

Dynamic data visualization with R

Laurent Rouvière

2020-10-11

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 - visualize data, models and results of a statistical analysis
 - discover (and master) some R visualization packages

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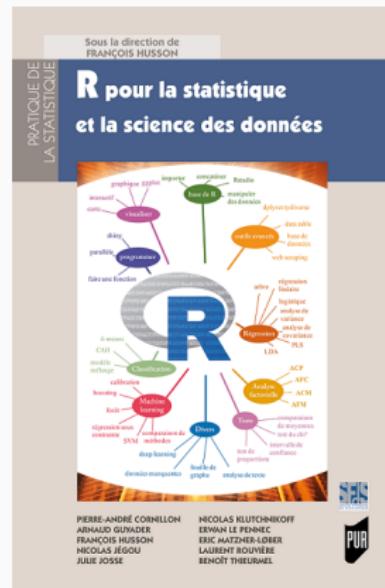
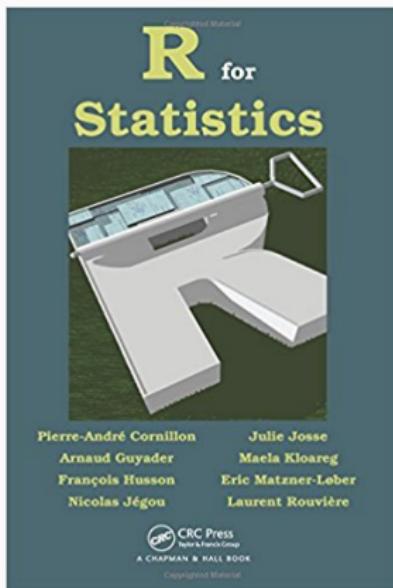
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 - understand **the importance of visualization** in datascience
 - visualize data, models and results of a statistical analysis
 - discover (and master) some R visualization packages
- **Teacher:** Laurent Rouvière, lrouviere@univ-rennes2.fr
 - **Research interests:** nonparametric statistics, statistical learning
 - **Teaching:** statistics and probability (University and engineer school)
 - **Consulting:** energy (ERDF), banks, marketing, sport

Resources

- Slides and tutorials (supplement materials + exercises) available at
<https://lrouvriere.github.io/VISU/>
- The web

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- Book: R for statistics, Chapman & Hall



Why data visualization in your Master?

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- Models are more and more complex
- Conclusions are more and more complex.

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 - describe data
 - calibrate models
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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.

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 \Rightarrow 3-4h.
 2. **Mapping** with **ggmap**, **sf** (static) **leaflet** (dynamic) \Rightarrow 3-4h.
 3. **Dynamic or interactive tools**
 - data with **rAmCharts** and **plotly** \Rightarrow 1h
 - dashboard with **flexdashboard** \Rightarrow 1h
 - web applications with **shiny** \Rightarrow 5h

Boxplot for the iris dataset

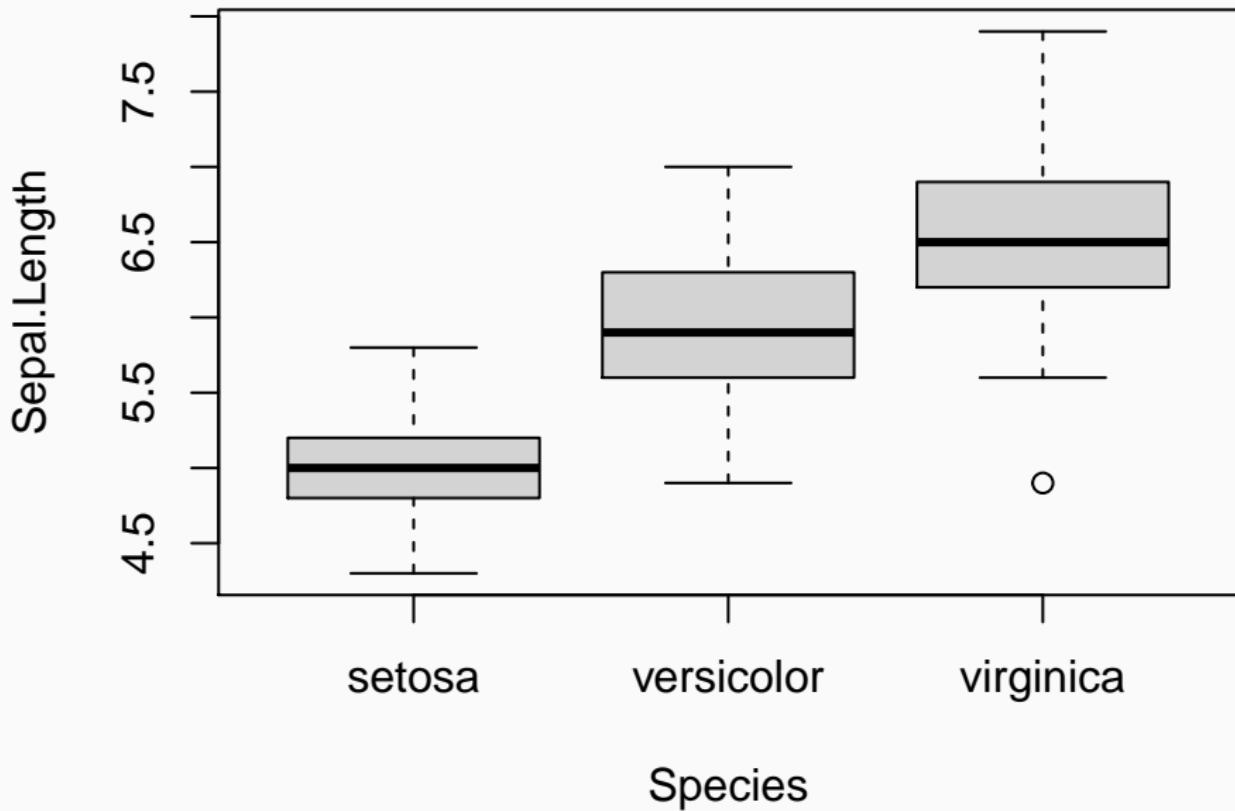
```
> data(iris)
> summary(iris)

  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
```

