Data Analysing & Preprocessing

In [1]:

```python
import numpy as np
import pandas as pd
from sklearn.preprocessing import LabelEncoder
import matplotlib.pyplot as plt
```

In [2]:

```python
main_df = pd.read_csv("Automobile_data.csv")
```

In [3]:

```python
main_df.head(n=10)
```

Out[3]:

	symboling	normalized-losses	make	fuel-type	aspiration	num-of-doors	body-style	drive-wheels	engine-location	wheel-base	...	engine-size	f sys
0	3	?	alfa-romero	gas	std	two	convertible	rwd	front	88.6	...	130	
1	3	?	alfa-romero	gas	std	two	convertible	rwd	front	88.6	...	130	
2	1	?	alfa-romero	gas	std	two	hatchback	rwd	front	94.5	...	152	
3	2	164	audi	gas	std	four	sedan	fwd	front	99.8	...	109	
4	2	164	audi	gas	std	four	sedan	4wd	front	99.4	...	136	
5	2	?	audi	gas	std	two	sedan	fwd	front	99.8	...	136	
6	1	158	audi	gas	std	four	sedan	fwd	front	105.8	...	136	
7	1	?	audi	gas	std	four	wagon	fwd	front	105.8	...	136	
8	1	158	audi	gas	turbo	four	sedan	fwd	front	105.8	...	131	
9	0	?	audi	gas	turbo	two	hatchback	4wd	front	99.5	...	131	

10 rows × 26 columns

In [4]:

```python
main_df.describe()
```

Out[4]:

	symboling	wheel-base	length	width	height	curb-weight	engine-size	compression-ratio	city-mp
count	205.000000	205.000000	205.000000	205.000000	205.000000	205.000000	205.000000	205.000000	205.00000
mean	0.834146	98.756585	174.049268	65.907805	53.724878	2555.565854	126.907317	10.142537	25.21951
std	1.245307	6.021776	12.337289	2.145204	2.443522	520.680204	41.642693	3.972040	6.54214
min	-2.000000	86.600000	141.100000	60.300000	47.800000	1488.000000	61.000000	7.000000	13.00000
25%	0.000000	94.500000	166.300000	64.100000	52.000000	2145.000000	97.000000	8.600000	19.00000
50%	1.000000	97.000000	173.200000	65.500000	54.100000	2414.000000	120.000000	9.000000	24.00000
75%	2.000000	102.400000	183.100000	66.900000	55.500000	2935.000000	141.000000	9.400000	30.00000
max	3.000000	120.900000	208.100000	72.300000	59.800000	4066.000000	326.000000	23.000000	49.00000

In [5]:

```
main_df.isna() #each element is null or not
```

Out[5]:

	symboling	normalized-losses	make	fuel-type	aspiration	num-of-doors	body-style	drive-wheels	engine-location	wheel-base	...	engine-size	fuel-system
0	False	False	False	False	False	False	False	False	False	False	...	False	False
1	False	False	False	False	False	False	False	False	False	False	...	False	False
2	False	False	False	False	False	False	False	False	False	False	...	False	False
3	False	False	False	False	False	False	False	False	False	False	...	False	False
4	False	False	False	False	False	False	False	False	False	False	...	False	False
...	...	...	...	...	...	...	...	...	...	...	...	...	..
200	False	False	False	False	False	False	False	False	False	False	...	False	False
201	False	False	False	False	False	False	False	False	False	False	...	False	False
202	False	False	False	False	False	False	False	False	False	False	...	False	False
203	False	False	False	False	False	False	False	False	False	False	...	False	False
204	False	False	False	False	False	False	False	False	False	False	...	False	False

205 rows × 26 columns

In [6]:

```
main_df.isna().sum()
```

Out[6]:

```
symboling            0
normalized-losses    0
make                 0
fuel-type            0
aspiration           0
num-of-doors         0
body-style           0
drive-wheels         0
engine-location      0
wheel-base           0
length               0
width                0
height               0
curb-weight          0
engine-type          0
num-of-cylinders     0
engine-size          0
fuel-system          0
bore                 0
stroke               0
compression-ratio    0
horsepower           0
peak-rpm             0
city-mpg             0
highway-mpg          0
price                0
dtype: int64
```

