COVID-19 Data Analysis with R - Worldwide*

Yanchang Zhao
yanchang@RDataMining.com
http://RDataMining.com

25 May 2020

Contents

1 Introduction

This is an analysis report of the Novel Coronavirus (COVID-19) around the world, to demonstrate data processing and visualisation with R, *tidyverse* and *ggplot2*. This report will be updated from time to time, with new data and more analysis. Please find its latest version at http://www.rdatamining.com/docs/Coronavirus-data-analysis-world.pdf.

A similar COVID-19 analysis report for China is available at http://www.rdatamining.com/docs/Coronavirus-data-analysis-china.pdf, if you are particually interested what has happened in China.

1.1 Data Source

The data source used for this analysis is *the 2019 Novel Coronavirus COVID-19 (2019-nCoV) Data Repository*[1] built by the Center for Systems Science and Engineering, Johns Hopkins University.

1.2 R Packages

Blow is a list of R packages used for this analysis. Package *magrittr* is for pipe operations like `%>%` and `%<>%` and *lubridate* for date operations. Package *tidyverse* is a collection of R packages for data science, including *dplyr* and *tidyr* for data processing and *ggplot2* for graphics. Package *gridExtra* is for arranging multiple grid-based plots on a page and *kableExtra* works together with `kable()` from *knitr* to build complex HTML or LaTeX tables.

```
library(magrittr) # pipe operations
library(lubridate) # date operations
library(tidyverse) # ggplot2, tidyr, dplyr...
library(gridExtra) # multiple grid-based plots on a page
library(ggforce) # accelerating ggplot2
library(kableExtra) # complex tables
library(leaflet) # map
```

2 Loading Data

At first, the datasets, which are three CSV files, are downloaded and saved as local files and then are loaded into R.

```
## source data files
filenames <- c('time_series_covid19_confirmed_global.csv',
               'time_series_covid19_deaths_global.csv',
               'time_series_covid19_recovered_global.csv')
url.path <- paste0('https://raw.githubusercontent.com/CSSEGISandData/COVID-19/',
                   'master/csse_covid_19_data/csse_covid_19_time_series/')

## download files to local
download <- function(filename) {
  url <- file.path(url.path, filename)
  dest <- file.path('./data', filename)
  download.file(url, dest)
}
bin <- lapply(filenames, download)

## load data into R
raw.data.confirmed <- read.csv('./data/time_series_covid19_confirmed_global.csv')
raw.data.deaths <- read.csv('./data/time_series_covid19_deaths_global.csv')
```

[1] https://github.com/CSSEGISandData/COVID-19

```
raw.data.recovered <- read.csv('./data/time_series_covid19_recovered_global.csv')

dim(raw.data.confirmed)
```

```
## [1] 266 128
```

Each dataset has 266 rows, corresponding to country/region/province/state. It has 128 columns. Starting from column 5, each column corresponds to a single day. Here we have a look at the first 10 rows and the first 10 columns.

```
raw.data.confirmed[1:10, 1:10] %>%
  kable('latex', booktabs=T, caption='Raw Data (Confirmed, First 10 Columns only)') %>%
  kable_styling(font_size=5, latex_options = c('striped', 'hold_position', 'repeat_header'))
```

Table 1: Raw Data (Confirmed, First 10 Columns only)

Province.State	Country.Region	Lat	Long	X1.22.20	X1.23.20	X1.24.20	X1.25.20	X1.26.20	X1.27.20
	Afghanistan	33.0000	65.0000	0	0	0	0	0	0
	Albania	41.1533	20.1683	0	0	0	0	0	0
	Algeria	28.0339	1.6596	0	0	0	0	0	0
	Andorra	42.5063	1.5218	0	0	0	0	0	0
	Angola	-11.2027	17.8739	0	0	0	0	0	0
	Antigua and Barbuda	17.0608	-61.7964	0	0	0	0	0	0
	Argentina	-38.4161	-63.6167	0	0	0	0	0	0
	Armenia	40.0691	45.0382	0	0	0	0	0	0
Australian Capital Territory	Australia	-35.4735	149.0124	0	0	0	0	0	0
New South Wales	Australia	-33.8688	151.2093	0	0	0	0	3	4

Below we check the time frame of the data.

```
n.col <- ncol(raw.data.confirmed)
## get dates from column names
dates <- names(raw.data.confirmed)[5:n.col] %>% substr(2,8) %>% mdy()
range(dates)
```

```
## [1] "2020-01-22" "2020-05-24"
```

```
min.date <- min(dates)
max.date <- max(dates)
min.date.txt <- min.date %>% format('%d %b %Y')
max.date.txt <- max.date %>% format('%d %b %Y') %>% paste('UTC')
```

It shows that the data was last updated on 24 May 2020 UTC and all the stats and charts in this report are based on that data.

3 Data Preparation

3.1 Data Cleaning

The three datesets are converted from wide to long format and then are aggregated by country. After that, they are merged into one single dataset.

```
## data cleaning and transformation
cleanData <- function(data) {
  ## remove some columns
  data %<>% select(-c(Province.State, Lat, Long)) %>% rename(country=Country.Region)
  ## convert from wide to long format
  data %<>% gather(key=date, value=count, -country)
  ## convert from character to date
  data %<>% mutate(date = date %>% substr(2,8) %>% mdy())
```

```
  ## aggregate by country
  data %<>% group_by(country, date) %>% summarise(count=sum(count, na.rm=T)) %>% as.data.frame()
  return(data)
}

## clean the three datasets
data.confirmed <- raw.data.confirmed %>% cleanData() %>% rename(confirmed=count)
data.deaths <- raw.data.deaths %>% cleanData() %>% rename(deaths=count)
data.recovered <- raw.data.recovered %>% cleanData() %>% rename(recovered=count)

## merge above 3 datasets into one, by country and date
data <- data.confirmed %>% merge(data.deaths, all=T) %>% merge(data.recovered, all=T)
# data %<>% mutate(recovered = ifelse(is.na(recovered), lag(recovered, 1), recovered))

## countries/regions with confirmed cases, excl. cruise ships
countries <- data %>% pull(country) %>% setdiff('Cruise Ship')

## first 10 records when it first broke out in China
data %>% filter(country=='China') %>% head(10) %>%
  kable('latex', booktabs=T, caption='Raw Data (with first 10 Columns Only)',
        format.args=list(big.mark=',')) %>%
  kable_styling(latex_options = c('striped', 'hold_position', 'repeat_header'))
```

Table 2: Raw Data (with first 10 Columns Only)

country	date	confirmed	deaths	recovered
China	2020-01-22	548	17	28
China	2020-01-23	643	18	30
China	2020-01-24	920	26	36
China	2020-01-25	1,406	42	39
China	2020-01-26	2,075	56	49
China	2020-01-27	2,877	82	58
China	2020-01-28	5,509	131	101
China	2020-01-29	6,087	133	120
China	2020-01-30	8,141	171	135
China	2020-01-31	9,802	213	214

There are 188 countries with confirmed COVID-19 cases, as of 24 May 2020 UTC.

3.2 Worldwide Cases

The raw data provide the daily number of cases in every country. They are aggregated below to derive the daily stats of the whole world.

```
## counts for the whole world
data.world <- data %>% group_by(date) %>%
  summarise(country='World',
            confirmed = sum(confirmed, na.rm=T),
            deaths = sum(deaths, na.rm=T),
            recovered = sum(recovered, na.rm=T))

data %<>% rbind(data.world)
```

```r
## current confirmed cases
data %<>% mutate(current.confirmed = confirmed - deaths - recovered)
```

3.3 Daily Increases and Death Rates

After that, the daily increases of death and recovered cases and the death rates are calculated.

`rate.upper` is caculated with the total dead and recovered cases. It is the upper bound of death rate and the reasons are

1) there were much more deaths than recovered cases when the coronavirus broke out and when it was not contained, and
2) the daily number of death will decrease and that of recovered will increase as it becomes contained and more effective measures and treatments are used.

`rate.lower` is caculated with total dead and confirmed cases. It is a lower bound of death rate, because there are and will be new deaths from the current confirmed cases. The final death rate is expected to be in between of the above two rates.

`rate.daily` is caculated with the daily dead and recovered cases and therefore is more volatile than the above two. However, it can give us a clue of the current situlation: whether it is very serious or is getting better.

```r
## sort by country and date
data %<>% arrange(country, date)

## daily increases of deaths and recovered cases
## set NA to the increases on day1
n <- nrow(data)
day1 <- min(data$date)
data %<>% mutate(new.confirmed = ifelse(date == day1, NA, confirmed - lag(confirmed, n=1)),
                 new.deaths = ifelse(date == day1, NA, deaths - lag(deaths, n=1)),
                 new.recovered = ifelse(date == day1, NA, recovered - lag(recovered, n=1)))

## change negative number of new cases to zero
data %<>% mutate(new.confirmed = ifelse(new.confirmed < 0, 0, new.confirmed),
                 new.deaths = ifelse(new.deaths < 0, 0, new.deaths),
                 new.recovered = ifelse(new.recovered < 0, 0, new.recovered))

## death rate based on total deaths and recovered cases
data %<>% mutate(rate.upper = (100 * deaths / (deaths + recovered)) %>% round(1))
## lower bound: death rate based on total confirmed cases
data %<>% mutate(rate.lower = (100 * deaths / confirmed) %>% round(1))
## death rate based on the number of death/recovered on every single day
data %<>% mutate(rate.daily = (100 * new.deaths / (new.deaths + new.recovered)) %>% round(1))


## convert from wide to long format, for drawing area plots
data.long <- data %>%
  select(c(country, date, confirmed, current.confirmed, recovered, deaths)) %>%
  gather(key=type, value=count, -c(country, date))
## set factor levels to show them in a desirable order
data.long %<>% mutate(type=recode_factor(type, confirmed='Total Confirmed',
                                         current.confirmed='Current Confirmed',
                                         recovered='Recovered',
```

```
                                        deaths='Deaths'))


## convert from wide to long format, for drawing area plots
rates.long <- data %>%
  # filter(country %in% top.countries) %>%
  select(c(country, date, rate.upper, rate.lower, rate.daily)) %>%
  # mutate(country=factor(country, levels=top.countries)) %>%
  gather(key=type, value=count, -c(country, date))
# set factor levels to show them in a desirable order
rates.long %<>% mutate(type=recode_factor(type, rate.daily='Daily',
                                          rate.lower='Lower bound',
                                          rate.upper='Upper bound'))
```

4 Worldwide Cases

After tidying up the data, we visualise it with various charts.

4.1 World Map

Below is a world map of vconfirmed cases. An interactive map can be created if running the code in R or RStudio, or knitting it into a HTML file.

```
## select last column, which is the number of latest confirmed cases
x <- raw.data.confirmed
x$confirmed <- x[, ncol(x)]
x %<>% select(c(Country.Region, Province.State, Lat, Long, confirmed)) %>%
  mutate(txt=paste0(Country.Region, ' - ', Province.State, ': ', confirmed))

m <- leaflet(width=1200, height=800) %>% addTiles()
# circle marker (units in pixels)
m %<>% addCircleMarkers(x$Long, x$Lat,
                        # radius=2+log2(x$confirmed),
                        radius=0.03*sqrt(x$confirmed),
                        stroke=F,
                        color='red', fillOpacity=0.3,
                        popup=x$txt)

# world
m
```

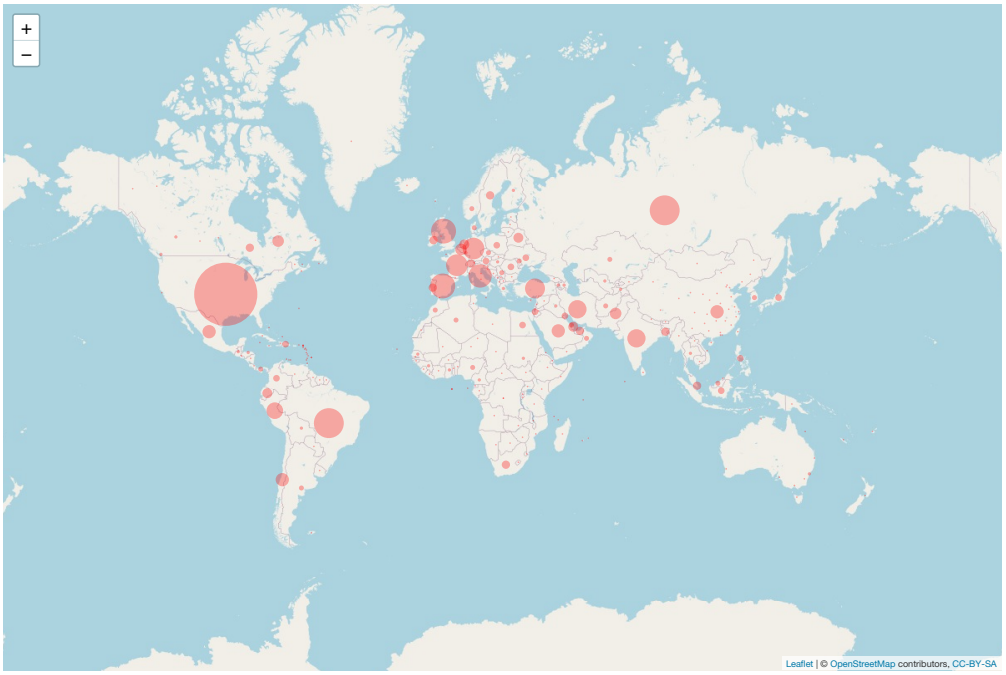


Figure 1: World Map

Views of some specific countries or regions can be produced with the script below.

```
## China
m %>% setView(95, 35, zoom=4)
## Australia and New Zealand
m %>% setView(135, -27, zoom=4)
## US and Canada
m %>% setView(-105, 40, zoom=4)
## Europe
m %>% setView(10, 50, zoom=4)
```

