Appendix

```
library(dplyr)
```

```
## Warning: package 'dplyr' was built under R version 4.0.5
```

```
##
## Attaching package: 'dplyr'
```

```
## The following objects are masked from 'package:stats':
##
##     filter, lag
```

```
## The following objects are masked from 'package:base':
##
##     intersect, setdiff, setequal, union
```

```
library(lubridate)
```

```
## Warning: package 'lubridate' was built under R version 4.0.5
```

```
##
## Attaching package: 'lubridate'
```

```
## The following objects are masked from 'package:base':
##
##     date, intersect, setdiff, union
```

```
library(forecast)
```

```
## Warning: package 'forecast' was built under R version 4.0.5
```

```
## Registered S3 method overwritten by 'quantmod':
##   method            from
##   as.zoo.data.frame zoo
```

```
library(TTR)
```

```
## Warning: package 'TTR' was built under R version 4.0.5
```

```
library(ggplot2)
```

```
## Warning: package 'ggplot2' was built under R version 4.0.5
```

```
library(tseries)
```

```
## Warning: package 'tseries' was built under R version 4.0.5
```

```
library(gridExtra)
```

```
## Warning: package 'gridExtra' was built under R version 4.0.5
```

```
## 
## Attaching package: 'gridExtra'
```

```
## The following object is masked from 'package:dplyr':
## 
##     combine
```

