

# Shared Bike Usage Study

real-time prediction of bicycle riding-time in the big data setting

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[Here is our project repository on Github.](#)

All three authors had equal contributions. Xuemei, Bangyao and Sunyi contributed to data preprocessing, Bangyao contributed to the linear regression model, Xuemei contributed to K means clustering, Sunyi contributed to map plots, Sunyi, Bangyao, and Xuemei contributed to machine learning models with cluster and parallel computing, and Sunyi and Bangyao contributed to the shiny app.

## Introduction

Bicycle sharing programs are getting popular today. They offer a convenient and affordable way to get around the city for both residents and tourists. Riding a bicycle is a fun exercise, and it is an environment-friendly transportation.

The Divvy Bikes is a bicycle sharing program in Chicago, Illinois. 6,133 bicycles can be rented from and returned to 621 stations. Given that the number of bicycles at each station is relatively limited, it is meaningful to predict the renting time of each bicycle so as to reasonably arrange the resting bicycles.

Our project aimed to predict the trip duration time of each Divvy Bike trip at the its start, using a set of covariates that can be obtained including information of the trip itself (start time and place) and the user (gender, age, and membership type).

## Data Description and Pre-processing

### Data Description

The dataset we used was the Divvy data set, which contained Divvy Bikes' using information in 2018. 3,603,082 samples (trips) were recorded. For each trip, there was information of start and end time and station, as well as information of the user. The original variables are listed in Table 1. Figure 1 shows a map of all the stations.

**Table 1: original variables in the Divvy Bikes data**

Variable name	Variable label
trip_id	trip ID
tripduration	end_time - start_time, in minutes.
Age	age of the user
from_station_id	ID of the station where the trip starts. There were 621 different stations.
from_station_name	name of the station where the trip started
usertype	user type, either "Subscriber" (Annual Members) or "Customer" (users who bought a single ride or a one-day pass)
Gender	gender of the user
start_time	start date and time of the trip

### Variable Transformation

To make full use of the variables, we extracted three variables from the original *start\_time*, as shown in Table 2.

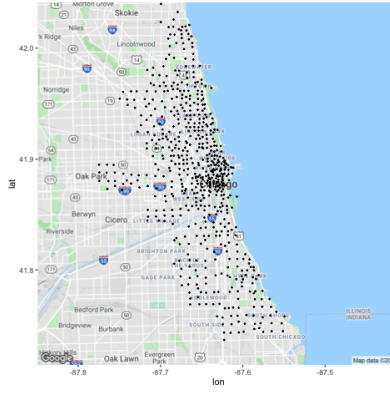


Figure 1: Map of Divvy Bikes stations

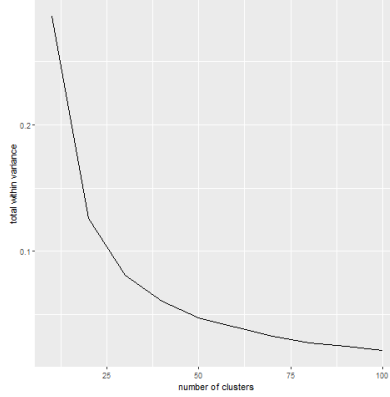


Figure 2: Total within cluster variance under different number of groups

**Table 2: extracted information from *start\_time***

Variable name	Variable label
Season	in which season the trip took place. Winter: Dec. - Feb., Spring: Mar. - May, etc.
hour	in which time slot of a day the trip took place
weekends	indicator of whether the trip happened on weekends

To reduce dimension of the categorical variable *from\_station\_name*, we searched for information of the stations on the Divvy Bikes webpage and found ID, name, latitude, longitude, and number of bikes (variable name *Docks.in.Service*) for 611 stations.

Based on these data, we used K-means clustering method to partition the stations by their locations. We first partitioned the stations into 10, 20, ..., 100 clusters ( $K = 10, 20, \dots, 100$ ) and caculated the total within cluster variance for each K. Then we plotted the total within cluster variance against K and selected an optimal K by minimizing the total within cluster variance with a smallest K. Figure 2 shows the plot of total within cluster variance with K from 10 to 100.

The total within cluster variance decreases sharply at first, but after K larger than 40, it becomes relatively steady. So we set  $K = 40$ , run the K-means clustering method, and partitioned the stations into 40 distinct, non-overlapping clusters. The clustering results are displayed in Figure 3.

## Data Cleaning

We first deleted data with user's age or gender missing. 562,565 out of 3,603,082 trips were deleted. We also noticed 2 out of 621 stations did not have any trips left after this step.

Among the 3,040,517 remaining trips, some had very short duration time and were unlikely to be normal trips, so we deleted trips that were shorter than half a minute (*tripduration* < 0.5). 34,849 trips were deleted in this step.

We also noticed that some users had implausibly large age, some users being older than 100. We drew a histogram of user's age, as shown in Figure 4.

From Figure 4, we can see that there are very few people older than 75, so we further deleted these people. In this step, 2,407 out of 3,005,668 trips were deleted.