4.2 Number of Cases

In the rest of this section, we will focuse on the cases worldwide. Similar analysis for a single country can be done by filter the data with the corresponding country name.

```
# data %<>% filter(country=='China')
# data %<>% filter(country=='Australia')
world.long <- data.long %>% filter(country == 'World')

## cases - area plot
plot1 <- world.long %>% filter(type != 'Total Confirmed') %>%
  ggplot(aes(x=date, y=count)) +
  geom_area(aes(fill=type), alpha=0.5) +
  labs(title=paste0('Numbers of Cases Worldwide - ', max.date.txt)) +
  scale_fill_manual(values=c('red', 'green', 'black')) +
  theme(legend.title=element_blank(), legend.position='bottom',
        plot.title = element_text(size=7),
        axis.title.x=element_blank(),
        axis.title.y=element_blank(),
```

```
        legend.key.size=unit(0.2, 'cm'),
        legend.text=element_text(size=6),
        axis.text=element_text(size=7),
        axis.text.x=element_text(angle=45, hjust=1))

plot2 <- world.long %>%
  ggplot(aes(x=date, y=count)) +
  geom_line(aes(color=type)) +
  labs(title=paste0('Numbers of Cases Worldwide (log scale) - ', max.date.txt)) +
  scale_color_manual(values=c('purple', 'red', 'green', 'black')) +
  theme(legend.title=element_blank(), legend.position='bottom',
        plot.title = element_text(size=7),
        axis.title.x=element_blank(),
        axis.title.y=element_blank(),
        legend.key.size=unit(0.2, 'cm'),
        legend.text=element_text(size=6),
        axis.text=element_text(size=7),
        axis.text.x=element_text(angle=45, hjust=1)) +
  scale_y_continuous(trans='log10')
## show two plots side by side
grid.arrange(plot1, plot2, ncol=2)
```

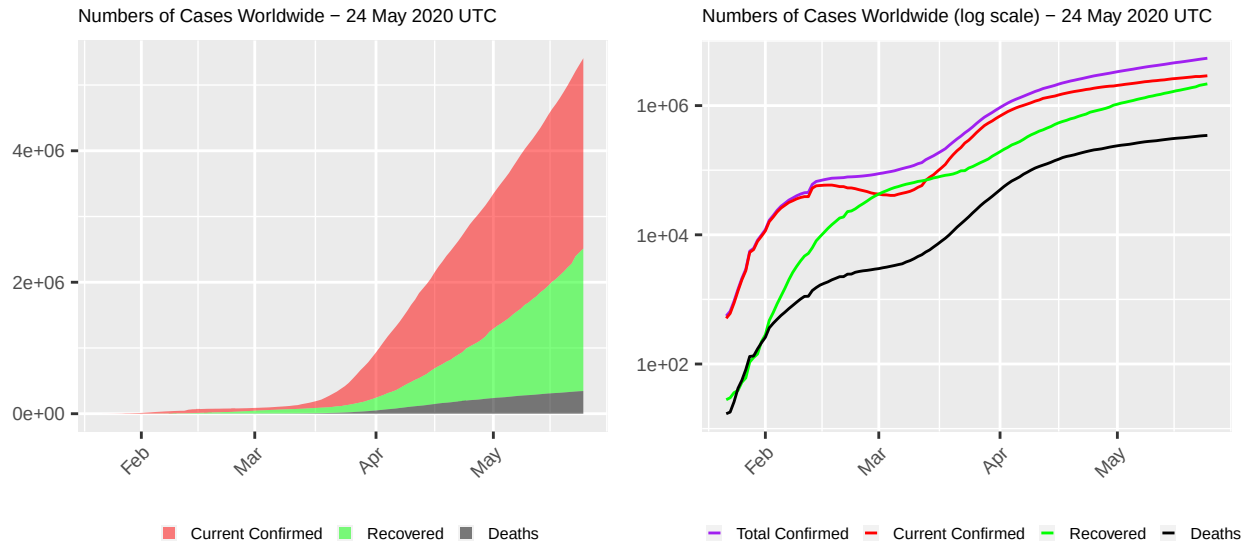


Figure 2: COVID-19 Cases Worldwide

4.3 Current Confirmed Cases

```
data.world <- data %>% filter(country=='World')
n <- nrow(data.world)
```

```
## current confirmed and daily new confirmed
plot1 <- ggplot(data.world, aes(x=date, y=current.confirmed)) +
  geom_point() + geom_smooth() +
  xlab('') + ylab('Count') + labs(title='Current Confirmed Cases') +
  theme(axis.text.x=element_text(angle=45, hjust=1))
plot2 <- ggplot(data.world, aes(x=date, y=new.confirmed)) +
```

```
  geom_point() + geom_smooth() +
  xlab('') + ylab('Count') + labs(title='Daily New Confirmed Cases') +
  theme(axis.text.x=element_text(angle=45, hjust=1))
## show two plots side by side
grid.arrange(plot1, plot2, ncol=2)
```

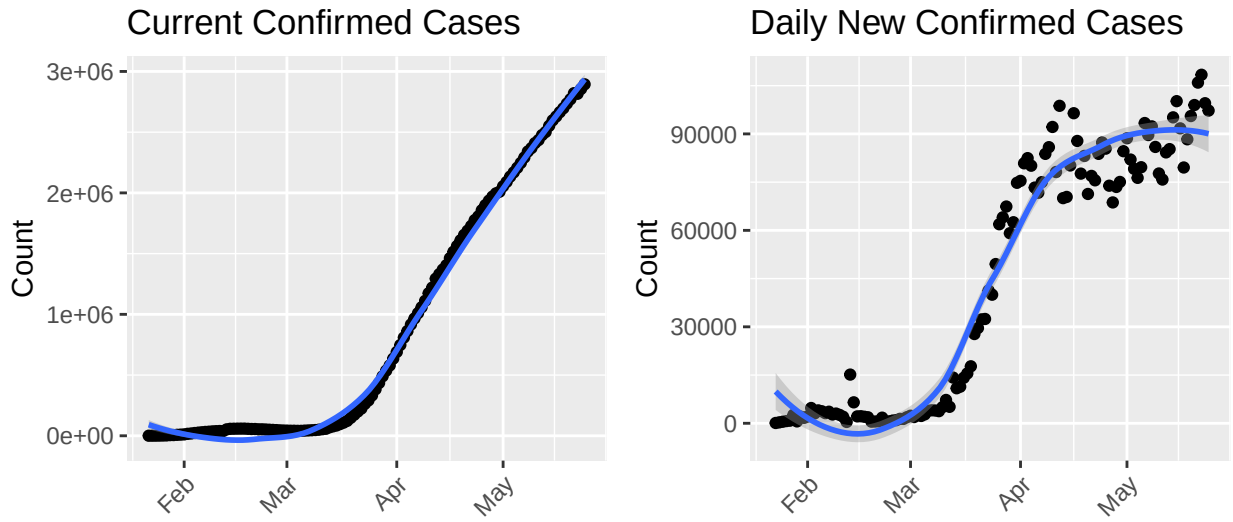


Figure 3: Current Confirmed Cases

Figure 3 shows the numbers of current (see left chart) and new (see right chart) confirmed cases. The blue lines are smoothed conditional means and the grey band around them show the 95% confidence interval.

4.4 Deaths and Recovered Cases

```
## a scatter plot with a smoothed line and vertical x-axis labels
plot1 <- ggplot(data.world, aes(x=date, y=deaths)) +
  geom_point() + geom_smooth() +
  xlab('') + ylab('Count') + labs(title='Accumulative Deaths') +
  theme(axis.text.x=element_text(angle=45, hjust=1))
plot2 <- ggplot(data.world, aes(x=date, y=recovered)) +
  geom_point() + geom_smooth() +
  xlab('') + ylab('Count') + labs(title='Accumulative Recovered Cases') +
  theme(axis.text.x=element_text(angle=45, hjust=1))
plot3 <- ggplot(data.world, aes(x=date, y=new.deaths))  +
  geom_point() + geom_smooth()  +
  xlab('') + ylab('Count') + labs(title='New Deaths') +
  theme(axis.text.x=element_text(angle=45, hjust=1))
plot4 <- ggplot(data.world, aes(x=date, y=new.recovered)) +
  geom_point() + geom_smooth()  +
  xlab('') + ylab('Count') + labs(title='New Recovered Cases') +
  theme(axis.text.x=element_text(angle=45, hjust=1))
## show four plots together, with 2 plots in each row
grid.arrange(plot1, plot2, plot3, plot4, nrow=2)
```

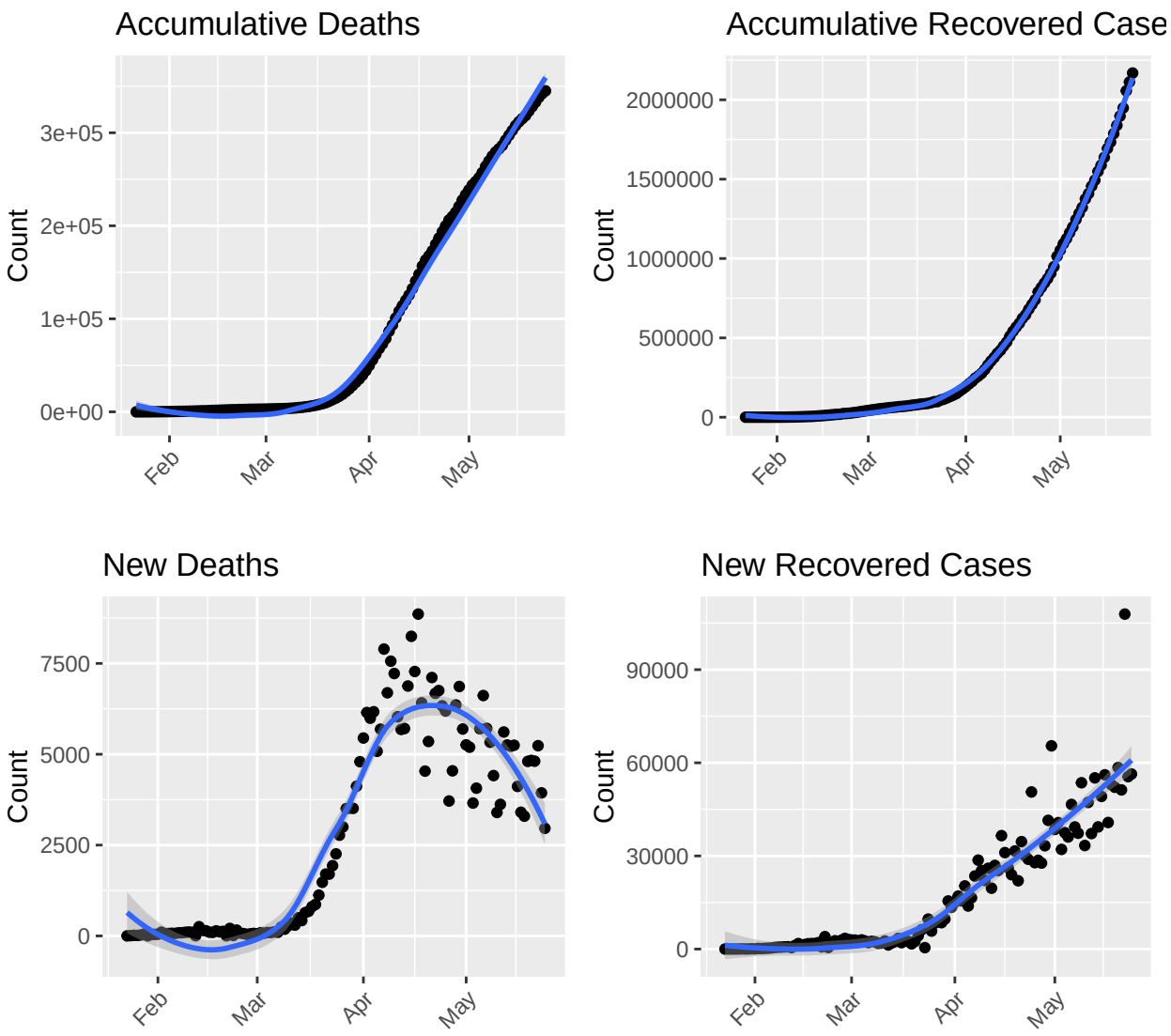


Figure 4: Deaths and Recovered Cases

4.5 Death Rates

Figure 5 shows death rates caculated in three different ways (see Section 3.3 for details). The left chart shows the death rates from 22 Jan 2020 to 24 May 2020 UTC and the right one is a zoom-in view of the rates in last two weeks.

In the right chart, the upper bound (in blue) is decreasing, as there will be more recovered cases and fewer dead ones daily as time goes on. However, the lower bound (in green) keeps going up, as there are and will be new deaths from the current confirmed cases. Therefore, the final death rate is expected to be in-between of those two rates, and based on the latest data retrieved as of 24 May 2020 UTC UTC, it will be between 6.4% and 13.7%.

