Taxi demand prediction in New York City

In [3]:

```
#Importing Libraries
# pip3 install graphviz
#pip3 install dask
#pip3 install toolz
#pip3 install cloudpickle
# https://www.youtube.com/watch?v=ieW3G7ZzRZ0
# https://github.com/dask/dask-tutorial
# please do go through this python notebook: https://github.com/dask/dask-
tutorial/blob/master/07_dataframe.ipynb
import dask.dataframe as dd#similar to pandas

import pandas as pd#pandas to create small dataframes

# pip3 install foliun
# if this doesnt work refere install_folium.JPG in drive
import folium #open street map

# unix time: https://www.unixtimestamp.com/
import datetime #Convert to unix time

import time #Convert to unix time

# if numpy is not installed already : pip3 install numpy
import numpy as np#Do aritmetic operations on arrays

# matplotlib: used to plot graphs
import matplotlib
# matplotlib.use('nbagg') : matplotlib uses this protocall which makes plots more user intractive
like zoom in and zoom out
matplotlib.use('nbagg')
import matplotlib.pylab as plt
import seaborn as sns#Plots
from matplotlib import rcParams#Size of plots

# this lib is used while we calculate the stight line distance between two (lat,lon) pairs in mile
s
#import gpxpy
import gpxpy.geo #Get the haversine distance

from sklearn.cluster import MiniBatchKMeans, KMeans#Clustering
import math
import pickle
import os

# download migwin: https://mingw-w64.org/doku.php/download/mingw-builds
# install it in your system and keep the path, migw_path ='installed path'
mingw_path = 'C:\\Program Files\\mingw-w64\\x86_64-5.3.0-posix-seh-rt_v4-rev0\\mingw64\\bin'
os.environ['PATH'] = mingw_path + ';' + os.environ['PATH']

# to install xgboost: pip3 install xgboost
# if it didnt happen check install_xgboost.JPG
import xgboost as xgb

# to install sklearn: pip install -U scikit-learn
from sklearn.ensemble import RandomForestRegressor
from sklearn.metrics import mean_squared_error
from sklearn.metrics import mean_absolute_error
import warnings
warnings.filterwarnings("ignore")
import scipy
```

```
/usr/local/lib/python3.6/dist-packages/statsmodels/tools/_testing.py:19: FutureWarning:
pandas.util.testing is deprecated. Use the functions in the public API at pandas.testing instead.
  import pandas.util.testing as tm
```

Data Information

Data Information

Ge the data from : http://www.nyc.gov/html/tlc/html/about/trip_record_data.shtml (2016 data) The data used in the attached datasets were collected and provided to the NYC Taxi and Limousine Commission (TLC)

Information on taxis:

Yellow Taxi: Yellow Medallion Taxicabs

These are the famous NYC yellow taxis that provide transportation exclusively through street-hails. The number of taxicabs is limited by a finite number of medallions issued by the TLC. You access this mode of transportation by standing in the street and hailing an available taxi with your hand. The pickups are not pre-arranged.

For Hire Vehicles (FHVs)

FHV transportation is accessed by a pre-arrangement with a dispatcher or limo company. These FHVs are not permitted to pick up passengers via street hails, as those rides are not considered pre-arranged.

Green Taxi: Street Hail Livery (SHL)

The SHL program will allow livery vehicle owners to license and outfit their vehicles with green borough taxi branding, meters, credit card machines, and ultimately the right to accept street hails in addition to pre-arranged rides.

Credits: Quora

Footnote:
In the given notebook we are considering only the yellow taxis for the time period between Jan - Mar 2015 & Jan - Mar 2016

Data Collection

We Have collected all yellow taxi trips data from jan-2015 to dec-2016(Will be using only 2015 data)

file name	file name size	number of records	number of features
yellow_tripdata_2016-01	1. 59G	10906858	19
yellow_tripdata_2016-02	1. 66G	11382049	19
yellow_tripdata_2016-03	1. 78G	12210952	19
yellow_tripdata_2016-04	1. 74G	11934338	19
yellow_tripdata_2016-05	1. 73G	11836853	19
yellow_tripdata_2016-06	1. 62G	11135470	19
yellow_tripdata_2016-07	884Mb	10294080	17
yellow_tripdata_2016-08	854Mb	9942263	17
yellow_tripdata_2016-09	870Mb	10116018	17
yellow_tripdata_2016-10	933Mb	10854626	17
yellow_tripdata_2016-11	868Mb	10102128	17
yellow_tripdata_2016-12	897Mb	10449408	17
yellow_tripdata_2015-01	1.84Gb	12748986	19
yellow_tripdata_2015-02	1.81Gb	12450521	19
yellow_tripdata_2015-03	1.94Gb	13351609	19
yellow_tripdata_2015-04	1.90Gb	13071789	19
yellow_tripdata_2015-05	1.91Gb	13158262	19
yellow_tripdata_2015-06	1.79Gb	12324935	19
yellow_tripdata_2015-07	1.68Gb	11562783	19
yellow_tripdata_2015-08	1.62Gb	11130304	19
yellow_tripdata_2015-09	1.63Gb	11225063	19

yellow_tripdata_2015-10	1.79Gb	12315488	19
yellow_tripdata_2015-11	1.65Gb	11312676	19
yellow_tripdata_2015-12	1.67Gb	11460573	19

In [4]:

```
from google.colab import drive
drive.mount('/content/drive')
```

```
Go to this URL in a browser: https://accounts.google.com/o/oauth2/auth?client_id=947318989803-6bn6
qk8qdgf4n4g3pfee6491hc0brc4i.apps.googleusercontent.com&redirect_uri=urn%3aietf%3awg%3aoauth%3a2.0%
b&response_type=code&scope=email%20https%3a%2f%2fwww.googleapis.com%2fauth%2fdocs.test%20https%3a%2
www.googleapis.com%2fauth%2fdrive%20https%3a%2f%2fwww.googleapis.com%2fauth%2fdrive.photos.readonly
ttps%3a%2f%2fwww.googleapis.com%2fauth%2fpeopleapi.readonly

Enter your authorization code:
··········
Mounted at /content/drive
```

In [5]:

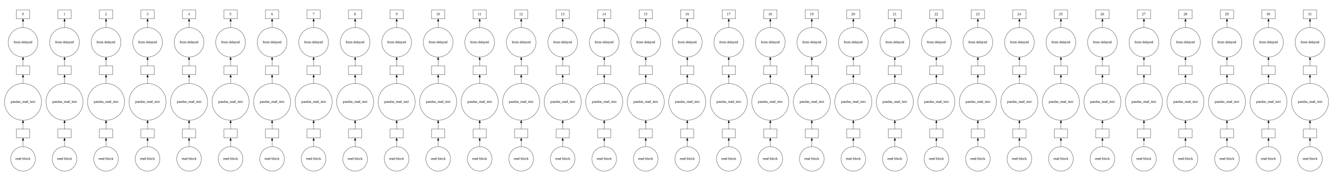
```
#Looking at the features
# dask dataframe   : # https://github.com/dask/dask-tutorial/blob/master/07_dataframe.ipynb
month = dd.read_csv('/content/drive/My Drive/Data_Notebooks/yellow_tripdata_2015-01.csv')
print(month.columns)
```

```
Index(['VendorID', 'tpep_pickup_datetime', 'tpep_dropoff_datetime',
       'passenger_count', 'trip_distance', 'pickup_longitude',
       'pickup_latitude', 'RateCodeID', 'store_and_fwd_flag',
       'dropoff_longitude', 'dropoff_latitude', 'payment_type', 'fare_amount',
       'extra', 'mta_tax', 'tip_amount', 'tolls_amount',
       'improvement_surcharge', 'total_amount'],
      dtype='object')
```

In [6]:

```
# However unlike Pandas, operations on dask.dataframes don't trigger immediate computation,
# instead they add key-value pairs to an underlying Dask graph. Recall that in the diagram below,
# circles are operations and rectangles are results.

# to see the visulaization you need to install graphviz
# pip3 install graphviz if this doesnt work please check the install_graphviz.jpg in the drive
month.visualize()
```

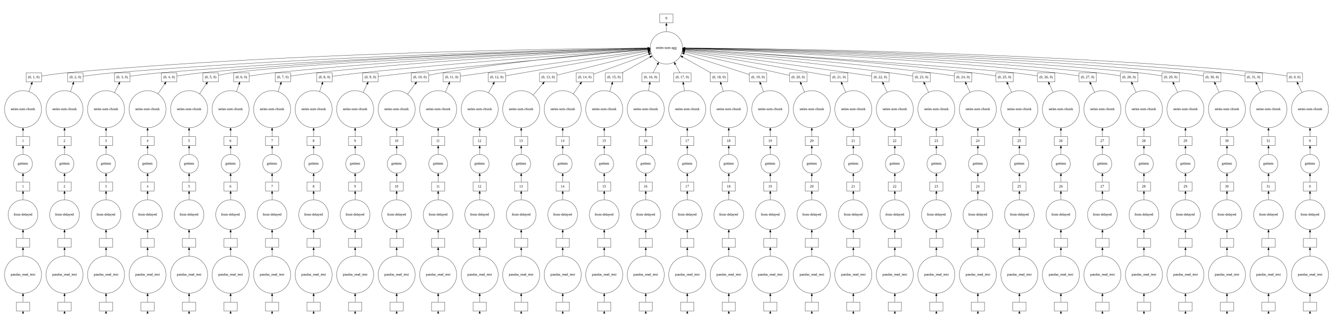
Out[6]:



In [7]:

```
month.fare_amount.sum().visualize()
```

Out[7]:



Features in the dataset:

Field Name	**Description**
VendorID	A code indicating the TPEP provider that provided the record. 1. Creative Mobile Technologies 2. VeriFone Inc.
tpep_pickup_datetime	The date and time when the meter was engaged.
tpep_dropoff_datetime	The date and time when the meter was disengaged.
Passenger_count	The number of passengers in the vehicle. This is a driver-entered value.
Trip_distance	The elapsed trip distance in miles reported by the taximeter.
Pickup_longitude	Longitude where the meter was engaged.
Pickup_latitude	Latitude where the meter was engaged.
RateCodeID	The final rate code in effect at the end of the trip. 1. Standard rate 2. JFK 3. Newark 4. Nassau or Westchester 5. Negotiated fare 6. Group ride
Store_and_fwd_flag	This flag indicates whether the trip record was held in vehicle memory before sending to the vendor, aka “store and forward,” because the vehicle did not have a connection to the server. Y= store and forward trip N= not a store and forward trip
Dropoff_longitude	Longitude where the meter was disengaged.
Dropoff_ latitude	Latitude where the meter was disengaged.
Payment_type	A numeric code signifying how the passenger paid for the trip. 1. Credit card 2. Cash 3. No charge 4. Dispute 5. Unknown 6. Voided trip
Fare_amount	The time-and-distance fare calculated by the meter.
Extra	Miscellaneous extras and surcharges. Currently, this only includes. the $0.50 and 1$ rush hour and overnight charges.
MTA_tax	0.50 MTA tax that is automatically triggered based on the metered rate in use.
Improvement_surcharge	0.30 improvement surcharge assessed trips at the flag drop. the improvement surcharge began being levied in 2015.
Tip_amount	Tip amount – This field is automatically populated for credit card tips.Cash tips are not included.
Tolls_amount	Total amount of all tolls paid in trip.
Total_amount	The total amount charged to passengers. Does not include cash tips.

ML Problem Formulation

Time-series forecasting and Regression

- To find number of pickups, given location cordinates(latitude and longitude) and time, in the query reigion and surrounding regions.

To solve the above we would be using data collected in Jan - Mar 2015 to predict the pickups in Jan - Mar 2016.

Performance metrics

1. Mean Absolute percentage error.
2. Mean Squared error.

Data Cleaning

In this section we will be doing univariate analysis and removing outlier/illegitimate values which may be caused due to some error

In [8]:

```
#table below shows few datapoints along with all our features
month.head(5)
```

Out[8]:

	VendorID	tpep_pickup_datetime	tpep_dropoff_datetime	passenger_count	trip_distance	pickup_longitude	pickup_latit
0	2	2015-01-15 19:05:39	2015-01-15 19:23:42	1	1.59	-73.993896	40.750111
1	1	2015-01-10 20:33:38	2015-01-10 20:53:28	1	3.30	-74.001648	40.724243
2	1	2015-01-10 20:33:38	2015-01-10 20:43:41	1	1.80	-73.963341	40.802788
3	1	2015-01-10 20:33:39	2015-01-10 20:35:31	1	0.50	-74.009087	40.713818
4	1	2015-01-10 20:33:39	2015-01-10 20:52:58	1	3.00	-73.971176	40.762428

1. Pickup Latitude and Pickup Longitude

It is inferred from the source https://www.flickr.com/places/info/2459115 that New York is bounded by the location cordinates(lat,long) - (40.5774, -74.15) & (40.9176,-73.7004) so hence any cordinates not within these cordinates are not considered by us as we are only concerned with pickups which originate within New York.

In [9]:

```
# Plotting pickup cordinates which are outside the bounding box of New-York
# we will collect all the points outside the bounding box of newyork city to outlier_locations
outlier_locations = month[((month.pickup_longitude <= -74.15) | (month.pickup_latitude <= 40.5774)|
\
                   (month.pickup_longitude >= -73.7004) | (month.pickup_latitude >= 40.9176))]

# creating a map with the a base location
# read more about the folium here: http://folium.readthedocs.io/en/latest/quickstart.html

# note: you dont need to remember any of these, you dont need indeepth knowledge on these maps and
plots

map_osm = folium.Map(location=[40.734695, -73.990372], tiles='Stamen Toner')

# we will spot only first 100 outliers on the map, plotting all the outliers will take more time
sample_locations = outlier_locations.head(10000)
for i,j in sample_locations.iterrows():
    if int(j['pickup_latitude']) != 0:
        folium.Marker(list((j['pickup_latitude'],j['pickup_longitude']))).add_to(map_osm)
map_osm
```

Out[9]:

Observation:- As you can see above that there are some points just outside the boundary but there are a few that are in either South america, Mexico or Canada

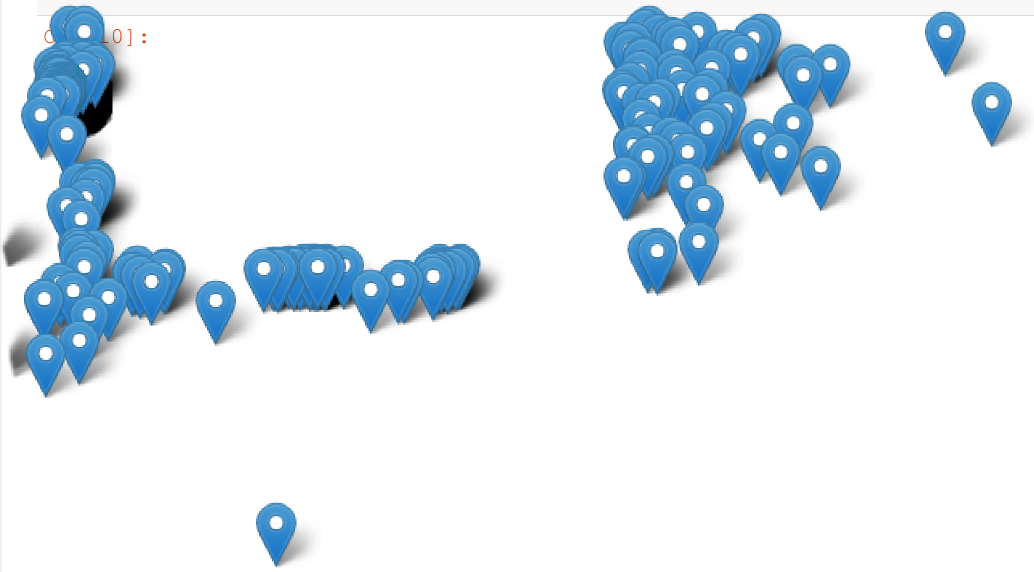
2. Dropoff Latitude & Dropoff Longitude

It is inferred from the source https://www.flickr.com/places/info/2459115 that New York is bounded by the location cordinates(lat,long) - (40.5774, -74.15) & (40.9176,-73.7004) so hence any cordinates not within these cordinates are not considered by us as we are only concerned with dropoffs which are within New York.

In [10]:

```
# Plotting dropoff cordinates which are outside the bounding box of New-York
# we will collect all the points outside the bounding box of newyork city to outlier_locations
outlier_locations = month[((month.dropoff_longitude <= -74.15) | (month.dropoff_latitude <= 40.5774
)| \
                   (month.dropoff_longitude >= -73.7004) | (month.dropoff_latitude >= 40.9176))]

# creating a map with the a base location
# read more about the folium here: http://folium.readthedocs.io/en/latest/quickstart.html

# note: you dont need to remember any of these, you dont need indeepth knowledge on these maps and
plots

map_osm = folium.Map(location=[40.734695, -73.990372], tiles='Stamen Toner')

# we will spot only first 100 outliers on the map, plotting all the outliers will take more time
sample_locations = outlier_locations.head(10000)
for i,j in sample_locations.iterrows():
    if int(j['pickup_latitude']) != 0:
        folium.Marker(list((j['dropoff_latitude'],j['dropoff_longitude']))).add_to(map_osm)
map_osm
```

Out[10]:



Observation:- The observations here are similar to those obtained while analysing pickup latitude and longitude

3. Trip Durations:

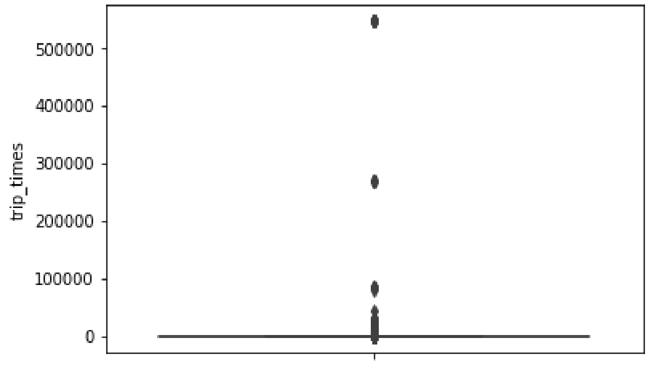
According to NYC Taxi & Limousine Commision Regulations **the maximum allowed trip duration in a 24 hour interval is 12 hours.**

In [0]:

```
#The timestamps are converted to unix so as to get duration(trip-time) & speed also pickup-times i
n unix are used while binning

# in out data we have time in the formate "YYYY-MM-DD HH:MM:SS" we convert thiss sting to python t
ime formate and then into unix time stamp
# https://stackoverflow.com/a/27914405
def convert_to_unix(s):
    return time.mktime(datetime.datetime.strptime(s, "%Y-%m-%d %H:%M:%S").timetuple())



# we return a data frame which contains the columns
# 1.'passenger_count' : self explanatory
# 2.'trip_distance' : self explanatory
# 3.'pickup_longitude' : self explanatory
# 4.'pickup_latitude' : self explanatory
# 5.'dropoff_longitude' : self explanatory
# 6.'dropoff_latitude' : self explanatory
# 7.'total_amount' : total fair that was paid
# 8.'trip_times' : duration of each trip
# 9.'pickup_times : pickup time converted into unix time
# 10.'Speed' : velocity of each trip
def return_with_trip_times(month):
    duration = month[['tpep_pickup_datetime','tpep_dropoff_datetime']].compute()
    #pickups and dropoffs to unix time
    duration_pickup = [convert_to_unix(x) for x in duration['tpep_pickup_datetime'].values]
    duration_drop = [convert_to_unix(x) for x in duration['tpep_dropoff_datetime'].values]
    #calculate duration of trips
    durations = (np.array(duration_drop) - np.array(duration_pickup))/float(60)

    #append durations of trips and speed in miles/hr to a new dataframe
    new_frame =
month[['passenger_count','trip_distance','pickup_longitude','pickup_latitude','dropoff_longitude',
'dropoff_latitude','total_amount']].compute()

    new_frame['trip_times'] = durations
    new_frame['pickup_times'] = duration_pickup
    new_frame['Speed'] = 60*(new_frame['trip_distance']/new_frame['trip_times'])

    return new_frame

# print(frame_with_durations.head())
#  passenger_count trip_distance pickup_longitude pickup_latitude dropoff_longitude
dropoff_latitude total_amount trip_times pickup_times Speed
#   1                  1.59      -73.993896        40.750111      -73.974785       40.750618
17.05      18.050000 1.421329e+09 5.285319
#   1                 3.30      -74.001648       40.724243     -73.994415       40.759109
.80    19.833333 1.420902e+09 9.983193
#   1                 1.80      -73.963341       40.802788      -73.951820       40.824413
10.80     10.050000 1.420902e+09 10.746269
#   1                 0.50      -74.009087       40.713818      -74.004326        40.719986
4.80      1.866667 1.420902e+09 16.071429
#   1                 3.00      -73.971176       40.762428      -74.004181       40.742653
6.30    19.316667 1.420902e+09 9.318378
frame_with_durations = return_with_trip_times(month)
```

In [12]:

```
%matplotlib inline

# the skewed box plot shows us the presence of outliers
sns.boxplot(y="trip_times", data =frame_with_durations)
plt.show()
```



In [13]:

```
#calculating 0-100th percentile to find a the correct percentile value for removal of outliers
for i in range(0,100,10):
    var =frame_with_durations["trip_times"].values
    var = np.sort(var,axis = None)
    print("{} percentile value is {}".format(i,var[int(len(var)*(float(i)/100))]))
print ("100 percentile value is ",var[-1])
```

```
0 percentile value is -1211.0166666666667
10 percentile value is 3.8333333333333335
20 percentile value is 5.383333333333334
30 percentile value is 6.816666666666666
40 percentile value is 8.3
50 percentile value is 9.95
60 percentile value is 11.866666666666667
70 percentile value is 14.283333333333333
80 percentile value is 17.633333333333333
90 percentile value is 23.45
100 percentile value is  548555.6333333333
```

In [14]:

```
#looking further from the 99th percecntile
for i in range(90,100):
    var =frame_with_durations["trip_times"].values
    var = np.sort(var,axis = None)
    print("{} percentile value is {}".format(i,var[int(len(var)*(float(i)/100))]))
print ("100 percentile value is ",var[-1])
```

