Use And Exploration of covid19.analytics R package for US (United States) cases and data

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Background and Motivation overview

It has been 2+ years that the Covid-19 pandemic has put our life and behaviors in check. This project uses the Covid-19 dataset maintained.For starting the virus is “peculiar” as not all the infected individuals experience the same symptoms. Some individuals display symptoms that are similar to the ones of a common cold or flu while other individuals experience serious symptoms that can cause death or hospitalization with different levels of severity, including staying in intensive-care units (ICU) for several weeks or even months.Elderly are the most vulnerable to the disease and reported mortality rates vary from 5 to 15% depending on the geographical location.

1. Introduction

The number of scientific papers related to CoViD19 published since the beginning of the pandemic, the amount of data and tools developed to track the evolution of pandemic. As a matter of fact, scientists are now drowning in publications related to the CoViD19, and some collaborative and community initiatives are trying to use machine learning techniques to facilitate identify and digest the most relevant sources for a given topic. The “R Language and Environment for Statistical Computing” is not exception here. Moreover,promoting and based on the open source and open community principles, R has empowered scientists and researchers since its inception. Not surprisingly then, the R community has contributed to the official CRAN repository already with more than a dozen of packages related to the CoViD19 pandemic since the beginning of the crisis.

Here we will introduce and discuss the covid19.analytics R package.which is mainly designed and focus in an open and modular approach to provide researchers quick access to the latest reported worldwide data of the CoViD19 cases, as well as, analytically and visualization tools to process this data.

This project is related to the Choose Your Own Project Submission Project of the HarvardX: PH125.9x Data Science: Capstone course. For this project we will use different covid19 related datasets to make the latest data from the reported cases of the current CoViD19 pandemic.

2. Aim of the project

The “covid19.analytics” R package allows users to obtain live worldwide data from the novel Coronavirus Disease originally reported in 2019, COVID-19. One of the main goals of this package is to make the latest data about the COVID-19 pandemic promptly available to researchers and the scientific community.

The package also provides basic analysis and visualization tools and functions to investigate datasets and other ones structured in a similar fashion. The covid19.analytics package is an open source tool, which its main implementation and API is the R package.

3. Data Ingestion

For this project the “covid19.analytics” package provides access to the following open-access data sources, One of the main objectives of the covid19.analytics package is to make the latest data from the reported cases of the current CoViD19 pandemic promptly available to researchers and the scientific community In what follows we describe the main functionalities from the package regarding data accessibility. The covid19.data function allows users to obtain realtime data about the CoViD19 reported cases from the JHU’s CCSE repository, in the following modalities.

aggregated data for the latest day, with a great ’granularity’ of geographical regions (ie. cities, provinces, states, countries)

- 2019 Novel CoronaVirus COVID-19 (2019-nCoV) Data Repository by Johns Hopkins University Center for Systems Science and Engineering (JHU CSSE) https://github.com/CSSEGISandData/COVID-19 (https://github.com/CSSEGISandData/COVID-19)

- COVID-19: Status of Cases in Toronto – City of Toronto https://www.toronto.ca/home/covid-19/covid-19-latest-city-of-toronto-news/covid-19-status-of-cases-in-toronto/ (https://www.toronto.ca/home/covid-19/covid-19-latest-city-of-toronto-news/covid-19-status-of-cases-in-toronto/)
- COVID-19: Open Data Toronto https://open.toronto.ca/dataset/covid-19-cases-in-toronto/ (https://open.toronto.ca/dataset/covid-19-cases-in-toronto/)
- COVID-19: Health Canada https://health-infobase.canada.ca/covid-19/ (https://health-infobase.canada.ca/covid-19/)
- Severe acute respiratory syndrome coronavirus 2 isolate Wuhan-Hu-1, complete genome NCBI Reference Sequence: NC_045512.2 https://www.ncbi.nlm.nih.gov/nuccore/NC_045512.2 (https://www.ncbi.nlm.nih.gov/nuccore/NC_045512.2)
- COVID-19 Vaccination and Testing records from “Our World In Data” (OWID) https://github.com/owid/ (https://github.com/owid/)
- Pandemics historical records from Visual Capitalist (and sources within) https://www.visualcapitalist.com/history-of-pandemics-deadliest/ (https://www.visualcapitalist.com/history-of-pandemics-deadliest/) https://www.visualcapitalist.com/the-race-to-save-lives-comparing-vaccine-development-timelines/ (https://www.visualcapitalist.com/the-race-to-save-lives-comparing-vaccine-development-timelines/)
- a backup data repository hosted at GitHub, https://github.com/mponce0/covid19analytics.datasets (https://github.com/mponce0/covid19analytics.datasets) – where replicas of the live datasets are stored for redundancy and robust accesibility sake.

  Overview of the Main Functions from the “covid19.analytics” Package Function

  covid19.data —-> obtain live* worldwide data for COVID-19 virus, from the JHU’s CCSE repository

  covid19.Toronto.data ——> obtain live* data for COVID-19 cases in the city of Toronto, ON Canada, from the City of Toronto reports–or–Open Data Toronto

  covid19.US.data ———> obtain live* US specific data for COVID-19 virus, from the JHU’s CCSE repository

  covid19.vaccination ——> obtain up-to-date COVID-19 vaccination records from

  covid19.testing.data ——> obtain up-to-date COVID-19 testing records from

  pandemics.data ———> obtain pandemics and pandemics vaccination *historical* records from

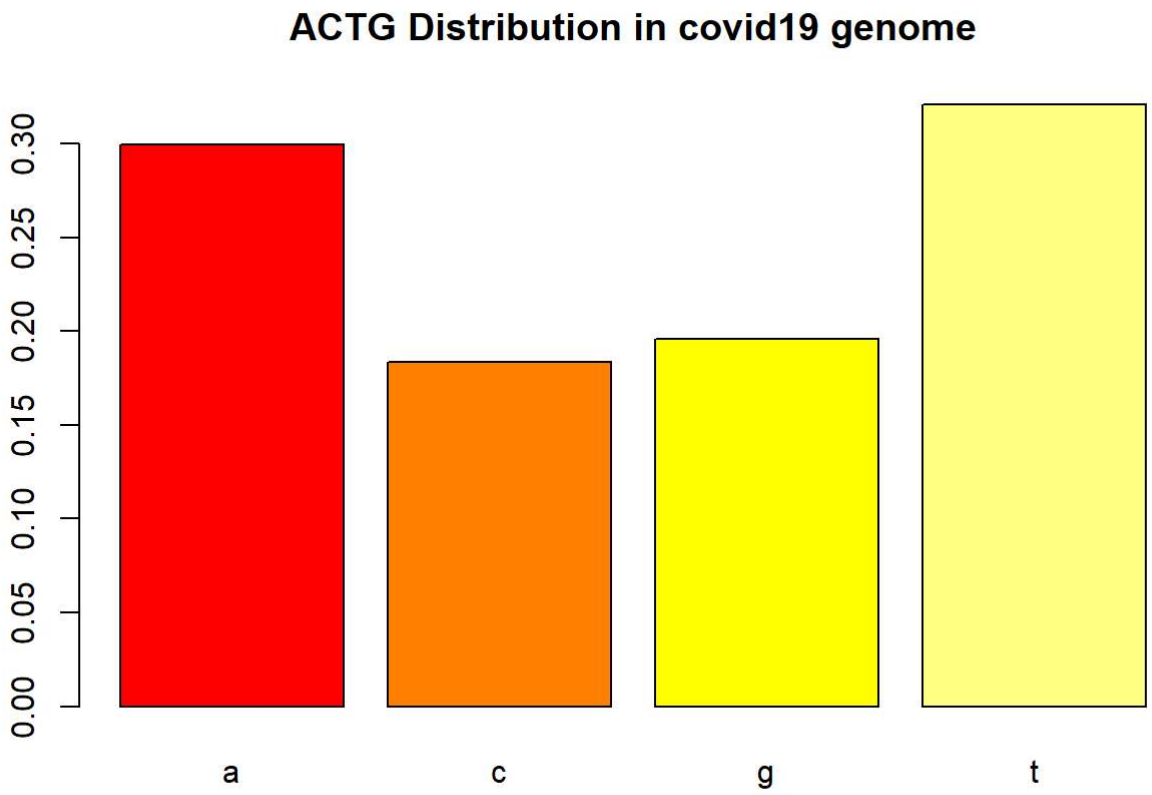
  covid19.genomic.data ————> obtain covid19’s genomic sequencing data from NCBI c19.refGenome.data c19.fasta.data c19.ptree.data c19.NPs.data c19.NP_fasta.data

```r
# First run below to load "covid19.analytics"
# install.packages("covid19.analytics")
# install.packages("devtools")
# devtools::install_github("mponce0/covid19.analytics")

library(covid19.analytics)

# obtain covid19's genomic data
covid19.gen.seq <- covid19.genomic.data()
```

```
## Loading required package: ape
```

```
## Retrieving data from NCBI...
```

```
## 29903-none-character
```



4. Genomics Data

Similarly to the rapid developments and updates in the reported cases of the disease, the genetic sequencing of the virus is moving almost at equal pace. That's why the covid19.analytics package provides access to a good number of the genomics data currently available. The covid19.genomic.data() function allows users to obtain the COVID-19's genomics data from NCBI's databases.

Although the package attempts to provide the latest available genomic data, there are a few important details and differences with respect to the reported cases data. For starting, the amount of genomic information available is way larger than the data reporting the number of cases which adds some additional constraints when retrieving this data. In addition to that, the hosting servers for the genomic databases impose certain limits on the rate and amounts of downloads.

In order to mitigate these factors, the covid19.analytics package employs a couple of different strategies as summarized below:

most of the data will be attempted to be retrieved live from NCBI databases – same as using src='livedata' if that is not possible, the package keeps a local version of some of the largest datasets (i.e. genomes, nucleotides and proteins) which might not be up-to-date – same as using src='repo'. the package will attempt to obtain the data from a mirror server with the datasets updated on a regular basis but not necessarily with the latest updates – same as using src='local'.