A surge in the daily death rate (in red) in late March suggests that the situlation is changing dramatically (actually, getting worse) and that above lower/upper bounds are likely to increase shortly. A likely reason of that surge is the outbreak of coronavirus in Iran, Europe and US.

```
## three death rates
plot1 <- ggplot(data.world, aes(x=date)) +
```

```
  geom_line(aes(y=rate.upper, colour='Upper bound')) +
  geom_line(aes(y=rate.lower, colour='Lower bound')) +
  geom_line(aes(y=rate.daily, colour='Daily')) +
  xlab('') + ylab('Death Rate (%)') + labs(title='Overall') +
  theme(legend.position='bottom', legend.title=element_blank(),
        legend.text=element_text(size=8),
        legend.key.size=unit(0.5, 'cm'),
        axis.text.x=element_text(angle=45, hjust=1)) +
  ylim(c(0, 99))
## focusing on last 2 weeks
# y.max <- data.world[n-(14:0), ] %>% select(rate.upper, rate.lower, rate.daily) %>% max()
plot2 <- ggplot(data.world[n-(14:0),], aes(x=date)) +
  geom_line(aes(y=rate.upper, colour='Upper bound')) +
  geom_line(aes(y=rate.lower, colour='Lower bound')) +
  geom_line(aes(y=rate.daily, colour='Daily')) +
  xlab('') + ylab('Death Rate (%)') + labs(title='Last two weeks') +
  theme(legend.position='bottom', legend.title=element_blank(),
        legend.text=element_text(size=8),
        legend.key.size=unit(0.5, 'cm'),
        axis.text.x=element_text(angle=45, hjust=1)) +
  ylim(c(0, 20))
grid.arrange(plot1, plot2, ncol=2)
```

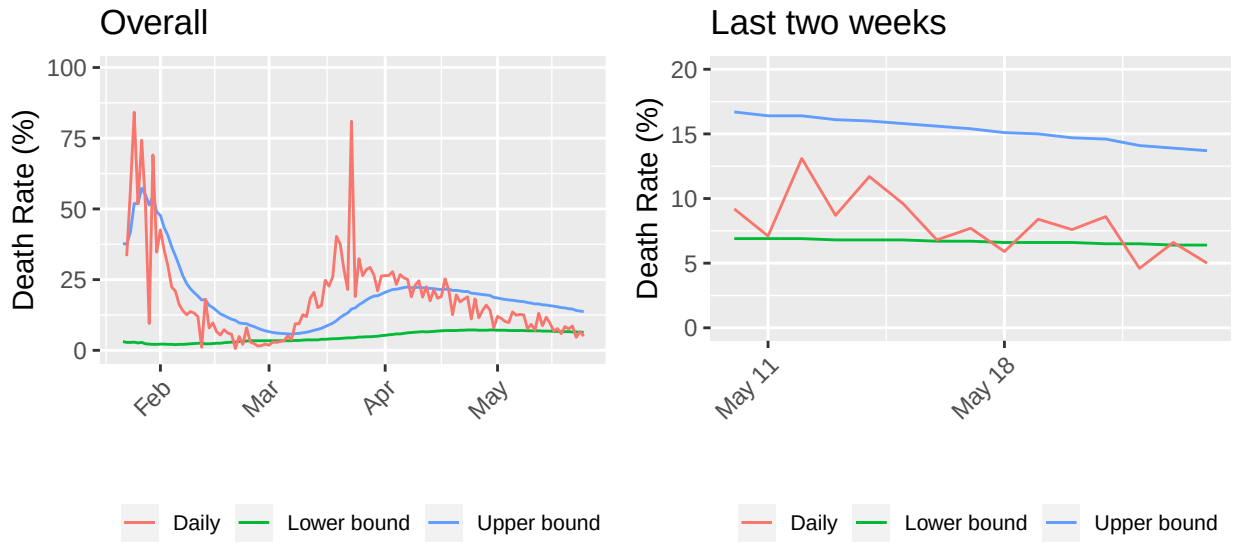


Figure 5: Death Rate

5 Top Twenty Countries

Next, we will have a look at the top 20 countries in total confirmed cases.

```
## ranking by confirmed cases
data.latest.all <- data %>% filter(date == max(date)) %>%
  select(country, date,
         confirmed, new.confirmed, current.confirmed,
         recovered, deaths, new.deaths, death.rate=rate.lower) %>%
  mutate(ranking = dense_rank(desc(confirmed)))
```

```r
k <- 20
## top 20 countries: 21 incl. 'World'
top.countries <- data.latest.all %>% filter(ranking <= k + 1) %>%
  arrange(ranking) %>% pull(country) %>% as.character()
top.countries %>% setdiff('World') %>% print()
```

```
##  [1] "US"             "Brazil"         "Russia"         "United Kingdom"
##  [5] "Spain"          "Italy"          "France"         "Germany"
##  [9] "Turkey"         "India"          "Iran"           "Peru"
## [13] "Canada"         "China"          "Saudi Arabia"   "Chile"
## [17] "Mexico"         "Belgium"        "Pakistan"       "Netherlands"
```

```r
## add 'Others'
# top.countries %<>% c('Others')
## put all others in a single group of 'Others'
data.latest <- data.latest.all %>% filter(!is.na(country)) %>%
  mutate(country=ifelse(ranking <= k + 1, as.character(country), 'Others')) %>%
  mutate(country=country %>% factor(levels=c(top.countries, 'Others')))
data.latest %<>% group_by(country) %>%
  summarise(confirmed=sum(confirmed), new.confirmed=sum(new.confirmed),
            current.confirmed=sum(current.confirmed),
            recovered=sum(recovered), deaths=sum(deaths), new.deaths=sum(new.deaths)) %>%
  mutate(death.rate=(100 * deaths/confirmed) %>% round(1))
data.latest %<>% select(c(country, confirmed, deaths, death.rate,
                 new.confirmed, new.deaths, current.confirmed))
```

```r
data.latest %>% mutate(death.rate=death.rate %>% format(nsmall=1) %>% paste0('%')) %>%
  kable('latex', booktabs=T, row.names=T, align=c('l', rep('r', 6)),
        caption=paste0('Cases in Top 20 Countries - ', max.date.txt,
                       '. See a complete list of all infected countries at the end of this report.'),
        format.args=list(big.mark=',')) %>%
  kable_styling(font_size=7, latex_options=c('striped', 'hold_position', 'repeat_header'))
```

```r
## convert from wide to long format, for drawing area plots
data.latest.long <- data.latest %>% filter(country!='World') %>%
  gather(key=type, value=count, -country)
## set factor levels to show them with proper text and in a desirable order
data.latest.long %<>% mutate(type=recode_factor(type,
                                     confirmed='Total Confirmed',
                                     deaths='Total Deaths',
                                     death.rate='Death Rate (%)',
                                     new.confirmed='New Confirmed (compared with one day before)',
                                     new.deaths='New Deaths (compared with one day before)',
                                     current.confirmed='Current Confirmed'))
```

```r
## bar chart
data.latest.long %>% ggplot(aes(x=country, y=count, fill=country, group=country)) +
  geom_bar(stat='identity') +
  geom_text(aes(label=count, y=count), size=2, vjust=0) +
  xlab('') + ylab('') +
  labs(title=paste0('Top 20 Countries with Most Confirmed Cases - ', max.date.txt)) +
  scale_fill_discrete(name='Country', labels=aes(count)) +
  theme(legend.title=element_blank(),
        legend.position='none',
        plot.title=element_text(size=11),
```

Table 3: Cases in Top 20 Countries - 24 May 2020 UTC. See a complete list of all infected countries at the end of this report.

	country	confirmed	deaths	death.rate	new.confirmed	new.deaths	current.confirmed
1	World	5,407,613	345,059	6.4%	97,251	2,962	2,893,991
2	US	1,643,246	97,720	5.9%	20,634	633	1,178,790
3	Brazil	363,211	22,666	6.2%	15,813	653	190,634
4	Russia	344,481	3,541	1.0%	8,599	153	227,641
5	United Kingdom	260,916	36,875	14.1%	2,412	118	222,890
6	Spain	235,772	28,752	12.2%	482	74	56,644
7	Italy	229,858	32,785	14.3%	531	50	56,594
8	France	182,709	28,370	15.5%	673	152	89,604
9	Germany	180,328	8,283	4.6%	342	22	11,764
10	Turkey	156,827	4,340	2.8%	1,141	32	33,793
11	India	138,536	4,024	2.9%	7,113	156	76,820
12	Iran	135,701	7,417	5.5%	2,180	58	22,483
13	Peru	119,959	3,456	2.9%	4,205	83	66,708
14	Canada	86,106	6,534	7.6%	955	68	35,574
15	China	84,095	4,638	5.5%	11	0	114
16	Saudi Arabia	72,560	390	0.5%	2,399	11	28,650
17	Chile	69,102	718	1.0%	3,709	45	40,236
18	Mexico	68,620	7,394	10.8%	2,764	215	14,247
19	Belgium	57,092	9,280	16.3%	282	43	32,540
20	Pakistan	54,601	1,133	2.1%	2,164	32	36,270
21	Netherlands	45,437	5,841	12.9%	172	11	39,422
22	Others	878,456	30,902	3.5%	20,670	353	432,573

```
      axis.text=element_text(size=7),
      axis.text.x=element_text(angle=45, hjust=1)) +
facet_wrap(~type, ncol=1, scales='free_y')
```

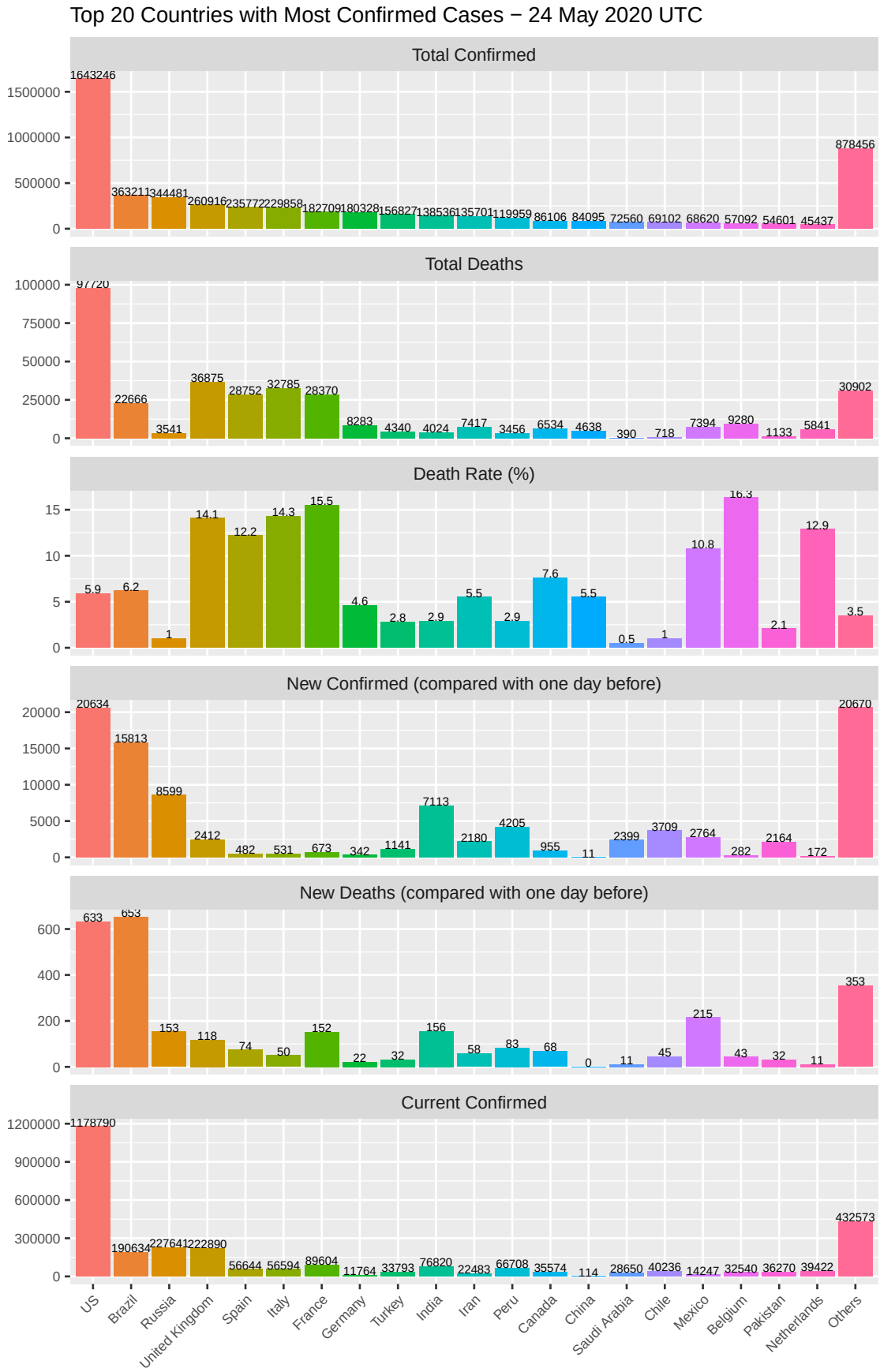
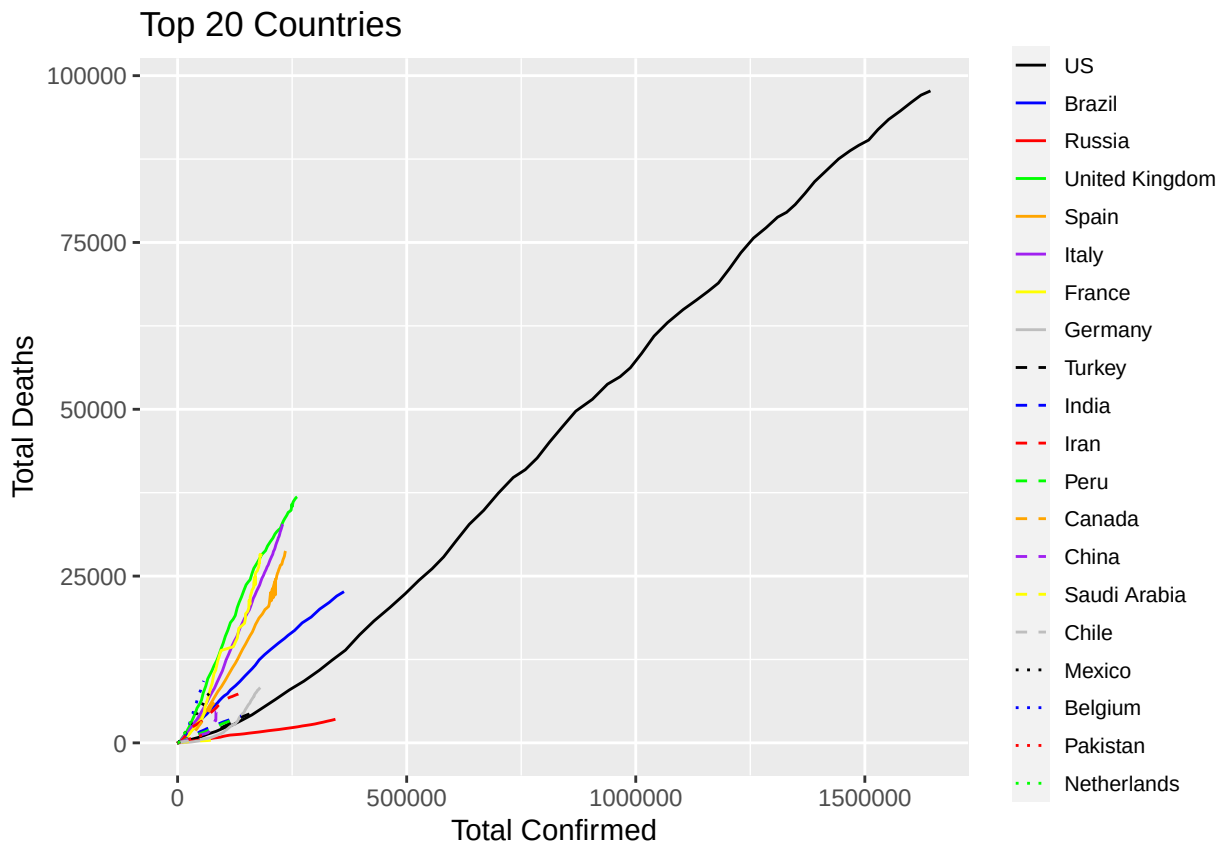


