MBA USP ESALQ

Database Structures, Types of Variables and Measurement Scales

Introduction to Machine Learning

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Data Science

Set of programming techniques focused on collection,treatment, manipulation, organization, analysis, extraction of information and data presentation, in the form of reports or graphics, in order to support the decision-making process.

Data Science techniques to be approached during the current Module:

Introduction to *data wrangling*;

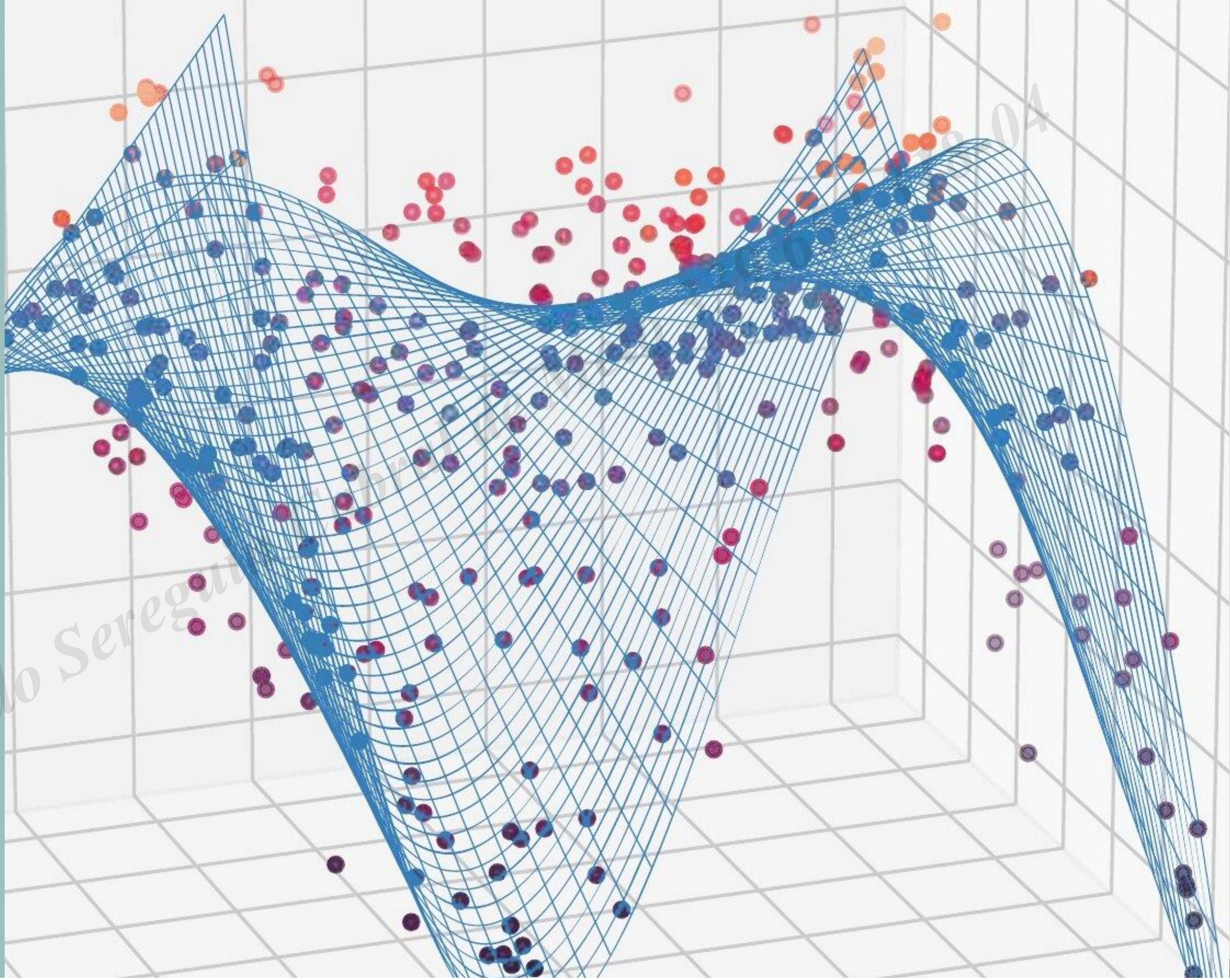
Construction and structuring *datasets*;

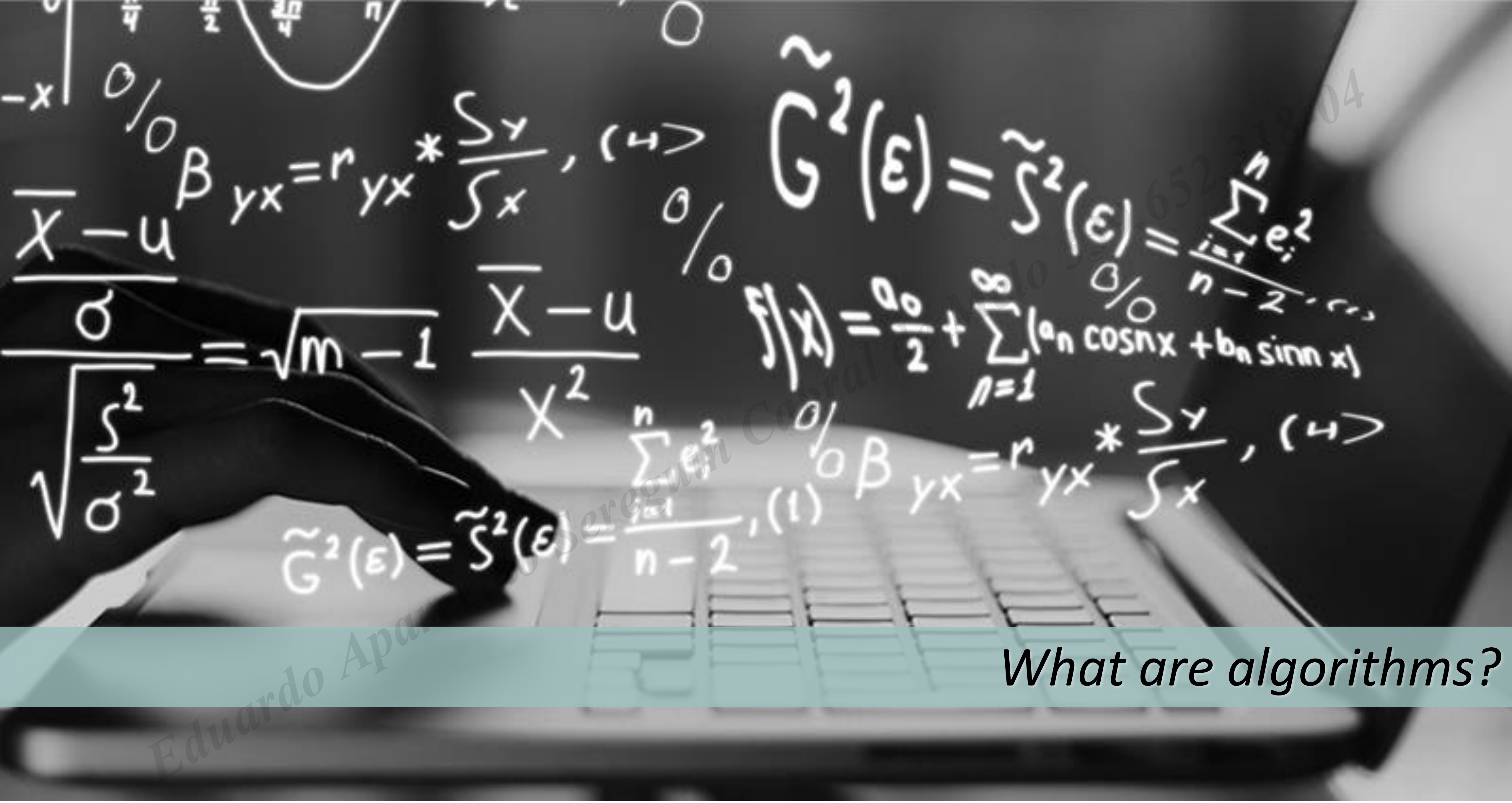
Scales of variables measurement;

Introduction to R programming language;

Algorithms of *machine learning*, encompassing:

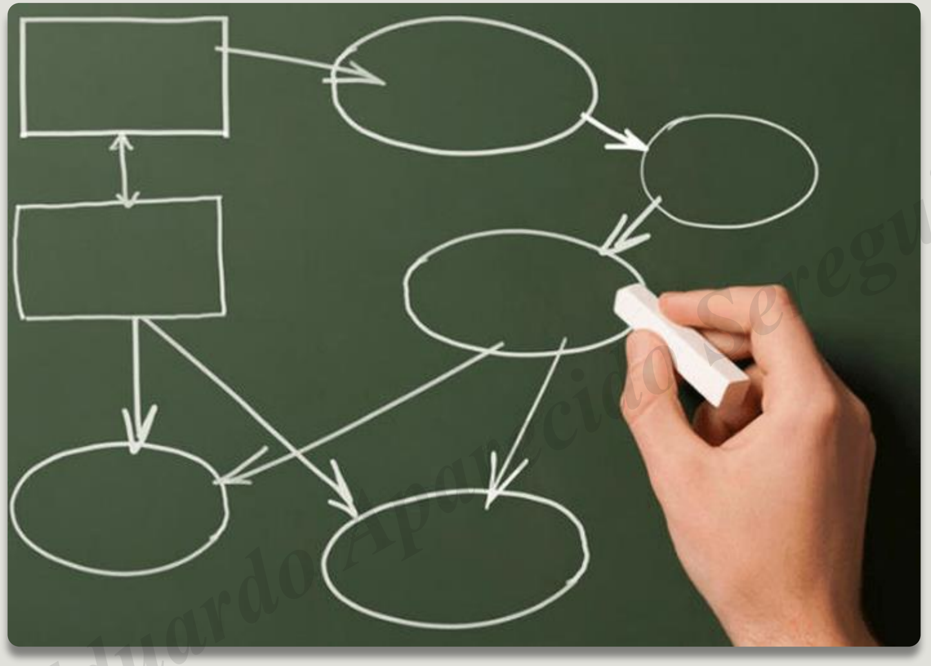
- Unsupervised Algorithms – exploratory techniques;
- Supervised algorithms – predictive techniques.




$\widetilde{G}^2(\varepsilon) = \widetilde{S}^2(\varepsilon) = \frac{\sum_{i=1}^{n} e_i^2}{n-2}$
$f(x) = \frac{a_0}{2} + \sum_{n=1}^{\infty} (a_n \cos nx + b_n \sin nx)$
$\beta_{yx} = r_{yx} * \frac{S_y}{S_x}$
$\frac{\frac{\overline{X}-u}{\sigma}}{\sqrt{\frac{S^2}{\sigma^2}}} = \sqrt{m-1}\,\frac{\overline{X}-u}{X^2}$
%

What are algorithms?

Algorithms – a concept:



Algorithms are explicit, literal, limited and systemic sequences of instructions and operations directed to the achievement of a preset objective data.

Basically, any known verb, as long as it denotes an action intended for humans, can be considered an algorithm.

Link: https://www.youtube.com/watch?v=pdhqwbUWf4U

Basic Taxonomy of Species of *Machine Learning* Algorithms

UNSUPERVISED

Machine learning techniques based on **unsupervised** algorithms (*unsupervised learning*) do not have the capacity of inference. They are dedicated to an exploratory, diagnostic analysis, of a studied phenomenon. Common examples: *Clusters* Analysis, Factorial Analysis of Main Components, Simple and Multiple Correspondence Analysis etc.

SUPERVISED

Machine learning techniques based on **supervised** algorithms (*supervised learning*) have the capacity of inference.