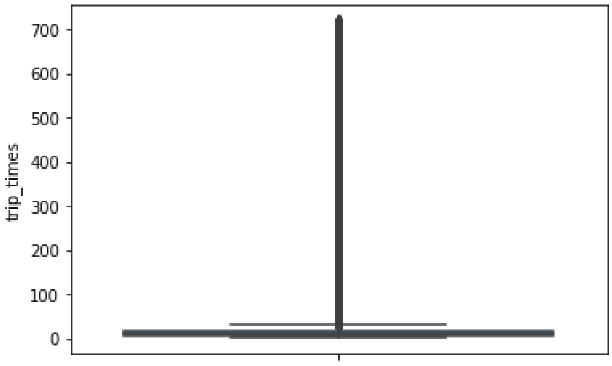
```
90 percentile value is 23.45
91 percentile value is 24.35
92 percentile value is 25.383333333333333
93 percentile value is 26.55
94 percentile value is 27.933333333333334
95 percentile value is 29.583333333333332
96 percentile value is 31.683333333333334
97 percentile value is 34.46666666666667
98 percentile value is 38.71666666666667
99 percentile value is 46.75
100 percentile value is  548555.6333333333
```

In [0]:

```
#removing data based on our analysis and TLC regulations
frame_with_durations_modified=frame_with_durations[(frame_with_durations.trip_times>1) &
(frame_with_durations.trip_times<720)]
```

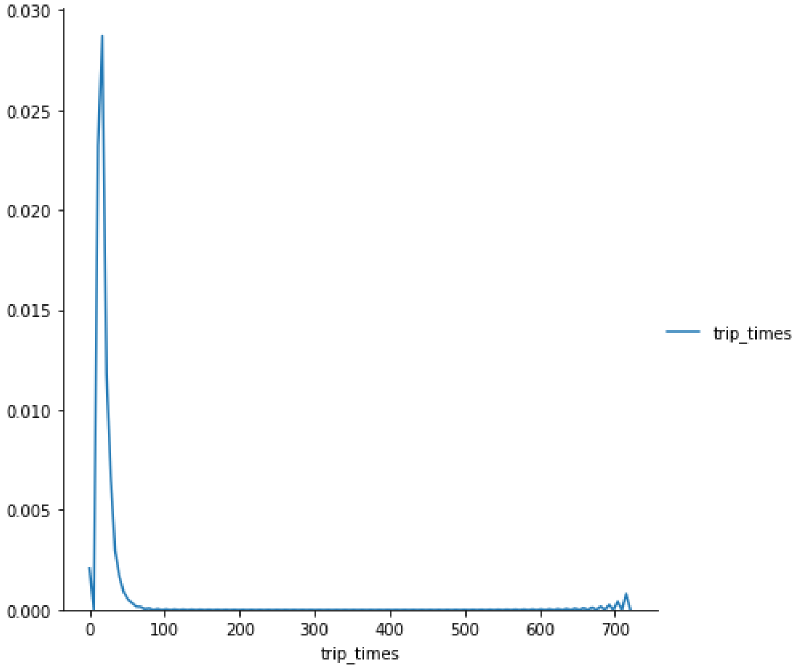
In [16]:

```python
%matplotlib inline


#box-plot after removal of outliers
sns.boxplot(y="trip_times", data =frame_with_durations_modified)
plt.show()
```



In [17]:

```python
#pdf of trip-times after removing the outliers
sns.FacetGrid(frame_with_durations_modified,size=6) \
      .map(sns.kdeplot,"trip_times") \
      .add_legend();
plt.show();
```

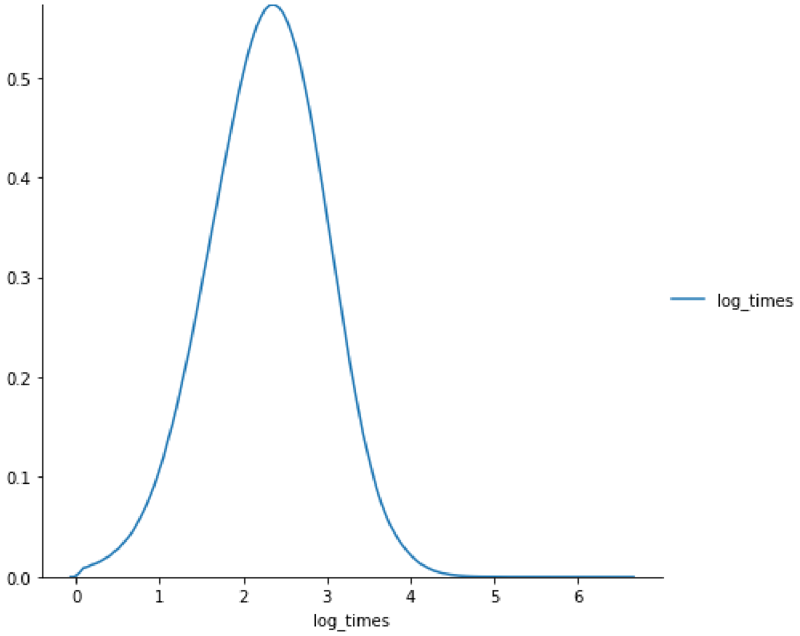


In [0]:

```python
#converting the values to log-values to chec for log-normal
import math
frame_with_durations_modified['log_times']=[math.log(i) for i in frame_with_durations_modified['tri
p_times'].values]
```

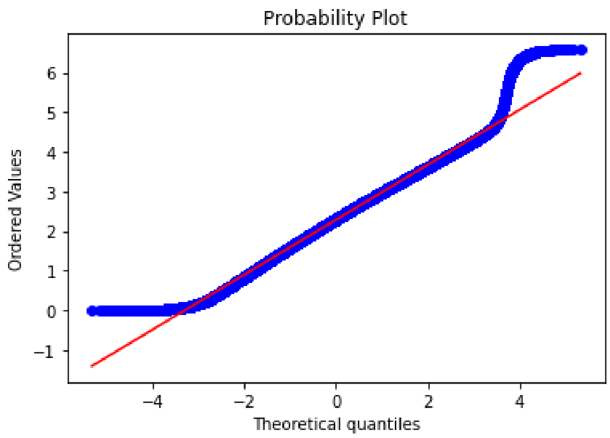
In [19]:

```python
#pdf of log-values
sns.FacetGrid(frame_with_durations_modified,size=6) \
      .map(sns.kdeplot,"log_times") \
      .add_legend();
plt.show();
```



In [20]:

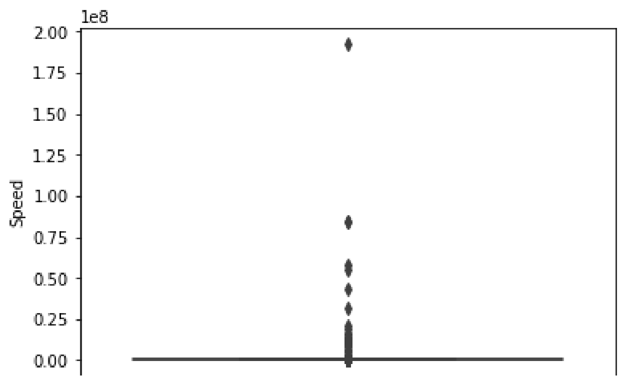
```
#Q-Q plot for checking if trip-times is log-normal
scipy.stats.probplot(frame_with_durations_modified['log_times'].values, plot=plt)
plt.show()
```



4. Speed

In [21]:

```
# check for any outliers in the data after trip duration outliers removed
# box-plot for speeds with outliers
frame_with_durations_modified['Speed'] =
60*(frame_with_durations_modified['trip_distance']/frame_with_durations_modified['trip_times'])
sns.boxplot(y="Speed", data =frame_with_durations_modified)
plt.show()
```



In [22]:

```
#calculating speed values at each percntile 0,10,20,30,40,50,60,70,80,90,100
for i in range(0,100,10):
    var =frame_with_durations_modified["Speed"].values
    var = np.sort(var,axis = None)
    print("{} percentile value is {}".format(i,var[int(len(var)*(float(i)/100))]))
print("100 percentile value is ",var[-1])
```

```
0 percentile value is 0.0
10 percentile value is 6.409495548961425
20 percentile value is 7.80952380952381
30 percentile value is 8.929133858267717
40 percentile value is 9.98019801980198
50 percentile value is 11.06865671641791
60 percentile value is 12.286689419795222
70 percentile value is 13.796407185628745
80 percentile value is 15.963224893917962
90 percentile value is 20.186915887850468
100 percentile value is  192857142.85714284
```

In [23]:

```
#calculating speed values at each percntile 90,91,92,93,94,95,96,97,98,99,100
for i in range(90,100):
    var =frame_with_durations_modified["Speed"].values
    var = np.sort(var,axis = None)
    print("{} percentile value is {}".format(i,var[int(len(var)*(float(i)/100))]))
print("100 percentile value is ",var[-1])
```

```
90 percentile value is 20.186915887850468
91 percentile value is 20.91645569620253
92 percentile value is 21.752988047808763
93 percentile value is 22.721893491124263
94 percentile value is 23.844155844155843
95 percentile value is 25.182552504038775
96 percentile value is 26.80851063829787
97 percentile value is 28.84304932735426
98 percentile value is 31.591128254580514
99 percentile value is 35.7513566847558
100 percentile value is  192857142.85714284
```

In [24]:

```
#calculating speed values at each percntile 99.0,99.1,99.2,99.3,99.4,99.5,99.6,99.7,99.8,99.9,100
for i in np.arange(0.0, 1.0, 0.1):
    var =frame_with_durations_modified["Speed"].values
    var = np.sort(var,axis = None)
    print("{} percentile value is {}".format(99+i,var[int(len(var)*(float(99+i)/100))]))
print("100 percentile value is ",var[-1])
```

```
99.0 percentile value is 35.7513566847558
99.1 percentile value is 36.31084727468969
99.2 percentile value is 36.91470054446461
99.3 percentile value is 37.588235294117645
99.4 percentile value is 38.33035714285714
99.5 percentile value is 39.17580340264651
99.6 percentile value is 40.15384615384615
99.7 percentile value is 41.338301043219076
99.8 percentile value is 42.86631016042781
99.9 percentile value is 45.3107822410148
100 percentile value is  192857142.85714284
```

In [0]:

```
#removing further outliers based on the 99.9th percentile value
frame_with_durations_modified=frame_with_durations[(frame_with_durations.Speed>0) &
(frame_with_durations.Speed<45.31)]
```

In [26]:

```
#avg.speed of cabs in New-York
sum(frame_with_durations_modified["Speed"]) / float(len(frame_with_durations_modified["Speed"]))
```

Out[26]:

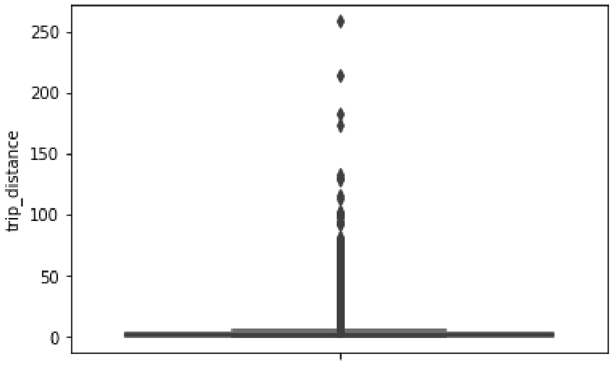
```
12.450173996027528
```

The avg speed in Newyork speed is 12.45miles/hr, so a cab driver can travel2 miles per 10min on avg.

4. Trip Distance

In [27]:

```
# up to now we have removed the outliers based on trip durations and cab speeds
# lets try if there are any outliers in trip distances
# box-plot showing outliers in trip-distance values
sns.boxplot(y="trip_distance", data =frame_with_durations_modified)
plt.show()
```



In [28]:

```
#calculating trip distance values at each percntile 0,10,20,30,40,50,60,70,80,90,100
for i in range(0,100,10):
    var =frame_with_durations_modified["trip_distance"].values
    var = np.sort(var,axis = None)
    print("{} percentile value is {}".format(i,var[int(len(var)*(float(i)/100))]))
print("100 percentile value is ",var[-1])
```

```
0 percentile value is 0.01
10 percentile value is 0.66
20 percentile value is 0.9
30 percentile value is 1.1
40 percentile value is 1.39
50 percentile value is 1.69
60 percentile value is 2.07
70 percentile value is 2.6
80 percentile value is 3.6
90 percentile value is 5.97
100 percentile value is  258.9
```

In [29]:

```
#calculating trip distance values at each percntile 90,91,92,93,94,95,96,97,98,99,100
for i in range(90,100):
    var =frame_with_durations_modified["trip_distance"].values
    var = np.sort(var,axis = None)
    print("{} percentile value is {}".format(i,var[int(len(var)*(float(i)/100))]))
print("100 percentile value is ",var[-1])
```

```
90 percentile value is 5.97
91 percentile value is 6.45
92 percentile value is 7.07
93 percentile value is 7.85
```

```
94 percentile value is 8.72
95 percentile value is 9.6
96 percentile value is 10.6
97 percentile value is 12.1
98 percentile value is 16.03
99 percentile value is 18.17
100 percentile value is  258.9
```

In [30]:

```
#calculating trip distance values at each percntile
99.0,99.1,99.2,99.3,99.4,99.5,99.6,99.7,99.8,99.9,100
for i in np.arange(0.0, 1.0, 0.1):
    var =frame_with_durations_modified["trip_distance"].values
    var = np.sort(var,axis = None)
    print("{} percentile value is {}".format(99+i,var[int(len(var)*(float(99+i)/100))]))
print("100 percentile value is ",var[-1])
```

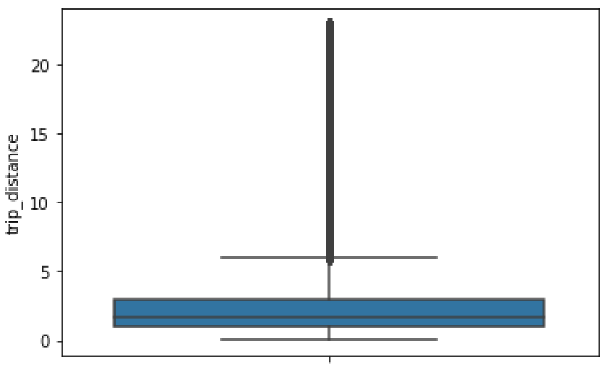
```
99.0 percentile value is 18.17
99.1 percentile value is 18.37
99.2 percentile value is 18.6
99.3 percentile value is 18.83
99.4 percentile value is 19.13
99.5 percentile value is 19.5
99.6 percentile value is 19.96
99.7 percentile value is 20.5
99.8 percentile value is 21.22
99.9 percentile value is 22.57
100 percentile value is  258.9
```

In [0]:

```
#removing further outliers based on the 99.9th percentile value
frame_with_durations_modified=frame_with_durations[(frame_with_durations.trip_distance>0) &
(frame_with_durations.trip_distance<23)]
```

In [32]:

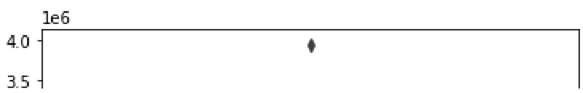
```
#box-plot after removal of outliers
sns.boxplot(y="trip_distance", data = frame_with_durations_modified)
plt.show()
```

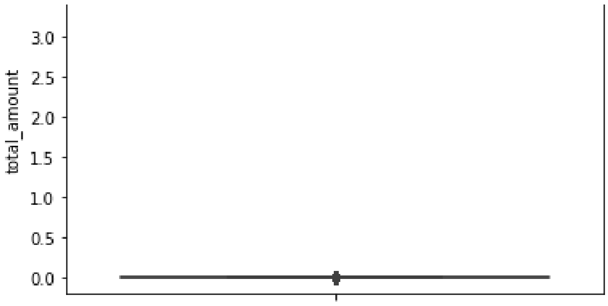


5. Total Fare

In [33]:

```
# up to now we have removed the outliers based on trip durations, cab speeds, and trip distances
# lets try if there are any outliers in based on the total_amount
# box-plot showing outliers in fare
sns.boxplot(y="total_amount", data =frame_with_durations_modified)
plt.show()
```





In [34]:

```
#calculating total fare amount values at each percntile 0,10,20,30,40,50,60,70,80,90,100
for i in range(0,100,10):
    var = frame_with_durations_modified["total_amount"].values
    var = np.sort(var,axis = None)
    print("{} percentile value is {}".format(i,var[int(len(var)*(float(i)/100))]))
print("100 percentile value is ",var[-1])
```

```
0 percentile value is -242.55
10 percentile value is 6.3
20 percentile value is 7.8
30 percentile value is 8.8
40 percentile value is 9.8
50 percentile value is 11.16
60 percentile value is 12.8
70 percentile value is 14.8
80 percentile value is 18.3
90 percentile value is 25.8
100 percentile value is  3950611.6
```

In [35]:

```
#calculating total fare amount values at each percntile 90,91,92,93,94,95,96,97,98,99,100
for i in range(90,100):
    var = frame_with_durations_modified["total_amount"].values
    var = np.sort(var,axis = None)
    print("{} percentile value is {}".format(i,var[int(len(var)*(float(i)/100))]))
print("100 percentile value is ",var[-1])
```

```
90 percentile value is 25.8
91 percentile value is 27.3
92 percentile value is 29.3
93 percentile value is 31.8
94 percentile value is 34.8
95 percentile value is 38.53
96 percentile value is 42.6
97 percentile value is 48.13
98 percentile value is 58.13
99 percentile value is 66.13
100 percentile value is  3950611.6
```

In [36]:

```
#calculating total fare amount values at each percntile
99.0,99.1,99.2,99.3,99.4,99.5,99.6,99.7,99.8,99.9,100
for i in np.arange(0.0, 1.0, 0.1):
    var = frame_with_durations_modified["total_amount"].values
    var = np.sort(var,axis = None)
    print("{} percentile value is {}".format(99+i,var[int(len(var)*(float(99+i)/100))]))
print("100 percentile value is ",var[-1])
```

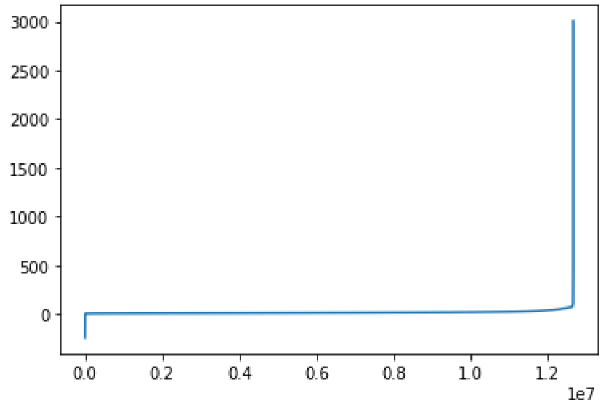
```
99.0 percentile value is 66.13
99.1 percentile value is 68.13
99.2 percentile value is 69.6
99.3 percentile value is 69.6
99.4 percentile value is 69.73
99.5 percentile value is 69.75
99.6 percentile value is 69.76
99.7 percentile value is 72.58
```

```
99.8 percentile value is 75.35
99.9 percentile value is 88.28
100 percentile value is  3950611.6
```

Observation:- As even the 99.9th percentile value doesnt look like an outlier,as there is not much difference between the 99.8th percentile and 99.9th percentile, we move on to do graphical analyis

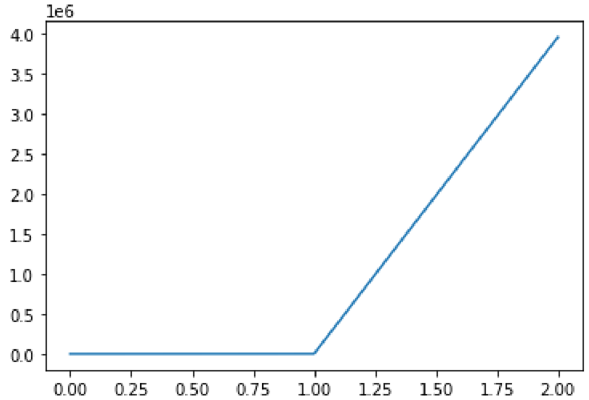
In [37]:

```
#below plot shows us the fare values(sorted) to find a sharp increase to remove those values as ou
tliers
# plot the fare amount excluding last two values in sorted data
plt.plot(var[:-2])
plt.show()
```



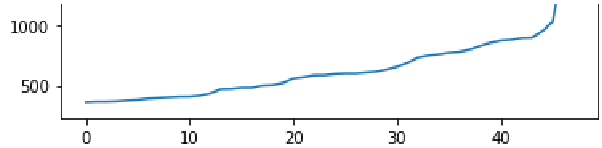
In [38]:

```
# a very sharp increase in fare values can be seen
# plotting last three total fare values, and we can observe there is share increase in the values
plt.plot(var[-3:])
plt.show()
```



In [39]:

```
#now looking at values not including the last two points we again find a drastic increase at aroun
d 1000 fare value
# we plot last 50 values excluding last two values
plt.plot(var[-50:-2])
plt.show()
```



Remove all outliers/erronous points.

