

Time Series Analysis of Capital Bike Share Data

STAT 8281-10

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ABSTRACT

Bike sharing system are a means of renting bicycles throughout the city. The process of membership registration, rental and return is automated via a network of kiosk locations. People can enjoy a more flexible low-rate public transit through streets than bus or metro. The status of kiosk location always influence the usage experience. There exists high correlations between usage and time. In this research, ARIMA(2,1,2) model with seasonal $(1,0,0)_{24}$ in time series analysis works well with the forecasting of usage for next 24 hours. The results show that users of bike sharing system have a high degree of regularity during the working days.

DATA AND MOTIVATION

INTRODUCTION

Washington DC is not only famous as the capital of United States, but also is an international metropolis. As the most big cities, the traffic of DC during rush hour always become terrible around downtown area. People always spend more time on the road than they expected. It makes no sense to drive their vehicles due to congested traffic and expensive parking fee. In this situation, public transits play an significantly important role. However, among several types of public transits, bike sharing system has significant advantages comparing with metro and shuttle. For instance, bike performs better than bus when meeting traffic jam and is more flexible than scheduled metro. In addition, average cost of rental bike is always cheaper than metro and shuttle.

There are not only advantages but also some weaknesses of bike sharing system. From its own shortcomings, bike is not a good choice under extreme weather, such as hot or cold temperature, rainy day or snow. Weather is an important factor of effect on the usage of bike. Since the entire bike sharing system is based on the network of kiosk locations, the limitation of location can also restrict the usage experience. Sometimes users find that there are no bikes in the station when they need to use or there is no space in the station while approaching destination. Therefore, this project used time series analysis to find the behavior of rental bike and forecast the usage situation for future few days.

DATASET

The capital bike sharing data comes from kaggle[1], which is a website for data science and machine learning. In this dataset, there are total 11 variables and their names and descriptions are shown on Table 0.1. Among these 11 variables, this project focused on *count* and *datetime*. The main purpose is to find a model to estimate the number of usage based on time and then to forecast the usage of rental bike for next 24 hours. In addition, there is a little more explanation about *datetime*.

DATETIME The variable *datetime* is from Jan 1st 2011 midnight to 11:00 p.m Dec 19th 2012 hourly. In *R* program, the normal method that using the function *ts()* creates a time series data is not suitable for hourly data. The idea to deal with this situation is to transform the *datetime* to numerical number and every numbers can represent a special hour with date. Between two consecutive numbers is divided into 24 equally pieces. For instance, "14975.042" can represent a special date with hour. The whole part of the number "14975" represents the date 01 – 01 – 2011, Jan 1th 2012. And the decimal part, $0.042 \approx \frac{1}{24}$, represents the second hour which is 1:00 a.m. So, it is obvious that the whole number represents the midnight of that day. Finally, the function *as.chron()* under the package *chron* can transform the numerical number back to the data form.

Table 0.1: Variables' name and description

Variables	Description
datetime	Time on hours from 1st Jan 2011 to 19th Dec 2012.
season	Dummy variables, 1–spring, 2–summer, 3–fall, 4–winter
holiday	Dummy variables, 0–not holiday, 1–holiday
workingday	Dummy variables, 0–not working day, 1–working day
weather	1– Clear, Few clouds, Partly cloudy, Partly cloudy; 2–Mist + Cloudy, Mist + Broken clouds, Mist + Few clouds, Mist 3–Light Snow, Light Rain + Thunderstorm + Scattered clouds, Light Rain + Scattered clouds
temp	Temperature in Celsius
atemp	Somatosensory temperature in Celsius
windspeed	Wind speed
casual	Number of non-registered user rentals initiated
registered	Number of registered user rentals initiated
count	Number of total rentals

COUNT There are three variables to display the number of user, including *casual*, *registered* and *count*. The *casual* means users who do not register before. And *registered* means users who have registered for a membership. The only difference between them is that casual users need to pay each rental but the registered users can rent bikes for free since they have paid for whole year. Therefore, this project has interested in the total number of users, *count*.

METHODS

There are two models to fit the capital bike sharing data. The first one is exponential trend seasonal(ETS) model[2], which is also named Holt-Winters seasonal model[2]. The other is seasonal autoregressive integrated moving average (SARIMA) model. Both of these are common methods in time series analysis.

ETS MODEL

The Holt-Winters seasonal model comprises the forecast equation and three smoothing equations—one for the level l_t , one for trend b_t , and one for the seasonal component denoted by s_t , with smoothing parameters α , β^* and γ . If the seasonal variations are approximately constant through the series, an additive model is preferred. Otherwise, the multiplicative model is better for seasonal variations with mutative proportional to the level of series. In this project, the seasonal variations of this data are roughly constant. So here, the additive model will be introduced particularly.