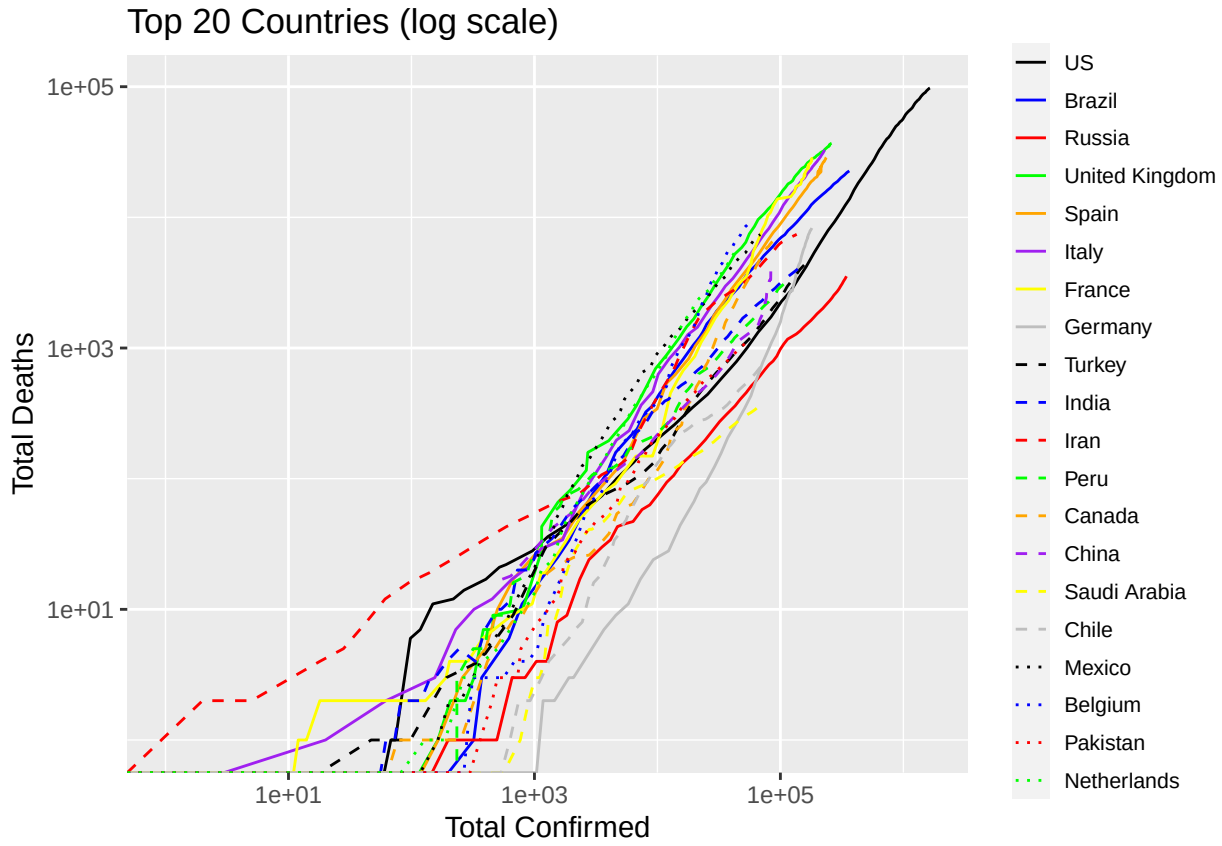
Figure 6: Top 20 Countries with Most Confirmed Cases

5.1 Confirmed vs Deaths

```
# linetypes <- rep(c("dotted", "dashed", "solid"), each=8)
# colors <- rep(c('grey', 'yellow', 'purple', 'orange', 'green', 'red', 'blue', 'black'), 3)
linetypes <- rep(c("solid", "dashed", "dotted"), each=8)
colors <- rep(c('black', 'blue', 'red', 'green', 'orange', 'purple', 'yellow', 'grey'), 3)
df <- data %>% filter(country %in% setdiff(top.countries, c('World'))) %>%
  mutate(country=country %>% factor(levels=c(top.countries)))
p <- df %>% ggplot(aes(x=confirmed, y=deaths, group=country)) +
  geom_line(aes(color=country, linetype=country)) +
  xlab('Total Confirmed') + ylab('Total Deaths') +
  scale_linetype_manual(values=linetypes) +
  scale_color_manual(values=colors) +
  theme(legend.title=element_blank(),
        legend.text=element_text(size=8),
        legend.key.size=unit(0.5, 'cm'))
p + labs(title=paste0('Top 20 Countries'))
```




```
p + scale_x_log10() + scale_y_log10() +
  labs(title=paste0('Top 20 Countries (log scale)'))
```



The two figures below show the numbers of confirmed cases and deaths of top 20 countries, as well as the death rates up to 24 May 2020 UTC.

```
df <- data.latest %>% filter(country %in% setdiff(top.countries, 'World'))
## breaks for circle size in legend; needs to be adjusted accordingly when the number of total confirme
breaks.confirmed <- c(5e3, 1e4, 2e4, 5e4, 1e5, 2e5, 5e5, 1e6, 2e6, 5e6, 1e7)

plot1 <- df %>% ggplot(aes(x=confirmed, y=deaths, col=death.rate, size=current.confirmed)) +
  scale_size(name='Current Confirmed', trans='log2', breaks=breaks.confirmed) +
  geom_text(aes(label=country), size=2.5, check_overlap=T, vjust=-1.6) +
  geom_point() +
  xlab('Total Confirmed') + ylab('Total Deaths') +
  labs(col="Death Rate (%)") +
  scale_color_gradient(low='#56B1F7', high='#132B43') +
  scale_x_log10() + scale_y_log10() +
  labs(title=paste0('Top 20 Countries - Confirmed vs Deaths (log scale)'))

plot2 <- df %>% ggplot(aes(x=new.confirmed, y=new.deaths, col=death.rate, size=current.confirmed)) +
  scale_size(name='Current Confirmed', trans='log2', breaks=breaks.confirmed) +
  geom_text(aes(label=country), size=2.5, check_overlap=T, vjust=-1.6) +
  geom_point() +
  xlab('New Confirmed') + ylab('New Deaths') +
  labs(col="Death Rate (%)") +
  scale_color_gradient(low='#56B1F7', high='#132B43') +
  scale_x_log10() + scale_y_log10() +
  labs(title=paste0('Top 20 Countries - New Confirmed vs New Deaths (log scale)'))
```

```
grid.arrange(plot1, plot2, ncol=1)
```

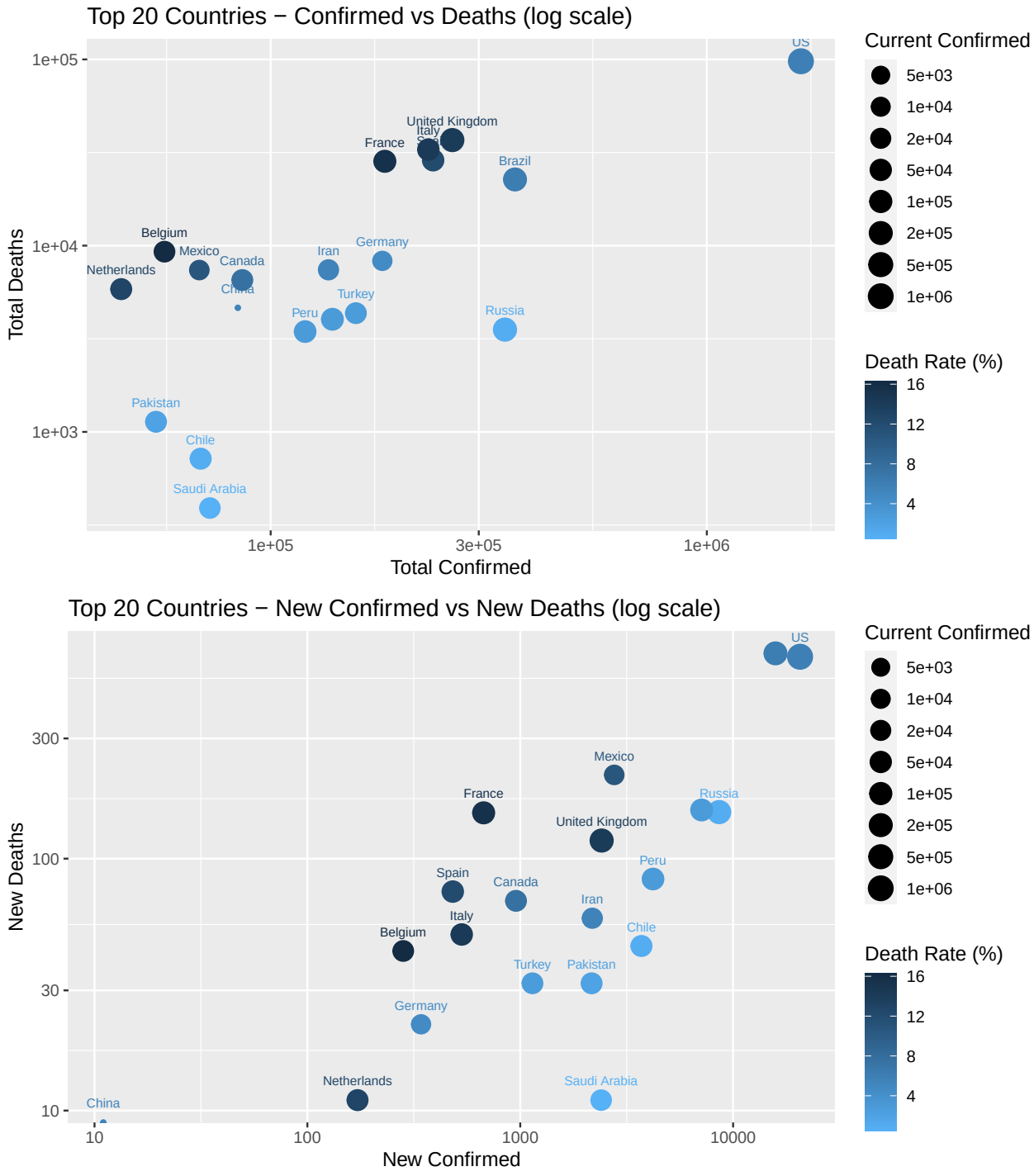


Figure 7: Top 20 Countries

5.2 Comparison across Countries

The area plots blow show the numbers of dead, recovered, total and current confimed cases. Note that, in the area plot, the total number of total confirmed cases is represented by the total areas of current confirmed,

recovered and dead.

```
## plot: cases by type
df <- data.long %>% filter(country %in% top.countries) %<>%
  mutate(country=country %>% factor(levels=c(top.countries)))

p <- df %>% filter(country != 'World') %>%
  ggplot(aes(x=date, y=count)) + xlab('') + ylab('Count')  +
  theme(legend.title=element_blank(),
        legend.text=element_text(size=8),
        legend.key.size=unit(0.5, 'cm'),
        plot.title=element_text(size=11),
        axis.text.x=element_text(angle=45, hjust=1)) +
  facet_wrap(~type, ncol=2, scales='free_y')

## area plot
plot1 <- p + geom_area(aes(fill=country)) +
  labs(title=paste0('Cases around the World - ', max.date.txt))

## line plot and in log scale
# linetypes <- rep(c("solid", "dashed", "dotted"), each=8)
# colors <- rep(c('black', 'blue', 'red', 'green', 'orange', 'purple', 'yellow', 'grey'), 3)
plot2 <- p + geom_line(aes(color=country, linetype=country)) +
  scale_linetype_manual(values=linetypes) +
  scale_color_manual(values=colors) +
  labs(title=paste0('Cases around the World - Log Scale - ', max.date.txt)) +
  scale_y_continuous(trans='log10')

grid.arrange(plot1, plot2, ncol=1)
```