Therefore, they are dedicated to a confirmatory, predictive analysis of a given phenomenon studied. Common examples: Linear Regressions, Logistic Regressions, Decision Trees, *Random Forests*, Neural Networks, etc.

How to choose the algorithms?

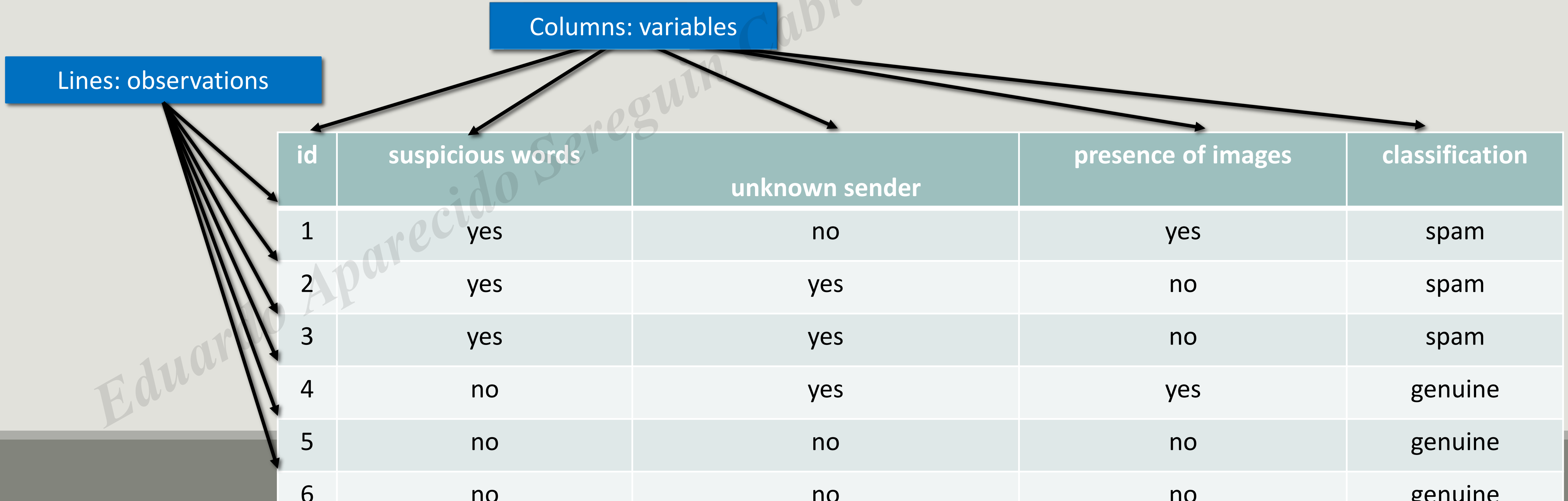
Step 1:
Unsupervised Algorithms or Supervised Algorithms?

The first step is the definition of the problem that you want to solve, whether academic or not.

- If there are objectives of **making inferences** for observations that are not present in the sample that was used for the training of the algorithm, **the ideal is the use of supervised algorithms**;
- If there are objectives of **making diagnoses**, without the intention of making inferences for observations that not present in the sample that was used for the algorithm training, **the ideal is the use of unsupervised algorithms of the unsupervised algorithms**.

Step 2: The Construction and Structure of a Database

As a general rule, the databases are structured in the following way: variables in columns and observations in lines.



Columns: variables

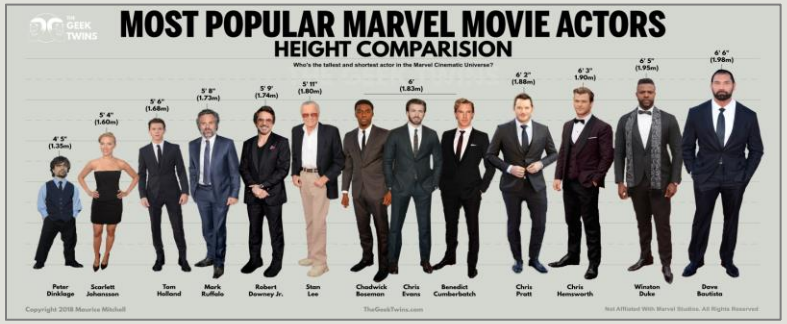
Lines: observations

id	suspicious words	unknown sender	presence of images	classification
1	yes	no	yes	spam
2	yes	yes	no	spam
3	yes	yes	no	spam
4	no	yes	yes	genuine
5	no	no	no	genuine
6	no	no	no	genuine

Step 3: What are the Measurement Scales of their Variables?

The incorrect definition of the scales of measurement of database variables is one of the main errors in the application of *machine learning* techniques. This error is irreparable, implying the restart of the entire modeling process, due to the biases created (e.g.: arbitrary weighting).

In short: are your variables only quantitative, only qualitative, or are both types present?



What is a variable?

What is a variable?

Variables can be understood as a characteristic of a sample or population, which can be measured, or counted or categorized.

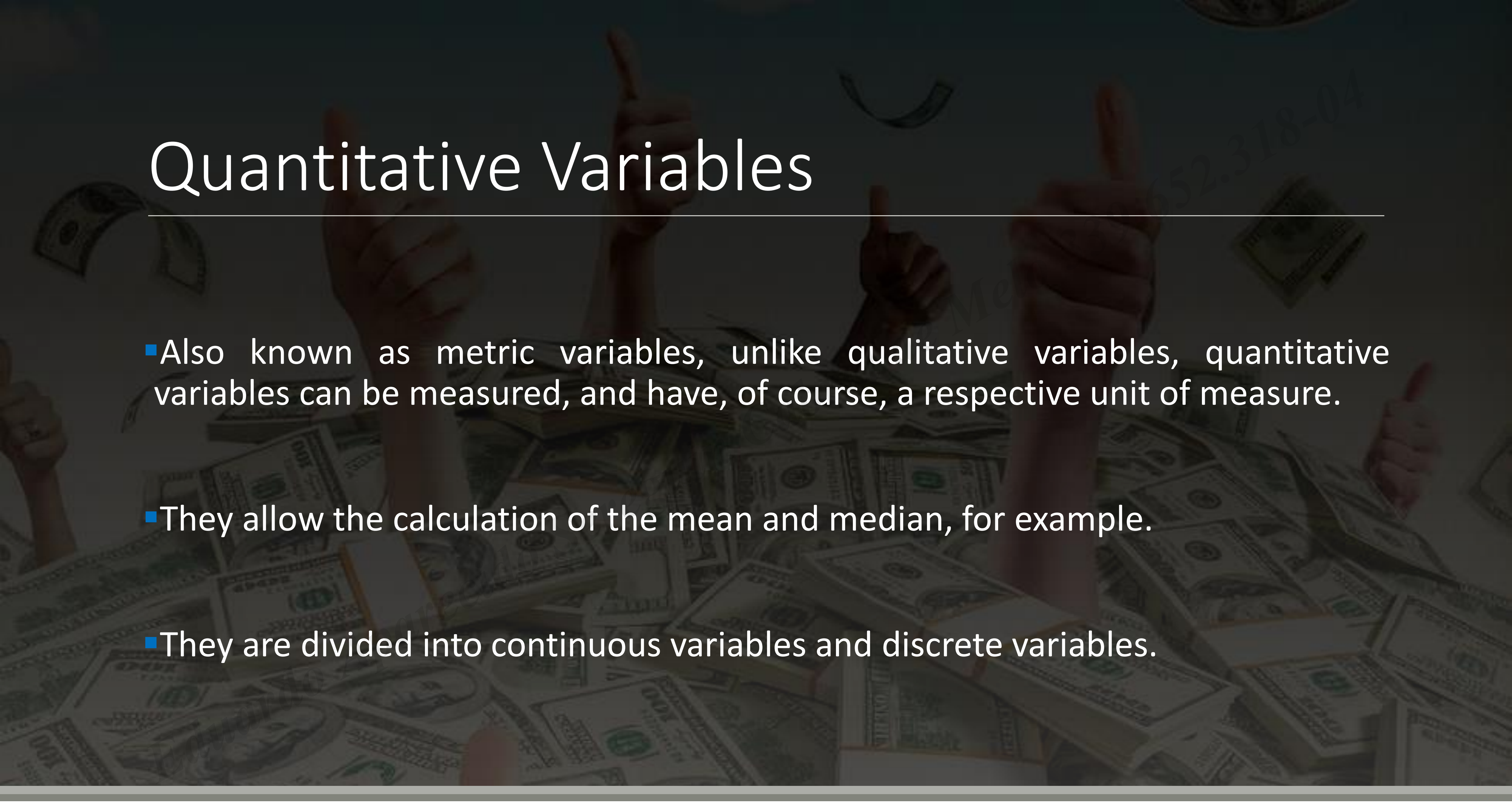
Good introduction examples are the height and/or weight of people, their income brackets, the color and/or model of cars they drive.

Individuals of a sample or population, not necessarily, need to be people in their physical sense. They can be objects, districts, municipalities, organizations, groups, cells, molecules, stars, etc. Thus, the characteristics of the individuals mentioned would be considered their variables.

For the course, we will establish the scale of measurement of variables in two: i) qualitative variables; and ii) quantitative variables.

Qualitative Variables

- They are also known as latent variables or categorical variables. They are variables that can not be measured; so only, categorized or counted.
- As they cannot be measured, they do not allow the calculation of descriptive statistics of position – e.g.: the mean and median.
- On the other hand, we can establish frequency tables for its categories.
- They are divided into nominal categories and ordinal categories.

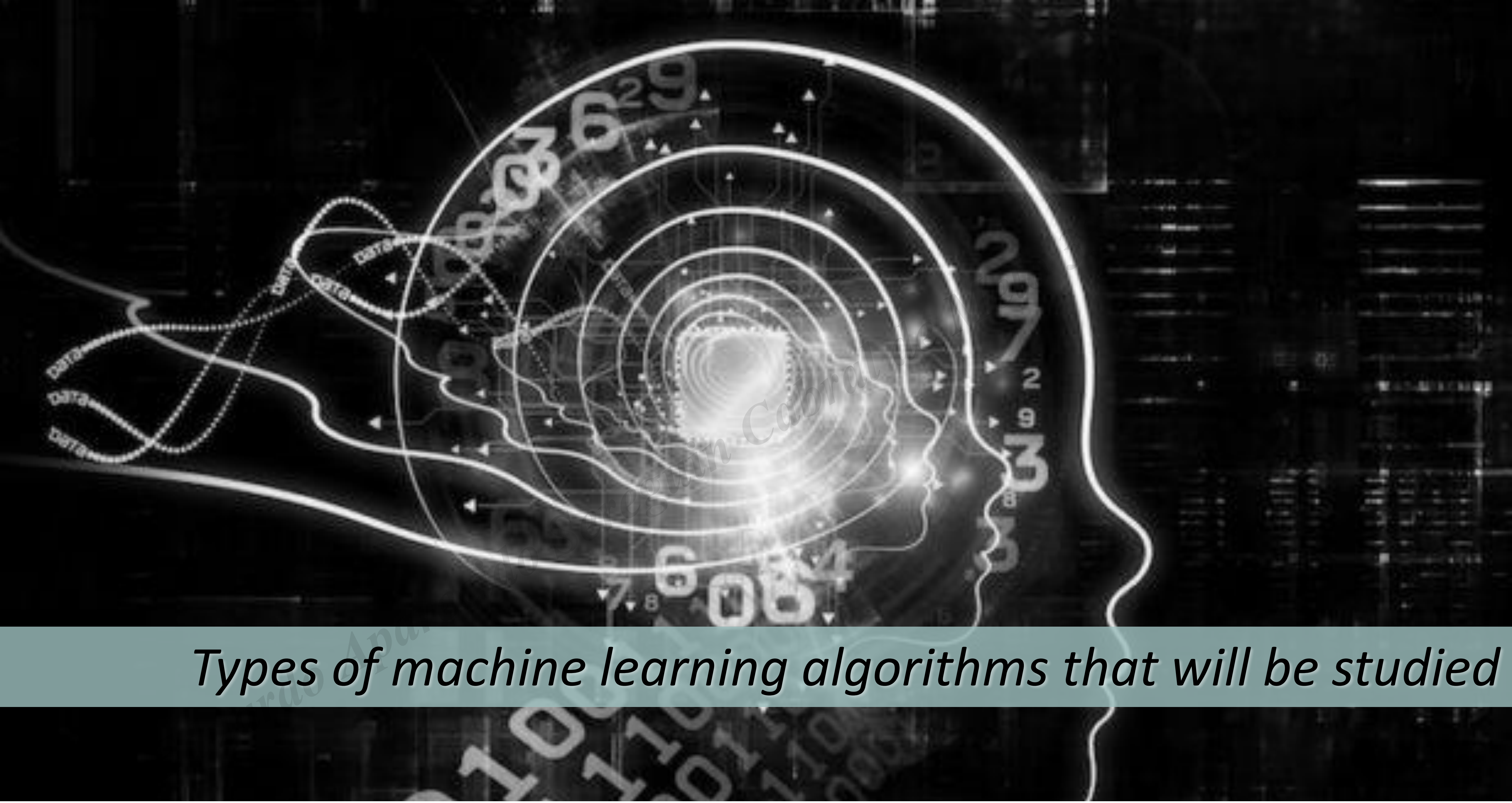


Quantitative Variables

- Also known as metric variables, unlike qualitative variables, quantitative variables can be measured, and have, of course, a respective unit of measure.