HOLT-WINTERS ADDITIVE MODEL The component form for the additive method is:

$$\begin{aligned} y_{t+h|t} &= l_t + hb_t + s_{t-m+h_m^+} \\ l_t &= \alpha(y_t - s_{t-m}) + (1 - \alpha)(l_{t-1} + b_{t-1}) \\ b_t &= \beta^*(l_t - l_{t-1}) + (1 - \beta^*)b_{t-1} \\ s_t &= \gamma(y_t - l_{t-1} - b_{t-1}) + (1 - \gamma)s_{t-m} \end{aligned}$$

where $h_m^+ = \lfloor (h - 1) \bmod m \rfloor + 1$, which makes sure that the estimates of the seasonal indices used for forecasting come from the final time of the sample. Now, for each equation, the second one is level equation which is a weighted average between the seasonally adjusted observation ($y_t - s_{t-m}$) and the non-seasonal forecast ($l_{t-1} + b_{t-1}$) for time t . The trend equation, the third one, is identical to Holt's linear model. And the last seasonal equation provides a weighted average between the current seasonal index, ($y_t - l_{t-1} - b_{t-1}$), and the seasonal index of the same season last period.

The error correction form of the smoothing equations is:

$$\begin{aligned} l_t &= l_{t-1} + b_{t-1} + \alpha\epsilon_t \\ b_t &= b_{t-1} + \alpha\beta^*\epsilon_t \\ s_t &= s_{t-m} + \gamma\epsilon_t \end{aligned}$$

where $\epsilon_t = y_t - (l_{t-1} + b_{t-1} + s_{t-m}) = y_t - \hat{y}_{t|t-1}$

R PROGRAM There are two functions can provide ETS model. One is *HoltWinters()*, just named by the creators, from the package *base*. The other is the function *ets()* from package *forecasting*. Even both these functions can fit the data with ETS model, the function *ets()* can provide the results from several test methods directly which helps to compare the goodness between different models.

SARIMA MODEL

ARMA MODEL By the definition from the textbook[3], a time series is ARMA(p,q) if it is stationary and

$$x_t = \phi_1 x_{t-1} + \dots + \phi_p x_{t-p} + w_t + \theta_1 w_{t-1} + \dots + \theta_q w_{t-q}$$

where $\phi_p \neq 0$, $\theta_q \neq 0$ and $\sigma_w^2 > 0$

ARIMA MODEL Then a process x_t is ARIMA(p,d,q) if

$$\nabla^d x_t = (1 - B)^d x_t$$

is ARMA(p,q).

SARIMA MODEL Finally, the multiplicative seasonal autoregressive integrated moving average (SARIMA) model is given by

$$\Phi_P(B^s)\phi(B)\nabla_s^D\nabla^d x_t = \delta + \Theta_Q(B^s)\theta(B)w_t$$

where w_t is the usual Gaussian white noise process.

RESULTS

DECOMPOSE

Decomposing time series data is important and necessary. A time series data can comprise three components: a seasonal component, a trend component and a remainder component (the hope is that the remainder component shows a white noise distribution).

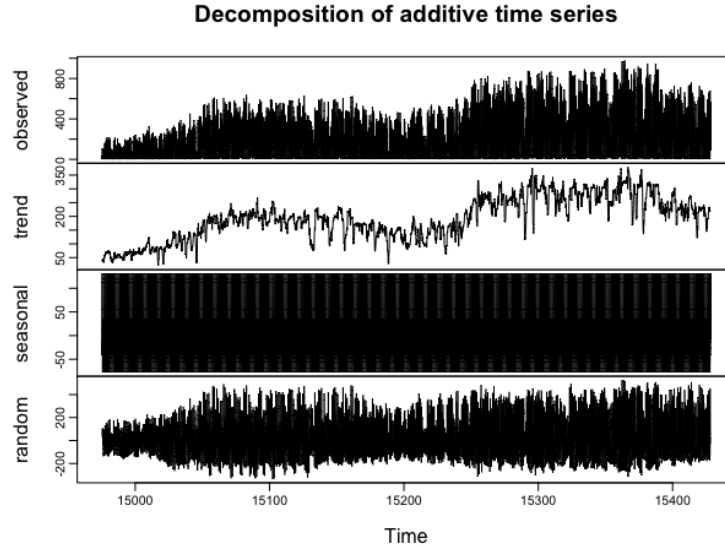


Fig.1:Full data decomposition

The Fig.1 shows the results from composition of full data. Since there are 10886 observations, the seasonal component cannot provide effective information. The trend component has a roughly increasing trend. And the remainder component (random part) looks like an approximated white noise. To deal with the seasonal part, the idea is to choose subset of full observations and check its composition.

Fig.2 is the plot of composition on first month data. Under first month, the trend component is not significant. However, the seasonal part displays a significantly cycle change. So, it is necessary to determine the frequency of seasonal changes.

