Dynamic data visualization with R

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Contents

Overview

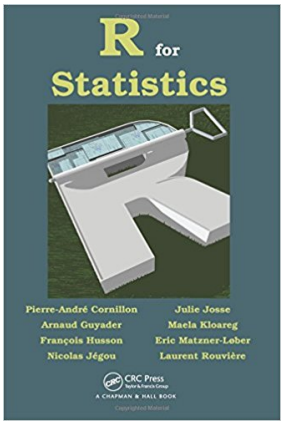
- *Materials*: available at https://lrouviere.github.io/page_perso/visualisationR.html
- *Prerequisites*: basics on **R**, probability, statistics and computer programming
- *Objectives*:
  - understand the importance of visualization in datascience
  - visualize data, models and results of a datascience project
  - discover (and master) some R visualization packages
- *Teacher*: Laurent Rouvière, laurent.rouviere@univ-rennes2.fr
  - Research interests: nonparametric statistics, statistical learning
  - Teaching: statistics and probability (University and engineer school)
  - Responsabilities: head of the Master Mathématiques Appliquées, Statistique of Rennes
  - Consulting: energy (ERDF), banks, marketing, sport

Resources

- *Slides* and *tutorials* (supplement materials + exercises) available at https://lrouviere.github.io/page_perso/visualisationR.html
- The *web*
- *Book*: R for statistics, Chapman & Hall

Why data visualization in your Master?

- Data are more and more *complex*
- Models are more and more *complex*



- Conclusions are more and more *complex*.
- We need visualization tools to:
  - *describe* data
  - *calibrate* models
  - *present* results and conclusions of the study.

Consequence

Visualization reveals crucial throughout a statistical study.

How to make visualization?

- (at least) 2 ways to understand *visualization*:
  1. Statistical methods or algorithms: PCA, LDA, trees...
  2. Computing tools: R packages.

- In this workshop, we will focus on some *R tools*:
  1. ggplot2: system for declaratively creating graphics $\Longrightarrow$ 3-4h.
  2. Mapping with *ggmap*, *sf* (static) *leaflet* (dynamic) $\Longrightarrow$ 3-4h.
  3. Dynamic or interactive tools
     - data with *rAmCharts* and *plotly* $\Longrightarrow$ 1h
     - dashboard with *flexdashboard* $\Longrightarrow$ 1h
     - web applications with *shiny* $\Longrightarrow$ 5h

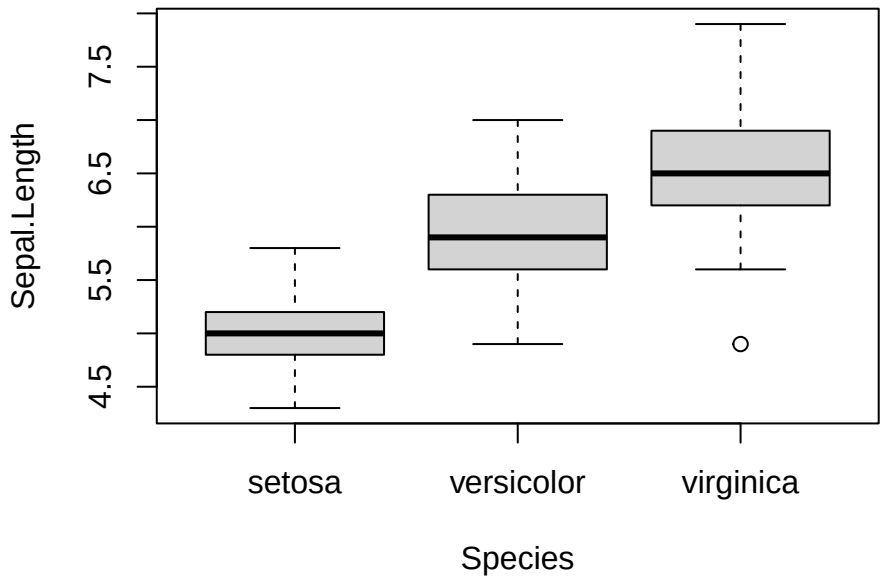
Boxplot for the iris dataset

```
> data(iris)
> summary(iris)
  Sepal.Length    Sepal.Width     Petal.Length    Petal.Width
 Min.   :4.300   Min.   :2.000   Min.   :1.000   Min.   :0.100
 1st Qu.:5.100   1st Qu.:2.800   1st Qu.:1.600   1st Qu.:0.300
 Median :5.800   Median :3.000   Median :4.350   Median :1.300
 Mean   :5.843   Mean   :3.057   Mean   :3.758   Mean   :1.199
 3rd Qu.:6.400   3rd Qu.:3.300   3rd Qu.:5.100   3rd Qu.:1.800
 Max.   :7.900   Max.   :4.400   Max.   :6.900   Max.   :2.500
       Species
```

```
 setosa    :50
 versicolor:50
 virginica :50
```

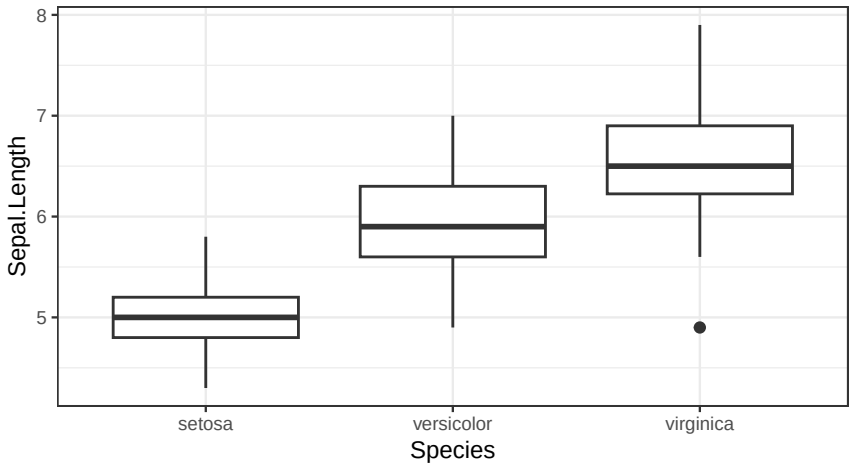
Classical tool

```
> boxplot(Sepal.Length~Species,data=iris)
```

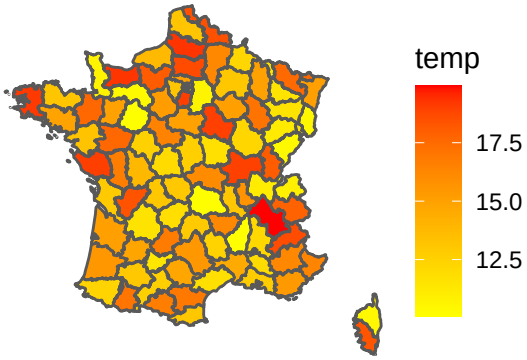


Ggplot tools

```
> library(tidyverse) #ggplot2 in tidyverse
> ggplot(iris)+aes(x=Species,y=Sepal.Length)+geom_boxplot()
```



A temperature map



Many informations

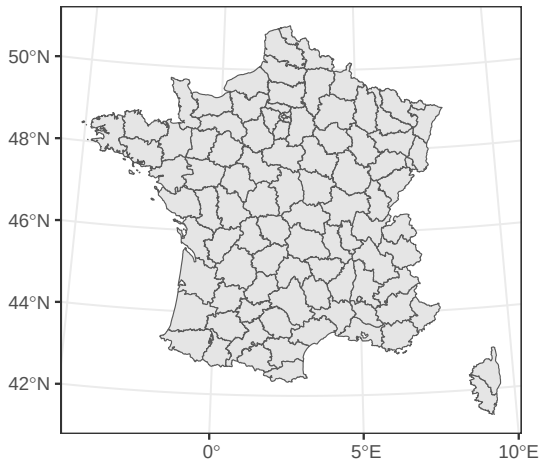
- Background map with boundaries of departments;
- Temperatures in each departments (meteofrance website).