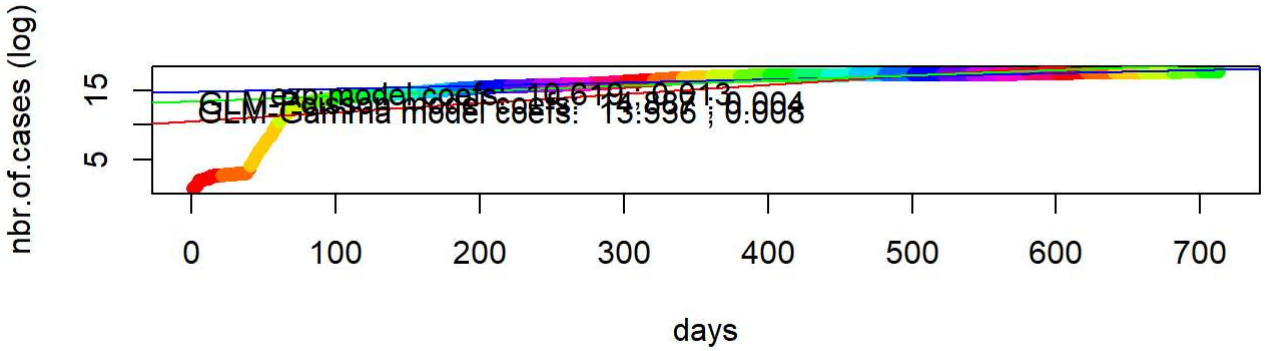
Methods and Analysis

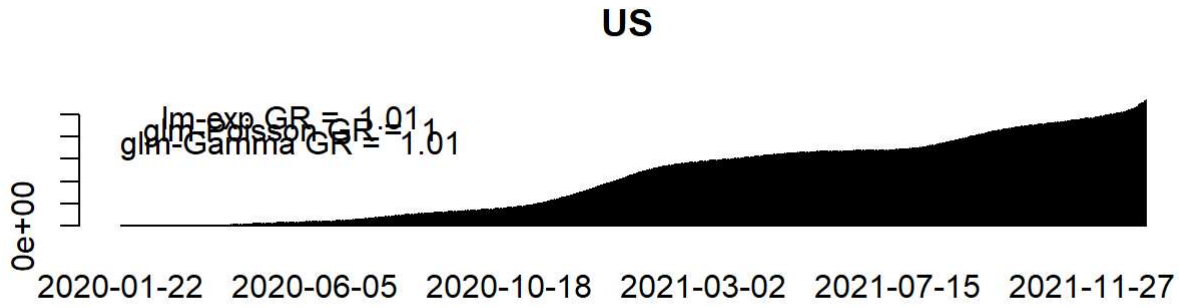
The report.summary() generates an overall report summarizing the different datasets. It can summarize the "Time Series" data (cases.to.process="TS"), the "aggregated" data (cases.to.process="AGG") or both (cases.to.process="ALL"). It will display the top 10 entries in each category, or the number indicated in the Nentries argument, for displaying all the records set Nentries=0.

1. Total per country (US) - Reports

The below figures show the total number of cases for United States (US) one the upper plot in log-scale with a linear fit to an exponential law and in linear scale in the bottom panel. Details about the models are included in the plot, in particular the growth rate which in several cases appears to be around 1.01+ which means the dispersion of the virus has reache its exponential growth.

```
covid19.confirmed.cases <- covid19.data("ts-confirmed")

# total for confirmed cases for "US"
tots.per.location(covid19.confirmed.cases,geo.loc="US")
```





2. Time Series - Confirmed US death and US Confirmed Growth Rate Cases - Reports

The function can also target specific geographical location(s) using the geo.loc argument. When a geographical location is indicated, the report will include an additional “Rel.Perc” column for the confirmed cases indicating the relative percentage among the locations indicated. Similarly the totals displayed at the end of the report will be for the selected locations.

In each case (“TS” or/and “AGG”) will present tables ordered by the different cases included, i.e. confirmed infected, deaths, recovered and active cases.

The dates when the report is generated and the date of the recorded data will be included at the beginning of each table.

It will also compute the totals, averages, standard deviations and percentages of various quantities:

it will determine the number of unique locations processed within the dataset

it will compute the total number of cases per case

Percentages: percentages are computed as follow:

for the “Confirmed” cases, as the ratio between the corresponding number of cases and the total number of cases, i.e. a sort of “global percentage” indicating the percentage of infected cases wrt the rest of the world

for “Confirmed” cases, when geographical locations are specified, a “Relative percentage” is given as the ratio of the confirmed cases over the total of the selected locations

for the other categories, “Deaths”/“Recovered”/“Active”, the percentage of a given category is computed as the ratio between the number of cases in the corresponding category divided by the “Confirmed” number of cases, i.e. a relative percentage with respect to the number of confirmed infected cases in the given region

For “Time Series” data:

it will show the delta (change or variation) in the last day, daily changes day before that (t-2), three days ago (t-3), a week ago (t-7), two weeks ago (t-14) and a month ago (t-30) when possible, it will also display the percentage of “Recovered” and “Deaths” with respect to the “Confirmed” number of cases The column “GlobalPerc” is computed as the ratio between the number of cases for a given country over the total of cases reported The “Global Perc. Average (SD: standard deviation)” is computed as the average (standard deviation) of the number of cases among all the records in the data The “Global Perc. Average (SD: standard deviation) in top X” is computed as the average (standard deviation) of the number of cases among the top X records Typical structure of a summary.report() output for the Time Series data:

```
# retrieve US time series data of total death cases
 US.deaths.cases <- covid19.data("ts-deaths-US")
```

```
## ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
## ------------------------------------------------------------------------------
```

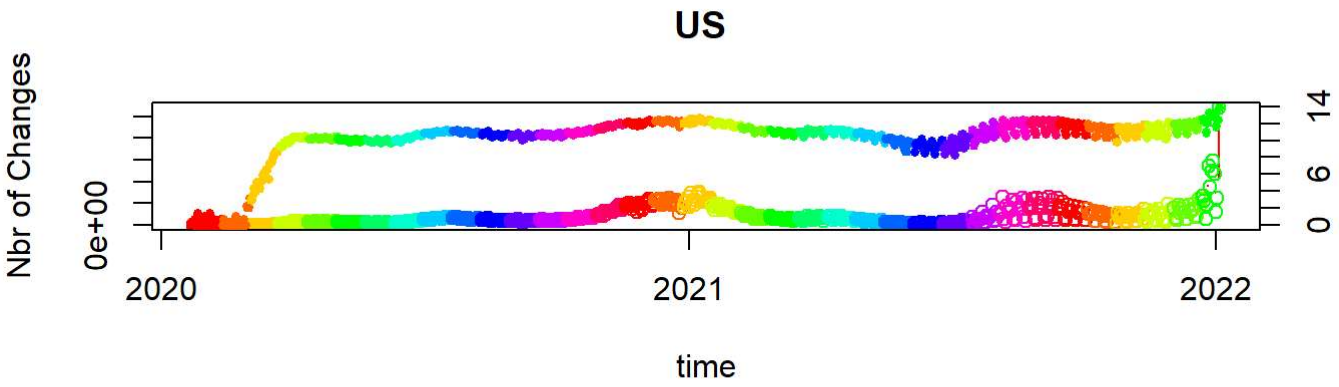
The below figures show on the upper panel the number of changes on a daily basis in linear scale (thin line, left y-axis) and log scale (thicker line, right y-axis), while the bottom panel displays the growth rate for the US.