```
covid <- read.csv("Bangladesh.csv")
summary(covid)
```

```
##  Date_reported      Country_code         Country           WHO_region       
##  Length:793         Length:793         Length:793         Length:793        
##  Class :character   Class :character   Class :character   Class :character  
##  Mode  :character   Mode  :character   Mode  :character   Mode  :character  
##                                                                             
##                                                                             
##                                                                             
##    New_cases     Cumulative_cases    New_deaths     Cumulative_deaths
##  Min.   :    0   Min.   :      3   Min.   : -6.00   Min.   :    0    
##  1st Qu.:  396   1st Qu.: 352178   1st Qu.:  6.00   1st Qu.: 5007    
##  Median : 1470   Median : 666132   Median : 22.00   Median : 9521    
##  Mean   : 2463   Mean   : 879287   Mean   : 36.73   Mean   :14097    
##  3rd Qu.: 2907   3rd Qu.:1567417   3rd Qu.: 39.00   3rd Qu.:27814    
##  Max.   :16230   Max.   :1952776   Max.   :264.00   Max.   :29127    
```

```
glimpse(covid)
```

```
## Rows: 793
## Columns: 8
## $ Date_reported     <chr> "08-03-20", "09-03-20", "10-03-20", "11-03-20", "12-~
## $ Country_code      <chr> "BD", "BD", "BD", "BD", "BD", "BD", "BD", "BD", "BD"~
## $ Country           <chr> "Bangladesh", "Bangladesh", "Bangladesh", "Banglades~
## $ WHO_region        <chr> "SEARO", "SEARO", "SEARO", "SEARO", "SEARO", "SEARO"~
## $ New_cases         <int> 3, 4, 0, 0, 0, 0, 0, 0, 1, 1, 1, 7, 0, 7, 0, 9, 6, 0~
## $ Cumulative_cases  <int> 3, 7, 7, 7, 7, 7, 7, 7, 8, 9, 10, 17, 17, 24, 24, 33~
## $ New_deaths        <int> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 1, 1, 1, 1~
## $ Cumulative_deaths <int> 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 1, 1, 2, 3, 4, 5~
```

```
#Checking Missing Values
colSums(is.na(covid))
```

```
##     Date_reported      Country_code           Country        WHO_region
##                 0                 0                 0                 0
##         New_cases  Cumulative_cases        New_deaths Cumulative_deaths
##                 0                 0                 0                 0
```

```
#Convert Date From Character
covid$Date_reported <- as.Date(covid$Date_reported,"%d-%m-%y")

#Checking Type and Class
typeof(covid$Date_reported)
```

```
## [1] "double"
```

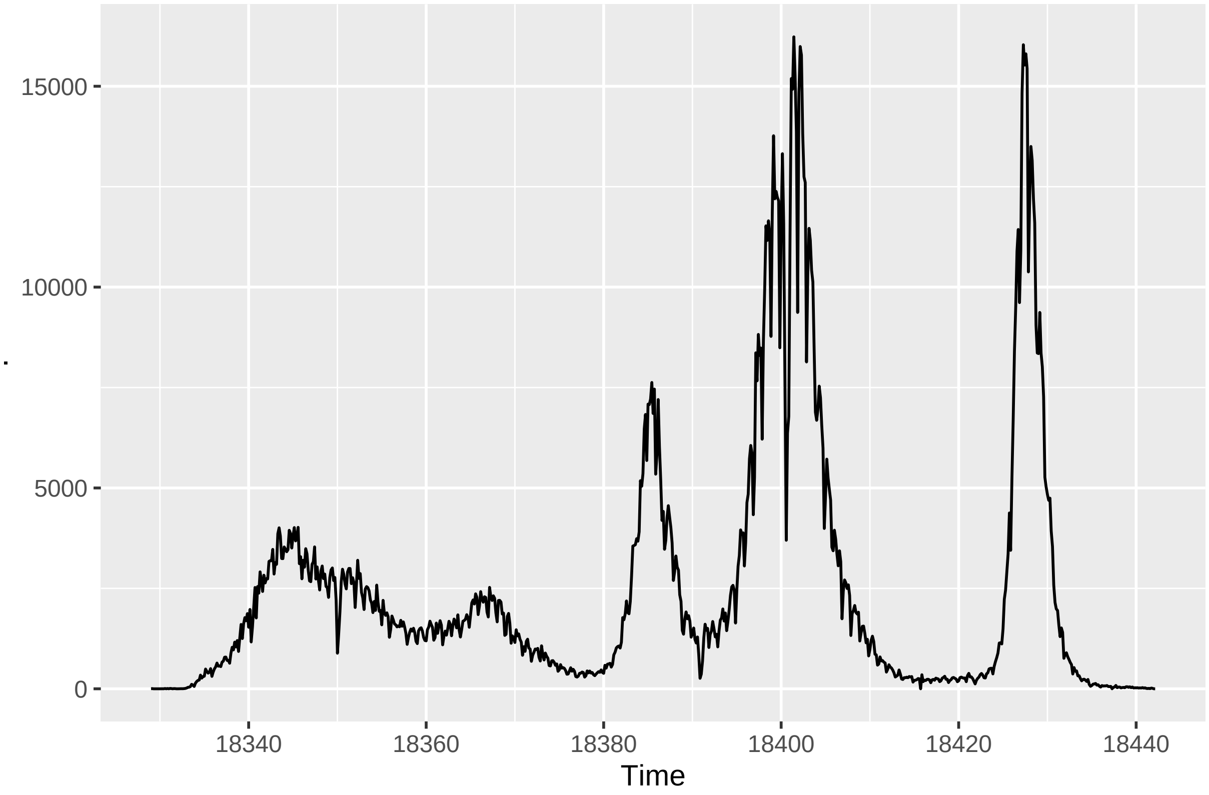
```
class(covid$Date_reported)
```

```
## [1] "Date"
```

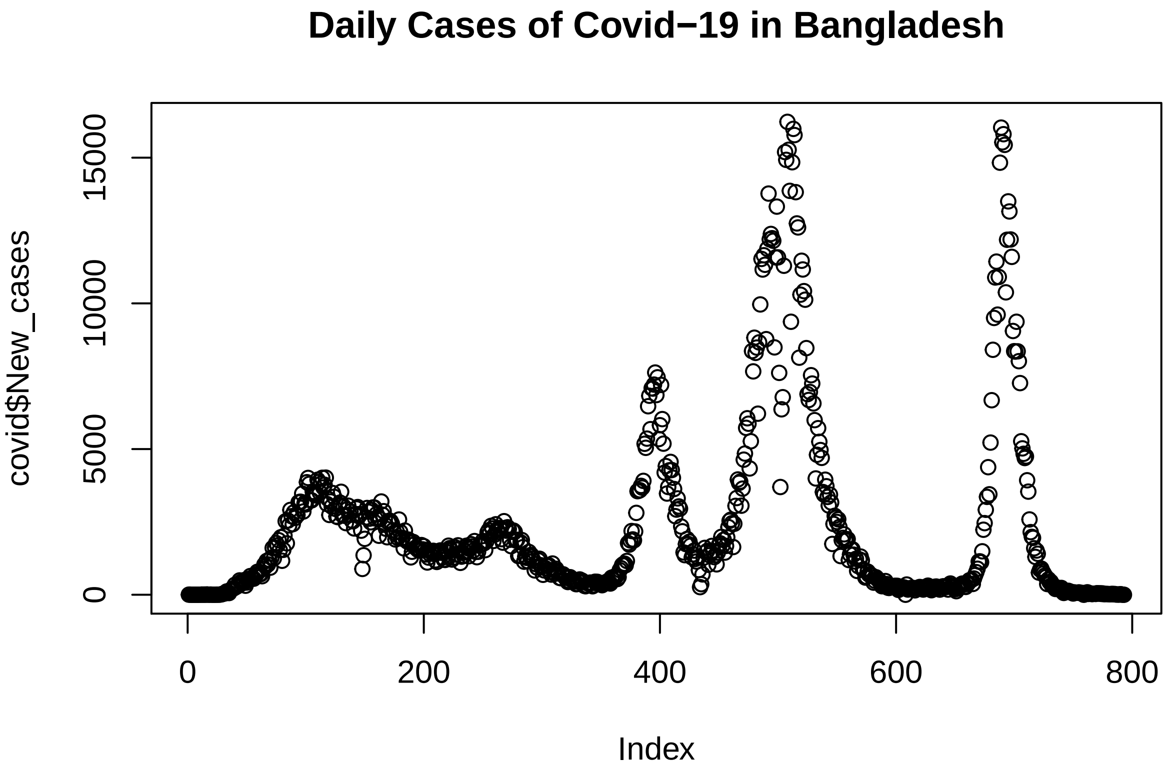
```
#Checking ranges of date variable
range(covid$Date_reported)