Mapping with sf

```
> library(sf)
> dpt <- read_sf("./DATA/dpt")
> dpt |> select(NOM_DEPT,geometry) |> head()
Simple feature collection with 6 features and 1 field
Geometry type: MULTIPOLYGON
Dimension:     XY
Bounding box:  xmin: 644570 ymin: 6272482 xmax: 1077507 ymax: 6997000
Projected CRS: RGF93 v1 / Lambert-93
# A tibble: 6 x 2
  NOM_DEPT                                                    geometry
  <chr>                                                <MULTIPOLYGON [m]>
1 AIN                    (((919195 6541470, 918932 6541203, 918628 6~
2 AISNE                  (((735603 6861428, 735234 6861392, 734504 6~
3 ALLIER                 (((753769 6537043, 753554 6537318, 752879 6~
4 ALPES-DE-HAUTE-PROVENCE (((992638 6305621, 992263 6305688, 991610 6~
5 HAUTES-ALPES           (((1012913 6402904, 1012577 6402759, 101085~
6 ALPES-MARITIMES        (((1018256 6272482, 1017888 6272559, 101677~
```

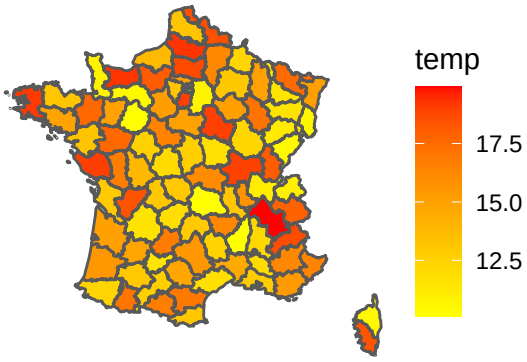
Background map

```
> ggplot(dpt)+geom_sf()
```



Temperature map

```
> ggplot(dpt) + geom_sf(aes(fill=temp)) +
+   scale_fill_continuous(low="yellow",high="red")+
+   theme_void()
```



Interactive charts with rAmCharts

```
> library(rAmCharts)
> amBoxplot(Sepal.Length~Species,data=iris)
```

Dashboard

- Useful to *publish* groups of related *data visualizations* (dataset, classical charts, simple models...)
- Package *flexdahboard*: https://rmarkdown.rstudio.com/flexdashboard/index.html
- Based on *Rmarkdown syntax*
- Example: https://lrouviere.shinyapps.io/dashboard/

Interactive web apps with shiny

- *Shiny* is a R package that makes it easy to build interactive web apps straight from R.
- *Examples*:

- understand overfitting in machine learning: https://lrouviere.shinyapps.io/overfitting_app/
- bike stations in Rennes: https://lrouviere.shinyapps.io/velib/

To summarize

- 15 hours for 3 (or 4) topics.
- 1 topic = slides + tutorial (supplement material + exercises).
- Require personal efforts.
- *To Practice*, to make mistakes and to correct these mistakes: *only way* to learn computer tools.
- You need to *work alone* between the sessions.
- Everyone can develop at its own pace (the goal is to progress), and *ask questions* during the sessions.
- I'm here to (try) to answer.

Outline

Contents

Data visualization with ggplot2

- *Graphs* are often the starting point for statistical analysis.

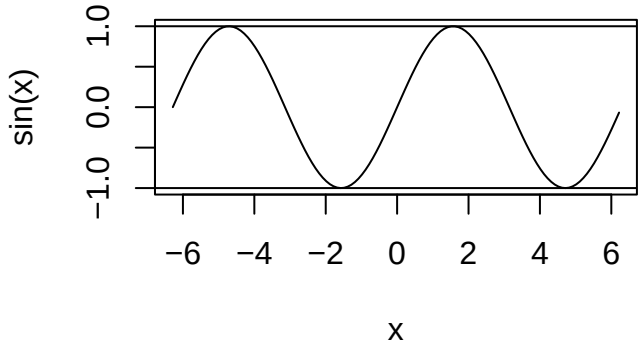
- One of the main advantages of **R** is how *easy* it is for the user to create many different kinds of graphs.
- We begin by a (short) review on *conventional graphs*,
- followed by an examination of some more complex representations, especially with *ggplot2 package*.

Conventional graphical functions (a reminder)

The plot function

- It is a *generic* function to represent all kind of data.
- For a *scatter plot*, we have to specify a vector for the x-axis and a vector for the y-axis.

```
> x <- seq(-2*pi,2*pi,by=0.1)
> plot(x,sin(x),type="l",xlab="x",ylab="sin(x)")
> abline(h=c(-1,1))
```



Graphs for datasets

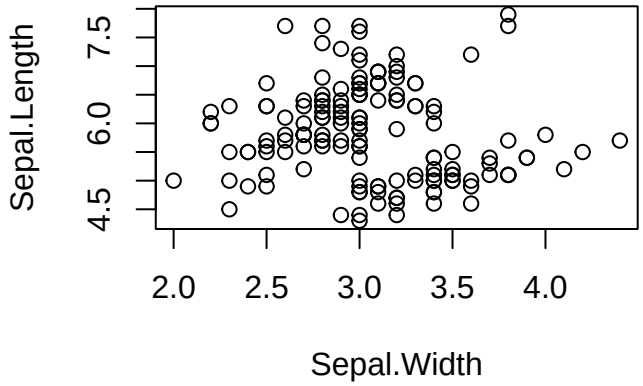
- *Many kind of representations* are needed according to the variables we want to visualize.
- Histogram for continuous variables, barplot for categorical variables.
- Scatterplot for 2 continuous variables.
- Boxplot to visualize distributions.

Fortunately

There is a R function for all representations.

Scatterplot with dataset

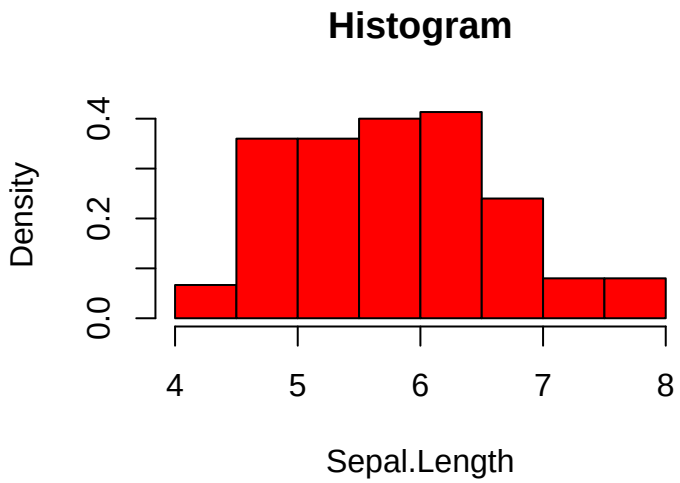
```
> plot(Sepal.Length~Sepal.Width,data=iris)
```




```
> plot(iris$Sepal.Width,iris$Sepal.Length) #similar
```

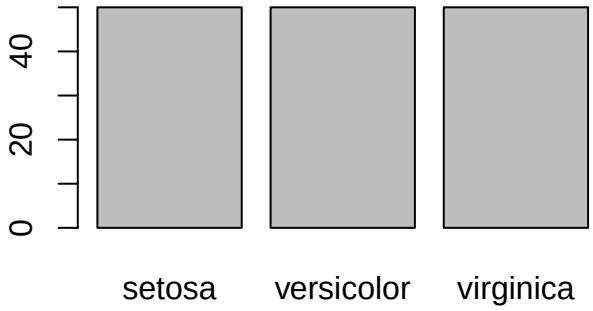
Histogram for continous variable

```
> hist(iris$Sepal.Length,probability=TRUE,
+      col="red",xlab="Sepal.Length",main="Histogram")
```



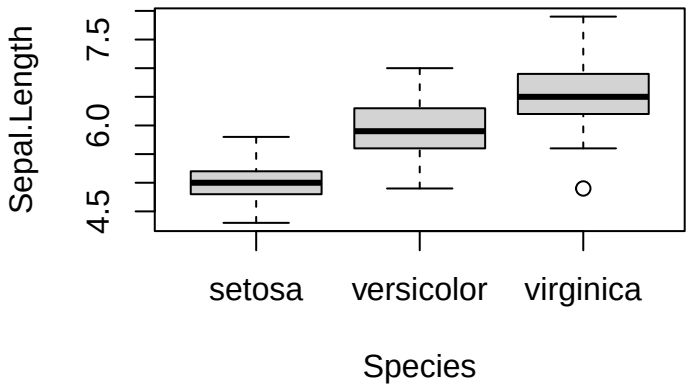
Barplot for categorical variables

```
> barplot(table(iris$Species))
```



Boxplot

```
> boxplot(Sepal.Length~Species,data=iris)
```



ggplot2 grammar

- *ggplot2* is a plotting system for R based on the grammar of graphics (as **dplyr** to manipulate data).
- The goal is to provide a *clear syntax* for an efficient visualization.
- Ggplot provides
  - "nice" graphs (nor always the case for conventional R graphs).
  - "complex" graphs with few command lines.
- Documentation: tutorial, book

Remark

Today, most of the charts are made with ggplot $\Longrightarrow$ important to master the syntax.

