Introduction to R

1.4 Object Classes

Vectors, Matrices, Data Frames, Lists

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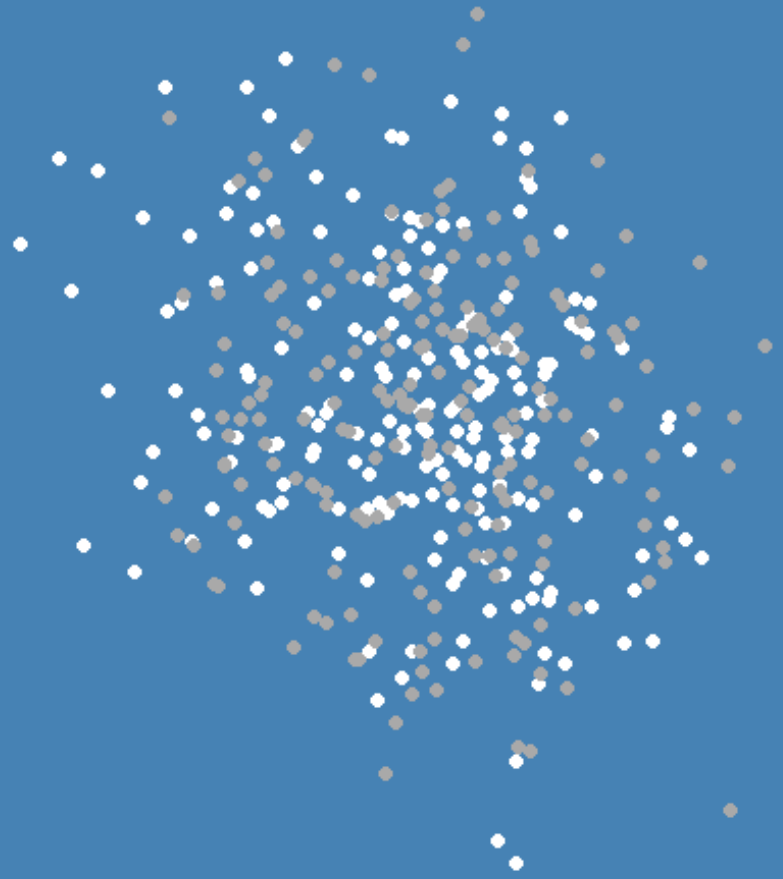

Basic R Functionality: Philosophy of R

"To understand computations in R, two slogans are helpful:

- *Everything that exists is an object.*
- *Everything that happens is a function call."*

---John Chambers, developer of R.

R Objects - Central Distinction

The central workhorse in R are objects which, in their most general sense, simply store information.

Data types

(how your data is stored)

- Numeric values (integers & doubles)
- Character strings
- Boolean values
- Factors
- ...

Data formats

(where your data is stored)

- Vectors
- Matrices
- Data frames/Tibbles
- Lists
- Arrays
- ...

Data Types

Numeric Values

There are two types of numerical values in R.

Integers are numbers without a decimal value. To explicitly denote that an object is an integer, you need to place an L behind the actual number.

```
x1 <- 5L
typeof(x1)
```

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

Doubles are numbers with (a) decimal value(s).

```
x2 <- 5.25
typeof(x2)
```

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

Both x1 and x2 are numeric objects.

```
is.numeric(x1)
```

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

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

Both x1 and x2 are numeric objects.

```
is.numeric(x2)
```

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

Character Strings

A string in R simply denotes a series of characters. Importantly, numbers (or any kind of symbol) can also be part of a string. To denote a character string in R, it is simply wrapped in quotation marks.

```
string1 <- "University of Mannheim" # example of a string
class(string1)
```

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

```
string2 <- "5" # still a string, not an integer as we use quotation marks
class(string2)
```

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

```
string3 <- "TRUE" # still a string
class(string3)
```

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

Factors

Factors are data types that consist of a pre-defined set of distinct categories, which are called levels in R.

- other than numeric objects, factors do not assume their values are continuous (e.g. ordinal, nominal)
- other than character strings, each value of a factor has to correspond to one of the pre-defined levels, while character strings can hold virtually any information

This is an example of a valid factor operation:

```
parties <- factor(levels=c("SPD", "CDU", "Greens", "FDP", "AfD", "Left")) # create an empty factor
parties[1:3] <- c("SPD", "Greens", "FDP") # fill with three values
print(parties)
```

```
## [1] SPD    Greens FDP
## Levels: SPD CDU Greens FDP AfD Left
```

This is an example of an invalid factor operation:

```
parties[4] <- "CSU" # add invalid value
```

```
## Warning in `[<-.factor`(`*tmp*`, 4, value = "CSU"): ungültiges
## Faktorniveau, NA erzeugt
```

Boolean Values

Boolean (or logical) values are either *TRUE* or *FALSE* values. You can produce these values by making logical requests on your data.

```
(7 - 3) > 1
```

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

Of course, logical values can be stored in objects as well.

```
bool <- 2 > 1
print(bool)
```

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

Operators in R

There are quite a few operators that you can use.