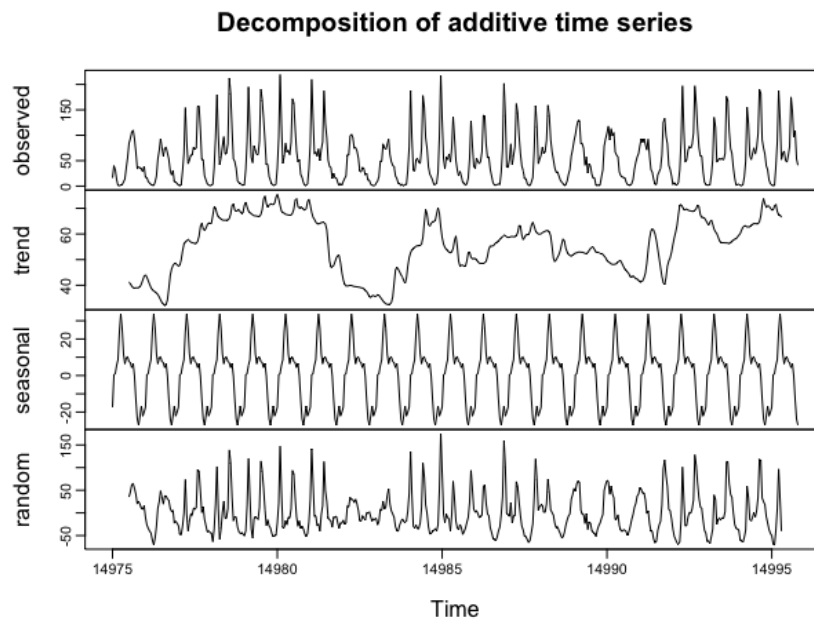


Fig.2: First month's decomposition

FREQUENCY The R program can estimate the frequency of time series data directly and the details of code can be found in Appendix part.

```
order = dd[order(-dd$spec),]
top2 = head(order, 2)
top2

##          freq      spec
## 456 0.04170096 66428532
## 457 0.04179241 39165185
1/top2$freq

## [1] 23.98026 23.92779
```

Fig 3.1: Result of Count

```
order = dd[order(-dd$spec),]
top2 = head(order, 2)
top2

##          freq      spec
## 456 0.0417009602 22767.59
## 2 0.0001828989 19917.01
1/top2$freq

## [1] 23.98026 5467.50000
```

Fig 3.2: Result of Temperature

The plots above, Fig 3.1 and Fig 3.2, are the results for frequency of Count and Temperature. The left one, Fig 3.1, is the first two estimated frequencies and periods and the result indicates that the period is approximate 24 hours. By the way, the second frequency of Temperature is a little bit interesting. From Fig 3.2, the first estimated period is about 24 hours, which is reasonable. However, the second estimated period is near 5468 hours, which is 228 days. In general opinion, the period need to be rough one year. Returing to check the data, the variable

datetime only records the first twenty days of each month. It makes sense that "one year" in this data only has 228 days.

ETS MODEL

First, I tried to fit the data with Exponential Trend Seasonal model. The following plots are the results from fitted model.

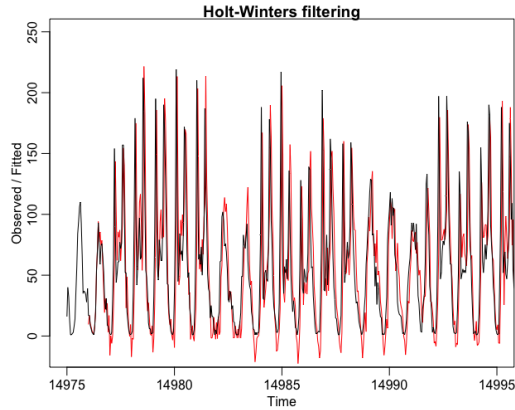


Fig 4.1: First month fitted values

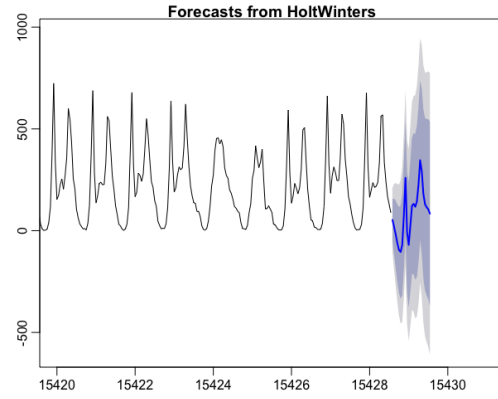


Fig 4.2: Forecasting for next 24 hours

The left plot above, Fig 4.1, displays the observed values and fitted values. Since the sample size is very huge, the plot only chooses the first month's results as example. The black line is observed values and the red line is fitted values. It is obvious that the red lines follows the behavior of black line closely, which means the model at least fits the data well. The next plot, Fig 4.2, provides the forecast for next 24 hours. In this plot, the blue line is predicted values of *count* for next 24 hours and the shaded part is confidence interval. The distribution of predicted line is very close the behavior of previous period and has a little decreasing trend.

SARIMA MODEL

After Exponential Trend Seasonal model, I tried to find some suitable SARIMA (seasonal autoregressive integrated moving average) models to fit the data. At beginning, I need to check whether there exists some tranformation on the variable *count*. From the following plot, x is original data, lx is the log-transformation on original data x . And dlx is the logged data differenced to remove trend. The last one $ddl x$ is stored a 24-order difference for persistence in the seasons. The last two planes indicate that dlx and $ddl x$ are approximate stationary. So, next step is to find suitable SARIMA models.