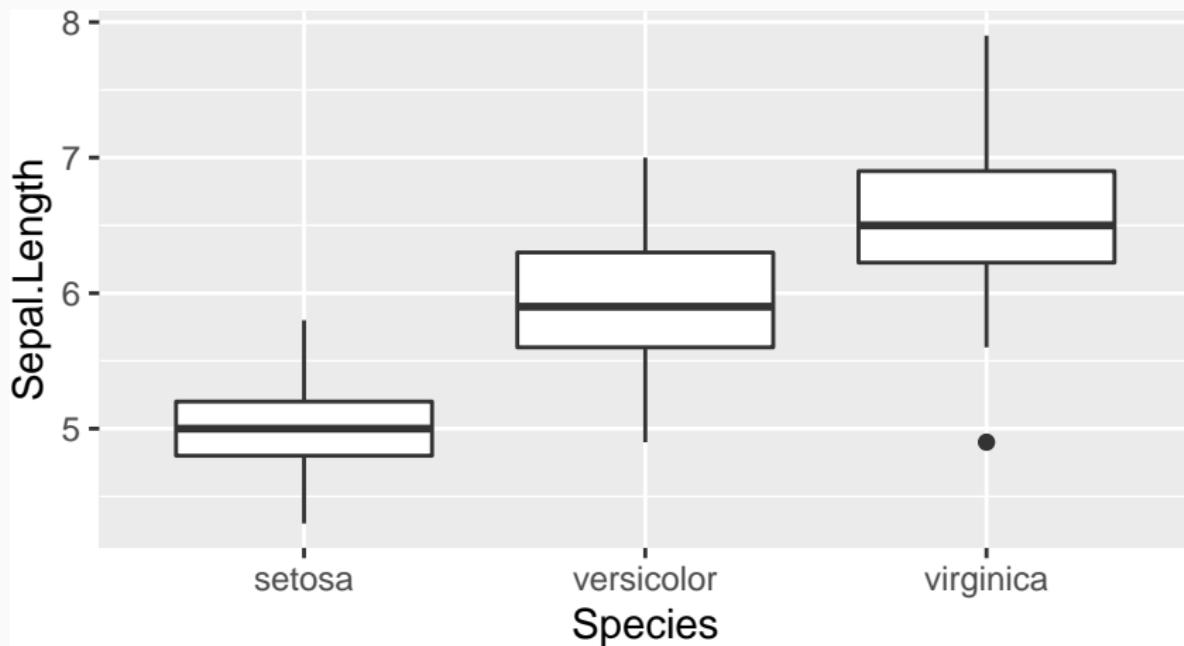
Classical tool

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

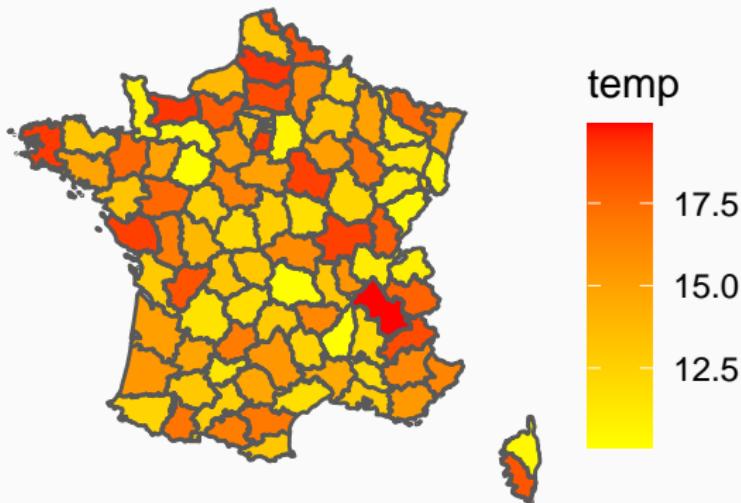


Ggplot tools

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



A temperature map



Many informations

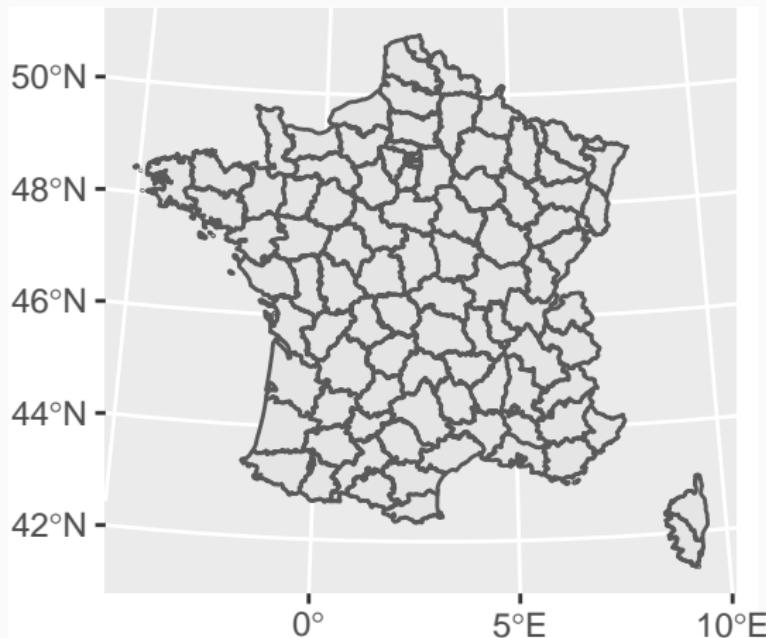
- **Background map** with boundaries of departments;
- **Temperatures** in each departments (meteofrance website).

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
bbox:           xmin: 644570  ymin: 6272482  xmax: 1077507  ymax: 6997000
CRS:            2154
# A tibble: 6 x 2
  NOM_DEPT                                geometry
  <chr>                                     <MULTIPOLYGON [m]>
1 AIN           (((919195 6541470, 918932 6541203, 918628 6540523~
2 AISNE         (((735603 6861428, 735234 6861392, 734504 6861270~
3 ALLIER        (((753769 6537043, 753554 6537318, 752879 6538099~
4 ALPES-DE-HAUTE-P~ (((992638 6305621, 992263 6305688, 991610 6306540~
5 HAUTES-ALPES   (((1012913 6402904, 1012577 6402759, 1010853 6402~
6 ALPES-MARITIMES (((1018256 6272482, 1017888 6272559, 1016779 6272~
```

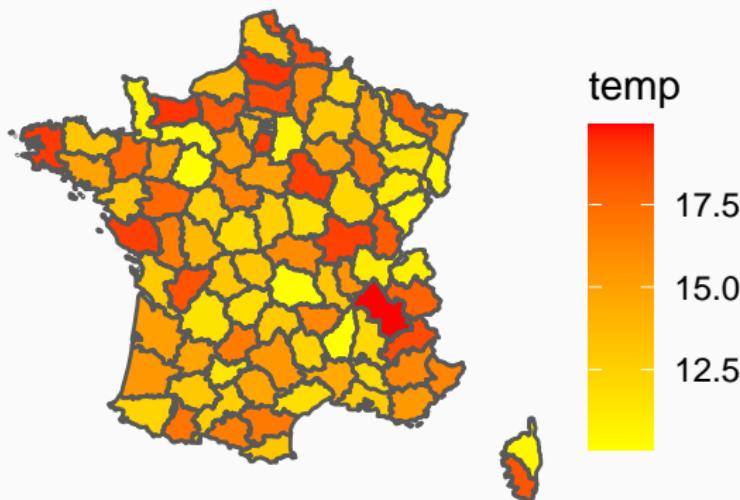
Background map

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



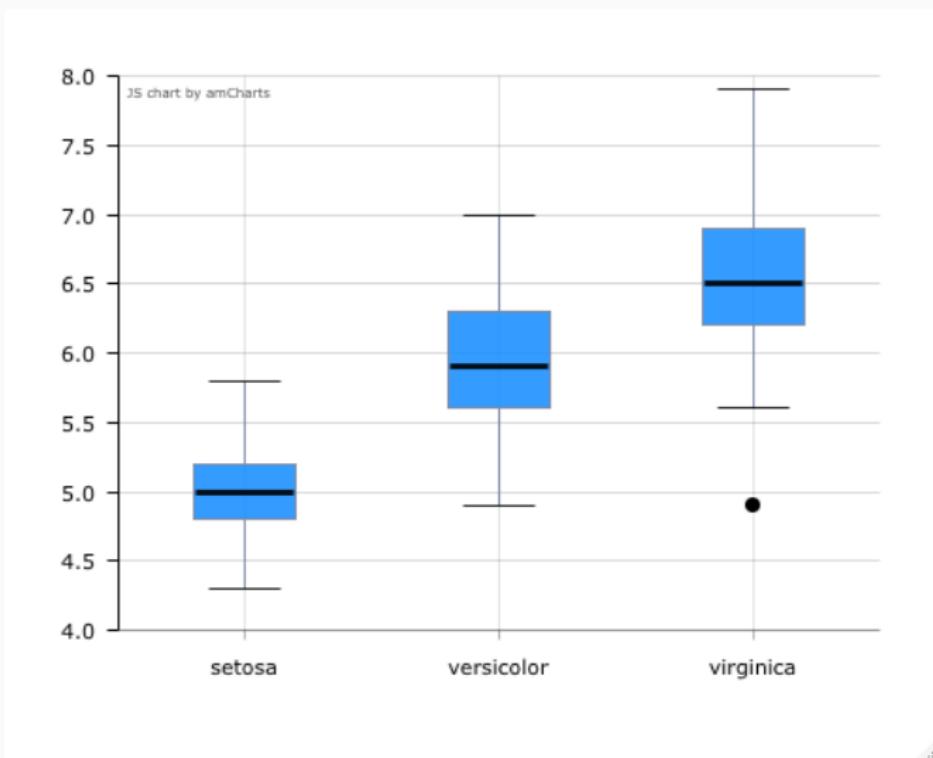
Temperature map

```
> 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 **flexdashboard**:
<https://rmarkdown.rstudio.com/flexdashboard/index.html>

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- Package **flexdashboard**:
<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 a computer tools.

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 a 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

1. Data visualization with ggplot2

Conventional graphical functions (a reminder)

ggplot2 grammar

2. Mapping

ggmap

Shapefile contours with sf

Interactive maps with leaflet

3. Some Dynamic visualization tools

rAmCharts and plotly

Graphs with visNetwork

Dashboard with flexdashboard

4. Assessment

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.

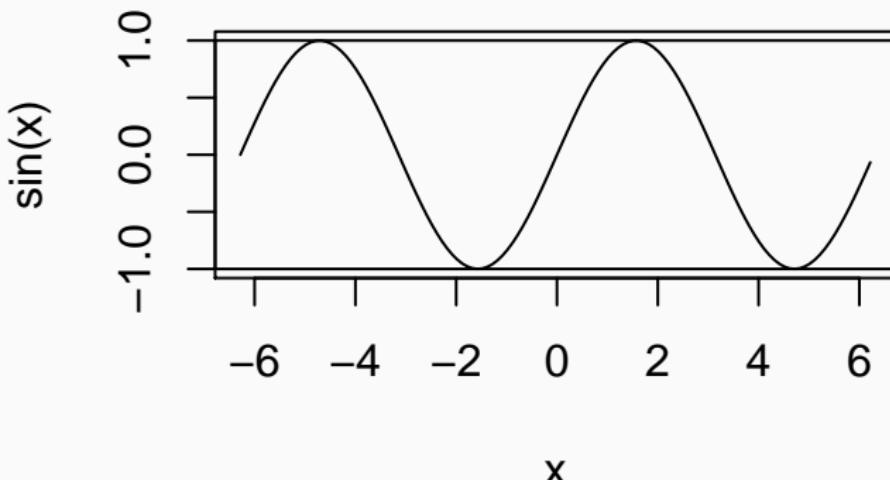
Data visualization with ggplot2

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.

Graphs for datasets

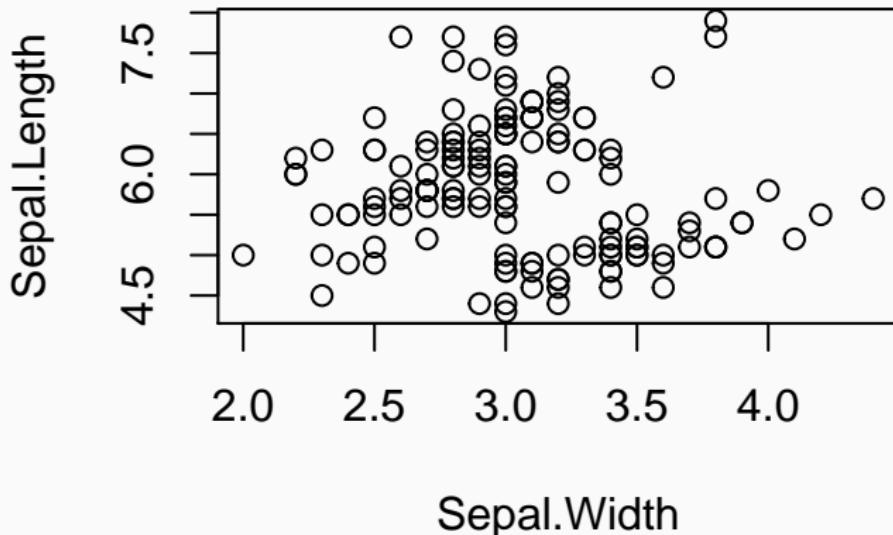
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Fortunately

There is a R function for all representations.