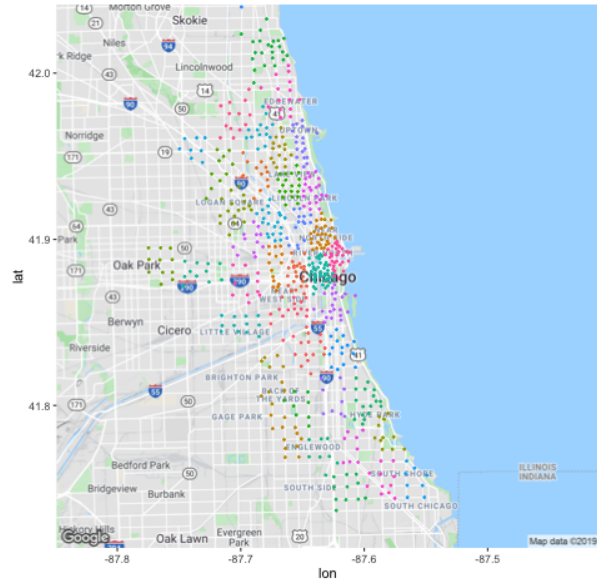


Figure 3: Map of Divvy Bikes stations, where spots in different colors represent stations in different clusters

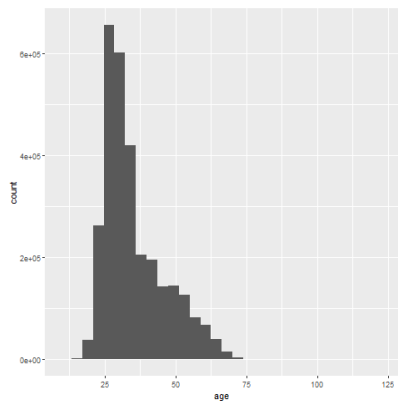


Figure 4: Histogram of users' age

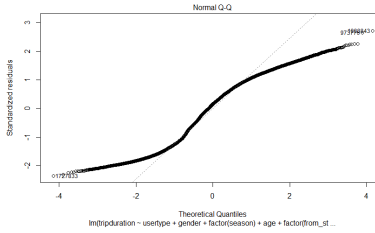


Figure 5: q-q Plot of the Linear Model

## Approach and Results

### Linear Model

We started with the linear regression as an exploration.

#### Memory issue

Our design matrix  $X$  is of dimension  $1490516 \times 653$  due to the presence of categorical variables, which is too large to fit in the memory. Therefore, we were not able to fit the model by `lm()` function. We solved this problem using the `bigmemory` package.

Another way to solve the Memory issue is to reduce dimension. We used the K-mean clustering method to group the stations by their distances and reduced the number of dummy variables. In this way, the design matrix became smaller and was able to fit in the memory. The model with cluster ID instead of station ID as a dummy variable had an  $RMSE = 33.67$ .

#### Constant Variance issue

As we can see from Figure 5, the normality assumption seemed to be violated in the model, so we decided to use a transformation to fix the problem and chose the square root transformation.

### Results

Even after fixing the transformation, the  $RMSE = 33.39$  was still unsatisfactory. Linear model might not be a perfect fit for this problem, so we decided to switch to other advanced non-parametric machine learning models.

### Non-parametric Model and parallel computing in cluster

Due to the memory limitation, we first tried a single tree model `rpart`, the Recursive Partitioning and Regression Trees model, to predict the duration of customers using Divvy Bikes. We used 20 cores to compute in parallel and used 5-fold cross validation to choose the best model. The procedure took one and a half hours. Since the single tree model was not good enough, we then used the ensemble tree models random forest and tree bag, and also `knn` and `SVM` with radial kernel. At first, we set memory as 50 GB in cluster but an out-of-memory issue came up. A trade-off was that the more cores we used, the faster the programs would finish, but the more memory we would need. Therefore, we used 150 GB memory and still used 20 cores. Fitted models are saved in [mbox](#).

### Prediction Results shown in interactive web apps

We predicted trip duration time of testing data with our fitted models and compared their RMSE. Due to a limit of time, we only used `rpart` (single tree) and `rf` (random forest) to perform prediction in the testing data. Figure 6 is a bar plot of RMSE in testing data of all methods and our shiny app's UI. The RMSE of non-parametric methods are slightly smaller than RMSE of linear model, which shows an improvement. One limitation of our project is that we didn't have enough computing resources to tune parameters by cross validation. So the results are based on the default parameters in R package `caret`.

# Divvy

Input Data

Usertype

Subscriber

Gender

Female

Season

Autumn

Which day in the week

Monday

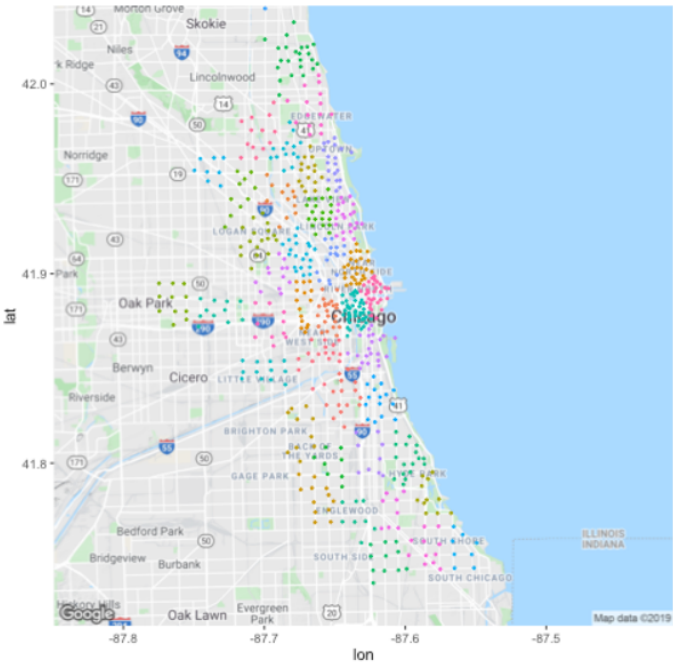
Station

Buckingham Fountain

Age:

1

80



Predicted duration of user using bike

41.29

Figure 6: A comparison of testing data RMSE and a screenshot of our shiny app