For a given dataset, a graph is defined from many **layers**. We have to specify:

- the *data*
- the *variables* we want to plot

- the *type of representation* (scatterplot, boxplot...).

Ggplot graphs are defined from these layers. We indicate

- the data with ggplot
- the variables with aes (aesthetics)
- the kind of representation with geom_...

The grammar

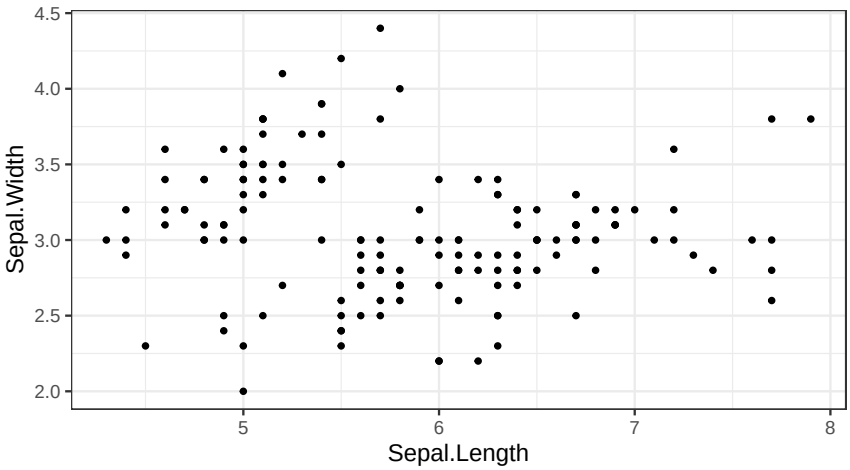
Main elements of the grammar are:

- Data (ggplot): the *dataset*, it should be a dataframe or a tibble.
- Aesthetics (aes): to describe the way that *variables* in the data are mapped. All the variables used in the graph should be specified in **aes**.
- Geometrics (geom_...): to control the *type* of plot.
- Statistics (stat_...): to describe *transformation* of the data.
- Scales (scale_...): to *control the mapping* from data to aesthetic attributes (change colors, size...).

All these elements are gathered with the operator +.

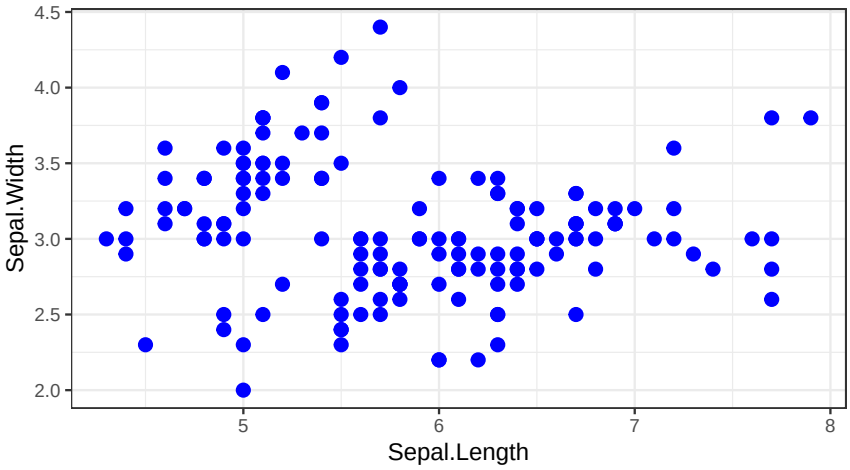
An example

```
> ggplot(iris)+aes(x=Sepal.Length,y=Sepal.Width)+geom_point()
```



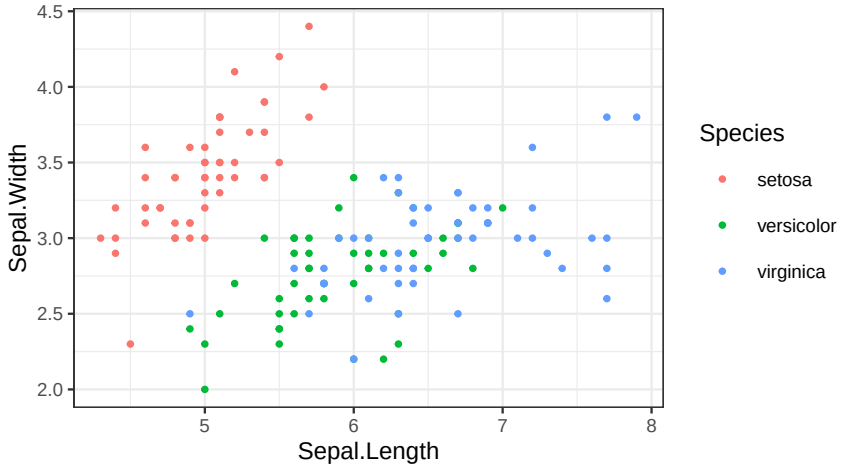
Color and size

```
> ggplot(iris)+aes(x=Sepal.Length,y=Sepal.Width)+
+   geom_point(color="blue",size=2)
```



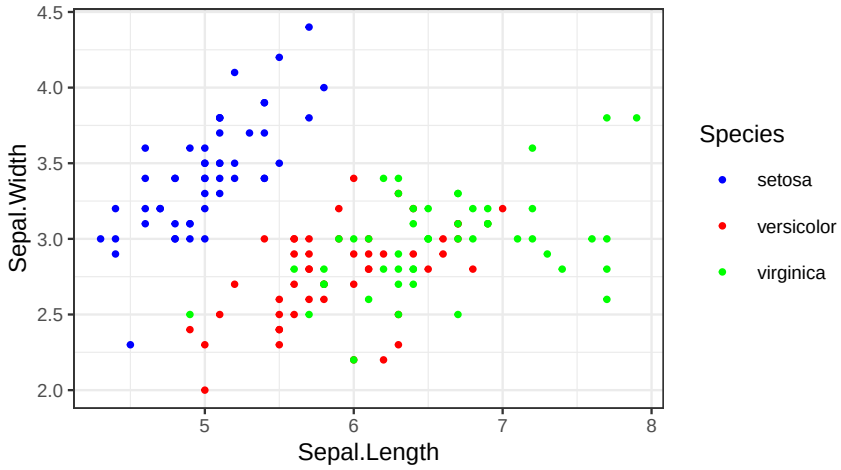
Color by (categorical) variable

```
> ggplot(iris)+aes(x=Sepal.Length,y=Sepal.Width,
+                  color=Species)+geom_point()
```



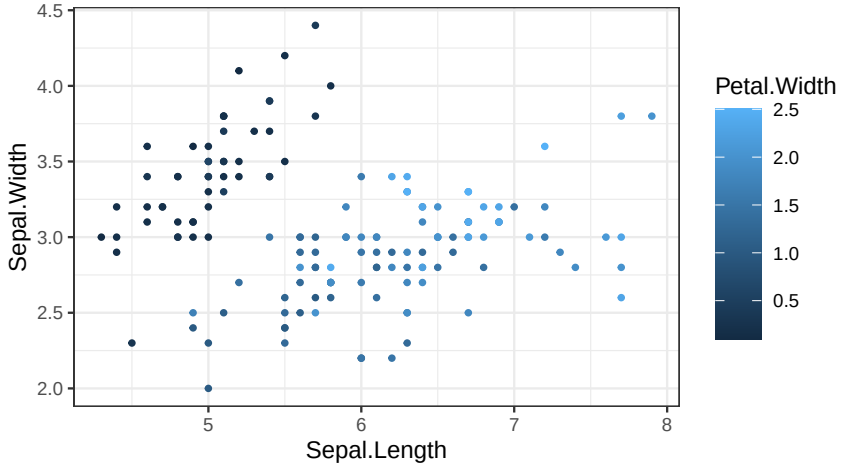
Changing the color

```
> ggplot(iris)+aes(x=Sepal.Length,y=Sepal.Width,
+                  color=Species)+geom_point()+
+   scale_color_manual(values=c("setosa"="blue","virginica"="green",
+                               "versicolor"="red"))
```



