Solving facilities location problem using GA- By Himanshu Bhardwaj

In developing operations strategy, facility location is of prime importance. Location of facility has impact on many things such as cost and time of delievery of goods. While establishing capacity of the factory, deciding customers to serve from a particular facility, we have to build a model that optimizes the profit or reduces the cost of operations. It has applications in disaster management also. For example, during pandemic, it was important to reduce the overall cost of vaccination. With help of the model discuss here, one can find the optimum facilities location while minimizing the overall cost of the operations. Genetic algorithm has been used as an optimizer in this case. In this case, each customer has been categoried into centroid or zones using unsupervised clustering.

In [1]:

```
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
import math
import random
```

In [2]:

```
#set parameters
num_customer = 10000
Max_facilities = 8
candidates_fac = 20
num_gaussian = 10
threshold =0.99
```

In [3]:

```
clusters = np.random.multinomial(num_customer, [1/num_gaussian]*num_gaussian)
```

In [4]:

```
customers = []
for i in range(num_gaussian):
    centers = (random.random()*0.1+28.5, random.random()*0.1+77)
    customers += [(random.gauss(0,0.01)+centers[0], random.gauss(0,0.01)+centers[1]) fo
r j in range(clusters[i])]
```

In [5]:

```
cust = pd.DataFrame(customers)
cust.columns = ['Lat', 'Lon']
```

In [6]:

```
import plotly.graph_objects as G
from sklearn.cluster import MiniBatchKMeans
```

In [7]:

```
lat_center = np.mean(cust['Lat'])
long_center = np.mean(cust['Lon'])
```

In [9]:

```
num_clusters = 10
```

In [10]:

```
seed = 1000
kmeans = MiniBatchKMeans(n_clusters=num_clusters, init_size=3*num_clusters,
                         random_state=seed).fit(customers)
memberships = list(kmeans.labels_)
centroids = list(kmeans.cluster_centers_) # Center point for each cluster
weights = list(np.histogram(memberships, bins=num_clusters)[0]) # Number of customers i
n each cluster
print('First cluster center:', centroids[0])
print('Weights for first 10 clusters:', weights[:10])
```

```
First cluster center: [28.59678407 77.01725118]
Weights for first 10 clusters: [867, 663, 1018, 1023, 1097, 906, 1785, 89
1, 948, 802]
```

In [11]:

```
centro = pd.DataFrame(centroids, columns=['Lat','Lon'])
centro['Demand'] = weights
```

In [12]:

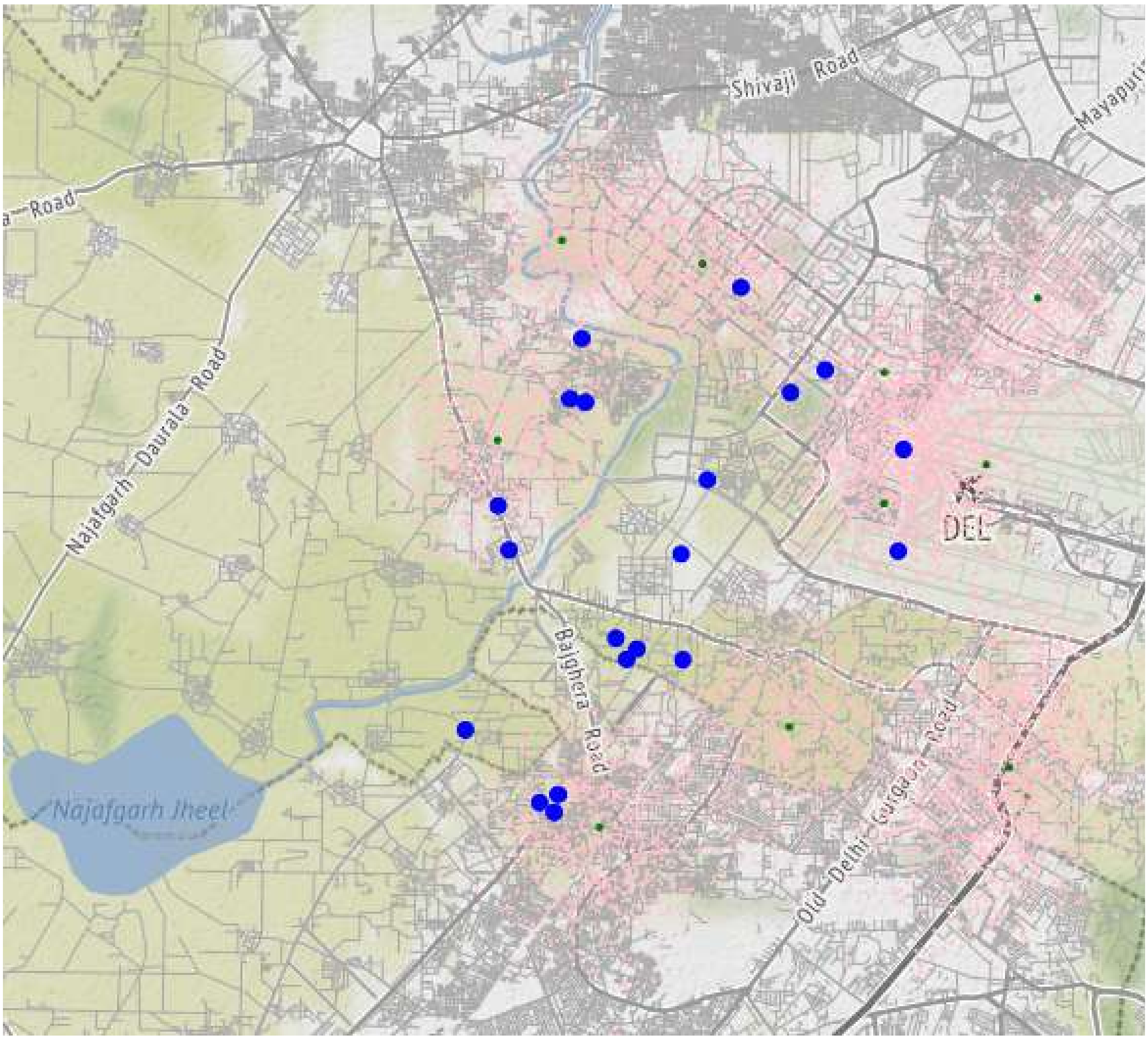
```
fac_loc = [(random.random()*0.09+28.5, random.random()*0.08+77) for x in range(candidat
es_fac)]
#fac_loc = pd.read_csv('fac_loc.csv')
faclities = pd.DataFrame(fac_loc, columns=['Lat','Lon'])
```