In [0]:

```
#removing all outliers based on our univariate analysis above
def remove_outliers(new_frame):


    a = new_frame.shape[0]
    print ("Number of pickup records = ",a)
    temp_frame = new_frame[((new_frame.dropoff_longitude >= -74.15) & (new_frame.dropoff_longitude
<= -73.7004) &\
                        (new_frame.dropoff_latitude >= 40.5774) & (new_frame.dropoff_latitude <=
40.9176)) & \
                        ((new_frame.pickup_longitude >= -74.15) & (new_frame.pickup_latitude >=
40.5774)& \
                        (new_frame.pickup_longitude <= -73.7004) & (new_frame.pickup_latitude <=
40.9176))]
    b = temp_frame.shape[0]
    print ("Number of outlier coordinates lying outside NY boundaries:",(a-b))


    temp_frame = new_frame[(new_frame.trip_times > 0) & (new_frame.trip_times < 720)]
    c = temp_frame.shape[0]
    print ("Number of outliers from trip times analysis:",(a-c))


    temp_frame = new_frame[(new_frame.trip_distance > 0) & (new_frame.trip_distance < 23)]
    d = temp_frame.shape[0]
    print ("Number of outliers from trip distance analysis:",(a-d))

    temp_frame = new_frame[(new_frame.Speed <= 65) & (new_frame.Speed >= 0)]
    e = temp_frame.shape[0]
    print ("Number of outliers from speed analysis:",(a-e))

    temp_frame = new_frame[(new_frame.total_amount <1000) & (new_frame.total_amount >0)]
    f = temp_frame.shape[0]
    print ("Number of outliers from fare analysis:",(a-f))


    new_frame = new_frame[((new_frame.dropoff_longitude >= -74.15) & (new_frame.dropoff_longitude <
= -73.7004) &\
                        (new_frame.dropoff_latitude >= 40.5774) & (new_frame.dropoff_latitude <=
40.9176)) & \
                        ((new_frame.pickup_longitude >= -74.15) & (new_frame.pickup_latitude >=
40.5774)& \
                        (new_frame.pickup_longitude <= -73.7004) & (new_frame.pickup_latitude <=
40.9176))]

    new_frame = new_frame[(new_frame.trip_times > 0) & (new_frame.trip_times < 720)]
    new_frame = new_frame[(new_frame.trip_distance > 0) & (new_frame.trip_distance < 23)]
    new_frame = new_frame[(new_frame.Speed < 45.31) & (new_frame.Speed > 0)]
    new_frame = new_frame[(new_frame.total_amount <1000) & (new_frame.total_amount >0)]

    print ("Total outliers removed",a - new_frame.shape[0])
    print ("---")
    return new_frame
```

In [41]:

```
print ("Removing outliers in the month of Jan-2015")
print ("----")
frame_with_durations_outliers_removed = remove_outliers(frame_with_durations)
print("fraction of data points that remain after removing outliers",
float(len(frame_with_durations_outliers_removed))/len(frame_with_durations))
```

```
Removing outliers in the month of Jan-2015
----
Number of pickup records =  12748986
Number of outlier coordinates lying outside NY boundaries: 293919
Number of outliers from trip times analysis: 23889
Number of outliers from trip distance analysis: 92597
Number of outliers from speed analysis: 24473
Number of outliers from fare analysis: 5275
Total outliers removed 377910
---
fraction of data points that remain after removing outliers 0.9703576425607495
```

Data-preperation

Clustering/Segmentation

In [42]:

```
#trying different cluster sizes to choose the right K in K-means
coords = frame_with_durations_outliers_removed[['pickup_latitude', 'pickup_longitude']].values
neighbours=[]

def find_min_distance(cluster_centers, cluster_len):
    nice_points = 0
    wrong_points = 0
    less2 = []
    more2 = []
    min_dist=1000
    for i in range(0, cluster_len):
        nice_points = 0
        wrong_points = 0
        for j in range(0, cluster_len):
            if j!=i:
                distance = gpxpy.geo.haversine_distance(cluster_centers[i][0], cluster_centers[i][1
,cluster_centers[j][0], cluster_centers[j][1])
                min_dist = min(min_dist,distance/(1.60934*1000))
                if (distance/(1.60934*1000)) <= 2:
                    nice_points +=1
                else:
                    wrong_points += 1
        less2.append(nice_points)
        more2.append(wrong_points)
    neighbours.append(less2)
    print ("On choosing a cluster size of ",cluster_len,"\nAvg. Number of Clusters within the vici
nity (i.e. intercluster-distance < 2):",
           np.ceil(sum(less2)/len(less2)), "\nAvg. Number of Clusters outside the vicinity (i.e. in
tercluster-distance > 2):", np.ceil(sum(more2)/len(more2)),
           "\nMin inter-cluster distance = ",min_dist,"\n---")

def find_clusters(increment):
    kmeans = MiniBatchKMeans(n_clusters=increment, batch_size=10000,random_state=42).fit(coords)
    frame_with_durations_outliers_removed['pickup_cluster'] =
kmeans.predict(frame_with_durations_outliers_removed[['pickup_latitude', 'pickup_longitude']])
    cluster_centers = kmeans.cluster_centers_
    cluster_len = len(cluster_centers)
    return cluster_centers, cluster_len

# we need to choose number of clusters so that, there are more number of cluster regions
#that are close to any cluster center
# and make sure that the minimum inter cluster should not be very less
for increment in range(10, 100, 10):
    cluster_centers, cluster_len = find_clusters(increment)
    find_min_distance(cluster_centers, cluster_len)
```

```
On choosing a cluster size of  10
Avg. Number of Clusters within the vicinity (i.e. intercluster-distance < 2): 2.0
Avg. Number of Clusters outside the vicinity (i.e. intercluster-distance > 2): 8.0
Min inter-cluster distance =  1.0945442325142662
---
On choosing a cluster size of  20
Avg. Number of Clusters within the vicinity (i.e. intercluster-distance < 2): 4.0
Avg. Number of Clusters outside the vicinity (i.e. intercluster-distance > 2): 16.0
Min inter-cluster distance =  0.7131298007388065
```

```
---
On choosing a cluster size of  30
Avg. Number of Clusters within the vicinity (i.e. intercluster-distance < 2): 8.0
Avg. Number of Clusters outside the vicinity (i.e. intercluster-distance > 2): 22.0
Min inter-cluster distance =  0.5185088176172186
---
On choosing a cluster size of  40
Avg. Number of Clusters within the vicinity (i.e. intercluster-distance < 2): 8.0
Avg. Number of Clusters outside the vicinity (i.e. intercluster-distance > 2): 32.0
Min inter-cluster distance =  0.5069768450365043
---
On choosing a cluster size of  50
Avg. Number of Clusters within the vicinity (i.e. intercluster-distance < 2): 12.0
Avg. Number of Clusters outside the vicinity (i.e. intercluster-distance > 2): 38.0
Min inter-cluster distance =  0.36536302598358383
---
On choosing a cluster size of  60
Avg. Number of Clusters within the vicinity (i.e. intercluster-distance < 2): 14.0
Avg. Number of Clusters outside the vicinity (i.e. intercluster-distance > 2): 46.0
Min inter-cluster distance =  0.34704283494173577
---
On choosing a cluster size of  70
Avg. Number of Clusters within the vicinity (i.e. intercluster-distance < 2): 16.0
Avg. Number of Clusters outside the vicinity (i.e. intercluster-distance > 2): 54.0
Min inter-cluster distance =  0.30502203163245994
---
On choosing a cluster size of  80
Avg. Number of Clusters within the vicinity (i.e. intercluster-distance < 2): 18.0
Avg. Number of Clusters outside the vicinity (i.e. intercluster-distance > 2): 62.0
Min inter-cluster distance =  0.292203245317388
---
On choosing a cluster size of  90
Avg. Number of Clusters within the vicinity (i.e. intercluster-distance < 2): 21.0
Avg. Number of Clusters outside the vicinity (i.e. intercluster-distance > 2): 69.0
Min inter-cluster distance =  0.18257992857033273
---
```

Inference:

- The main objective was to find a optimal min. distance(Which roughly estimates to the radius of a cluster) between the clusters which we got was 40

In [0]:

```
# if check for the 50 clusters you can observe that there are two clusters with only 0.3 miles apa
rt from each other
# so we choose 40 clusters for solve the further problem

# Getting 40 clusters using the kmeans
kmeans = MiniBatchKMeans(n_clusters=40, batch_size=10000,random_state=0).fit(coords)
frame_with_durations_outliers_removed['pickup_cluster'] =
kmeans.predict(frame_with_durations_outliers_removed[['pickup_latitude', 'pickup_longitude']])
```

Plotting the cluster centers:

In [44]:

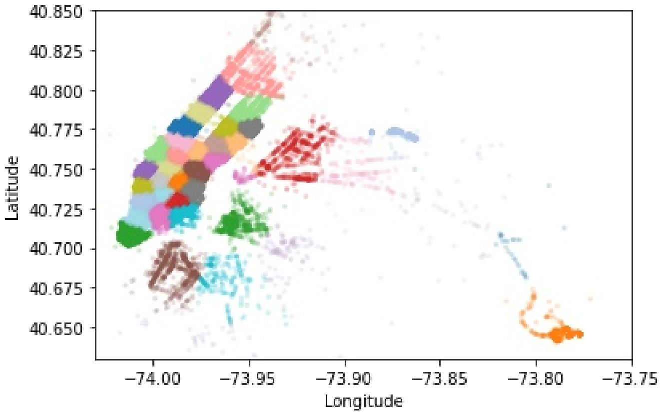
```
# Plotting the cluster centers on OSM
cluster_centers = kmeans.cluster_centers_
cluster_len = len(cluster_centers)
map_osm = folium.Map(location=[40.734695, -73.990372], tiles='Stamen Toner')
for i in range(cluster_len):
    folium.Marker(list((cluster_centers[i][0],cluster_centers[i][1])), popup=(str(cluster_centers[i
][0])+str(cluster_centers[i][1]))).add_to(map_osm)
map_osm
```

Out[44]:

Plotting the clusters:

In [45]:

```
# visualise clusters on map

def plot_clusters(frame):
    city_long_border = (-74.03, -73.75)
    city_lat_border = (40.63, 40.85)
    fig, ax = plt.subplots(ncols=1,nrows=1)
    ax.scatter(frame.pickup_longitude.values[:100000], frame.pickup_latitude.values[:100000],
               s=10,lw=0, c= frame.pickup_cluster.values[:100000],cmap='tab20',alpha=0.2)
    ax.set_xlim(city_long_border)
    ax.set_ylim(city_lat_border)
    ax.set_xlabel('Longitude')
    ax.set_ylabel('Latitude')
    plt.show()


plot_clusters(frame_with_durations_outliers_removed)
```



Time-binning

In [0]:

```
def add_pickup_bins(frame,month,year):
  unix_pickup_times = [i for i in frame['pickup_times'].values]
  unix_times = [[1420070400,1422748800,1425168000,1427846400,1430438400,1433116800],\
                [1451606400,1454284800,1456790400,1459468800,1462060800,1464739200]]
  start_pickup_unix = unix_times[year-2015][month-1]
```

```
    start_pickup_unix = unix_times[year-2015][month-1]
    tenminutewise_binned_unix_pickup_times=[(int((i-start_pickup_unix)/600)+33) for i in unix_pickup_
times]
    frame['pickup_bins'] = np.array(tenminutewise_binned_unix_pickup_times)

    return frame
```

In [0]:

```
# clustering, making pickup bins and grouping by pickup cluster and pickup bins
frame_with_durations_outliers_removed['pickup_cluster'] =
kmeans.predict(frame_with_durations_outliers_removed[['pickup_latitude', 'pickup_longitude']])
jan_2015_frame = add_pickup_bins(frame_with_durations_outliers_removed,1,2015)
```

In [0]:

```
  jan_2015_groupby =
jan_2015_frame[['pickup_cluster','pickup_bins','trip_distance']].groupby(['pickup_cluster','pickup_
bins']).count()
```

In [49]:

```
# we add two more columns 'pickup_cluster'(to which cluster it belogns to)
# and 'pickup_bins' (to which 10min intravel the trip belongs to)
jan_2015_frame.head()
```

Out[49]:

	passenger_count	trip_distance	pickup_longitude	pickup_latitude	dropoff_longitude	dropoff_latitude	total_amount	tri
0	1	1.59	-73.993896	40.750111	-73.974785	40.750618	17.05	18
1	1	3.30	-74.001648	40.724243	-73.994415	40.759109	17.80	19
2	1	1.80	-73.963341	40.802788	-73.951820	40.824413	10.80	10
3	1	0.50	-74.009087	40.713818	-74.004326	40.719986	4.80	1.
4	1	3.00	-73.971176	40.762428	-74.004181	40.742653	16.30	19

In [50]:

```
# hear the trip_distance represents the number of pickups that are happend in that particular 10mi
n intravel
# this data frame has two indices
# primary index: pickup_cluster (cluster number)
# secondary index : pickup_bins (we devid whole months time into 10min intravels 24*31*60/10 =4464
bins)
jan_2015_groupby.head()
```

Out[50]:

		trip_distance
pickup_cluster	**pickup_bins**	
0	**33**	104
	34	200
	35	208
	36	141
	37	155

In [51]:

```
# upto now we cleaned data and prepared data for the month 2015,

# now do the same operations for months Jan, Feb, March of 2016
# 1. get the dataframe which inlcudes only required colums
```

```
# 2. adding trip times, speed, unix time stamp of pickup_time
# 4. remove the outliers based on trip_times, speed, trip_duration, total_amount
# 5. add pickup_cluster to each data point
# 6. add pickup_bin (index of 10min intravel to which that trip belongs to)
# 7. group by data, based on 'pickup_cluster' and 'pickuo_bin'

# Data Preparation for the months of Jan,Feb and March 2016
def datapreparation(month,kmeans,month_no,year_no):

    print ("Return with trip times..")

    frame_with_durations = return_with_trip_times(month)

    print ("Remove outliers..")
    frame_with_durations_outliers_removed = remove_outliers(frame_with_durations)

    print ("Estimating clusters..")
    frame_with_durations_outliers_removed['pickup_cluster'] =
kmeans.predict(frame_with_durations_outliers_removed[['pickup_latitude', 'pickup_longitude']])
    #frame_with_durations_outliers_removed_2016['pickup_cluster'] =
kmeans.predict(frame_with_durations_outliers_removed_2016[['pickup_latitude',
'pickup_longitude']])

    print ("Final groupbying..")
    final_updated_frame = add_pickup_bins(frame_with_durations_outliers_removed,month_no,year_no)
    final_groupby_frame = final_updated_frame[['pickup_cluster','pickup_bins','trip_distance']].grc
upby(['pickup_cluster','pickup_bins']).count()

    return final_updated_frame,final_groupby_frame

month_jan_2016 = dd.read_csv('/content/drive/My Drive/Data_Notebooks/yellow_tripdata_2016-01.csv')
month_feb_2016 = dd.read_csv('/content/drive/My Drive/Data_Notebooks/yellow_tripdata_2016-02.csv')
month_mar_2016 = dd.read_csv('/content/drive/My Drive/Data_Notebooks/yellow_tripdata_2016-03.csv')

jan_2016_frame,jan_2016_groupby = datapreparation(month_jan_2016,kmeans,1,2016)
feb_2016_frame,feb_2016_groupby = datapreparation(month_feb_2016,kmeans,2,2016)
mar_2016_frame,mar_2016_groupby = datapreparation(month_mar_2016,kmeans,3,2016)
```

```
Return with trip times..
Remove outliers..
Number of pickup records =  10906858
Number of outlier coordinates lying outside NY boundaries: 214677
Number of outliers from trip times analysis: 27190
Number of outliers from trip distance analysis: 79742
Number of outliers from speed analysis: 21047
Number of outliers from fare analysis: 4991
Total outliers removed 297784
---
Estimating clusters..
Final groupbying..
Return with trip times..
Remove outliers..
Number of pickup records =  11382049
Number of outlier coordinates lying outside NY boundaries: 223161
Number of outliers from trip times analysis: 27670
Number of outliers from trip distance analysis: 81902
Number of outliers from speed analysis: 22437
Number of outliers from fare analysis: 5476
Total outliers removed 308177
---
Estimating clusters..
Final groupbying..
Return with trip times..
Remove outliers..
Number of pickup records =  12210952
Number of outlier coordinates lying outside NY boundaries: 232444
Number of outliers from trip times analysis: 30868
Number of outliers from trip distance analysis: 87318
Number of outliers from speed analysis: 23889
Number of outliers from fare analysis: 5859
Total outliers removed 324635
---
Estimating clusters..
Final groupbying..
```

Smoothing

In [0]:

```
# Gets the unique bins where pickup values are present for each each reigion

# for each cluster region we will collect all the indices of 10min intravels in which the pickups are happened
# we got an observation that there are some pickpbins that doesnt have any pickups
def return_unq_pickup_bins(frame):
    values = []
    for i in range(0,40):
        new = frame[frame['pickup_cluster'] == i]
        list_unq = list(set(new['pickup_bins']))
        list_unq.sort()
        values.append(list_unq)
    return values
```

In [0]:

```
# for every month we get all indices of 10min intravels in which atleast one pickup got happened

#jan
jan_2015_unique = return_unq_pickup_bins(jan_2015_frame)
jan_2016_unique = return_unq_pickup_bins(jan_2016_frame)

#feb
feb_2016_unique = return_unq_pickup_bins(feb_2016_frame)

#march
mar_2016_unique = return_unq_pickup_bins(mar_2016_frame)
```

In [54]:

```
# for each cluster number of 10min intravels with 0 pickups
for i in range(40):
    print("for the ",i,"th cluster number of 10min intavels with zero pickups: ",4464 - len(set(jan_2015_unique[i])))
    print('-'*60)
```

```
for the  0 th cluster number of 10min intavels with zero pickups:  40
------------------------------------------------------------
for the  1 th cluster number of 10min intavels with zero pickups:  1985
------------------------------------------------------------
for the  2 th cluster number of 10min intavels with zero pickups:  29
------------------------------------------------------------
for the  3 th cluster number of 10min intavels with zero pickups:  354
------------------------------------------------------------
for the  4 th cluster number of 10min intavels with zero pickups:  37
------------------------------------------------------------
for the  5 th cluster number of 10min intavels with zero pickups:  153
------------------------------------------------------------
for the  6 th cluster number of 10min intavels with zero pickups:  34
------------------------------------------------------------
for the  7 th cluster number of 10min intavels with zero pickups:  34
------------------------------------------------------------
for the  8 th cluster number of 10min intavels with zero pickups:  117
------------------------------------------------------------
for the  9 th cluster number of 10min intavels with zero pickups:  40
------------------------------------------------------------
for the  10 th cluster number of 10min intavels with zero pickups:  25
------------------------------------------------------------
for the  11 th cluster number of 10min intavels with zero pickups:  44
------------------------------------------------------------
for the  12 th cluster number of 10min intavels with zero pickups:  42
------------------------------------------------------------
for the  13 th cluster number of 10min intavels with zero pickups:  28
------------------------------------------------------------
for the  14 th cluster number of 10min intavels with zero pickups:  26
------------------------------------------------------------
for the  15 th cluster number of 10min intavels with zero pickups:  31
------------------------------------------------------------
for the  16 th cluster number of 10min intavels with zero pickups:  40
------------------------------------------------------------
```

```
------------------------------------------------------------
for the  17 th cluster number of 10min intavels with zero pickups:  58
------------------------------------------------------------
for the  18 th cluster number of 10min intavels with zero pickups:  1190
------------------------------------------------------------
for the  19 th cluster number of 10min intavels with zero pickups:  1357
------------------------------------------------------------
for the  20 th cluster number of 10min intavels with zero pickups:  53
------------------------------------------------------------
for the  21 th cluster number of 10min intavels with zero pickups:  29
------------------------------------------------------------
for the  22 th cluster number of 10min intavels with zero pickups:  29
------------------------------------------------------------
for the  23 th cluster number of 10min intavels with zero pickups:  163
------------------------------------------------------------
for the  24 th cluster number of 10min intavels with zero pickups:  35
------------------------------------------------------------
for the  25 th cluster number of 10min intavels with zero pickups:  41
------------------------------------------------------------
for the  26 th cluster number of 10min intavels with zero pickups:  31
------------------------------------------------------------
for the  27 th cluster number of 10min intavels with zero pickups:  214
------------------------------------------------------------
for the  28 th cluster number of 10min intavels with zero pickups:  36
------------------------------------------------------------
for the  29 th cluster number of 10min intavels with zero pickups:  41
------------------------------------------------------------
for the  30 th cluster number of 10min intavels with zero pickups:  1180
------------------------------------------------------------
for the  31 th cluster number of 10min intavels with zero pickups:  42
------------------------------------------------------------
for the  32 th cluster number of 10min intavels with zero pickups:  44
------------------------------------------------------------
for the  33 th cluster number of 10min intavels with zero pickups:  43
------------------------------------------------------------
for the  34 th cluster number of 10min intavels with zero pickups:  39
------------------------------------------------------------
for the  35 th cluster number of 10min intavels with zero pickups:  42
------------------------------------------------------------
for the  36 th cluster number of 10min intavels with zero pickups:  36
------------------------------------------------------------
for the  37 th cluster number of 10min intavels with zero pickups:  321
------------------------------------------------------------
for the  38 th cluster number of 10min intavels with zero pickups:  36
------------------------------------------------------------
for the  39 th cluster number of 10min intavels with zero pickups:  43
------------------------------------------------------------
```

there are two ways to fill up these values

- Fill the missing value with 0's
- Fill the missing values with the avg values
  - Case 1:(values missing at the start)
    Ex1: _ _ _ x =>ceil(x/4), ceil(x/4), ceil(x/4), ceil(x/4)
    Ex2: _ _ x => ceil(x/3), ceil(x/3), ceil(x/3)
  - Case 2:(values missing in middle)
    Ex1: x _ _ y => ceil((x+y)/4), ceil((x+y)/4), ceil((x+y)/4), ceil((x+y)/4)
    Ex2: x _ _ _ y => ceil((x+y)/5), ceil((x+y)/5), ceil((x+y)/5), ceil((x+y)/5), ceil((x+y)/5)
  - Case 3:(values missing at the end)
    Ex1: x _ _ _ => ceil(x/4), ceil(x/4), ceil(x/4), ceil(x/4)
    Ex2: x _ => ceil(x/2), ceil(x/2)

In [0]:

```python
# Fills a value of zero for every bin where no pickup data is present
# the count_values: number pickps that are happened in each region for each 10min intravel
# there wont be any value if there are no picksups.
# values: number of unique bins

# for every 10min intravel(pickup_bin) we will check it is there in our unique bin,
# if it is there we will add the count_values[index] to smoothed data
# if not we add 0 to the smoothed data
# we finally return smoothed data
def fill_missing(count_values,values):
```

```
    smoothed_regions=[]
    ind=0
    for r in range(0,40):
        smoothed_bins=[]
        for i in range(4464):
            if i in values[r]:
                smoothed_bins.append(count_values[ind])
                ind+=1
            else:
                smoothed_bins.append(0)
        smoothed_regions.extend(smoothed_bins)
    return smoothed_regions
```