Scatterplot with dataset

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

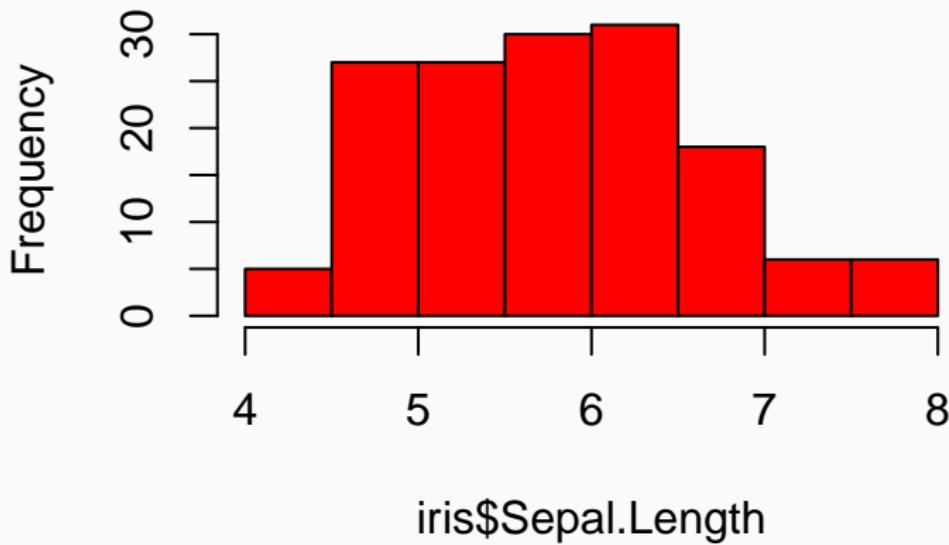


```
> #same as  
> plot(iris$Sepal.Width,iris$Sepal.Length)
```

Histogram for continuous variable

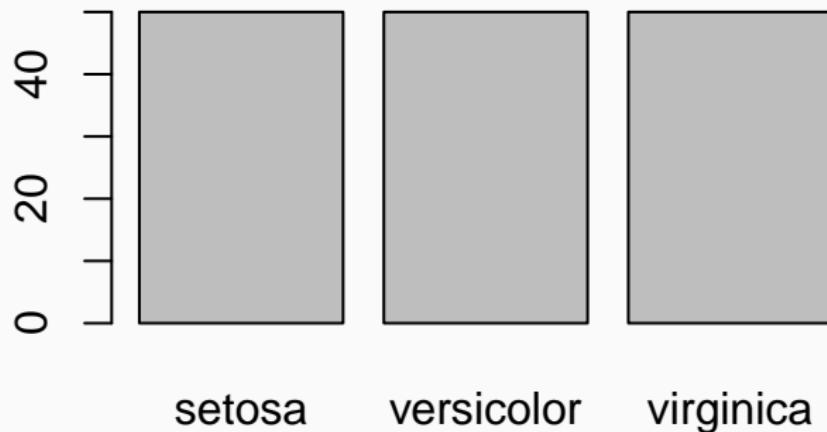
```
> hist(iris$Sepal.Length, col="red")
```

Histogram of iris\$Sepal.Length



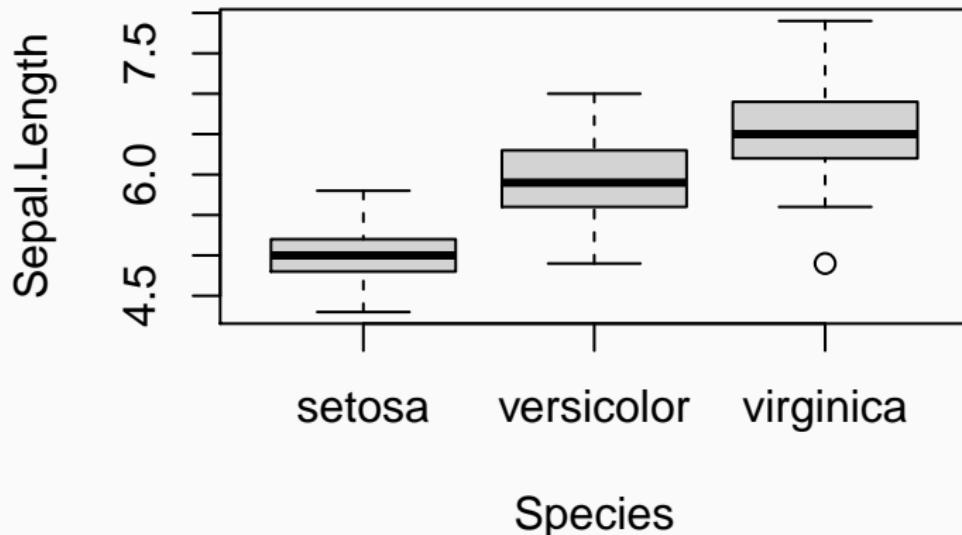
Barplot for categorical variables

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



Boxplot

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



Data visualization with ggplot2

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 "**elegant**" graphs (nor always the case for conventional R graphs).
- Documentation: [tutorial](#), [book](#)

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. . .).

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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:

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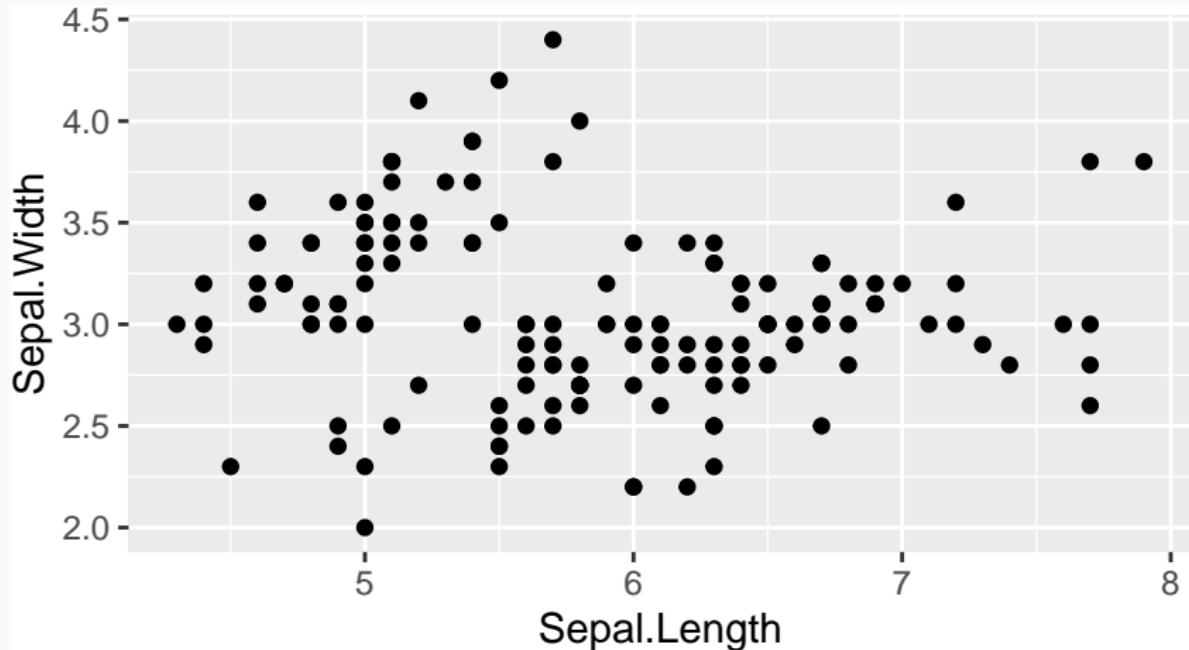
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- **Geometrics (geom_...)**: to control the **type** of plot.
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All these elements are gathered with the operator **+**.