In [7]:

```
(main_df == "?").sum()
```

Out[7]:

```
symboling              0
```

```
normalized-losses    41
make                  0
fuel-type             0
aspiration            0
num-of-doors          2
body-style            0
drive-wheels          0
engine-location       0
wheel-base            0
length                0
width                 0
height                0
curb-weight           0
engine-type           0
num-of-cylinders      0
engine-size           0
fuel-system           0
bore                  4
stroke                4
compression-ratio     0
horsepower            2
peak-rpm              2
city-mpg              0
highway-mpg           0
price                 4
dtype: int64
```

In [8]:

```
res_df=main_df[main_df.price!='?']
res_df=res_df[['symboling','wheel-base','length','width','height','curb-weight','engine-si
res_df
```

Out[8]:

	symboling	wheel-base	length	width	height	curb-weight	engine-size	compression-ratio	city-mpg	highway-mpg	price
0	3	88.6	168.8	64.1	48.8	2548	130	9.0	21	27	13495
1	3	88.6	168.8	64.1	48.8	2548	130	9.0	21	27	16500
2	1	94.5	171.2	65.5	52.4	2823	152	9.0	19	26	16500
3	2	99.8	176.6	66.2	54.3	2337	109	10.0	24	30	13950
4	2	99.4	176.6	66.4	54.3	2824	136	8.0	18	22	17450
...	...	...	...	...	...	...	...	...	...	...	...
200	-1	109.1	188.8	68.9	55.5	2952	141	9.5	23	28	16845
201	-1	109.1	188.8	68.8	55.5	3049	141	8.7	19	25	19045
202	-1	109.1	188.8	68.9	55.5	3012	173	8.8	18	23	21485
203	-1	109.1	188.8	68.9	55.5	3217	145	23.0	26	27	22470
204	-1	109.1	188.8	68.9	55.5	3062	141	9.5	19	25	22625

201 rows × 11 columns

In [9]:

```
res_df.describe()
```

Out[9]:

	symboling	wheel-base	length	width	height	curb-weight	engine-size	compression-ratio	city-mp
count	201.000000	201.000000	201.000000	201.000000	201.000000	201.000000	201.000000	201.000000	201.0000

	symboling	wheel-base	length	width	height	curb-weight	engine-size	compression-ratio	city-mp
mean	0.840796	98.797015	174.200995	65.889055	53.766667	2555.666667	126.875622	10.164279	25.1791(
std	1.254802	6.066366	12.322175	2.101471	2.447822	517.296727	41.546834	4.004965	6.42322
min	-2.000000	86.600000	141.100000	60.300000	47.800000	1488.000000	61.000000	7.000000	13.0000(
25%	0.000000	94.500000	166.800000	64.100000	52.000000	2169.000000	98.000000	8.600000	19.0000(
50%	1.000000	97.000000	173.200000	65.500000	54.100000	2414.000000	120.000000	9.000000	24.0000(
75%	2.000000	102.400000	183.500000	66.600000	55.500000	2926.000000	141.000000	9.400000	30.0000(
max	3.000000	120.900000	208.100000	72.000000	59.800000	4066.000000	326.000000	23.000000	49.0000(

In [10]:

```
print(res_df.dtypes)
```

```
symboling              int64
wheel-base           float64
length               float64
width                float64
height               float64
curb-weight            int64
engine-size            int64
compression-ratio    float64
city-mpg               int64
highway-mpg            int64
price                 object
dtype: object
```

In [11]:

```
convert_dict = {'price':float}
res_df = res_df.astype(convert_dict)
print(res_df.dtypes)
```