In [0]:

```
# Fills a value of zero for every bin where no pickup data is present
# the count_values: number pickps that are happened in each region for each 10min intravel
# there wont be any value if there are no picksups.
# values: number of unique bins

# for every 10min intravel(pickup_bin) we will check it is there in our unique bin,
# if it is there we will add the count_values[index] to smoothed data
# if not we add smoothed data (which is calculated based on the methods that are discussed in the
above markdown cell)
# we finally return smoothed data
def smoothing(count_values,values):
    smoothed_regions=[] # stores list of final smoothed values of each reigion
    ind=0
    repeat=0
    smoothed_value=0
    for r in range(0,40):
        smoothed_bins=[] #stores the final smoothed values
        repeat=0
        for i in range(4464):
            if repeat!=0: # prevents iteration for a value which is already visited/resolved
                repeat-=1
                continue
            if i in values[r]: #checks if the pickup-bin exists
                smoothed_bins.append(count_values[ind]) # appends the value of the pickup bin if it
exists
            else:
                if i!=0:
                    right_hand_limit=0
                    for j in range(i,4464):
                        if  j not in values[r]: #searches for the left-limit or the pickup-bin
value which has a pickup value
                            continue
                        else:
                            right_hand_limit=j
                            break
                    if right_hand_limit==0:
                    #Case 1: When we have the last/last few values are found to be missing,hence we
have no right-limit here
                        smoothed_value=count_values[ind-1]*1.0/((4463-i)+2)*1.0

                        for j in range(i,4464):
                            smoothed_bins.append(math.ceil(smoothed_value))
                        smoothed_bins[i-1] = math.ceil(smoothed_value)
                        repeat=(4463-i)
                        ind-=1
                    else:
                    #Case 2: When we have the missing values between two known values
                        smoothed_value=(count_values[ind-1]+count_values[ind])*1.0/((right_hand_lim
t-i)+2)*1.0
                        for j in range(i,right_hand_limit+1):
                            smoothed_bins.append(math.ceil(smoothed_value))
                        smoothed_bins[i-1] = math.ceil(smoothed_value)
                        repeat=(right_hand_limit-i)
                else:
                    #Case 3: When we have the first/first few values are found to be missing,hence
we have no left-limit here
                    right_hand_limit=0
                    for j in range(i,4464):
                        if  j not in values[r]:
                            continue
                        else:
```

```
                        right_hand_limit=j
                        break
                smoothed_value=count_values[ind]*1.0/((right_hand_limit-i)+1)*1.0
                for j in range(i,right_hand_limit+1):
                        smoothed_bins.append(math.ceil(smoothed_value))
                repeat=(right_hand_limit-i)
            ind+=1
        smoothed_regions.extend(smoothed_bins)
    return smoothed_regions
```

In [0]:

```
#Filling Missing values of Jan-2015 with 0
# here in jan_2015_groupby dataframe the trip_distance represents the number of pickups that are h
appened
jan_2015_fill = fill_missing(jan_2015_groupby['trip_distance'].values,jan_2015_unique)
```

In [0]:

```
#Smoothing Missing values of Jan-2015
jan_2015_smooth = smoothing(jan_2015_groupby['trip_distance'].values,jan_2015_unique)
```

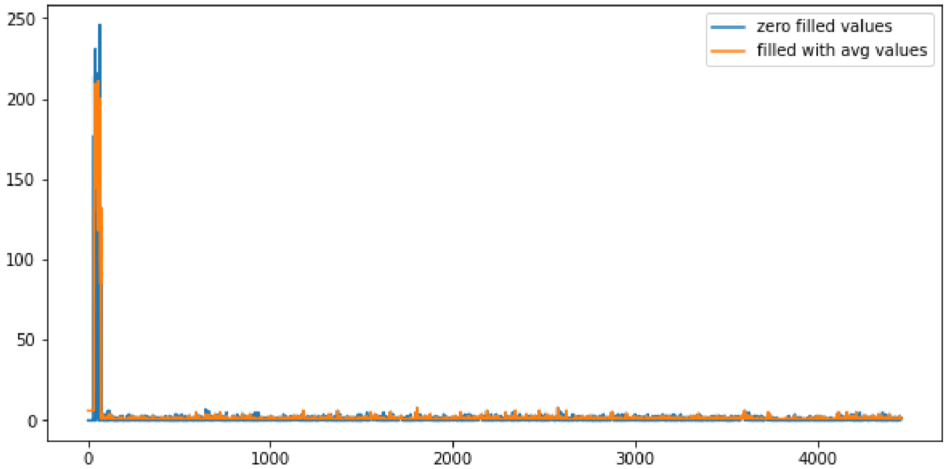
In [59]:

```
# number of 10min indices for jan 2015= 24*31*60/10 = 4464
# number of 10min indices for jan 2016 = 24*31*60/10 = 4464
# number of 10min indices for feb 2016 = 24*29*60/10 = 4176
# number of 10min indices for march 2016 = 24*30*60/10 = 4320
# for each cluster we will have 4464 values, therefore 40*4464 = 178560 (length of the
jan_2015_fill)
print("number of 10min intravels among all the clusters ",len(jan_2015_fill))
```

```
number of 10min intravels among all the clusters  178560
```

In [60]:

```
# Smoothing vs Filling
# sample plot that shows two variations of filling missing values
# we have taken the number of pickups for cluster region 2
plt.figure(figsize=(10,5))
plt.plot(jan_2015_fill[4464:8920], label="zero filled values")
plt.plot(jan_2015_smooth[4464:8920], label="filled with avg values")
plt.legend()
plt.show()
```



In [0]:

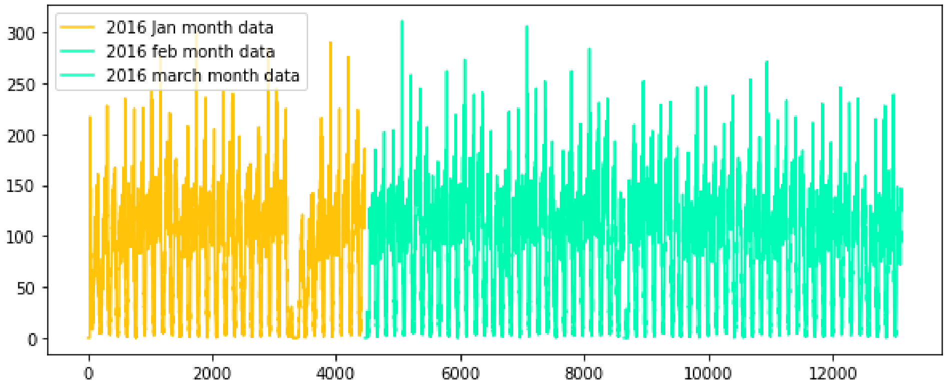
```
# Jan-2015 data is smoothed, Jan,Feb & March 2016 data missing values are filled with zero
jan_2015_smooth = smoothing(jan_2015_groupby['trip_distance'].values,jan_2015_unique)
jan_2016_smooth = fill_missing(jan_2016_groupby['trip_distance'].values,jan_2016_unique)
feb_2016_smooth = fill_missing(feb_2016_groupby['trip_distance'].values,feb_2016_unique)
mar_2016_smooth = fill_missing(mar_2016_groupby['trip_distance'].values,mar_2016_unique)
```

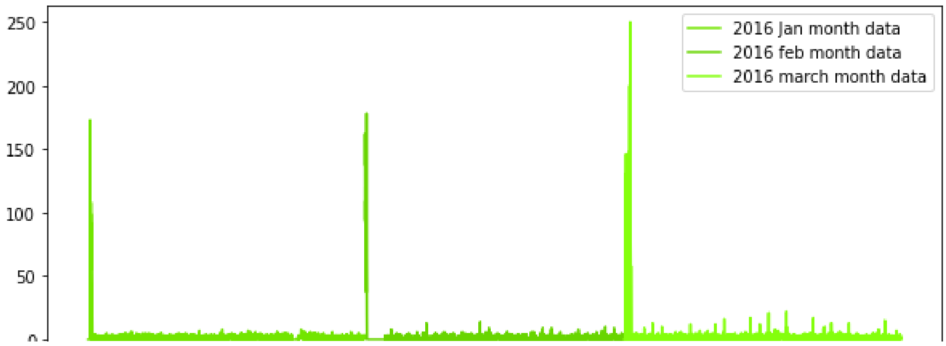
```
# Making list of all the values of pickup data in every bin for a period of 3 months and storing t
hem region-wise
regions_cum = []

# a =[1,2,3]
# b = [2,3,4]
# a+b = [1, 2, 3, 2, 3, 4]

# number of 10min indices for jan 2015= 24*31*60/10 = 4464
# number of 10min indices for jan 2016 = 24*31*60/10 = 4464
# number of 10min indices for feb 2016 = 24*29*60/10 = 4176
# number of 10min indices for march 2016 = 24*31*60/10 = 4464
# regions_cum: it will contain 40 lists, each list will contain 4464+4176+4464 values which repres
ents the number of pickups
# that are happened for three months in 2016 data

for i in range(0,40):
    regions_cum.append(jan_2016_smooth[4464*i:4464*(i+1)]+feb_2016_smooth[4176*i:4176*(i+1)]+mar_20
16_smooth[4464*i:4464*(i+1)])

# print(len(regions_cum))
# 40
# print(len(regions_cum[0]))
# 13104
```

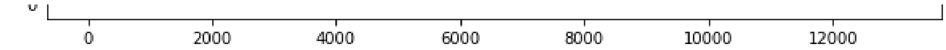
Time series and Fourier Transforms

In [62]:

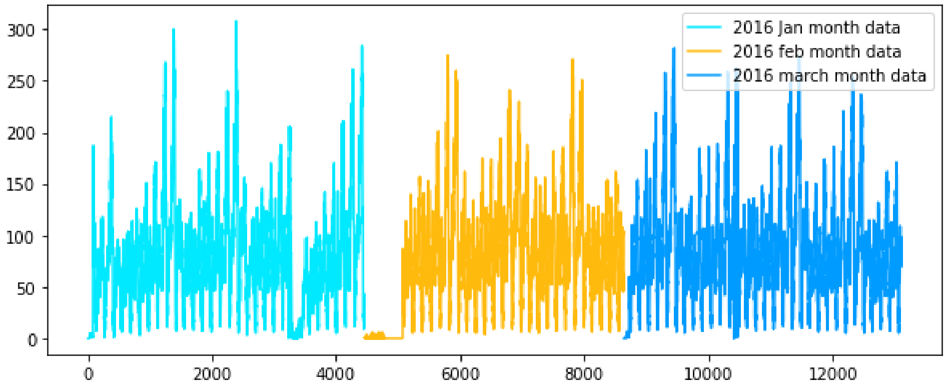
```
def uniqueish_color():
    """There're better ways to generate unique colors, but this isn't awful."""
    return plt.cm.gist_ncar(np.random.random())
first_x = list(range(0,4464))
second_x = list(range(4464,8640))
third_x = list(range(8640,13104))
for i in range(40):
    plt.figure(figsize=(10,4))
    plt.plot(first_x,regions_cum[i][:4464], color=uniqueish_color(), label='2016 Jan month data')
    plt.plot(second_x,regions_cum[i][4464:8640], color=uniqueish_color(), label='2016 feb month dat
a')
    plt.plot(third_x,regions_cum[i][8640:], color=uniqueish_color(), label='2016 march month data')
    plt.legend()
    plt.show()
```



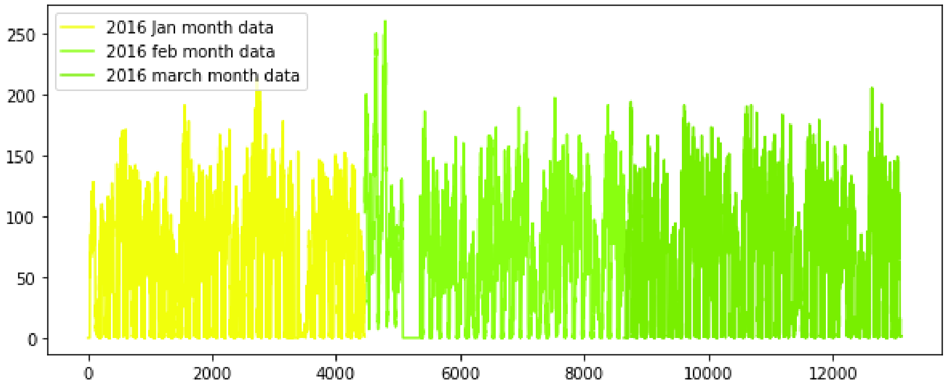




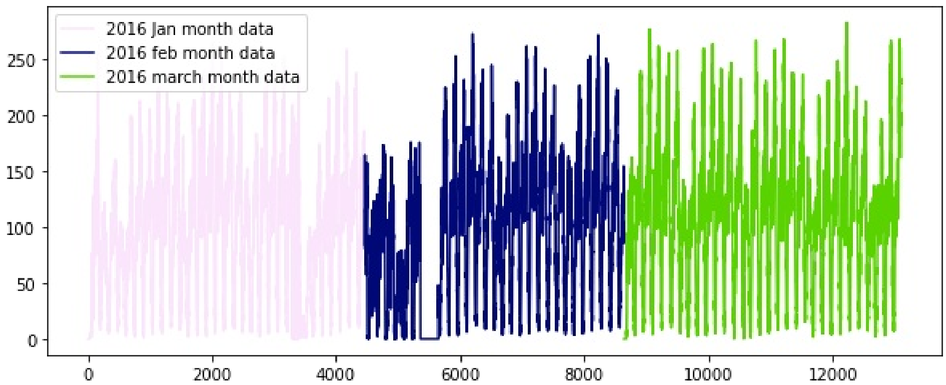
0
0 2000 4000 6000 8000 10000 12000



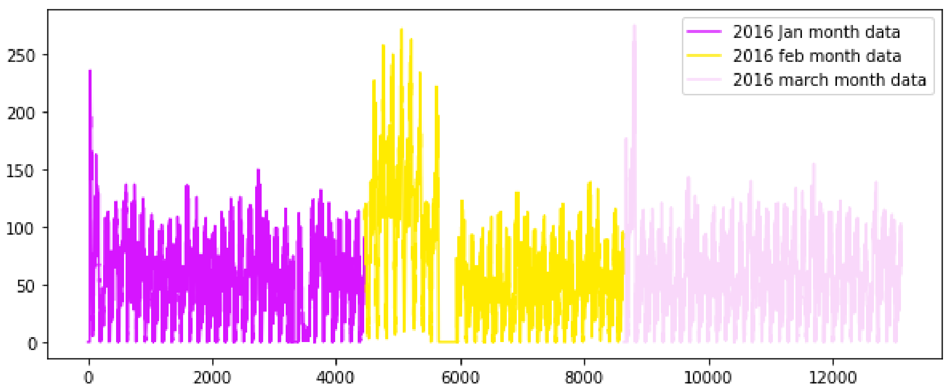
2016 Jan month data
2016 feb month data
2016 march month data
0 50 100 150 200 250 300
0 2000 4000 6000 8000 10000 12000



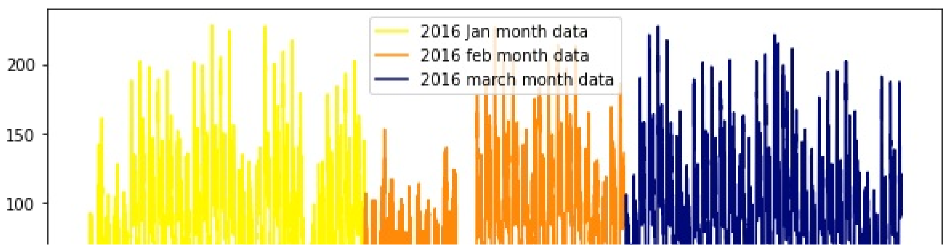
2016 Jan month data
2016 feb month data
2016 march month data
0 50 100 150 200 250
0 2000 4000 6000 8000 10000 12000



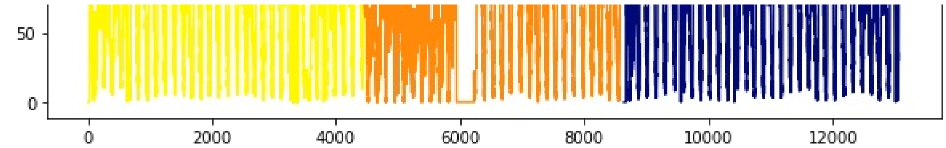
2016 Jan month data
2016 feb month data
2016 march month data
0 50 100 150 200 250
0 2000 4000 6000 8000 10000 12000

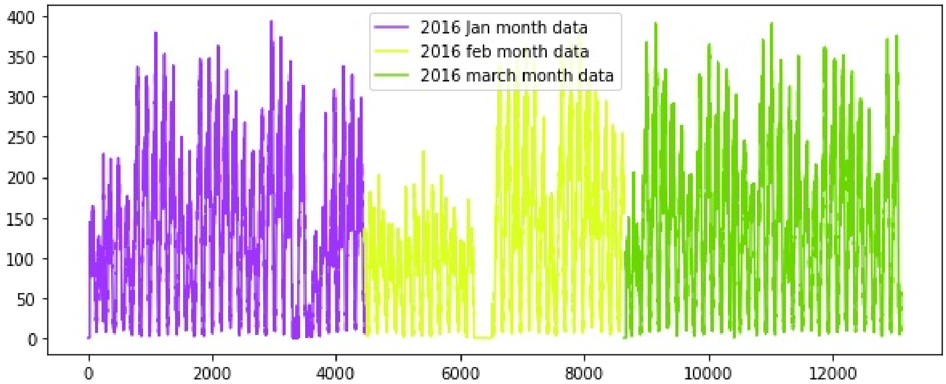


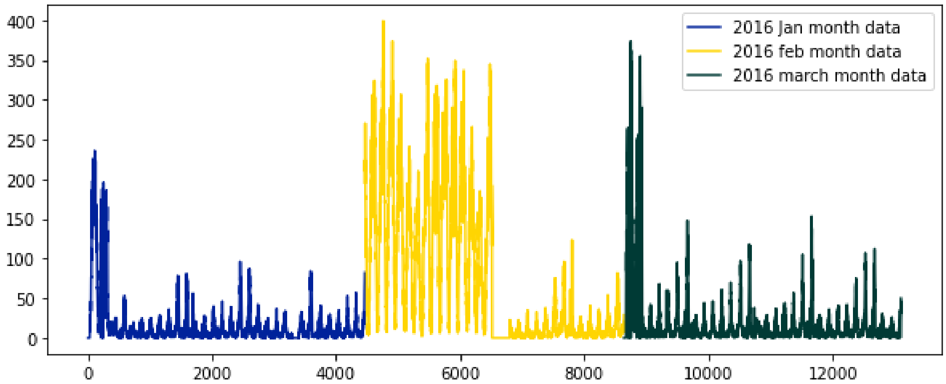
2016 Jan month data
2016 feb month data
2016 march month data
0 50 100 150 200 250
0 2000 4000 6000 8000 10000 12000

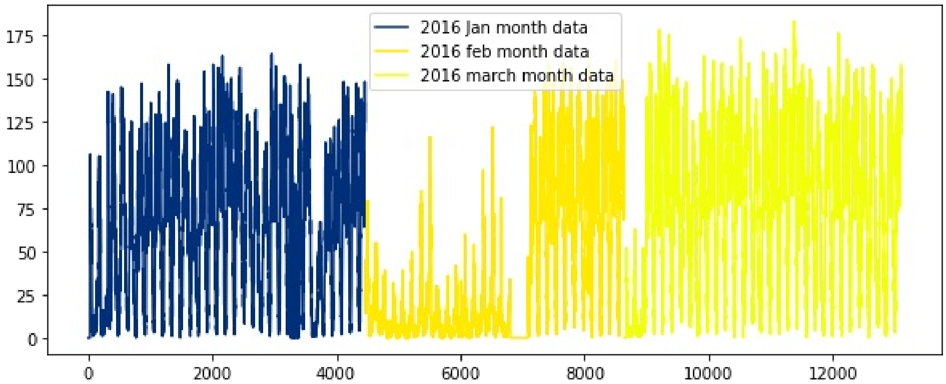


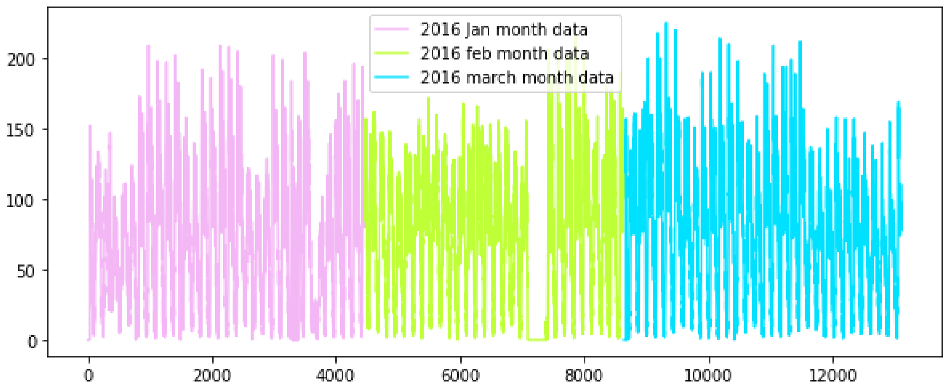
2016 Jan month data
2016 feb month data
2016 march month data
100 150 200