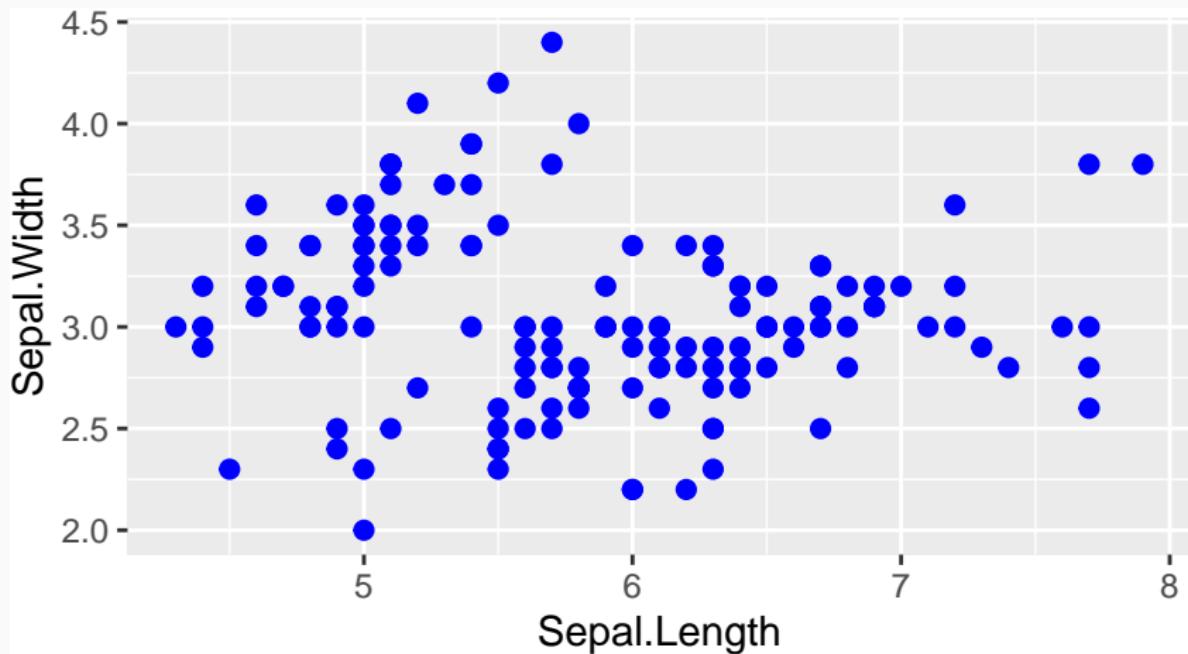
An example

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



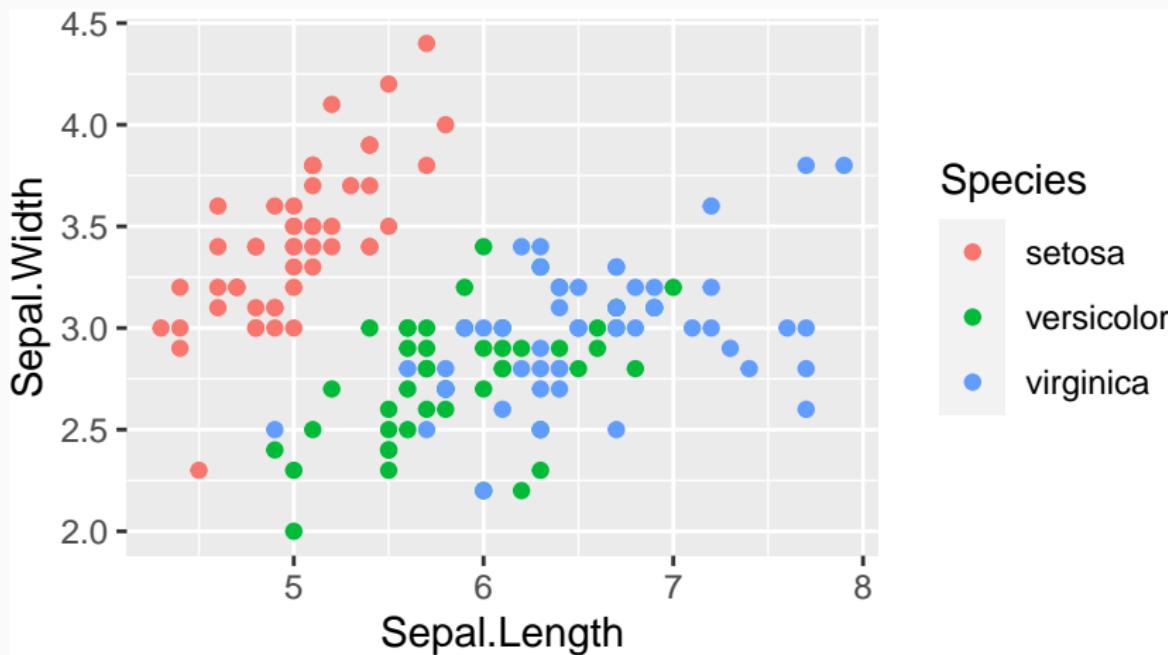
Color and size

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



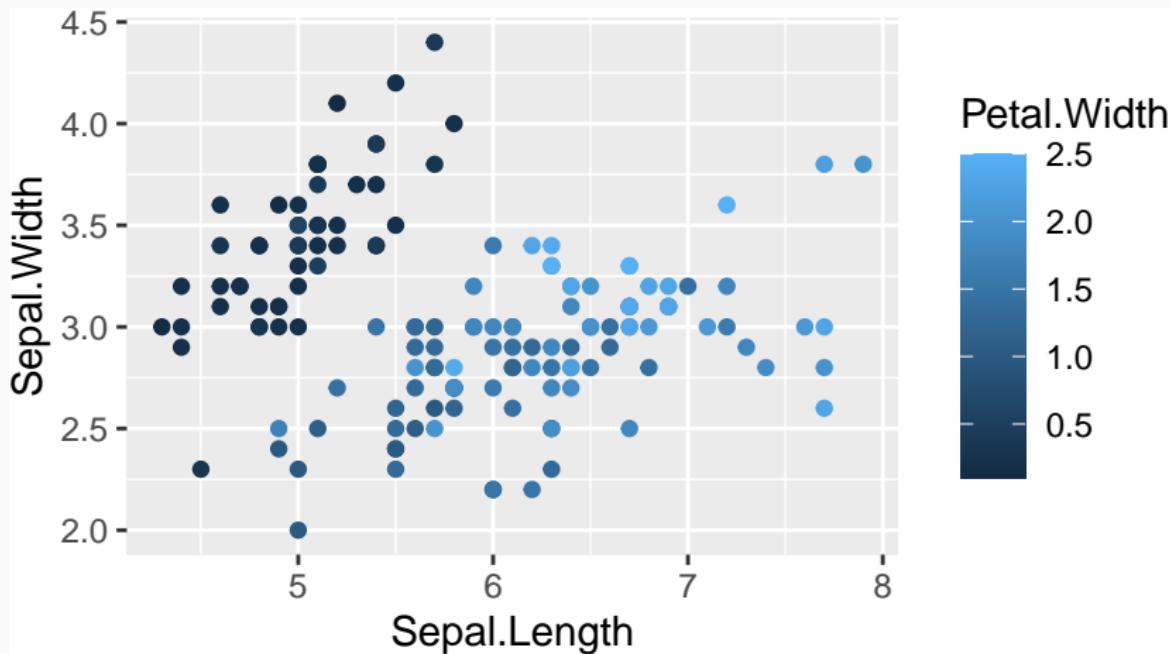
Color by (categorical) variable

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



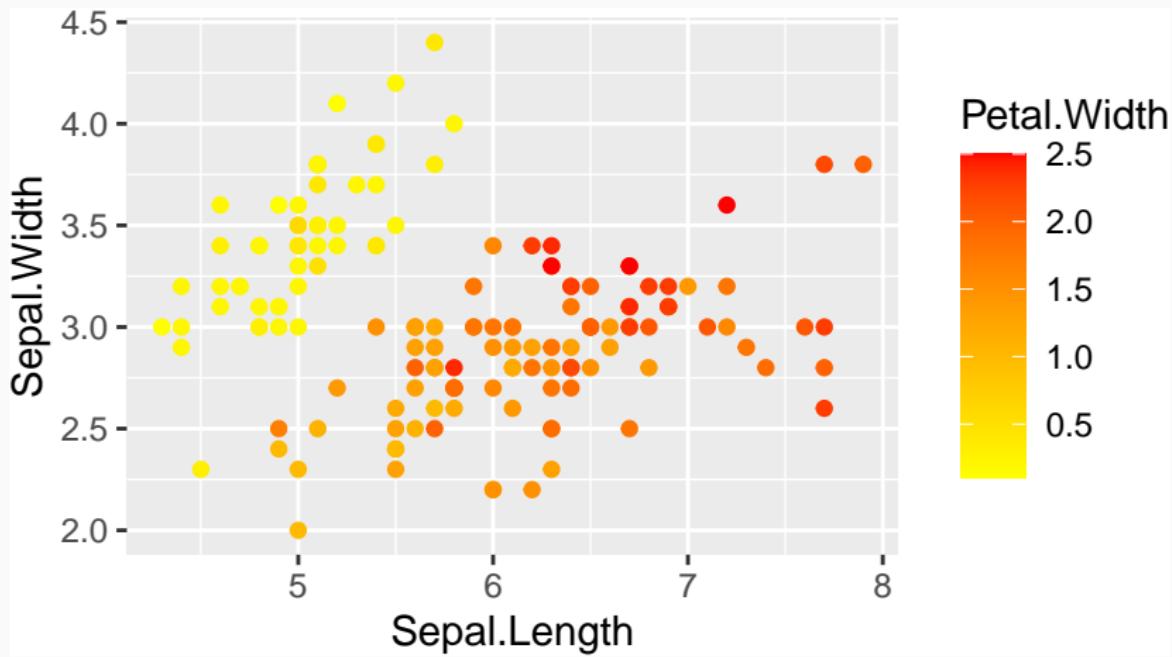
Color by (continuous) variable

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



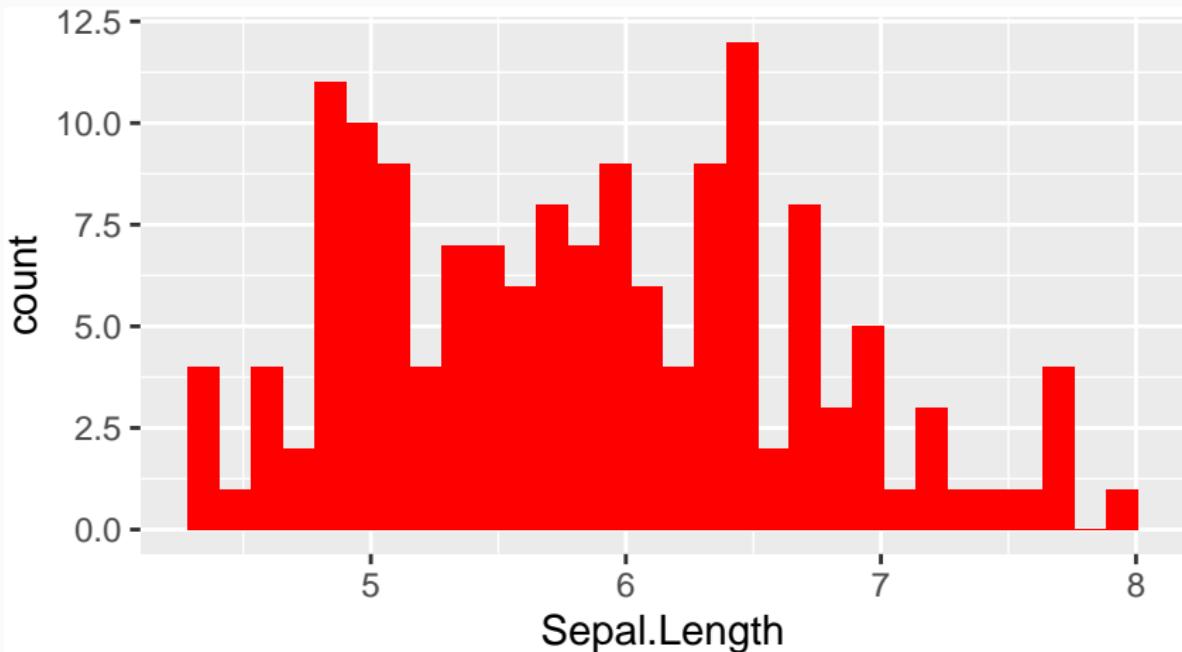
Color by (continuous) variable

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



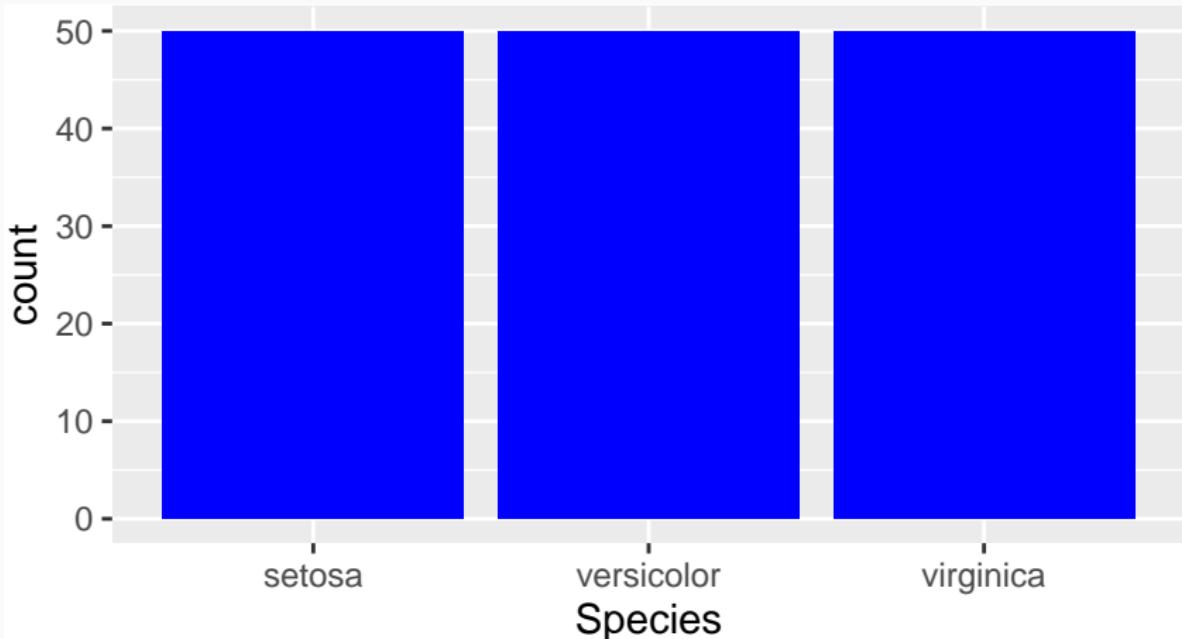
Histogram

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



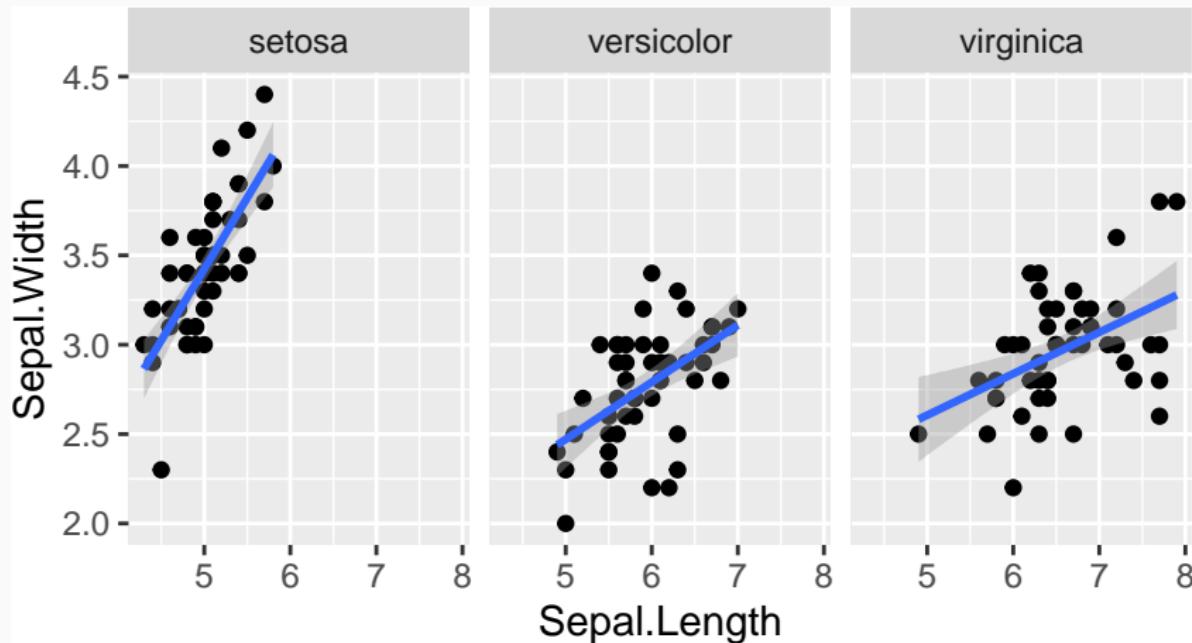