In [13]:

```
faclities['Capacity'] = np.ones(len(faclities))*1000
```

In [14]:

```
fig = G.Figure(G.Scattermapbox(
    name='customers',
    mode='markers',
    lon = cust['Lon'],
    lat= cust['Lat'],
    marker = {'size': 3},
    line = dict(width = 4.5, color = 'pink')))
fig.add_traces(G.Scattermapbox(
    name='centroids',
    mode='markers',
    lon = centro['Lon'],
    lat= centro['Lat'],
    marker = {'size': 5},
    line = dict(width = 4.5, color = 'green')))
fig.add_traces(G.Scattermapbox(
    name='Candidate Facilities',
    mode='markers',
    lon = faclities['Lon'],
    lat= faclities['Lat'],
    marker = {'size': 10},
    line = dict(width = 4.5, color = 'blue')))
lat_center = np.mean(cust['Lat'])
long_center = np.mean(cust['Lon'])
fig.update_layout(mapbox_style = 'stamen-terrain', mapbox_center_lat = lat_center, mapb
ox_center_lon = long_center)
fig.update_layout(margin={"r":0,"l":0,"t":0,"b":0}, mapbox = {'center':{'lat':lat_cente
r,'lon':long_center},'zoom':11})
fig.show()
```



In [15]:

```
def distance(p1,p2):
    Lo1 = p1[1]
    La1 = p1[0]
    Lo2 = p2[1]
    La2 = p2[0]
    Lo1 = math.radians(Lo1)
    Lo2 = math.radians(Lo2)
    La1 = math.radians(La1)
    La2 = math.radians(La2)
    # Using the "Haversine formula"
    D_Lo = Lo2 - Lo1
    D_La = La2 - La1
    P = math.sin(D_La / 2)**2 + math.cos(La1) * math.cos(La2) * math.sin(D_Lo / 2)**2
    Q = 2 * math.asin(math.sqrt(P))
    # The radius of earth in kilometres.
    R_km = 6371
    # Then, we will calculate the result
    return(Q * R_km)
```

In [16]:

```python
def dist_mat(centroids, facilities):
    dmat = []
    for i in range(len(centroids)):
        for j in range(len(facilities)):
            dmat.append(['centroid:'+str(i), 'facility:'+str(j), distance(centroids[i], 
facilities[j])])
    dfm = pd.DataFrame(dmat, columns=['Centroid','facility','distance'])
    return dfm
```

In [17]:

```python
distf = dist_mat(centroids, fac_loc)
```

In [22]:

```python
pop_size =100
cross_rate = 0.9
mut_rate = 1/50
iterations = 500
```