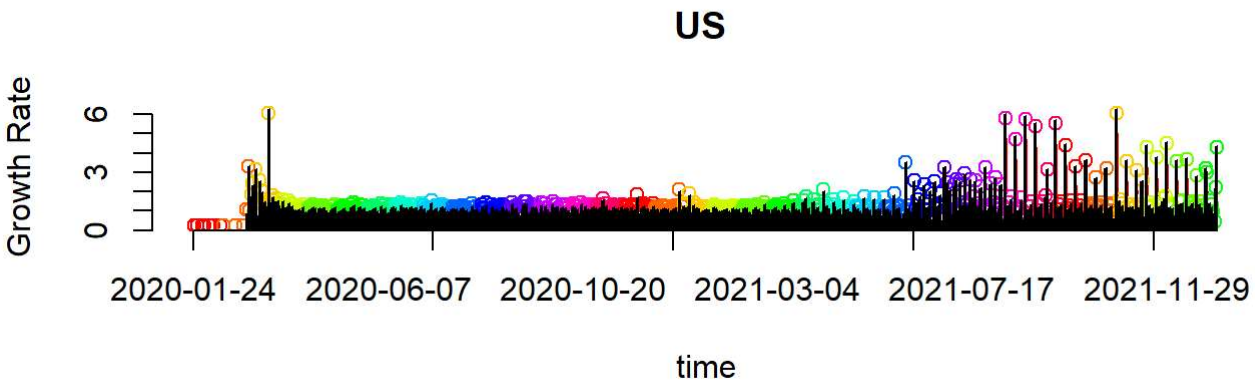
```
# read time series data for confirmed cases
TS.data <- covid19.data("ts-confirmed")
```

```
## ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
## --------------------------------------------------------------------------------
```

```
# compute changes and growth rates per location for US
growth.rate(TS.data,geo.loc=c("US"))
```

```
## Processing...  US
```





```
## $Changes
##   geo.loc 2020-01-23 2020-01-24 2020-01-25 2020-01-26 2020-01-27 2020-01-28
## 1      US          0          1          0          3          0          0
##   2020-01-29 2020-01-30 2020-01-31 2020-02-01 2020-02-02 2020-02-03 2020-02-04
## 1          1          0          2          0          0          3          0
##   2020-02-05 2020-02-06 2020-02-07 2020-02-08 2020-02-09 2020-02-10 2020-02-11
## 1          0          1          0          0          0          0          1
##   2020-02-12 2020-02-13 2020-02-14 2020-02-15 2020-02-16 2020-02-17 2020-02-18
## 1          0          1          0          0          0          0          0
##   2020-02-19 2020-02-20 2020-02-21 2020-02-22 2020-02-23 2020-02-24 2020-02-25
## 1          0          0          2          0          0          0          0
##   2020-02-26 2020-02-27 2020-02-28 2020-02-29 2020-03-01 2020-03-02 2020-03-03
## 1          0          1          0          8          7         23         19
##   2020-03-04 2020-03-05 2020-03-06 2020-03-07 2020-03-08 2020-03-09 2020-03-10
## 1         33         77         53        166        116         75        188
##   2020-03-11 2020-03-12 2020-03-13 2020-03-14 2020-03-15 2020-03-16 2020-03-17
## 1        365        439        633        759        234       1467       1833
##   2020-03-18 2020-03-19 2020-03-20 2020-03-21 2020-03-22 2020-03-23 2020-03-24
## 1       2657       4494       6367       5995       8919      11152      10618
##   2020-03-25 2020-03-26 2020-03-27 2020-03-28 2020-03-29 2020-03-30 2020-03-31
## 1      12127      17821      18591      22164      16127      22154      26381
##   2020-04-01 2020-04-02 2020-04-03 2020-04-04 2020-04-05 2020-04-06 2020-04-07
## 1      32232      32230      32482      32176      29604      31858      30343
##   2020-04-08 2020-04-09 2020-04-10 2020-04-11 2020-04-12 2020-04-13 2020-04-14
## 1      31149      36443      34347      29278      26872      26924      28395
##   2020-04-15 2020-04-16 2020-04-17 2020-04-18 2020-04-19 2020-04-20 2020-04-21
## 1      25900      29956      33157      27994      25923      29680      26170
##   2020-04-22 2020-04-23 2020-04-24 2020-04-25 2020-04-26 2020-04-27 2020-04-28
## 1      29419      32768      32152      30994      26547      23750      24690
##   2020-04-29 2020-04-30 2020-05-01 2020-05-02 2020-05-03 2020-05-04 2020-05-05
## 1      26220      29242      35021      27824      24492      23713      24329
##   2020-05-06 2020-05-07 2020-05-08 2020-05-09 2020-05-10 2020-05-11 2020-05-12
## 1      24263      27657      27273      24446      19148      19034      22843
##   2020-05-13 2020-05-14 2020-05-15 2020-05-16 2020-05-17 2020-05-18 2020-05-19
## 1      20576      26532      24821      24233      18798      22134      20761
##   2020-05-20 2020-05-21 2020-05-22 2020-05-23 2020-05-24 2020-05-25 2020-05-26
## 1      22723      25806      23619      20979      20591      18653      18576
##   2020-05-27 2020-05-28 2020-05-29 2020-05-30 2020-05-31 2020-06-01 2020-06-02
## 1      19407      21646      24735      24084      19454      16965      21283
```

```
##   2020-06-03 2020-06-04 2020-06-05 2020-06-06 2020-06-07 2020-06-08 2020-06-09
## 1      19771      21723      25001      21298      18413      16504      18092
##   2020-06-10 2020-06-11 2020-06-12 2020-06-13 2020-06-14 2020-06-15 2020-06-16
## 1      21068      22383      25326      24972      19420      18522      23839
##   2020-06-17 2020-06-18 2020-06-19 2020-06-20 2020-06-21 2020-06-22 2020-06-23
## 1      27389      28315      31697      32613      26189      30973      37222
##   2020-06-24 2020-06-25 2020-06-26 2020-06-27 2020-06-28 2020-06-29 2020-06-30
## 1      36232      40369      46210      41737      41862      39642      48312
##   2020-07-01 2020-07-02 2020-07-03 2020-07-04 2020-07-05 2020-07-06 2020-07-07
## 1      51567      56348      52620      48946      50438      42801      58857
##   2020-07-08 2020-07-09 2020-07-10 2020-07-11 2020-07-12 2020-07-13 2020-07-14
## 1      59723      60875      67778      61371      60684      57560      66439
##   2020-07-15 2020-07-16 2020-07-17 2020-07-18 2020-07-19 2020-07-20 2020-07-21
## 1      67966      76039      72251      63797      61449      60212      65582
##   2020-07-22 2020-07-23 2020-07-24 2020-07-25 2020-07-26 2020-07-27 2020-07-28
## 1      70385      68257      74149      66999      56156      56170      63694
##   2020-07-29 2020-07-30 2020-07-31 2020-08-01 2020-08-02 2020-08-03 2020-08-04
## 1      68375      67966      68468      59132      46006      45284      54974
##   2020-08-05 2020-08-06 2020-08-07 2020-08-08 2020-08-09 2020-08-10 2020-08-11
## 1      55883      57231      61063      55176      48137      45221      52600
##   2020-08-12 2020-08-13 2020-08-14 2020-08-15 2020-08-16 2020-08-17 2020-08-18
## 1      52802      51529      65073      49656      40104      35662      42905
##   2020-08-19 2020-08-20 2020-08-21 2020-08-22 2020-08-23 2020-08-24 2020-08-25
## 1      44263      44589      48789      44404      34566      34881      40927
##   2020-08-26 2020-08-27 2020-08-28 2020-08-29 2020-08-30 2020-08-31 2020-09-01
## 1      43956      45988      46535      44241      34928      32614      42943
##   2020-09-02 2020-09-03 2020-09-04 2020-09-05 2020-09-06 2020-09-07 2020-09-08
## 1      40642      44353      50689      43509      31050      23898      25689
##   2020-09-09 2020-09-10 2020-09-11 2020-09-12 2020-09-13 2020-09-14 2020-09-15
## 1      34537      35898      48020      41688      34533      33167      39543
##   2020-09-16 2020-09-17 2020-09-18 2020-09-19 2020-09-20 2020-09-21 2020-09-22
## 1      38874      45251      49222      42739      38917      50594      40161
##   2020-09-23 2020-09-24 2020-09-25 2020-09-26 2020-09-27 2020-09-28 2020-09-29
## 1      38852      47475      48548      44930      38154      32449      43514
##   2020-09-30 2020-10-01 2020-10-02 2020-10-03 2020-10-04 2020-10-05 2020-10-06
## 1      39079      46096      55130      50659      34632      38231      45219
##   2020-10-07 2020-10-08 2020-10-09 2020-10-10 2020-10-11 2020-10-12 2020-10-13
## 1      51217      58915      56750      55740      46832      41732      51091
##   2020-10-14 2020-10-15 2020-10-16 2020-10-17 2020-10-18 2020-10-19 2020-10-20
```

```
## 1      59302      65114      69122      57692      50990      66739      61697
##   2020-10-21 2020-10-22 2020-10-23 2020-10-24 2020-10-25 2020-10-26 2020-10-27
## 1      63321      76225      82478      83728      62667      65976      77161
##   2020-10-28 2020-10-29 2020-10-30 2020-10-31 2020-11-01 2020-11-02 2020-11-03
## 1      79268      91219     100091      90736     105645      83333     127834
##   2020-11-04 2020-11-05 2020-11-06 2020-11-07 2020-11-08 2020-11-09 2020-11-10
## 1     104175     130016     127812     132124     115355     118046     140271
##   2020-11-11 2020-11-12 2020-11-13 2020-11-14 2020-11-15 2020-11-16 2020-11-17
## 1     149488     161766     181126     172284     137913     159178     164163
##   2020-11-18 2020-11-19 2020-11-20 2020-11-21 2020-11-22 2020-11-23 2020-11-24
## 1     173413     191899     201436     182034     146647     171946     177235
##   2020-11-25 2020-11-26 2020-11-27 2020-11-28 2020-11-29 2020-11-30 2020-12-01
## 1     184893     118386     203021     158756     140840     155690     194035
##   2020-12-02 2020-12-03 2020-12-04 2020-12-05 2020-12-06 2020-12-07 2020-12-08
## 1     204501     224156     235313     221907     179217     190149     230948
##   2020-12-09 2020-12-10 2020-12-11 2020-12-12 2020-12-13 2020-12-14 2020-12-15
## 1     221135     234673     240256     222163     186699     200627     222046
##   2020-12-16 2020-12-17 2020-12-18 2020-12-19 2020-12-20 2020-12-21 2020-12-22
## 1     240685     237223     248954     202570     185344     189716     201963
##   2020-12-23 2020-12-24 2020-12-25 2020-12-26 2020-12-27 2020-12-28 2020-12-29
## 1     225778     204883     108685     218991     154991     166683     201693
##   2020-12-30 2020-12-31 2021-01-01 2021-01-02 2021-01-03 2021-01-04 2021-01-05
## 1     222936     258109     166257     295875     203648     181645     231242
##   2021-01-06 2021-01-07 2021-01-08 2021-01-09 2021-01-10 2021-01-11 2021-01-12
## 1     256866     288608     303459     259530     213373     210834     218900
##   2021-01-13 2021-01-14 2021-01-15 2021-01-16 2021-01-17 2021-01-18 2021-01-19
## 1     229840     238040     247026     208632     176592     141080     164285
##   2021-01-20 2021-01-21 2021-01-22 2021-01-23 2021-01-24 2021-01-25 2021-01-26
## 1     185390     192326     189527     174863     137834     142117     144780
##   2021-01-27 2021-01-28 2021-01-29 2021-01-30 2021-01-31 2021-02-01 2021-02-02
## 1     155135     167435     165847     145683     115429     129367     113872
##   2021-02-03 2021-02-04 2021-02-05 2021-02-06 2021-02-07 2021-02-08 2021-02-09
## 1     123111     123925     131659     110953      91883      85008      94595
##   2021-02-10 2021-02-11 2021-02-12 2021-02-13 2021-02-14 2021-02-15 2021-02-16
## 1      95832     106303     100029      88854      66349      54643      58604
##   2021-02-17 2021-02-18 2021-02-19 2021-02-20 2021-02-21 2021-02-22 2021-02-23
## 1      70068      71356      78185      73407      57896      54837      72013
##   2021-02-24 2021-02-25 2021-02-26 2021-02-27 2021-02-28 2021-03-01 2021-03-02
## 1      75011      78057      78734      66065      51867      54488      57066
```

```
##   2021-03-03 2021-03-04 2021-03-05 2021-03-06 2021-03-07 2021-03-08 2021-03-09
## 1      67149      68532      66865      59295      42066      44313      55806
##   2021-03-10 2021-03-11 2021-03-12 2021-03-13 2021-03-14 2021-03-15 2021-03-16
## 1      58233      62896      62073      53592      38852      54767      54381
##   2021-03-17 2021-03-18 2021-03-19 2021-03-20 2021-03-21 2021-03-22 2021-03-23
## 1      59488      60525      62065      57021      34978      49480      53298
##   2021-03-24 2021-03-25 2021-03-26 2021-03-27 2021-03-28 2021-03-29 2021-03-30
## 1      87120      67976      77536      62223      46354      67297      61437
##   2021-03-31 2021-04-01 2021-04-02 2021-04-03 2021-04-04 2021-04-05 2021-04-06
## 1      66971      79186      71849      64246      36649      73153      61143
##   2021-04-07 2021-04-08 2021-04-09 2021-04-10 2021-04-11 2021-04-12 2021-04-13
## 1      74986      80252      84337      69294      46443      66957      79144
##   2021-04-14 2021-04-15 2021-04-16 2021-04-17 2021-04-18 2021-04-19 2021-04-20
## 1      75316      73910      80377      54161      42882      66174      60920
##   2021-04-21 2021-04-22 2021-04-23 2021-04-24 2021-04-25 2021-04-26 2021-04-27
## 1      63824      66990      62379      54193      33974      45660      50733
##   2021-04-28 2021-04-29 2021-04-30 2021-05-01 2021-05-02 2021-05-03 2021-05-04
## 1      55093      58913      58159      46660      30062      48771      40799
##   2021-05-05 2021-05-06 2021-05-07 2021-05-08 2021-05-09 2021-05-10 2021-05-11
## 1      45704      46955      48106      34519      22100      35152      34061
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##   2021-05-27 2021-05-28 2021-05-29 2021-05-30 2021-05-31 2021-06-01 2021-06-02
## 1   1.106632  0.8075067  0.5755599  0.5687114  0.8515886   3.517591  0.7999163
##   2021-06-03 2021-06-04 2021-06-05 2021-06-06 2021-06-07 2021-06-08 2021-06-09
## 1   1.111021  0.8968802  0.8523987   0.398836   2.545751  0.8821229   1.451647
```

```
##   2021-06-10 2021-06-11 2021-06-12 2021-06-13 2021-06-14 2021-06-15 2021-06-16
## 1  0.7564379   1.728906  0.3529033   0.600639   2.307371  0.8974148   1.153853
##   2021-06-17 2021-06-18 2021-06-19 2021-06-20 2021-06-21 2021-06-22 2021-06-23
## 1   0.844637   2.011202  0.4063187   0.528165    2.47241   0.958451   1.211045
##   2021-06-24 2021-06-25 2021-06-26 2021-06-27 2021-06-28 2021-06-29 2021-06-30
## 1   1.038304   1.781218  0.3645778  0.4939134   3.264948  0.4741036   2.406457
##   2021-07-01 2021-07-02 2021-07-03 2021-07-04 2021-07-05 2021-07-06 2021-07-07
## 1  0.8807817   2.043472  0.1667518  0.7960808   2.284359   2.589965  0.9808876
##   2021-07-08 2021-07-09 2021-07-10 2021-07-11 2021-07-12 2021-07-13 2021-07-14
## 1  0.8407193   2.495848  0.1849192   1.292986     2.9107  0.7984932    1.25683
##   2021-07-15 2021-07-16 2021-07-17 2021-07-18 2021-07-19 2021-07-20 2021-07-21
## 1  0.9016853   2.590578  0.1599659   1.629417   2.544788   0.789403   1.246863
##   2021-07-22 2021-07-23 2021-07-24 2021-07-25 2021-07-26 2021-07-27 2021-07-28
## 1   1.080678   2.184121  0.2186943   1.001034   3.255375  0.8078483   1.010183
##   2021-07-29 2021-07-30 2021-07-31 2021-08-01 2021-08-02 2021-08-03 2021-08-04
## 1   1.141866   2.371938  0.1819526   1.281122   2.685926  0.8764342  0.9367351
##   2021-08-05 2021-08-06 2021-08-07 2021-08-08 2021-08-09 2021-08-10 2021-08-11
## 1   1.147416    2.30157  0.2016201  0.5696967   5.998534  0.6890808   1.289151
##   2021-08-12 2021-08-13 2021-08-14 2021-08-15 2021-08-16 2021-08-17 2021-08-18
## 1  0.9100142   1.616398  0.2254935   0.855795    4.84207  0.7115565   1.037999
##   2021-08-19 2021-08-20 2021-08-21 2021-08-22 2021-08-23 2021-08-24 2021-08-25
## 1  0.9912437     1.5625  0.2845828   0.557925   5.932195  0.6790012   1.078319
##   2021-08-26 2021-08-27 2021-08-28 2021-08-29 2021-08-30 2021-08-31 2021-09-01
## 1   1.088613   1.320591  0.2681553  0.6973835   5.532436   0.679653   1.180846
##   2021-09-02 2021-09-03 2021-09-04 2021-09-05 2021-09-06 2021-09-07 2021-09-08
## 1  0.8656633   1.345608  0.3145467  0.6387558   1.702736   3.161305  0.7183377
##   2021-09-09 2021-09-10 2021-09-11 2021-09-12 2021-09-13 2021-09-14 2021-09-15
## 1   0.874819   1.425246  0.3226297  0.5827346   5.699243  0.5978505   1.166872
##   2021-09-16 2021-09-17 2021-09-18 2021-09-19 2021-09-20 2021-09-21 2021-09-22
## 1  0.9116511    1.34312  0.3077549  0.6564979   4.464562  0.6457176   1.094313
##   2021-09-23 2021-09-24 2021-09-25 2021-09-26 2021-09-27 2021-09-28 2021-09-29
## 1  0.9499823    1.39877   0.305413  0.9185638   3.317872  0.6763934   1.108099
##   2021-09-30 2021-10-01 2021-10-02 2021-10-03 2021-10-04 2021-10-05 2021-10-06
## 1  0.8909163   1.390347  0.2942692  0.9286683   3.620781  0.6437472   1.135676
##   2021-10-07 2021-10-08 2021-10-09 2021-10-10 2021-10-11 2021-10-12 2021-10-13
## 1  0.9091698   1.257902  0.2596361   1.145837   2.674702   1.056975     1.1429
##   2021-10-14 2021-10-15 2021-10-16 2021-10-17 2021-10-18 2021-10-19 2021-10-20
## 1  0.7104856   1.271111  0.3311687  0.8781937   3.200551  0.7920548   1.129812
##   2021-10-21 2021-10-22 2021-10-23 2021-10-24 2021-10-25 2021-10-26 2021-10-27
```

```
## 1   0.862699   1.205998  0.3167669  0.6046581   6.271715  0.6011356   1.468484
##   2021-10-28 2021-10-29 2021-10-30 2021-10-31 2021-11-01 2021-11-02 2021-11-03
## 1   0.768595   1.206739  0.3480472  0.9732285   3.595678  0.6239264   1.189266
##   2021-11-04 2021-11-05 2021-11-06 2021-11-07 2021-11-08 2021-11-09 2021-11-10
## 1  0.9675207   1.174227  0.3544496   1.053967   3.081263  0.7262149   1.182986
##   2021-11-11 2021-11-12 2021-11-13 2021-11-14 2021-11-15 2021-11-16 2021-11-17
## 1  0.6015933   2.534795  0.2936942  0.7306373   4.401216  0.6419213   1.271922
##   2021-11-18 2021-11-19 2021-11-20 2021-11-21 2021-11-22 2021-11-23 2021-11-24
## 1  0.9876311   1.140616  0.3472078  0.8908288   3.794046   0.627747   1.204116
##   2021-11-25 2021-11-26 2021-11-27 2021-11-28 2021-11-29 2021-11-30 2021-12-01
## 1  0.3117387   1.496624   0.489403   1.653317   4.574191  0.6093842   1.179819
##   2021-12-02 2021-12-03 2021-12-04 2021-12-05 2021-12-06 2021-12-07 2021-12-08
## 1  0.9987663   1.109932  0.4140467  0.7827638   3.610088  0.6302159   1.331568
##   2021-12-09 2021-12-10 2021-12-11 2021-12-12 2021-12-13 2021-12-14 2021-12-15
## 1  0.8100509   1.397041  0.3207429  0.9233972   3.703627   0.619756   1.241456
##   2021-12-16 2021-12-17 2021-12-18 2021-12-19 2021-12-20 2021-12-21 2021-12-22
## 1   0.983414   1.361281  0.3962043   1.136467   2.787115  0.7393323   1.350309
##   2021-12-23 2021-12-24 2021-12-25 2021-12-26 2021-12-27 2021-12-28 2021-12-29
## 1   1.114002  0.8151378  0.2599721   3.199881   2.981546  0.6515967   1.401257
##   2021-12-30 2021-12-31 2022-01-01 2022-01-02 2022-01-03 NA
## 1   1.188277  0.8000427  0.2454761   2.143675   4.354021 NA
```