```

```
## [1] "2020-03-08" "2022-05-09"
```

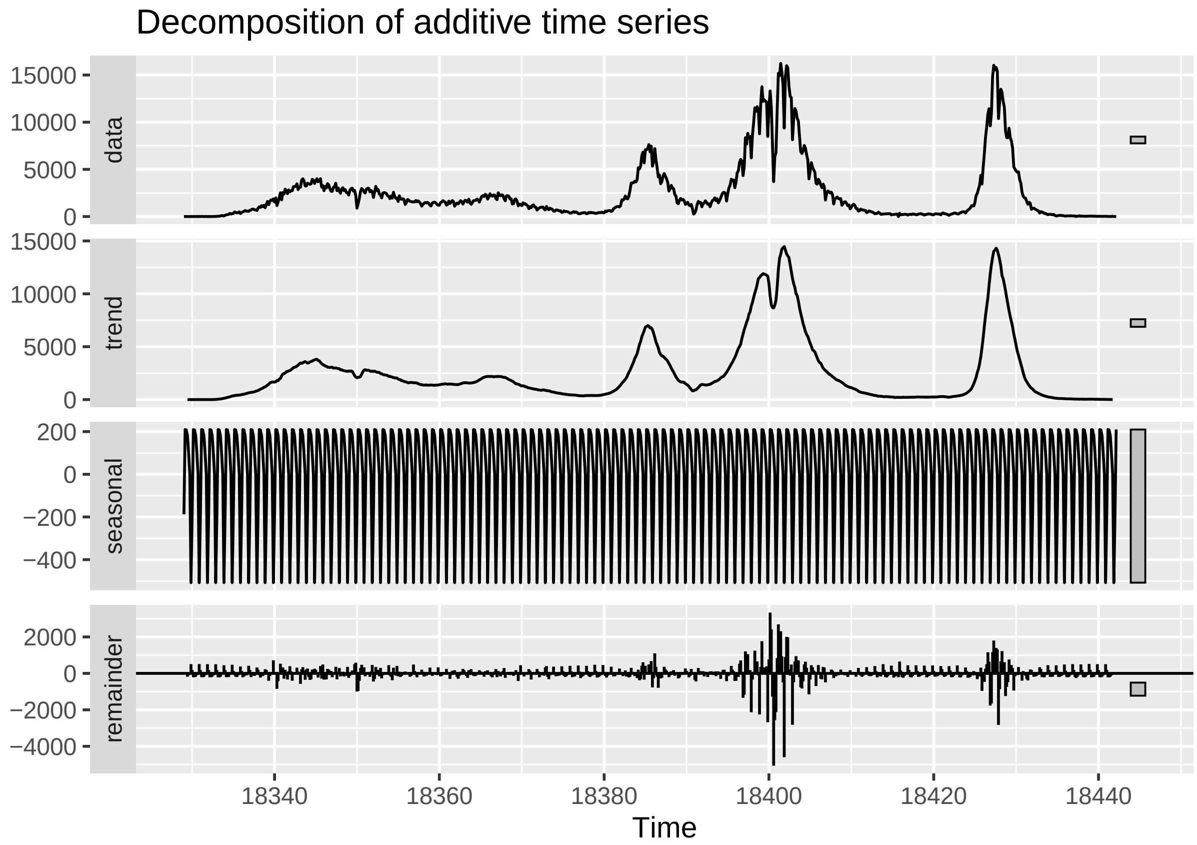
```
#create object ts
covid_ts <- ts(data = covid$New_cases,
               start = min(covid$Date_reported),
               frequency = 7) #weekly seasonality

#visualise object covid_ts
covid_ts %>% autoplot()
```



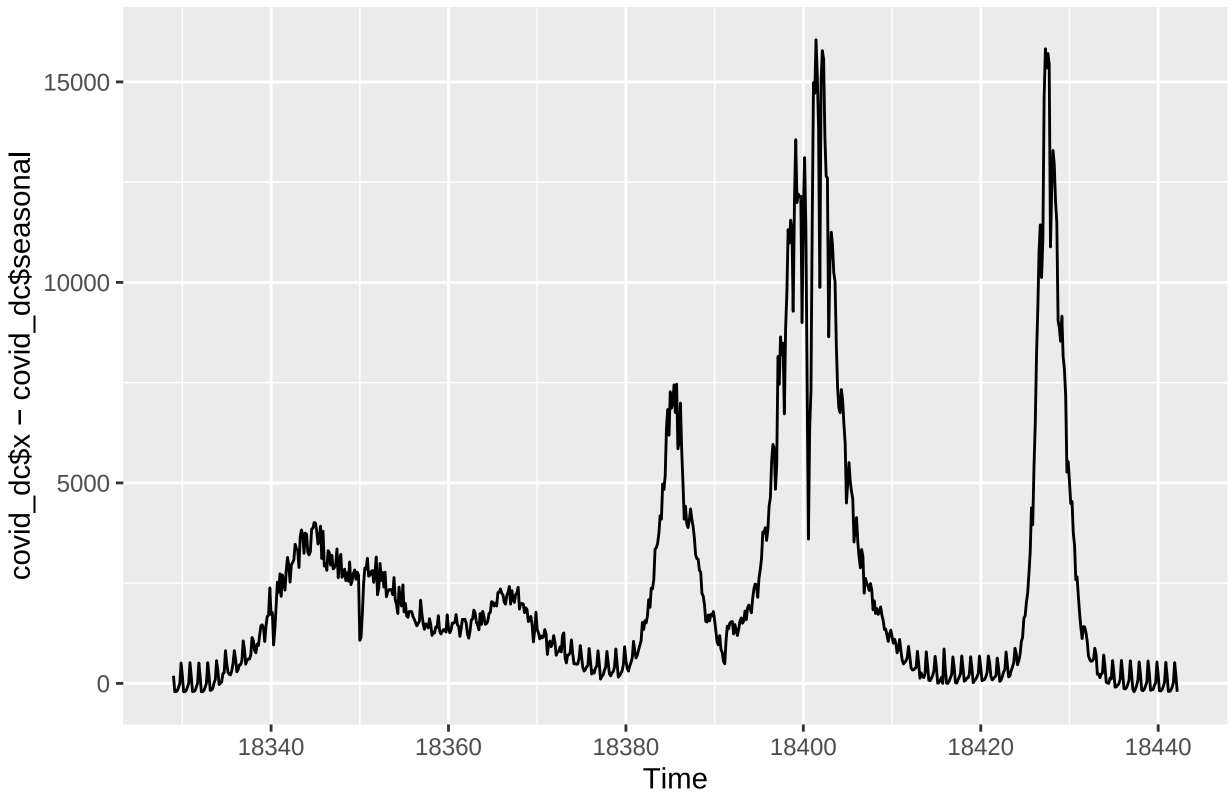
```
#Visualize New Cases
plot(covid$New_cases, main = "Daily Cases of Covid-19 in Bangladesh")
```



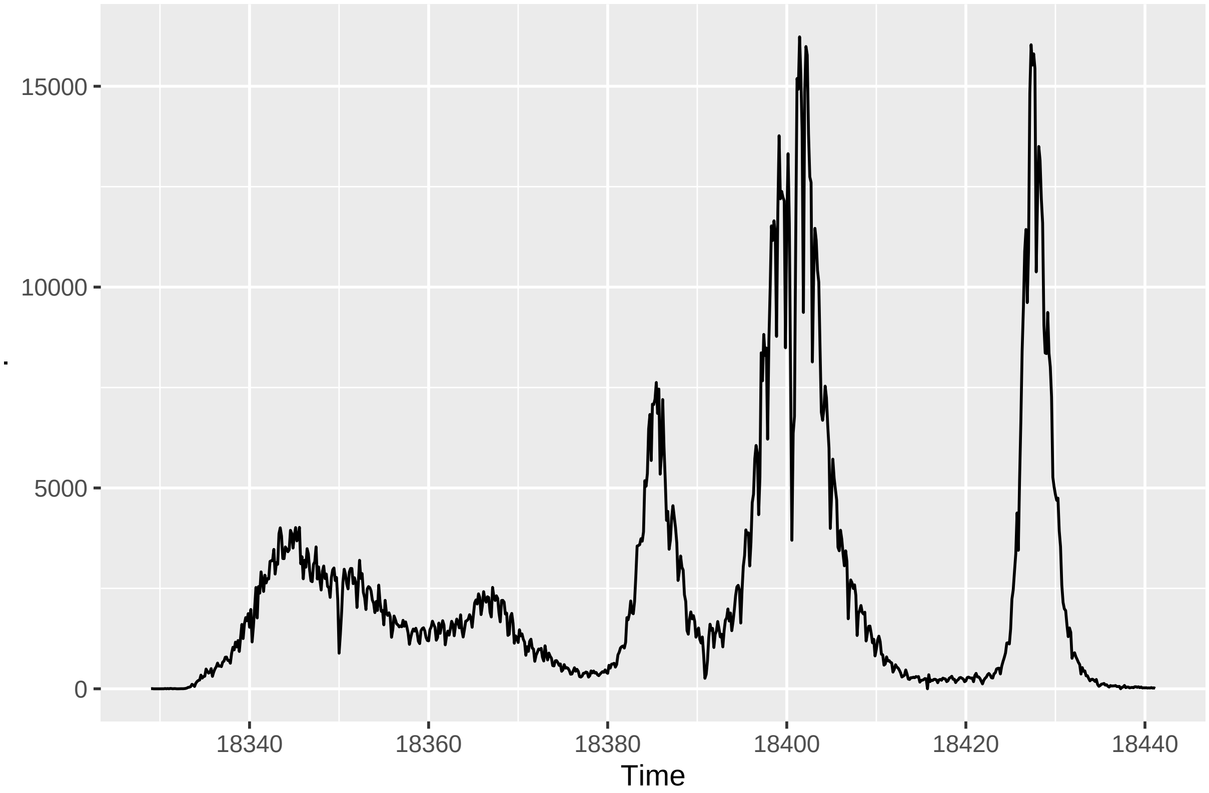
```
#Decompose TS
covid_dc <- decompose(covid_ts)
covid_dc %>% autoplot()
```



```
autoplot(covid_dc$x - covid_dc$seasonal)
```



```
#Setting Testing and Training data
test <- tail(covid_ts, 7) #get 7 last days
train <- head(covid_ts, length(covid_ts) - length(test)) #get the rest data

train %>% autoplot()
```



```
#ETS Model
covid_ets <- ets(y = train, model = "ZZZ")
covid_ets
```

```
## ETS(A,N,A)
##
## Call:
##  ets(y = train, model = "ZZZ")
##
##   Smoothing parameters:
##     alpha = 0.9999
##     gamma = 1e-04
##
##   Initial states:
##     l = 51.5322
##     s = -512.2099 -0.1892 98.2421 182.1805 210.1997 211.5393
##            -189.7625
##
##   sigma:  667.05
##
##      AIC     AICc      BIC
## 15473.68 15473.96 15520.35
```

```
#Holt Model
covid_holt <- HoltWinters(x = train, gamma = F)
covid_holt
```