Barplot

```
> 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)
```

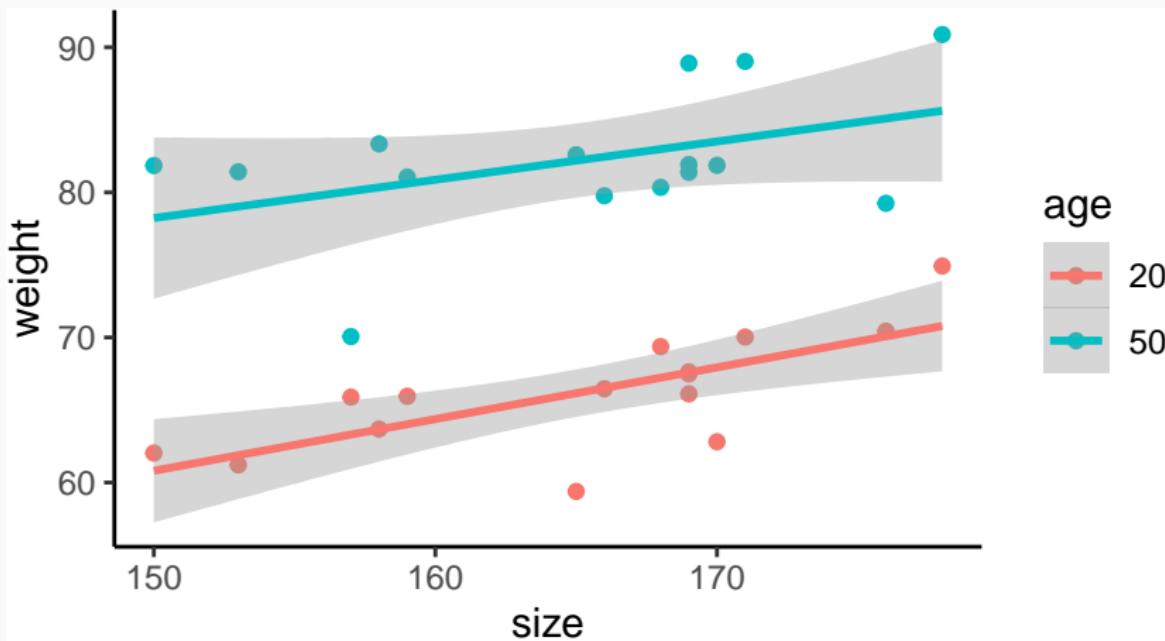


Combining ggplot with dplyr

- 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



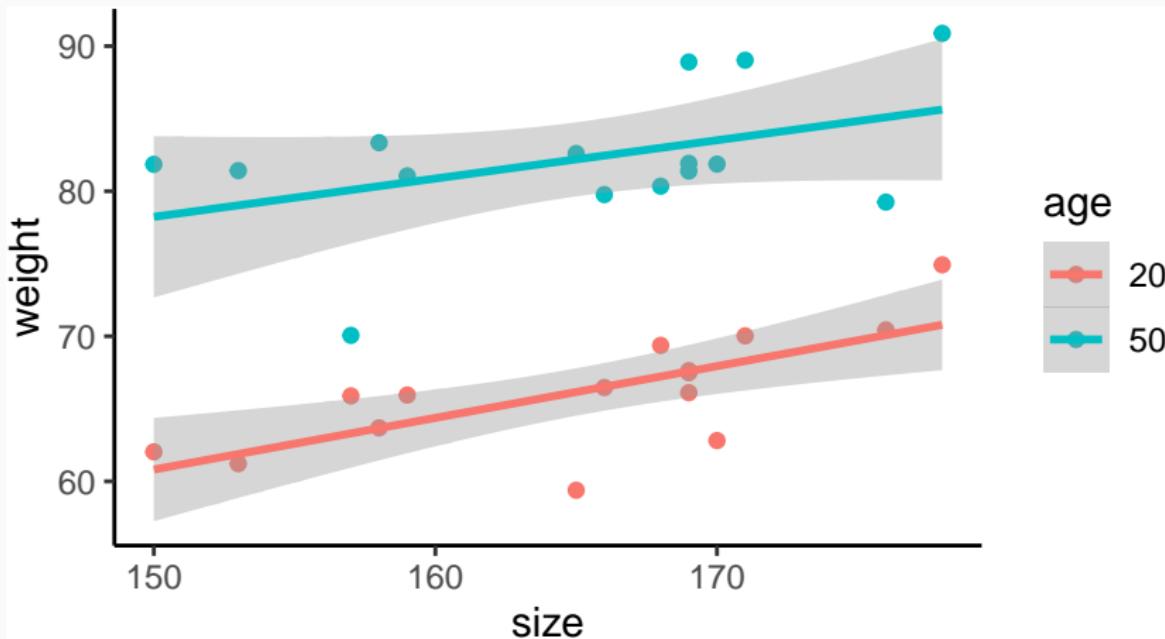
dplyr step

- 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()
```



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)
```

Complement: some demos

```
> demo(image)
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> library("lattice");demo(lattice)
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> example(persp3d)
> demo(plotmath);demo(Hershey)
```

⇒ 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).

Mapping

ggmap

Ggmap

- Similar to `ggplot`...