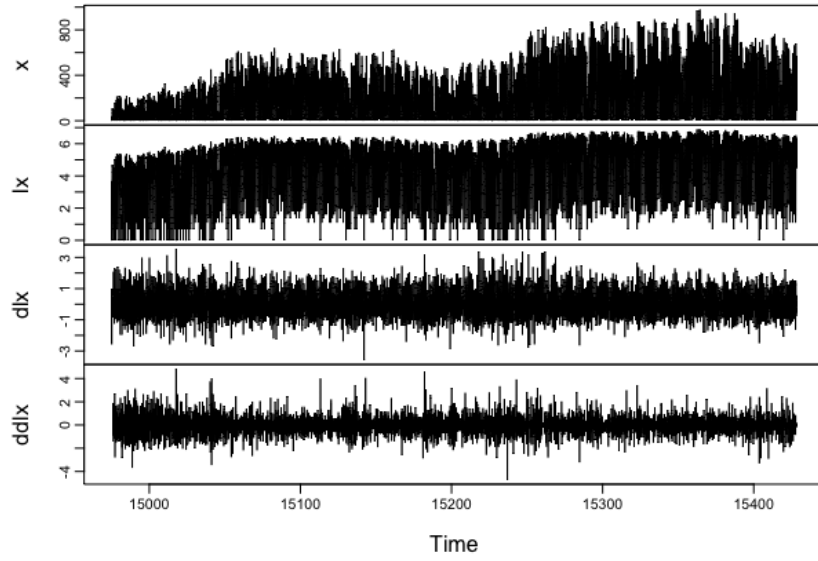


Fig.5: Results of Tranformation

ACF AND PACF The common method to determine suitable SARIMA models is to analysis ACF (the autocorrelation function) and PACF (the partial autocorrelation function) and find several satisfied models by the distributions of ACF and PACF plots.

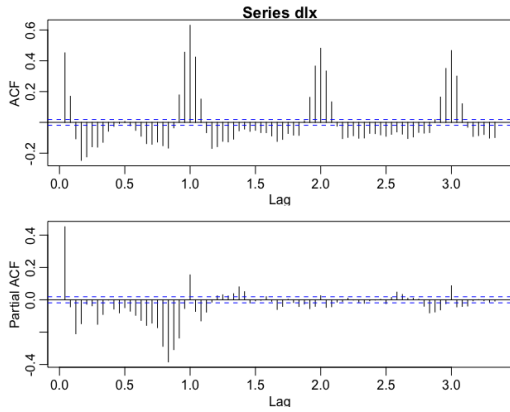


Fig 6.1: ACF and PACF of Seasonal Part

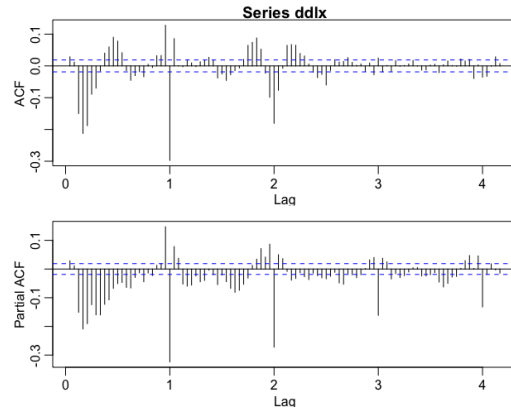


Fig 6.2: ACF and PACF of Non-seasonal Part

SEASONAL Considering about the ACF and PACF plots, Fig 6.1, of seasonal part, there are two optional analysis. One is that ACF tails off at lag $24k$ with $k = 1, 2, 3, \dots$ and PACF cuts off after lag 1. The other one is that ACF cuts off after 2 and PACF tails off at lags $24k$ with $k = 1, 2, 3, \dots$

Therefore, concluding to ARIMA models, there are two different models to be considered, which are $AR(1)_{24}$ and $MA(2)_{24}$

NON-SEASONAL Considering the right plane, Fig 6.2 , ACF and PACF of nonseasonal component, both ACF and PACF tail off at $24k$ with $k = 1, 2, 3, \dots$. So the optional models are $ARIMA(1,1,1)$ or $ARIMA(2,1,2)$.

Table 6: Possible Combinations of Models

	$AR(1)_{24}$	$MA(2)_{24}$
$ARIMA(1, 1, 1)$	$SARIMA(1, 1, 1)(1, 1, 0)_{24}$	$SARIMA(1, 1, 1)(0, 1, 2)_{24}$
$ARIMA(2, 1, 2)$	$SARIMA(2, 1, 2)(1, 1, 0)_{24}$	$SARIMA(2, 1, 2)(0, 1, 2)_{24}$

Combining all the possible models of seasonal and non-seasonal components, Table 6 shows all the four combinations of SARIMA models. The following plots are the results of these models.