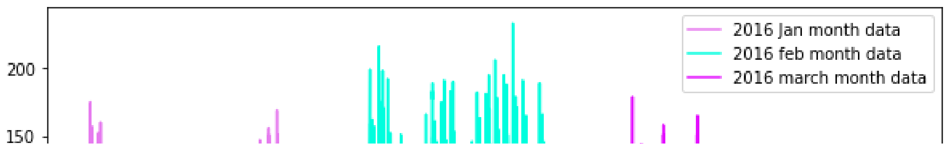


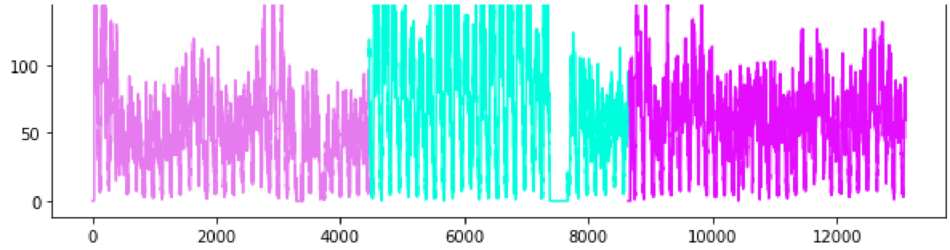

2016 Jan month data
2016 feb month data
2016 march month data

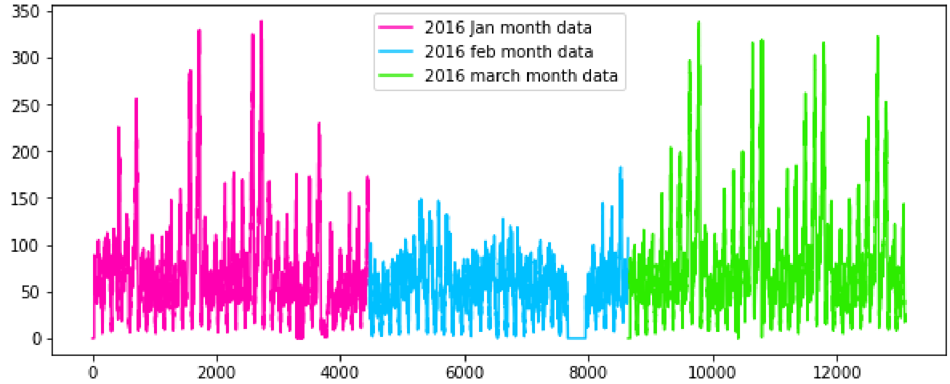

2016 Jan month data
2016 feb month data
2016 march month data

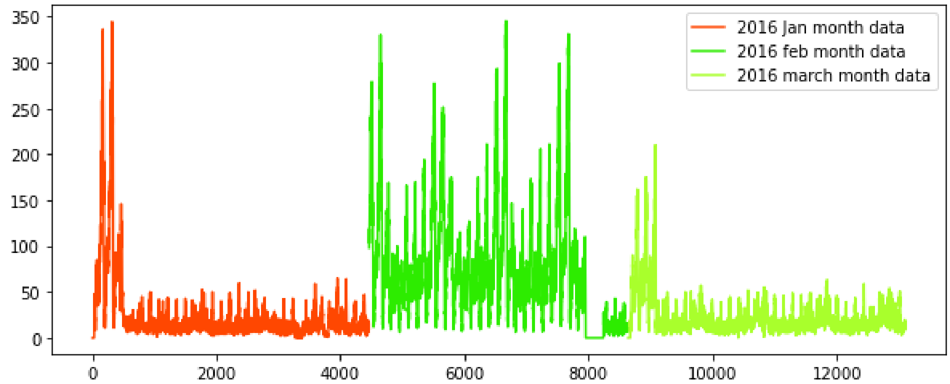

2016 Jan month data
2016 feb month data
2016 march month data

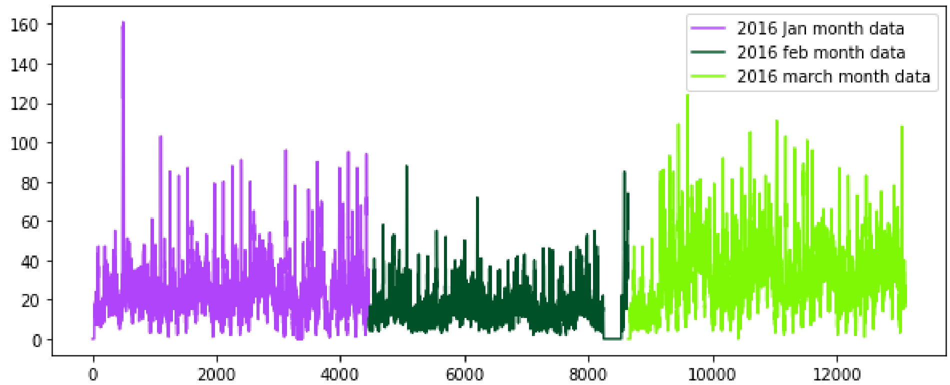

2016 Jan month data
2016 feb month data
2016 march month data

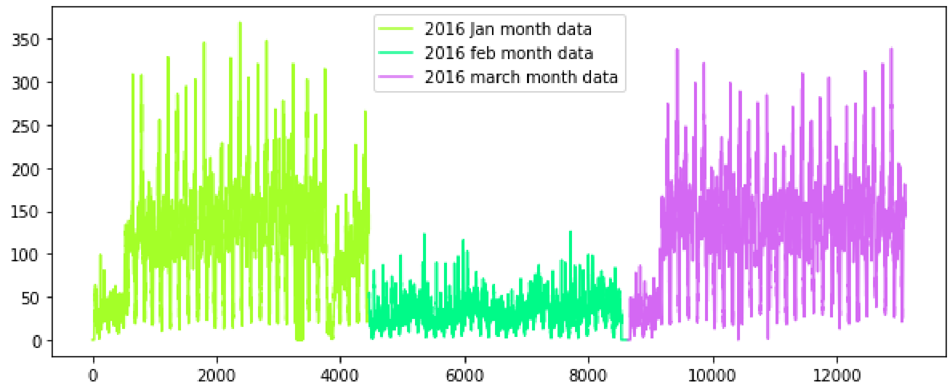

2016 Jan month data
2016 feb month data
2016 march month data



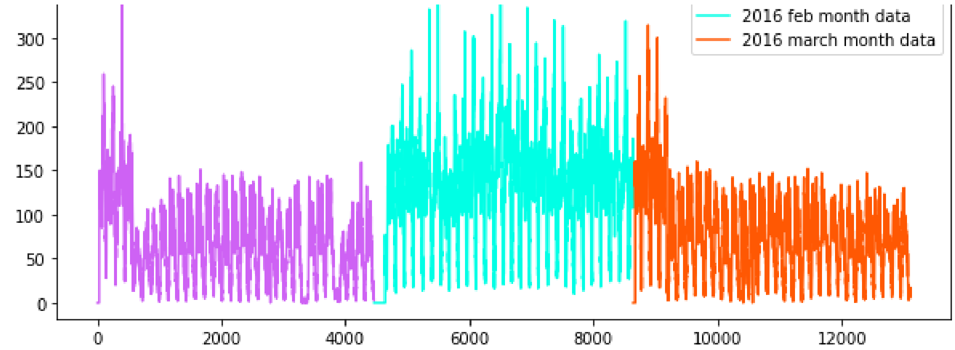

2016 Jan month data
2016 feb month data
2016 march month data

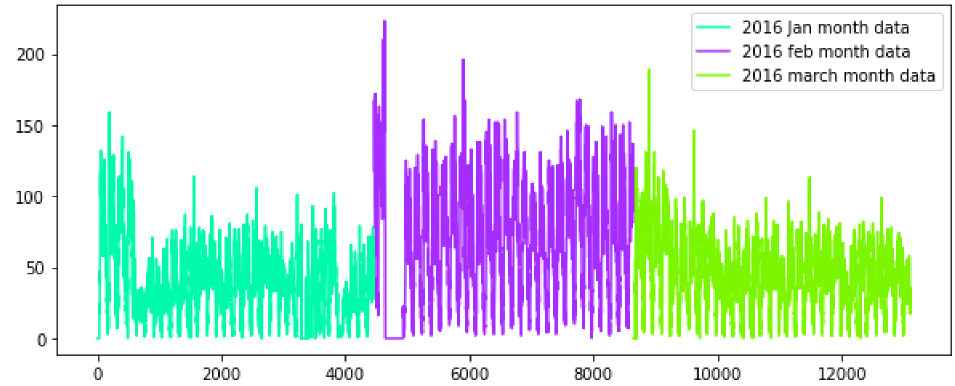

2016 Jan month data
2016 feb month data
2016 march month data

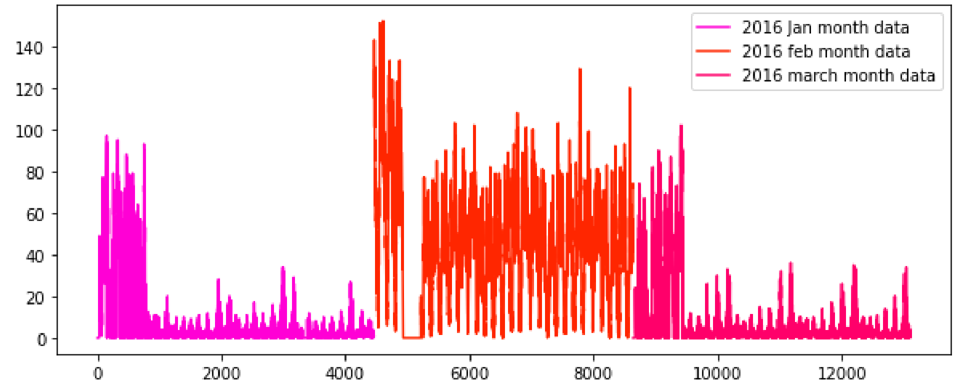

2016 Jan month data
2016 feb month data
2016 march month data

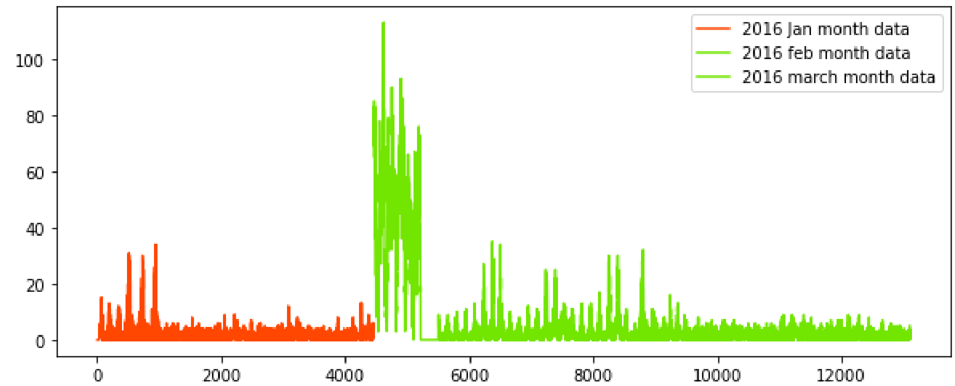

2016 Jan month data
2016 feb month data
2016 march month data

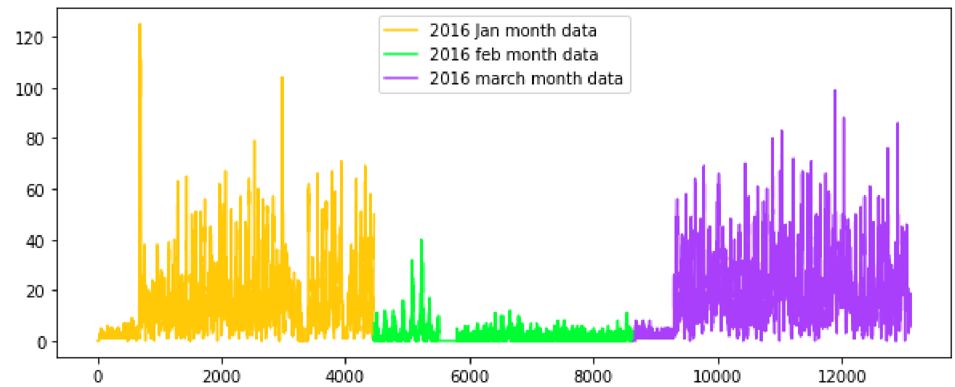

2016 Jan month data

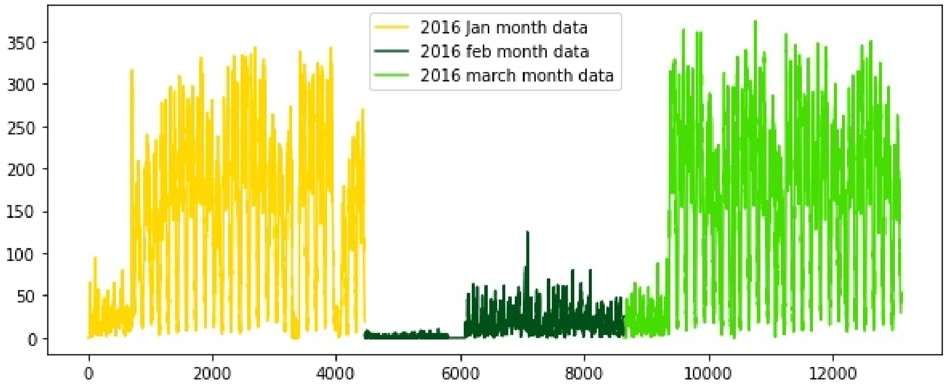

2016 feb month data
2016 march month data
0 50 100 150 200 250 300
0 2000 4000 6000 8000 10000 12000

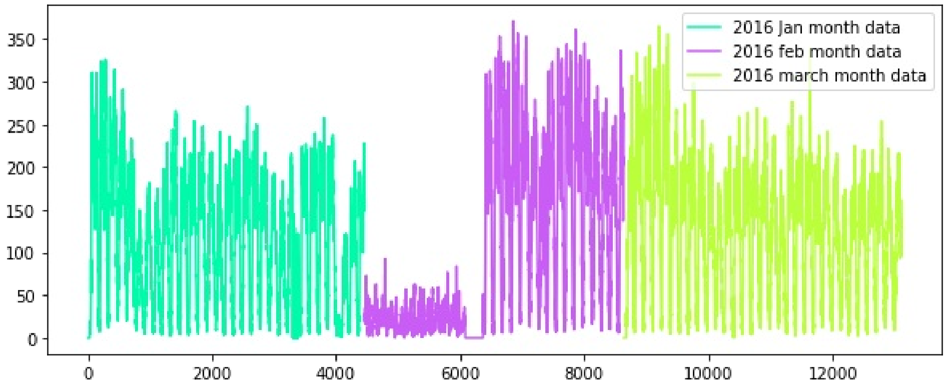

2016 Jan month data
2016 feb month data
2016 march month data
0 50 100 150 200
0 2000 4000 6000 8000 10000 12000

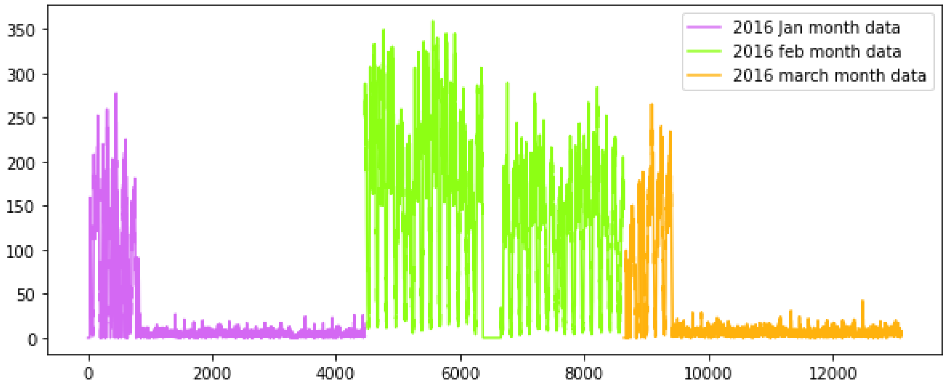

2016 Jan month data
2016 feb month data
2016 march month data
0 20 40 60 80 100 120 140
0 2000 4000 6000 8000 10000 12000

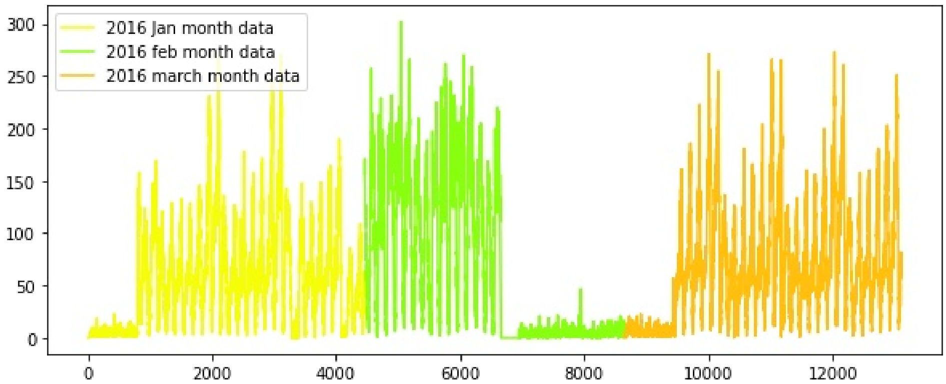

2016 Jan month data
2016 feb month data
2016 march month data
0 20 40 60 80 100
0 2000 4000 6000 8000 10000 12000


2016 Jan month data
2016 feb month data
2016 march month data
0 20 40 60 80 100 120
0 2000 4000 6000 8000 10000 12000


2016 Jan month data
2016 feb month data
2016 march month data
0
50
100
150
200
250
300
350
0
2000
4000
6000
8000
10000
12000


2016 Jan month data
2016 feb month data
2016 march month data
0
50
100
150
200
250
300
350
0
2000
4000
6000
8000
10000
12000


2016 Jan month data
2016 feb month data
2016 march month data
0
50
100
150
200
250
300
350
0
2000
4000
6000
8000
10000
12000


2016 Jan month data
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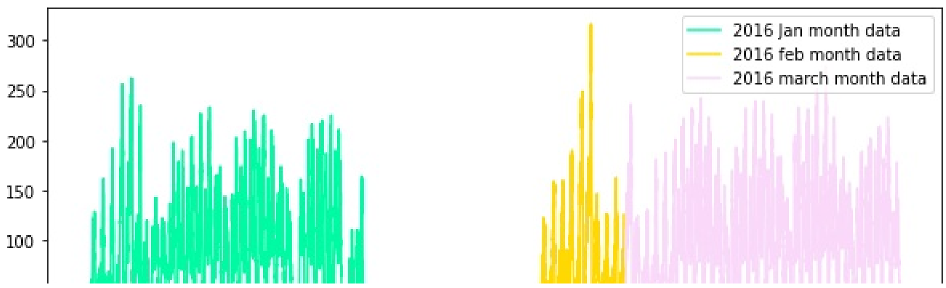
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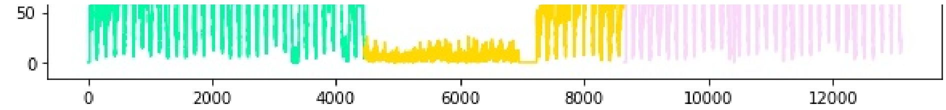
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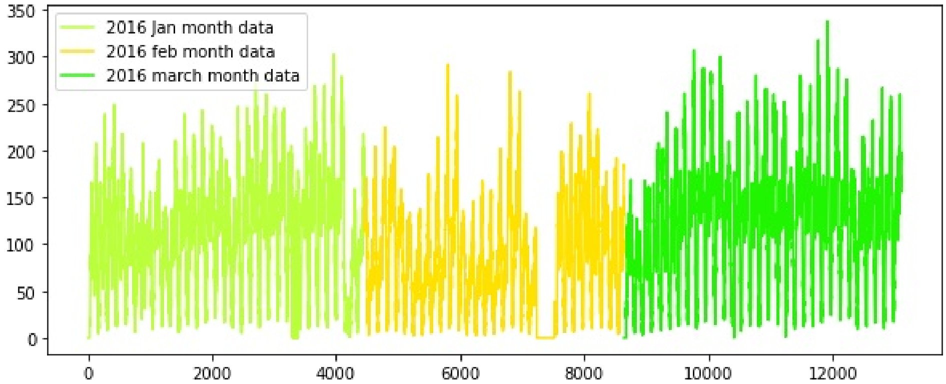
2016 Jan month data
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2016 march month data
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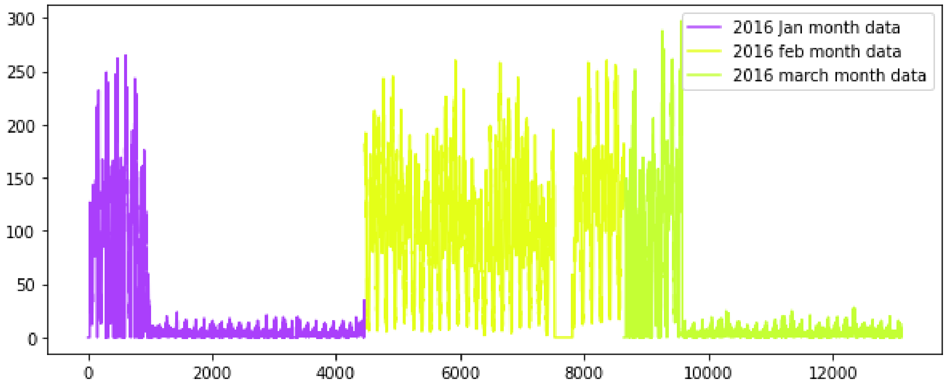
2016 Jan month data
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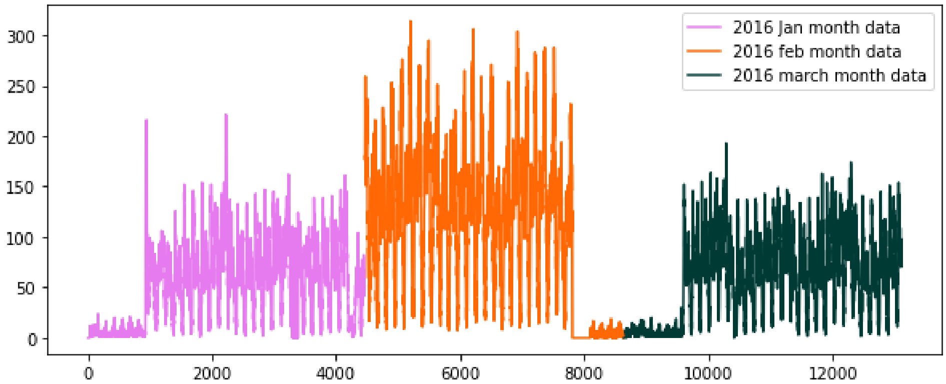
2016 Jan month data
2016 feb month data
2016 march month data
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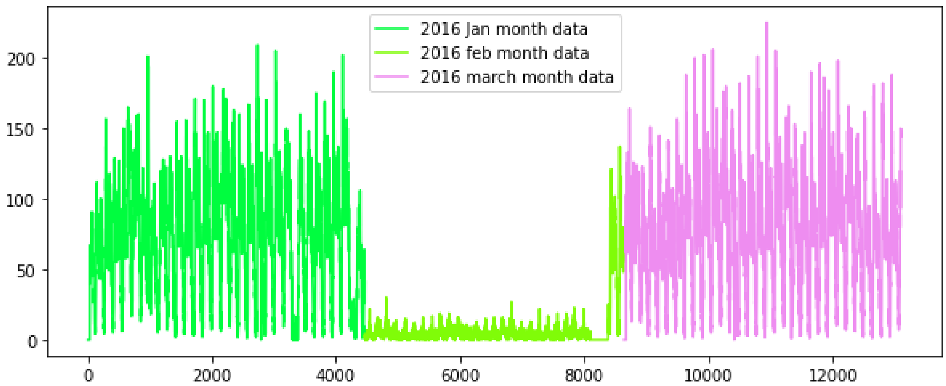
2016 Jan month data
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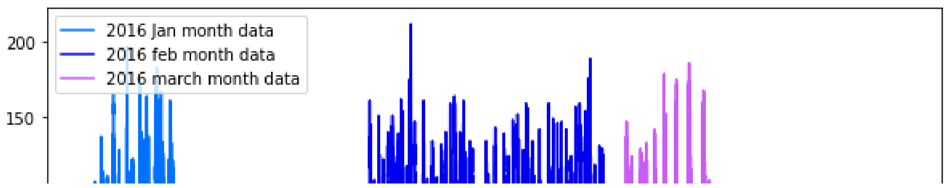
2016 Jan month data
2016 feb month data
2016 march month data
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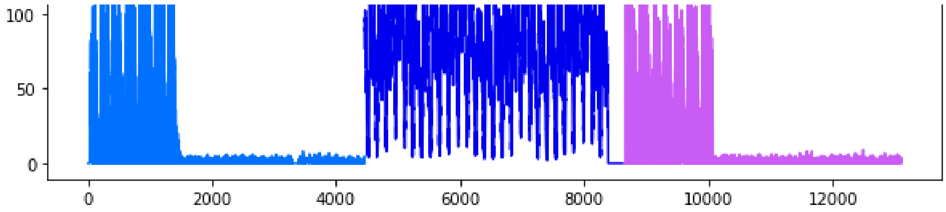