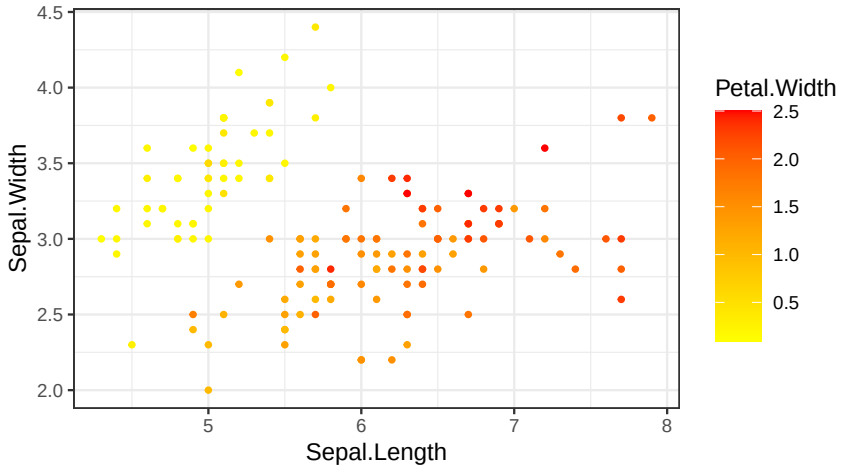
Color by (continous) variable

```
> ggplot(iris)+aes(x=Sepal.Length,y=Sepal.Width,
+                  color=Petal.Width)+geom_point()
```



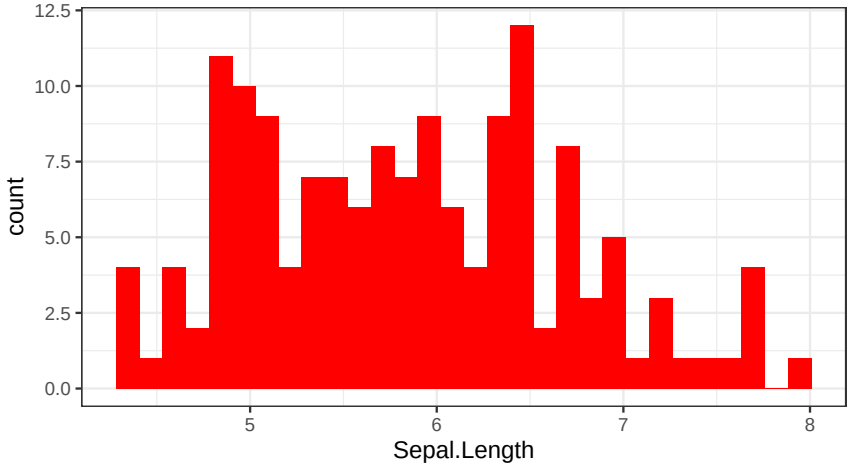
Color by (continous) variable

```
> ggplot(iris)+aes(x=Sepal.Length,y=Sepal.Width,
+                  color=Petal.Width)+geom_point()+
+            scale_color_continuous(low="yellow",high="red")
```



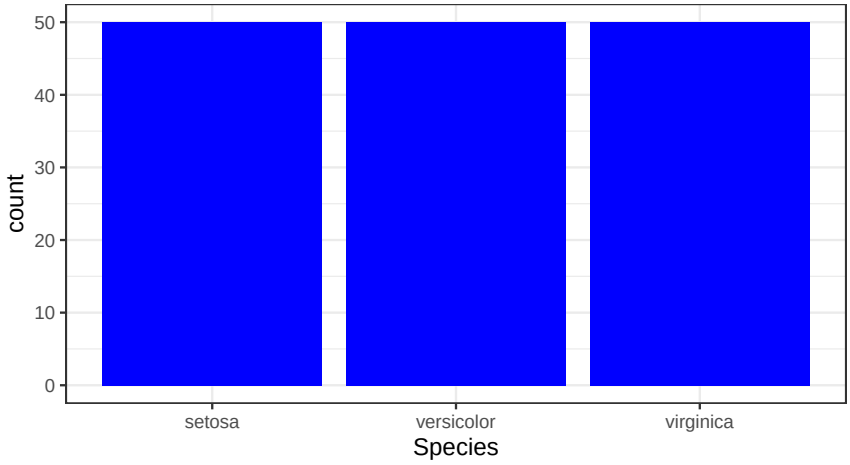
Histogram

```
> ggplot(iris)+aes(x=Sepal.Length)+geom_histogram(fill="red")
```



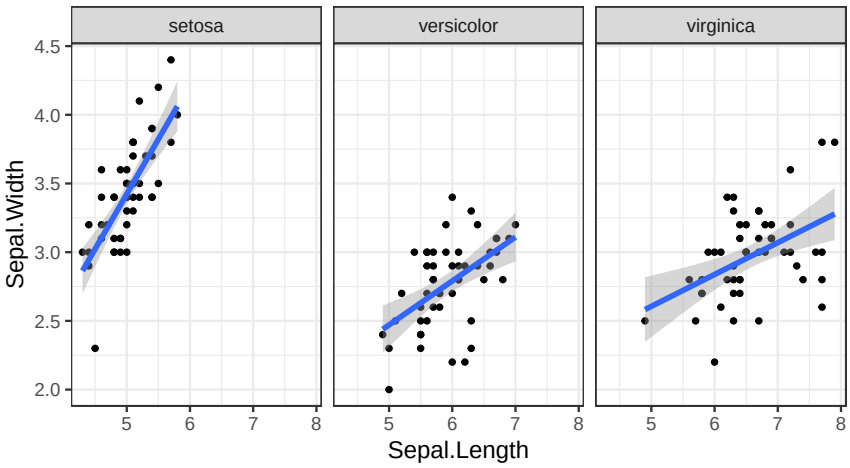
Barplot

```
> ggplot(iris)+aes(x=Species)+geom_bar(fill="blue")
```



Facetting (more "complex")

```
> ggplot(iris)+aes(x=Sepal.Length,y=Sepal.Width)+geom_point()+
+         geom_smooth(method="lm")+facet_wrap(~Species)
```

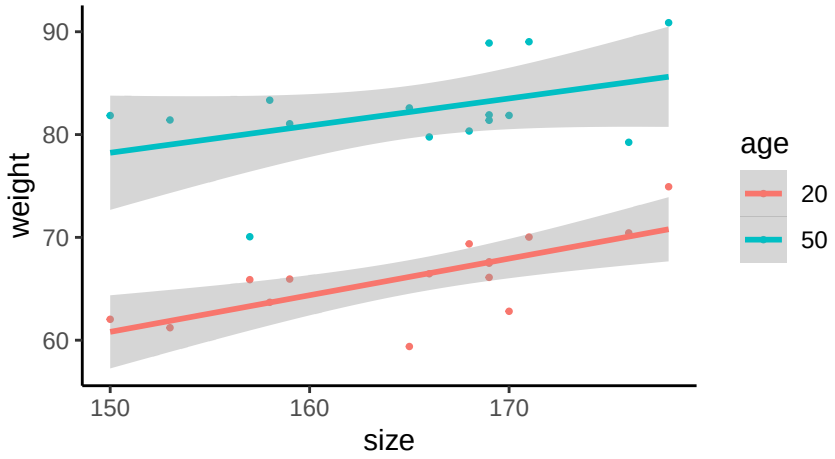


Combining ggplot with dplyr

- We often have to *work on the dataframe* to obtain an efficient ggplot syntax.
- For instance

```
> head(df)
# A tibble: 6 x 3
   size weight.20 weight.50
  <dbl>     <dbl>     <dbl>
1   153      61.2      81.4
2   169      67.5      81.4
3   168      69.4      80.3
4   169      66.1      81.9
5   176      70.4      79.2
6   169      67.6      88.9
```