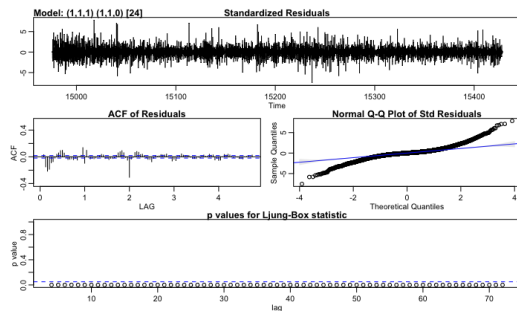


Fig 7.1: $SARIMA(1,1,1)(1,1,0)_{24}$

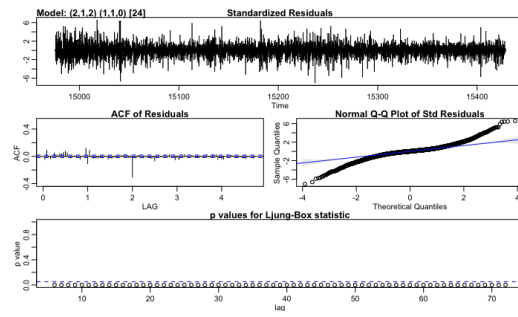


Fig 7.2: $SARIMA(2,1,2)(1,1,0)_{24}$

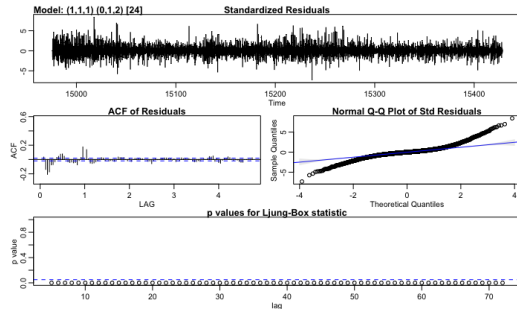


Fig 7.1: $SARIMA(1,1,1)(0,1,2)_{24}$

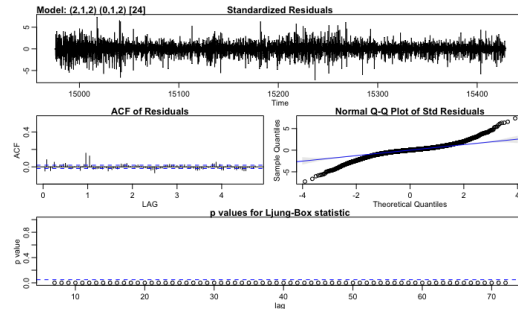


Fig 7.2: $SARIMA(2,1,2)(0,1,2)_{24}$

DISCUSSION AND CONCLUSION

Until now, there are five models to fit this data. However, we need to find a evaluation criteria to find which is the best model among these five.

EVALUATION CRITERIA: RMSE

RMSE The evaluation criteria I chosen is root-mean-square error (RMSE). For two time series $x_{1,t}$ and $x_{2,t}$, the root-mean-square error is:

$$RMSE = \sqrt{\frac{\sum_{t=1}^n (x_{1,t} - x_{2,t})^2}{n}}$$

Here, $x_{1,t}$ is observed value and $x_{2,t}$ is fitted value. Applying RMSE to all the five models ,we can get a list to compare them. In Fig 8 below, [1] is SARIMA(1,1,1)(1,1,0)₂₄. [2] is SARIMA(2,1,2)(1,1,0)₂₄. [3] is SARIMA(1,1,1)(0,1,2)₂₄. [4] is SARIMA(2,1,2)(0,1,2)₂₄ and [5] is ETS model.

[[1]]								
	ME	RMSE	MAE	MPE	MAPE	MASE	ACF1	
Training set	0	77.49	46.75	-4.82	64.42	0.7	-0.02	
[[2]]								
	ME	RMSE	MAE	MPE	MAPE	MASE	ACF1	
Training set	-0.22	69.17	43.05	-22.59	57.44	0.65	0	
[[3]]								
	ME	RMSE	MAE	MPE	MAPE	MASE	ACF1	
Training set	0	67.78	42.98	0.73	56.41	0.65	-0.02	
[[4]]								
	ME	RMSE	MAE	MPE	MAPE	MASE	ACF1	
Training set	-0.36	60.72	39.54	-31.45	56.62	0.6	0	
[[5]]								
	ME	RMSE	MAE	MPE	MAPE	MASE	ACF1	
Training set	0.01	80.2	54.82	-25.5	113.63	0.83	0.32	

Fig.8:Test Results

It is obvious that [4] has the smallest RMSE among these five models. So, the final model that I choose is SARIMA(2,1,2)(0,1,2)₂₄. And the following list is the summary of our final model.

```

$fit

Call:
stats::arima(x = xdata, order = c(p, d, q), seasonal = list(order = c(P, D,
Q), period = S), include.mean = !no.constant, optim.control = list(trace = trc,
REPORT = 1, reltol = tol))

Coefficients:
      ar1      ma1      sar1
    0.1388  -0.0284  -0.3233
s.e.  0.0411   0.0406   0.0094

sigma^2 estimated as 0.3249:  log likelihood = -9306.5,  aic = 18621

$degrees_of_freedom
[1] 10858

$tttable
      Estimate      SE  t.value p.value
ar1    0.1388  0.0411   3.3746  0.0007
ma1   -0.0284  0.0406  -0.7004  0.4837
sar1  -0.3233  0.0094 -34.5624  0.0000

$AIC
[1] -0.1238249

$AICc
[1] -0.1236408

$BIC
[1] -1.121814

```

Fig.9: Summary of SARIMA(2,1,2)(0,1,2)₂₄

The purpose of this project is to find the approximate distribution of number of bike rental and forecast the usage for next 24 hours. The next plot is forecasting for next 24 hours by SARIMA(2,1,2)(0,1,2)₂₄. In Fig 10, the black line is the observed value and the red line is forecast for the coming day. It is reasonable for this forecasting part. Comparing with the previous observed period, the forecast line follows a similar distribution. Then, the first peak of red line is at 8:00 a.m and the second peak is around 4:00 or 5:00 p.m. These two time are the rush hours on going to work or getting off work.

To conclude, until now, the final model is SARIMA(2,1,2)(0,1,2)₂₄ model. Under forecast by the final model, the rush hours of rental bikes happens at 8:00 a.m and 4:00 or 5:00 p.m. In the other words, the sheduled regularity office worker and students in DC area constitute the majority of rental bike users during working day.

