Analyzing the NYC Subway Dataset

Section 0. References

- Dataset
  - https://www.dropbox.com/s/meyki2wl9xfa7yk/turnstile_data_master_with_weather.csv
- API references
  - http://docs.scipy.org/doc/scipy/reference/stats.html
  - http://docs.scipy.org/doc/numpy/reference/
  - http://ggplot.yhathq.com/docs/index.html
- Statistical Tests
  - http://www.itl.nist.gov/div898/handbook/prc/section1/prc131.htm
  - https://en.wikipedia.org/wiki/Null_hypothesis
  - https://en.wikipedia.org/wiki/Mann%E2%80%93Whitney_U_test
  - http://www.graphpad.com/guides/prism/6/statistics/index.htm?how_the_mann-whitney_test_works.htm
- Linear Regression
  - http://en.wikipedia.org/wiki/Ordinary_least_squares
  - http://en.wikipedia.org/w/index.php?title=Linear_least_squares_(mathematics)
  - http://en.wikipedia.org/wiki/Polynomial_regression
  - https://en.wikipedia.org/wiki/Coefficient_of_determination
  - http://www.itl.nist.gov/div898/handbook/pri/section2/pri24.htm
  - http://blog.minitab.com/blog/adventures-in-statistics/why-you-need-to-check-your-residual-plots-for-regression-analysis
  - http://blog.minitab.com/blog/adventures-in-statistics/regression-analysis-how-do-i-interpret-r-squared-and-assess-the-goodness-of-fit
  - http://www.statsoft.com/Textbook/Multiple-Regression

Section 1. Statistical Test

1.1 Which statistical test did you use to analyze the NYC subway data? Did you use a one-tail or a two-tail P value? What is the null hypothesis? What is your p-critical value?

- **Statistical Test:** Mann Whitney U-test.

- **Null hypothesis:** Is the hourly entries of rainy and not rainy days sampled from populations with identical distributions? This is a two tailed hypothesis.
- **p-critical value:** I used a significance level of 0.05 (5%)

1.2 Why is this statistical test applicable to the dataset? In particular, consider the assumptions that the test is making about the distribution of ridership in the two samples.

After plotting the histograms of both samples, I decided to use the Mann Whitney U-test as the samples didn't seem normally distributed but shared a similar shape.

1.3 What results did you get from this statistical test? These should include the following numerical values: p-values, as well as the means for each of the two samples under test.

- **Mean hourly entries for rainy days:** 1105.4463767458733
- **Mean hourly entries for non-rainy days:** 1090.278780151855
- **Mann-Whitney statistics value:** 1924409167.0
- **Two tailed p-value:** 0.049999826

1.4 What is the significance and interpretation of these results?

Mean hourly entries in rainy and non-rainy groups were 1105.45 and 1090.28 respectively; the distributions in the two groups differed significantly (Mann–Whitney U = 1924409167.0, n1 = 44104, n2 = 87847, $p < 0.05$ two-tailed).

Section 2. Linear Regression

2.1 What approach did you use to compute the coefficients theta and produce prediction for ENTRIESn_hourly in your regression model.

I tried both Gradient Descent and Ordinary Least Squares (OLS) and they produced similar results when using the same input features. I then proceeded to improve the OLS model to generate the final predictions for ENTRIESn_hourly.

2.2 What features (input variables) did you use in your model? Did you use any dummy variables as part of your features?

- Columns from the dataset used: *fog, rain, meantempi*.
- 25th degree polynomial from the input variable *hour*.
- Dummy feature for each type of UNIT.

2.3 Why did you select these features in your model? We are looking for specific reasons that lead you to believe that the selected features will contribute to the predictive power of your model.

- I started by including the following columns: *fog*, *rain*, *hour*, *meantempi*. I also included a dummy feature for each type of unit. This selection was heavily based on intuition and some minor experimentation. For all this features, it was fair for me to assume they would impact the use of subway, e.g. people would travel more during certain hours of the day or some units would get more traffic than other given the location. After trying them out I could see that the coefficients obtained reflected this, e.g the predicted coefficients for some dummy features were larger than others and the coefficient for the hours had the largest magnitude of the non-dummy coefficients.
- Thanks to a hint in the assignment, I decided to explore the use polynomial terms for the column *hour* as it was the non-boolean feature with the largest coefficient value and my intuition suggested the model would benefit from this. I ran local tests where only the degree of the polynomial was changed and recorded the R^2 values and execution time obtained, reflected by the supporting graphs 6.1 and 6.2 respectively. From this I concluded that using a 25th degree polynomial was the simplest model within the explored interval of [20, 30).