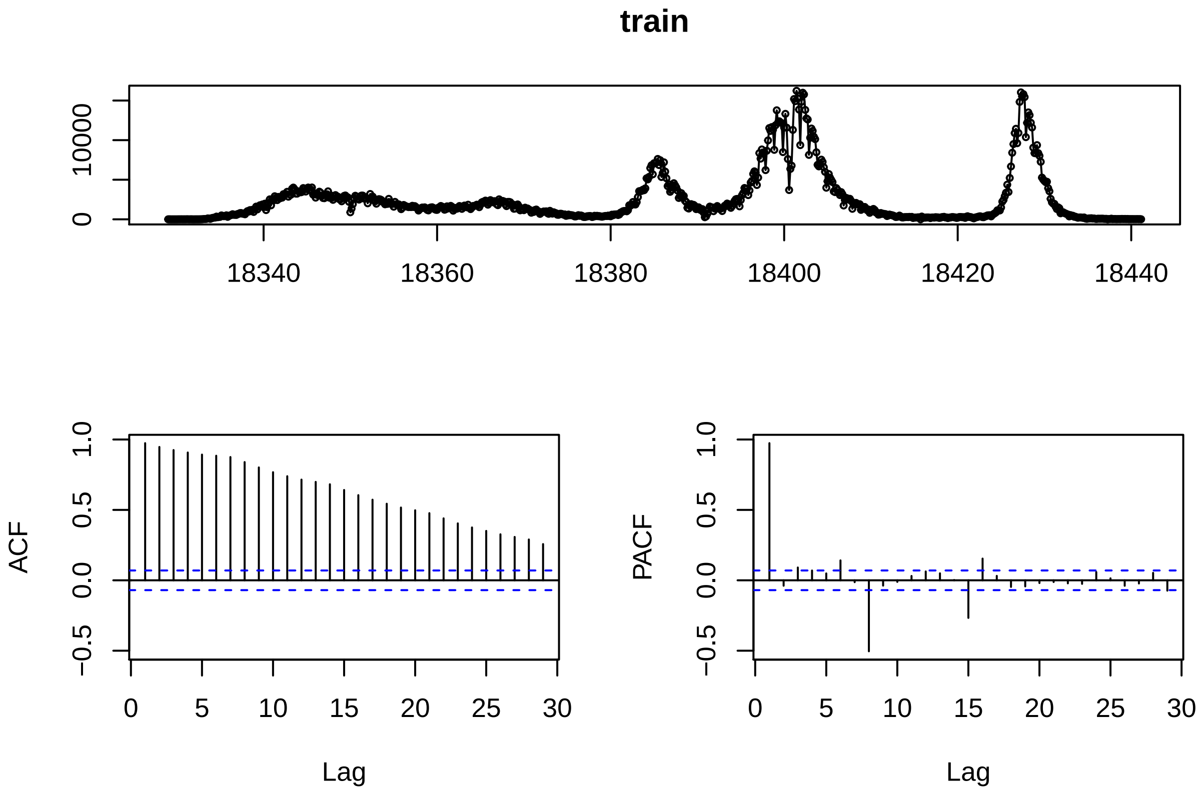
```
## Holt-Winters exponential smoothing with trend and without seasonal component.
##
## Call:
## HoltWinters(x = train, gamma = F)
##
## Smoothing parameters:
##  alpha: 1
##  beta : 0
##  gamma: FALSE
##
## Coefficients:
##   [,1]
## a   10
## b    1
```

```
#Testing Stationarity
adf.test(train)
```

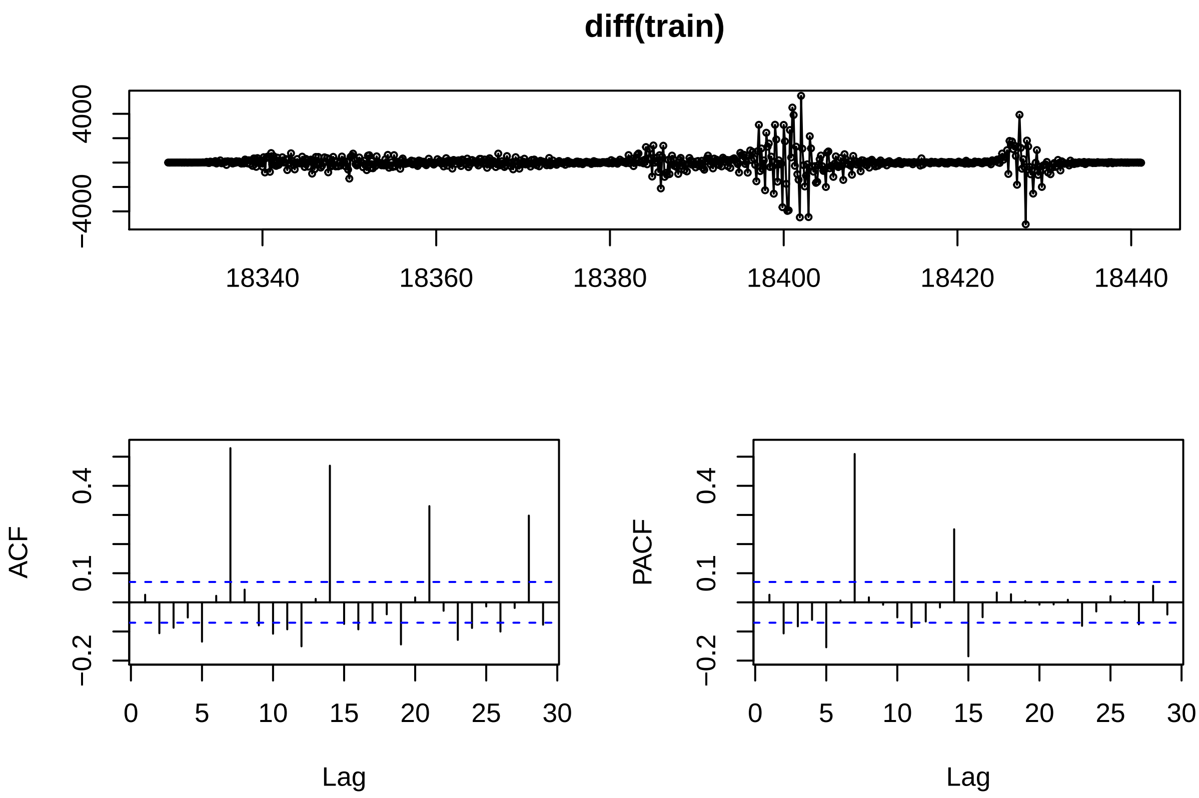
```
## Warning in adf.test(train): p-value smaller than printed p-value
```

```
##
##  Augmented Dickey-Fuller Test
##
## data:  train
## Dickey-Fuller = -4.0373, Lag order = 9, p-value = 0.01
## alternative hypothesis: stationary
```

```
#Plot of ACF & PACF
tsdisplay(train)
```



```
#Plot of ACF & PACF (Diff)
tsdisplay(diff(train))
```



```
#Testing ARIMA modeling
covid_arima1 <- Arima(y = train, order = c(1,0,1))
covid_arima2 <- Arima(y = train, order = c(1,0,2))
covid_arima3 <- Arima(y = train, order = c(1,0,3))

#Testing Auto ARIMA
covid_arima_auto <- auto.arima(y = train)
covid_arima_auto
```

```
## Series: train
## ARIMA(1,1,3)(1,0,1)[7]
##
## Coefficients:
##           ar1     ma1     ma2      ma3   sar1     sma1
##       -0.9578  0.9986  0.0255  -0.0415  0.807  -0.3954
## s.e.   0.0279  0.0452  0.0507   0.0361  0.034   0.0544
##
## sigma^2 estimated as 346509:  log likelihood=-6119.06
## AIC=12252.11   AICc=12252.26   BIC=12284.77
```

```
#Accuracy

accuracy(covid_ets)
```

```
##                      ME   RMSE      MAE MPE MAPE      MASE       ACF1
## Training set -0.3218918 663.22 355.8808 NaN  Inf 0.4493051 0.02240211
```

```
accuracy(covid_arima1)
```

```
##                    ME     RMSE      MAE  MPE MAPE      MASE         ACF1
## Training set 2.225368 713.3017 342.9311 -Inf  Inf 0.4329559 -0.003235571
```

```
accuracy(covid_arima2)
```

```
##                    ME     RMSE      MAE  MPE MAPE      MASE        ACF1
## Training set 2.390689 710.2794 339.2293 -Inf  Inf 0.4282823 0.009282414
```