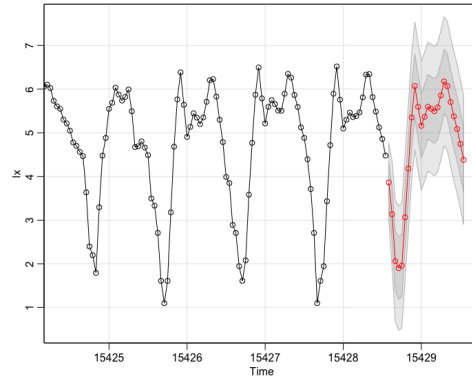


Fig.10: Forecasting for next 24 hours

DISCUSSIONG The SARIMA(2,1,2)(0,1,2)₂₄ model is only the final model instead of best model, since it just comes from the suitable models which we choose and there are a lot of other time series model that can try to fit this data. Furthermore, the final model, SARIMA(2,1,2)(0,1,2)₂₄, has a good performance of forecast but only for working days. Looking at Fig 11[5], the forecast of final model can predict approximate usage from Monday to Friday. However, focusing on Saturday and Sunday, the model SARIMA(2,1,2)(0,1,2)₂₄ is not able to predict usage situation on Sunday and Saturday, which is the weakness of SARIMA model. In the further, I will consider about *workingday* and *holiday* to fit a model to forecast the difference between weekdays and weekends.

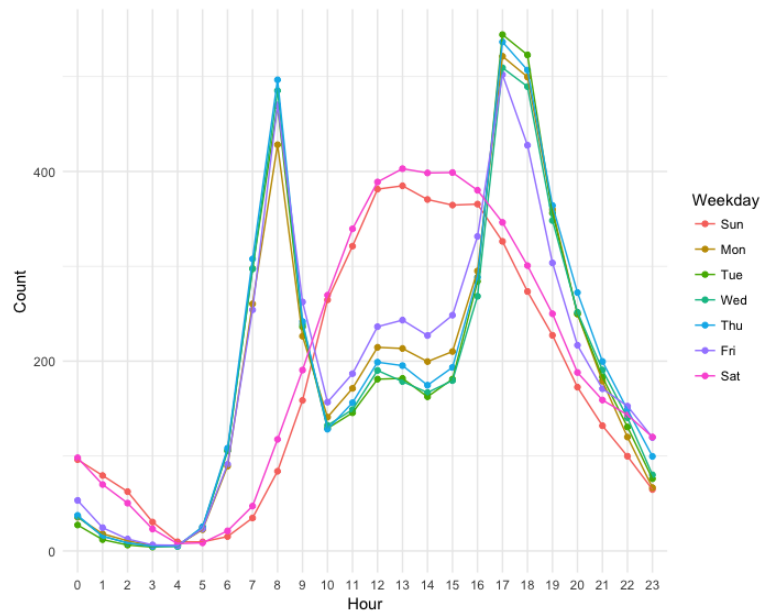


Fig.11: Usage on Weekdays

REFERENCES

- [1] Capital Bike Sharing Data <https://www.kaggle.com/c/bike-sharing-demand>
- [2] Holt-Winters seasonal method <https://www.otexts.org/fpp/7/5>
- [3] Robert H.Shumway, David S.Stoffer *Time Series Analysis and Its applications, Fourth Edition*
- [4] Hadley Wickham, Garrett Grolemond *R for Data Science*
- [5] David Huang <https://www.kaggle.com/h19881812/data-vizualization/code>

APPENDIX

```
library(astsa)
library(forecast)
library(zoo)
library(chron)
library(TSA)
library(vars)
###only count
d<-c(16L, 40L, 32L, 13L, 1L, 1L, 2L, 3L, 8L, 14L, 36L,
56L, 84L, 94L, 106L, 110L, 93L, 67L, 35L, 37L, 36L, 34L, 28L,
39L, 17L, 17L, 9L, 6L, 3L, 2L, 1L, 8L, 20L, 53L, 70L, 93L, 75L,
59L, 74L, 76L, 65L, 53L, 30L, 22L, 31L, 9L, 8L, 5L, 2L, 1L, 3L,
30L, 64L, 154L, 88L, 44L, 51L, 61L, 61L, 77L, 72L, 76L, 157L,
157L, 110L, 52L, 52L, 20L, 12L, 5L, 2L, 1L, 2L, 4L, 36L, 94L,
179L, 100L, 42L, 57L, 78L, 97L, 63L, 65L, 83L, 212L, 182L, 112L,
54L, 48L, 35L, 11L, 6L, 6L, 2L, 2L, 3L, 33L, 88L, 195L, 115L,
57L, 46L, 79L, 71L, 62L, 62L, 89L, 190L, 169L, 132L, 89L, 43L,
42L, 19L, 11L, 4L, 2L, 1L, 4L, 36L, 95L, 219L, 122L, 45L, 59L,
84L, 67L, 70L, 62L, 86L, 172L, 163L, 112L, 69L, 48L, 52L, 23L,
17L, 7L, 1L, 1L, 5L, 34L, 84L, 210L, 134L, 63L, 67L, 59L, 73L,
50L, 72L, 87L, 187L, 123L, 95L, 51L, 39L, 36L, 15L, 25L, 16L,
16L, 7L, 1L, 5L, 2L, 9L, 15L, 20L, 61L, 62L, 98L, 102L, 95L,
74L, 76L, 69L, 55L, 30L, 28L, 37L, 34L, 22L, 25L, 12L, 11L, 4L,
1L, 1L, 1L, 6L, 10L, 19L, 49L, 49L, 83L, 75L, 72L, 82L, 92L,
62L, 48L, 41L, 38L, 20L, 15L, 6L, 5L, 1L, 3L, 1L, 3L, 3L, 31L,
77L, 188L, 94L, 31L, 30L, 52L, 54L, 47L, 45L, 74L, 178L, 155L,
95L, 74L, 38L, 24L, 18L, 12L, 3L, 3L, 6L, 27L, 99L, 217L, 130L,
54L, 35L, 57L, 52L, 63L, 47L, 76L, 136L, 95L, 51L, 32L, 20L,
29L, 19L, 7L, 6L, 1L, 5L, 16L, 54L, 128L, 81L, 39L, 35L, 55L,
49L, 44L, 49L, 68L, 139L, 137L, 83L, 56L, 57L, 33L, 20L, 7L,
2L, 2L, 3L, 4L, 3L, 28L, 72L, 202L, 139L, 38L, 37L, 52L, 83L,
```