3. Trend - US Confirmed, US Recovered, US Deaths & US Active Cases - Graph

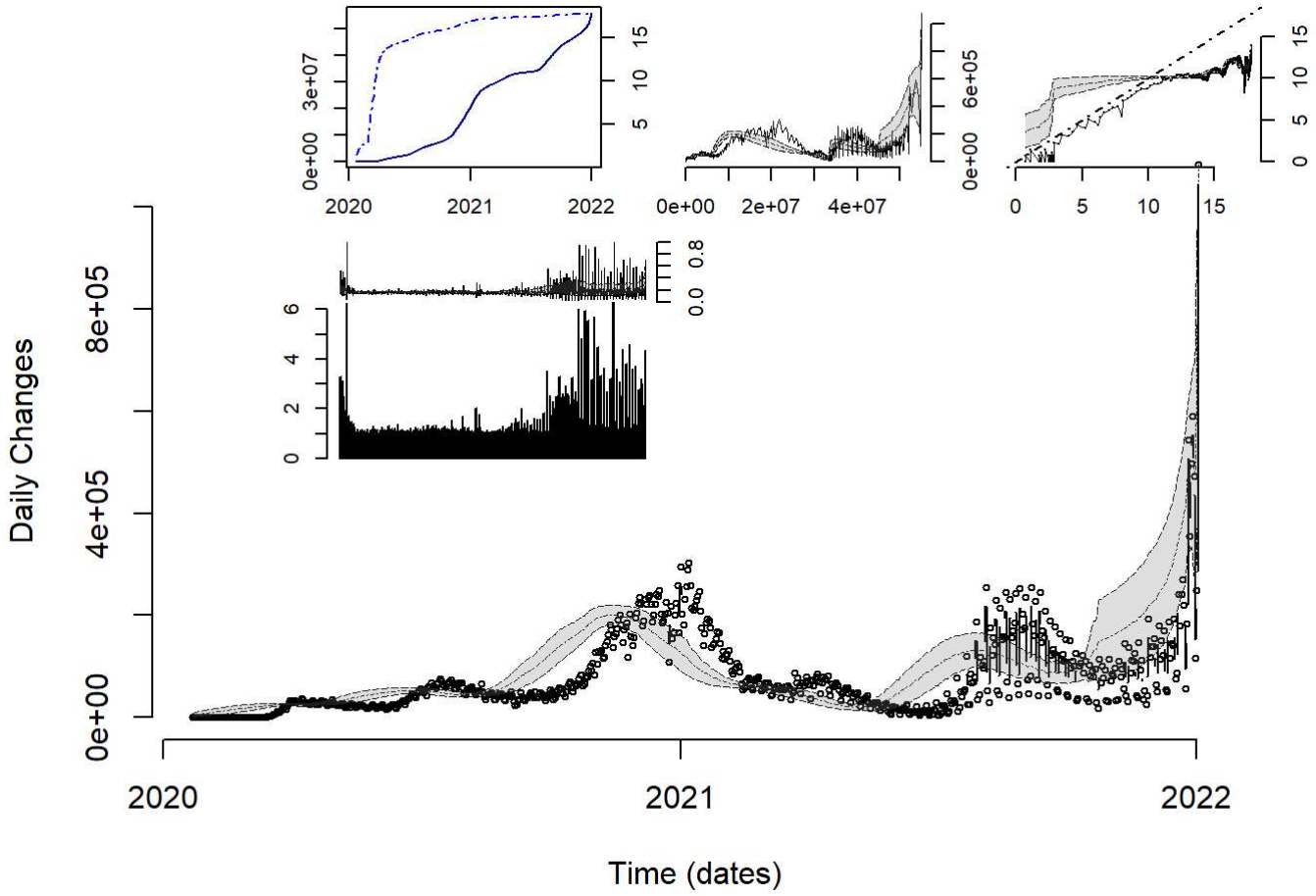
It is possible to estimate the global trends per location employing the functions single.trend, mtrends and itrends. The first two functions generate static plots of different quantities that can be used as indicators, while the third function generates an interactive representation of a normalized a-dimensional trend, below graph show the the single trend for US location on covid confirmed cases over time period.