Ggmap

- Similar to `ggplot`...
- Instead of

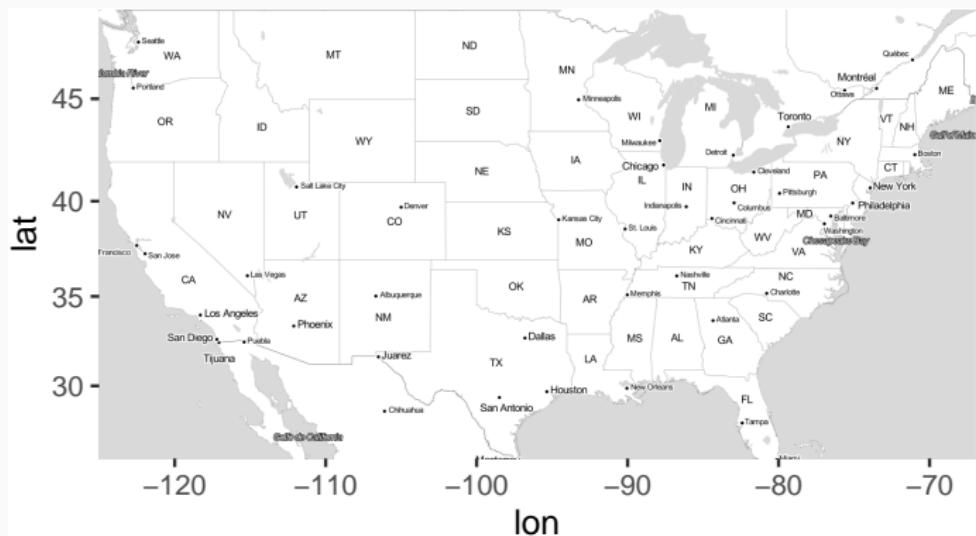
```
> ggplot(data)+...
```

- use

```
> ggmap(backgroundmap)+...
```

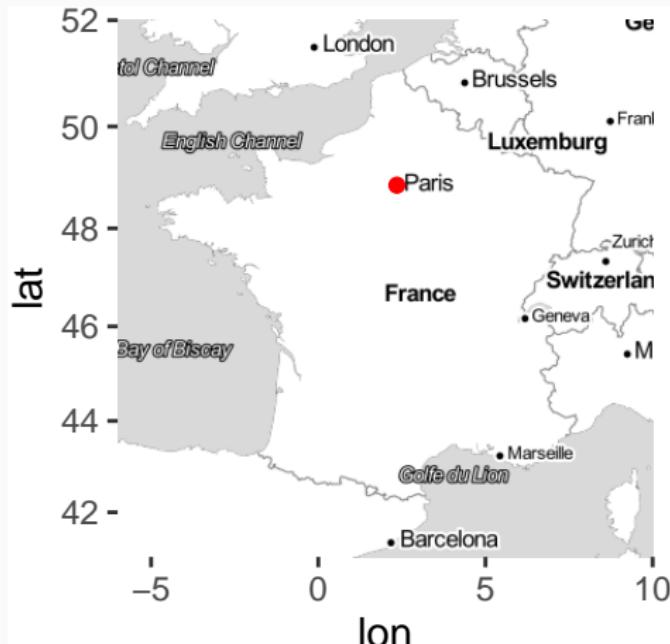
Background map

```
> 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")
```



Mapping

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` 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`.

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.

References

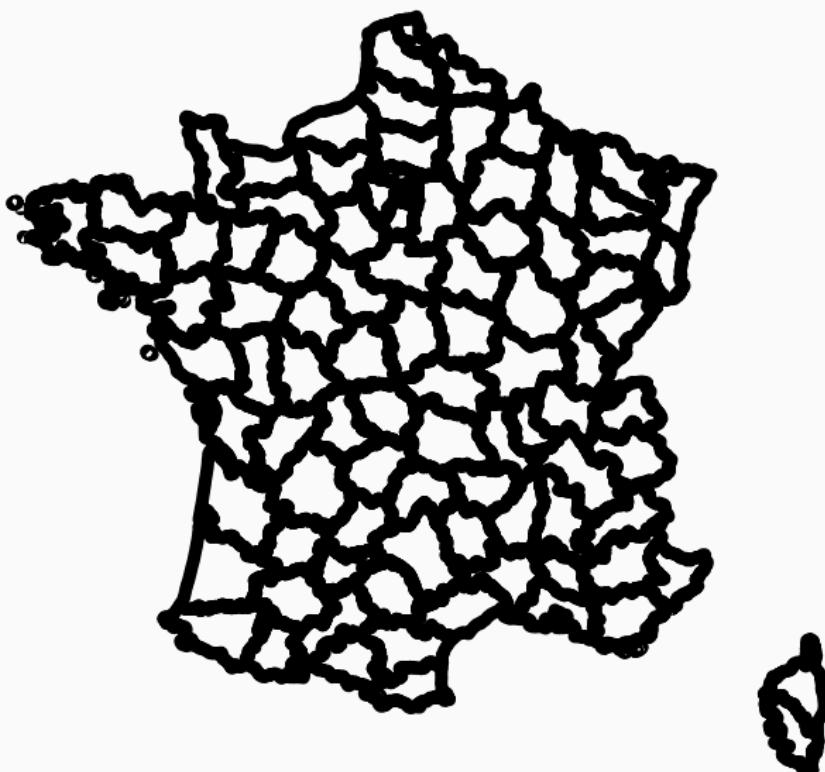
- <https://statnmap.com/fr/2018-07-14-initiation-a-la-cartographie-avec-sf-et-compagnie/>
- Vignettes on the cran :
<https://cran.r-project.org/web/packages/sf/index.html>.

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
bbox:             xmin: 644570 ymin: 6290136 xmax: 1022851 ymax: 6997000
CRS:              2154
# A tibble: 5 x 2
  NOM_DEPT                                geometry
  <chr>                                     <MULTIPOLYGON [m]>
1 AIN           (((919195 6541470, 918932 6541203, 918628 6540523~
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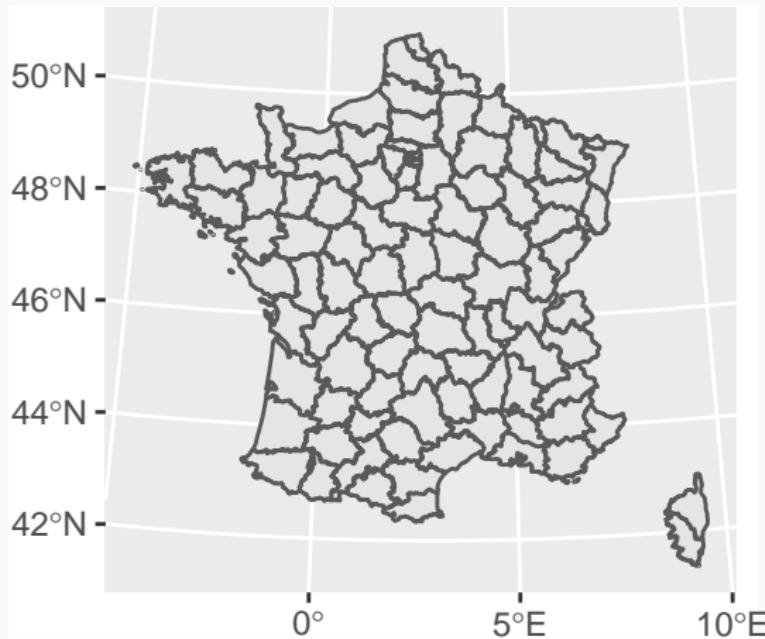
Visualize with plot

```
> 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)))
```

Adding points on the map

- Define coordinates with `st_point`

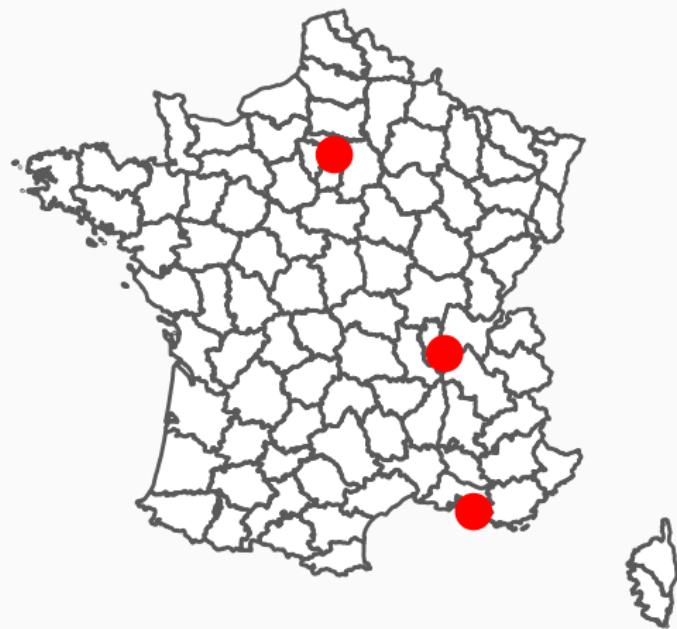
```
> point <- st_sfc(st_point(c(2.351462,48.85670)),  
+                   st_point(c(4.832011,45.75781)),  
+                   st_point(c(5.369953,43.29617)))
```

- 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  
bbox: xmin: 2.351462 ymin: 43.29617 xmax: 5.369953 ymax: 48.85670  
CRS: EPSG:4326
```

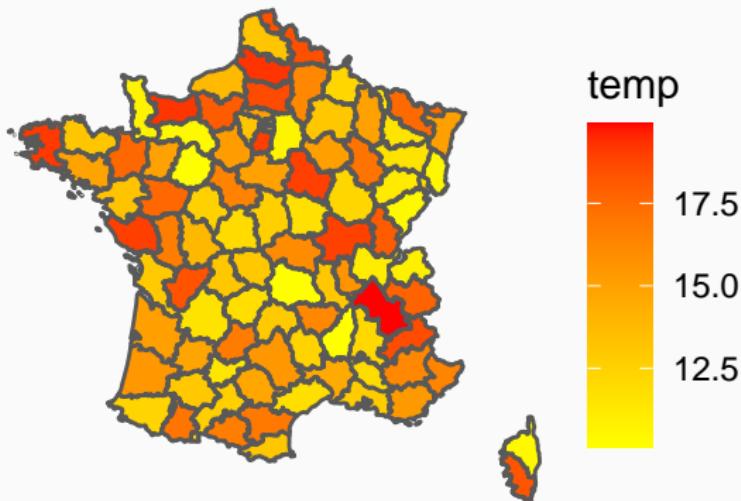
ggplot step