42L, 60L, 78L, 162L, 144L, 99L, 64L, 40L, 30L, 15L, 14L, 5L,
 1L, 1L, 8L, 17L, 70L, 158L, 117L, 44L, 53L, 61L, 77L, 64L, 68L,
 90L, 159L, 139L, 92L, 68L, 52L, 36L, 27L, 28L, 20L, 12L, 8L,
 5L, 1L, 3L, 10L, 23L, 33L, 59L, 72L, 89L, 101L, 118L, 129L, 128L,
 83L, 84L, 74L, 41L, 57L, 26L, 44L, 39L, 23L, 16L, 15L, 1L, 2L,
 1L, 3L, 18L, 32L, 79L, 93L, 104L, 118L, 91L, 113L, 99L, 105L,
 67L, 61L, 57L, 28L, 21L, 18L, 17L, 16L, 8L, 2L, 3L, 1L, 5L, 13L,
 33L, 47L, 57L, 64L, 80L, 93L, 86L, 93L, 82L, 71L, 92L, 60L, 33L,
 27L, 13L, 4L, 3L, 22L, 28L, 35L, 61L, 125L, 133L, 99L, 83L, 41L,
 33L, 20L, 3L, 7L, 3L, 2L, 7L, 32L, 90L, 197L, 109L, 47L, 52L,
 70L, 78L, 75L, 82L, 104L, 197L, 161L, 112L, 76L, 59L, 59L, 28L,
 8L, 3L, 2L, 2L, 3L, 22L, 52L, 135L, 116L, 47L, 51L, 55L, 52L,
 54L, 52L, 64L, 176L, 168L, 108L, 74L, 64L, 36L, 16L, 2L, 3L,
 4L, 1L, 1L, 3L, 18L, 49L, 155L, 123L, 61L, 52L, 64L, 75L, 63L,
 76L, 103L, 190L, 182L, 91L, 75L, 63L, 40L, 32L, 12L, 5L, 2L,
 1L, 2L, 39L, 87L, 188L, 133L, 52L, 64L, 69L, 51L, 47L, 60L, 78L,
 175L, 147L, 96L, 109L, 54L, 41L, 38L, 13L, 7L, 1L, 1L, 7L, 28L,
 87L, 220L, 127L, 51L, 64L, 86L, 82L, 91L, 90L, 99L, 205L, 155L,
 103L, 71L, 43L, 46L, 31L, 39L, 18L, 17L, 11L, 8L, 9L, 4L, 4L,
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 89L, 117L, 174L, 182L, 161L, 182L, 157L, 121L, 78L, 21L, 26L,
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 37L, 25L, 10L, 4L, 2L, 1L, 3L, 2L, 39L, 100L, 243L, 135L, 48L,
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 12L, 17L, 7L, 3L, 2L, 7L, 43L, 99L, 199L, 123L, 59L, 41L, 61L,
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 4L, 24L, 74L, 216L, 140L, 44L, 64L, 71L, 110L, 84L, 74L, 125L,
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 1L, 2L, 11L, 30L, 43L, 84L, 114L, 120L, 135L, 120L, 174L, 145L,
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 66L, 41L, 20L, 15L, 9L, 1L, 1L, 5L, 33L, 108L, 230L, 124L, 69L,
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193L, 177L, 179L, 289L, 259L, 274L, 401L, 273L, 234L, 146L, 81L,
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246L, 182L, 209L, 160L, 162L, 118L, 102L, 78L, 48L, 12L, 8L,
6L, 23L, 69L, 103L, 219L, 250L, 315L, 285L, 232L, 225L, 253L,
229L, 198L, 122L, 108L, 96L, 78L, 51L, 20L, 4L, 5L, 4L, 12L,
27L, 123L, 294L, 584L, 284L, 133L, 134L, 173L, 220L, 210L, 236L,
345L, 616L, 564L, 427L, 300L, 245L, 126L, 84L, 31L, 8L, 1L, 3L,
8L, 41L, 118L, 380L, 724L, 334L, 154L, 173L, 226L, 254L, 204L,
270L, 358L, 601L, 546L, 433L, 257L, 207L, 106L, 64L, 34L, 21L,
9L, 10L, 4L, 37L, 128L, 369L, 688L, 285L, 136L, 172L, 232L, 238L,
225L, 228L, 329L, 561L, 540L, 402L, 268L, 202L, 122L, 79L, 32L,
23L, 8L, 2L, 8L, 33L, 114L, 385L, 679L, 325L, 167L, 189L, 282L,
271L, 242L, 280L, 406L, 550L, 466L, 348L, 241L, 213L, 148L, 120L,
47L, 26L, 9L, 12L, 10L, 34L, 113L, 308L, 636L, 343L, 190L, 211L,
273L, 313L, 299L, 309L, 417L, 622L, 455L, 319L, 221L, 172L, 138L,
134L, 94L, 95L, 69L, 23L, 6L, 3L, 11L, 48L, 119L, 220L, 273L,
393L, 453L, 456L, 426L, 447L, 413L, 309L, 272L, 257L, 201L, 184L,
156L, 119L, 110L, 96L, 87L, 38L, 11L, 9L, 6L, 27L, 88L, 132L,
257L, 295L, 417L, 356L, 310L, 338L, 400L, 243L, 107L, 109L, 122L,
106L, 89L, 33L, 28L, 15L, 5L, 3L, 5L, 24L, 108L, 319L, 592L,
282L, 135L, 170L, 232L, 210L, 181L, 211L, 302L, 495L, 507L, 340L,
200L, 120L, 54L, 47L, 18L, 15L, 7L, 5L, 8L, 36L, 118L, 355L,
662L, 326L, 184L, 269L, 313L, 286L, 247L, 246L, 363L, 572L, 525L,
353L, 268L, 168L, 132L, 81L, 41L, 15L, 3L, 5L, 7L, 31L, 112L,
363L, 678L, 317L, 164L, 200L, 236L, 213L, 218L, 237L, 334L, 562L,
569L, 336L, 241L, 168L, 129L, 88L)
dcount<-ts(d,start = as.Date("2011-01-01"),frequency = 24)

```