single.trend graph - compose of static plots: total number of cases vs time, daily changes vs total changes in different representations.

```
ts.data <- covid19.data("ts-confirmed")
```

```
## ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
## ------------------------------------------------------------------------------
```

```
# Single location trend, in this case using the data for US
single.trend(ts.data[ ts.data$Country.Region=="US",])
```



4. Visualization - Interactive & Static Plot

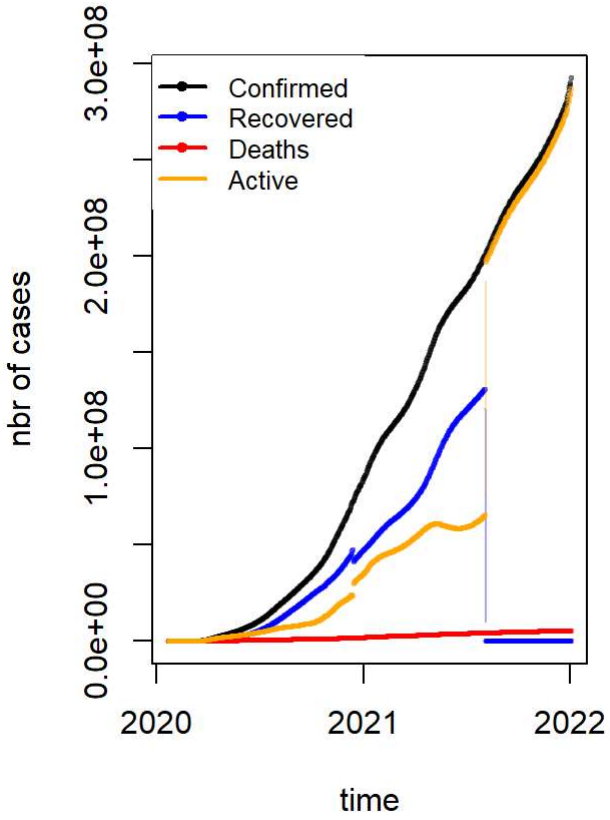
plots in a static and interactive plot total number of cases per day, the user can specify multiple locations or global totals. Plotting Totals. The function totals.plt will generate plots of the total number of cases as a function of time. It can be used for the total data or for a specific or multiple locations. The function can generate static plots and/or interactive ones, as well, as linear and/or semi-log plots.

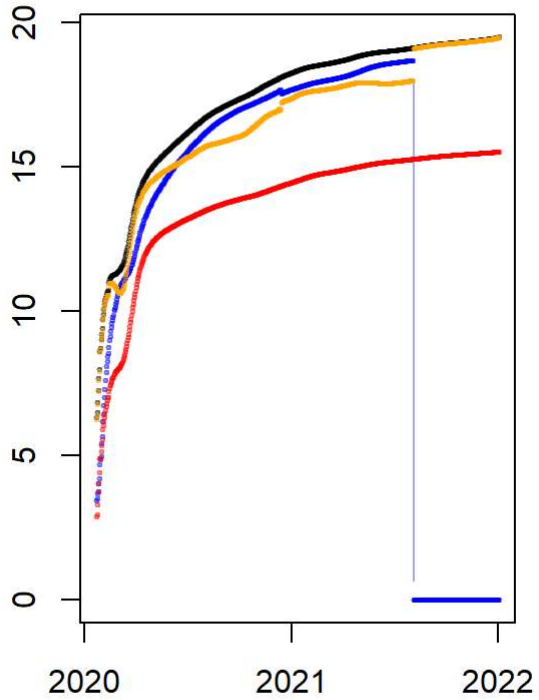
Plotting Cases in the US (United States). The function live.map will display the different cases in each corresponding location all around the US (United States) in an interactive map of the world. It can be used with time series data of the US. In particular the live.map function is an utility function which allows to plot the location of the recorded cases around the world. This function in particular allows for several customizable features, such as, the type of projection used in the map or to select different types of projection operators in a pull down menu, displaying or not the legend of the regions, specify re scaling factors for the sizes representing the number of cases, among others. The function will generate a live representation of the cases, utilizing the plotly package and ultimately open the map in a browser, where the user can explore the map, drag the representation, zoom in/out, turn on/off legends, etc

```
# retrieve time series data
TS.data <- covid19.data("ts-ALL")
```

```
## ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
## --------------------------------------------------------------------------------
## ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
## --------------------------------------------------------------------------------
## ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
## --------------------------------------------------------------------------------
```

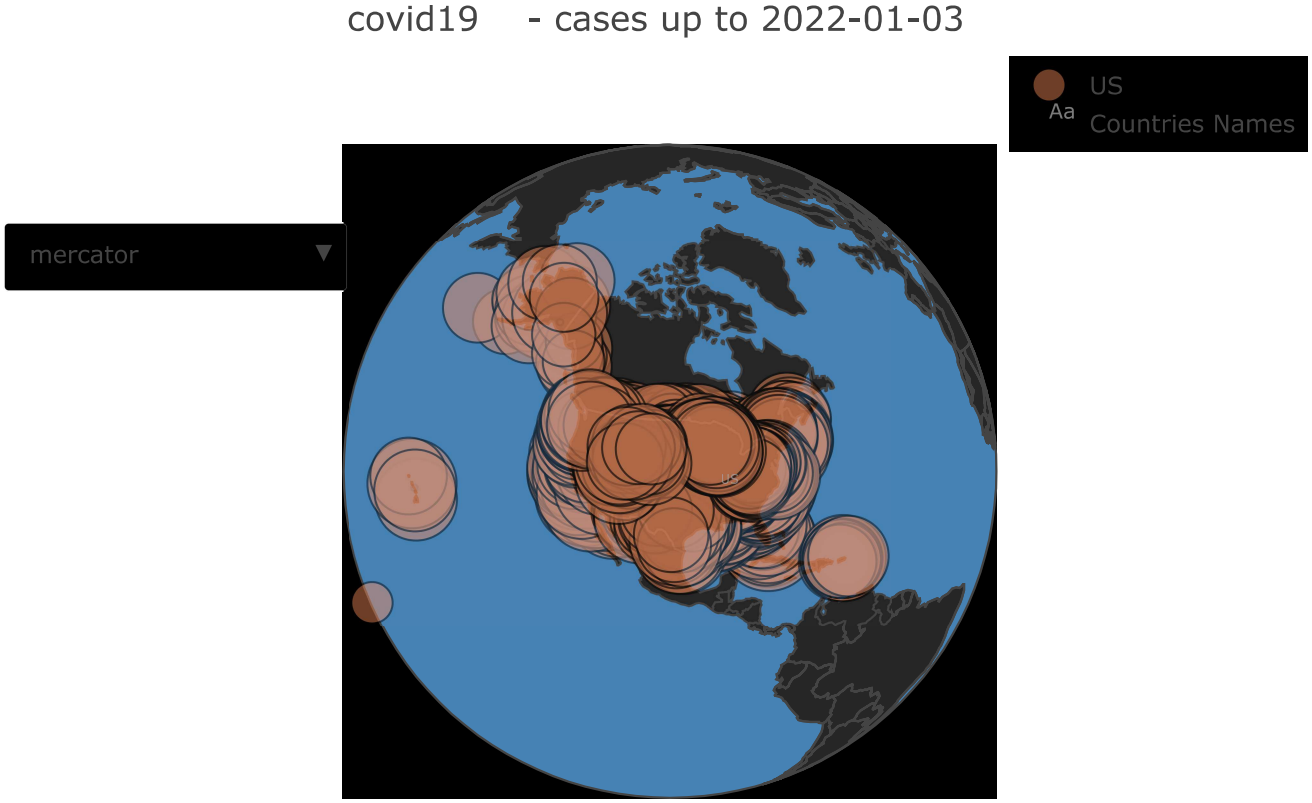
```
# static and interactive plot
totals.plt(TS.data)
```


Confirmed
Recovered
Deaths
Active
nbr of cases
0.0e+00
1.0e+08
2.0e+08
3.0e+08
2020
2021
2022
time


0
5
10
15
20
2020
2021
2022

```
# retrieve interactive map of the time series data of the US confirmed cases datas spatial resolution.
live.map(covid19.data("ts-confirmed-US"))
```

```
## ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
## ----------------------------------------------------------------------------------------
```