2.4 What are the coefficients (or weights) of the non-dummy features in your linear regression model?

Feature	Coefficient
fog	4.11E+01
rain	-1.82E+01
meantempi	-6.03E+01
Hour1	-8.65E+06
Hour2	4.94E+08
Hour3	-1.03E+10
Hour4	1.12E+11
Hour5	-7.15E+11
Hour6	2.89E+12

Hour7	-7.76E+12
Hour8	1.42E+13
Hour9	-1.80E+13
Hour10	1.54E+13
Hour11	-8.57E+12
Hour12	2.80E+12
Hour13	-4.07E+11
Hour14	-1.46E+05
Hour15	2.21E+03
Hour16	1.79E+03
Hour17	-3.77E+03
Hour18	1.07E+04
Hour19	-1.12E+05
Hour20	-3.32E+05
Hour21	-2.21E+09
Hour22	1.69E+09
Hour23	7.06E+08
Hour24	-1.56E+08
ones	1.10E+03

2.5 What is your model's R2 (coefficients of determination) value?

R^2 = 0.526331531875

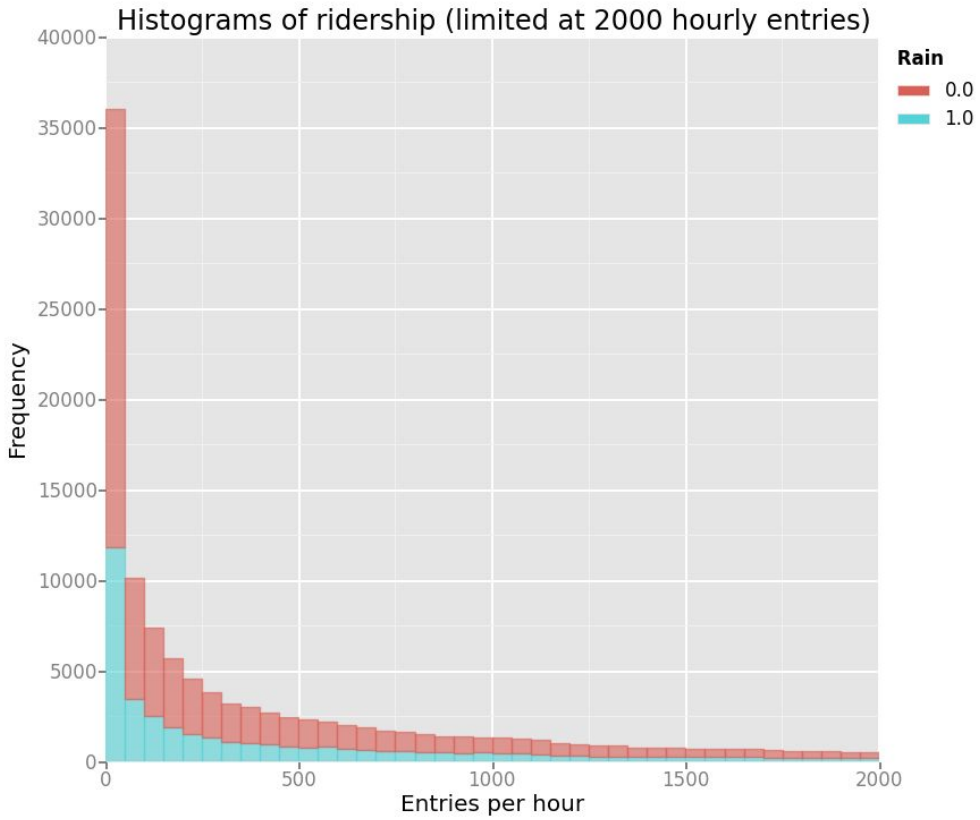
2.6 What does this R2 value mean for the goodness of fit for your regression model? Do you think this linear model to predict ridership is appropriate for this dataset, given this R2 value?

R^2 reflects how much of the original variability is explained by the regression model, with a larger value indicating more of the variability explained. This can be used as evidence of a linear correlation between the independent variables (predictor features) and dependent variable (hourly entries), where a value of 1 indicates perfect linear relationship and 0 no linear relationship at all.