```
> 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()
```



⇒ Work on **this part** of the tutorial.

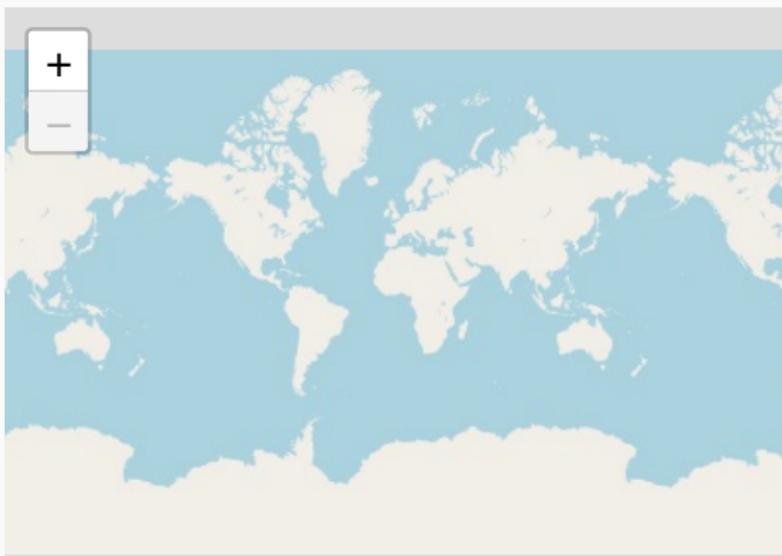
Mapping

Interactive maps with leaflet

Background map

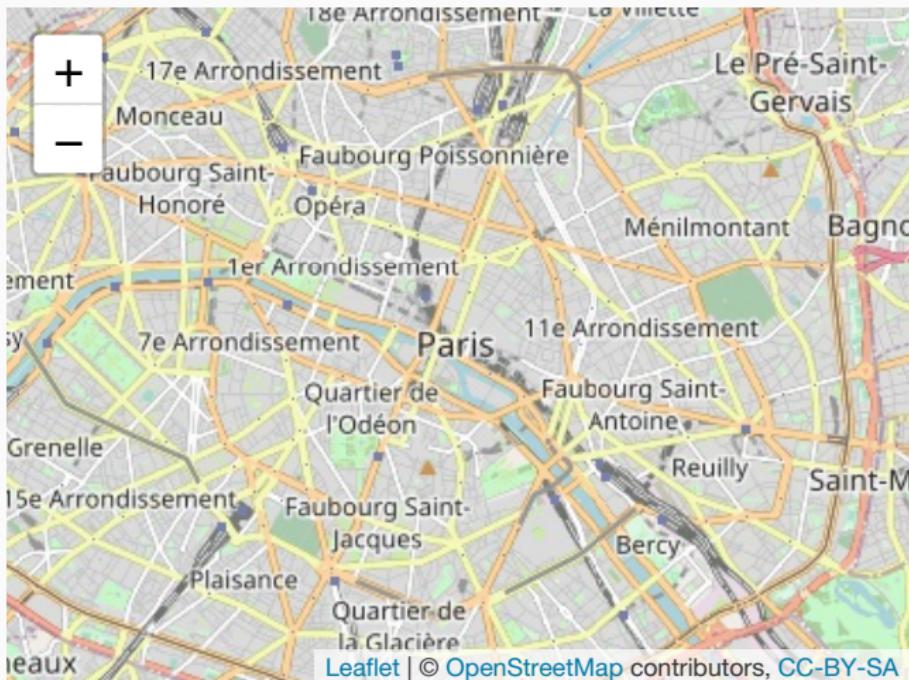
- Leaflet is one of the most popular open-source JavaScript libraries for interactive maps.
- Documentation: [here](#)

```
> 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

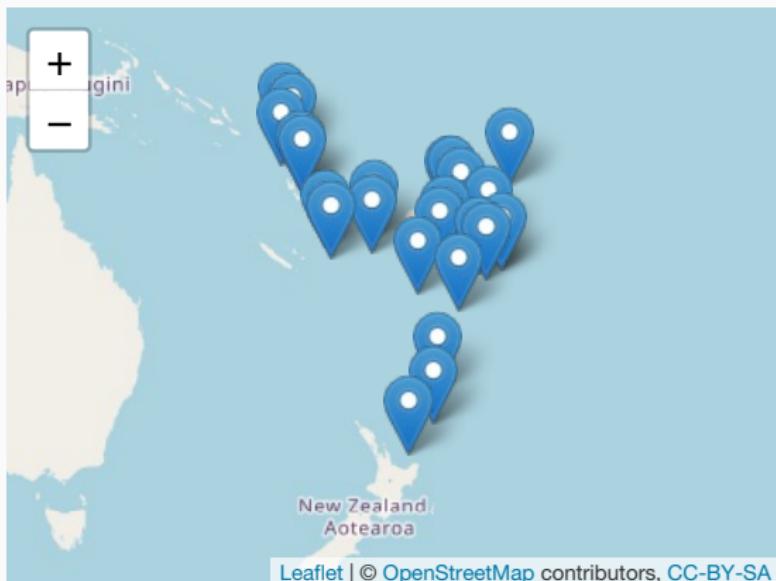
- Location of 1000 seismic events near Fiji

```
> 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.

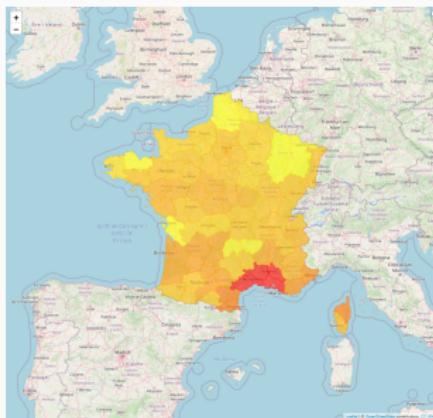
addCircleMarkers

```
> 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=" : "))
```



⇒ 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`.

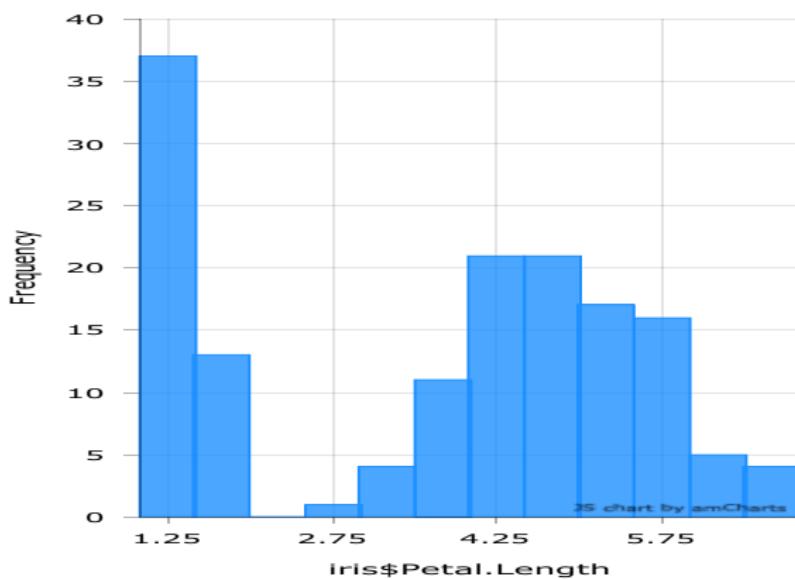
Some Dynamic visualization tools

rAmCharts and plotly

- **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/

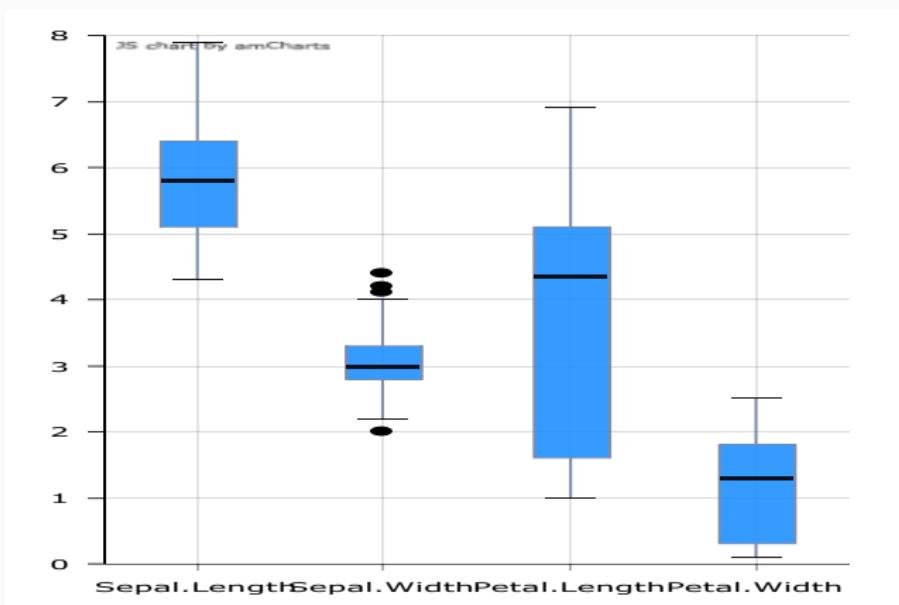
rAmCharts Histogram

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



rAmcharts Boxplot