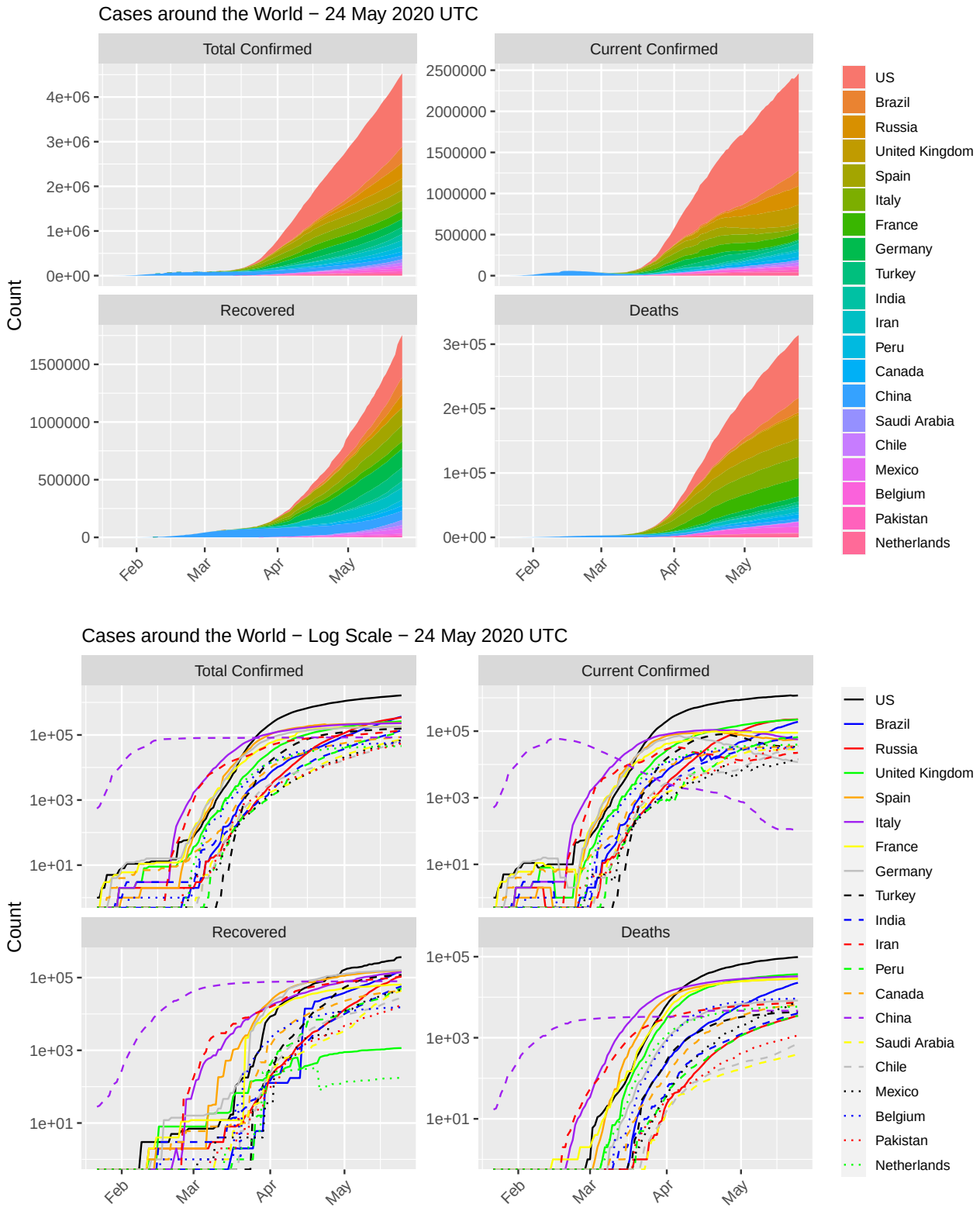


Figure 8: Cases around the World

```
## plot: excluding China
p <- df %>% filter(!(country %in% c('World', 'China'))) %>%
```

```
  ggplot(aes(x=date, y=count)) + xlab('') + ylab('Count') +
  theme(legend.title=element_blank(),
        legend.text=element_text(size=8),
        legend.key.size=unit(0.5, 'cm'),
        plot.title=element_text(size=11),
        axis.text.x=element_text(angle=45, hjust=1)) +
  facet_wrap(~type, ncol=2, scales='free_y')
p + geom_area(aes(fill=country)) +
  labs(title=paste0('Cases around the World (excl. China) - ', max.date.txt))
```

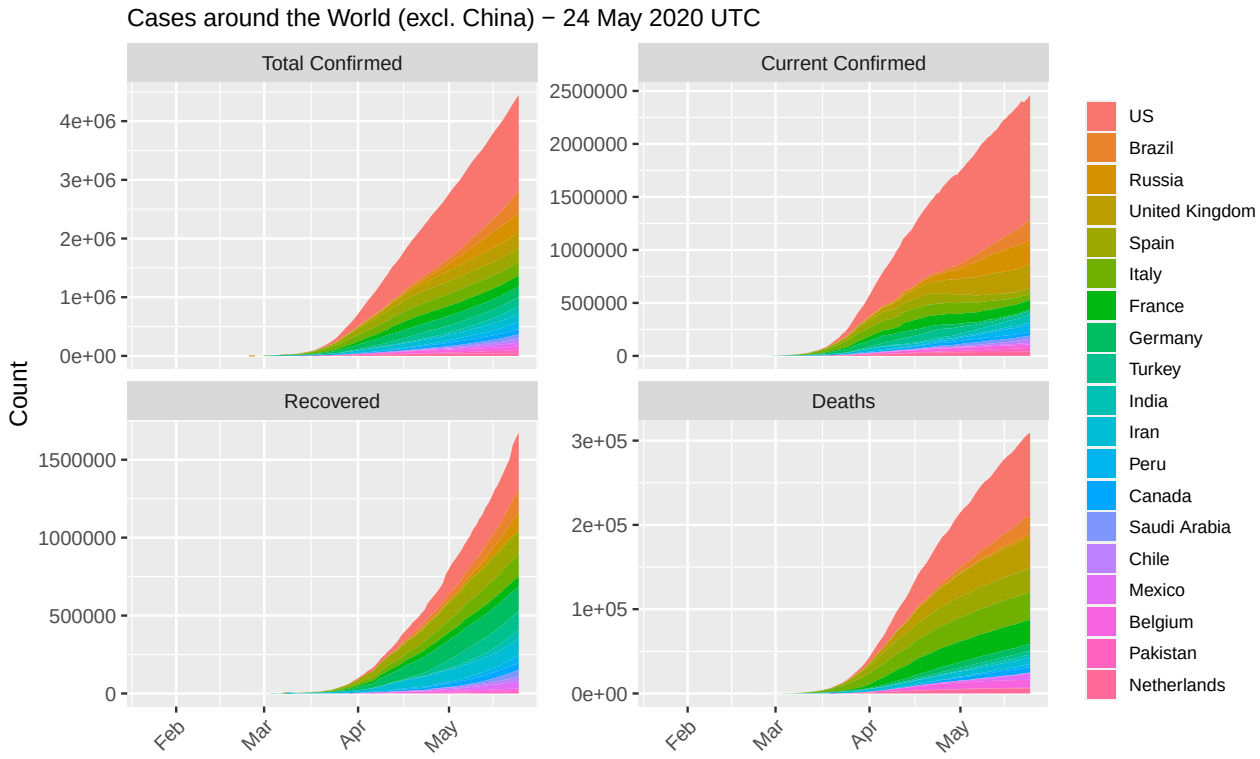


Figure 9: Cases around the World (excl. China)

```
## if Australia in not in top 20, add it in and remove 'Others'
if(!('Australia' %in% top.countries)) {
  top.countries %<>% setdiff('Others') %>% c('Australia')
  df <- data.long %>% filter(country %in% top.countries) %<>%
    mutate(country=country %>% factor(levels=c(top.countries)))
}

## cases by country - area plot
df %>% filter(country != 'World' & type != 'Total Confirmed') %>%
  ggplot(aes(x=date, y=count, fill=type)) +
  geom_area(alpha=0.5) +
  # xlab('') + ylab('') +
  labs(title=paste0('Numbers of COVID-19 Cases in Top 20 Countries - ',
                    max.date.txt)) +
  scale_fill_manual(values=c('red', 'green', 'black')) +
  theme(legend.title=element_blank(), legend.position='bottom',
```

```
      plot.title = element_text(size=12),
      axis.title.x=element_blank(),
      axis.title.y=element_blank(),
      legend.key.size=unit(0.4, 'cm'),
      # legend.text=element_text(size=7),
      strip.text.x=element_text(size=7),
      axis.text=element_text(size=7),
      axis.text.x=element_text(angle=45, hjust=1)) +
facet_wrap(~country, ncol=4, scales='free_y')
```

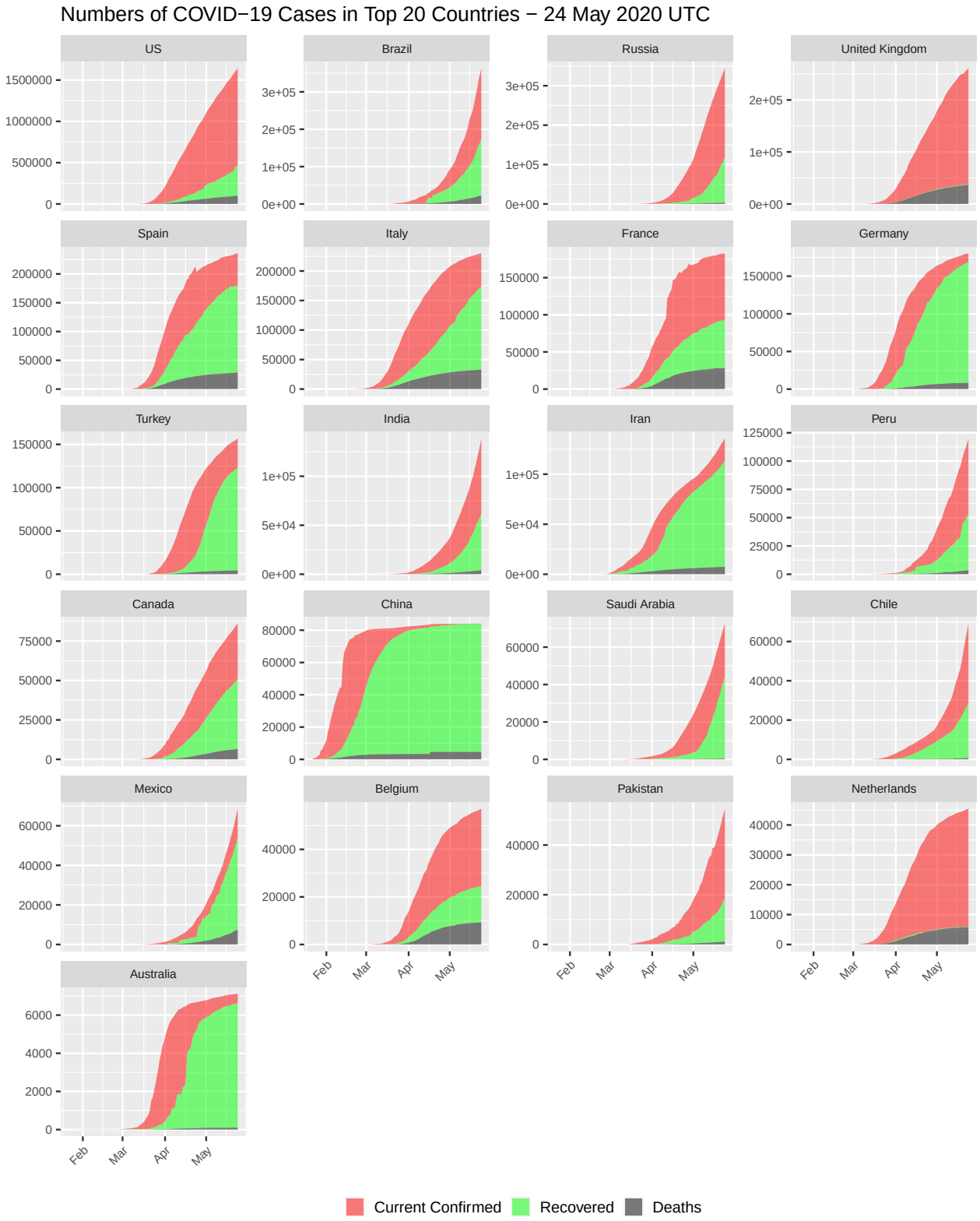


Figure 10: COVID-19 Cases in Top 20 Countries. Ordered descendingly by number of confirmed cases.

```r
## cases by country - line plot - log scale
p <- df %>% filter(country != 'World') %>%
  ggplot(aes(x=date, y=count, color=type)) +
  geom_line() +
  labs(title=paste0('Numbers of COVID-19 Cases in Top 20 Countries (log scale) - ',
                    max.date.txt)) +
  scale_color_manual(values=c('purple', 'red', 'green', 'black')) +
  theme(legend.title=element_blank(), legend.position='bottom',
        plot.title = element_text(size=12),
        axis.title.x=element_blank(),
        axis.title.y=element_blank(),
        legend.key.size=unit(0.4, 'cm'),
        # legend.text=element_text(size=7),
        strip.text.x=element_text(size=7),
        axis.text=element_text(size=7),
        axis.text.x=element_text(angle=45, hjust=1)) +
  scale_y_continuous(trans='log10')
p + facet_wrap(~country, ncol=4, scales='free_y')
```