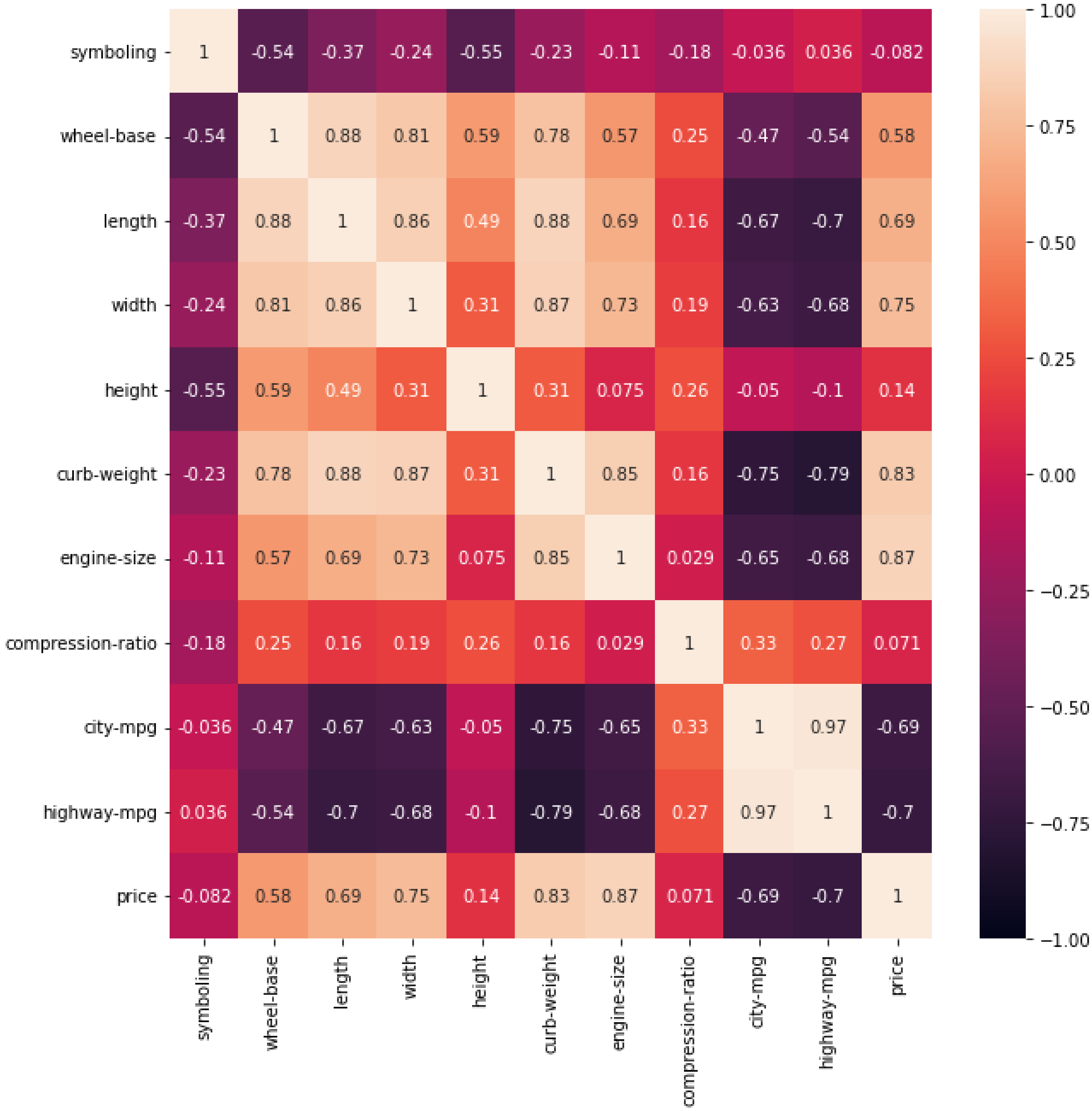
```
symboling              int64
wheel-base           float64
length               float64
width                float64
height               float64
curb-weight            int64
engine-size            int64
compression-ratio    float64
city-mpg               int64
highway-mpg            int64
price                float64
dtype: object
```

In [12]:

```
import seaborn as sns
plt.figure(figsize=(10,10))
sns.heatmap(res_df.corr(), vmin=-1, annot=True)
```

Out[12]:

```
<AxesSubplot:>
```



In [13]:

```
(res_df == "?").sum()
```

Out[13]:

```
symboling            0
wheel-base           0
length               0
width                0
height               0
curb-weight          0
engine-size          0
compression-ratio    0
city-mpg             0
highway-mpg          0
price                0
dtype: int64
```

In [14]:

```
#deleting duplicate rows
res_df=res_df.drop_duplicates(keep='first')
res_df
```

Out[14]:

symboling	wheel-base	length	width	height	curb-weight	engine-size	compression-ratio	city-mpg	highway-mpg	price

	symboling	wheel-base	length	width	height	curb-weight	engine-size	compression-ratio	city-mpg	highway-mpg	price
0	3	88.6	168.8	64.1	48.8	2548	130	9.0	21	27	13495.0
1	3	88.6	168.8	64.1	48.8	2548	130	9.0	21	27	16500.0
2	1	94.5	171.2	65.5	52.4	2823	152	9.0	19	26	16500.0
3	2	99.8	176.6	66.2	54.3	2337	109	10.0	24	30	13950.0
4	2	99.4	176.6	66.4	54.3	2824	136	8.0	18	22	17450.0
...	...	...	...	...	...	...	...	...	...	...	...
200	-1	109.1	188.8	68.9	55.5	2952	141	9.5	23	28	16845.0
201	-1	109.1	188.8	68.8	55.5	3049	141	8.7	19	25	19045.0
202	-1	109.1	188.8	68.9	55.5	3012	173	8.8	18	23	21485.0
203	-1	109.1	188.8	68.9	55.5	3217	145	23.0	26	27	22470.0
204	-1	109.1	188.8	68.9	55.5	3062	141	9.5	19	25	22625.0