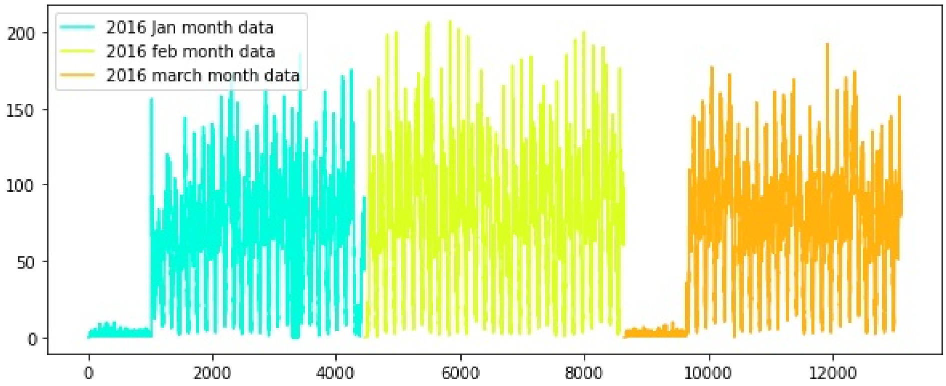
2016 Jan month data
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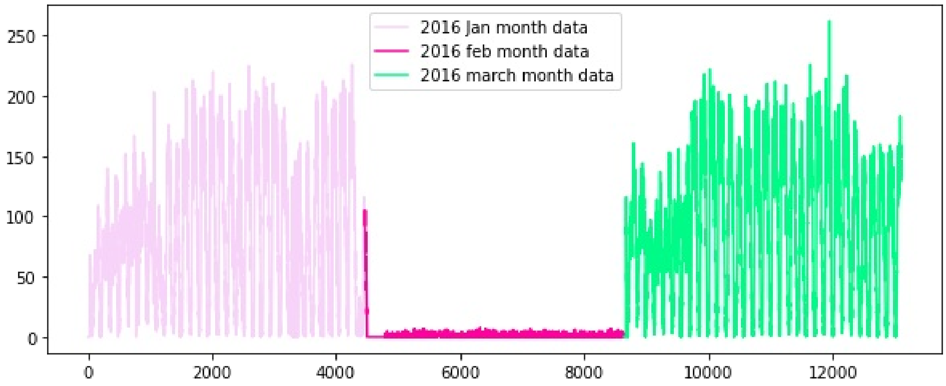
2016 march month data


2016 Jan month data
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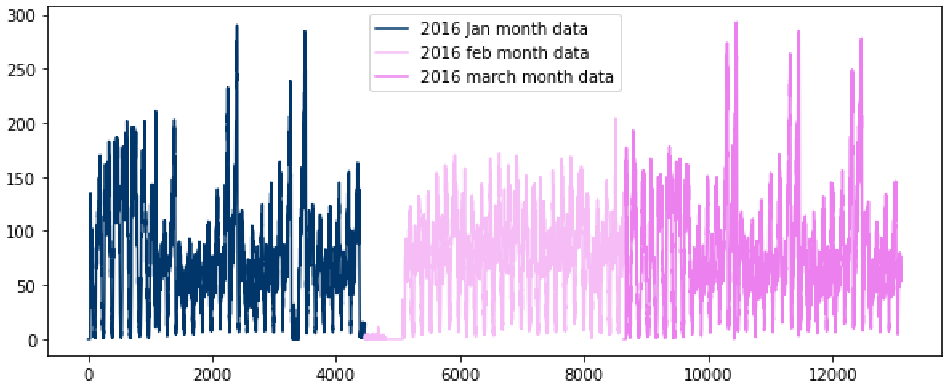
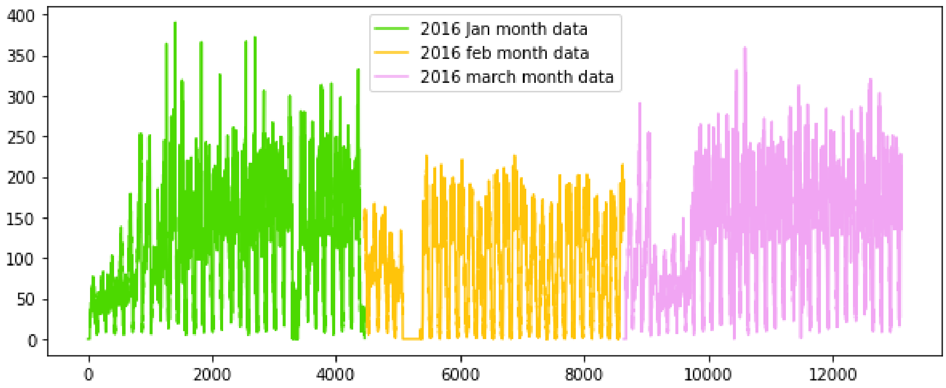
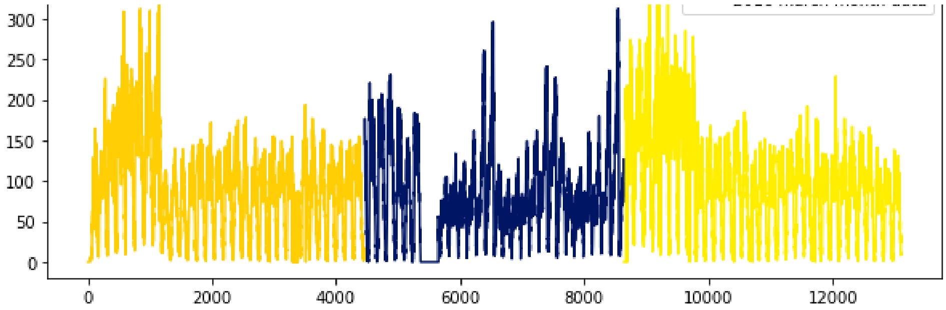
2016 march month data


2016 Jan month data
2016 feb month data
2016 march month data


2016 Jan month data
2016 feb month data
2016 march month data


2016 Jan month data
2016 feb month data
2016 march month data



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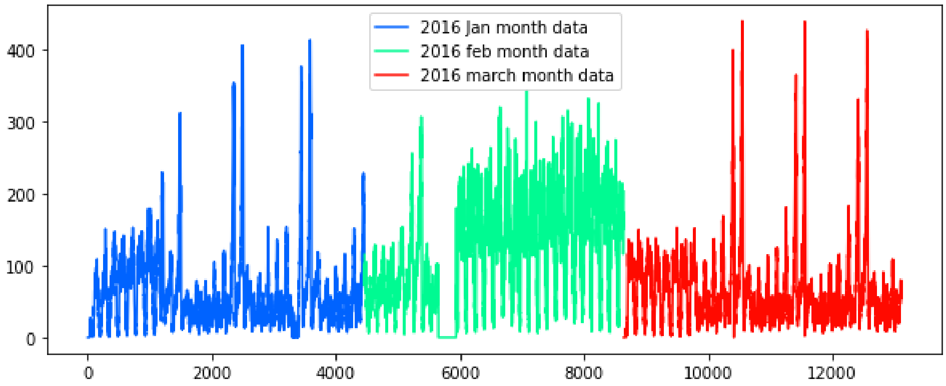

2016 Jan month data
2016 feb month data
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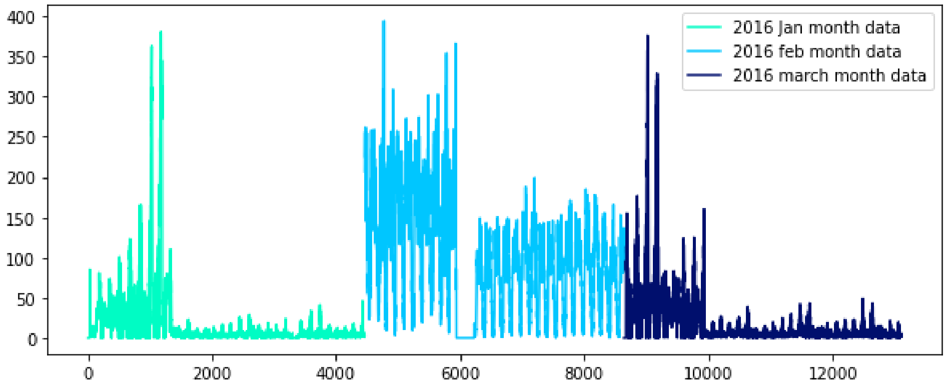

2016 Jan month data
2016 feb month data
2016 march month data
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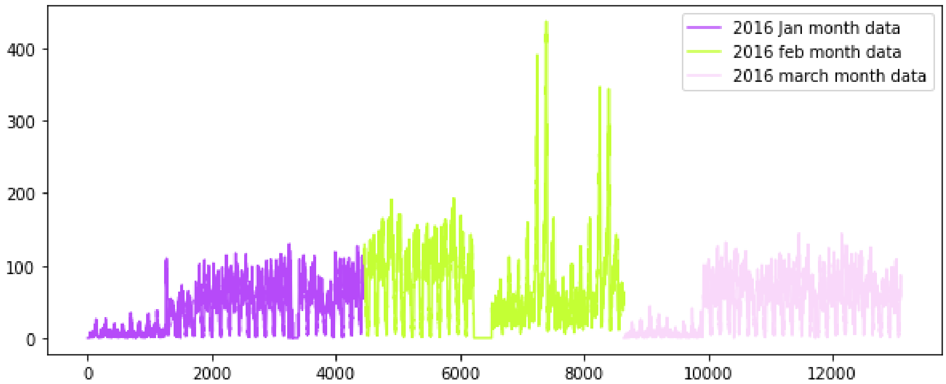

2016 Jan month data
2016 feb month data
2016 march month data
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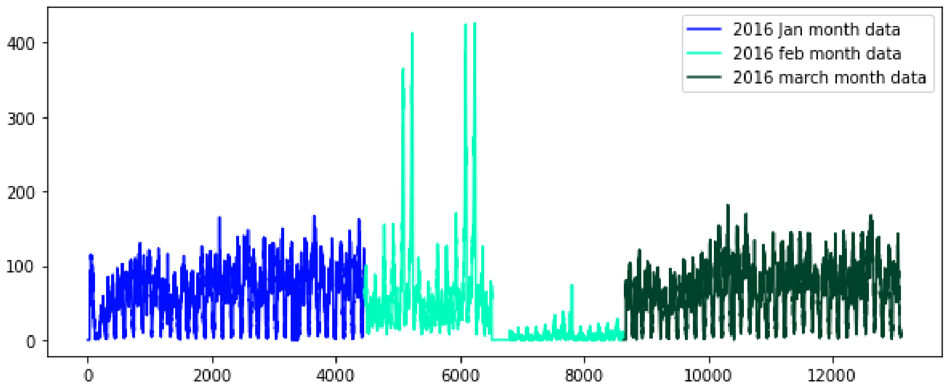

2016 Jan month data
2016 feb month data
2016 march month data
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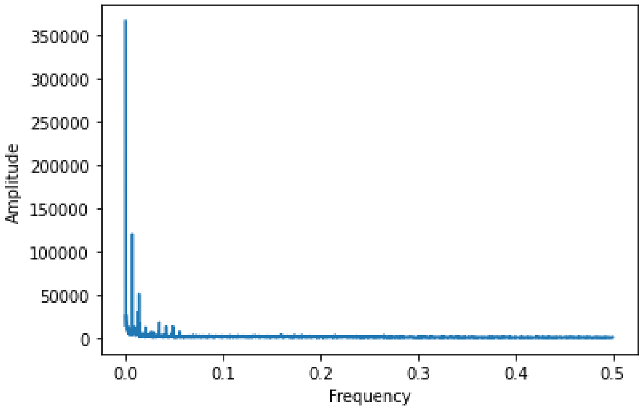
In [63]:

```
# getting peaks: https://blog.ytotech.com/2015/11/01/findpeaks-in-python/
# read more about fft function :
https://docs.scipy.org/doc/numpy/reference/generated/numpy.fft.fft.html
Y    = np.fft.fft(np.array(jan_2016_smooth)[0:4460])
# read more about the fftfreq:
https://docs.scipy.org/doc/numpy/reference/generated/numpy.fft.fftfreq.html
freq = np.fft.fftfreq(4460, 1)
n = len(freq)
plt.figure()
plt.plot( freq[:int(n/2)], np.abs(Y)[:int(n/2)] )
plt.xlabel("Frequency")
plt.ylabel("Amplitude")
plt.show()
```



In [0]:

```
#Preparing the Dataframe only with x(i) values as jan-2015 data and y(i) values as jan-2016
ratios_jan = pd.DataFrame()
ratios_jan['Given']=jan_2015_smooth
ratios_jan['Prediction']=jan_2016_smooth
ratios_jan['Ratios']=ratios_jan['Prediction']*1.0/ratios_jan['Given']*1.0
```

Modelling: Baseline Models

Now we get into modelling in order to forecast the pickup densities for the months of Jan, Feb and March of 2016 for which we are using multiple models with two variations

1. Using Ratios of the 2016 data to the 2015 data i.e $R_t = P_t^{2016}/P_t^{2015}$
2. Using Previous known values of the 2016 data itself to predict the future values

Simple Moving Averages

The First Model used is the Moving Averages Model which uses the previous n values in order to predict the next value

In [65]:

```
a = ratios_jan[8926:8929]
a
```

Out[65]:

	Given	Prediction	Ratios
8926	1	1	1.0
8927	1	3	3.0
8928	1	0	0.0

Using Ratio Values - $R_t = (R_{t-1} + R_{t-2} + R_{t-3} \ldots R_{t-n})/n$

In [0]:

```
def MA_R_Predictions(ratios,month):
    predicted_ratio=(ratios['Ratios'].values)[0]
    error=[]
    predicted_values=[]
    window_size=3
    predicted_ratio_values=[]
    for i in range(0,4464*40):
        if i%4464==0:
            predicted_ratio_values.append(0)
            predicted_values.append(0)
            error.append(0)
            continue
        predicted_ratio_values.append(predicted_ratio)
        predicted_values.append(int(((ratios['Given'].values)[i])*predicted_ratio))
        error.append(abs((math.pow(int(((ratios['Given'].values)[i])*predicted_ratio)-(ratios['Pred
iction'].values)[i],1))))
        if i+1>=window_size:
            predicted_ratio=sum((ratios['Ratios'].values)[(i+1)-window_size:(i+1)])/window_size
        else:
            predicted_ratio=sum((ratios['Ratios'].values)[0:(i+1)])/(i+1)


    ratios['MA_R_Predicted'] = predicted_values
    ratios['MA_R_Error'] = error
    mape_err = (sum(error)/len(error))/(sum(ratios['Prediction'].values)/len(ratios['Prediction'].v
alues))
    mse_err = sum([e**2 for e in error])/len(error)
    return ratios,mape_err,mse_err
```

For the above the Hyperparameter is the window-size (n) which is tuned manually and it is found that the window-size of 3 is optimal for getting the best results using Moving Averages using previous Ratio values therefore we get $R_t = (R_{t-1} + R_{t-2} + R_{t-3})/3$

Next we use the Moving averages of the 2016 values itself to predict the future value using $P_t = (P_{t-1} + P_{t-2} + P_{t-3} \ldots P_{t-n})/n$

In [0]:

```
def MA_P_Predictions(ratios,month):
    predicted_value=(ratios['Prediction'].values)[0]
    error=[]
    predicted_values=[]
    window_size=1
    predicted_ratio_values=[]
    for i in range(0,4464*40):
        predicted_values.append(predicted_value)
        error.append(abs((math.pow(predicted_value-(ratios['Prediction'].values)[i],1))))
        if i+1>=window_size:
            predicted_value=int(sum((ratios['Prediction'].values)[(i+1)-window_size:
(i+1)])/window_size)
        else:
            predicted_value=int(sum((ratios['Prediction'].values)[0:(i+1)])/(i+1))

    ratios['MA_P_Predicted'] = predicted_values
    ratios['MA_P_Error'] = error
    mape_err = (sum(error)/len(error))/(sum(ratios['Prediction'].values)/len(ratios['Prediction'].v
alues))
    mse_err = sum([e**2 for e in error])/len(error)
    return ratios,mape_err,mse_err
```

For the above the Hyperparameter is the window-size (n) which is tuned manually and it is found that the window-size of 1 is optimal for getting the best results using Moving Averages using previous 2016 values therefore we get $P_t = P_{t-1}$

Weighted Moving Averages

The Moving Avergaes Model used gave equal importance to all the values in the window used, but we know intuitively that the future is more likely to be similar to the latest values and less similar to the older values. Weighted Averages converts this analogy into a mathematical relationship giving the highest weight while computing the averages to the latest previous value and decreasing weights mathematical relationship giving the highest weight while computing the averages to the latest previous value and decreasing weights to the subsequent older ones

Weighted Moving Averages using Ratio Values - $R_t = (N*R_{t-1} + (N-1)*R_{t-2} + (N-2)*R_{t-3} \ldots 1*R_{t-n})/(N*(N+1)/2)$

In [0]:

```
def WA_R_Predictions(ratios,month):
    predicted_ratio=(ratios['Ratios'].values)[0]
    alpha=0.5
    error=[]
    predicted_values=[]
    window_size=5
    predicted_ratio_values=[]
    for i in range(0,4464*40):
        if i%4464==0:
            predicted_ratio_values.append(0)
            predicted_values.append(0)
            error.append(0)
            continue
        predicted_ratio_values.append(predicted_ratio)
        predicted_values.append(int(((ratios['Given'].values)[i])*predicted_ratio))
        error.append(abs((math.pow(int(((ratios['Given'].values)[i])*predicted_ratio)-(ratios['Pred
iction'].values)[i],1))))
        if i+1>=window_size:
            sum_values=0
            sum_of_coeff=0
            for j in range(window_size,0,-1):
                sum_values += j*(ratios['Ratios'].values)[i-window_size+j]
                sum_of_coeff+=j
            predicted_ratio=sum_values/sum_of_coeff
        else:
            sum_values=0
            sum_of_coeff=0
            for j in range(i+1,0,-1):
                sum_values += j*(ratios['Ratios'].values)[j-1]
                sum_of_coeff+=j
            predicted_ratio=sum_values/sum_of_coeff

    ratios['WA_R_Predicted'] = predicted_values
    ratios['WA_R_Error'] = error
    mape_err = (sum(error)/len(error))/(sum(ratios['Prediction'].values)/len(ratios['Prediction'].v
alues))
    mse_err = sum([e**2 for e in error])/len(error)
    return ratios,mape_err,mse_err
```

For the above the Hyperparameter is the window-size (n) which is tuned manually and it is found that the window-size of 5 is optimal for getting the best results using Weighted Moving Averages using previous Ratio values therefore we get $R_t = (5*R_{t-1} + 4*R_{t-2} + 3*R_{t-3} + 2*R_{t-4} + R_{t-5})/15$

Weighted Moving Averages using Previous 2016 Values - $P_t = (N*P_{t-1} + (N-1)*P_{t-2} + (N-2)*P_{t-3} \ldots 1*P_{t-n})/(N*(N+1)/2)$

In [0]:

```
def WA_P_Predictions(ratios,month):
    predicted_value=(ratios['Prediction'].values)[0]
    error=[]
    predicted_values=[]
    window_size=2
    for i in range(0,4464*40):
        predicted_values.append(predicted_value)
        error.append(abs((math.pow(predicted_value-(ratios['Prediction'].values)[i],1))))
        if i+1>=window_size:
            sum_values=0
            sum_of_coeff=0
            for j in range(window_size,0,-1):
                sum_values += j*(ratios['Prediction'].values)[i-window_size+j]
                sum_of_coeff+=j
            predicted_value=int(sum_values/sum_of_coeff)

        else:
            sum_values=0
            sum_of_coeff=0
            for j in range(i+1,0,-1):
```

```
            for j in range(i+1,0,-1):
                sum_values += j*(ratios['Prediction'].values)[j-1]
                sum_of_coeff+=j
            predicted_value=int(sum_values/sum_of_coeff)

    ratios['WA_P_Predicted'] = predicted_values
    ratios['WA_P_Error'] = error
    mape_err = (sum(error)/len(error))/(sum(ratios['Prediction'].values)/len(ratios['Prediction'].v
alues))
    mse_err = sum([e**2 for e in error])/len(error)
    return ratios,mape_err,mse_err
```

For the above the Hyperparameter is the window-size (n) which is tuned manually and it is found that the window-size of 2 is optimal for getting the best results using Weighted Moving Averages using previous 2016 values therefore we get $P_t = (2 * P_{t-1} + P_{t-2})/3$

Exponential Weighted Moving Averages

https://en.wikipedia.org/wiki/Moving_average#Exponential_moving_average Through weighted averaged we have satisfied the analogy of giving higher weights to the latest value and decreasing weights to the subsequent ones but we still do not know which is the correct weighting scheme as there are infinetly many possibilities in which we can assign weights in a non-increasing order and tune the the hyperparameter window-size. To simplify this process we use Exponential Moving Averages which is a more logical way towards assigning weights and at the same time also using an optimal window-size.