- They allow the calculation of the mean and median, for example.

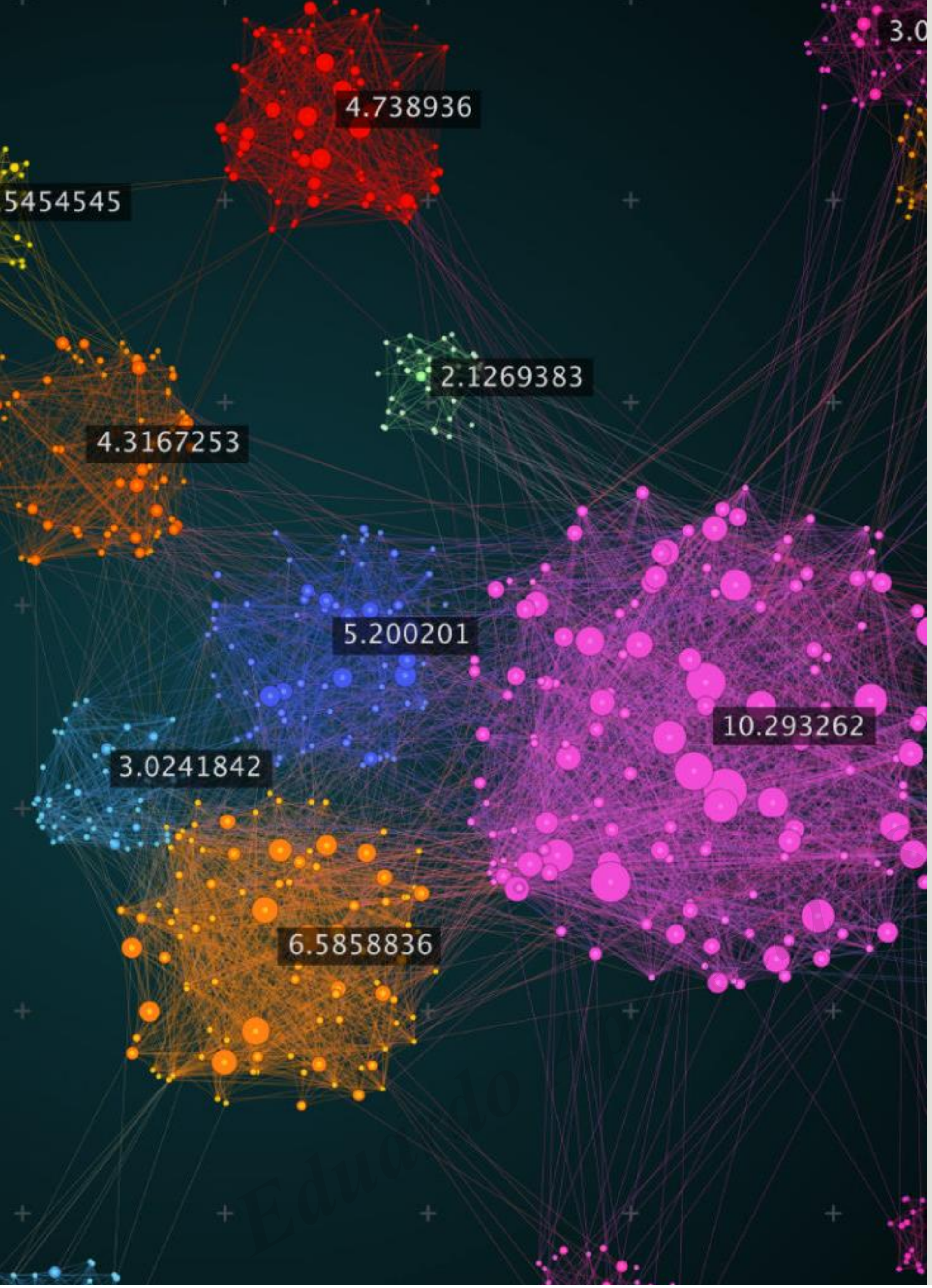
- They are divided into continuous variables and discrete variables.



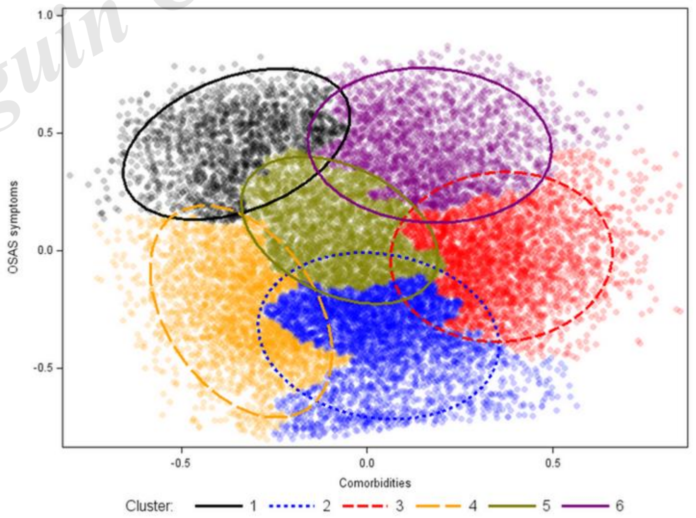
Types of machine learning algorithms that will be studied

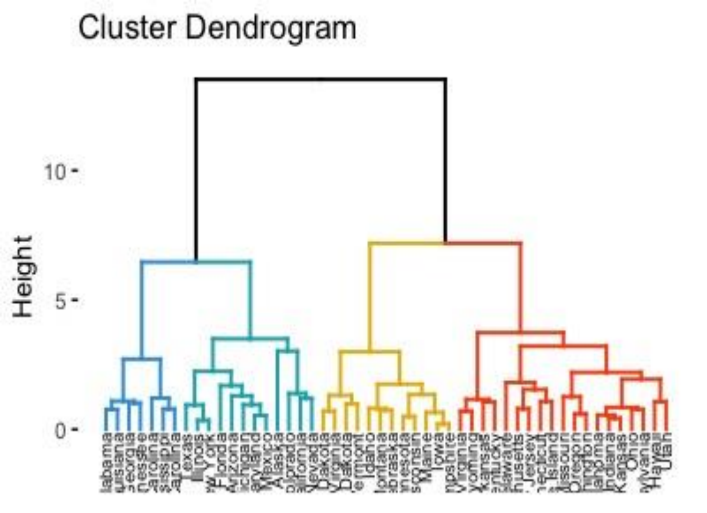
Unsupervised Algorithms

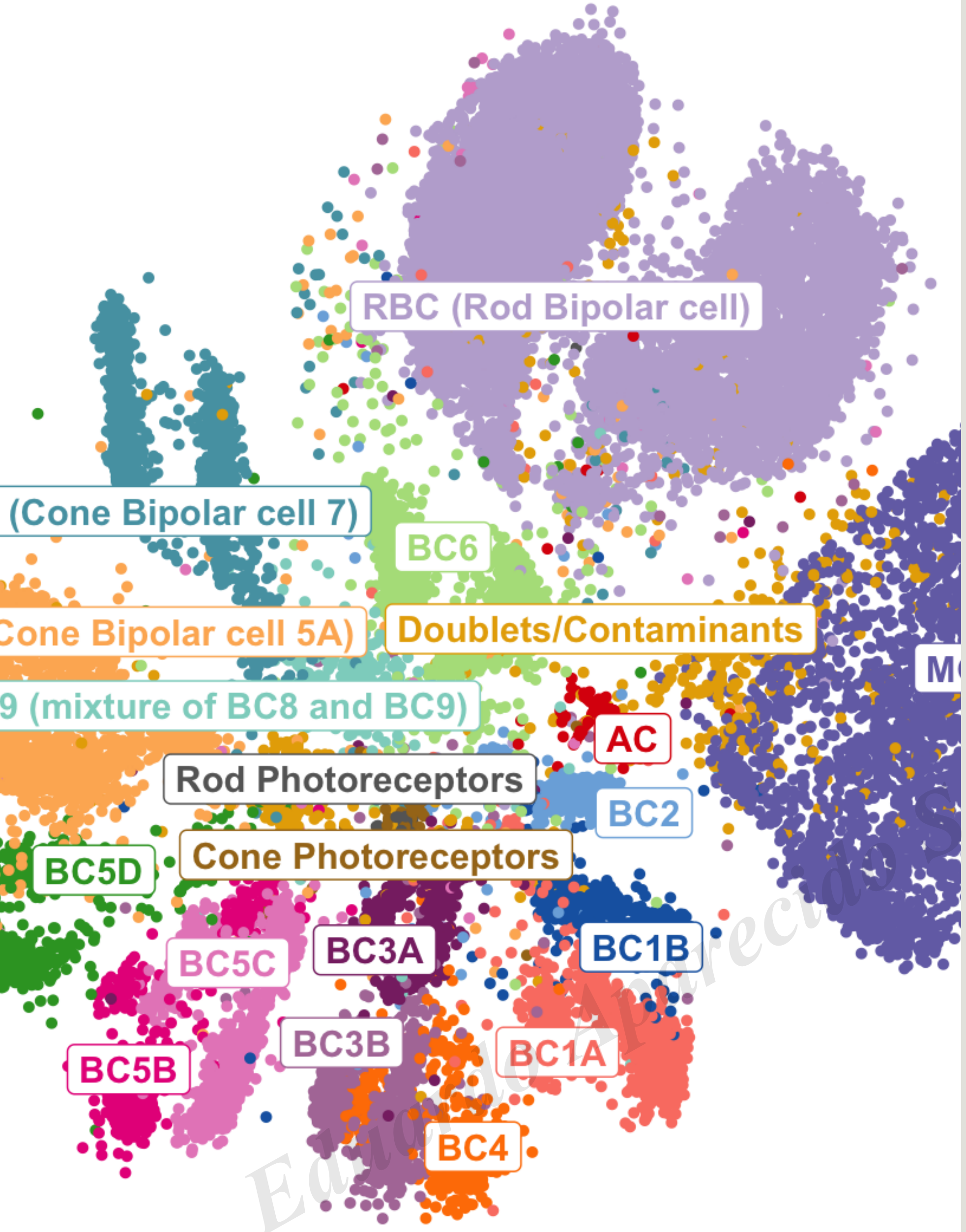
Grouping Analysis	▪ Metric variables (distance measurement); ▪ Binary variables (similarity measurement).
Factor Analysis by Principal Components	▪ Metric variables.
Simple and Multiple Correspondence Analyses	▪ Categorical variables.