Modeling of COVID 19 Virus Spread

1. SIR Model for U.S

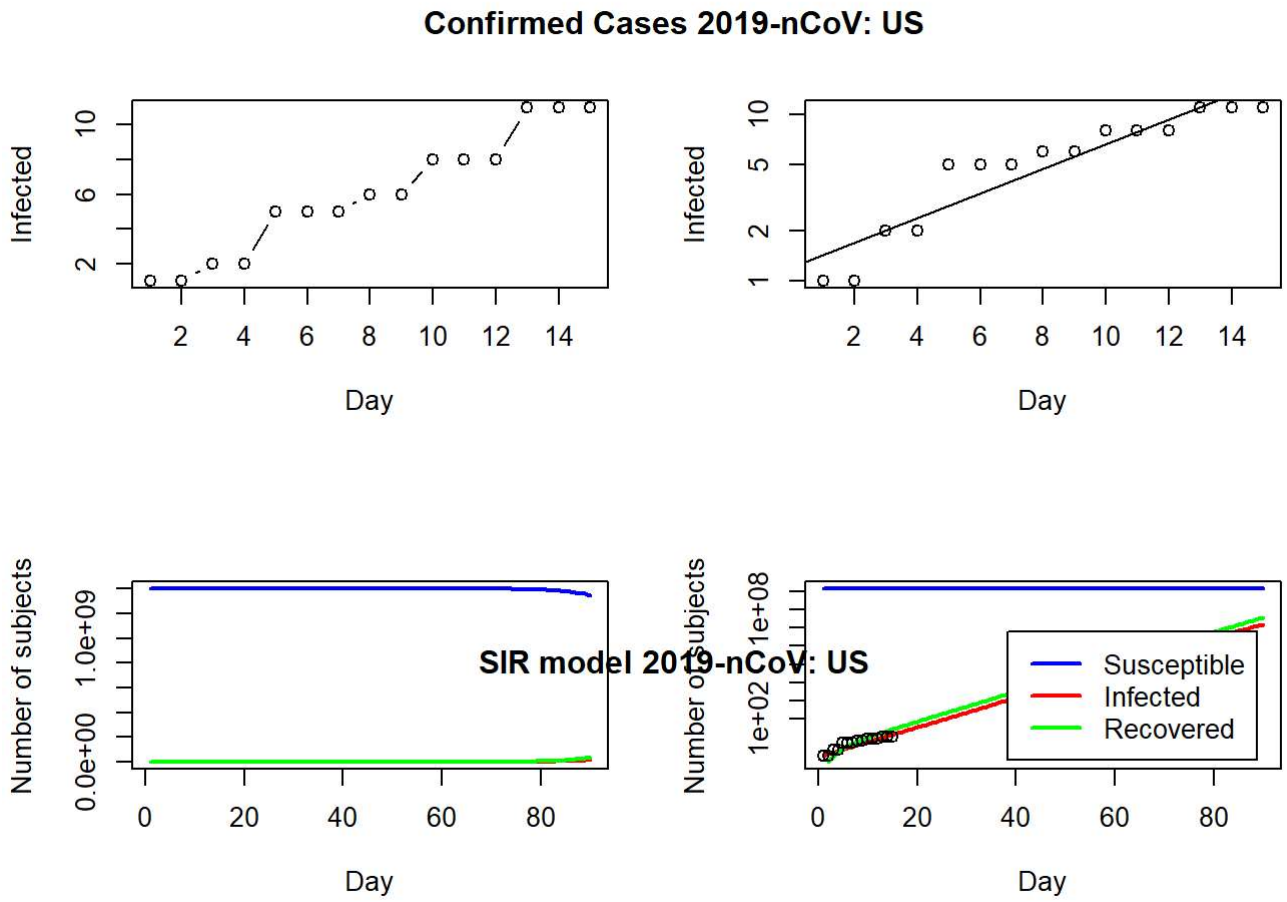
Important features added by the covid19.analytics package, is the ability of model the spread of the virus by incorporating real data. As described in below figure. generate.SIR.model function, implements a simple SIR model employing the data reported from an specified dataset and a particular location. Examples of this are shown in The generate.SIR.model function is complemented with the plt.SIR.model function which can be used to generate static or interactive figures as shown in below.

```
# read time series data for confirmed cases
data <- covid19.data("ts-confirmed")
```

```
## ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
## ------------------------------------------------------------------------------
```

```
# run a SIR model for a US geographical location
generate.SIR.model(data,"US", t0=1,t1=15)
```

```
## ##############################################################################
## ##############################################################################
## Processing...  US
##  [1]  1  1  2  2  5  5  5  6  6  8  8  8 11 11 11
## ------------------------  Parameters used to create model ------------------------
##      Region: US
##      Time interval to consider: t0=1 - t1=15 ; tfinal=90
##          t0: 2020-01-23 -- t1: 2020-02-06
##      Number of days considered for initial guess: 15
##      Fatality rate: 0.02
##      Population of the region: 1.4e+09
## ------------------------------------------------------------------------------
## [1] "CONVERGENCE: REL_REDUCTION_OF_F <= FACTR*EPSMCH"
##      beta     gamma
## 0.5937806 0.4062194
##   R0 = 1.46172359241922
##   Max nbr of infected: 15725188.9  ( 1.12 %)
##   Max nbr of casualties, assuming  2% fatality rate: 314503.78
##   Max reached at day : 90 ==>  2020-04-22
## ==============================================================================
```


Confirmed Cases 2019-nCoV: US
Infected
Day
Infected
Day
SIR model 2019-nCoV: US
Number of subjects
Day
Number of subjects
Susceptible
Infected
Recovered
Day

```
## $Infected
##  [1]  1  1  2  2  5  5  5  6  6  8  8  8 11 11 11
##
## $model
##    time          S            I            R
## 1     1 1399999999 1.000000e+00 0.000000e+00
## 2     2 1399999998 1.206304e+00 4.468132e-01
## 3     3 1399999998 1.455169e+00 9.858052e-01
## 4     4 1399999997 1.755377e+00 1.635994e+00
## 5     5 1399999995 2.117518e+00 2.420319e+00
## 6     6 1399999994 2.554371e+00 3.366453e+00
## 7     7 1399999992 3.081348e+00 4.507779e+00
## 8     8 1399999990 3.717043e+00 5.884565e+00
## 9     9 1399999988 4.483885e+00 7.545390e+00
## 10   10 1399999985 5.408927e+00 9.548845e+00
## 11   11 1399999982 6.524810e+00 1.196562e+01
## 12   12 1399999977 7.870905e+00 1.488099e+01
## 13   13 1399999972 9.494704e+00 1.839781e+01
## 14   14 1399999966 1.145350e+01 2.264017e+01
## 15   15 1399999958 1.381640e+01 2.775774e+01
## 16   16 1399999949 1.666678e+01 3.393109e+01
## 17   17 1399999939 2.010521e+01 4.137802e+01
## 18   18 1399999925 2.425299e+01 5.036128e+01
## 19   19 1399999910 2.925648e+01 6.119783e+01
## 20   20 1399999890 3.529221e+01 7.427000e+01
## 21   21 1399999867 4.257313e+01 9.003901e+01
## 22   22 1399999840 5.135614e+01 1.090612e+02
## 23   23 1399999806 6.195111e+01 1.320078e+02
## 24   24 1399999766 7.473187e+01 1.596884e+02
## 25   25 1399999717 9.014934e+01 1.930795e+02
## 26   26 1399999658 1.087475e+02 2.333594e+02
## 27   27 1399999587 1.311825e+02 2.819492e+02
## 28   28 1399999501 1.582460e+02 3.405632e+02
## 29   29 1399999398 1.908927e+02 4.112695e+02
## 30   30 1399999273 2.302746e+02 4.965629e+02
## 31   31 1399999123 2.777811e+02 5.994525e+02
## 32   32 1399998941 3.350883e+02 7.235686e+02
## 33   33 1399998722 4.042182e+02 8.732904e+02
## 34   34 1399998458 4.876097e+02 1.053900e+03
```

```
## 35   35 1399998140 5.882052e+02 1.271770e+03
## 36   36 1399997756 7.095536e+02 1.534588e+03
## 37   37 1399997292 8.559365e+02 1.851625e+03
## 38   38 1399996733 1.032518e+03 2.234069e+03
## 39   39 1399996059 1.245529e+03 2.695411e+03
## 40   40 1399995246 1.502484e+03 3.251929e+03
## 41   41 1399994264 1.812449e+03 3.923257e+03
## 42   42 1399993081 2.186358e+03 4.733082e+03
## 43   43 1399991653 2.637404e+03 5.709973e+03
## 44   44 1399989930 3.181499e+03 6.888397e+03
## 45   45 1399987852 3.837837e+03 8.309928e+03
## 46   46 1399985346 4.629572e+03 1.002472e+04
## 47   47 1399982322 5.584634e+03 1.209326e+04
## 48   48 1399978675 6.736710e+03 1.458854e+04
## 49   49 1399974275 8.126440e+03 1.759857e+04
## 50   50 1399968968 9.802840e+03 2.122955e+04
## 51   51 1399962565 1.182503e+04 2.560955e+04
## 52   52 1399954843 1.426434e+04 3.089308e+04
## 53   53 1399945527 1.720677e+04 3.726651e+04
## 54   54 1399934289 2.075606e+04 4.495461e+04
## 55   55 1399920734 2.503735e+04 5.422855e+04
## 56   56 1399904383 3.020155e+04 6.541535e+04
## 57   57 1399884660 3.643062e+04 7.890949e+04
## 58   58 1399860869 4.394404e+04 9.518672e+04
## 59   59 1399832173 5.300643e+04 1.148208e+05
## 60   60 1399797559 6.393687e+04 1.385039e+05
## 61   61 1399755810 7.712002e+04 1.670703e+05
## 62   62 1399705454 9.301959e+04 2.015266e+05
## 63   63 1399644719 1.121945e+05 2.430861e+05
## 64   64 1399571470 1.353182e+05 2.932119e+05
## 65   65 1399483130 1.632023e+05 3.536678e+05
## 66   66 1399376596 1.968241e+05 4.265799e+05
## 67   67 1399248129 2.373607e+05 5.145106e+05
## 68   68 1399093223 2.862288e+05 6.205479e+05
## 69   69 1398906456 3.451329e+05 7.484115e+05
## 70   70 1398681295 4.161229e+05 9.025820e+05
## 71   71 1398409884 5.016621e+05 1.088454e+06
## 72   72 1398082772 6.047084e+05 1.312520e+06
## 73   73 1397688599 7.288102e+05 1.582591e+06
```

```
## 74   74 1397213724 8.782195e+05 1.908057e+06
## 75   75 1396641774 1.058024e+06 2.300202e+06
## 76   76 1395953128 1.274302e+06 2.772570e+06
## 77   77 1395124294 1.534298e+06 3.341408e+06
## 78   78 1394127199 1.846628e+06 4.026173e+06
## 79   79 1392928354 2.221505e+06 4.850141e+06
## 80   80 1391487903 2.670993e+06 5.841103e+06
## 81   81 1389758550 3.209277e+06 7.032173e+06
## 82   82 1387684358 3.852940e+06 8.462702e+06
## 83   83 1385199446 4.621240e+06 1.017931e+07
## 84   84 1382226610 5.536348e+06 1.223704e+07
## 85   85 1378675935 6.623521e+06 1.470054e+07
## 86   86 1374443478 7.911146e+06 1.764538e+07
## 87   87 1369410177 9.430580e+06 2.115924e+07
## 88   88 1363441187 1.121570e+07 2.534311e+07
## 89   89 1356385898 1.330201e+07 3.031209e+07
## 90   90 1348079006 1.572519e+07 3.619580e+07
##
## $params
## $params$beta
##      beta
## 0.5937806
##
## $params$gamma
##     gamma
## 0.4062194
##
## $params$R0
##       R0
## 1.461724
```