```
> amBoxplot(iris)
```

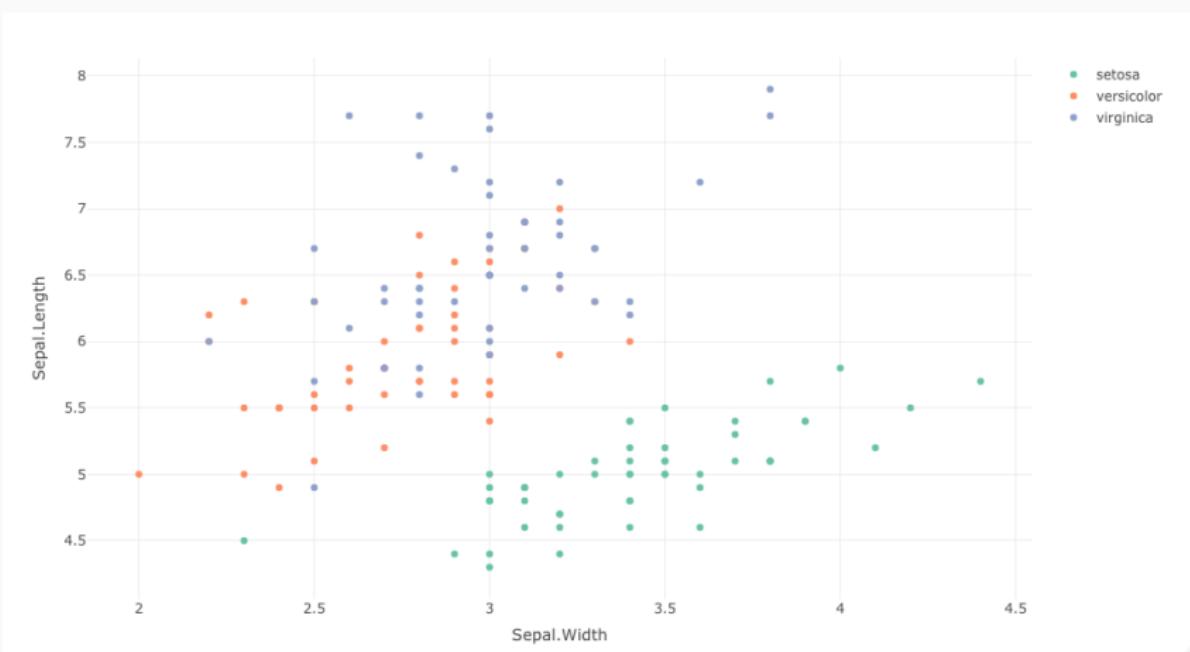


Plotly

- 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/>

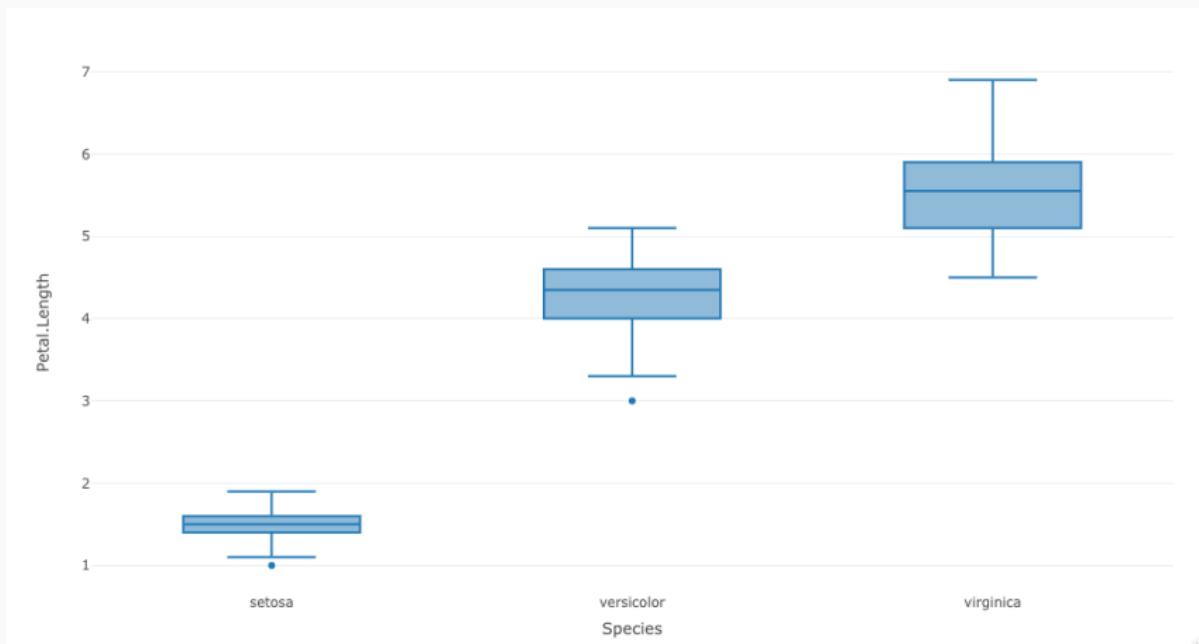
Scatter plot

```
> 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()
```



Some Dynamic visualization tools

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...).

Connections between individuals

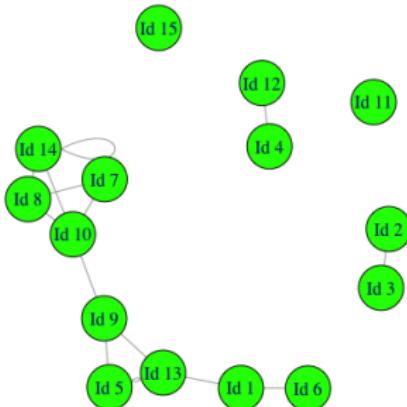
- Many datasets can be visualized with **graphs**, especially when one has to study **connections** between individuals (genomic, social network...).
- One individual = **one node** and one connection = **one edge**.

```
> 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)
```

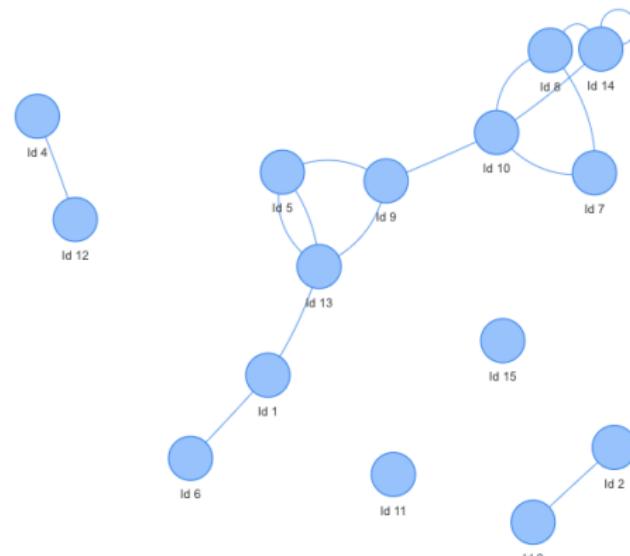


Dynamic graph: visNetwork Package

- Reference:

<https://datastorm-open.github.io/visNetwork/interaction.html>

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



Some Dynamic visualization tools

Dashboard with flexdasboard

- Just a tool... but an **important visualization tool** in datascience
- Allow to **gather important messages** on datasets and/or models

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

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)
```

```
```
```

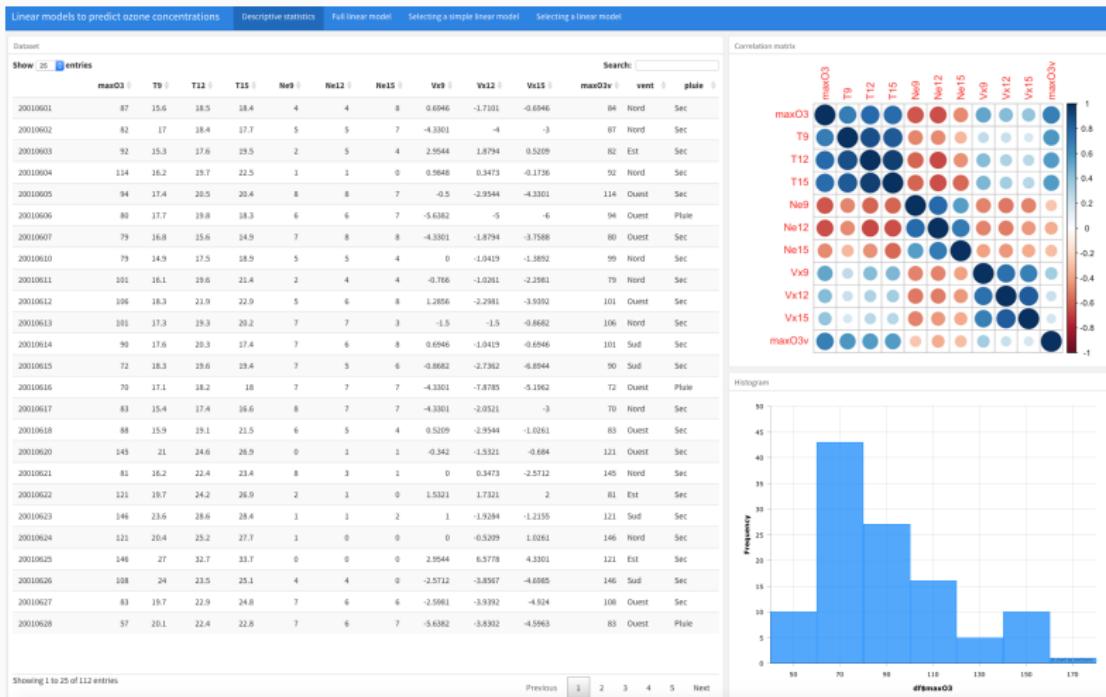
```
### Histogram
```

```
```{r}
```

```
amHist(df$max03)
```

```
```
```

Flexdashboard | dashboard



⇒ 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 markdown 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 13th, 5pm.

Some examples (students of Rennes University, M1 2020)

- <https://kabdallah.shinyapps.io/shinyapp/>
- https://quentincarric.shinyapps.io/FooTooL_by_CARRIC_DIALLO_MAHE/
- <https://pierrelepagnol.shinyapps.io/Reporting/>
- <https://hersantmarc.shinyapps.io/projet/>
- https://euvrardq.shinyapps.io/etude_tendances_youtube/