```
accuracy(covid_arima3)
```

```
##                    ME     RMSE      MAE  MPE MAPE      MASE         ACF1
## Training set 1.828161 707.4105 338.4331 -Inf  Inf 0.4272772 -0.004163246
```

```
accuracy(covid_arima_auto)
```

```
##                       ME     RMSE     MAE MPE MAPE      MASE          ACF1
## Training set -0.01705068 586.0228 285.705 NaN  Inf 0.3607071 -9.795246e-05
```

```
#AIC
covid_ets$aic
```

```
## [1] 15473.68
```

```
covid_arima1$aic
```

```
## [1] 12569.45
```

```
covid_arima2$aic
```

```
## [1] 12564.79
```

```
covid_arima3$aic
```

```
## [1] 12560.46
```

```
covid_arima_auto$aic
```

```
## [1] 12252.11
```

```
#Forecasting
covid_ets_f <- forecast(covid_ets, h = 7)
covid_holt_f <- forecast(covid_holt, h = 7)
covid_arima_f <- forecast(covid_arima1, h = 7)

covid_ets_f
```

```
##          Point Forecast       Lo 80     Hi 80     Lo 95    Hi 95
## 18441.29       8.740591  -846.1184  863.5996 -1298.653 1316.135
## 18441.43     -19.243960 -1228.1319 1189.6439 -1868.078 1829.591
## 18441.57    -103.193359 -1583.7459 1377.3592 -2367.503 2161.116
## 18441.71    -201.651852 -1911.2313 1507.9276 -2816.228 2412.924
## 18441.86    -713.607019 -2624.9646 1197.7506 -3636.776 2209.562
## 18442.00    -391.204816 -2484.9846 1702.5750 -3593.365 2810.955
## 18442.14      10.003313 -2251.5639 2271.5705 -3448.765 3468.772
```

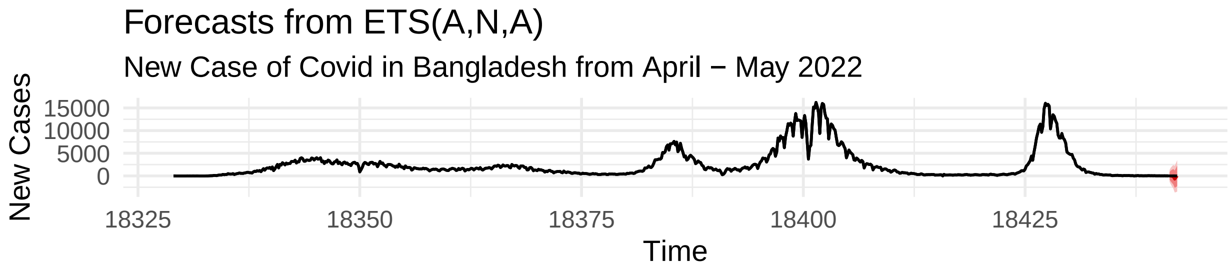
```
covid_holt_f
```

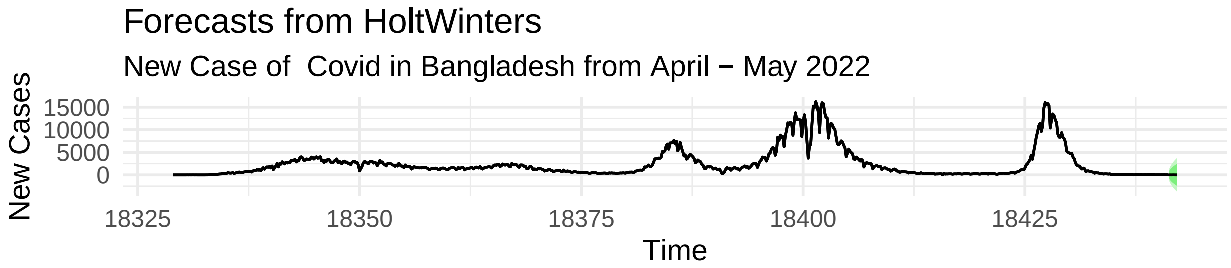
```
##          Point Forecast       Lo 80     Hi 80     Lo 95    Hi 95
## 18441.29             11  -911.2149  933.2149 -1399.406 1421.406
## 18441.43             12 -1292.2088 1316.2088 -1982.615 2006.615
## 18441.57             13 -1584.3231 1610.3231 -2429.895 2455.895
## 18441.71             14 -1830.4298 1858.4298 -2806.812 2834.812
## 18441.86             15 -2047.1352 2077.1352 -3138.764 3168.764
## 18442.00             16 -2242.9560 2274.9560 -3438.775 3470.775
## 18442.14             17 -2422.9513 2456.9513 -3714.584 3748.584
```