2. SweepSIR Model for U.S

Below shows an example of the generation of a sequence of values for R0, and actually any of the parameteres (β, γ) describing the SIR model. In this case, the function takes a range of values for the initial date t0 and generates different date intervals, this allows the function to generate multiple SIR models and return the corresponding parameters for each model.

```
# read TimeSeries data
TS.data <- covid19.data("TS-confirmed")
```

```
## ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
## ------------------------------------------------------------------------------
```

```
# select a location of interest, eg. US
US.data <- TS.data[ (TS.data$Country.Region == "US") & (TS.data$Province.State == ""),]

# sweep values of R0 based on range of dates to consider for the model
ranges <- 15:25
deltaT <- 35
params_sweep <- sweep.SIR.models(data=US.data,geo.loc="US", t0_range=ranges, deltaT=deltaT)
```

```
## ################################################################################
## ################################################################################
## Processing...  US
##  [1]   11   12   12   12   12   12   13   13   14   14   14   14   14   14   14
## [16]   14   16   16   16   16   16   16   17   17   25   32   55   74  107  184
## [31]  237  403  519  594  782 1147
## ------------------------  Parameters used to create model -----------------------
##      Region: US
##      Time interval to consider: t0=15 - t1= ; tfinal=90
##          t0: 2020-02-06 -- t1:
##      Number of days considered for initial guess: 36
##      Fatality rate: 0.02
##      Population of the region: 1.4e+09
## --------------------------------------------------------------------------------
## [1] "CONVERGENCE: REL_REDUCTION_OF_F <= FACTR*EPSMCH"
##      beta     gamma
## 0.5601095 0.4398905
##   R0 = 1.27329296259747
##   Max nbr of infected: 484001.13  ( 0.03 %)
##   Max nbr of casualties, assuming  2% fatality rate: 9680.02
##   Max reached at day : 90 ==>  2020-05-06
## ================================================================================
## ################################################################################
## ################################################################################
## Processing...  US
##  [1]   12   12   12   12   12   13   13   14   14   14   14   14   14   14   14
## [16]   16   16   16   16   16   16   17   17   25   32   55   74  107  184  237
## [31]  403  519  594  782 1147 1586
## ------------------------  Parameters used to create model -----------------------
##      Region: US
##      Time interval to consider: t0=16 - t1= ; tfinal=90
##          t0: 2020-02-07 -- t1:
##      Number of days considered for initial guess: 36
##      Fatality rate: 0.02
##      Population of the region: 1.4e+09
## --------------------------------------------------------------------------------
## [1] "CONVERGENCE: REL_REDUCTION_OF_F <= FACTR*EPSMCH"
##      beta     gamma
## 0.5638631 0.4361369
```

```
##   R0 = 1.29285801363221
##   Max nbr of infected: 1022905.12  ( 0.07 %)
##   Max nbr of casualties, assuming  2% fatality rate: 20458.1
##   Max reached at day : 90 ==>  2020-05-07
## ================================================================================
## ################################################################################
## ################################################################################
## Processing...  US
##  [1]   12   12   12   12   13   13   14   14   14   14   14   14   14   14   16
## [16]   16   16   16   16   16   17   17   25   32   55   74  107  184  237  403
## [31]  519  594  782 1147 1586 2219
## ------------------------  Parameters used to create model -----------------------
##      Region: US
##      Time interval to consider: t0=17 - t1= ; tfinal=90
##          t0: 2020-02-08 -- t1:
##      Number of days considered for initial guess: 36
##      Fatality rate: 0.02
##      Population of the region: 1.4e+09
## --------------------------------------------------------------------------------
## [1] "CONVERGENCE: REL_REDUCTION_OF_F <= FACTR*EPSMCH"
##      beta     gamma
## 0.5690889 0.4309110
##   R0 = 1.32066457358112
##   Max nbr of infected: 2548921.83  ( 0.18 %)
##   Max nbr of casualties, assuming  2% fatality rate: 50978.44
##   Max reached at day : 90 ==>  2020-05-08
## ================================================================================
## ################################################################################
## ################################################################################
## Processing...  US
##  [1]   12   12   12   13   13   14   14   14   14   14   14   14   14   16   16
## [16]   16   16   16   16   17   17   25   32   55   74  107  184  237  403  519
## [31]  594  782 1147 1586 2219 2978
## ------------------------  Parameters used to create model -----------------------
##      Region: US
##      Time interval to consider: t0=18 - t1= ; tfinal=90
##          t0: 2020-02-09 -- t1:
##      Number of days considered for initial guess: 36
##      Fatality rate: 0.02
```

```
##      Population of the region: 1.4e+09
## ------------------------------------------------------------------------
## [1] "CONVERGENCE: REL_REDUCTION_OF_F <= FACTR*EPSMCH"
##      beta     gamma
## 0.5740815 0.4259185
##   R0 = 1.34786685652538
##   Max nbr of infected: 5981873.5  ( 0.43 %)
##   Max nbr of casualties, assuming  2% fatality rate: 119637.47
##   Max reached at day : 90 ==>  2020-05-09
## ========================================================================
## ########################################################################
## ########################################################################
## Processing...  US
##  [1]   12   12   13   13   14   14   14   14   14   14   14   14   16   16   16
## [16]   16   16   16   17   17   25   32   55   74  107  184  237  403  519  594
## [31]  782 1147 1586 2219 2978 3212
## -----------------------  Parameters used to create model -----------------------
##      Region: US
##      Time interval to consider: t0=19 - t1= ; tfinal=90
##          t0: 2020-02-10 -- t1:
##      Number of days considered for initial guess: 36
##      Fatality rate: 0.02
##      Population of the region: 1.4e+09
## ------------------------------------------------------------------------
## [1] "CONVERGENCE: REL_REDUCTION_OF_F <= FACTR*EPSMCH"
##      beta     gamma
## 0.5776621 0.4223379
##   R0 = 1.367772142714
##   Max nbr of infected: 10783375.04  ( 0.77 %)
##   Max nbr of casualties, assuming  2% fatality rate: 215667.5
##   Max reached at day : 90 ==>  2020-05-10
## ========================================================================
## ########################################################################
## ########################################################################
## Processing...  US
##  [1]   12   13   13   14   14   14   14   14   14   14   14   16   16   16   16
## [16]   16   16   17   17   25   32   55   74  107  184  237  403  519  594  782
## [31] 1147 1586 2219 2978 3212 4679
## -----------------------  Parameters used to create model -----------------------
```

```
##      Region: US
##      Time interval to consider: t0=20 - t1= ; tfinal=90
##          t0: 2020-02-11 -- t1:
##      Number of days considered for initial guess: 36
##      Fatality rate: 0.02
##      Population of the region: 1.4e+09
## ------------------------------------------------------------------------------
## [1] "CONVERGENCE: REL_REDUCTION_OF_F <= FACTR*EPSMCH"
##      beta     gamma
## 0.5820347 0.4179653
##   R0 = 1.39254285135887
##   Max nbr of infected: 21135888.33  ( 1.51 %)
##   Max nbr of casualties, assuming  2% fatality rate: 422717.77
##   Max reached at day : 90 ==>  2020-05-11
## ==============================================================================
## ##############################################################################
## ##############################################################################
## Processing...  US
##  [1]   13   13   14   14   14   14   14   14   14   14   16   16   16   16   16
## [16]   16   17   17   25   32   55   74  107  184  237  403  519  594  782 1147
## [31] 1586 2219 2978 3212 4679 6512
## ----------------------  Parameters used to create model -----------------------
##      Region: US
##      Time interval to consider: t0=21 - t1= ; tfinal=90
##          t0: 2020-02-12 -- t1:
##      Number of days considered for initial guess: 36
##      Fatality rate: 0.02
##      Population of the region: 1.4e+09
## ------------------------------------------------------------------------------
## [1] "CONVERGENCE: REL_REDUCTION_OF_F <= FACTR*EPSMCH"
##      beta     gamma
## 0.5854415 0.4145585
##   R0 = 1.41220492300581
##   Max nbr of infected: 35563067.55  ( 2.54 %)
##   Max nbr of casualties, assuming  2% fatality rate: 711261.35
##   Max reached at day : 90 ==>  2020-05-12
## ==============================================================================
## ##############################################################################
## ##############################################################################
```

```
## Processing...  US
##  [1]   13   14   14   14   14   14   14   14   14   16   16   16   16   16   16
## [16]   17   17   25   32   55   74  107  184  237  403  519  594  782 1147 1586
## [31] 2219 2978 3212 4679 6512 9169
## ------------------------  Parameters used to create model -----------------------
##      Region: US
##      Time interval to consider: t0=22 - t1= ; tfinal=90
##          t0: 2020-02-13 -- t1:
##      Number of days considered for initial guess: 36
##      Fatality rate: 0.02
##      Population of the region: 1.4e+09
## ------------------------------------------------------------------------------
## [1] "CONVERGENCE: REL_REDUCTION_OF_F <= FACTR*EPSMCH"
##      beta     gamma
## 0.5903441 0.4096559
##   R0 = 1.44107283884622
##   Max nbr of infected: 59516799.05  ( 4.25 %)
##   Max nbr of casualties, assuming  2% fatality rate: 1190335.98
##   Max reached at day : 90 ==>  2020-05-13
## ==============================================================================
## ##############################################################################
## ##############################################################################
## Processing...  US
##  [1]    14    14    14    14    14    14    14    14    16    16    16    16
## [13]    16    16    17    17    25    32    55    74   107   184   237   403
## [25]   519   594   782  1147  1586  2219  2978  3212  4679  6512  9169 13663
## ------------------------  Parameters used to create model -----------------------
##      Region: US
##      Time interval to consider: t0=23 - t1= ; tfinal=90
##          t0: 2020-02-14 -- t1:
##      Number of days considered for initial guess: 36
##      Fatality rate: 0.02
##      Population of the region: 1.4e+09
## ------------------------------------------------------------------------------
## [1] "CONVERGENCE: REL_REDUCTION_OF_F <= FACTR*EPSMCH"
##      beta     gamma
## 0.1892631 0.0000000
##   R0 = Inf
##   Max nbr of infected: 239855996.09  ( 17.13 %)
```

```
##   Max nbr of casualties, assuming  2% fatality rate: 4797119.92
##   Max reached at day : 90 ==>  2020-05-14
## ================================================================================
## ################################################################################
## ################################################################################
## Processing...  US
##  [1]    14    14    14    14    14    14    14    16    16    16    16    16
## [13]    16    17    17    25    32    55    74   107   184   237   403   519
## [25]   594   782  1147  1586  2219  2978  3212  4679  6512  9169 13663 20030
## ------------------------  Parameters used to create model -----------------------
##      Region: US
##      Time interval to consider: t0=24 - t1= ; tfinal=90
##          t0: 2020-02-15 -- t1:
##      Number of days considered for initial guess: 36
##      Fatality rate: 0.02
##      Population of the region: 1.4e+09
## --------------------------------------------------------------------------------
## [1] "CONVERGENCE: REL_REDUCTION_OF_F <= FACTR*EPSMCH"
##      beta     gamma
## 0.6002458 0.3997542
##   R0 = 1.50153713788751
##   Max nbr of infected: 88620088.01  ( 6.33 %)
##   Max nbr of casualties, assuming  2% fatality rate: 1772401.76
##   Max reached at day : 87 ==>  2020-05-12
## ================================================================================
## ################################################################################
## ################################################################################
## Processing...  US
##  [1]    14    14    14    14    14    14    16    16    16    16    16    16
## [13]    17    17    25    32    55    74   107   184   237   403   519   594
## [25]   782  1147  1586  2219  2978  3212  4679  6512  9169 13663 20030 26025
## ------------------------  Parameters used to create model -----------------------
##      Region: US
##      Time interval to consider: t0=25 - t1= ; tfinal=90
##          t0: 2020-02-16 -- t1:
##      Number of days considered for initial guess: 36
##      Fatality rate: 0.02
##      Population of the region: 1.4e+09
## --------------------------------------------------------------------------------
```

```
## [1] "CONVERGENCE: REL_REDUCTION_OF_F <= FACTR*EPSMCH"
##      beta     gamma
## 0.2103038 0.0000000
##   R0 = Inf
##   Max nbr of infected: 802973960.93  ( 57.36 %)
##   Max nbr of casualties, assuming  2% fatality rate: 16059479.22
##   Max reached at day : 90 ==>  2020-05-16
## ================================================================================
```