Optimization using Genetic Alogrithm

In [28]:

```python
import hemi_GA6 as hga
```

In [29]:

```python
error = []
best, best_value = hga.GA_function(hga.fitness, iterations, pop_size, cross_rate, 
                                   mut_rate, centroids, distf, error,Max_facilities)
```

```
100%|██████████████████████████████████████████████████████████████████████
███████████| 500/500 [00:41<00:00, 12.08it/s]
```

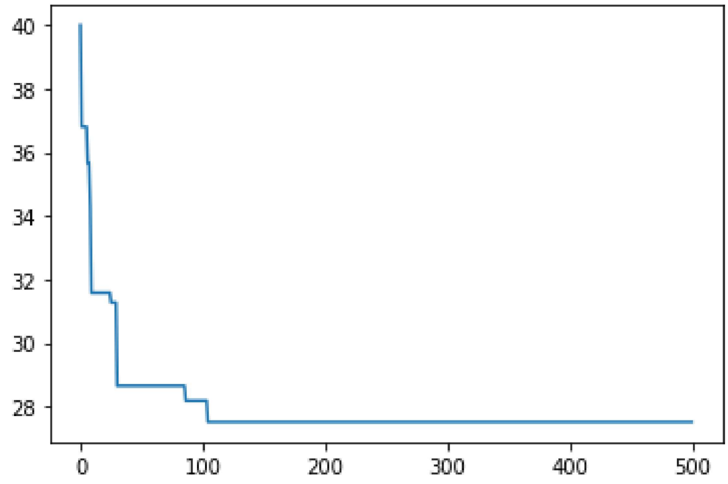
Cost function

In [30]:

```
plt.plot(error)
```

Out[30]:

```
[<matplotlib.lines.Line2D at 0x2a0f46f8e88>]
```



In [31]:

```
faclities['assign'] = np.array(best[1])
```

In [32]:

```
selected_fac = faclities[faclities['assign']==1]
selected_fac
```

Out[32]:

	Lat	Lon	Capacity	assign
1	28.589627	77.048463	1000.0	1
8	28.532529	77.028528	1000.0	1
11	28.581767	77.020696	1000.0	1
13	28.549275	77.008006	1000.0	1
14	28.535773	77.026644	1000.0	1
17	28.556095	77.006106	1000.0	1
18	28.573435	77.057163	1000.0	1
19	28.549114	77.075961	1000.0	1

In [33]:

```
vv = best[0]
```

In [34]:

```
aaa=np.where(np.array(vv[9])==1)
```

In [35]:

```
arr = np.array([11,12,13,14])
```

In [36]:

```
selected_fac.iloc[7,0]
```

Out[36]:

```
28.549113757276082
```

In [38]:

```
qq = [selected_fac.iloc[[np.where(np.array(vv[i])==1)[0][0]]] for i in range(len(centro
))]
```

In [39]:

```
aa = []
bb = []
for i in range(len(centro)):
    xx = np.where(np.array(vv[i])==1)[0][0]
    print(xx)
    aa.append(selected_fac.iloc[xx,0])
    bb.append(selected_fac.iloc[xx,1])
```

```
2
7
1
1
0
7
7
2
3
7
```

In [40]:

```
centro['fac_lat'] = np.array(aa)
centro['fac_lon'] = np.array(bb)
```