In exponential moving averages we use a single hyperparameter alpha (α) which is a value between 0 & 1 and based on the value of the hyperparameter alpha the weights and the window sizes are configured.
For eg. If $\alpha = 0.9$ then the number of days on which the value of the current iteration is based is~ $1/(1 - \alpha) = 10$ i.e. we consider values 10 days prior before we predict the value for the current iteration. Also the weights are assigned using $2/(N + 1) = 0.18$,where N = number of prior values being considered, hence from this it is implied that the first or latest value is assigned a weight of 0.18 which keeps exponentially decreasing for the subsequent values.

$R_t^{'} = \alpha * R_{t-1} + (1 - \alpha) * R_{t-1}^{'}$

In [0]:

```
def EA_R1_Predictions(ratios,month):
    predicted_ratio=(ratios['Ratios'].values)[0]
    alpha=0.6
    error=[]
    predicted_values=[]
    predicted_ratio_values=[]
    for i in range(0,4464*40):
        if i%4464==0:
            predicted_ratio_values.append(0)
            predicted_values.append(0)
            error.append(0)
            continue
        predicted_ratio_values.append(predicted_ratio)
        predicted_values.append(int(((ratios['Given'].values)[i])*predicted_ratio))
        error.append(abs((math.pow(int(((ratios['Given'].values)[i])*predicted_ratio)-(ratios['Pred
iction'].values)[i],1))))
        predicted_ratio = (alpha*predicted_ratio) + (1-alpha)*((ratios['Ratios'].values)[i])

    ratios['EA_R1_Predicted'] = predicted_values
    ratios['EA_R1_Error'] = error
    mape_err = (sum(error)/len(error))/(sum(ratios['Prediction'].values)/len(ratios['Prediction'].v
alues))
    mse_err = sum([e**2 for e in error])/len(error)
    return ratios,mape_err,mse_err
```

$P_t^{'} = \alpha * P_{t-1} + (1 - \alpha) * P_{t-1}^{'}$

In [0]:

```
def EA_P1_Predictions(ratios,month):
    predicted_value= (ratios['Prediction'].values)[0]
    alpha=0.3
    error=[]
```

```
    predicted_values=[]
    for i in range(0,4464*40):
        if i%4464==0:
            predicted_values.append(0)
            error.append(0)
            continue
        predicted_values.append(predicted_value)
        error.append(abs((math.pow(predicted_value-(ratios['Prediction'].values)[i],1))))
        predicted_value =int((alpha*predicted_value) + (1-alpha)*((ratios['Prediction'].values)[i])
)

    ratios['EA_P1_Predicted'] = predicted_values
    ratios['EA_P1_Error'] = error
    mape_err = (sum(error)/len(error))/(sum(ratios['Prediction'].values)/len(ratios['Prediction'].v
alues))
    mse_err = sum([e**2 for e in error])/len(error)
    return ratios,mape_err,mse_err
```

In [0]:

```
mean_err=[0]*10
median_err=[0]*10
ratios_jan,mean_err[0],median_err[0]=MA_R_Predictions(ratios_jan,'jan')
ratios_jan,mean_err[1],median_err[1]=MA_P_Predictions(ratios_jan,'jan')
ratios_jan,mean_err[2],median_err[2]=WA_R_Predictions(ratios_jan,'jan')
ratios_jan,mean_err[3],median_err[3]=WA_P_Predictions(ratios_jan,'jan')
ratios_jan,mean_err[4],median_err[4]=EA_R1_Predictions(ratios_jan,'jan')
ratios_jan,mean_err[5],median_err[5]=EA_P1_Predictions(ratios_jan,'jan')
```

Comparison between baseline models

We have chosen our error metric for comparison between models as **MAPE (Mean Absolute Percentage Error)** so that we can know that on an average how good is our model with predictions and **MSE (Mean Squared Error)** is also used so that we have a clearer understanding as to how well our forecasting model performs with outliers so that we make sure that there is not much of a error margin between our prediction and the actual value

In [73]:

```
print ("Error Metric Matrix (Forecasting Methods) - MAPE & MSE")
print ("--------------------------------------------------------------------------------------------
----------")
print ("Moving Averages (Ratios) -                             MAPE: ",mean_err[0],"      MSE: ",me
ian_err[0])
print ("Moving Averages (2016 Values) -                        MAPE: ",mean_err[1],"       MSE: ",m
dian_err[1])
print ("--------------------------------------------------------------------------------------------
----------")
print ("Weighted Moving Averages (Ratios) -                    MAPE: ",mean_err[2],"      MSE: ",me
dian_err[2])
print ("Weighted Moving Averages (2016 Values) -               MAPE: ",mean_err[3],"      MSE: ",me
dian_err[3])
print ("--------------------------------------------------------------------------------------------
----------")
print ("Exponential Moving Averages (Ratios) -              MAPE: ",mean_err[4],"      MSE: ",media
n_err[4])
print ("Exponential Moving Averages (2016 Values) -         MAPE: ",mean_err[5],"      MSE: ",media
n_err[5])
```

```
Error Metric Matrix (Forecasting Methods) - MAPE & MSE
--------------------------------------------------------------------------------------------
-
Moving Averages (Ratios) -                             MAPE:  0.22785156353133512       MSE:  1196.
953853046595
Moving Averages (2016 Values) -                        MAPE:  0.15583458712025738        MSE:  254.
6309363799283
--------------------------------------------------------------------------------------------
-
Weighted Moving Averages (Ratios) -                    MAPE:  0.22706529144871415       MSE:  
1053.083529345878
Weighted Moving Averages (2016 Values) -               MAPE:  0.1479482182992932       MSE:  
224.81054547491038
--------------------------------------------------------------------------------------------
```

```
-
Exponential Moving Averages (Ratios) -            MAPE:  0.2275474636148534      MSE:
1019.3071012544802
Exponential Moving Averages (2016 Values) -       MAPE:  0.1475381297798153      MSE:
222.35159610215055
```

Plese Note:- The above comparisons are made using Jan 2015 and Jan 2016 only

From the above matrix it is inferred that the best forecasting model for our prediction would be:- $P^{'}_{t} = \alpha * P_{t-1} + (1-\alpha) * P^{'}_{t-1}$ i.e Exponential Moving Averages using 2016 Values

Regression Models

Train-Test Split

Before we start predictions using the tree based regression models we take 3 months of 2016 pickup data and split it such that for every region we have 70% data in train and 30% in test, ordered date-wise for every region

In [0]:

```
# Preparing data to be split into train and test, The below prepares data in cumulative form which
will be later split into test and train
# number of 10min indices for jan 2015= 24*31*60/10 = 4464
# number of 10min indices for jan 2016 = 24*31*60/10 = 4464
# number of 10min indices for feb 2016 = 24*29*60/10 = 4176
# number of 10min indices for march 2016 = 24*31*60/10 = 4464
# regions_cum: it will contain 40 lists, each list will contain 4464+4176+4464 values which repres
ents the number of pickups
# that are happened for three months in 2016 data

# print(len(regions_cum))
# 40
# print(len(regions_cum[0]))
# 12960

# we take number of pickups that are happened in last 5 10min intravels
number_of_time_stamps = 5

# output varaible
# it is list of lists
# it will contain number of pickups 13099 for each cluster
output = []


# tsne_lat will contain 13104-5=13099 times lattitude of cluster center for every cluster
# Ex: [[cent_lat 13099times],[cent_lat 13099times], [cent_lat 13099times].... 40 lists]
# it is list of lists
tsne_lat = []


# tsne_lon will contain 13104-5=13099 times logitude of cluster center for every cluster
# Ex: [[cent_long 13099times],[cent_long 13099times], [cent_long 13099times].... 40 lists]
# it is list of lists
tsne_lon = []

# we will code each day
# sunday = 0, monday=1, tue = 2, wed=3, thur=4, fri=5,sat=6
# for every cluster we will be adding 13099 values, each value represent to which day of the week
that pickup bin belongs to
# it is list of lists
tsne_weekday = []

# its an numbpy array, of shape (523960, 5)
# each row corresponds to an entry in out data
# for the first row we will have [f0,f1,f2,f3,f4] fi=number of pickups happened in i+1th 10min int
ravel(bin)
# the second row will have [f1,f2,f3,f4,f5]
# the third row will have [f2,f3,f4,f5,f6]
# and so on...
tsne_feature = []
```

```
tsne_feature = [0]*number_of_time_stamps
for i in range(0,40):
    tsne_lat.append([kmeans.cluster_centers_[i][0]]*13099)
    tsne_lon.append([kmeans.cluster_centers_[i][1]]*13099)
    # jan 1st 2016 is thursday, so we start our day from 4: "(int(k/144))%7+4"
    # our prediction start from 5th 10min intravel since we need to have number of pickups that ar
e happened in last 5 pickup bins
    tsne_weekday.append([int(((int(k/144))%7+4)%7) for k in range(5,4464+4176+4464)])
    # regions_cum is a list of lists [[x1,x2,x3..x13104], [x1,x2,x3..x13104], [x1,x2,x3..x13104],
[x1,x2,x3..x13104], [x1,x2,x3..x13104], .. 40 lsits]
    tsne_feature = np.vstack((tsne_feature, [regions_cum[i][r:r+number_of_time_stamps] for r in ran
ge(0,len(regions_cum[i])-number_of_time_stamps)]))
    output.append(regions_cum[i][5:])
tsne_feature = tsne_feature[1:]
```

In [76]:

```
len(tsne_lat[0])*len(tsne_lat) == tsne_feature.shape[0] == len(tsne_weekday)*len(tsne_weekday[0]) =
= 40*13099 == len(output)*len(output[0])
```

Out[76]:

```
True
```

In [0]:

```
# Getting the predictions of exponential moving averages to be used as a feature in cumulative for
m

# upto now we computed 8 features for every data point that starts from 50th min of the day
# 1. cluster center lattitude
# 2. cluster center longitude
# 3. day of the week
# 4. f_t_1: number of pickups that are happened previous t-1th 10min intravel
# 5. f_t_2: number of pickups that are happened previous t-2th 10min intravel
# 6. f_t_3: number of pickups that are happened previous t-3th 10min intravel
# 7. f_t_4: number of pickups that are happened previous t-4th 10min intravel
# 8. f_t_5: number of pickups that are happened previous t-5th 10min intravel

# from the baseline models we said the exponential weighted moving avarage gives us the best error
# we will try to add the same exponential weighted moving avarage at t as a feature to our data
# exponential weighted moving avarage => p'(t) = alpha*p'(t-1) + (1-alpha)*P(t-1)
alpha=0.3

# it is a temporary array that store exponential weighted moving avarage for each 10min intravel,
# for each cluster it will get reset
# for every cluster it contains 13104 values
predicted_values=[]

# it is similar like tsne_lat
# it is list of lists
# predict_list is a list of lists [[x5,x6,x7..x13104], [x5,x6,x7..x13104], [x5,x6,x7..x13104], [x5
,x6,x7..x13104], [x5,x6,x7..x13104], .. 40 lsits]
predict_list = []
tsne_flat_exp_avg = []
for r in range(0,40):
    for i in range(0,13104):
        if i==0:
            predicted_value= regions_cum[r][0]
            predicted_values.append(0)
            continue
        predicted_values.append(predicted_value)
        predicted_value =int((alpha*predicted_value) + (1-alpha)*(regions_cum[r][i]))
    predict_list.append(predicted_values[5:])
    predicted_values=[]
```

In [78]:

```
# train, test split : 70% 30% split
# Before we start predictions using the tree based regression models we take 3 months of 2016 pick
up data
# and split it such that for every region we have 70% data in train and 30% in test,
# ordered date-wise for every region
```

```
print("size of train data :", int(13099*0.7))
print("size of test data :", int(13099*0.3))
```

```
size of train data : 9169
size of test data : 3929
```

In [0]:

```
# extracting first 9169 timestamp values i.e 70% of 13099 (total timestamps) for our training data
train_features =  [tsne_feature[i*13099:(13099*i+9169)] for i in range(0,40)]
# temp = [0]*(12955 - 9068)
test_features = [tsne_feature[(13099*(i))+9169:13099*(i+1)] for i in range(0,40)]
```

In [80]:

```
print("Number of data clusters",len(train_features), "Number of data points in trian data",
len(train_features[0]), "Each data point contains", len(train_features[0][0]),"features")
print("Number of data clusters",len(train_features), "Number of data points in test data",
len(test_features[0]), "Each data point contains", len(test_features[0][0]),"features")
```

```
Number of data clusters 40 Number of data points in trian data 9169 Each data point contains 5 fea
tures
Number of data clusters 40 Number of data points in test data 3930 Each data point contains 5 feat
ures
```

In [0]:

```
# extracting first 9169 timestamp values i.e 70% of 13099 (total timestamps) for our training data
tsne_train_flat_lat = [i[:9169] for i in tsne_lat]
tsne_train_flat_lon = [i[:9169] for i in tsne_lon]
tsne_train_flat_weekday = [i[:9169] for i in tsne_weekday]
tsne_train_flat_output = [i[:9169] for i in output]
tsne_train_flat_exp_avg = [i[:9169] for i in predict_list]
```

In [0]:

```
# extracting the rest of the timestamp values i.e 30% of 12956 (total timestamps) for our test dat
a
tsne_test_flat_lat = [i[9169:] for i in tsne_lat]
tsne_test_flat_lon = [i[9169:] for i in tsne_lon]
tsne_test_flat_weekday = [i[9169:] for i in tsne_weekday]
tsne_test_flat_output = [i[9169:] for i in output]
tsne_test_flat_exp_avg = [i[9169:] for i in predict_list]
```

In [0]:

```
# the above contains values in the form of list of lists (i.e. list of values of each region), her
e we make all of them in one list
train_new_features = []
for i in range(0,40):
    train_new_features.extend(train_features[i])
test_new_features = []
for i in range(0,40):
    test_new_features.extend(test_features[i])
```

In [0]:

```
# converting lists of lists into sinle list i.e flatten
# a  = [[1,2,3,4],[4,6,7,8]]
# print(sum(a,[]))
# [1, 2, 3, 4, 4, 6, 7, 8]

tsne_train_lat = sum(tsne_train_flat_lat, [])
tsne_train_lon = sum(tsne_train_flat_lon, [])
tsne_train_weekday = sum(tsne_train_flat_weekday, [])
tsne_train_output = sum(tsne_train_flat_output, [])
tsne_train_exp_avg = sum(tsne_train_flat_exp_avg,[])
```

In [0]:

In [0]:

```
# converting lists of lists into sinle list i.e flatten
# a  = [[1,2,3,4],[4,6,7,8]]
# print(sum(a,[]))
# [1, 2, 3, 4, 4, 6, 7, 8]

tsne_test_lat = sum(tsne_test_flat_lat, [])
tsne_test_lon = sum(tsne_test_flat_lon, [])
tsne_test_weekday = sum(tsne_test_flat_weekday, [])
tsne_test_output = sum(tsne_test_flat_output, [])
tsne_test_exp_avg = sum(tsne_test_flat_exp_avg,[])
```

In [86]:

```
# Preparing the data frame for our train data
columns = ['ft_5','ft_4','ft_3','ft_2','ft_1']
df_train = pd.DataFrame(data=train_new_features, columns=columns)
df_train['lat'] = tsne_train_lat
df_train['lon'] = tsne_train_lon
df_train['weekday'] = tsne_train_weekday
df_train['exp_avg'] = tsne_train_exp_avg

print(df_train.shape)
```

```
(366760, 9)
```

In [87]:

```
# Preparing the data frame for our train data
df_test = pd.DataFrame(data=test_new_features, columns=columns)
df_test['lat'] = tsne_test_lat
df_test['lon'] = tsne_test_lon
df_test['weekday'] = tsne_test_weekday
df_test['exp_avg'] = tsne_test_exp_avg
print(df_test.shape)
```

```
(157200, 9)
```

In [88]:

```
df_test.head()
```

Out[88]:

	ft_5	ft_4	ft_3	ft_2	ft_1	lat	lon	weekday	exp_avg
0	143	145	119	113	124	40.776228	-73.982119	4	121
1	145	119	113	124	121	40.776228	-73.982119	4	120
2	119	113	124	121	131	40.776228	-73.982119	4	127
3	113	124	121	131	110	40.776228	-73.982119	4	115
4	124	121	131	110	116	40.776228	-73.982119	4	115

Adding Fourier Featurs

In [0]:

```
# https://stackoverflow.com/questions/3694918/how-to-extract-frequency-associated-with-fft-values-in-python
# https://github.com/jinalsalvi/NYC-Taxi-Demand-Prediction/blob/master/NYC%20Final.ipynb

fourier_features = pd.DataFrame(columns= ['f_1','a_1','f_2','a_2','f_3','a_3','f_4','a_4','f_5','a_5'])


for r in range(0,40):
```

```
    df_jan = pd.DataFrame()
    df_feb = pd.DataFrame()
    df_mar = pd.DataFrame()


    aJan = np.fft.fft(np.array(regions_cum[r][0:4464]))
    freqJan = np.fft.fftfreq((4464), 1)
    df_jan['Frequency'] = freqJan
    df_jan['Amplitude'] = aJan


    aFeb = np.fft.fft(np.array(regions_cum[r])[4464:(4176+4464)])
    freqFeb = np.fft.fftfreq((4176), 1)
    df_feb['Frequency'] = freqFeb
    df_feb['Amplitude'] = aFeb


    aMar = np.fft.fft(np.array(regions_cum[r])[(4176+4464):(4176+4464+4464)])
    freqMar = np.fft.fftfreq((4464), 1)
    df_mar['Frequency'] = freqMar
    df_mar['Amplitude'] = aMar

    list_jan = []
    list_feb = []
    list_mar = []

    jan_sorted = df_jan.sort_values(by=["Amplitude"], ascending=False)[:5].reset_index(drop=True).T
    feb_sorted = df_feb.sort_values(by=["Amplitude"], ascending=False)[:5].reset_index(drop=True).T
    mar_sorted = df_mar.sort_values(by=["Amplitude"], ascending=False)[:5].reset_index(drop=True).T


    for i in range(0,5):
        list_jan.append(float(jan_sorted[i]['Frequency']))
        list_jan.append(float(jan_sorted[i]['Amplitude']))

        list_feb.append(float(feb_sorted[i]['Frequency']))
        list_feb.append(float(feb_sorted[i]['Amplitude']))

        list_mar.append(float(mar_sorted[i]['Frequency']))
        list_mar.append(float(mar_sorted[i]['Amplitude']))

    frame_jan = pd.DataFrame([list_jan]*4464)
    frame_feb = pd.DataFrame([list_feb]*4176)
    frame_mar = pd.DataFrame([list_mar]*4464)

    frame_jan.columns = ['f_1','a_1','f_2','a_2','f_3','a_3','f_4','a_4','f_5','a_5',]
    frame_feb.columns = ['f_1','a_1','f_2','a_2','f_3','a_3','f_4','a_4','f_5','a_5',]
    frame_mar.columns = ['f_1','a_1','f_2','a_2','f_3','a_3','f_4','a_4','f_5','a_5',]

    fourier_features = fourier_features.append(frame_jan, ignore_index=True)
    fourier_features = fourier_features.append(frame_feb, ignore_index=True)
    fourier_features = fourier_features.append(frame_mar, ignore_index=True)


    for i in range(0,13104):
        if i==0:
            predicted_value= regions_cum[r][0]
            predicted_values.append(0)
            continue
        predicted_values.append(predicted_value)
        predicted_value =int((alpha*predicted_value) + (1-alpha)*(regions_cum[r][i]))
    predict_list.append(predicted_values[5:])
    predicted_values=[]
fourier_features.drop(['f_1'],axis=1,inplace=True)

fourier_features = fourier_features.fillna(0)
```

In [0]:

```
final_fourier_train = pd.DataFrame(columns=['a_1','f_2','a_2','f_3','a_3','f_4','a_4','f_5','a_5'])
final_fourier_test = pd.DataFrame(columns=['a_1','f_2','a_2','f_3','a_3','f_4','a_4','f_5','a_5'])

# extracting first 9169 timestamp values i.e 70% of 13099 (total timestamps) for our training data
for i in range(0,40):
  final_fourier_train = final_fourier_train.append(fourier_features[i*13099:(13099*i+9169)])
  final_fourier_test = final_fourier_test.append(fourier_features[(13099*(i))+9169:13099*(i+1)])
```

```
final_fourier_train.reset_index(inplace=True)
final_fourier_test.reset_index(inplace=True)
```