Goal



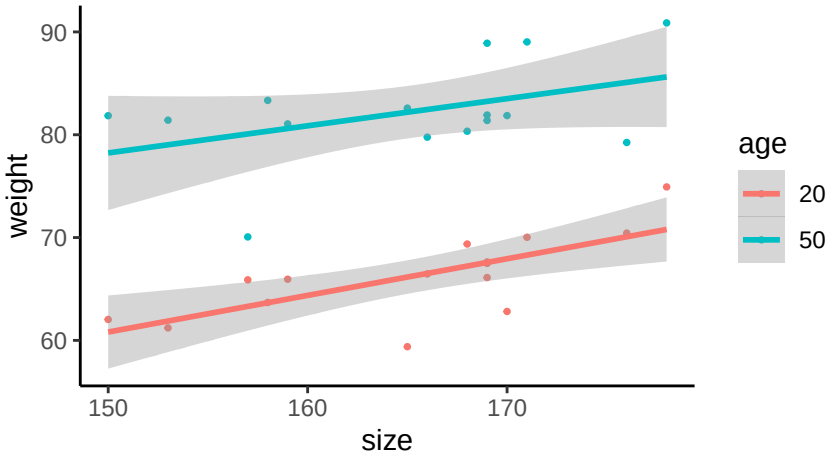
dplyr step

Gather column weight.M and weight.W into one column weight with *pivot_longer*:

```
> df1 <- df |> pivot_longer(-size,names_to="age",values_to="weight")
> df1 |> head()
# A tibble: 6 x 3
   size age       weight
  <dbl> <chr>      <dbl>
1   153 weight.20   61.2
2   153 weight.50   81.4
3   169 weight.20   67.5
4   169 weight.50   81.4
5   168 weight.20   69.4
6   168 weight.50   80.3
> df1 <- df1 |>
+   mutate(age=recode(age,"weight.20"="20","weight.50"="50"))
```

ggplot step

```
> ggplot(df1)+aes(x=size,y=weight,color=age)+
+   geom_point()+geom_smooth(method="lm")+theme_classic()
```



Statistics

- Some charts requires to compute *statistics*
- Histogram example: count the number of observations in each bins (or the density)

Consequence

geom_histogram calls stat_bin function to compute these statistics.

```
> geom_histogram(...,stat = "bin",...)
```

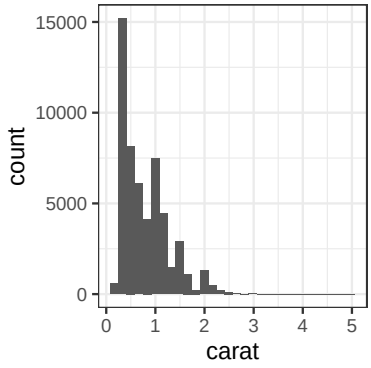
```
help(stat_bin)
Computed variables
count
number of points in bin

density
```

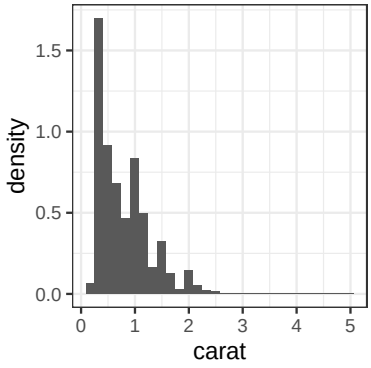
```
density of points in bin, scaled to integrate to 1
...
```

Visualize another statistics

```
> ggplot(diamonds)+aes(x=carat)+
+   geom_histogram()
```



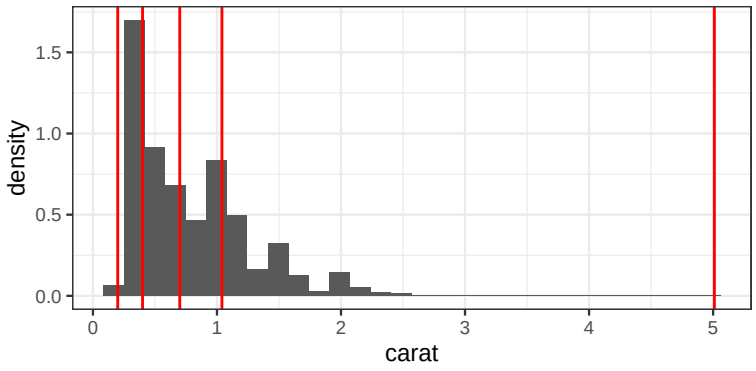

```
> ggplot(diamonds)+
+   aes(x=carat,y=after_stat(density))+
+ #or aes(x=carat,y=..density..)
+   geom_histogram()
```



stat_summary

- More generally, `stat_summary` allows to computes *any statistics* for a graph.

```
> ggplot(diamonds)+aes(x=carat)+
+   geom_histogram(aes(y=after_stat(density)))+
+   stat_summary(aes(y=0,xintercept=after_stat(x)),
+            fun="quantile",geom="vline",
+            orientation = "y",color="red")
```



Complement: some demos

```
> demo(image)
> example(contour)
> demo(persp)
> library("lattice");demo(lattice)
> example(wireframe)
> library("rgl");demo(rgl)
> example(persp3d)
> demo(plotmath);demo(Hershey)
```

$\Longrightarrow$ Work on this part of the tutorial.

Mapping

Introduction

- Many applications require *maps* to visualize data or results of a model;
- Many *R packages*: ggmap, RgoogleMaps, maps...
- In this part: *ggmap*, *sf* (static mapping) and *leaflet* (interactive mapping).

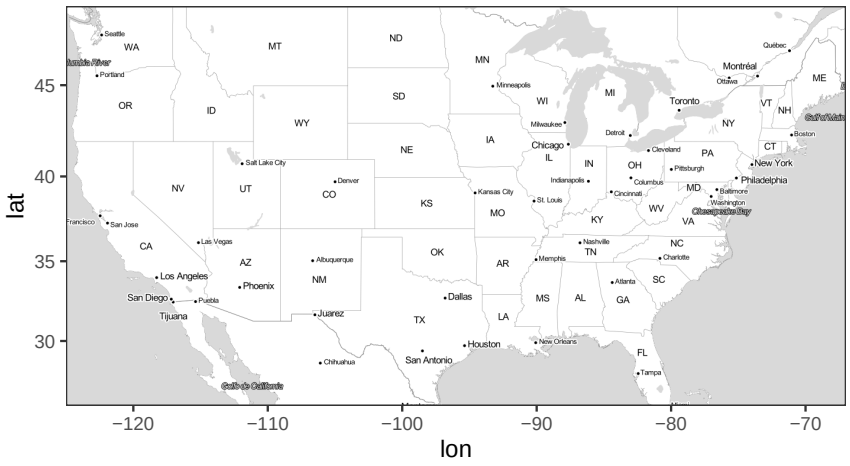
ggmap

Syntax

- Similar to *ggplot*...
- Instead of
  ```
  > ggplot(data)+...
  ```
- use
  ```
  > ggmap(backgroundmap)+...
  ```

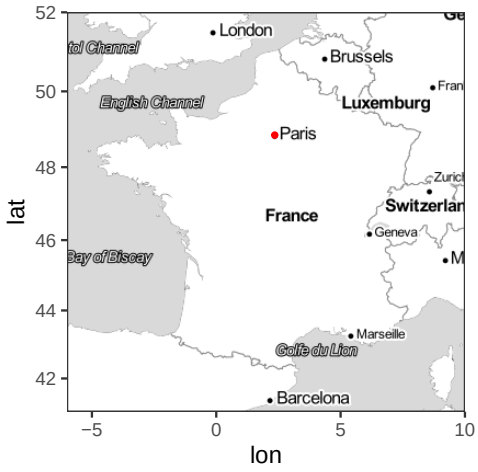
Background map

```
> library(ggmap)
> us <- c(left = -125, bottom = 25.75, right = -67, top = 49)
> map <- get_stamenmap(us, zoom = 5, maptype = "toner-lite")
> ggmap(map)
```



Adding informations with ggplot

```
> fr <- c(left = -6, bottom = 41, right = 10, top = 52)
> fond <- get_stamenmap(fr, zoom = 5,"toner-lite")
> Paris <- data.frame(lon=2.351499,lat=48.85661)
> ggmap(fond)+geom_point(data=Paris,aes(x=lon,y=lat),color="red")
```



Shapefile contours with sf

sf package

- *Ggmap*: ok for easy maps (background with some points).
- *Not sufficient* for more complex representations (color countries according to variables).
- *sf* allows to manage *specific tools for mapping*: boundaries for countries or department, coordinate systems (latitudes-longitudes, World Geodesic System 84. . .)
- Background map with format *shapefile* (contours = polygons)
- Compatible with *ggplot* (geom_sf verb).