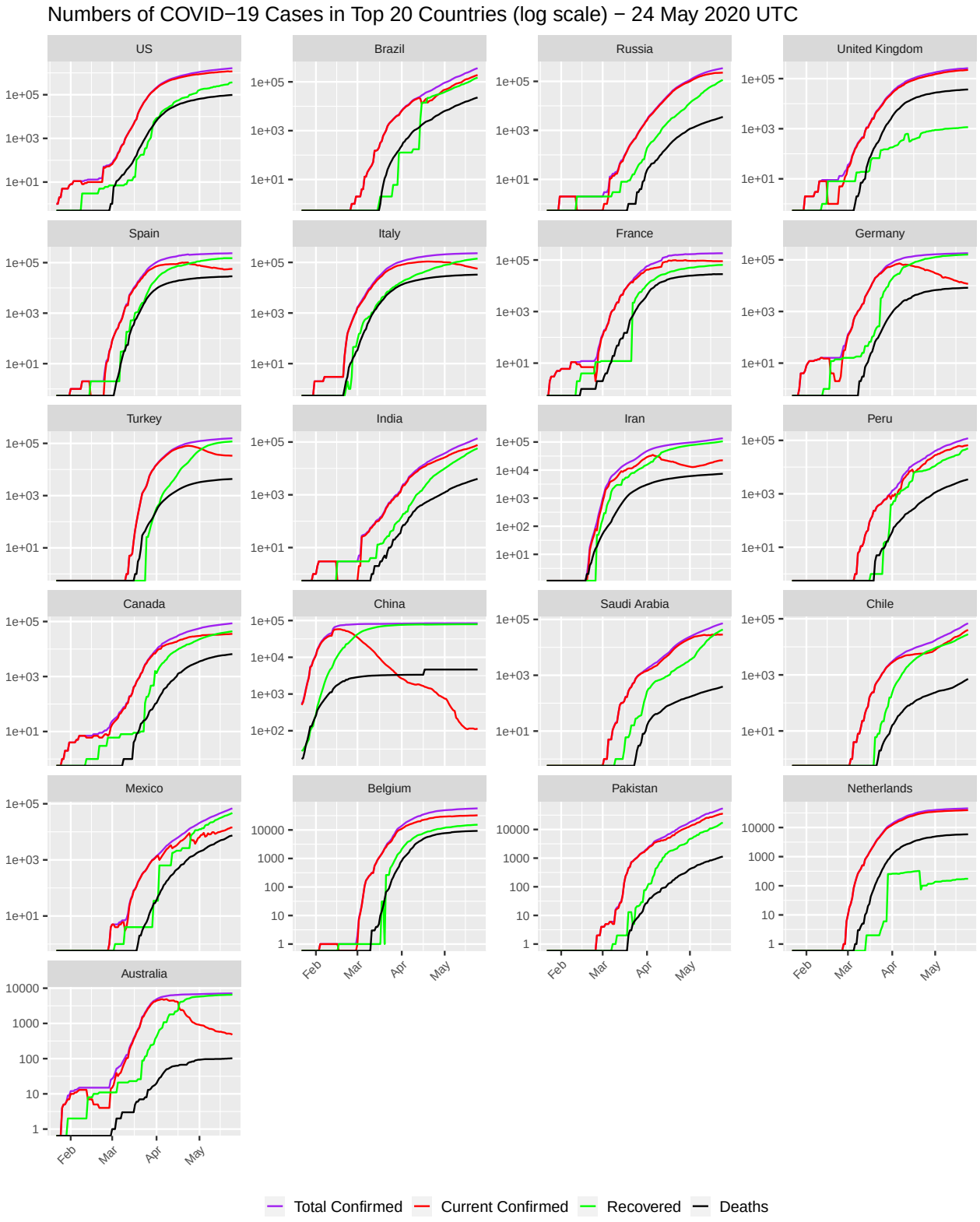


Figure 11: COVID-19 Cases Top 20 Countries (log scale). Ordered descendingly by number of confirmed cases.

```
## plot over multiple pages
# p + facet_wrap_paginate(~country, nrow=4, ncol=3, page=1, scales='free_y')
# p + facet_wrap_paginate(~country, nrow=4, ncol=3, page=2, scales='free_y')
```

Figures 10 and 11 show that China has entered a post-epidemic phase, followed by Australia and Germany, with an increase of recovered cases (in green) every day and a shrinking of the current confirmed cases (in red). In contrast, there are sharp surges in Russia, South America (incl. Brazil, Peru, Chile and Mexico) and West/South Asia (incl. Saudi Arabia, India and Pakistan), which suggests that the virus spread is accerelating there.

5.3 Death Rates

```
## three death rates
rate.max <- rates.long$count %>% max(na.rm=T)
df <- rates.long %>% filter(country %in% setdiff(top.countries, 'World')) %>%
  mutate(country=factor(country, levels=top.countries))
df %>% ggplot(aes(x=date, y=count, color=type)) +
  geom_line() +
  xlab('') + ylab('Death Rate (%)') +
  theme(legend.position='bottom', legend.title=element_blank(),
        legend.text=element_text(size=8),
        legend.key.size=unit(0.5, 'cm'),
        axis.text.x=element_text(angle=45, hjust=1)) +
  ylim(c(0, 99)) +
  facet_wrap(~country, ncol=4)
```

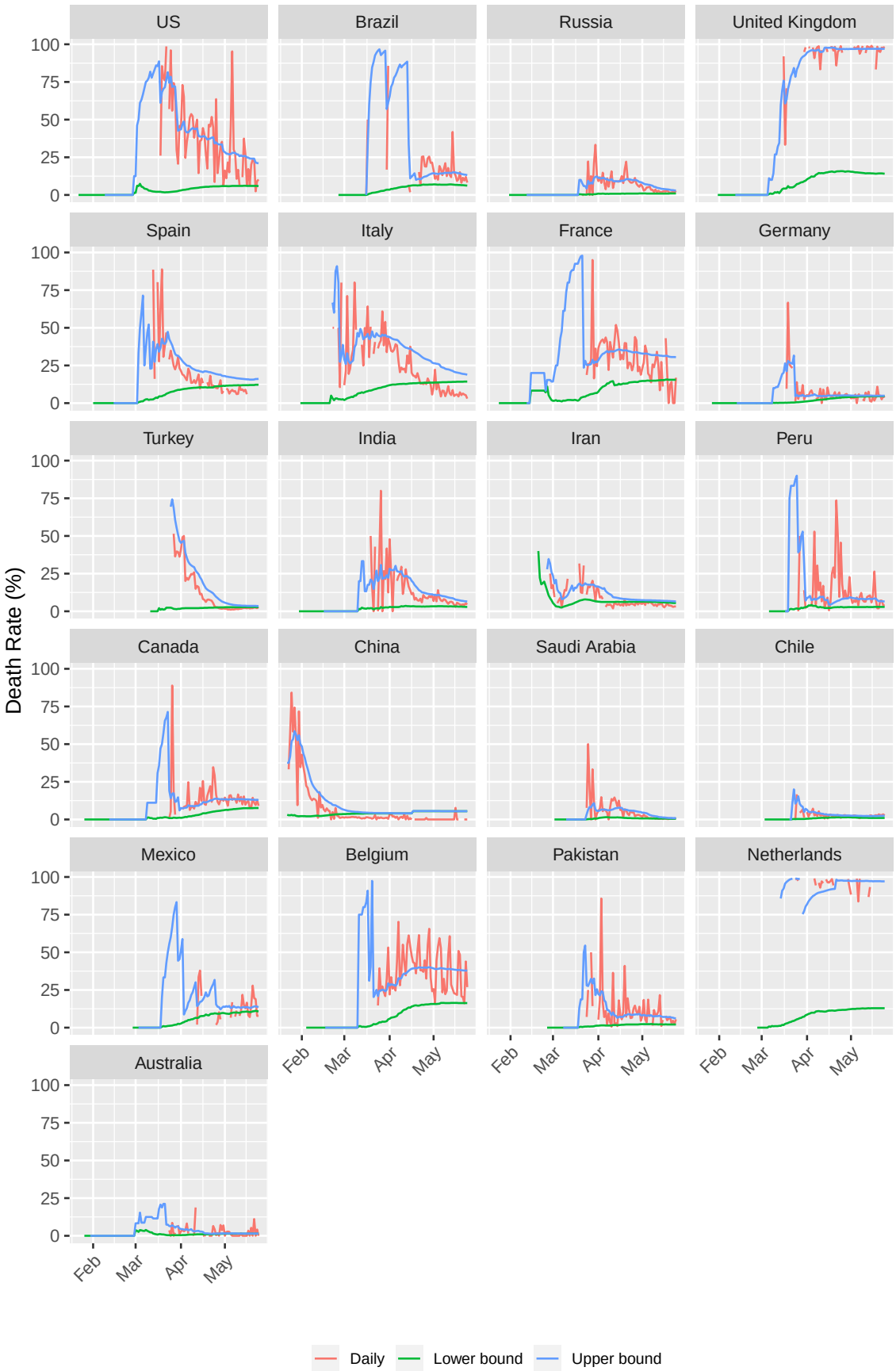


Figure 12: Death Rates

5.4 Countries with Highest Death Rates

Below are a list of top 20 countries with the highest death rates out of countires having 2000+ confirmed cases.

```
## sort the latest data by death rate, and if tie, by confirmed
df <- data %>% filter(date == max(date) & country != 'World' & confirmed >= 2000) %>%
  select(country, confirmed, new.confirmed, current.confirmed,
         recovered, deaths, new.deaths, death.rate=rate.lower) %>%
  arrange(desc(death.rate, confirmed))

df %>% head(20) %>%
  mutate(death.rate=death.rate %>% format(nsmall=1) %>% paste0('%')) %>%
  kable('latex', booktabs=T, row.names=T, align=c('l', rep('r', 7)),
        caption=paste0('Top 20 Countries with Highest Death Rates - ', max.date.txt),
        format.args=list(big.mark=',')) %>%
  kable_styling(font_size=7, latex_options=c('striped', 'hold_position', 'repeat_header'))
```

Table 4: Top 20 Countries with Highest Death Rates - 24 May 2020 UTC

	country	confirmed	new.confirmed	current.confirmed	recovered	deaths	new.deaths	death.rate
1	Belgium	57,092	282	32,540	15,272	9,280	43	16.3%
2	France	182,709	673	89,604	64,735	28,370	152	15.5%
3	Italy	229,858	531	56,594	140,479	32,785	50	14.3%
4	United Kingdom	260,916	2,412	222,890	1,151	36,875	118	14.1%
5	Hungary	3,741	28	1,565	1,690	486	4	13.0%
6	Netherlands	45,437	172	39,422	174	5,841	11	12.9%
7	Spain	235,772	482	56,644	150,376	28,752	74	12.2%
8	Sweden	33,459	271	24,490	4,971	3,998	6	11.9%
9	Mexico	68,620	2,764	14,247	46,979	7,394	215	10.8%
10	Ecuador	36,756	498	30,088	3,560	3,108	12	8.5%
11	Canada	86,106	955	35,574	43,998	6,534	68	7.6%
12	Algeria	8,306	193	2,922	4,784	600	8	7.2%
13	Romania	18,070	213	5,486	11,399	1,185	9	6.6%
14	Ireland	24,639	57	1,971	21,060	1,608	4	6.5%
15	Brazil	363,211	15,813	190,634	149,911	22,666	653	6.2%
16	Indonesia	22,271	526	15,497	5,402	1,372	21	6.2%
17	Philippines	14,035	258	9,918	3,249	868	5	6.2%
18	Switzerland	30,736	11	730	28,100	1,906	1	6.2%
19	Bosnia and Herzegovina	2,401	10	577	1,680	144	3	6.0%
20	Greece	2,878	2	1,333	1,374	171	0	5.9%

6 Conclusions

As of 24 May 2020 UTC, there are 188 countries with confirmed COVID-19 cases. It seems to be contained in China, but starts to break out in rest of the world. The current death rate is in between 6.4% and 13.7%, but it is likely to change dramatically with the breakout in many countries, such as European countries.

Appendix A. Processed Data

Blow is the processed data for this analysis.

Appendix A.1 COVID-19 Cases Worldwide

```
## sort by date descendingly and re-order columns
data.world %<>% arrange(desc(date)) %>%
```

```
  select(c(date, confirmed, deaths, recovered, current.confirmed,
           new.confirmed, new.deaths, new.recovered, rate.lower, rate.upper, rate.daily))
## output as a table
data.world %>%
  mutate(rate.upper = rate.upper %>% format(nsmall=1) %>% paste0('\\%'),
         rate.lower = rate.lower %>% format(nsmall=1) %>% paste0('\\%'),
         rate.daily = rate.daily %>% format(nsmall=1) %>% paste0('\\%')) %>%
  kable('latex', escape=F, booktabs=T, longtable=T,
        caption='Cases in the Whole World',
        format.args=list(big.mark=','),
        align=c('l', rep('r', 10))) %>%
  kable_styling(font_size=4, latex_options=c('striped', 'hold_position', 'repeat_header'))
```