Is hard to say if the obtained value of $R^2 = 0.526331531875$ is appropriate for this dataset without following a formal benchmark comparison process. In light of this limitation, I decided to examine the residuals plot obtained after applying the model to the sample data (supporting graph 6.3). Given that the residuals distribution has long tails and we have yet to explain approximately %46 of the original variability, then I would conclude that this is not an appropriate model unless the accepted margin of error is large.

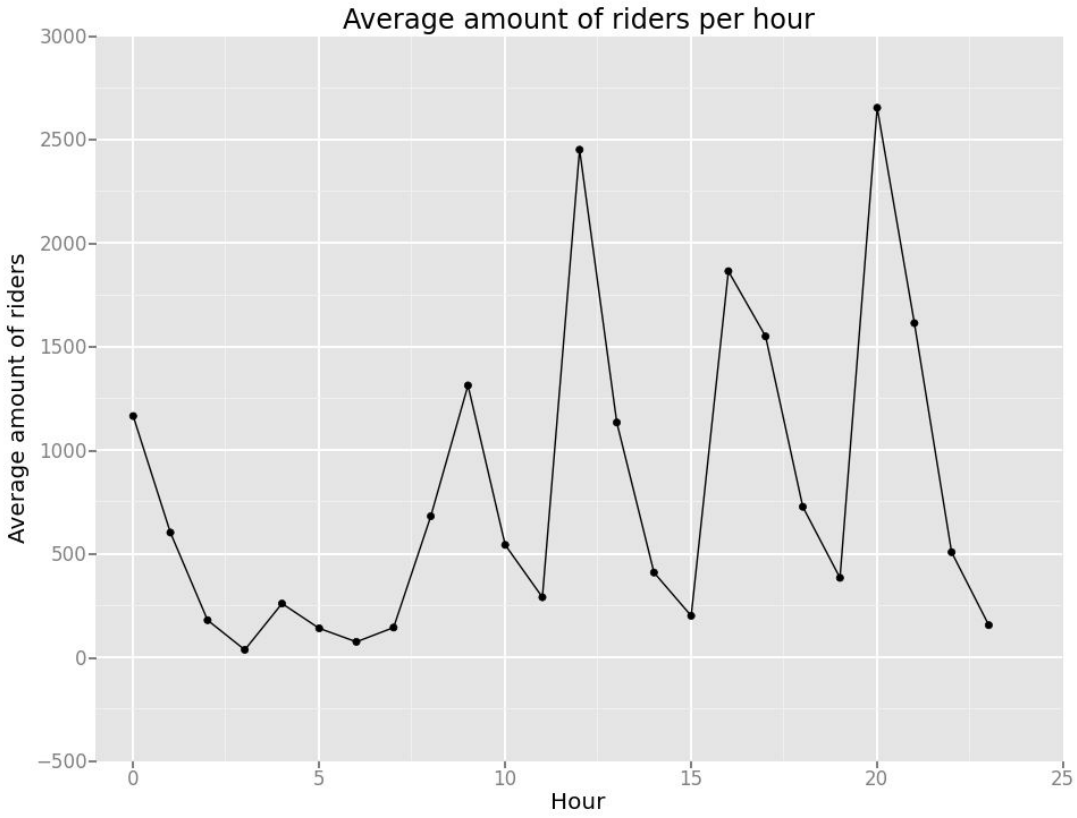
Section 3. Visualization

3.1 Histograms of ridership for rainy and non-rainy days (limited at 2000 hourly entries)



Histogram of hourly entries for rainy days (blue bars) and non-rainy days (red bars). None of the distributions are bell shaped but they are closely similar to each other, which point towards the use of the Mann Whitney U statistical test for the comparison of this two samples.

3.2 Average amount of riders per hour



Graph illustrating the average amount of riders per hour of the day. On average, ridership numbers peaks at 20h (8pm), followed closely by 12h (noon).

Section 4. Conclusion

4.1 From your analysis and interpretation of the data, do more people ride the NYC subway when it is raining or when it is not raining?

Based on my analysis, I can say with a enough confidence that more people ride the NYC subway when is raining.

4.2 What analyses lead you to this conclusion? You should use results from both your statistical tests and your linear regression to support your analysis.

1. The results obtained from running the Mann Whitney U-test led me to conclude with a 95% of confidence that the hourly entries of rainy and not rainy days are sampled from populations with non-identical distributions.
2. We find that the mean hourly entries for rainy days is 1105.45, which is larger than the obtained value of 1090.28 for non-rainy days.