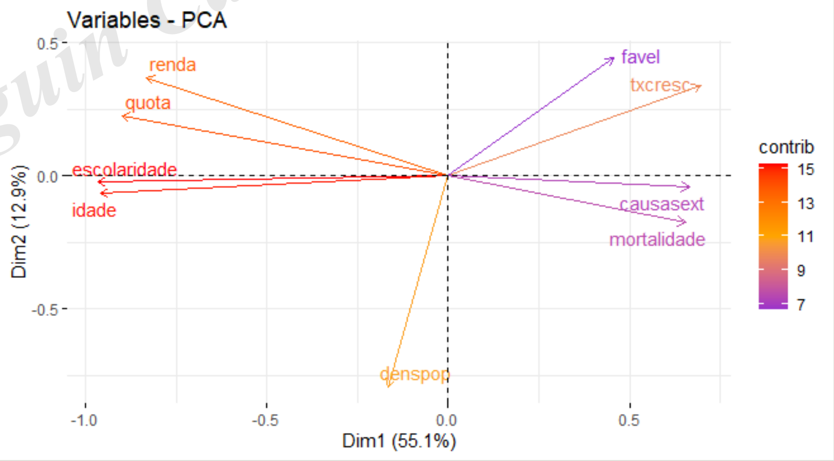
Grouping Analysis

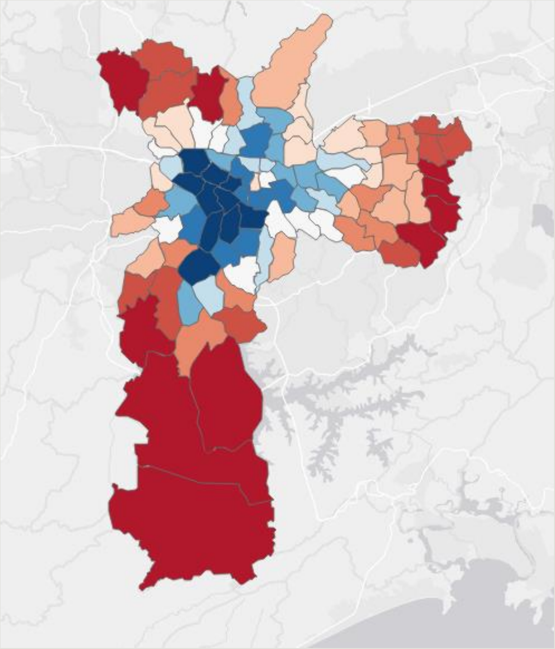


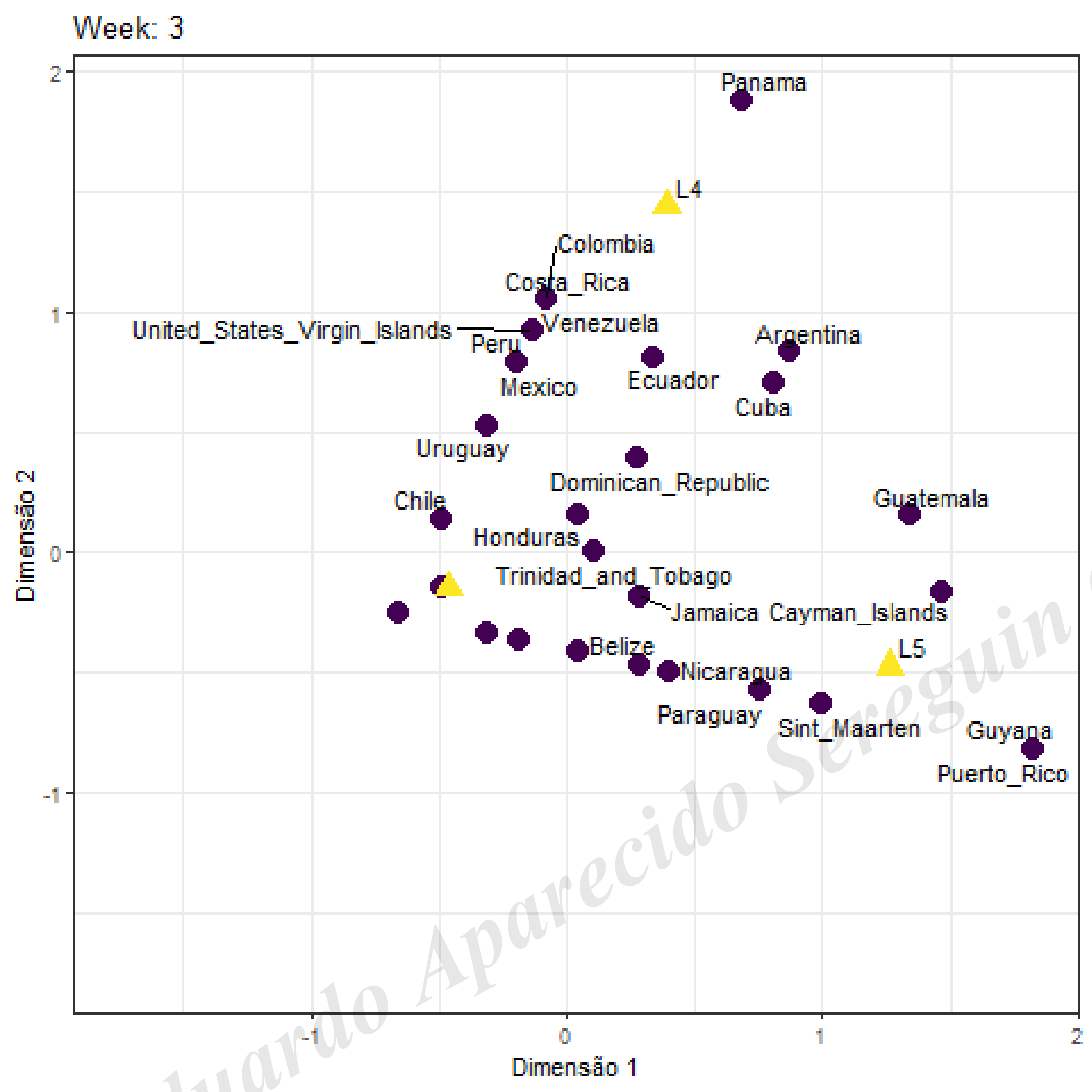




Factor Analysis – PCA







Simple and Multiple Correspondence Analysis

Supervised Algorithms

Generalized Linear Models

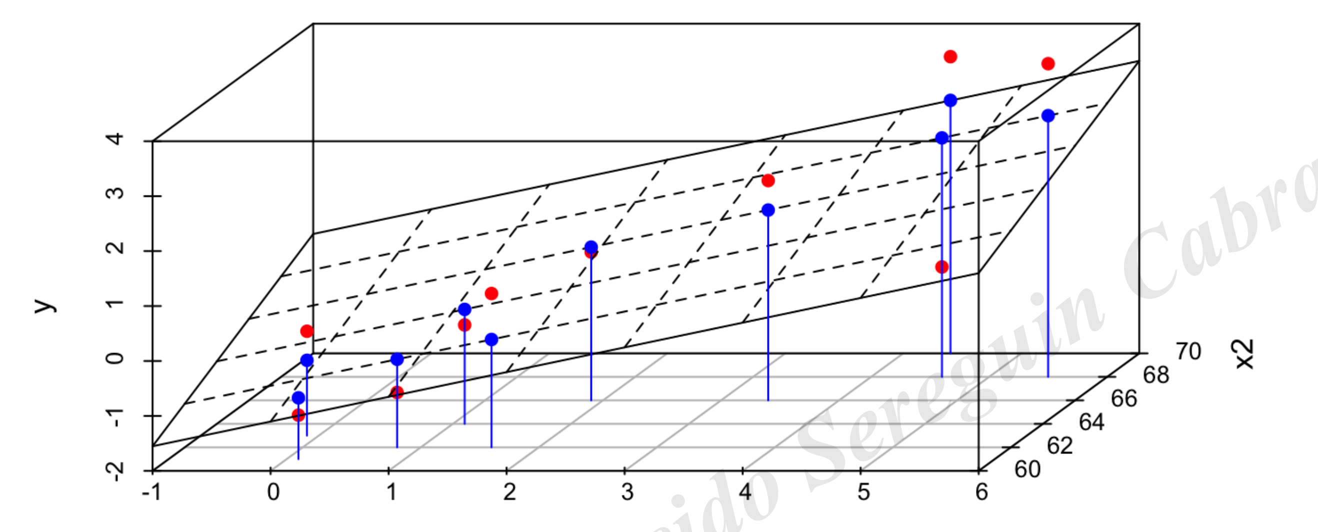
- Simple and Multiple Linear Regression;
- Binary and Multinomial Logistic Regression;
- Regression for Count Data;
- Zero-inflated Regression for Count Data.

Generalized Linear Mixed Models

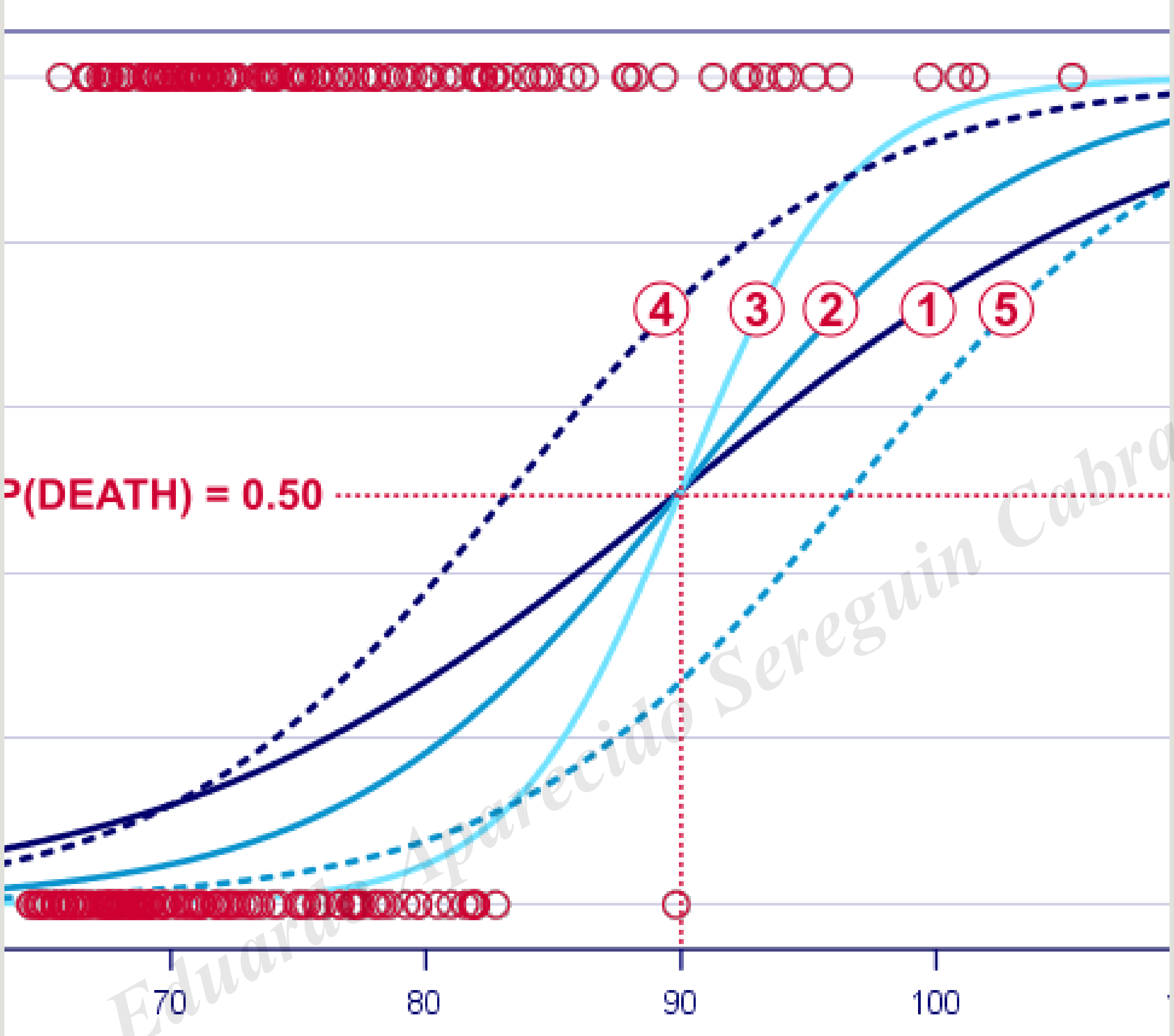
- Multilevel Linear Regression of 2 and 3 Levels.