Table 5: Cases in the Whole World

date	confirmed	deaths	recovered	current.confirmed	new.confirmed	new.deaths	new.recovered	rate.lower	rate.upper	rate.daily
2020-05-24	5,407,613	345,059	2,168,563	2,893,991	97,251	2,962	56,378	6.4%	13.7%	5.0%
2020-05-23	5,310,362	342,097	2,112,185	2,856,080	99,545	3,937	55,542	6.4%	13.9%	6.6%
2020-05-22	5,210,817	338,160	2,056,643	2,816,014	108,393	5,236	107,904	6.5%	14.1%	4.6%
2020-05-21	5,102,424	332,924	1,948,739	2,820,761	105,952	4,809	51,273	6.5%	14.6%	8.6%
2020-05-20	4,996,472	328,115	1,897,466	2,770,891	98,980	4,830	58,471	6.6%	14.7%	7.6%
2020-05-19	4,897,492	323,285	1,838,995	2,735,212	95,549	4,804	52,120	6.6%	15.0%	8.4%
2020-05-18	4,801,943	318,481	1,786,875	2,696,587	88,323	3,296	52,912	6.6%	15.1%	5.9%
2020-05-17	4,713,620	315,185	1,733,963	2,664,472	79,552	3,404	40,766	6.7%	15.4%	7.7%
2020-05-16	4,634,068	311,781	1,693,197	2,629,090	91,721	4,115	56,130	6.7%	15.6%	6.8%
2020-05-15	4,542,347	307,666	1,637,067	2,597,614	100,184	5,248	49,174	6.8%	15.8%	9.6%
2020-05-14	4,442,163	302,418	1,587,893	2,551,852	95,145	5,221	39,346	6.8%	16.0%	11.7%
2020-05-13	4,347,018	297,197	1,548,547	2,501,274	85,271	5,255	55,133	6.8%	16.1%	8.7%
2020-05-12	4,261,747	291,942	1,493,414	2,476,391	84,245	5,612	37,205	6.9%	16.4%	13.1%
2020-05-11	4,177,502	286,330	1,456,209	2,434,963	75,803	3,621	47,229	6.9%	16.4%	7.1%
2020-05-10	4,101,699	282,709	1,408,980	2,410,010	77,690	3,398	33,356	6.9%	16.7%	9.2%
2020-05-09	4,024,009	279,311	1,375,624	2,369,074	85,945	4,413	53,574	6.9%	16.9%	7.6%
2020-05-08	3,938,064	274,898	1,322,050	2,341,116	92,346	5,331	37,309	7.0%	17.2%	12.5%
2020-05-07	3,845,718	269,567	1,284,741	2,291,410	89,649	5,712	39,328	7.0%	17.3%	12.7%
2020-05-06	3,756,069	263,855	1,245,413	2,246,801	93,378	6,616	46,581	7.0%	17.5%	12.4%
2020-05-05	3,662,691	257,239	1,198,832	2,206,620	79,636	5,702	36,108	7.0%	17.7%	13.6%
2020-05-04	3,583,055	251,537	1,162,724	2,168,794	76,326	4,067	37,488	7.0%	17.8%	9.8%
2020-05-03	3,506,729	247,470	1,125,236	2,134,023	79,145	3,657	32,099	7.1%	18.0%	10.2%
2020-05-02	3,427,584	243,813	1,093,137	2,090,634	82,026	5,194	40,722	7.1%	18.2%	11.3%
2020-05-01	3,345,558	238,619	1,052,415	2,054,524	88,648	5,259	38,529	7.1%	18.5%	12.0%
2020-04-30	3,256,910	233,360	1,013,886	2,009,664	84,623	5,695	65,461	7.2%	18.7%	8.0%
2020-04-29	3,172,287	227,665	948,425	1,996,197	75,058	6,864	41,470	7.2%	19.4%	14.2%
2020-04-28	3,097,229	220,801	906,955	1,969,473	73,507	6,357	33,278	7.1%	19.6%	16.0%
2020-04-27	3,023,722	214,444	873,677	1,935,601	68,689	4,544	27,692	7.1%	19.7%	14.1%
2020-04-26	2,955,033	209,900	845,985	1,899,148	73,893	3,713	28,580	7.1%	19.9%	11.5%
2020-04-25	2,881,140	206,187	817,405	1,857,548	85,409	6,190	27,820	7.2%	20.1%	18.2%
2020-04-24	2,795,731	199,997	789,585	1,806,149	87,328	6,332	50,605	7.2%	20.2%	11.1%
2020-04-23	2,708,403	193,665	738,980	1,775,758	83,795	6,753	28,934	7.2%	20.8%	18.9%
2020-04-22	2,624,608	186,912	710,046	1,727,650	75,562	6,676	30,141	7.1%	20.8%	18.1%
2020-04-21	2,549,046	180,236	679,905	1,688,905	76,937	7,112	34,597	7.1%	21.0%	17.1%
2020-04-20	2,472,109	173,124	645,308	1,653,677	71,322	5,352	22,001	7.0%	21.2%	19.6%
2020-04-19	2,400,787	167,772	623,307	1,609,708	83,151	4,536	31,588	7.0%	21.2%	12.6%
2020-04-18	2,317,636	163,236	591,719	1,562,681	77,646	6,415	23,954	7.0%	21.6%	21.1%
2020-04-17	2,239,990	156,821	567,765	1,515,404	87,809	8,858	26,173	7.0%	21.6%	25.3%
2020-04-16	2,152,181	147,963	541,592	1,462,626	96,433	7,278	31,076	6.9%	21.5%	19.0%
2020-04-15	2,055,748	140,685	510,516	1,404,547	80,182	8,246	36,536	6.8%	21.6%	18.4%
2020-04-14	1,975,566	132,439	473,980	1,369,147	70,401	6,878	25,308	6.7%	21.8%	21.4%
2020-04-13	1,905,165	125,561	448,672	1,330,932	70,020	5,708	26,950	6.6%	21.9%	17.5%
2020-04-12	1,835,145	119,853	421,722	1,293,570	98,733	5,683	19,602	6.5%	22.1%	22.5%
2020-04-11	1,736,412	114,170	402,120	1,220,122	78,151	6,033	26,016	6.6%	22.1%	18.8%
2020-04-10	1,658,261	108,137	376,104	1,174,020	92,159	7,222	22,115	6.5%	22.3%	24.6%
2020-04-09	1,566,102	100,915	353,989	1,111,198	85,870	7,561	25,286	6.4%	22.2%	23.0%
2020-04-08	1,480,232	93,354	328,703	1,058,175	83,794	6,692	28,649	6.3%	22.1%	18.9%
2020-04-07	1,396,438	86,662	300,054	1,009,722	75,002	7,895	23,520	6.2%	22.4%	25.1%
2020-04-06	1,321,436	78,767	276,534	966,135	71,693	5,690	16,511	6.0%	22.2%	25.6%
2020-04-05	1,249,743	73,077	260,023	916,643	73,307	5,081	13,871	5.8%	21.9%	26.8%
2020-04-04	1,176,436	67,996	246,152	862,288	80,112	6,170	20,338	5.8%	21.6%	23.3%
2020-04-03	1,096,324	61,826	225,814	808,684	82,461	5,992	15,545	5.6%	21.5%	27.8%
2020-04-02	1,013,863	55,834	210,269	747,760	80,853	6,149	17,071	5.5%	21.0%	26.5%
2020-04-01	933,010	49,685	193,198	690,127	75,402	5,447	15,164	5.3%	20.5%	26.4%
2020-03-31	857,608	44,238	178,034	635,336	74,792	4,795	13,468	5.2%	19.9%	26.3%
2020-03-30	782,816	39,443	164,566	578,807	62,525	4,120	15,484	5.0%	19.3%	21.0%
2020-03-29	720,291	35,323	149,082	535,886	59,117	3,512	9,667	4.9%	19.2%	26.6%
2020-03-28	661,174	31,811	139,415	489,948	67,410	3,519	8,500	4.8%	18.6%	29.3%
2020-03-27	593,764	28,292	130,915	434,557	64,042	3,504	8,765	4.8%	17.8%	28.6%
2020-03-26	529,722	24,788	122,150	382,784	61,905	2,999	8,363	4.7%	16.9%	26.4%
2020-03-25	467,817	21,789	113,787	332,241	49,522	2,772	5,787	4.7%	16.1%	32.4%
2020-03-24	418,295	19,017	108,000	291,278	39,994	2,258	9,649	4.5%	15.0%	19.0%
2020-03-23	378,301	16,759	98,351	263,191	41,279	1,933	452	4.4%	14.6%	81.0%
2020-03-22	337,022	14,826	97,899	224,297	32,442	1,701	6,207	4.4%	13.2%	21.5%
2020-03-21	304,580	13,125	91,692	199,763	32,316	1,702	4,272	4.3%	12.5%	28.5%
2020-03-20	272,264	11,423	87,420	173,421	29,632	1,476	2,445	4.2%	11.6%	37.6%

Table 5: Cases in the Whole World *(continued)*

date	confirmed	deaths	recovered	current.confirmed	new.confirmed	new.deaths	new.recovered	rate.lower	rate.upper	rate.daily
2020-03-19	242,632	9,947	84,975	147,710	27,759	1,123	1,663	4.1%	10.5%	40.3%
2020-03-18	214,873	8,824	83,312	122,737	17,723	867	2,472	4.1%	9.6%	26.0%
2020-03-17	197,150	7,957	80,840	108,353	15,497	806	2,752	4.0%	9.0%	22.7%
2020-03-16	181,653	7,151	78,088	96,414	14,146	678	2,054	3.9%	8.4%	24.8%
2020-03-15	167,507	6,473	76,034	85,000	11,387	641	3,410	3.9%	7.8%	15.8%
2020-03-14	156,120	5,832	72,624	77,664	10,895	423	2,373	3.7%	7.4%	15.1%
2020-03-13	145,225	5,409	70,251	69,565	14,218	497	1,927	3.7%	7.1%	20.5%
2020-03-12	131,007	4,912	68,324	57,771	5,128	298	1,321	3.7%	6.7%	18.4%
2020-03-11	125,879	4,614	67,003	54,262	7,256	351	2,599	3.7%	6.4%	11.9%
2020-03-10	118,623	4,263	64,404	49,956	5,028	276	1,910	3.6%	6.2%	12.6%
2020-03-09	113,595	3,987	62,494	47,114	3,773	186	1,800	3.5%	6.0%	9.4%
2020-03-08	109,822	3,801	60,694	45,327	3,974	243	2,336	3.5%	5.9%	9.4%
2020-03-07	105,848	3,558	58,358	43,932	4,042	99	2,493	3.4%	5.7%	3.8%
2020-03-06	101,806	3,459	55,865	42,482	3,918	112	2,069	3.4%	5.8%	5.1%
2020-03-05	97,888	3,347	53,796	40,745	2,768	93	2,626	3.4%	5.9%	3.4%
2020-03-04	95,120	3,254	51,170	40,696	2,280	94	2,942	3.4%	6.0%	3.1%
2020-03-03	92,840	3,160	48,228	41,452	2,534	75	2,626	3.4%	6.1%	2.8%
2020-03-02	90,306	3,085	45,602	41,619	1,937	89	2,886	3.4%	6.3%	3.0%
2020-03-01	88,369	2,996	42,716	42,657	2,358	55	2,934	3.4%	6.6%	1.8%
2020-02-29	86,011	2,941	39,782	43,288	1,899	69	3,071	3.4%	6.9%	2.2%
2020-02-28	84,112	2,872	36,711	44,529	1,366	58	3,434	3.4%	7.3%	1.7%
2020-02-27	82,746	2,814	33,277	46,655	1,358	44	2,893	3.4%	7.8%	1.5%
2020-02-26	81,388	2,770	30,384	48,234	982	62	2,479	3.4%	8.4%	2.4%
2020-02-25	80,406	2,708	27,905	49,793	845	79	2,678	3.4%	8.8%	2.9%
2020-02-24	79,561	2,629	25,227	51,705	603	160	1,833	3.3%	9.4%	8.0%
2020-02-23	78,958	2,469	23,394	53,095	386	11	508	3.1%	9.5%	2.1%
2020-02-22	78,572	2,458	22,886	53,228	1,753	207	3,996	3.1%	9.7%	4.9%
2020-02-21	76,819	2,251	18,890	55,678	622	4	713	2.9%	10.6%	0.6%
2020-02-20	76,197	2,247	18,177	55,773	558	125	2,056	2.9%	11.0%	5.7%
2020-02-19	75,639	2,122	16,121	57,396	503	115	1,769	2.8%	11.6%	6.1%
2020-02-18	75,136	2,007	14,352	58,777	1,878	139	1,769	2.7%	12.3%	7.3%
2020-02-17	73,258	1,868	12,583	58,807	2,034	98	1,718	2.5%	12.9%	5.4%
2020-02-16	71,224	1,770	10,865	58,589	2,194	104	1,470	2.5%	14.0%	6.6%
2020-02-15	69,030	1,666	9,395	57,969	2,145	143	1,337	2.4%	15.1%	9.7%
2020-02-14	66,885	1,523	8,058	57,304	6,517	152	1,763	2.3%	15.9%	7.9%
2020-02-13	60,368	1,371	6,295	52,702	15,147	253	1,145	2.3%	17.9%	18.1%
2020-02-12	45,221	1,118	5,150	38,953	419	5	467	2.5%	17.8%	1.1%
2020-02-11	44,802	1,113	4,683	39,006	2,040	100	737	2.5%	19.2%	11.9%
2020-02-10	42,762	1,013	3,946	37,803	2,612	107	702	2.4%	20.4%	13.2%
2020-02-09	40,150	906	3,244	36,000	3,030	100	628	2.3%	21.8%	13.7%
2020-02-08	37,120	806	2,616	33,698	2,729	87	605	2.2%	23.6%	12.6%
2020-02-07	34,391	719	2,011	31,661	3,597	85	524	2.1%	26.3%	14.0%
2020-02-06	30,794	634	1,487	28,673	3,159	70	363	2.1%	29.9%	16.2%
2020-02-05	27,635	564	1,124	25,947	3,743	72	272	2.0%	33.4%	20.9%
2020-02-04	23,892	492	852	22,548	4,011	66	229	2.1%	36.6%	22.4%
2020-02-03	19,881	426	623	18,832	3,094	64	151	2.1%	40.6%	29.8%
2020-02-02	16,787	362	472	15,953	4,749	103	188	2.2%	43.4%	35.4%
2020-02-01	12,038	259	284	11,495	2,111	46	62	2.2%	47.7%	42.6%
2020-01-31	9,927	213	222	9,492	1,693	42	79	2.1%	49.0%	34.7%
2020-01-30	8,234	171	143	7,920	2,068	38	17	2.1%	54.5%	69.1%
2020-01-29	6,166	133	126	5,907	588	2	19	2.2%	51.4%	9.5%
2020-01-28	5,578	131	107	5,340	2,651	49	46	2.3%	55.0%	51.6%
2020-01-27	2,927	82	61	2,784	809	26	9	2.8%	57.3%	74.3%
2020-01-26	2,118	56	52	2,010	684	14	13	2.6%	51.9%	51.9%
2020-01-25	1,434	42	39	1,353	493	16	3	2.9%	51.9%	84.2%
2020-01-24	941	26	36	879	287	8	6	2.8%	41.9%	57.1%
2020-01-23	654	18	30	606	99	1	2	2.8%	37.5%	33.3%
2020-01-22	555	17	28	510				3.1%	37.8%	NA%

Appendix A.2 Latest Cases by Country

```
## hightlight high death rates (if >= 5%) for those countries with 2000+ confirmed cases
data.latest.all %>% arrange(desc(confirmed)) %>% select(-c(date, ranking)) %>%
  mutate(death.rate=ifelse(confirmed >= 2000 & death.rate >= 5,
                           cell_spec(format(death.rate, big.mark=',') %>% paste0('%'),
                                     "latex", color="red", bold=T),
                           cell_spec(format(death.rate, big.mark=',') %>% paste0('%'),
                                     "latex", color="black", bold=F))) %>%
  kable(format='latex', escape=F, booktabs=T, longtable=T, row.names=T,
        caption=paste0('Cases by Country (', max.date.txt, ')'),
        format.args=list(big.mark=','),
        align=c('l', rep('r', 7))) %>%
  kable_styling(font_size=6, latex_options=c('striped', 'hold_position', 'repeat_header'))
```