Arithmetic Operators

- + Addition
- - Subtraction
- * Multiplication
- / Division
- ^ Exponentiation
- %% Modulus (remainder from division)

Relational Operators

- < Less than
- > Greater than
- <= Less than or equal to
- >= Greater than or equal to
- == Equal to
- != Not equal to

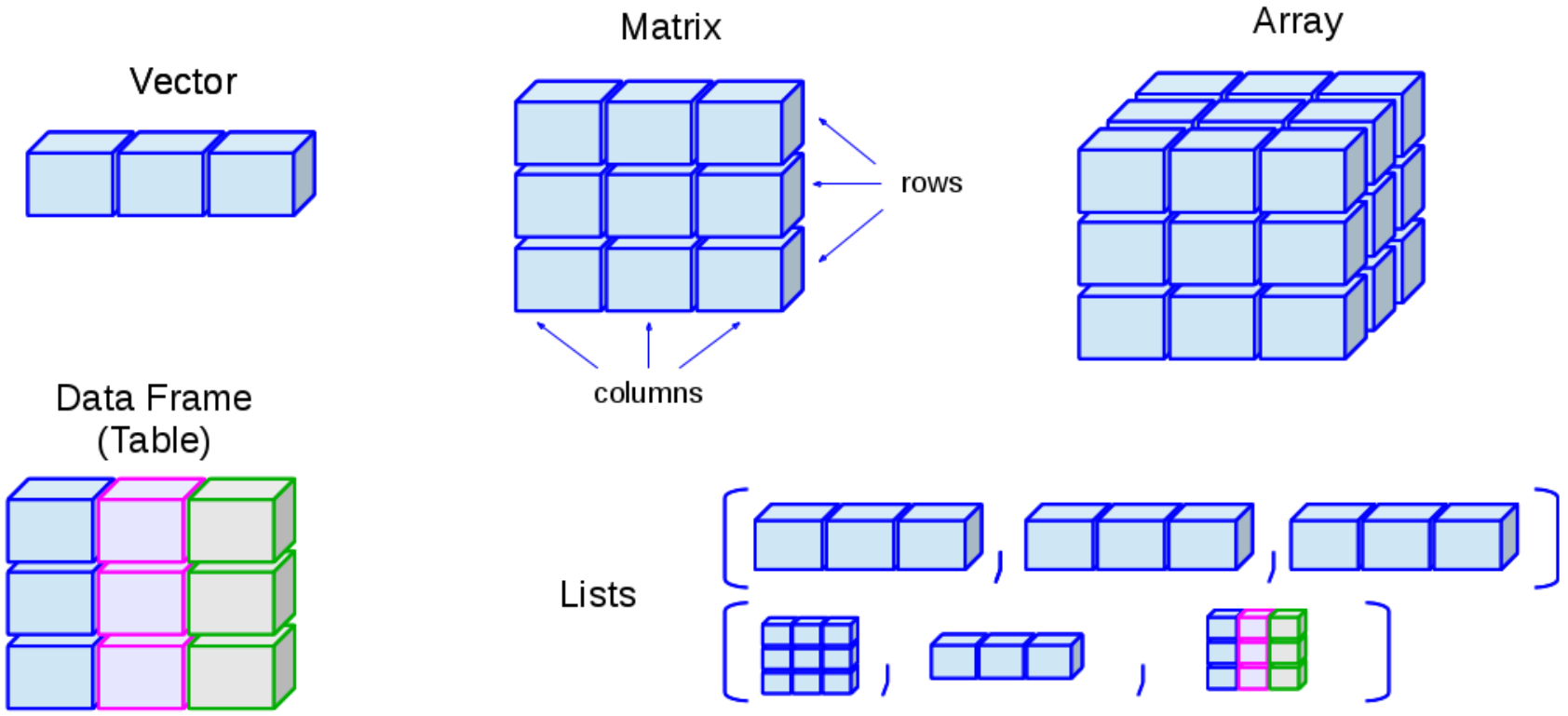
Logical Operators

- & And
- | Or

Data Formats

Data Formats

Individual objects can be stored in different data types, or containers.



Source: https://devopedia.org/r-data-structures.

Data Format: Vector

Vectors are built by combining (or "concatenating") individual objects with c().

```
numeric_vector <- c(1, 2, 3, 4, 5)
print(numeric_vector)
```

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

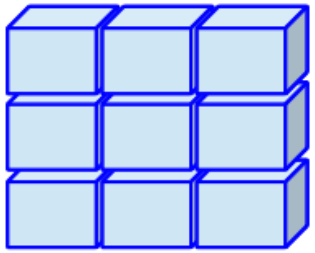
```
character_vector <- c("Austria", "England", "Brazil", "Germany")
print(character_vector)
```

```
## [1] "Austria" "England" "Brazil"  "Germany"
```

```
logical_vector <- c(TRUE, FALSE, FALSE, TRUE)
print(logical_vector)
```