References

- https://statnmap.com/fr/2018-07-14-initiation-a-la-cartographie-avec-sf-et-compagnie/

- Vignettes on the cran: https://cran.r-project.org/web/packages/sf/index.html.
- A complete tutorial: <https://r-spatial.github.io/sf/articles/>

Example

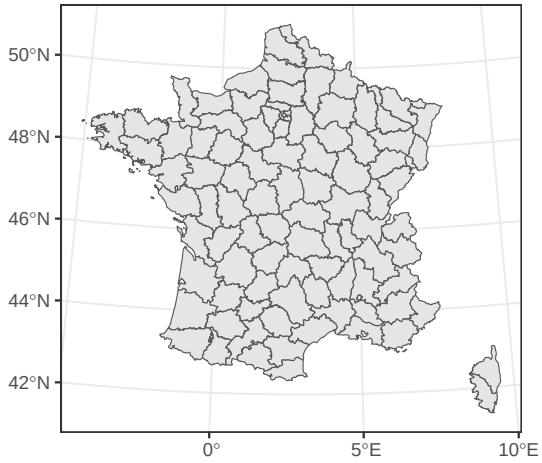
```
> library(sf)
> dpt <- read_sf("./DATA/dpt")
> dpt[1:5,3]
Simple feature collection with 5 features and 1 field
Geometry type: MULTIPOLYGON
Dimension:     XY
Bounding box:  xmin: 644570 ymin: 6290136 xmax: 1022851 ymax: 6997000
Projected CRS: RGF93 v1 / Lambert-93
# A tibble: 5 x 2
  NOM_DEPT                                                    geometry
  <chr>                                                <MULTIPOLYGON [m]>
1 AIN                    (((919195 6541470, 918932 6541203, 918628 6~
2 AISNE                  (((735603 6861428, 735234 6861392, 734504 6~
3 ALLIER                 (((753769 6537043, 753554 6537318, 752879 6~
4 ALPES-DE-HAUTE-PROVENCE (((992638 6305621, 992263 6305688, 991610 6~
5 HAUTES-ALPES           (((1012913 6402904, 1012577 6402759, 101085~
```

Visualize with plot

```
> plot(st_geometry(dpt))
```

Visualize with ggplot

```
> ggplot(dpt)+geom_sf()
```



Adding points on the map

- Define coordinates with *st_point*

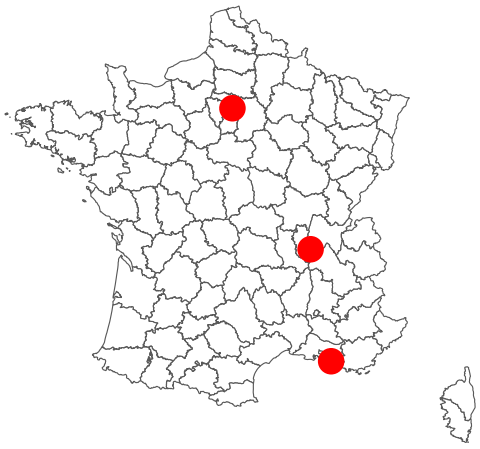
```
> point <- st_sfc(st_point(c(2.351462,48.85670)),
+             st_point(c(4.832011,45.75781)),
+             st_point(c(5.369953,43.29617)))
```

- Specify the *coordinate system* (4326 for lat-lon)

```
> st_crs(point) <- 4326 #lat-lon
> point
Geometry set for 3 features
Geometry type: POINT
Dimension:     XY
Bounding box:  xmin: 2.351462 ymin: 43.29617 xmax: 5.369953 ymax: 48.8567
Geodetic CRS:  WGS 84
POINT (2.351462 48.8567)
POINT (4.832011 45.75781)
POINT (5.369953 43.29617)
```

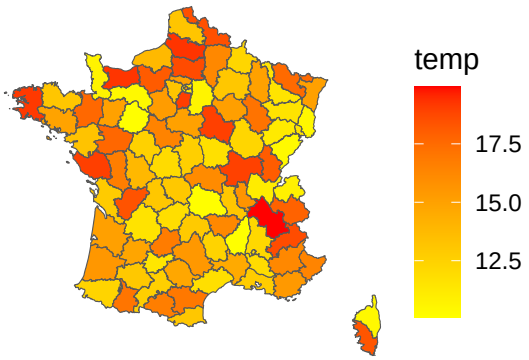
ggplot step

```
> ggplot(dpt) + geom_sf(fill="white")+
+   geom_sf(data=point,color="red",size=4)+theme_void()
```



Coloring polygons

```
> set.seed(1234)
> dpt1 <- dpt |> mutate(temp=runif(96,10,20))
> ggplot(dpt1) + geom_sf(aes(fill=temp)) +
+   scale_fill_continuous(low="yellow",high="red")+
+   theme_void()
```



Supplement: geometry class

- One of the main advantage of *sf* is the geometry class.
- It allows to conduct the representation with plot or geom_sf:
  - *point* or *multipoint* $\Longrightarrow$ points to locate a place;
  - *polygon* or *multipolygon* $\Longrightarrow$ contours to visualize boundaries.
- Some useful functions:
  - **st_point** and **st_multipoint**: create points or sequence of points
  - **st_sfc**: create a list of *sf objects*
  - **st_crs**: specify coordinate reference system
  - **st_cast**: cast geometry to another type (convert a multipoint object to many point objects)
  - ...

- Creation of a **sf object**

```
> b1 <- st_point(c(3,4))
> b1
POINT (3 4)
> class(b1)
[1] "XY"    "POINT" "sfg"
```

- Creation of a **sfc object** (list of **sf objects**)

```
> b2 <- st_sfc(st_point(c(1,2)),st_point(c(3,4)))
> b2
Geometry set for 2 features
Geometry type: POINT
Dimension:     XY
Bounding box:  xmin: 1 ymin: 2 xmax: 3 ymax: 4
CRS:           NA
POINT (1 2)
POINT (3 4)
> class(b2)
[1] "sfc_POINT" "sfc"
```

- Extract **geometry** in a **sf object**

```
> class(dpt)
[1] "sf"         "tbl_df"     "tbl"        "data.frame"
> b3 <- st_geometry(dpt)
```

```
> b3
Geometry set for 96 features
Geometry type: MULTIPOLYGON
Dimension:     XY
Bounding box:  xmin: 99226 ymin: 6049647 xmax: 1242375 ymax: 7110524
Projected CRS: RGF93 v1 / Lambert-93
First 5 geometries:
MULTIPOLYGON (((919195 6541470, 918932 6541203,...
MULTIPOLYGON (((735603 6861428, 735234 6861392,...
MULTIPOLYGON (((753769 6537043, 753554 6537318,...
MULTIPOLYGON (((992638 6305621, 992263 6305688,...
MULTIPOLYGON (((1012913 6402904, 1012577 640275...
> class(b3)
[1] "sfc_MULTIPOLYGON" "sfc"
```

$\Longrightarrow$ Work on this part of the tutorial.