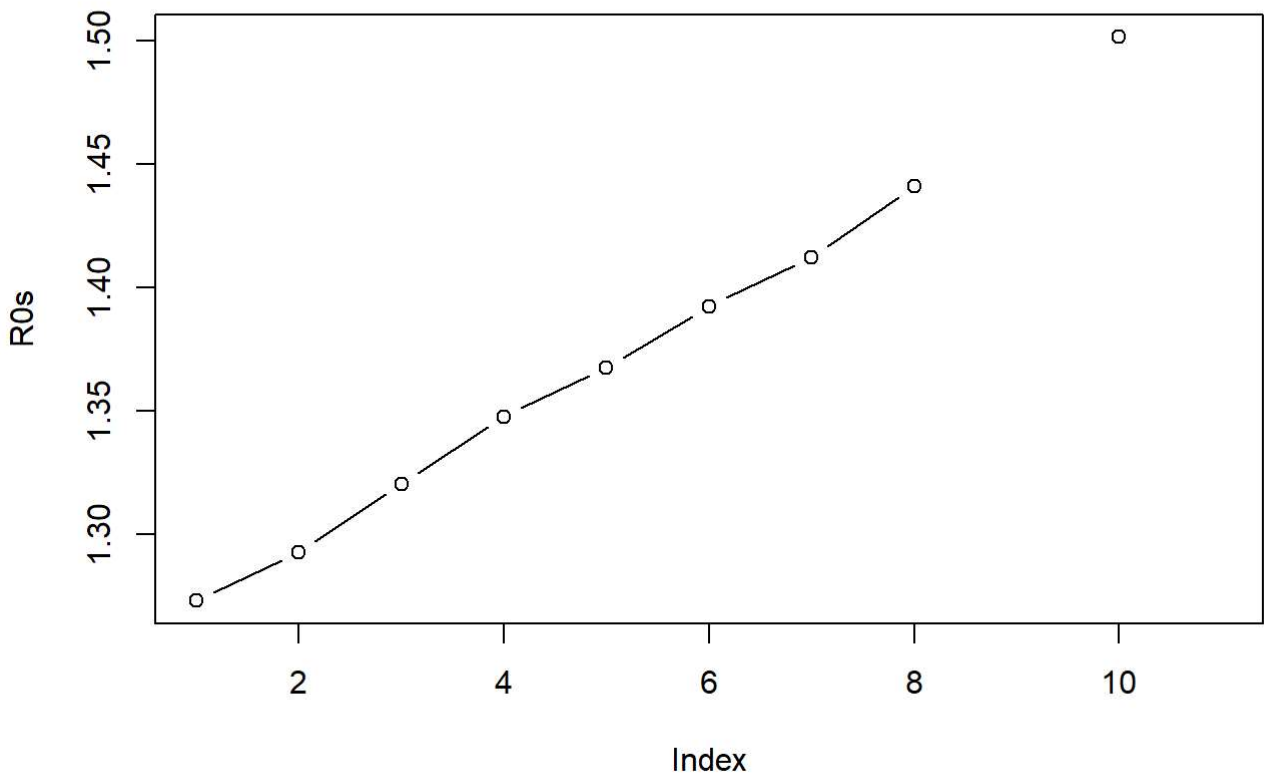
```
# the parameters --beta,gamma,R0-- are returned in a "matrix" "array" object
print(params_sweep)
```

```
##       [,1]      [,2]      [,3]      [,4]      [,5]      [,6]      [,7]
## beta  0.5601095 0.5638631 0.5690889 0.5740815 0.5776621 0.5820347 0.5854415
## gamma 0.4398905 0.4361369 0.430911  0.4259185 0.4223379 0.4179653 0.4145585
## R0    1.273293  1.292858  1.320665  1.347867  1.367772  1.392543  1.412205
##       [,8]      [,9]      [,10]     [,11]
## beta  0.5903441 0.1892631 0.6002458 0.2103038
## gamma 0.4096559 0         0.3997542 0
## R0    1.441073  Inf       1.501537  Inf
```

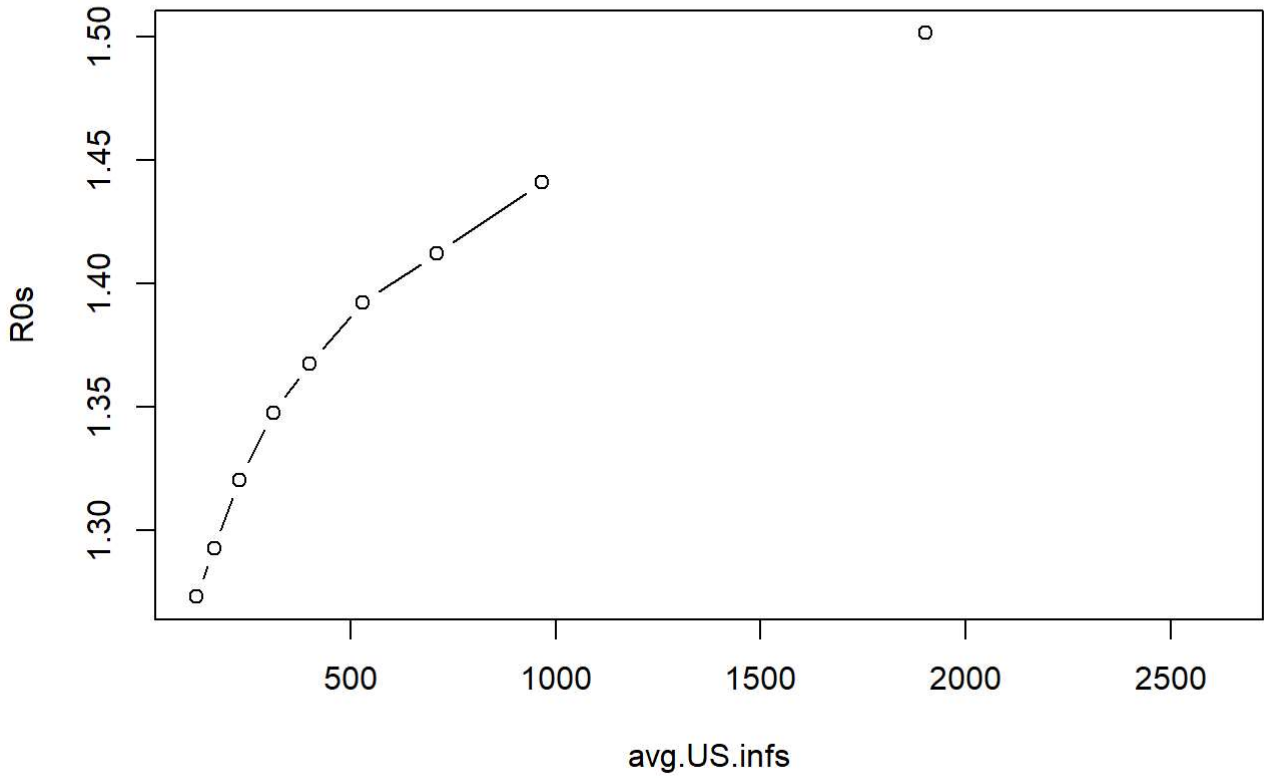
```
#       [,1]      [,2]      [,3]      [,4]      [,5]      [,6]      [,7]
# beta  0.5231031 0.5250777 0.5323438 0.5217565 0.5355503 0.5473388 0.559132
# gamma 0.4768969 0.4749223 0.4676562 0.4782435 0.4644497 0.4526611 0.440868
# R0    1.096889  1.105608  1.138323  1.090985  1.153086  1.209158  1.268253
#       [,8]      [,9]      [,10]     [,11]
# beta  0.5668948 0.5753911 0.5835743 0.592407
# gamma 0.4331052 0.4246089 0.4164257 0.407593
# R0    1.308908  1.355108  1.401389  1.453428

# obtain the R0 values from the parameters
R0s <- unlist(params_sweep["R0",])
# nbr of infected cases
US.infs<- preProcessingData(US.data,"US")
```

```
## Processing...  US
```

```r
# average per range
# define ranges
lst.ranges <- lapply(ranges, function(x) x:(x+deltaT))

# compute averages
avg.US.infs <- lapply(lst.ranges, function(x) mean(US.infs[x]))

# plots
plot(R0s, type='b')
```



```
# plot vs average number of infected cases
plot(avg.US.infs, R0s, type='b')
```



Results

1. SIR Model for U.S: The generate.SIR.model function will attempt to obtain proper values for the parameters β and γ, by inferring the onset of the epidemic using the actual data. This is also listed in the output of the function, and it can be controlled by setting the parameters t0 and t1 or deltaT, which are used to specify the range of dates to be considered for using when determining the values of β and γ. The fatality rate (constant) can also be indicated via the fatality.rate argument, as well, as the total population of the region with tot.population.

2. SweepSIR Model for U.S: The results are then bundle in a “matrix”/“array” object which can be accessed by column for each model or by row for each parameter sets.

Conclusion

The “covid19.analytics” R package allows users to obtain live* worldwide data from the novel Coronavirus Disease originally reported in 2019, COVID-19. One of the main goals of this package is to make the latest data about the COVID-19 pandemic promptly available to researchers and the scientific community. The “covid19.analytics” package also provides basic analysis tools and functions to investigate these datasets, which are being used and demonstrated in above project work with its description and several usages.

Reference: Ponce et al., (2021). covid19.analytics: An R Package to Obtain, Analyze and Visualize Data from the 2019 Coronavirus Disease Pandemic. Journal of Open Source Software, 6(59), 2995. https://doi.org/10.21105/joss.02995 (https://doi.org/10.21105/joss.02995)