Data manipulation

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Today we are going to learn...

1. Generate a sequence
2. Vectors and matrices
3. Vectorization
4. Data Structures

Sequences

- Generate a sequence: `seq()`
- Repeat a vector: `rep()`

Vectors

- Numerical vectors
- Logical vectors
- Characters
- Length of a vector
- Vector calculations

Mathematical functions

- `sqrt()`, `log()`
- `sin()`,`cos()`, `tan()`

Matrices

- Create a matrix: `matrix()`
- Dimension of a matrix: `dim()`
- How many elements in a matrix: `length()`
- Extract elements from a matrix.
- Replace elements with new entries.
- Create special matrices: diagonal matrix, identity matrix, zero matrix...
- Matrix multiplications: %*%
- Matrix inverse: `solve()`
- Transpose of a matrix: `t()`
- Element-wise operation with a matrix.
- Combine two or more matrices: `rbind()`, `cbind()`

The concept of vectorization

- Vectorization: same operation applies to each element of an object.
- It is not a loop.
- If you want to do four additions

$$
\begin{aligned}
c_1 &= a_1 + b_1 \\
c_2 &= a_2 + b_2 \\
c_3 &= a_3 + b_3 \\
c_4 &= a_4 + b_4
\end{aligned}
$$

  in C you have to write it as

```
for (i=0; i<4; i++)
    c[i] = a[i] + b[i];
```

- There is a vectorizing compiler in C that transform such a loop into a sequence of vector operations, that perform additions on length-four (in our example) blocks of elements from the arrays a, b and c when you compile you C code.
- In R, you can just do it as

```
c = a + b
```

  and R will do the rest for you.

Vectorization with vectors and matrices

- Vectorize your code as much as possible.
- Vectorization works with vectors, matrices and arrays.
- Special case
  - When matrix multiplies (*) a scaler or a vector, it will first repeat the vector to be the same length of the matrix. Then do the element-wise multiplication.
  - Same rule applies to other types of arithmetic.

Array

- An array is a high dimensional matrix.
- A matrix is a special case of an array when the dimension is two.
- A vector is a special array when their is no dimension (In R the dimension is usually dropped in this situation)

List

- Special data structure that matrix could not handle.
  - Data length are not the same.
  - Data type are not the same.
  - Nested data structure within a list.
- Create a list: `list()`
- Extract elements of a `list`: `[[]]` or `$`
- Delete an element within a list: set `NULL` to that element.

Data frame

- `data.frame()`: tightly coupled collections of variables which share many of the properties of matrices and of lists, used as the fundamental data structure by most of R's modeling software.
- In most cases, the operation with a data frame is similar to matrix operation.
- See also `dplyr` package.
  - written by Hadley Wickham of RStudio
  - everything dplyr does could already be done with base R, but it greatly simplifies existing functionality in R.
  - it provides a "grammar" (in particular, verbs) for data manipulation and for operating on data frames.
  - the dplyr functions are very fast, as many key operations are coded in C++.

Discussion

What type of data structure would you choose when you meet the following situations.

- Data are of the same length but different types.
- Data are not of the same length.
- Hierarchical structure of the data.

Suggested reading

- R-intro: **Chapter 2, 3, 5, 6**
- Exploratory Data Analysis with R: **Chapter 4**