In [91]:

```
print("fourier_train shape",final_fourier_train.shape)
print("fourier_test shape",final_fourier_test.shape)
```

```
fourier_train shape (366760, 10)
fourier_test shape (157200, 10)
```

In [0]:

```
final_tr_frames = [final_fourier_train, df_train]
final_test_frames = [final_fourier_test, df_test]

final_train = pd.concat(final_tr_frames, axis=1)
final_test = pd.concat(final_test_frames, axis=1)
```

In [93]:

```
print("final train shape",final_train.shape)
print("final test shape",final_test.shape)
```

```
final train shape (366760, 19)
final test shape (157200, 19)
```

In [94]:

```
final_train.head()
```

Out[94]:

	index	a_1	f_2	a_2	f_3	a_3	f_4	a_4	f_5	a_5	ft_5	f
0	0	367173.0	-0.006944	94490.188858	0.006944	94490.188858	-0.041667	14349.849101	0.041667	14349.849101	0	(
1	1	367173.0	-0.006944	94490.188858	0.006944	94490.188858	-0.041667	14349.849101	0.041667	14349.849101	0	(
2	2	367173.0	-0.006944	94490.188858	0.006944	94490.188858	-0.041667	14349.849101	0.041667	14349.849101	0	(
3	3	367173.0	-0.006944	94490.188858	0.006944	94490.188858	-0.041667	14349.849101	0.041667	14349.849101	0	(
4	4	367173.0	-0.006944	94490.188858	0.006944	94490.188858	-0.041667	14349.849101	0.041667	14349.849101	0	(

Using Linear Regression

Hyperparam Tuning for Linear Regression

In [0]:

```
from sklearn.linear_model import LinearRegression, SGDRegressor
from sklearn.model_selection import GridSearchCV
from datetime import datetime

#Declaring parameters
params = {'normalize':[True, False],
          'fit_intercept':[True, False]}

start =datetime.now()
print('Hyperparameter tuning: \n')
model=LinearRegression(n_jobs=-1)
```

```
gsearch=GridSearchCV(model, params, scoring='neg_mean_absolute_error',cv=3,n_jobs=-1)
gsearch.fit(final_train, tsne_train_output)

#Getting the best hyperparameter tuned model
best_model=gsearch.best_estimator_
print("Best estimator: ",best_model)

#Fitting the best model to our training data
best_model.fit(final_train, tsne_train_output)
```

```
Hyperparameter tuning:

Best estimator:  LinearRegression(copy_X=True, fit_intercept=True, n_jobs=-1, normalize=True)
```

Out[0]:

```
LinearRegression(copy_X=True, fit_intercept=True, n_jobs=-1, normalize=True)
```

In [0]:

```
#Using the best model to make predictions
y_pred = best_model.predict(final_test)
lr_test_predictions = [round(value) for value in y_pred] #rounding the values to get integer
predictionss
y_pred = best_model.predict(final_train)
lr_train_predictions = [round(value) for value in y_pred]
```

In [0]:

```
train_mape_lr = (mean_absolute_error(tsne_train_output,
lr_train_predictions))/(sum(tsne_train_output)/len(tsne_train_output))
test_mape_lr = (mean_absolute_error(tsne_test_output, lr_test_predictions))/(sum(tsne_test_output)/
len(tsne_test_output))
```

In [0]:

```
print ("Error Metric Matrix (Tree Based Regression Methods) -  MAPE")
print ("-------------------------------------------------------------------------------------------------
----------")

print ("Linear Regression -                         Train: ",train_mape_lr,"      Test: ",test_mape
lr)

print ("-------------------------------------------------------------------------------------------------
----------")
```

```
Error Metric Matrix (Tree Based Regression Methods) -  MAPE
--------------------------------------------------------------------------------------------------
-
Linear Regression -                         Train:  0.14210483617977826       Test:
0.13468579269091166
--------------------------------------------------------------------------------------------------
-
```

Using Random Forest Regressor

Hyperparam tuning for Random Forest Regressor

In [0]:

```
from sklearn.model_selection import RandomizedSearchCV

#Declaring parameters
params = {'max_depth' : [3,4,5,6,7,8,9,10],
          'min_samples_split' : [2,3,5,7,9],
          'max_features':['auto','sqrt', 'log2'],
          'min_samples_leaf':[1, 10, 25, 50, 75, 100],
          'n_estimators': [10,20,30,40,50,60,80,100,500,1000,1500,2000,3000],
          'max_leaf_nodes': [None, 10, 25, 50, 100, 500]}
```

```
#Tuning hyperparameters
#start =datetime.now()
print('Hyperparameter tuning: \n')
model= RandomForestRegressor(n_jobs=-1)
rsearch = RandomizedSearchCV(model,params,n_iter=20,scoring='neg_mean_absolute_error',cv=3,n_jobs=-
1)
rsearch.fit(final_train, tsne_train_output)
print('Time taken to perform Hyperparameter tuning :',datetime.now()-start)

#Getting the best hyperparameter tuned model
best_model=rsearch.best_estimator_
print("Best estimator: ",best_model)

#Fitting the best model to our training data
best_model.fit(final_train, tsne_train_output)
```

In [0]:

```
y_pred = best_model.predict(final_test)
clf_xgb_test_predictions = [round(value) for value in y_pred]
y_pred = best_model.predict(final_train)
clf_xgb_train_predictions = [round(value) for value in y_pred]
```

In [0]:

```
train_mape_xgb = mean_absolute_error(tsne_train_output, clf_xgb_train_predictions)/(sum(tsne_train_
output)/len(tsne_train_output))
test_mape_xgb = mean_absolute_error(tsne_test_output, clf_xgb_test_predictions)/(sum(tsne_test_outp
ut)/len(tsne_test_output))
```

In [0]:

```
print ("Error Metric Matrix (Tree Based Regression Methods) -  MAPE")
print ("---------------------------------------------------------------------------------------------
----------")

print ("Random Forest Regressor-                         Train: ",train_mape_rf,"      Test: ",test
mape_rf)

print ("---------------------------------------------------------------------------------------------
----------")
```

```
Error Metric Matrix (Tree Based Regression Methods) -  MAPE
----------------------------------------------------------------------------------------------------
-
Random Forest Regressor-                         Train:  0.14098134853726882       Test:  0.1343031
497109533
----------------------------------------------------------------------------------------------------
-
```

Using XgBoost Regressor

Hyperparam Tuning for XgBoost Regressor

In [96]:

```
from xgboost import XGBRegressor
from sklearn.model_selection import RandomizedSearchCV

#Declaring parameters
params = {'learning_rate':[0.1,0.01,0.001,0.0001],
          'n_estimators':[250,500,750,1000,1500,2000,3000],
          'subsample':[0.6,0.7,0.8,0.9],
          'min_child_weight':[3,5,7,9],
          'reg_lambda':[100,200,300,400],
          'reg_alpha':[100,200,300, 400],
          'max_depth': [3,4,5,6,7,9],
          'colsample_bytree':[0.6,0.7,0.8],
          'gamma':[0,0.5,1]}
```

```
#Tuning hyperparameters
#start =datetime.now()
print('Hyperparameter tuning: \n')
model= XGBRegressor(random_state=0,n_jobs=-1)
rsearch = RandomizedSearchCV(model,params,n_iter=20,scoring='neg_mean_absolute_error',cv=3,n_jobs=-
1)
rsearch.fit(final_train, tsne_train_output)
#print('Time taken to perform Hyperparameter tuning :',datetime.now()-start)

#Getting the best hyperparameter tuned model
best_model=rsearch.best_estimator_
print("Best estimator: ",best_model)

#Fitting the best model to our training data
best_model.fit(final_train, tsne_train_output)
```

```
Hyperparameter tuning:

[20:13:40] WARNING: /workspace/src/objective/regression_obj.cu:152: reg:linear is now deprecated i
n favor of reg:squarederror.
Best estimator:  XGBRegressor(base_score=0.5, booster='gbtree', colsample_bylevel=1,
             colsample_bynode=1, colsample_bytree=0.6, gamma=0,
             importance_type='gain', learning_rate=0.01, max_delta_step=0,
             max_depth=6, min_child_weight=9, missing=None, n_estimators=3000,
             n_jobs=-1, nthread=None, objective='reg:linear', random_state=0,
             reg_alpha=100, reg_lambda=100, scale_pos_weight=1, seed=None,
             silent=None, subsample=0.8, verbosity=1)
[20:30:33] WARNING: /workspace/src/objective/regression_obj.cu:152: reg:linear is now deprecated i
n favor of reg:squarederror.
```

Out[96]:

```
XGBRegressor(base_score=0.5, booster='gbtree', colsample_bylevel=1,
             colsample_bynode=1, colsample_bytree=0.6, gamma=0,
             importance_type='gain', learning_rate=0.01, max_delta_step=0,
             max_depth=6, min_child_weight=9, missing=None, n_estimators=3000,
             n_jobs=-1, nthread=None, objective='reg:linear', random_state=0,
             reg_alpha=100, reg_lambda=100, scale_pos_weight=1, seed=None,
             silent=None, subsample=0.8, verbosity=1)
```

In [0]:

```
#Using the best model to make predictions
y_pred = best_model.predict(final_test)
xgb_test_predictions = [round(value) for value in y_pred] #rounding the values to get integer
predictionss
y_pred = best_model.predict(final_train)
xgb_train_predictions = [round(value) for value in y_pred]
```

In [0]:

```
train_mape_xgb = mean_absolute_error(tsne_train_output, xgb_train_predictions)/(sum(tsne_train_outp
ut)/len(tsne_train_output))
test_mape_xgb = mean_absolute_error(tsne_test_output, xgb_test_predictions)/(sum(tsne_test_output)/
len(tsne_test_output))
```

In [99]:

```
print ("Error Metric Matrix (Tree Based Regression Methods) -  MAPE")
print ("--------------------------------------------------------------------------------------------
----------")

print ("Random Forest Regressor-                         Train: ",train_mape_xgb,"      Test: ",tes
_mape_xgb)

print ("--------------------------------------------------------------------------------------------
----------")
```

```
Error Metric Matrix (Tree Based Regression Methods) -  MAPE
---------------------------------------------------------------------------------------------------
-
Random Forest Regressor-                         Train:   0.13601309624638208       Test:   0.132051C
```

```
581227566
--------------------------------------------------------------------------------------------------------
-
```

Holt Winter forecasting

Triple Exponential Smoothing

In [0]:

```
# https://grisha.org/blog/2016/02/17/triple-exponential-smoothing-forecasting-part-iii/
# https://www.itl.nist.gov/div898/handbook/pmc/section4/pmc435.htm
def initial_trend(series, slen):
    sum = 0.0
    for i in range(slen):
        sum += float(series[i+slen] - series[i]) / slen
    return sum / slen

def initial_seasonal_components(series, slen):
    seasonals = {}
    season_averages = []
    n_seasons = int(len(series)/slen)
    # compute season averages
    for j in range(n_seasons):
        season_averages.append(sum(series[slen*j:slen*j+slen])/float(slen))
    # compute initial values
    for i in range(slen):
        sum_of_vals_over_avg = 0.0
        for j in range(n_seasons):
            sum_of_vals_over_avg += series[slen*j+i]-season_averages[j]
        seasonals[i] = sum_of_vals_over_avg/n_seasons
    return seasonals


def triple_exponential_smoothing(series, slen, alpha, beta, gamma, n_preds):
    result = []
    seasonals = initial_seasonal_components(series, slen)
    for i in range(len(series)+n_preds):
        if i == 0: # initial values
            smooth = series[0]
            trend = initial_trend(series, slen)
            result.append(series[0])
            continue
        if i >= len(series): # we are forecasting
            m = i - len(series) + 1
            result.append((smooth + m*trend) + seasonals[i%slen])
        else:
            val = series[i]
            last_smooth, smooth = smooth, alpha*(val-seasonals[i%slen]) + (1-alpha)*(smooth+trend)
            trend = beta * (smooth-last_smooth) + (1-beta)*trend
            seasonals[i%slen] = gamma*(val-smooth) + (1-gamma)*seasonals[i%slen]
            result.append(smooth+trend+seasonals[i%slen])
    return result
```

In [0]:

```
#Holt Winters initialization of variables: # https://robjhyndman.com/hyndsight/hw-initialization/
alpha = 0.2
beta = 0.1
gamma = 0.1
season_len = 24

#Prepare the features for all points for all clusters
predict_values_three =[]
predict_list_three = []
for r in range(0,40):
    predict_values_three = triple_exponential_smoothing(regions_cum[r][0:13104], season_len, alpha,
beta, gamma, 0)
    predict_list_three.append(predict_values_three[5:])
```

In [129]:

```
"""train, test split : 70% 30% split Before we start predictions using the tree based regression m
odels we take 3
months of 2016 pickup data and split it such that for every region we have 70% data in train and 3
0% in test,
ordered date-wise for every region"""

print("Size of train data :", int(13099*0.7))
print("Size of test data :", int(13099*0.3))
```

```
Size of train data : 9169
Size of test data : 3929
```

In [0]:

```
# extracting first 9169 timestamp values i.e 70% of 13099 (total timestamps) for our training data
train_features =  [tsne_feature[i*13099:(13099*i+9169)] for i in range(0,40)]
# temp = [0]*(12955 - 9068)
test_features = [tsne_feature[(13099*(i))+9169:13099*(i+1)] for i in range(0,40)]
```

In [131]:

```
print("Number of data clusters",len(train_features), ", Number of data points in trian data", len(
train_features[0]), ", Each data point contains", len(train_features[0][0]),"features")
print("Number of data clusters",len(train_features), ", Number of data points in test data", len(t
est_features[0]), ", Each data point contains", len(test_features[0][0]),"features")
```

```
Number of data clusters 40 , Number of data points in trian data 9169 , Each data point contains 5
features
Number of data clusters 40 , Number of data points in test data 3930 , Each data point contains 5
features
```

In [0]:

```
#Extracting first 9169 timestamp values i.e 70% of 13099 (total timestamps) for our training data
tsne_train_flat_lat = [i[:9169] for i in tsne_lat]
tsne_train_flat_lon = [i[:9169] for i in tsne_lon]
tsne_train_flat_weekday = [i[:9169] for i in tsne_weekday]
tsne_train_flat_output = [i[:9169] for i in output]
#tsne_train_flat_exp_avg = [i[:9169] for i in predict_list]
tsne_train_flat_triple_exp = [i[:9169] for i in predict_list_three]
```

In [0]:

```
#Extracting the rest of the timestamp values i.e 30% of 12956 (total timestamps) for our test data
tsne_test_flat_lat = [i[9169:] for i in tsne_lat]
tsne_test_flat_lon = [i[9169:] for i in tsne_lon]
tsne_test_flat_weekday = [i[9169:] for i in tsne_weekday]
tsne_test_flat_output = [i[9169:] for i in output]
#tsne_test_flat_exp_avg = [i[9169:] for i in predict_list]
tsne_test_flat_triple_exp = [i[9169:] for i in predict_list_three]
```

In [0]:

```
# the above contains values in the form of list of lists (i.e. list of values of each region), her
e we make all of them in one list
train_new_features = []
for i in range(0,40):
    train_new_features.extend(train_features[i])
test_new_features = []
for i in range(0,40):
    test_new_features.extend(test_features[i])
```

In [0]:

```
# converting lists of lists into single list i.e flatten
# a  = [[1,2,3,4],[4,6,7,8]]
# print(sum(a,[]))
# [w1, 2, 3, 4, 4, 6, 7, 8]
```

```
tsne_train_lat = sum(tsne_train_flat_lat, [])
tsne_train_lon = sum(tsne_train_flat_lon, [])
tsne_train_weekday = sum(tsne_train_flat_weekday, [])
tsne_train_output = sum(tsne_train_flat_output, [])
#tsne_train_exp_avg = sum(tsne_train_flat_exp_avg,[])
tsne_train_flat_triple_exp = sum(tsne_train_flat_triple_exp,[])
```

In [0]:

```
# converting lists of lists into sinle list i.e flatten
# a  = [[1,2,3,4],[4,6,7,8]]
# print(sum(a,[]))
# [1, 2, 3, 4, 4, 6, 7, 8]

tsne_test_lat = sum(tsne_test_flat_lat, [])
tsne_test_lon = sum(tsne_test_flat_lon, [])
tsne_test_weekday = sum(tsne_test_flat_weekday, [])
tsne_test_output = sum(tsne_test_flat_output, [])
#tsne_test_exp_avg = sum(tsne_test_flat_exp_avg,[])
tsne_test_flat_triple_exp = sum(tsne_test_flat_triple_exp,[])
```

In [137]:

```
# Preparing the data frame for our train data
columns = ['ft_5','ft_4','ft_3','ft_2','ft_1']
df_train = pd.DataFrame(data=train_new_features, columns=columns)
df_train['lat'] = tsne_train_lat
df_train['lon'] = tsne_train_lon
df_train['weekday'] = tsne_train_weekday
#df_train['exp_avg'] = tsne_train_exp_avg
df_train['triple_exp'] = tsne_train_flat_triple_exp

print(df_train.shape)
```

```
(366760, 9)
```

In [138]:

```
# Preparing the data frame for our train data
df_test = pd.DataFrame(data=test_new_features, columns=columns)
df_test['lat'] = tsne_test_lat
df_test['lon'] = tsne_test_lon
df_test['weekday'] = tsne_test_weekday
#df_test['exp_avg'] = tsne_test_exp_avg
df_test['triple_exp'] = tsne_test_flat_triple_exp
print(df_test.shape)
```

```
(157200, 9)
```

In [0]:

```
#Mering the train and test df with fourier features train and test df
df_train = pd.concat([df_train, final_fourier_train], axis = 1)
df_test = pd.concat([df_test, final_fourier_test], axis = 1)
```

Save the train and test dataframes along with the class labels

In [0]:

```
#Save the final dataframes along with output
df_test.to_csv("df_test.csv", index=None)
df_train.to_csv("df_train.csv", index=None)
```

Load the train and test dataframes along with the class labels

In [142]:

```
df_test=pd.read_csv("df_test.csv")
df_test.head()
```

Out[142]:

	ft_5	ft_4	ft_3	ft_2	ft_1	lat	lon	weekday	triple_exp	index	a_1	f_2	a_2	f_3
0	143	145	119	113	124	40.776228	-73.982119	4	122.433559	9169	387761.0	0.006944	91160.781939	-0.006944
1	145	119	113	124	121	40.776228	-73.982119	4	119.929763	9170	387761.0	0.006944	91160.781939	-0.006944
2	119	113	124	121	131	40.776228	-73.982119	4	113.804501	9171	387761.0	0.006944	91160.781939	-0.006944
3	113	124	121	131	110	40.776228	-73.982119	4	114.446710	9172	387761.0	0.006944	91160.781939	-0.006944
4	124	121	131	110	116	40.776228	-73.982119	4	123.544165	9173	387761.0	0.006944	91160.781939	-0.006944

In [143]:

```
df_train=pd.read_csv("df_train.csv")
df_train.head()
```

Out[143]:

	ft_5	ft_4	ft_3	ft_2	ft_1	lat	lon	weekday	triple_exp	index	a_1	f_2	a_2	f_3
0	0	0	0	0	0	40.776228	-73.982119	4	10.232196	0	367173.0	-0.006944	94490.188858	0.006944
1	0	0	0	0	0	40.776228	-73.982119	4	9.224937	1	367173.0	-0.006944	94490.188858	0.006944
2	0	0	0	0	0	40.776228	-73.982119	4	7.677488	2	367173.0	-0.006944	94490.188858	0.006944
3	0	0	0	0	0	40.776228	-73.982119	4	4.430264	3	367173.0	-0.006944	94490.188858	0.006944
4	0	0	0	0	0	40.776228	-73.982119	4	5.807946	4	367173.0	-0.006944	94490.188858	0.006944

Using Linear Regression

Hyperparam Tuning for Linear Regression

In [144]:

```
from sklearn.linear_model import LinearRegression, SGDRegressor
from sklearn.model_selection import GridSearchCV

#Declaring parameters
params = {'normalize':[True, False],
          'fit_intercept':[True, False]}

#Using SGRRegressor with squared loss, in order to fine tune he hyperparameters. SGRRegressor with squared loss is linear regression.
print('Hyperparameter tuning: \n')
model=LinearRegression(n_jobs=-1)
gsearch=GridSearchCV(model, params, scoring='neg_mean_absolute_error',cv=3,n_jobs=-1)
gsearch.fit(df_train, tsne_train_output)

#Getting the best hyperparameter tuned model
best_model=gsearch.best_estimator_
print("Best estimator: ",best_model)
```

```
#Fitting the best model to our training data
best_model.fit(df_train, tsne_train_output)
```

```
Hyperparameter tuning:

Best estimator:  LinearRegression(copy_X=True, fit_intercept=True, n_jobs=-1, normalize=False)
```

Out[144]:

```
LinearRegression(copy_X=True, fit_intercept=True, n_jobs=-1, normalize=False)
```

In [0]:

```
#Using the best model to make predictions
y_pred = best_model.predict(df_test)
lr_test_predictions = [round(value) for value in y_pred] #rounding the values to get integer
predictionss
y_pred = best_model.predict(df_train)
lr_train_predictions = [round(value) for value in y_pred]
```

In [0]:

```
train_mape_lr = (mean_absolute_error(tsne_train_output,
lr_train_predictions))/(sum(tsne_train_output)/len(tsne_train_output))
test_mape_lr = (mean_absolute_error(tsne_test_output, lr_test_predictions))/(sum(tsne_test_output)/
len(tsne_test_output))
```

In [147]:

```
print ("Error Metric Matrix (Tree Based Regression Methods) -  MAPE")
print ("--------------------------------------------------------------------------------------
----------")

print ("Linear Regression -                         Train: ",train_mape_lr,"      Test: ",test_mape
lr)

print ("--------------------------------------------------------------------------------------
----------")
```

```
Error Metric Matrix (Tree Based Regression Methods) -  MAPE
-------------------------------------------------------------------------------------------
-
Linear Regression -                         Train:  0.12730064668181643       Test:
0.11586937283886654
-------------------------------------------------------------------------------------------
-
```