Ensemble Models and *Neural Networks*

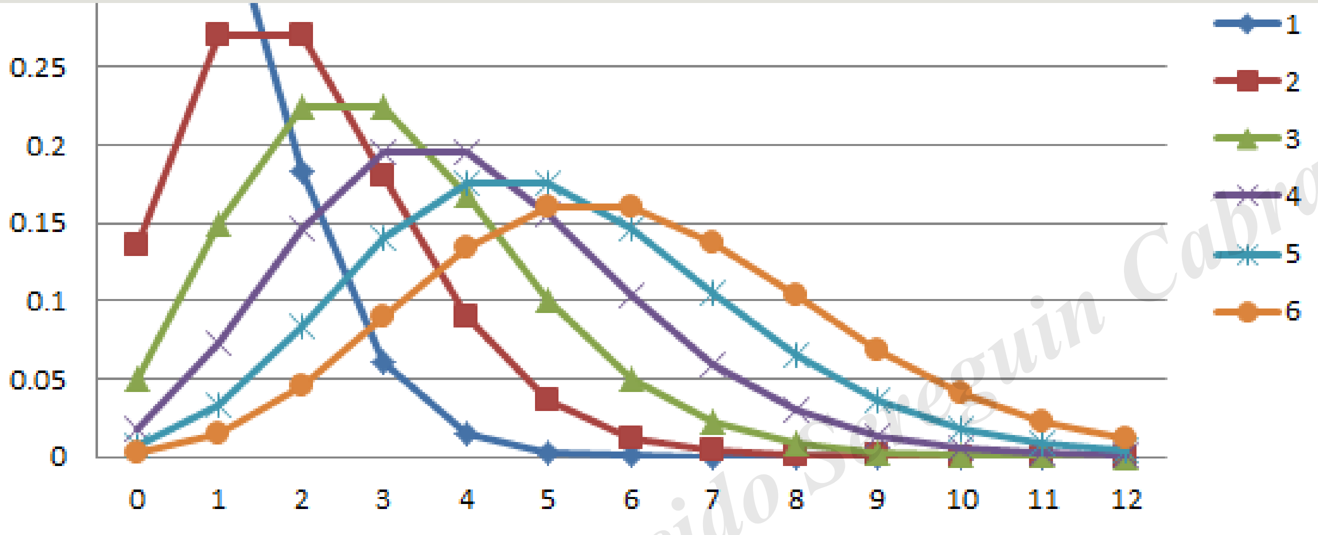
- Decision Trees of Classification or Regression;
- *Boosting*;
- *Bagging*;
- *Random Forests*;
- Artificial Neural Networks.