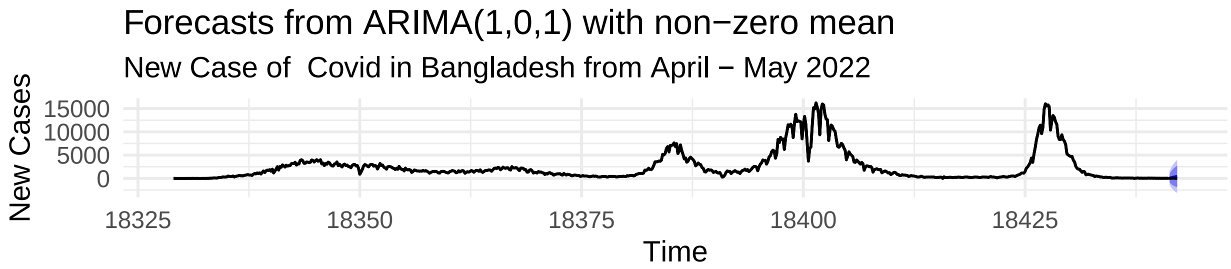
```
covid_arima_f
```

```
##          Point Forecast       Lo 80     Hi 80     Lo 95    Hi 95
## 18441.29       72.93587  -842.9466  988.8184 -1327.786 1473.657
## 18441.43      137.94148 -1170.7657 1446.6487 -1863.553 2139.436
## 18441.57      201.11518 -1392.0041 1794.2345 -2235.351 2637.581
## 18441.71      262.50858 -1558.8873 2083.9044 -2523.076 3048.093
## 18441.86      322.17186 -1691.1896 2335.5333 -2756.999 3401.342
## 18442.00      380.15378 -1799.0341 2559.3417 -2952.627 3712.934
## 18442.14      436.50171 -1888.4634 2761.4669 -3119.226 3992.229
```

```
#Plot of forecasting

a <- autoplot(covid_ets_f, series = "ETS", fcol = "red") +
  autolayer(covid_ts, series = "Actual", color = "black") +
  labs(subtitle = "New Case of Covid in Bangladesh from April - May 2022",
       y = "New Cases") +
  theme_minimal()

b <- autoplot(covid_holt_f, series = "HOLT", fcol = "green") +
  autolayer(covid_ts, series = "Actual", color = "black") +
  labs(subtitle = "New Case of  Covid in Bangladesh from April - May 2022",
       y = "New Cases") +
  theme_minimal()

c <- autoplot(covid_arima_f, series = "ARIMA", fcol = "blue") +
  autolayer(covid_ts, series = "Actual", color = "black") +
  labs(subtitle = "New Case of  Covid in Bangladesh from April - May 2022",
       y = "New Cases") +
  theme_minimal()

grid.arrange(a,b,c)
```







```r
#Accuracy of Forecasting
accuracy(covid_ets_f, test)
```

```
##                         ME     RMSE      MAE MPE MAPE      MASE       ACF1
## Training set  -0.3218918 663.2200 355.8808 NaN  Inf 0.4493051 0.02240211
## Test set     208.5938717 324.6502 211.9493 NaN  Inf 0.2675893 0.26552305
##              Theil's U
## Training set        NA
## Test set         19.72
```