Section 5. Reflection

5.1 Please discuss potential shortcomings of the methods of your analysis, including: Dataset, Analysis, such as the linear regression model or statistical test.

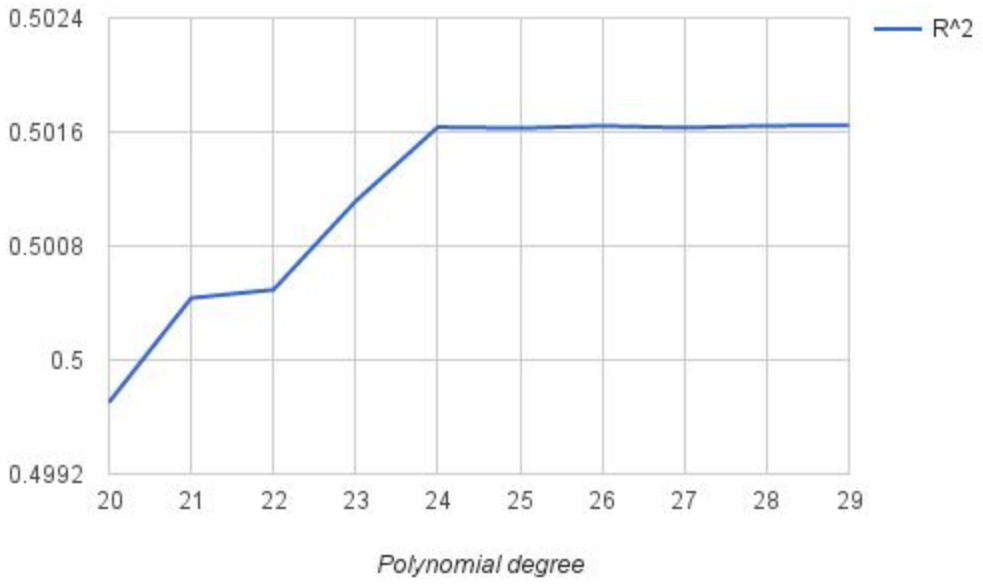
- A linear regression model might be too simple for this dataset, but is unclear unless a the performance of this method is compared against others with a benchmark dataset.
- It could be useful to remove outliers from the column ENTRIESn_hourly to reduce noise in the analysis.
- The sample size in the real world context will be much more larger, so the method will also need to take into account performance and potentially take advantage of a distributed environment.
- I only worked with one null hypothesis, but others could be used that I imagine have a great potential for real world impact. For example: Does a particular unit gets more passengers than others? Does a particular date had more riders than usual?

5.2 (Optional) Do you have any other insight about the dataset that you would like to share with us?

- According to the graph for the average amount of riders per hour, more riders take the subway during 8pm, followed closely by 12pm. More analysis is required, but just by looking at the graph is easy to see that there's no clear linear relationship between the ridership and time of day, instead reflecting the real life behavior where we come to expect more riders during particular peak hours.