Linear Regression

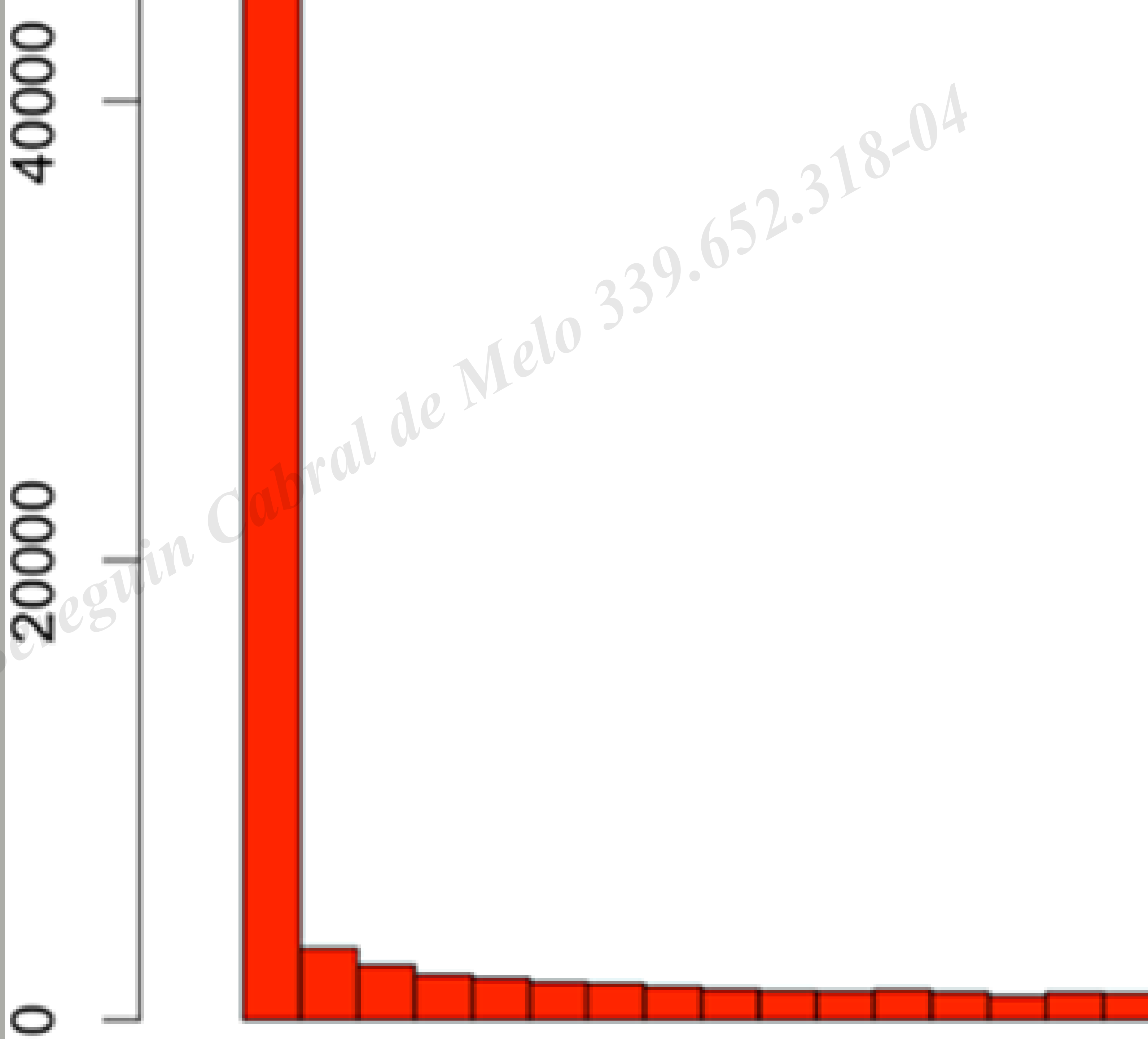


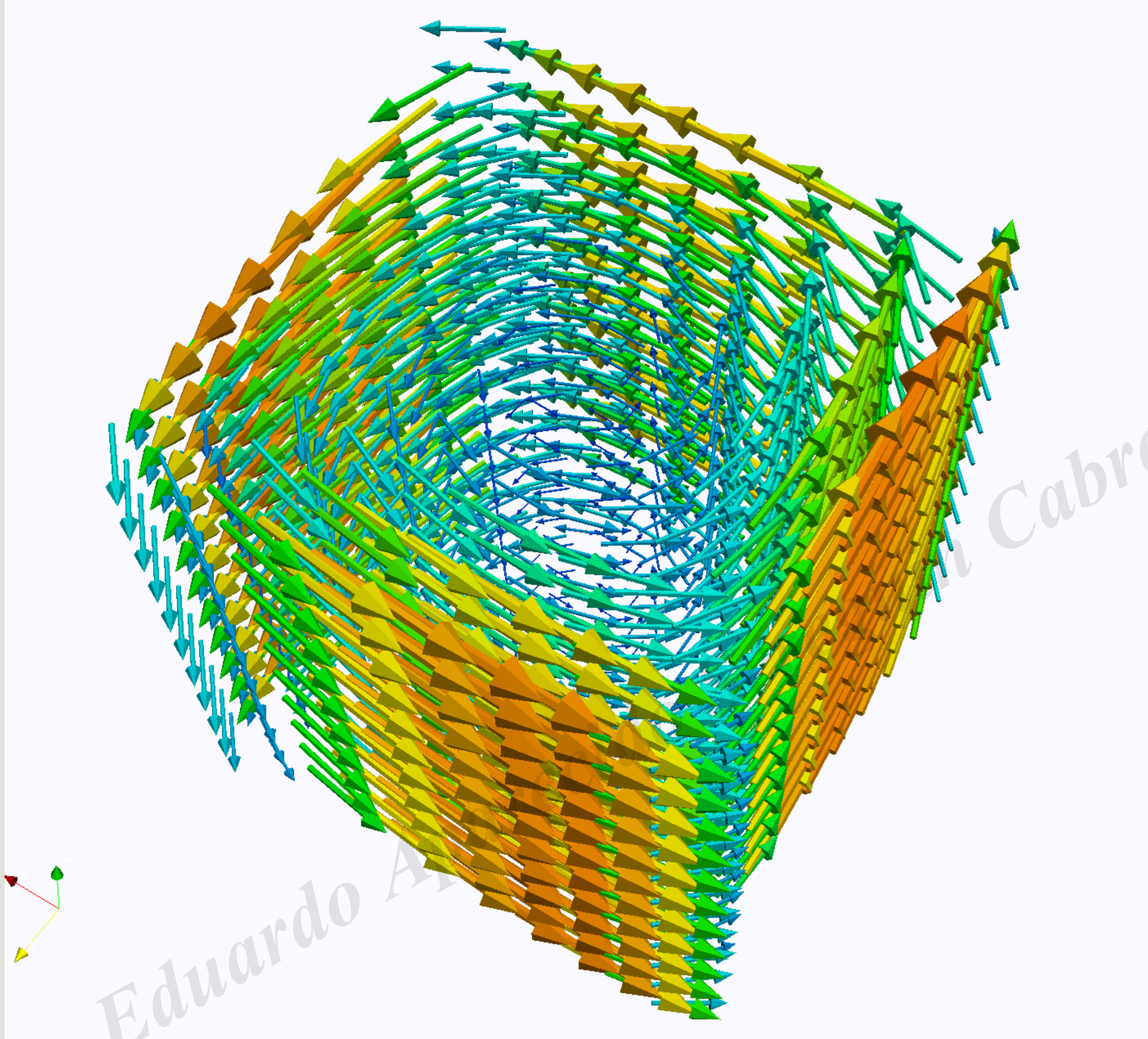
Logistic Regression



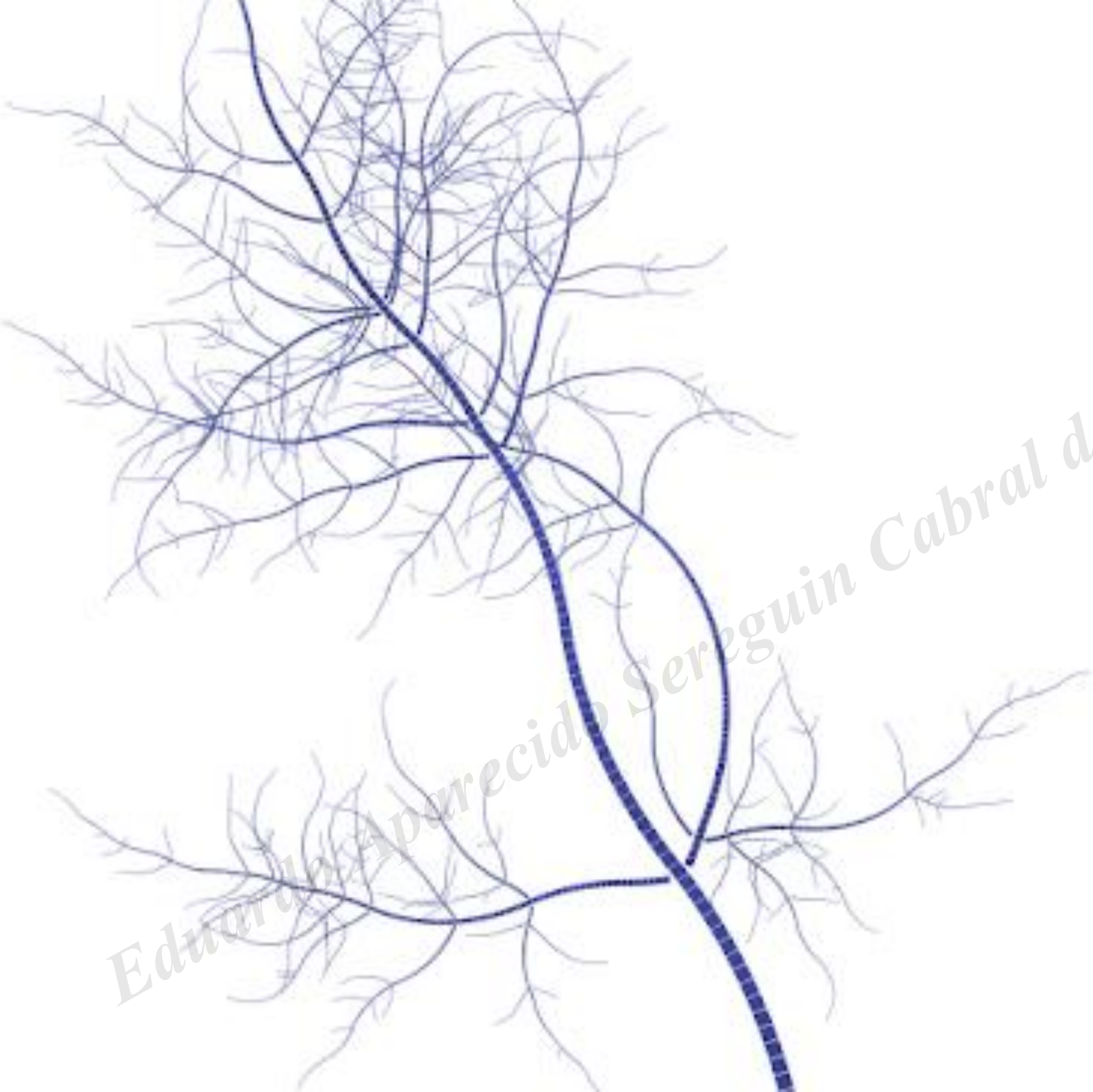
Regression for Count Data

Zero-inflated Regression for Count Data.

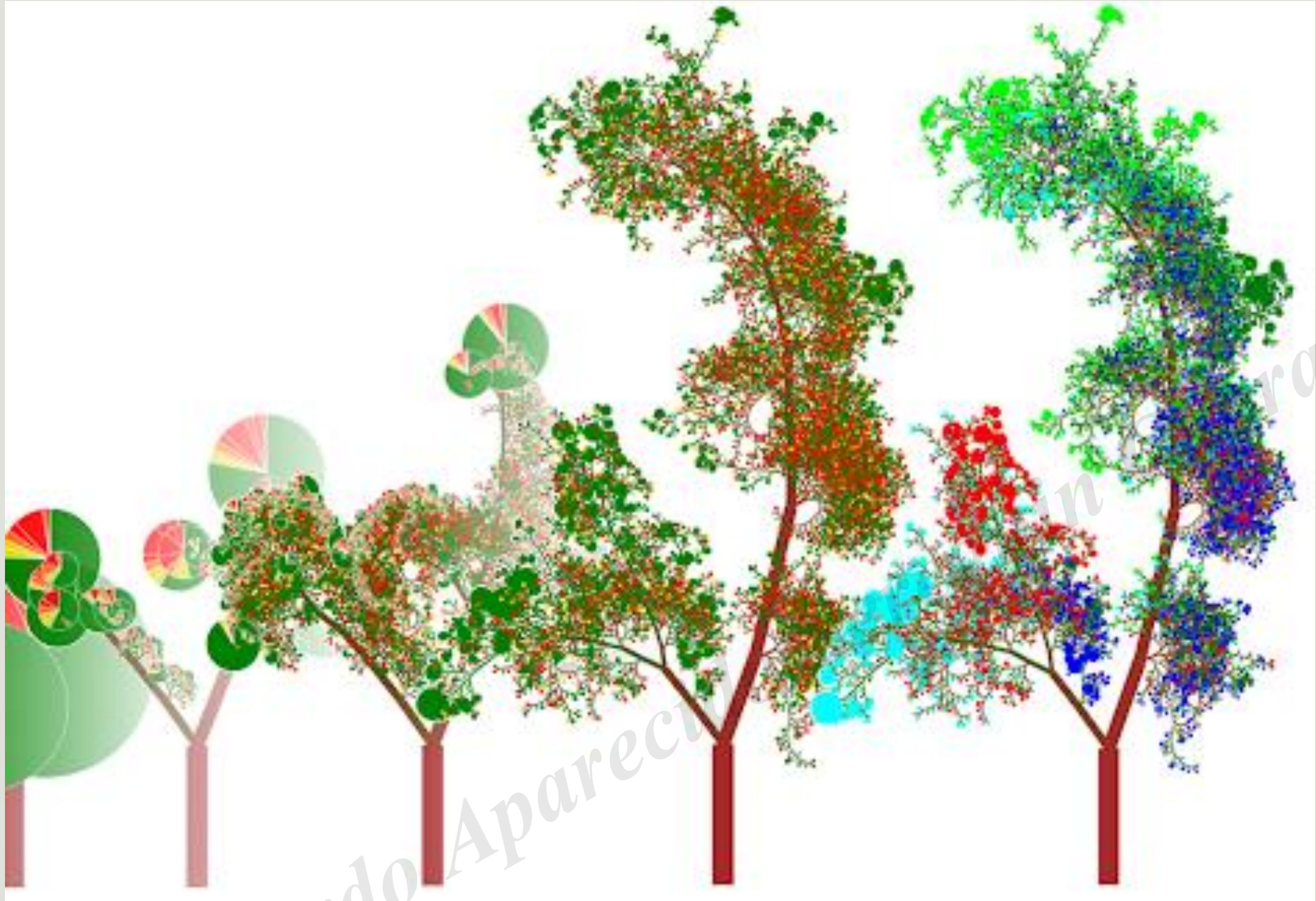




Multilevel Regression



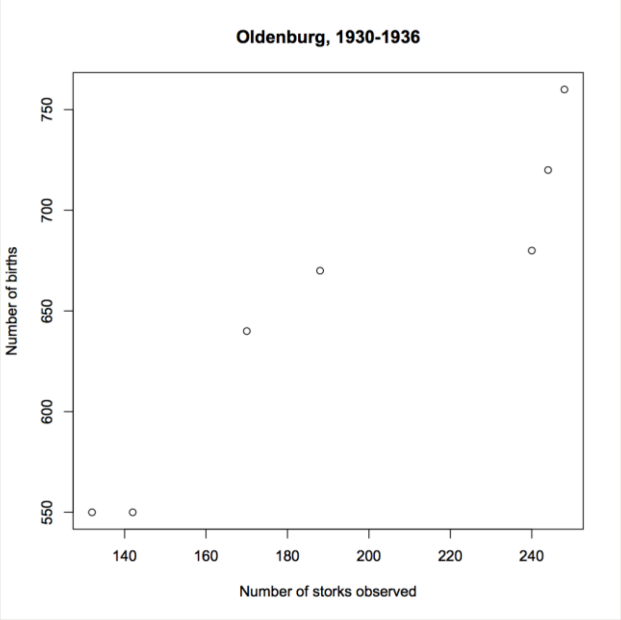
Decision Trees



Random Forests

Neural Networks

Cause and Effect Relationship

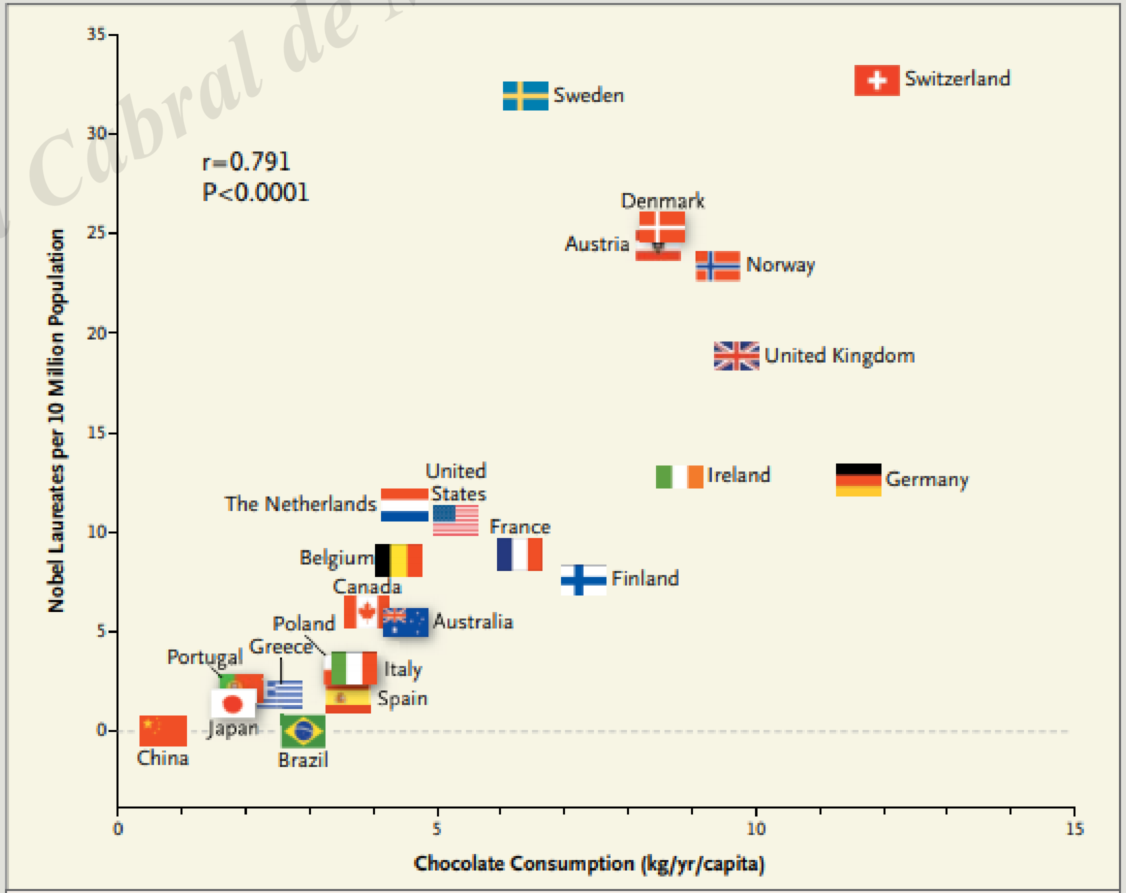


Didactic Example - 01

Data adapted by ox, Hunter, e Hunter de G. Fischer, Ornithologische Monatsberichte, vol. 44, no. 2, Jahrgang, 1936, Berlin e vol. 48, No. 1, Jahrgang, 1940, Berlin, e Statistiches Jahrbuch Deutscher Gemeinden, 27-33, Jahrgang, 1932-1938.