```

####transformations
x<-dcount
lx<-log(x)
dlx<-diff(lx)
ddlx<-diff(dlx,24)
plot.ts(cbind(x, lx , dlx , ddlx) ,main="")

```

```

####check the frequency
p<-periodogram(d)
dd = data.frame(freq=p$freq , spec=p$spec)
order = dd[order(-dd$spec) ,]
top2 = head(order , 2)
top2
1/top2$freq####almost 24

####decompose
plot(decompose(dcount))
dcount1<-ts(d[1:500] , start = as.Date("2011-01-01") , frequency = 24)
plot(decompose(dcount1))

####ETS
ets<-HoltWinters(dcount)
plot(ets)
plot(ets , xlim=c(14975,14995) , ylim=c(-15,250))
plot(forecast(ets,24) , xlim=c(15420,15431))
ets<-ets(dcount)

####using diff(log(x))
####seasonal
par(mfrow=c(2,1))
acf(dlx,80)
pacf(dlx,80) ##AP(1)s or MA(2)s
####non-seasonal
acf(ddlx,100)
pacf(ddlx,100) ##ARMA(1,1)
par(mfrow=c(1,1))
fit11<-sarima(lx,1,1,1,1,1,0,24)
fit22<-sarima(lx,2,1,2,1,1,0,24)
fit33<-sarima(lx,1,1,1,0,1,2,24)
fit44<-sarima(lx,2,1,2,0,1,2,24)
pre44<-sarima.for(lx,24,2,1,2,0,1,2,24)

####compare by RMSE
fit11<-Arima(dcount, order=c(1,1,1) , seasonal = c(1,1,0))

```

```

fit22<-Arima(dcount, order=c(2,1,2), seasonal=c(1,1,0))
fit33<-Arima(dcount, order=c(1,1,1), seasonal = c(0,1,2))
fit44<-Arima(dcount, order=c(2,1,2), seasonal = c(0,1,2))
list(round(accuracy(fit11),2),round(accuracy(fit22),2),round(accuracy(
  fit33),2),round(accuracy(fit44),2),round(accuracy(ets),2))

###weekday
library(ggplot2)
library(lubridate)
library(scales)
library(plyr)
library(readr)
train<-read.csv("~/desktop/train.csv")
train$season <- factor(train$season, labels = c("Spring", "Summer", "
  Fall", "Winter"))
train$weather <- factor(train$weather, labels = c("Good", "Normal", "Bad
  ", "Very_Bad"))
train$hour <- factor(hour(ymd_hms(train$datetime)))
train$times <- as.POSIXct(strptime(ymd_hms(train$datetime), format="%H
  :%M:%S"), format="%H:%M:%S")
train$Weekday <- wday(ymd_hms(train$datetime), label=TRUE)
day_summary <- ddply(train,.(Weekday,hour),
  summarise, count = mean(count))
ggplot(train, aes(x = hour, y = count, colour = Weekday)) +
  geom_point(data = day_summary, aes(group=Weekday)) +
  geom_line(data = day_summary, aes(group=Weekday)) +
  scale_x_discrete("Hour") +
  scale_y_continuous("Count") +
  theme_minimal()

```