 1 0
```

Coverts to double:

```
c(1L, as.integer(2), 3.14)
```

```
#> [1] 1.00 2.00 3.14
```

Other ways to make a vector

Sequences (we saw these last week):

```
seq(1, 5)
```

```
#> [1] 1 2 3 4 5
```

```
1:5
```

```
#> [1] 1 2 3 4 5
```

Repeating a value:

```
rep(5, 3)
```

```
#> [1] 5 5 5
```

```
rep("snarf", 3)
```

```
#> [1] "snarf" "snarf" "snarf"
```

Repeating a vector

Repeating a sequence

```
x <- rep(seq(1, 3), times = 3)
x
```

```
#> [1] 1 2 3 1 2 3 1 2 3
```

```
length(x)
```

```
#> [1] 9
```

Note what the `each` argument does:

```
x <- rep(seq(1, 3), each = 3)
x
```

```
#> [1] 1 1 1 2 2 2 3 3 3
```

```
length(x)
```

```
#> [1] 9
```

Quick code tracing

01:00

What will each of these lines produce?

```
rep(c(TRUE, FALSE, "TRUE"), 2)
```

```
seq(FALSE, 3)
```

```
rep(c(seq(3), seq(2)), each = 2)
```

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Math on vectors is done **by element**

```
x <- 1:10
```

```
x + 2
```

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

```
x - 2
```

```
#>  [1] -1  0  1  2  3  4  5  6  7  8
```

```
x * 2
```

```
#>  [1]  2  4  6  8 10 12 14 16 18 20
```

```
x / 2
```

```
#>  [1] 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0
```

Math on vectors is done **by element**

```r
x1 <- c(1, 2, 3)
x2 <- c(4, 5, 6)
```

```r
x1 + x2 # Returns (1+4, 2+5, 3+6)
```

```
#> [1] 5 7 9
```

```r
x1 - x2 # Returns (1-4, 2-5, 3-6)
```

```
#> [1] -3 -3 -3
```

```r
x1 * x2 # Returns (1*4, 2*5, 3*6)
```

```
#> [1]  4 10 18
```

```r
x1 / x2 # Returns (1/4, 2/5, 3/6)
```

```
#> [1] 0.25 0.40 0.50
```

If dimensions don't match, R "wraps" the vector

```
x1 <- c(1, 2, 3, 4)
x2 <- c(4, 5)
```

```
x1 + x2
```

```
#> [1] 5 7 7 9
```

```
x1 <- c(1, 2, 3, 4)
x2 <- c(1)
```

```
x1 + x2
```

```
#> [1] 2 3 4 5
```

Most R functions work on vectors

```
x <- c(3.1415, 1.618, 2.718)
x
```

```
#> [1] 3.1415 1.6180 2.7180
```

```
round(x, 2)
```

```
#> [1] 3.14 1.62 2.72
```

```
sqrt(x)
```

```
#> [1] 1.772428 1.272006 1.648636
```

Works with your own functions too:

```
isEven <- function(x) {
    return((x %% 2) == 0)
}
```

```
x <- c(1, 4, 5, 10)
isEven(x)
```

```
#> [1] FALSE  TRUE FALSE  TRUE
```

Using vectors instead of a loop: **Summation**

Example: Sum the integers from 1 to 10

Summing with a loop:

```
x <- seq(1, 10)

total <- 0
for (i in x) {
    total <- total + i
}
total
```

```
#> [1] 55
```

Use a *summary function* on the vector:

```
sum(x)
```

```
#> [1] 55
```

Summary functions return one value

```
x <- 1:10
```

```
length(x)
```

```
#> [1] 10
```

```
sum(x)
```

```
#> [1] 55
```

```
prod(x)
```

```
#> [1] 3628800
```

```
min(x)
```

```
#> [1] 1
```

```
max(x)
```

```
#> [1] 10
```

```
mean(x)
```

```
#> [1] 5.5
```

```
median(x)
```

```
#> [1] 5.5
```

Quick code tracing

03:00

Consider this function:

```
f <- function(x) {
    m <- x
    n <- sum(x + 4)
    m <- m + 5
    return(c(m, n))
}
```

What will each of these lines return?