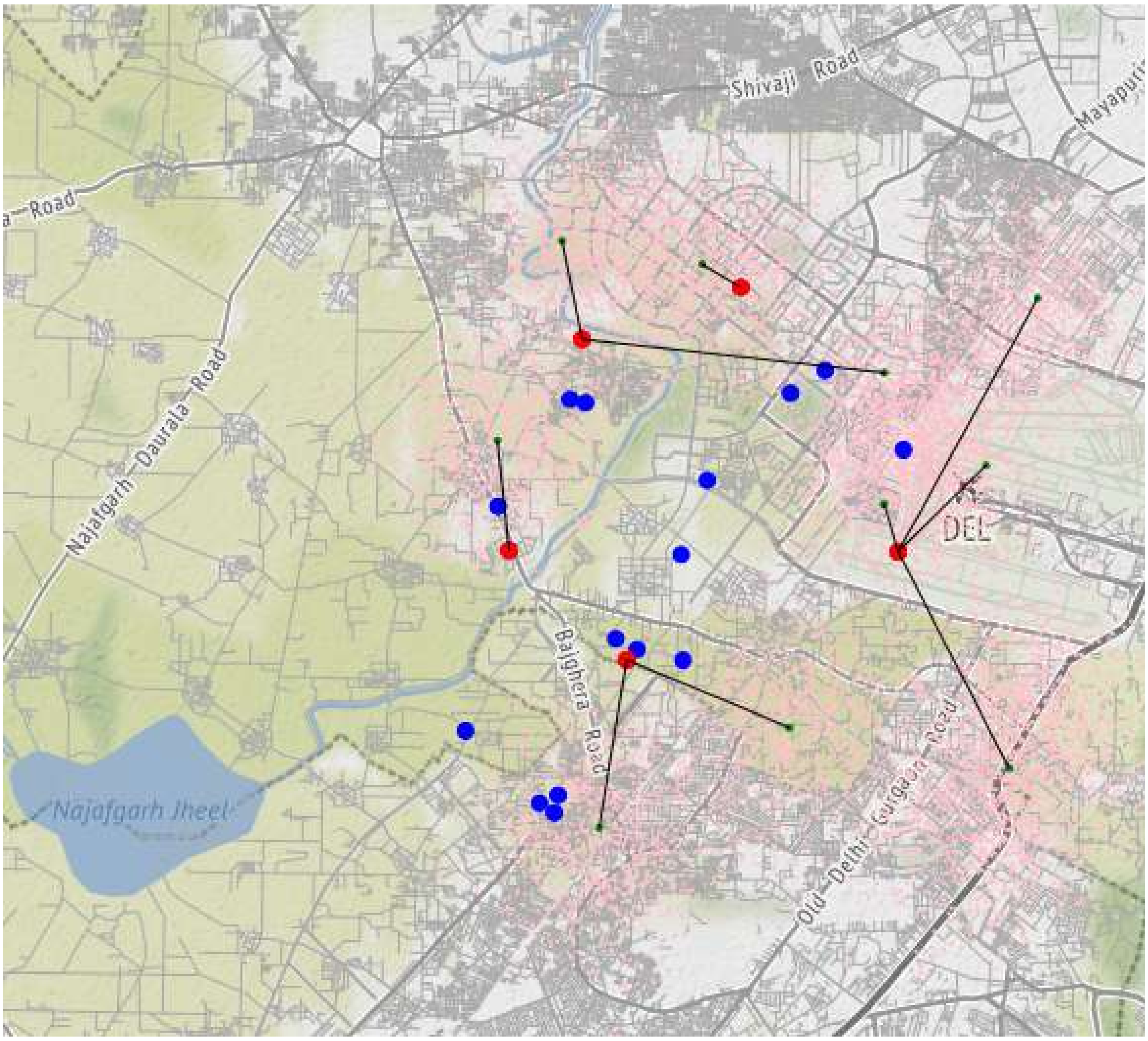
In [41]:

```
centro.to_csv('result.csv')
```

Selected facilities has been shown in below plot (with red dot) along with the assigned centroid of customers with connected lines

In [42]:

```
fig = G.Figure(G.Scattermapbox(
    name='customers',
    mode='markers',
    lon = cust['Lon'],
    lat= cust['Lat'],
    marker = {'size': 3},
    line = dict(width = 4.5, color = 'pink')))
fig.add_traces(G.Scattermapbox(
    name='centroids',
    mode='markers',
    lon = centro['Lon'],
    lat= centro['Lat'],
    marker = {'size': 5},
    line = dict(width = 4.5, color = 'green')))
fig.add_traces(G.Scattermapbox(
    name='Candidate Facilities',
    mode='markers',
    lon = faclities['Lon'],
    lat= faclities['Lat'],
    marker = {'size': 10},
    line = dict(width = 4.5, color = 'blue')))
fig.add_traces(G.Scattermapbox(
    name='Selected Facilities',
    mode='markers',
    lon = centro['fac_lon'],
    lat= centro['fac_lat'],
    marker = {'size': 10},
    line = dict(width = 4.5, color = 'red')))
for i in range(len(centro)):
    fig.add_traces(G.Scattermapbox(
        name='assigned Facilities',
        mode='lines',
        lon = [centro.iloc[i,1], centro.iloc[i,4]],
        lat= [centro.iloc[i,0], centro.iloc[i,3]],
        line = dict(width = 1, color = 'black')))
lat_center = np.mean(cust['Lat'])
long_center = np.mean(cust['Lon'])
fig.update_layout(mapbox_style = 'stamen-terrain', mapbox_center_lat = lat_center, mapb
ox_center_lon = long_center)
fig.update_layout(margin={"r":0,"l":0,"t":0,"b":0}, mapbox = {'center':{'lat':lat_cente
r,'lon':long_center},'zoom':11})
fig.show()
```


Shivaji Road
Mayapuri
a-Road
Najafgarh-Daurala-Road
DEL
Bajghera Road
Old-Delhi-Gurgaon-Road
Najafgarh Jheel

In [ ]: