Spatial, Temporal and Spatio-Temporal Data in R

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Packages for Visualizing Spatiotemporal Data

- Spatial visualization is a key step on spatio-temporal data analysis
- R has several packages that can help with these tasks
- Some of the most useful are:
  - **ggmap**, a package that combines spatial information from providers of maps (e.g. Google Maps) with the beautiful graphics of the **ggplot2** package (`https://github.com/dkahle/ggmap`)
  - **leaflet**, a package that links R with one of the most popular open-source JavaScript libraries for interactive maps (`https://rstudio.github.io/leaflet/`)
  - **mapview** a package that provides functions to very quickly and conveniently create interactive visualisations of spatial data (`https://r-spatial.github.io/mapview/`)

The Package **ggmap**

- As **ggmap** uses **ggplot2** graphics, the graphs have the typical properties/components found in **ggplot2** plots
- However, some of these are fixed to map-related information:
  - The *x* aesthetic is fixed to longitude
  - The *y* aesthetic is fixed to latitude
  - The coordinate system is fixed to the Mercator projection

The process of using **ggmap**

- Download a map image
- Plot it as basic layer using **ggplot2**
- Plot additional layers of data, statistics or models on top
- In **ggmap** this is done using:
  - `get_map()` to obtain the map image
  - `ggmap()` to make the actual plot

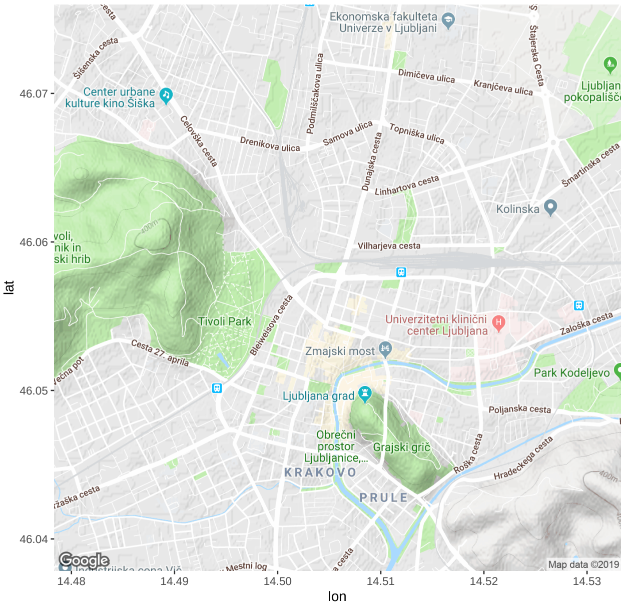
The function get_map()

- **ggmap** can use several map providers
  Google Maps, OpenStreet Maps, Stamen Maps and CloudMade Maps
- Recently (mid 2018), Google changed the policies to access map data. Now you need an API Key to obtain maps from Google Maps. Check the help page of the function `register_google` for further details/instructions

The function get_map()

A simple example

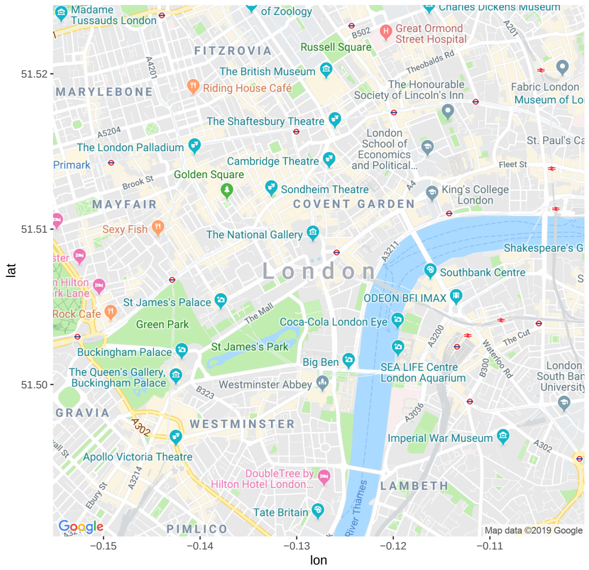
```
library(ggmap)
map <- get_map("Ljubljana",
               zoom=14)
ggmap(map)
```

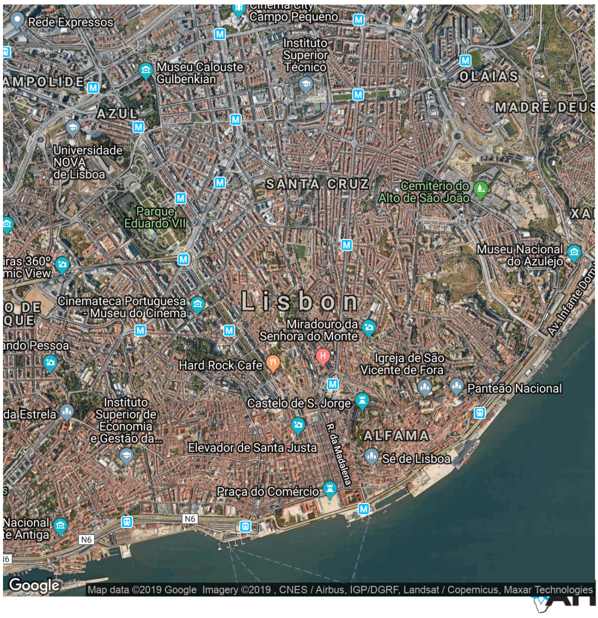


The function get_map() - a few examples

```
library(ggmap)
map <- get_map("London",zoom=14,
               maptype="roadmap")
ggmap(map)
```

```
map <- get_map("Lisbon",zoom=14,
               maptype="hybrid")
ggmap(map,extent="device")
```




Rede Expressos
Campo Pequeno
Instituto Superior Técnico
Museu Calouste Gulbenkian
AMPOLIDE
AZUL
OLAIAS
MADRE DEUS
Universidade NOVA de Lisboa
SANTA CRUZ
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Parque Eduardo VII
Museu Nacional do Azulejo
Cinemateca Portuguesa - Museu do Cinema
Lisbon
Miradouro da Senhora do Monte
Hard Rock Cafe
Igreja de São Vicente de Fora
Panteão Nacional
Instituto Superior de Economia e Gestão da...
Castelo de S. Jorge
ALFAMA
Elevador de Santa Justa
Sé de Lisboa
Praça do Comércio
Google
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A Simple Illustration

Fires data of 500m^2 regions of Portugal

- Official data on fires in different regions of Portugal
- The data set we will use contains information on 25000 locations

```
library(readr)
df <- read_csv("firesnew_25000_500m.txt")
```

```
df[1:3,]


## # A tibble: 3 x 14
##   FID_    CID ano1991 ano1992 ano1993 ano1994 ano1995 ano1996 ano1997
##   <lgl> <dbl>   <dbl>   <dbl>   <dbl>   <dbl>   <dbl>   <dbl>   <dbl>
## 1 NA        1       0       0       0       0       0       0       0
## 2 NA        2       0       0       0       0       0       0       0
## 3 NA        3       0       0       0       0       0       0       0
## # ... with 5 more variables: ano1998 <dbl>, ano1999 <dbl>, ano2000 <dbl>,
## #   x <dbl>, y <dbl>
```

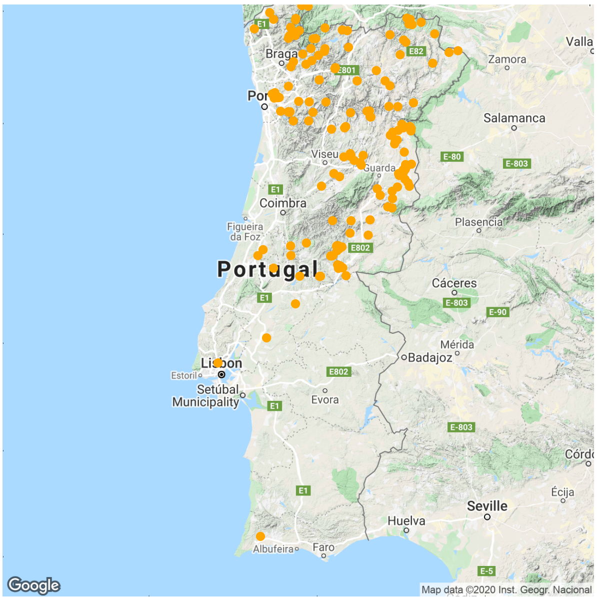
Putting the data in long format

```
library(tidyr)
dat <- gather(df[,3:14],year, burnt, ano1991:ano2000)
dat$year <- substr(dat$year,4,7)
head(dat,4)

## # A tibble: 4 x 4
##         x      y year  burnt
##     <dbl>  <dbl> <chr> <dbl>
## 1 -7.32   38.5 1991      0
## 2 -7.64   40.5 1991      0
## 3 -7.90   40.3 1991      0
## 4 -7.26   39.3 1991      0
```

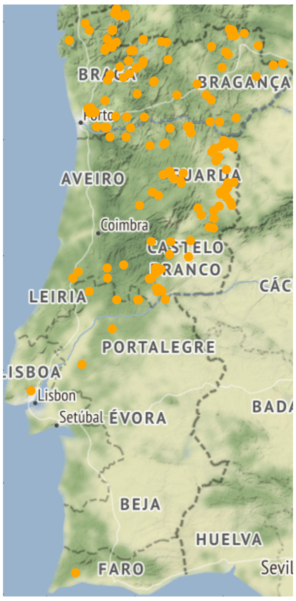
Plotting the Fires in 1999

```
library(ggmap)
pt <- get_map("Portugal",zoom=7)
data2plot <- dat[dat$year==1999 & dat$burnt == 1,]
ggmap(pt,extent="device") +
    geom_point(data=data2plot,
               aes(x=x,y=y),
               color="orange",size=3)
```



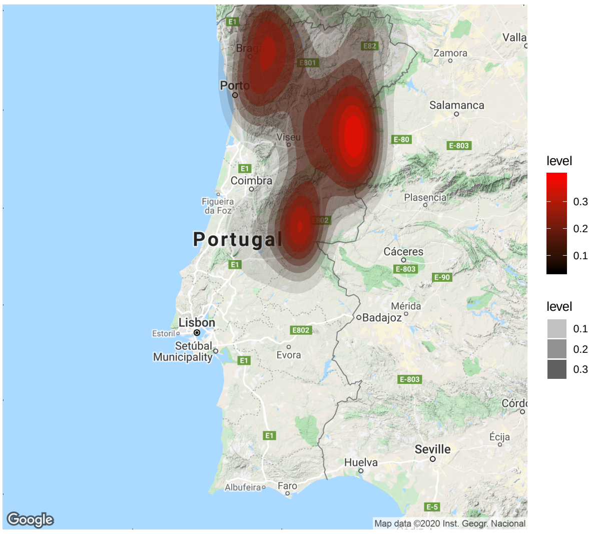
If you don't have the Google Maps API Key

```
library(ggmap)
rlat <- range(df$x)
rlon <- range(df$y)
bb <- c(left=rlat[1],bottom=rlon[1],right=rlat[2],top=rlon[2])
pt2 <- get_map(bb,source="stamen",zoom=7)
data2plot <- dat[dat$year==1999 & dat$burnt == 1,]
ggmap(pt2,extent="device") +
    geom_point(data=data2plot,
               aes(x=x,y=y),
               color="orange",size=3)
```



Adding some spatial interpolation

```
ggmap(pt,extent="device",
      base_layer=ggplot(data2plot,aes(x=x,y=y))
      ) +
    stat_density2d(aes(fill=..level..,
                       alpha=..level..),
                   bins=10,
                   geom="polygon") +
    scale_fill_gradient(low="black",high="red")
```

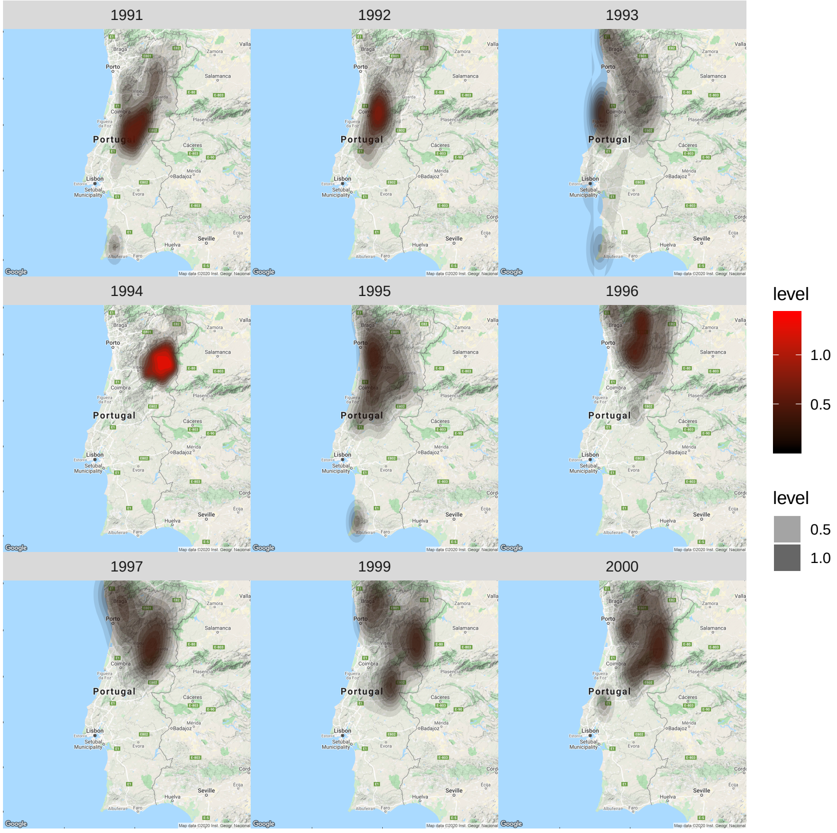


Spatio-temporal Visualization

- We need to add faceting along the year an everything else stays the same

```
data2plot <- dat[dat$burnt == 1,]
ggmap(pt,extent="device",
      base_layer=ggplot(data2plot,aes(x=x,y=y))
      ) +
    stat_density2d(aes(fill=..level.., alpha=..level..),
                   bins=10,
                   geom="polygon") +
    scale_fill_gradient(low="black",high="red") +
    facet_wrap( ~  year)
```

Spatio-temporal Visualization (cont.)



Getting geographic information of a location

- Taking advantage of the Google Maps API we can obtain information on a location

```
geocode("Ljubljana")

## # A tibble: 1 x 2
##     lon   lat
##   <dbl> <dbl>
## 1  14.5  46.1

geocode("Ljubljana",output="more")

## # A tibble: 1 x 9
##     lon   lat type     loctype    address            north south  east  west
##   <dbl> <dbl> <chr>    <chr>      <chr>              <dbl> <dbl> <dbl> <dbl>
## 1  14.5  46.1 locality approxima~ ljubljana, slove~   46.1  46.0  14.6  14.4
```

Note: Please note that the Google Maps API has several request limitations. Namely, it has an unspecified short-term rate limit as well as a 24-hour limit of 2500 requests.

Getting physical addresses from a long/lat pair

- Checking the address of one of the fire locations

```
df[1000,c("x","y")]

## # A tibble: 1 x 2
##         x     y
##     <dbl> <dbl>
## 1 -7.02   39.0

revgeocode(as.numeric(df[1000,c("x","y")]))

## [1] "Unnamed Road, 7370, Portugal"
```

Calculating distances between locations

- The distance from New York to three other cities
- Note that the default mode is driving
- Again several request limitations are imposed by Google

```
from <- rep("New York",3)
to <- c("Los Angeles","San Francisco","Toronto")
mapdist(from,to)
```

```
## # A tibble: 3 x 9
##   from     to                  m    km miles seconds minutes hours mode
##   <chr>    <chr>           <int> <dbl> <dbl>   <int>   <dbl> <dbl> <chr>
## 1 New York Los Angeles   4489747 4490. 2790.  148474   2475. 41.2  driving
## 2 New York San Francisco 4671018 4671. 2903.  155544   2592. 43.2  driving
## 3 New York Toronto        790320  790.  491.   28580    476.  7.94 driving
```

```
mapdist("Chinatown","Times Square",mode="walking")
```

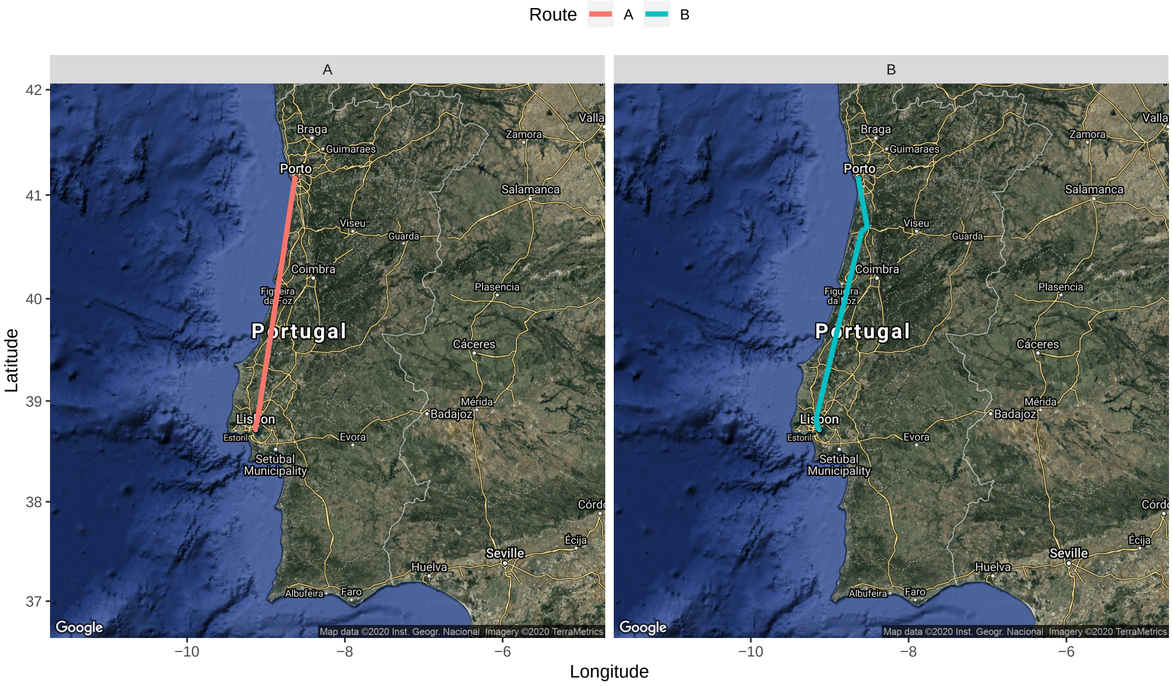
```
## # A tibble: 1 x 9
##   from      to               m    km miles seconds minutes hours mode
##   <chr>     <chr>        <int> <dbl> <dbl>   <int>   <dbl> <dbl> <chr>
## 1 Chinatown Times Square  4872  4.87  3.03    3751    62.5  1.04 walking
```

Routes between locations

- Note that the default mode is driving
- Again several request limitations are imposed by Google

```
rtDat <- route("Porto","Lisbon",mode="driving",structure="route",alternatives=TRUE)
mp <- get_map("Portugal",zoom=7,maptype="hybrid")
ggmap(mp,
      base_layer=ggplot(rtDat,aes(x=lon,y=lat,colour=route))) +
      geom_path(size=1.5,lineend="round") +
      facet_wrap(~ route) +
      labs(x = "Longitude", y = "Latitude", colour = "Route") +
      theme(legend.position = "top")
```

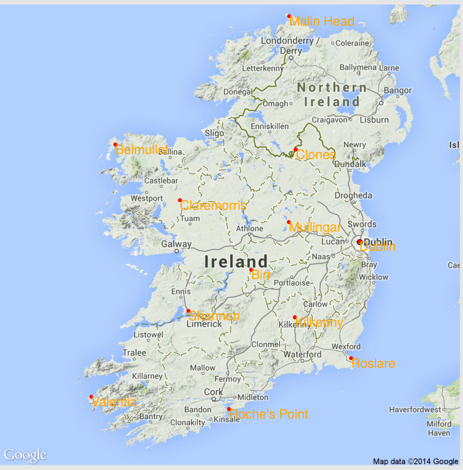
Routes between locations (cont.)



Hands On Spatio-Temporal Data with ggmap

The file `irishWind.Rdata` contains two data frames with information on wind data values collected in several meteorological stations in Ireland along several years. The data frame **wind** contains the wind values for the different stations (in wide format), while the **wind.loc** data frame contains information on the stations. Using this data set answer the following questions:

1. Obtain the geographic coordinates of the stations
2. Reproduce the graph to the right



Hands On Spatio-Temporal Data with ggmap (cont.)

3. Using the functionalities provided by packages **tidyr** and **dplyr** obtain a data frame with the average yearly wind speed for each station.
4. Produce a spatio-temporal showing theses yearly averages on the stations.

Interactive spatial visualization using package `leaflet`

- Leaflet is a very popular open-source JavaScript library for interactive maps
- The R package **leaflet** allows you to create this type of graphs in R
- After installing the package we can try it using the forest fires data

Interactive spatial visualization of the forest fires

```
library(readr)
df <- read_csv("firesnew_25000_500m.txt")
```

- The following shows the fires in 1999 in an interactive map

```
library(sp)
spatialCoords <- cbind(long=df$x, lat=df$y)
coordRefSys <- CRS("+proj=longlat +ellps=WGS84")
fires1999 <- SpatialPointsDataFrame(spatialCoords,
                                    df[, "ano1999", drop=FALSE],
                                    proj4string=coordRefSys)
library(leaflet)
leaflet() %>%
    addTiles() %>%
    addCircleMarkers(data=fires1999[fires1999$ano1999==1,])
```

Improving a bit the visualization

- Getting the addresses of the places where there were fires

```
library(ggmap)
placesWithFires <- which(fires1999$ano1999 == 1)
coord <- coordinates(fires1999)[placesWithFires,]
## Note that the Google API imposes limits on the following...
adds <- apply(coord,1,function(cs) revgeocode(cs))
## Now the interactive map (try clicking on a dot)
leaflet() %>%
    addTiles() %>%
    addCircleMarkers(data=fires1999[fires1999$ano1999==1,],
                     popup=adds,
                     clusterOptions = markerClusterOptions())
```

Learning more about leaflet

You may learn more at `https://rstudio.github.io/leaflet/`