```
x <- c(1, 3)
f(x)
```

```
y <- c(TRUE, FALSE, 1)
f(y)
```

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Comparing vectors

Check if 2 vectors are the same:

```
x <- c(1, 2, 3)
y <- c(1, 2, 3)
```

```
x == y
```

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

Comparing vectors with `all()` and `any()`

`all()`: Check if *all* elements are the same

```
x <- c(1, 2, 3)
y <- c(1, 2, 3)
all(x == y)
```

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

```
x <- c(1, 2, 3)
y <- c(-1, 2, 3)
all(x == y)
```

```
#> [1] FALSE
```

`any()`: Check if *any* elements are the same

```
x <- c(1, 2, 3)
y <- c(1, 2, 3)
any(x == y)
```

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

```
x <- c(1, 2, 3)
y <- c(-1, 2, 3)
any(x == y)
```

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

`all()` vs. `identical()`

```
x <- c(1, 2, 3)
y <- c(1, 2, 3)
names(x) <- c('a', 'b', 'c')
names(y) <- c('one', 'two', 'three')
```

`all()` only compares the element *values*:

```
all(x == y)
```

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

`identical()` compares *values* and *names*:

```
identical(x, y)
```

```
#> [1] FALSE
```

```
names(y) <- names(x)
identical(x, y)
```

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

Your turn

15:00

Re-write `isPrime(n)` from last week, but **without loops!**.

Remember, `isPrime(n)` takes a non-negative integer, `n`, and returns `TRUE` if it is a prime number and `FALSE` otherwise. Here are some test cases:

- `isPrime(1) == FALSE`
- `isPrime(2) == TRUE`
- `isPrime(7) == TRUE`
- `isPrime(13) == TRUE`
- `isPrime(14) == FALSE`

(If you're stuck, go to the next slide for a hint)

Hint

Loop solution:

```
isPrime <- function(n) {
    if (n <= 1) {
        return(FALSE)
    }
    if (n == 2) {
        return(TRUE)
    }
    for (i in seq(2, (n - 1))) {
        if ((n %% i) == 0) {
            return(FALSE)
        }
    }
    return(TRUE)
}
```

Break

05:00

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Use brackets `[ ]` to get elements from a vector

```
x <- seq(1, 10)
```

Indices start at 1:

```
x[1] # Returns the first element
```

```
#> [1] 1
```

```
x[3] # Returns the third element
```

```
#> [1] 3
```

```
x[length(x)] # Returns the last element
```

```
#> [1] 10
```

Slicing with a vector of indices:

```
x[1:3]  # Returns the first three elements
```

```
#> [1] 1 2 3
```

```
x[c(2, 7)] # Returns the 2nd and 7th
elements
```

```
#> [1] 2 7
```

Use negative integers to *remove* elements

```
x <- seq(1, 10)
```

```
x[-1] # Drops the first element
```

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

```
x[-1:-3] # Drops the first three elements
```

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

```
x[-c(2, 7)] # Drops the 2nd and 7th elements
```

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

```
x[-length(x)] # Drops the last element
```

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

Slicing with logical indices

```
x <- seq(1, 20, 3)
x
```

```
#> [1]  1  4  7 10 13 16 19
```

Create a logical vector based on some condition:

```
x > 10
```

```
#> [1] FALSE FALSE FALSE FALSE  TRUE  TRUE  TRUE
```

Slice `x` with logical vector - only `TRUE` indices will be returned:

```
x[x > 10]
```

```
#> [1] 13 16 19
```

You can also use `which()` to find indices

```
x <- seq(1, 20, 3)
x
```

```
#> [1]  1  4  7 10 13 16 19
```

Use `which()` around a condition to get the indices where condition is `TRUE`:

```
which(x > 10)
```

```
#> [1] 5 6 7
```

```
x[which(x > 10)]
```

```
#> [1] 13 16 19
```

You can name vector elements

```
x <- seq(5)
x
```

```
#> [1] 1 2 3 4 5
```

1) Add names with the `names()` function:

```
names(x) <- c('a', 'b', 'c', 'd', 'e')
x
```

```
#> a b c d e
#> 1 2 3 4 5
```

2) Create a named vector:

```
y <- c('a'=1, 'b'=2, 'c'=3, 'd'=4, 'e'=5)
y
```

```
#> a b c d e
#> 1 2 3 4 5
```

Using names to slice a vector

```
x
```

```
#> a b c d e
#> 1 2 3 4 5
```

```
x['a']
```

```
#> a
#> 1
```

```
x[c('a', 'c')]
```

```
#> a c
#> 1 3
```

Sorting vectors with `sort()`

```
a = c(2, 4, 6, 3, 1, 5)
a
```

```
#> [1] 2 4 6 3 1 5
```

```
sort(a)
```

```
#> [1] 1 2 3 4 5 6
```

```
sort(a, decreasing = TRUE)
```

```
#> [1] 6 5 4 3 2 1
```

`order()` returns the indices of the sorted vector

```
a
```

```
#> [1] 2 4 6 3 1 5
```

```
order(a)
```

```
#> [1] 5 1 4 2 6 3
```

This does the same thing as `sort(a)`:

```
a[order(a)]
```

```
#> [1] 1 2 3 4 5 6
```

Quick code tracing

02:00

Consider this function:

```
f <- function(x) {
    for (i in seq(length(x))) {
        x[i] <- x[i] + sum(x) + max(x)
    }
    return(x)
}
```

What will this code return?

```
x <- c(1, 2, 3)
f(x)
```

Think-Pair-Share

15:00

1) `reverse(x)`: Write a function that returns the vector in reverse order. You cannot use the `rev()` function.

- `all(reverseVector(c(5, 1, 3)) == c(3, 1, 5))`
- `all(reverseVector(c('a', 'b', 'c')) == c('c', 'b', 'a'))`
- `all(reverseVector(c(FALSE, TRUE, TRUE)) == c(TRUE, TRUE, FALSE))`

2) `alternatingSum(a)`: Write a function that takes a vector of numbers `a` and returns the alternating sum, where the sign alternates from positive to negative or vice versa.

- `alternatingSum(c(5,3,8,4)) == (5 - 3 + 8 - 4)`
- `alternatingSum(c(1,2,3)) == (1 - 2 + 3)`
- `alternatingSum(c(0,0,0)) == 0`
- `alternatingSum(c(-7,5,3)) == (-7 - 5 + 3)`

Challenge: For each function, try writing a solution that uses loops and another that only uses vectors.

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Lists are like vectors that can store anything

Vectors force things to one type:

```
c(1, "foo", TRUE)
```

```
#> [1] "1"    "foo"  "TRUE"
```

Lists store any type:

```
list(1, "foo", TRUE)
```

```
#> [[1]]
#> [1] 1
#>
#> [[2]]
#> [1] "foo"
#>
#> [[3]]
#> [1] TRUE
```

Elements in lists can be any object

List of vectors:

```
list(c(1, 2, 3), c("foo", "bar"), TRUE)
```

```
#> [[1]]
#> [1] 1 2 3
#>
#> [[2]]
#> [1] "foo" "bar"
#>
#> [[3]]
#> [1] TRUE
```

List of vector and function:

```
vector <- c(1, 2, 3)
square <- function(x) {
    return(x^2)
}

list(vector, square)
```

```
#> [[1]]
#> [1] 1 2 3
#>
#> [[2]]
#> function(x) {
#>     return(x^2)
#> }
#> <environment: 0x7f90cbab31f8>
```

Slice list with indices or names

Slice with index using `[[]]`

```
x <- list(
  c(1, 2, 3),
  c("foo", "bar"),
  TRUE
)
```

```
x[[1]]
```

```
#> [1] 1 2 3
```

```
x[[2]]
```

```
#> [1] "foo" "bar"
```

Slice with name using `` `[[]] `` or `$`

```
x <- list(
  numbers = c(1, 2, 3),
  chars   = c("foo", "bar"),
  logical = TRUE
)
```

```
x[['numbers']]
```

```
#> [1] 1 2 3
```

```
x$numbers
```

```
#> [1] 1 2 3
```

HW 6

- Next week is Quiz 4 - the last quiz before the midterm.
- Midterm is during class period on 3/10.