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

Data Format: Matrix

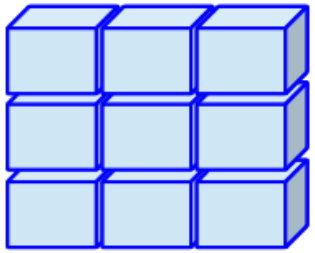


- Matrices are the most genuine rectangular data format in R.
- A matrix consists of n rows and k columns and hence has the dimensionality n x k .

```
matrix_example <- matrix(1:20, nrow = 4, ncol = 5) # create numeric matrix
print(matrix_example)
```

```
##      [,1] [,2] [,3] [,4] [,5]
## [1,]    1    5    9   13   17
## [2,]    2    6   10   14   18
## [3,]    3    7   11   15   19
## [4,]    4    8   12   16   20
```

Data Format: Matrix



- Matrices are the most genuine rectangular data format in R.
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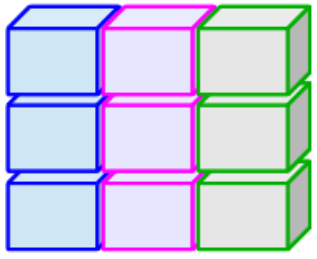
Let's check the dimensionality of this matrix.

```
dim(matrix_example)
```

```
## [1] 4 5
```

- *Note:* You cannot store multiple data types (e.g. character strings and numeric values in the same matrix or vector.)
- If you attempt this, all of your entries will be converted to character values.

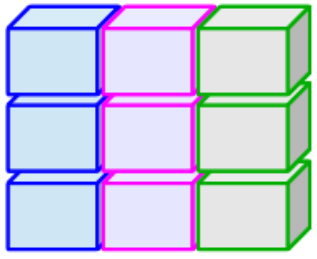
Data Format: Data Frame



- Data frames are R's equivalent of data sets as you know them from Stata, SPSS or other programs
- Data frames also are rectangular of dimensionality n rows x k columns
- *Note:* Data frames store variables of different classes.

```
df_example <-
  data.frame(
    country = c("Austria", "England", "Brazil", "Germany"),
    capital = c("Vienna", "London", "Brasília", "Berlin"),
    elo = c(1761, 1938, 2166, 1988)
  )
```

Data Format: Data Frame



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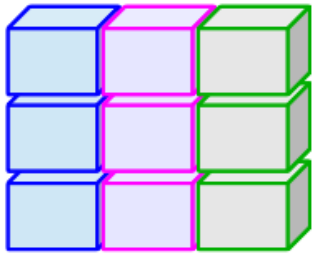
```
print(df_example)
```

```
##   country  capital  elo
## 1 Austria   Vienna 1761
## 2 England   London 1938
## 3  Brazil Brasília 2166
## 4 Germany   Berlin 1988
```

Data Format: Data Frame



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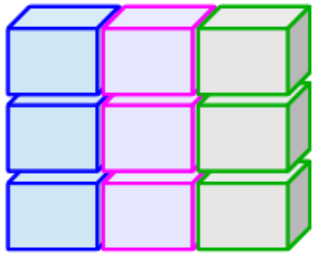
```
dim(df_example) # dimensions of the data frame
```

```
## [1] 4 3
```

Data Format: Data Frame



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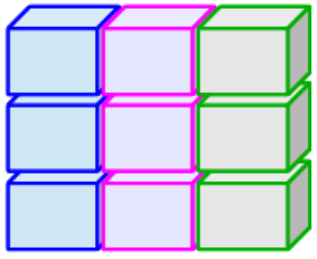
```
nrow(df_example) # number of observations
```

```
## [1] 4
```

Data Format: Data Frame



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```
ncol(df_example) # number of variables
```

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

Data Format: List

Essentially, lists just bind any number of objects together, even if these are of different classes.

```
list_example <-
  list(numeric_vector,
       character_vector,
       logical_vector,
       matrix_example,
       df_example)
```

Data Format: List

```
print(list_example)
```

```
## [[1]]
## [1] 1 2 3 4 5
##
## [[2]]
## [1] "Austria" "England" "Brazil"  "Germany"
##
## [[3]]
## [1]  TRUE FALSE FALSE  TRUE
##
## [[4]]
##      [,1] [,2] [,3] [,4] [,5]
## [1,]    1    5    9   13   17
## [2,]    2    6   10   14   18
## [3,]    3    7   11   15   19
## [4,]    4    8   12   16   20
##
## [[5]]
##   country  capital  elo
## 1 Austria   Vienna 1761
## 2 England   London 1938
## 3  Brazil Brasília 2166
## 4 Germany   Berlin 1988
```

References

Parts of this course are inspired by the following resources:

- Wickham, Hadley and Garrett Grolemund, 2017. *R for Data Science - Import, Tidy, Transform, Visualize, and Model Data*. O'Reilly.
- Bahnsen, Oke and Guido Ropers, 2022. *Introduction to R for Quantitative Social Science*. Course held as part of the GESIS Workshop Series.
- Breuer, Johannes and Stefan Jünger, 2021. *Introduction to R for Data Analysis*. Course held as part of the GESIS Summer School in Survey Methodology.
- Teaching material developed by Verena Kunz, David Weyrauch, Oliver Rittmann and Viktoriia Semenova.