Interactive maps with leaflet

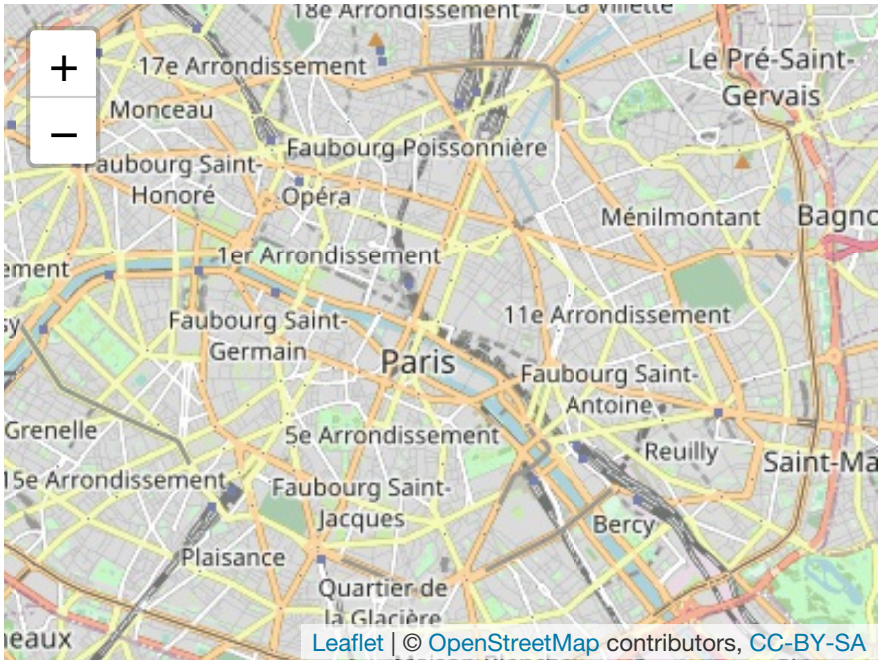
Background map

- *Leaflet* is one of the most popular open-source JavaScript libraries for interactive maps.
- *Documentation*: here

```
> library(leaflet)
> leaflet() |> addTiles()
```

Many background styles

```
> Paris <- c(2.35222,48.856614)
> leaflet() |> addTiles() |>
+   setView(lng = Paris[1], lat = Paris[2],zoom=12)
```




```
> leaflet() |> addProviderTiles("Stamen.Toner") |>
+   setView(lng = Paris[1], lat = Paris[2], zoom = 12)
```

Leaflet with data

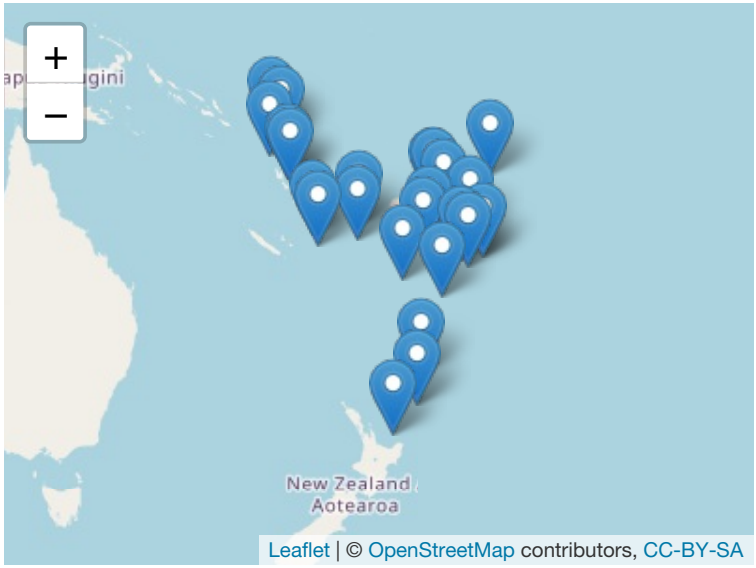
- Location of 1000 seismic events near Fiji

```
> data(quakes)
> head(quakes)
     lat   long depth mag stations
1 -20.42 181.62   562 4.8       41
2 -20.62 181.03   650 4.2       15
3 -26.00 184.10    42 5.4       43
4 -17.97 181.66   626 4.1       19
5 -20.42 181.96   649 4.0       11
```

```
6 -19.68 184.31   195 4.0       12
```

Visualize seismics with magnitude more than 5.5

```
> quakes1 <- quakes |> filter(mag>5.5)
> leaflet(data = quakes1) |> addTiles() |>
+   addMarkers(~long, ~lat, popup = ~as.character(mag))
```

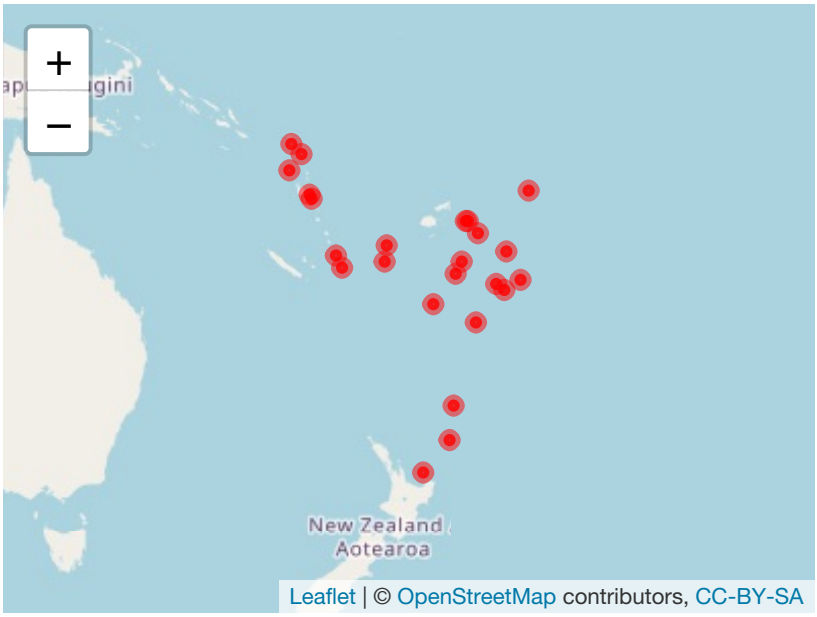


Remark

When you *click* on a marker, the *magnitude* appears.

addCircleMarkers

```
> leaflet(data = quakes1) |> addTiles() |>
+   addCircleMarkers(~long, ~lat, popup=~as.character(mag),
+                    radius=3,fillOpacity = 0.8,color="red")
```



Color polygon (combining leaflet and sf)

```
> leaflet() |> addTiles() |>
+   addPolygons(data = dpt2,color=~pal1(t_prev),fillOpacity = 0.6,
+               stroke = TRUE,weight=1,
+               popup=~paste(as.character(NOM_DEPT),
+                            as.character(t_prev),sep=" : "))
```

$\Longrightarrow$ Work on this part of the tutorial.

Some Dynamic visualization tools

Some R tools for dynamic visualization

- Classical charts with *rAmCharts* and *plotly*.
- Graphs with *visNetwork*.
- Dashboard with *flexdashboard*.

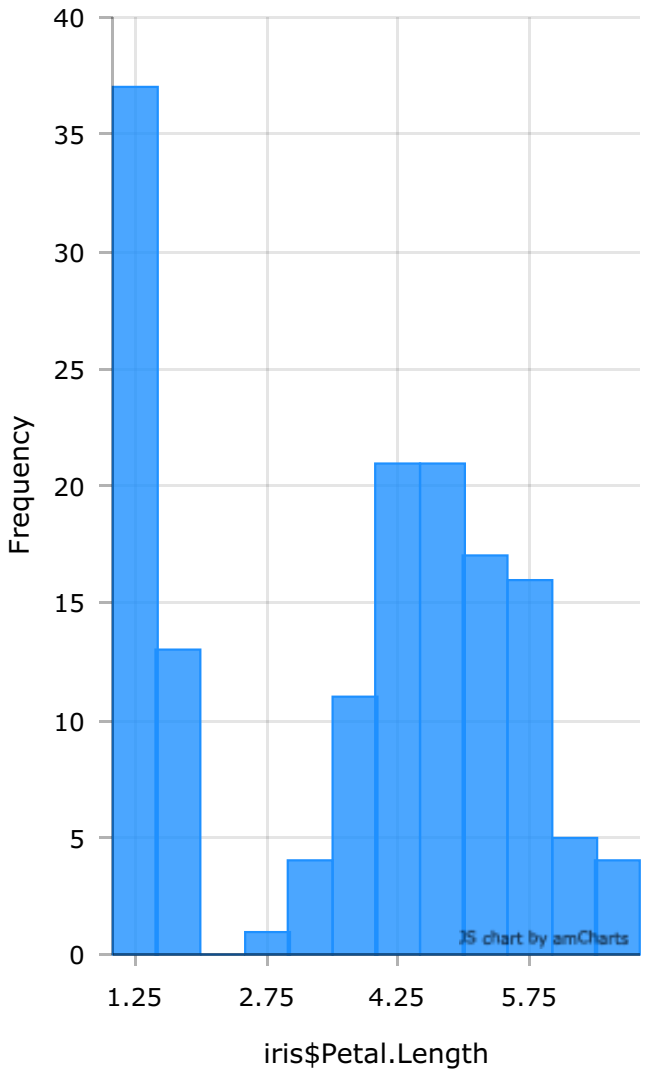
rAmCharts and plotly

rAmCharts

- *user-friendly* for standard graphs (scatterplot, times series, histogram...).
- We just have to use classical **R** functions with the prefix am.
- *Examples*: amPlot, amHist, amBoxplot.
- *References*: https://datastorm-open.github.io/introduction_ramcharts/