```r
accuracy(covid_holt_f, test)
```

```
##                        ME       RMSE        MAE  MPE MAPE       MASE       ACF1
## Training set -0.9923469 719.149723 339.397959 -Inf  Inf 0.42849527 0.02607242
## Test set     -6.8571429   9.971388   8.285714 -Inf  Inf 0.01046084 0.20672007
##              Theil's U
## Training set        NA
## Test set     0.5666677
```

```r
accuracy(covid_arima_f, test)
```

```
##                         ME     RMSE      MAE  MPE MAPE      MASE         ACF1
## Training set    2.225368 713.3017 342.9311 -Inf  Inf 0.4329559 -0.003235571
## Test set     -251.904067 280.6547 251.9041 -Inf  Inf 0.3180329  0.571029803
##              Theil's U
## Training set        NA
## Test set      19.70011
```

```
#Residuals
shapiro.test(covid_ets_f$residuals)
```

```
##
##  Shapiro-Wilk normality test
##
## data:  covid_ets_f$residuals
## W = 0.72639, p-value < 2.2e-16
```

```
shapiro.test(covid_holt_f$residuals)
```

```
##
##  Shapiro-Wilk normality test
##
## data:  covid_holt_f$residuals
## W = 0.67157, p-value < 2.2e-16
```

```
shapiro.test(covid_arima_f$residuals)
```

```
##
##  Shapiro-Wilk normality test
##
## data:  covid_arima_f$residuals
## W = 0.66739, p-value < 2.2e-16
```

```
#Box Plot
Box.test(covid_ets_f$residuals, type = "Ljung-Box")
```

```
##
##  Box-Ljung test
##
## data:  covid_ets_f$residuals
## X-squared = 0.39596, df = 1, p-value = 0.5292
```

```
Box.test(covid_holt_f$residuals, type = "Ljung-Box")
```

```
##
##  Box-Ljung test
##
## data:  covid_holt_f$residuals
## X-squared = 0.53498, df = 1, p-value = 0.4645
```

```
Box.test(covid_arima_f$residuals, type = "Ljung-Box")
```

```
##
##  Box-Ljung test
##
## data:  covid_arima_f$residuals
## X-squared = 0.00826, df = 1, p-value = 0.9276
```