Table 6: Cases by Country (24 May 2020 UTC)

	country	confirmed	new.confirmed	current.confirmed	recovered	deaths	new.deaths	death.rate
1	World	5,407,613	97,251	2,893,991	2,168,563	345,059	2,962	**6.4%**
2	US	1,643,246	20,634	1,178,790	366,736	97,720	633	**5.9%**
3	Brazil	363,211	15,813	190,634	149,911	22,666	653	**6.2%**
4	Russia	344,481	8,599	227,641	113,299	3,541	153	1.0%
5	United Kingdom	260,916	2,412	222,890	1,151	36,875	118	**14.1%**
6	Spain	235,772	482	56,644	150,376	28,752	74	**12.2%**
7	Italy	229,858	531	56,594	140,479	32,785	50	**14.3%**
8	France	182,709	673	89,604	64,735	28,370	152	**15.5%**
9	Germany	180,328	342	11,764	160,281	8,283	22	4.6%
10	Turkey	156,827	1,141	33,793	118,694	4,340	32	2.8%
11	India	138,536	7,113	76,820	57,692	4,024	156	2.9%
12	Iran	135,701	2,180	22,483	105,801	7,417	58	**5.5%**
13	Peru	119,959	4,205	66,708	49,795	3,456	83	2.9%
14	Canada	86,106	955	35,574	43,998	6,534	68	**7.6%**
15	China	84,095	11	114	79,343	4,638	0	**5.5%**
16	Saudi Arabia	72,560	2,399	28,650	43,520	390	11	0.5%
17	Chile	69,102	3,709	40,236	28,148	718	45	1.0%
18	Mexico	68,620	2,764	14,247	46,979	7,394	215	**10.8%**
19	Belgium	57,092	282	32,540	15,272	9,280	43	**16.3%**
20	Pakistan	54,601	2,164	36,270	17,198	1,133	32	2.1%
21	Netherlands	45,437	172	39,422	174	5,841	11	**12.9%**
22	Qatar	43,714	1,501	34,521	9,170	23	2	0.1%
23	Ecuador	36,756	498	30,088	3,560	3,108	12	**8.5%**
24	Belarus	36,198	954	21,844	14,155	199	5	0.5%
25	Bangladesh	33,610	1,532	26,229	6,901	480	28	1.4%
26	Sweden	33,459	271	24,490	4,971	3,998	6	**11.9%**
27	Singapore	31,616	548	16,717	14,876	23	0	0.1%
28	Switzerland	30,736	11	730	28,100	1,906	1	**6.2%**
29	Portugal	30,623	152	11,758	17,549	1,316	14	4.3%
30	United Arab Emirates	29,485	781	14,184	15,056	245	1	0.8%
31	Ireland	24,639	57	1,971	21,060	1,608	4	**6.5%**
32	South Africa	22,583	1,240	11,054	11,100	429	22	1.9%
33	Indonesia	22,271	526	15,497	5,402	1,372	21	**6.2%**
34	Poland	21,326	395	11,136	9,194	996	3	4.7%
35	Kuwait	21,302	838	15,029	6,117	156	8	0.7%
36	Colombia	21,175	998	15,432	5,016	727	22	3.4%
37	Ukraine	20,986	406	13,261	7,108	617	12	2.9%
38	Romania	18,070	213	5,486	11,399	1,185	9	**6.6%**
39	Egypt	17,265	752	11,694	4,807	764	29	4.4%
40	Israel	16,717	5	2,285	14,153	279	0	1.7%
41	Japan	16,550	14	2,317	13,413	820	12	**5.0%**
42	Austria	16,503	17	800	15,063	640	1	3.9%
43	Dominican Republic	14,801	379	6,210	8,133	458	0	3.1%
44	Philippines	14,035	258	9,918	3,249	868	5	**6.2%**
45	Argentina	12,076	723	7,892	3,732	452	7	3.7%
46	Denmark	11,559	72	899	10,098	562	1	4.9%
47	Korea, South	11,206	16	713	10,226	267	1	2.4%
48	Serbia	11,159	67	5,064	5,857	238	0	2.1%
49	Panama	10,926	349	4,341	6,279	306	7	2.8%
50	Afghanistan	10,582	584	9,289	1,075	218	2	2.1%
51	Bahrain	9,138	336	4,537	4,587	14	1	0.2%
52	Czechia	8,955	65	2,562	6,078	315	1	3.5%
53	Kazakhstan	8,531	612	4,144	4,352	35	0	0.4%
54	Norway	8,352	6	390	7,727	235	0	2.8%
55	Algeria	8,306	193	2,922	4,784	600	8	**7.2%**
56	Nigeria	7,839	313	5,350	2,263	226	5	2.9%
57	Oman	7,770	513	5,800	1,933	37	1	0.5%
58	Morocco	7,433	27	2,531	4,703	199	1	2.7%
59	Malaysia	7,245	60	1,185	5,945	115	0	1.6%
60	Australia	7,114	0	481	6,531	102	0	1.4%
61	Moldova	7,093	99	3,130	3,713	250	8	3.5%
62	Ghana	6,683	66	4,653	1,998	32	1	0.5%
63	Armenia	6,661	359	3,516	3,064	81	4	1.2%
64	Finland	6,579	11	1,472	4,800	307	1	4.7%
65	Bolivia	6,263	348	5,384	629	250	10	4.0%
66	Cameroon	4,890	490	2,860	1,865	165	6	3.4%
67	Iraq	4,469	197	1,571	2,738	160	8	3.6%
68	Azerbaijan	4,122	140	1,466	2,607	49	0	1.2%

Table 6: Cases by Country (24 May 2020 UTC) *(continued)*

	country	confirmed	new.confirmed	current.confirmed	recovered	deaths	new.deaths	death.rate
69	Luxembourg	3,992	2	115	3,767	110	1	2.8%
70	Honduras	3,950	473	3,302	468	180	13	4.6%
71	Sudan	3,820	192	3,197	458	165	19	4.3%
72	Hungary	3,741	28	1,565	1,690	486	4	**13.0%**
73	Guatemala	3,424	370	3,108	258	58	3	1.7%
74	Guinea	3,275	99	1,582	1,673	20	0	0.6%
75	Uzbekistan	3,164	49	586	2,565	13	0	0.4%
76	Senegal	3,047	71	1,556	1,456	35	1	1.1%
77	Thailand	3,040	0	63	2,921	56	0	1.8%
78	Tajikistan	2,929	191	1,582	1,301	46	2	1.6%
79	Greece	2,878	2	1,333	1,374	171	0	**5.9%**
80	Bulgaria	2,427	19	1,457	840	130	4	**5.4%**
81	Bosnia and Herzegovina	2,401	10	577	1,680	144	3	**6.0%**
82	Cote d'Ivoire	2,376	10	1,127	1,219	30	0	1.3%
83	Djibouti	2,270	0	1,196	1,064	10	0	0.4%
84	Croatia	2,244	1	118	2,027	99	0	4.4%
85	Congo (Kinshasa)	2,141	116	1,761	317	63	0	2.9%
86	North Macedonia	1,978	37	443	1,422	113	0	5.7%
87	Cuba	1,941	10	170	1,689	82	1	4.2%
88	Gabon	1,934	0	1,463	459	12	0	0.6%
89	El Salvador	1,915	96	1,247	633	35	2	1.8%
90	Estonia	1,823	2	227	1,532	64	0	3.5%
91	Iceland	1,804	0	3	1,791	10	0	0.6%
92	Lithuania	1,623	7	422	1,138	63	0	3.9%
93	Somalia	1,594	0	1,329	204	61	0	3.8%
94	Slovakia	1,509	5	180	1,301	28	0	1.9%
95	New Zealand	1,504	0	27	1,456	21	0	1.4%
96	Slovenia	1,468	0	21	1,340	107	1	7.3%
97	Kyrgyzstan	1,403	38	409	980	14	0	1.0%
98	Maldives	1,371	58	1,223	144	4	0	0.3%
99	Kenya	1,214	22	780	383	51	1	4.2%
100	Sri Lanka	1,141	52	458	674	9	0	0.8%
101	Venezuela	1,121	111	849	262	10	0	0.9%
102	Guinea-Bissau	1,114	0	1,066	42	6	0	0.5%
103	Lebanon	1,114	17	400	688	26	0	2.3%
104	Tunisia	1,051	3	86	917	48	0	4.6%
105	Latvia	1,047	1	313	712	22	0	2.1%
106	Kosovo	1,032	7	218	785	29	0	2.8%
107	Mali	1,030	15	368	597	65	2	6.3%
108	Albania	998	9	177	789	32	1	3.2%
109	Equatorial Guinea	960	0	784	165	11	0	1.1%
110	Niger	945	2	101	783	61	0	6.5%
111	Cyprus	935	8	324	594	17	0	1.8%
112	Costa Rica	930	12	300	620	10	0	1.1%
113	Zambia	920	0	577	336	7	0	0.8%
114	Haiti	865	0	817	22	26	0	3.0%
115	Paraguay	862	12	544	307	11	0	1.3%
116	Burkina Faso	814	0	90	672	52	0	6.4%
117	Uruguay	769	5	129	618	22	0	2.9%
118	Andorra	762	0	58	653	51	0	6.7%
119	Georgia	730	2	196	522	12	0	1.6%
120	Diamond Princess	712	0	48	651	13	0	1.8%
121	Jordan	708	4	228	471	9	0	1.3%
122	Sierra Leone	707	86	426	241	40	1	5.7%
123	Chad	675	27	400	215	60	0	8.9%
124	San Marino	665	0	357	266	42	0	6.3%
125	South Sudan	655	0	641	6	8	0	1.2%
126	Malta	610	1	128	476	6	0	1.0%
127	Central African Republic	604	52	581	22	1	0	0.2%
128	Nepal	603	19	513	87	3	0	0.5%
129	Ethiopia	582	88	425	152	5	0	0.9%
130	Jamaica	552	2	332	211	9	0	1.6%
131	Madagascar	527	39	383	142	2	0	0.4%
132	Tanzania	509	0	305	183	21	0	4.1%
133	Congo (Brazzaville)	487	0	324	147	16	0	3.3%
134	Taiwan*	441	0	20	414	7	0	1.6%
135	West Bank and Gaza	423	0	63	357	3	0	0.7%
136	Togo	381	8	228	141	12	0	3.1%

Table 6: Cases by Country (24 May 2020 UTC) *(continued)*

	country	confirmed	new.confirmed	current.confirmed	recovered	deaths	new.deaths	death.rate
137	Cabo Verde	380	9	222	155	3	0	0.8%
138	Mauritius	334	2	2	322	10	0	3.0%
139	Rwanda	327	2	90	237	0	0	0.0%
140	Vietnam	325	0	58	267	0	0	0.0%
141	Montenegro	324	0	0	315	9	0	2.8%
142	Nicaragua	279	0	63	199	17	0	6.1%
143	Liberia	265	10	100	139	26	0	9.8%
144	Sao Tome and Principe	251	0	239	4	8	0	3.2%
145	Eswatini	250	12	92	156	2	0	0.8%
146	Mauritania	237	10	216	15	6	0	2.5%
147	Yemen	222	10	170	10	42	3	18.9%
148	Burma	201	0	73	122	6	0	3.0%
149	Uganda	198	0	130	68	0	0	0.0%
150	Mozambique	194	26	143	51	0	0	0.0%
151	Benin	191	56	106	82	3	0	1.6%
152	Brunei	141	0	3	137	1	0	0.7%
153	Mongolia	141	0	109	32	0	0	0.0%
154	Guyana	135	8	63	62	10	0	7.4%
155	Cambodia	124	0	2	122	0	0	0.0%
156	Trinidad and Tobago	116	0	0	108	8	0	6.9%
157	Bahamas	100	0	44	45	11	0	11.0%
158	Monaco	98	0	4	90	4	0	4.1%
159	Barbados	92	0	15	70	7	0	7.6%
160	Comoros	87	9	65	21	1	0	1.1%
161	Syria	86	16	41	41	4	0	4.7%
162	Malawi	83	1	46	33	4	1	4.8%
163	Liechtenstein	82	0	26	55	1	0	1.2%
164	Libya	75	0	33	39	3	0	4.0%
165	Angola	69	8	47	18	4	0	5.8%
166	Zimbabwe	56	0	27	25	4	0	7.1%
167	Burundi	42	0	21	20	1	0	2.4%
168	Eritrea	39	0	0	39	0	0	0.0%
169	Botswana	35	5	15	19	1	0	2.9%
170	Antigua and Barbuda	25	0	3	19	3	0	12.0%
171	Gambia	25	0	11	13	1	0	4.0%
172	Bhutan	24	0	18	6	0	0	0.0%
173	Timor-Leste	24	0	0	24	0	0	0.0%
174	Grenada	22	0	5	17	0	0	0.0%
175	Namibia	21	1	7	14	0	0	0.0%
176	Laos	19	0	5	14	0	0	0.0%
177	Belize	18	0	0	16	2	0	11.1%
178	Fiji	18	0	3	15	0	0	0.0%
179	Saint Lucia	18	0	0	18	0	0	0.0%
180	Saint Vincent and the Grenadines	18	0	4	14	0	0	0.0%
181	Dominica	16	0	0	16	0	0	0.0%
182	Saint Kitts and Nevis	15	0	0	15	0	0	0.0%
183	Holy See	12	0	10	2	0	0	0.0%
184	Seychelles	11	0	0	11	0	0	0.0%
185	Suriname	11	0	1	9	1	0	9.1%
186	MS Zaandam	9	0	7	0	2	0	22.2%
187	Western Sahara	9	3	3	6	0	0	0.0%
188	Papua New Guinea	8	0	0	8	0	0	0.0%
189	Lesotho	2	0	2	0	0	0	0.0%

Appendix B. How to Cite This Work

Citation

Yanchang Zhao, COVID-19 Data Analysis with R – Worldwide. RDataMining.com, 2020. URL: http://www.rdatamining.com/docs/Coronavirus-data-analysis-world.pdf.

BibTex

@techreport{Zhao2020Covid19world,
Author = {Yanchang Zhao},

Institution = {RDataMining.com},
Title = {COVID-19 Data Analysis with R – Worldwide},
Url = {http://www.rdatamining.com/docs/Coronavirus-data-analysis-world.pdf},
Year = {2020}}

Appendix C. Contact

Contact:

Dr. Yanchang Zhao

Email: yanchang@RDataMining.com

Twitter: @RDataMining

LinkedIn: http://group.rdatamining.com

Comments and suggestions and welcome. Thanks!