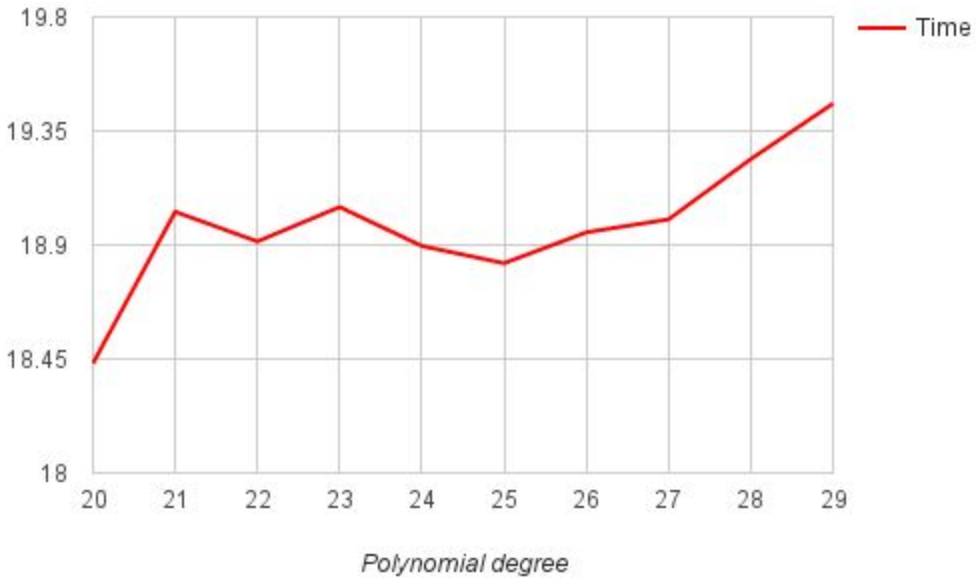
Section 6. Supporting Graphs

6.1 R^2 obtained for choices of polynomial degree in the interval [20, 30) for the *hour* input feature



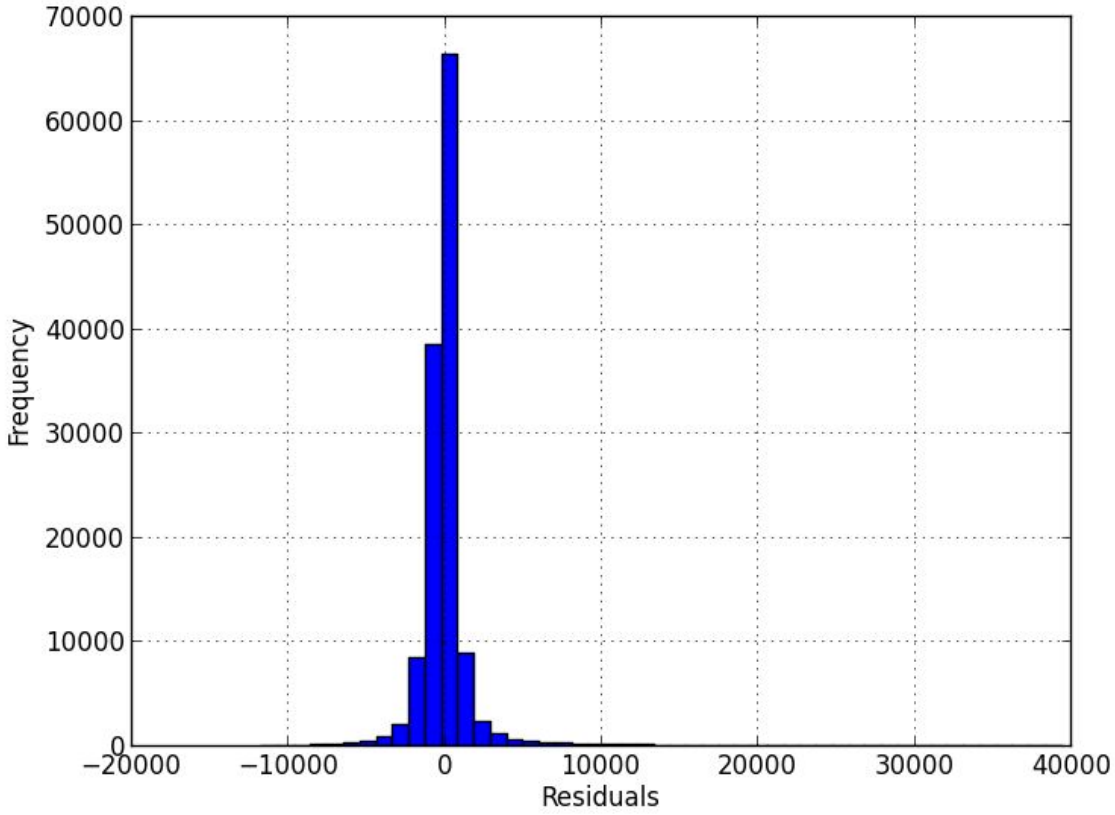
R-Square values obtained when applying the linear regression constructed with different polynomial degrees for the representation of the input feature *hour* and holding the rest of the model constant. In the interval evaluated, we can observe that the value improves as we increase the degree but starting from 24 the change is negligible.

6.2 Execution time obtained for choices of polynomial degree in the interval [20, 30) for the *hour* input feature



Execution time in seconds obtained when applying the linear regression constructed with different polynomial degrees for the representation of the input feature *hour* and holding the rest of the model constant. In the interval evaluated we can observe time roughly increasing as the degree increases.

6.3 Histogram of residuals obtained after applying the model to predict ridership level per hour



Histogram of residuals illustrating an approximately normal distribution with long tails obtained after applying the model to predict ridership level per hour.