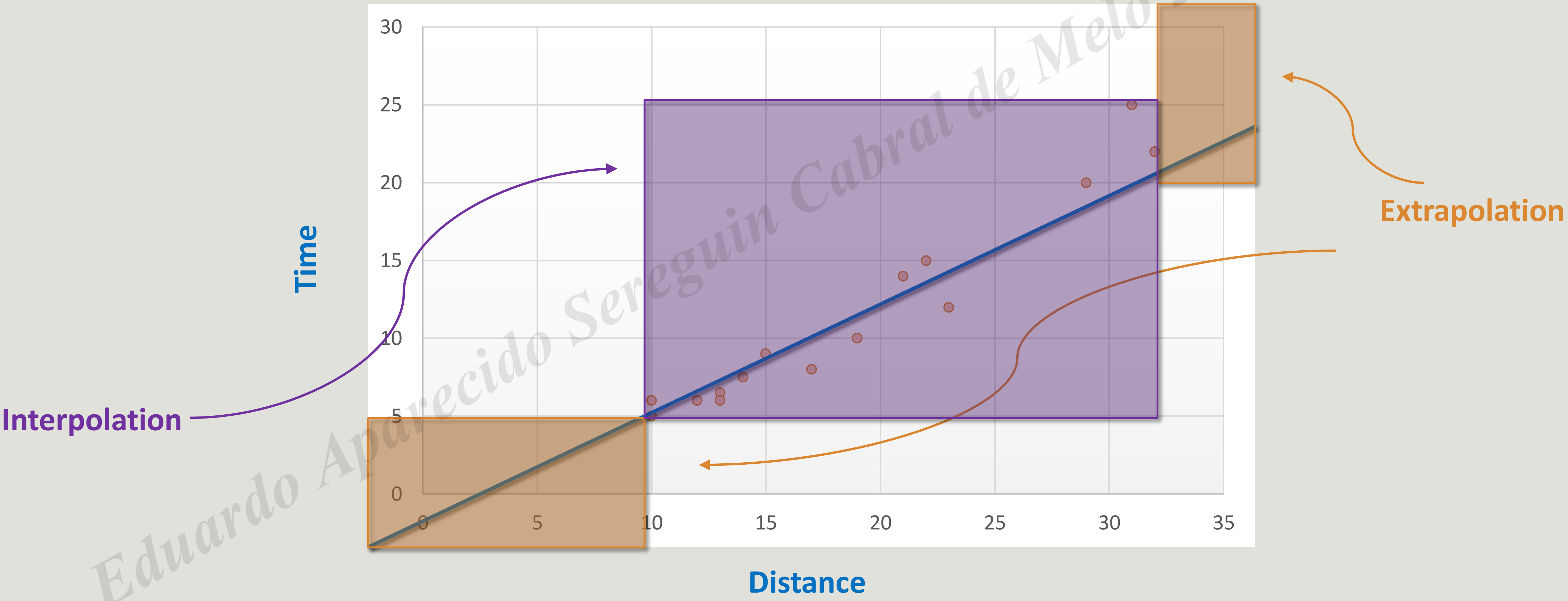
Didactic Example - 02

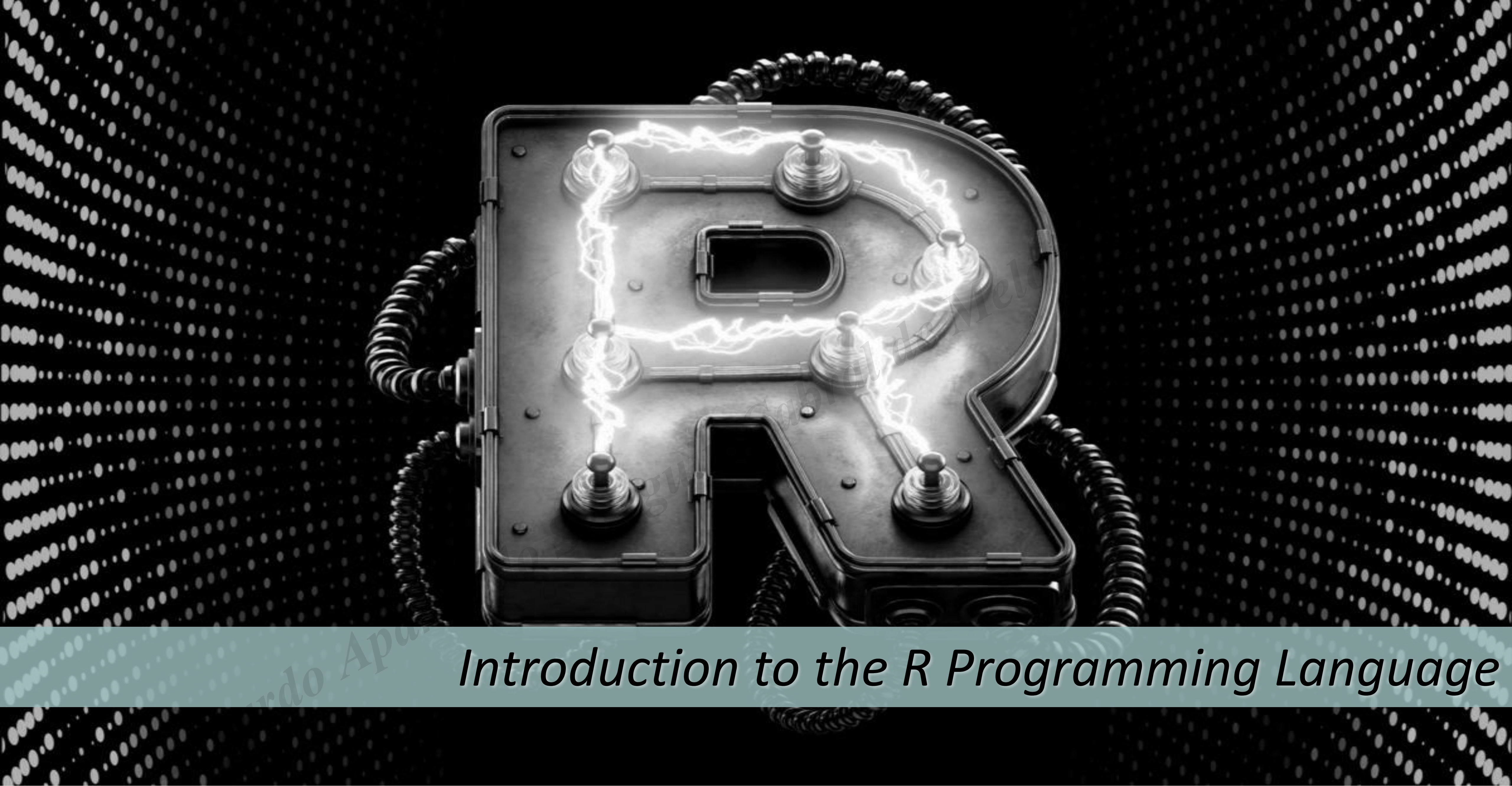
Data of Messerli, F. (2012). Chocolate Consumption, Cognitive Function, and Nobel Laureates. The New England Journal of Medicine, 367, pp. 1562-1564



Interpolation x Extrapolation

Interpolation and Extrapolation





Introduction to the R Programming Language

Why Learn a Programming language?

- Learn to program is very important when we want to understand the data! Plus: it is important to ensure that we can interpret the data so we can transform them into information!

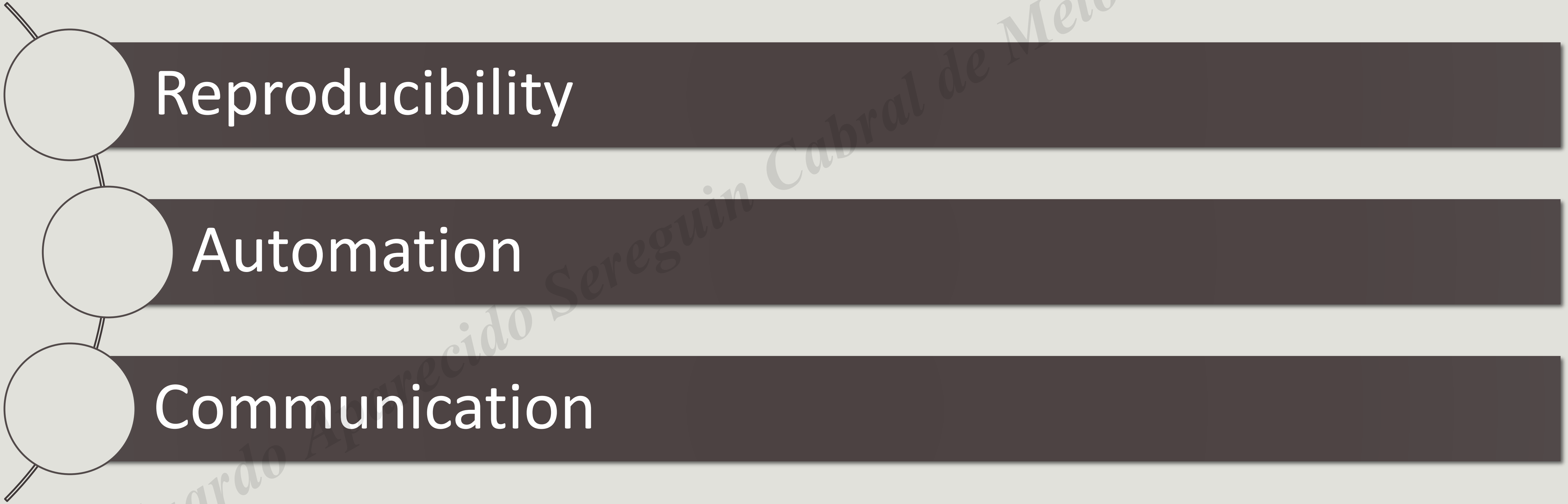
- If you work or want to work with data, programming is an extremely relevant skill

A fair question would be :

"I already work or wish to work with data, and I already have access to them via Windows, OSx, Android, iOS, Chrome, Mozilla, Edge, Safari...

Still, do I need to learn to program?"