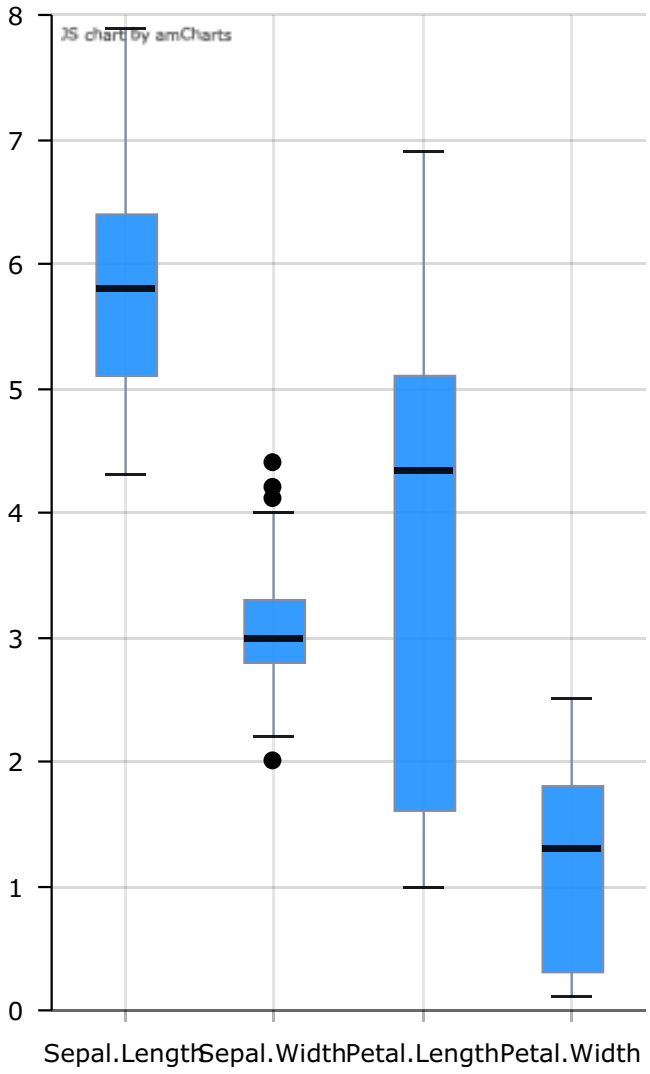
rAmCharts Histogram

```
> library(rAmCharts)
> amHist(iris$Petal.Length)
```



rAmcharts Boxplot

```
> amBoxplot(iris)
```



Plotly

- R package for creating *interactive web-based graphs* via the open source JavaScript graphing library plotly.js.
- Commands are expanded into *3 parts*:
  - dataset and variables (plot_ly) ;
  - additional representations (add_trace, add_markers. . .) ;
  - options (axis, titles. . .) (layout).
- References: https://plot.ly/r/reference/

Scatter plot

```
> library(plotly)
> iris |> plot_ly(x=~Sepal.Width,y=~Sepal.Length,color=~Species) |>
+   add_markers(type="scatter")
```

Plotly boxplot

```
> iris |> plot_ly(x=~Species,y=~Petal.Length) |> add_boxplot()
```

Graphs with visNetwork

Connections between individuals

- Many datasets can be visualized with *graphs*, especially when one has to study connections between individuals (genomic, social network...).
- One individual = *one node* and one connection = *one edge*.

```
> set.seed(123)
> nodes <- data.frame(id = 1:15, label = paste("Id", 1:15))
> edges <- data.frame(from = trunc(runif(15)*(15-1))+1,
+                     to = trunc(runif(15)*(15-1))+1)
> head(edges)
  from to
1    5 13
2   12  4
3    6  1
4   13  5
5   14 14
6    1 13
```

Static graph: igraph package

- *References*: http://igraph.org/r/, http://kateto.net/networks-r-igraph

```
> library(igraph)
> net <- graph_from_data_frame(d=edges, vertices=nodes, directed=F)
> plot(net,vertex.color="green",vertex.size=25)
```

Dynamic graph: visNetwork Package

- *Reference*: https://datastorm-open.github.io/visNetwork/interaction.html

```
> library(visNetwork)
> visNetwork(nodes,edges)
```

Nodes color

```
> nodes$group <- c(rep("A",8),rep("B",7))
> visNetwork(nodes,edges) |>
+   visGroups(groupname = "A", color = "darkblue",
+             shape = "square") |>
+     visGroups(groupname = "B", color = "red",
+             shape = "triangle")
```

Edeges width

```
> edges$width <- round(runif(nrow(edges),1,10))
> visNetwork(nodes,edges) |>
+   visEdges(shadow = TRUE,
+            arrows =list(to = list(enabled = TRUE)),
+            color = list(color = "black", highlight = "red"))
```

Dashboard with flexdasboard

- Just a tool... but an *important visualization tool* in datascience
- Allow to *gather important messages* on datasets and/or models
- *Package*: flexdasboard
- *Syntax*: simple... only Rmarkdown
- *Reference*: https://pkgs.rstudio.com/flexdashboard/index.html

Header

```
---
title: "My title"
output:
  flexdashboard::flex_dashboard:
    orientation: columns
    vertical_layout: fill
    theme: default
---
```

- Default theme could be replaced by *other themes* (cosmo, bootstrap, cerulean...) (see here). You just have to add

  ```
  theme: yeti
  ```

Flexdashboard | code

````
Descriptive statistics
======================================
Column {data-width=650}
-------------------------------------------------------------------------
### Dataset
```{r}
DT::datatable(df, options = list(pageLength = 25))
```
Column {data-width=350}
-------------------------------------------------------------------------
### Correlation matrix
````

```r
cc <- cor(df[,1:11])
mat.cor <- corrplot::corrplot(cc)
```
Histogram
```r
amHist(df$maxO3)
```

Flexdashboard | dashboard

$\Longrightarrow$ Work on this part of the tutorial.

Assessment

Visualization project

- Group (2 members)
- Find a *visualization problem* (for instance a dataset with a statistical problem: classification, regression...)
- Build a shiny web application to visualize important informations on the problem
- Don't hesitate to use tools presented in the lecture (you can also use other tools)
- Deploy the application on the web with *shinyapps*, see https://docs.rstudio.com/shinyapps.io/index.html
- Make a markdwon document (4 or 5 pages) which presents your work, use pdf or html output.

Process

You have to submit on moodle:

- Rmarkdown document (html or pdf output) which presents your work and the url of the shiny application
- shiny files (app.R or ui.R and server.R)
- the dataset (or an url where we can download the data)
- all files needed to test your application

before November 15th, 5pm.

Some examples (Smart Data, 2021)

- https://jmlascar.shinyapps.io/Fraisse_Lascar_App/
- https://mssdprojectriemerleroy.shinyapps.io/MSSD-Project-Riemer-Le-Roy/
- https://abdessamadmarc.shinyapps.io/R_viz_project/
- https://razvanvisoiu.shinyapps.io/USA_Election_Analysis/