Introduction to GIS

Smart Analytics for Big Data

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Overview

Overview

Conclusion

Keywords

Geovizualisation [1]

Faced with the abundance of data and tools *(multi-sensor, multi-source, multi-scale, more or less precise, more or less massive data)*, - need to visualize various geographic data (satellite imagery, maps, databases, GPS data, collaborative data, etc.), - and add quantitative / qualitative data, (also textual archives, photos old or historical image databases), - to navigate in this data, and to add / extract information yourself.

1. La géovisualisation, késako ? par Sidonie Christophe (LASTIG)

Geovisualization

- is the set of knowledge and techniques
- used to visualize a territory (or a spatial phenomenon)
- by interacting with geographic or geolocated data,
- using the user's perception and cognition capacities.

The objective of geovisualization

- is to give to see, perceive, understand and interpret,
- while preserving what has meaning, for the user,
- in the geographical space and in the spatio-temporal phenomenon represented
- (for example, flood simulation, weather prediction, climate scenarios, past urban dynamics, urban planning, etc.).

The challenge of geovisualization, as an interdisciplinary research field,

- is to design graphic representations and means of interaction with geographic data,
- to effectively help a user to see, perceive, understand, interpret, analyze or even take decisions on a spatial phenomenon.

The goal of this post is to introduce the basic landscape of working with spatial data in R from the perspective of a non-specialist.

The use of the `ggmap` package is to geocode data and create maps using the `ggplot2` system.

The `sp` and `sf` packages use different methodologies for integrating spatial data into R.

The `sp` package introduced a coherent set of classes and methods for handling spatial data in 2005. The package remains the backbone of many packages that provide GIS capabilities in R.

The `sf` package implements the simple features open standard for the representation of geographic vector data in R.

The package first appeared on CRAN at the end of 2016 and is under very active development. The sf package is meant to supersede sp, implementing ways to store spatial data in R that integrate with the `tidyverse` workflow of the packages developed

Leaving point & click softs

Objectives 1 : access to a powerful (geo)statistical and visualization programming language and the benefits of a command-line approach (Sherman 2008) :

> *With the advent of 'modern' GIS software, most people want to point and click their way through life. That's good, but there is a tremendous amount of flexibility and power waiting for you with the command line.*

Some desktop Geographic Information System (GIS) are QGIS, ArcMap, GRASS or SAGA,

Using a command-line interface has the benefits of enabling both steps analysis and visualization in customizable, transparent and reproducible manner.

Objectives 2 : access a range of spatial skills, including :

- *reading, writing and manipulating geographic data ;*
- *making static and interactive maps ;*
- *applying geocomputation to solve real-world problems ;*
- *and modeling geographic phenomena.*

Using integrated reproducible 'code chunks' in the text, this lesson teaches a transparent and thus scientific workflow.

Table 1 – Differences in emphasis between software packages (Graphical User Interface (GUI) of Geographic Information Systems (GIS) and R).

Attribute	Desktop GIS (GUI)	R
Home disciplines	Geography	Computing, Statistics
Software focus	Graphical User Interface	Command line
Reproducibility	Minimal	Maximal

All classical operations on spatialized data can be completely performed in :

- Reading and exploration of spatialized / geographic data
- Attributes manipulation (creation, selection)
- Geomatics processing (intersection, joint, surface calculation)
- Map creation (static, interactive)

To create a 2-dimensional map, a projection must be made. The areas you study will be more or less distorted by the projection you chose.

Simple Features for R : the sf package

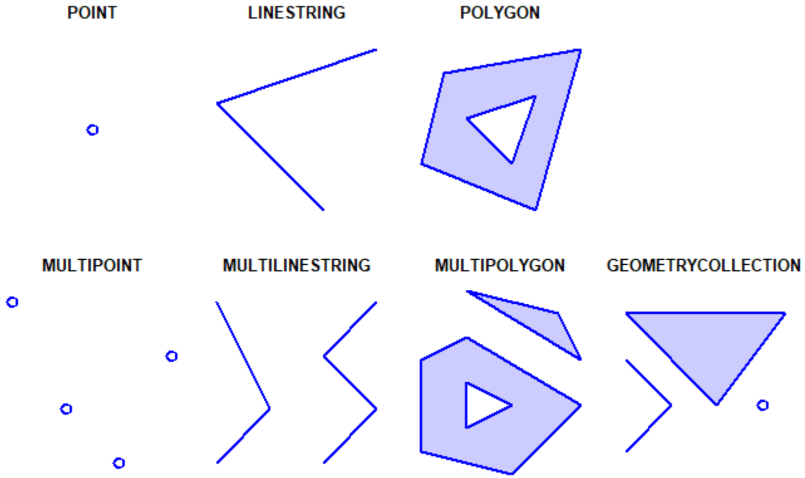
Vector layers in `sf`

- The `sf` class is a hierarchical structure composed of 3 classes
- **sf** - Vector layer object, `data.frame` with ≥ 1 attribute columns and 1 geometry column
- **sfc** - Geometric part of vector layer - geometry column
- **sfg** - Geometry of individual *simple feature*

Example of layer

X_CENTROID	Y_CENTROID	CODE_REG	NOM_REG	geometry
886172	6641548	27	BOURGOGNE-FRANCHE-COMTE	MULTIPOLYGON (((886244.2 66...
795655	6521581	84	AUVERGNE-RHONE-ALPES	MULTIPOLYGON (((764370.3 65...
550942	6952842	28	NORMANDIE	MULTIPOLYGON (((511688.8 69...
748211	6750855	27	BOURGOGNE-FRANCHE-COMTE	MULTIPOLYGON (((709449.1 67...
1016174	6763894	44	ALSACE-CHAMPAGNE-ARDENNE-LORRAINE	MULTIPOLYGON (((992779.1 67...
579506	6810114	24	CENTRE-VAL DE LOIRE	MULTIPOLYGON (((548948.9 68...

Simple feature geometry `sfg`



- spatial entities are called *features*, but for statisticians it is a record - but with a *geometry*
- column `geometry` :
    - It is where the feature's store its geometry. Each feature, in the example each department of France has a geometry, here it is Polygons.
- the *Simple Features* is made of *Points* known in coordinates (`lon` and `lat`).
- *Polygons summits* are Points and the *perimeter* can be view as a *LineString*.

Note that for the polygons, the first summit and the last summit needs to have exactly the same coordinates.

That's the way for the computer to know that it is a closed polygon and not an open LineString.

Projection Issue

Let start with the illustration of the problem.

Several CRS (*Coordinate Reference System*) exist per country [2]

Projection of Metropolitan France [3]

```
path <- 'G:/Ira_Lessons_with_Rmd/SABD_SmartAnalytics/GIS/data'

departements_L93 <- st_read(dsn   = path,
                            layer = "DEPARTEMENT",
                            quiet = TRUE) %>%
  st_transform(2154)
```

2. Example from : (https://statnmap.com/2018-07-14-introduction-to-mapping-with-sf-and-co/) Rochette (2018)
3. Example from : (https://statnmap.com/2018-07-14-introduction-to-mapping-with-sf-and-co/) Rochette (2018)

Difference between projections

```r
ggplot(departements_L93) +
  aes(fill = CODE_REG) +
  scale_fill_viridis_d() +
  geom_sf() +
  coord_sf(crs = 4326) +
  guides(fill = FALSE) +
  ggtitle("Coord. géographiques") +
  theme(title = element_text(size = 16),
        plot.margin = unit(c(0,0.1,0,0.25), "inches"))
```

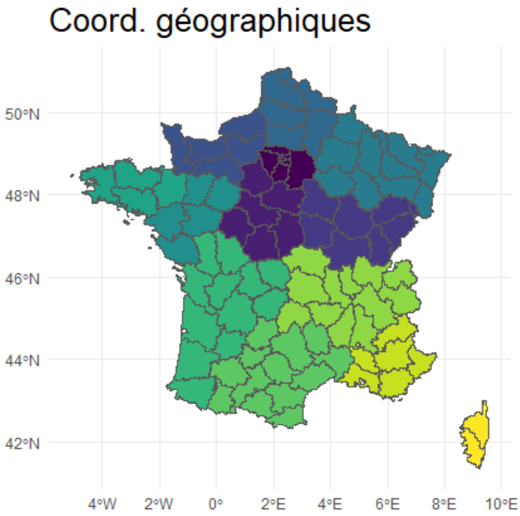
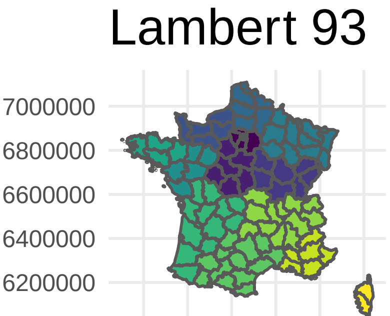


Figure 1 – France

```r
g_dept <- ggplot(departements_L93) +
  aes(fill = CODE_REG) +
  scale_fill_viridis_d() +
  geom_sf() +
  coord_sf(crs = 2154, datum = sf::st_crs(2154)) +
  guides(fill = FALSE) +
  ggtitle("Lambert 93") +
  theme(title = element_text(size = 16))
g_dept
```



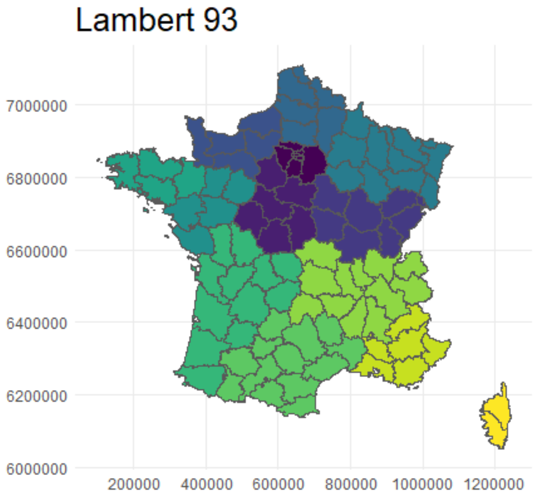
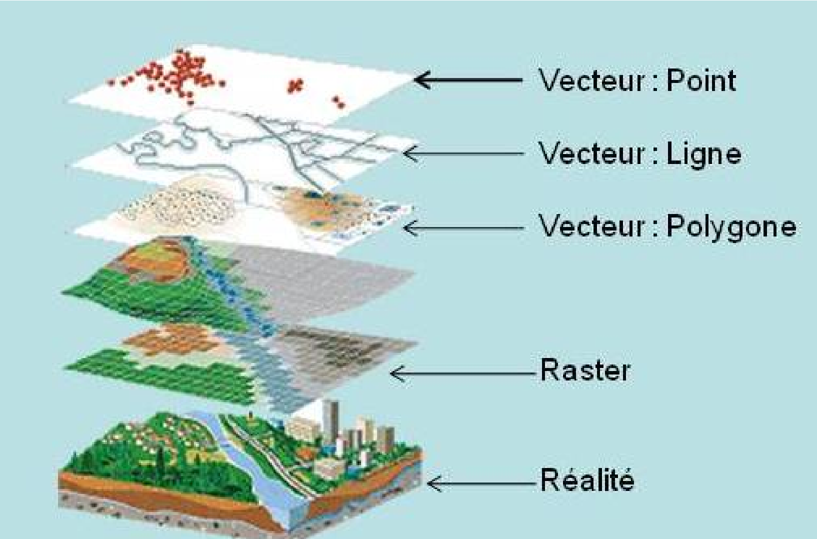


Figure 2 – France en Lambert 93

Figure 3 – Illustration of vector (point) data in which location of London (the red X) is represented with reference to an origin (the blue circle). The left plot represents a geographic CRS with an origin at 0° longitude and latitude. The right plot represents a projected CRS with an origin located in the sea west of the South West Peninsula.

Vector layer file format

We will focus only on vector data.



Vector layer file format

- `sf` reads with `st_read` all formats managed by GDAL (http://www.gdal.org/)
- ESRI shapfile format are 4 files minium `shp, shx, dbf, prj`
- with `sf` the shapefiles becomes a 'classic' dataframe

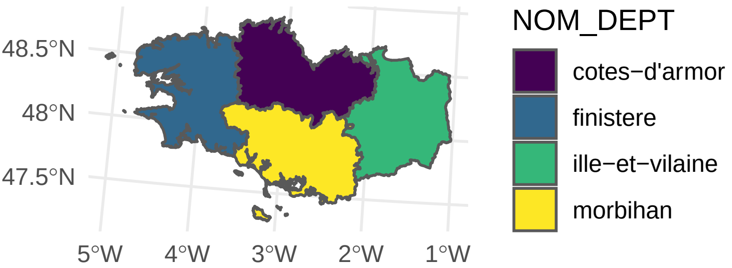
Example of manipulation

Mapping Bretagne region

```
Bret_L93 <-
  departements_L93 %>%
  mutate_at(
    vars(NOM_DEPT, NOM_REG),
    tolower) %>%
  select(CODE_DEPT, NOM_DEPT, NOM_REG) %>%
  filter(NOM_REG == "bretagne")
Bret_L93
```

CODE_DEPT	NOM_DEPT	NOM_REG	geometry
35	ille-et-vilaine	bretagne	MULTIPOLYGON (((3304
22	cotes-d'armor	bretagne	MULTIPOLYGON (((2598
29	finistere	bretagne	MULTIPOLYGON (((1161
56	morbihan	bretagne	MULTIPOLYGON (((2562

```r
ggplot(Bret_L93) +
  geom_sf(aes(fill = NOM_DEPT)) +
  scale_fill_viridis_d()
```



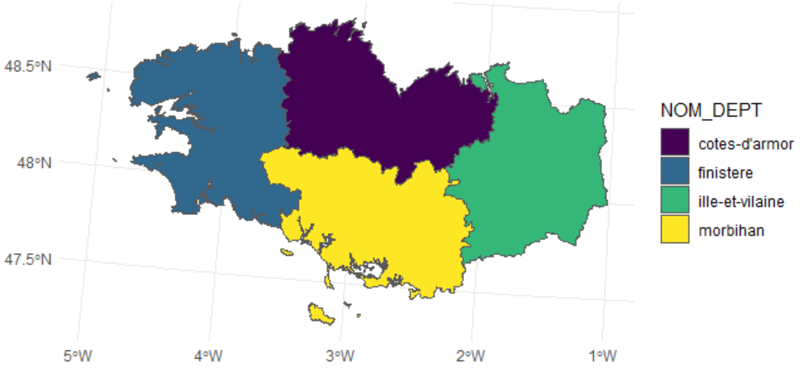
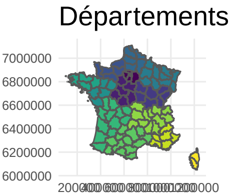


Figure 5 – Bretagne

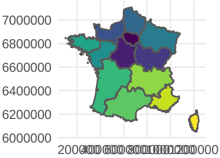
Merge spatial features with `group_by` & `summarize`

```r
region_L93 <- departements_L93 %>%
  group_by(CODE_REG) %>%
  summarize()
g_region <- ggplot(region_L93)   +
   aes(fill = CODE_REG) +
   scale_fill_viridis_d() +
   geom_sf() +
   coord_sf(crs = 2154, datum = sf::st_crs(2154)) +
   guides(fill = FALSE) +
   ggtitle("Régions") +
   theme(title = element_text(size = 16))
```

```
g_region
```


Départements
7000000
6800000
6600000
6400000
6200000
6000000
200000400000600000800000100000012000000

Régions

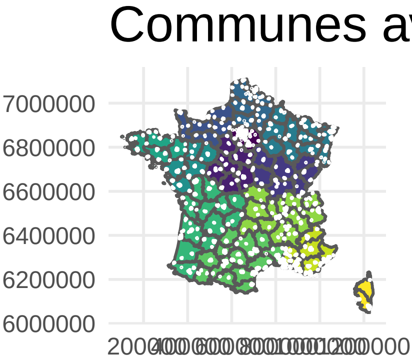


```r
# Read shapefile of French communes
communes <- st_read(dsn = path, layer = 'COMMUNE', quiet =
  select(NOM_COM, INSEE_COM)
# Read file of maternities for 2016
data.maternite <- readr::read_csv(file.path( path, "Matern
  filter(an == 2016)
```

```r
# Join database with shapefile by attributes
maternites_L93 <- communes %>%
  right_join(data.maternite,
             by = "INSEE_COM") %>%
  st_transform(2154)
```

```r
g_dept2 <- g_dept +
  geom_sf(data = maternites_L93, fill = "white", colour = '
  coord_sf(crs = 2154, datum = sf::st_crs(2154)) +
  ggtitle("Communes avec une maternité en 2016")
```

```
g_dept2
```



Communes avec une
7000000
6800000
6600000
6400000
6200000
6000000
200000
400000
600000
800000
1000000
1200000

Conclusion

Wrap up : Geometric calculations

Geometric operations on vector layers can conceptually be divided into **three groups** according to their output :

- **Numeric** values : Functions that summarize geometrical properties of :
  - A **single layer** (e.g. area, length)
  - A **pair of layers** (e.g. distance)
- **Logical** values : Functions that evaluate whether a certain condition holds true, regarding :
  - A **single layer** (e.g. geometry is valid)
  - A **pair of layers** (e.g. feature A intersects feature B)
- **Spatial** layers : Functions that create a new layer based on :
  - A **single layer** (e.g. centroids)
  - A **pair of layers** (e.g. intersection area)

Numeric

- Several functions to calculate **numeric geometric properties** of vector layers :
  - `st_length`
  - `st_area`
  - `st_distance`
  - `st_bbox`
  - ...

Logical

- Given two layers, `x` and `y`, the following **logical geometric functions** check whether each feature in `x` maintains the specified **relation** with each feature in `y` :
    - `st_intersects`
    - `st_disjoint`
    - `st_touches`
    - `st_crosses`
    - `st_within`
    - `st_contains`
    - `st_overlaps`
    - `st_covers`
    - `st_equals`
    - ...

Spatial

- Common **geometry-generating** functions applicable to **individual** geometries :
  - `st_centroid`
  - `st_buffer`
  - `st_union`
  - `st_sample`
  - `st_convex_hull`
  - `st_voronoi`
  - ...

All sf methods

```r
methods(class='sf')
```

```
##  [1] $<-                 [                   [[<-
##  [4] aggregate           anti_join           arrange
##  [7] as.data.frame       cbind               coerce
## [10] dbDataType          dbWriteTable        distinc
## [13] dplyr_reconstruct   filter              full_jo
## [16] gather              group_by            group_s
## [19] identify            initialize          inner_j
## [22] left_join           merge               mutate
## [25] nest                plot                print
## [28] rbind               rename              right_j
## [31] sample_frac         sample_n            select
## [34] semi_join           separate            separat
## [37] show                slice               slotsFr
## [40] spread              st_agr              st_agr
```

To dive even deeper into sf

- Detailed sf package vignettes
- Blog posts : here, here, here, here, here and there (in French)

- Video of Edzer Pebesma at rstudio::conf 2018
- wiki page describing sp-sf migration
- Awesome online book Geocomputation with R by Lovelace, Nowosad and Muenchow

The RStudio Cheat Sheets

Spatial manipulation with sf: : CHEAT SHEET

The sf package provides a set of tools for working with geospatial vectors, i.e. points, lines, polygons, etc.

Geometric confirmation

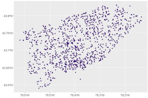
- st_contains(x, y, ...) Identifies if x is within y (i.e. point within polygon)
- st_covered_by(x, y, ...) Identifies if x is completely within y (i.e. polygon completely within polygon)
- st_covers(x, y, ...) Identifies if any point from x is outside of y (i.e. polygon outside polygon)
- st_crosses(x, y, ...) Identifies if any geometry of x have commonalities with y
- st_disjoint(x, y, ...) Identifies when geometries from x do not share space with y
- st_equals(x, y, ...) Identifies if x and y share the same geometry
- st_intersects(x, y, ...) Identifies if x and y geometry share any space
- st_overlaps(x, y, ...) Identifies if geometries of x and y share space, are of the same dimension, but are not completely contained by each other
- st_touches(x, y, ...) Identifies if geometries of x and y share a common point but their interiors do not intersect
- st_within(x, y, ...) Identifies if x is in a specified distance to y

Geometric operations

- st_boundary(x) Creates a polygon that encompasses the full extent of the geometry
- st_buffer(x, dist, nQuadSegs) Creates a polygon covering all points of the geometry within a given distance
- st_centroid(x, ..., of_largest_polygon) Creates a point at the geometric centre of the geometry
- st_convex_hull(x) Creates geometry that represents the minimum convex geometry of x
- st_line_merge(x) Creates linestring geometry from sewing multi linestring geometry together
- st_node(x) Creates nodes on overlapping geometry where nodes do not exist
- st_point_on_surface(x) Creates a point that is guarenteed to fall on the surface of the geometry
- st_polygonize(x) Creates polygon geometry from linestring geometry
- st_segmentize(x, dfMaxLength, ...) Creates linesting geometry from x based on a specified length
- st_simplify(x, preserveTopology, dTolerance) Creates a simplified version of the geometry based on a specified tolerance

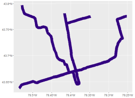
Geometry creation

- st_triangulate(x, dTolerance, bOnlyEdges) Creates polygon geometry as triangles from point geometry
- st_voronoi(x, envelope, dTolerance, bOnlyEdges) Creates polygon geometry covering all points of x, with x at the centre of the geometry
- st_point(x, c(numeric vector), dim = "XYZ") Creating point geometry from numeric values
- st_multipoint(x = matrix(numeric values in rows), dim = "XYZ") Creating multi point geometry from numeric values
- st_linestring(x = matrix(numeric values in rows), dim = "XYZ") Creating linestring geometry from numeric values
- st_multilinestring(x = list(numeric matricesin rows), dim = "XYZ") Creating multi linestring geometry from numeric values
- st_polygon(x = list(numeric matrices in rows), dim = "XYZ") Creating polygon geometry from numeric values
- st_multipolygon(x = list(numeric matrices in rows), dim = "XYZ") Creating multi polygon geometry from numeric values



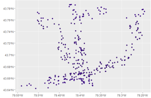
ggplot() +
geom_sf(data = schools)

\+



ggplot() +
geom_sf(data = subway)

=>



ggplot() +
geom_sf(data = st_intersection(schools, st_buffer(subway, 1000)))

This cheatsheet presents the sf package [Edzer Pebesma 2018] in version 0.6.3. See https://github.com/r-spatial/sf for more details.

Spatial manipulation with sf: : CHEAT SHEET

The sf package provides a set of tools for working with geospatial vectors, i.e. points, lines, polygons, etc.

Geometry operations

st_contains(x, y, ...) Identifies if x is within y (i.e. point within polygon)

st_crop(x, y, ..., xmin, ymin, xmax, ymax) Creates geometry of x that intersects a specified rectangle

st_difference(x, y) Creates geometry from x that does not intersect with y

st_intersection(x, y) Creates geometry of the shared portion of x and y

st_sym_difference(x, y) Creates geometry representing portions of x and y that do not intersect

st_snap(x, y, tolerance) Snap nodes from geometry x to geometry y

st_union(x, y, ..., by_feature) Creates multiple geometries into a a single geometry, consisiting of all geometry elements

Geometric measurement

st_area(x) Calculate the surface area of a polygon geometry based on the current coordinate reference system

st_distance(x, y, ..., dist_fun, by_element, which) Calculates the 2D distance between x and y based on the current coordinate system

st_length(x) Calculates the 2D length of a geometry based on the current coordinate system

Misc operations

st_cast(x, to, ...) Change x geometry to a different geometry type

st_coordinates(x, ...) Creates a matrix of coordinate values from x

st_crs(x, ...) Identifies the coordinate reference system of x

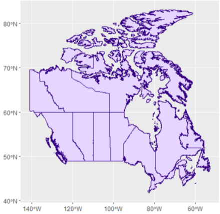
st_join(x, y, join, FUN, suffix, ...) Performs a spatial left or inner join between x and y

st_make_grid(x, cellsize, offset, n, crs, what) Creates rectangular grid geometry over the bounding box of x

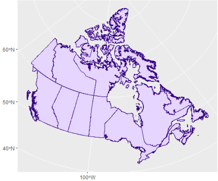
st_nearest_feature(x, y) Creates an index of the closest feature between x and y

st_nearest_points(x, y, ...) Returns the closest point between x and y

st_transform(x, crs, ...) Convert coordinates of x to a different coordinate reference system




```
ggplot() +
  geom_sf(data = cdn) +
  coord_sf(crs = st_crs(4326))
```



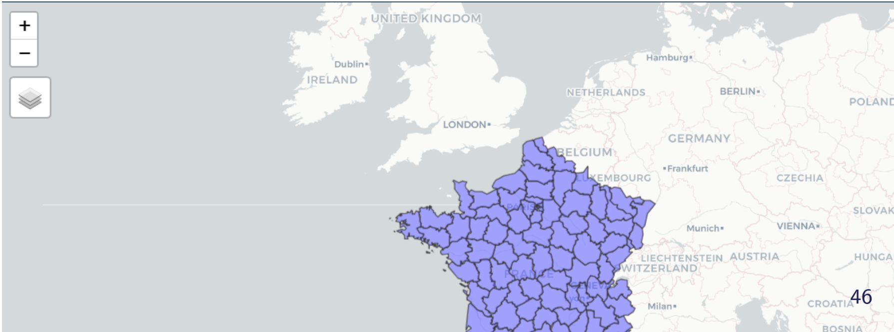

```
ggplot() +
  geom_sf(data = cdn) +
  coord_sf(crs = st_crs(3347))
```

This cheatsheet presents the sf package [Edzer Pebesma 2018] in version 0.6.3. See https://github.com/r-spatial/sf for more details.

Miscellaneous

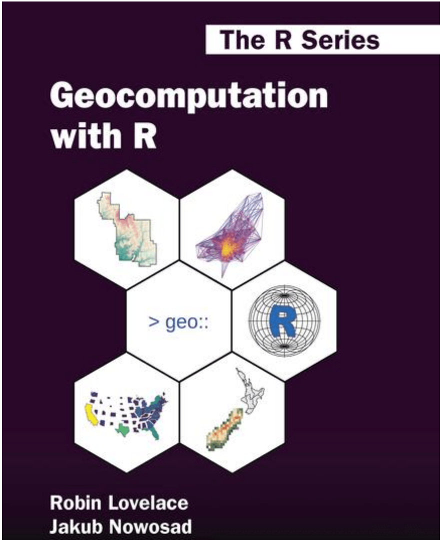
- What about raster data ? Check out package **star**
- `mapview::mapview()` creates interactive maps in html pages, using package `leaflet`, very useful to inspect spatial data (see also package `tmap`)

```
mapview::mapview(departements_2)
```



References

- Geocomputation with R by Robin Lovelace, Jakub Nowosad, Jannes Muenchow



- R Spatial by Edzer Pebesma
- Tidy spatial data analysis (video) by Edzer Pebesma at rstudio : :conf 2018
- Introduction to mapping with {sf} & Co. on spatial analysis with R by Sebastien Rochette
- Introduction to GIS and mapping in R using the sf package, olivier gimenez
- Nick Eubank's, GIS in R
- The package vignettes for sf are very helpful for providing an introduction to the package.
- (https://tender-curie-5b83bc.netlify.app/2019/03/01/mapping-sncf-stations/)

Bibliography

Rochette, Sébastien. 2018. "Introduction to Mapping with sf & Co." https://statnmap.com/2018-07-14-introduction-to-mapping-with-sf-and-co/.