The Limitations of a *Graphic User Interface* (GUI)



Reproducibility

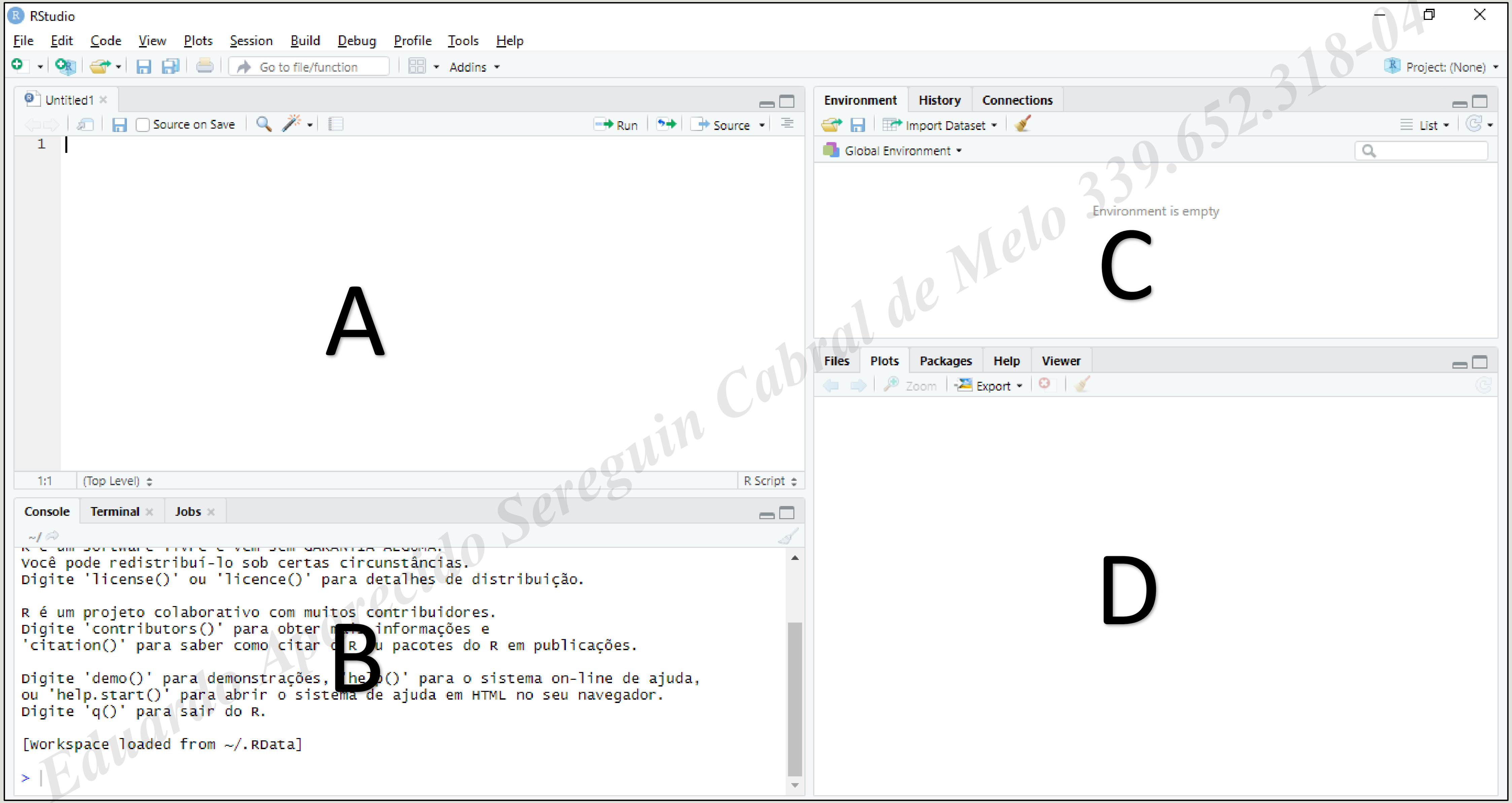
Automation

Communication

Why the R?

About the R

- The R language emerged in 1995, derived from the S language, and is object-oriented.
- It has several packages (over 17 thousand) with advantage for the application of the Advanced Statistics and a vast support community, in addition to strong capacities focused on the Data Science.
- Comprehensive R Archive Network (CRAN) is the R language repository in which each user can contribute to new packages (collections of functions in R with a compiled code). These packages can be easily installed with a command line.
- Recommended readings for those who are not yet familiar with the R language and wish to delve deeper:
  - Hands-On Programming with R (Grolemund, 2014);
  - R for Data Science (Wickham & Grolemund, 2016);
  - Ciência de Dados com R (Oliveira, Guerra & McDonnell, 2018).



```
R é um software livre e vem sem GARANTIA ALGUMA.
Você pode redistribuí-lo sob certas circunstâncias.
Digite 'license()' ou 'licence()' para detalhes de distribuição.

R é um projeto colaborativo com muitos contribuidores.
Digite 'contributors()' para obter mais informações e
'citation()' para saber como citar o R ou pacotes do R em publicações.

Digite 'demo()' para demonstrações, 'help()' para o sistema on-line de ajuda,
ou 'help.start()' para abrir o sistema de ajuda em HTML no seu navegador.
Digite 'q()' para sair do R.

[Workspace loaded from ~/.RData]

> 
```

Objects, Functions and Arguments

There are authors who define R objects as being a variable. For the course, we will understand that variables correspond to characteristics of a sample or population.

- Objects are simple ways of accessing something that was saved in the machine memory. It can be a value, a word, one or more variables, an URL, a sample or population database, a list of different things containing information and different sizes, a graph, a graph, a graph, an image, a new command, etc. **In R EVERYTHING is an object!** Each of these objects has a class!
- Functions correspond to actions, to orders directed to the machine;
- Arguments correspond to refinement or a better direction of the actions or orders proposed by the functions.

Creating an Object in the R

- There are two ways of creating an object in the R language:
  - Using the symbol =; or
  - Using the symbol <− called the assignment operator (prefer this form, reserving the symbol = for the value assignments of function arguments or for mathematical operations). The assignment sign can be quickly declared by pressing the ‘Alt’ and ‘-’ keys together.

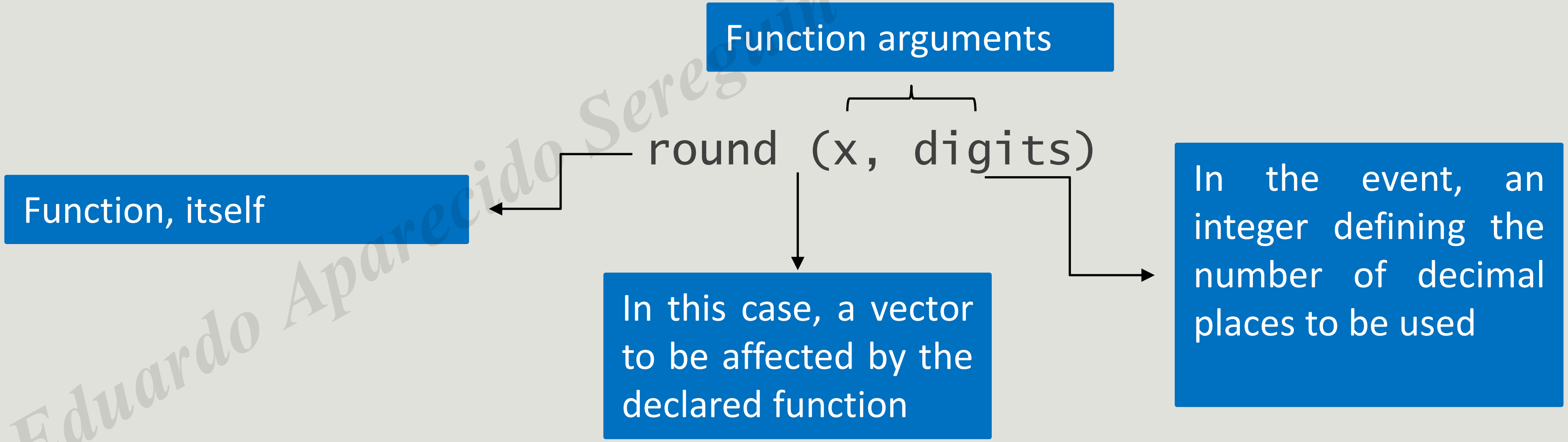
- The names of objects established in R must follow certain rules:
  1. They must not start with numbers and neither by points;
  2. It is not desirable that they contain spaces, although the situation is possible with the use of symbols ``;
  3. Their nomenclatures also do not accept special characters, such as !, ~, $, @, +, --, /*.
  4. It is recommended to avoid appointing the objects with the same name of functions already established;
  5. It is recommended not to use accents and, whenever possible, avoid capital letters, as the language is *case sensitive.*

Main Introductive Functions of the Course

Function	Serves to:
args()	Verify the arguments of a given function in R
round()	Round numbers
sample()	Create samples
class()	Verify the classes of R objects
View()	View objects in spreadsheet form
head()	View the first observations of a database
tail()	View the latest observations of a database
str()	Observe the structure of a database
length()	Observe the length of a vector or of a data list
dim()	Discover the dimensions of an object
nrow()	Count the number of lines of a database
ncol()	Count the number of columns in a database
rm()	Remove an object from the work environment
install.packages()	Install packages
library()	Load packages

Using functions in R

To use a function in R, we must know its functional form, that is, we must, as a rule, declare the arguments inherent to it. Example of using the `round()` function:



Function arguments

`round (x, digits)`

Function, itself

In this case, a vector to be affected by the declared function

In the event, an integer defining the number of decimal places to be used

Packages in R Language

- The R language has thousands of packages directed to the most diverse areas of knowledge, and most is not installed in our computers. To install a package, we must command:

```
install.packages("package name here")
```

- The installation of a package is not enough for its use. Thus, in each new open section of RStudio, we must call them in the following way:

```
library(package name here)
```

Creating and Excluding Variables in a *Dataset*

- Creating a variable:

```
basededados$nova_variável <-
NA
or
mtcars[“nova_variável"] <- NA
```

- Excluding a variable:

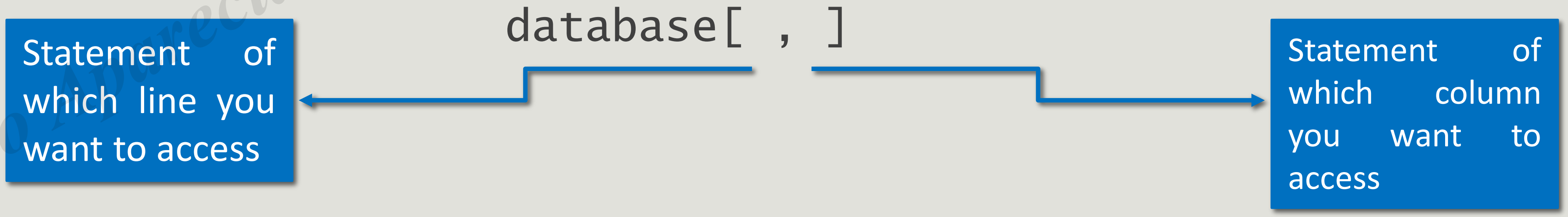
```
basededados$nova_variável <- NULL
```

Extracting Values from a *Dataset*

- To extract a column from a *dataset*, use the operator $:

```
basededados$nova_variável
```

- More precisely, values can also be extracted from the *dataset* with the operator [,]:



```
database[ , ]
```

Statement of which line you want to access

Statement of which column you want to access

Functions if, else and ifelse:

```
if(logical test)${
if the answer of the logical test is TRUE, do this

} else {
if the answer of the logical test is FALSE, do this other thing
}
```

```
ifelse(logical test,
yes =  if the answer of the logical test is TRUE, do this ,
no =  if the answer of the logical test is FALSE, do this other thing)
```

Functions `for`, `while` and `repeat`

```
y <- 10

for(i in 1:5){
      print(y + i)
}
```

For each `i` (could be any symbol or word), present in the sequence of 1 to 5, print the value of the sum between `y` and `i`

Functions for, while and repeat

```
z <- 0

while(z < 10){
        print(z)
       z <- z + 1
}
```

While z is smaller than 10, print z and then update the value of z by adding its value in a unit

Functions for, while and repeat

```
w - <- 3


repeat{
        print(w)
        w <- w + 2
         if(w > 18) break()


}
```

Repeate the steps below:

- Print the value of w;
- Update the value of w, adding it in two units;
- If w becomes greater than 18, stop everything.
-

Visualization of Data with `ggplot2`

- The most basic syntax of the `ggplot2`, for the creation of a chart from a *data frame*, is the following:

```
ggplot(data = database here) +
geom_geometry chosen here(aes(main elements of chart here))
```

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