198 rows × 11 columns

In [17]:

```
#Selecting engine-size as the feature for univariate linear regression for its high co-re
f_df=res_df[['engine-size','price']]
#deleting duplicate rows
f_df=f_df.drop_duplicates(keep='first')
f_df
```

Out[17]:

	engine-size	price
0	130	13495.0
1	130	16500.0
2	152	16500.0
3	109	13950.0
4	136	17450.0
...	...	...
200	141	16845.0
201	141	19045.0
202	173	21485.0
203	145	22470.0
204	141	22625.0

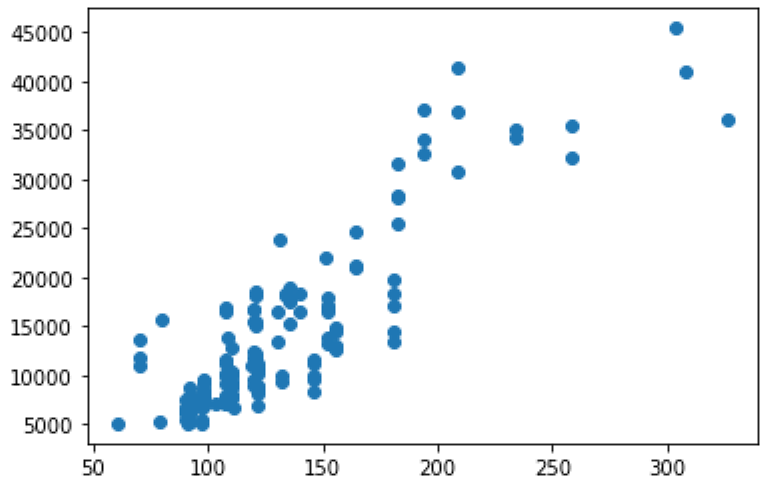
193 rows × 2 columns

In [18]:

```
#Train Test split
x=f_df["engine-size"].tolist()
y=f_df["price"].tolist()
train_x=np.array(x[0:160]).astype(np.float64)
train_y=np.array(y[0:160]).astype(np.float64)
test_x=np.array(x[160:194]).astype(np.float64)
test_y=np.array(y[160:194]).astype(np.float64)
```

In [19]:
```
plt.scatter(train_x,train_y)
```

Out[19]:
```
<matplotlib.collections.PathCollection at 0x264b1b2c670>
```



UNIVARIATE LINEAR REGRESSION USING GRADIENT DESCENT

In [20]:
```
def uni_gradient_descent(x,y):
    m=0
    c=0
    cost_val=[]
    iterations = 2000
    n=len(train_x)
    k=.0000001      #learning rate
    for i in range(iterations):
        y_pred = m*x+c
        d_wrt_m=-(1/n)*sum(x.transpose()*(y-y_pred))
        d_wrt_c=-(1/n)*sum(y-y_pred)
        m=m-k*d_wrt_m
        c=c-k*d_wrt_c
        cost=(1/(2*n))*(sum(np.square(y-m*x-c)))
        cost_val.append(cost)
        print("m = {}, c = {}, cost = {},in iteration = {}".format(m,c,cost,i))

    return m,c,cost,cost_val;
```

In [21]:
```
x=uni_gradient_descent(train_x,train_y)
x
```

```
m = 0.203586039375, c = 0.0013350743750000001, cost = 125418011.98791619,in iteration = 0
m = 0.40680193203588616, c = 0.002667558111382792, cost = 125005402.67439102,in iteration
= 1
m = 0.6096483509610868, c = 0.003997455919293031, cost = 124594292.35937093,in iteration =
2
m = 0.8121259679054639, c = 0.005324772500311678 6, cost = 124184675.59703334,in iteration
= 3
m = 1.0142354534025326, c = 0.006649512547471563, cost = 123776546.96134081,in iteration =
4
m = 1.215977476766686, c = 0.00797168074527292, cost = 123369901.04596825,in iteration = 5
m = 1.4173527060954094, c = 0.009291281769698912, cost = 122964732.46423176,in iteration =
6
m = 1.6183618082714935, c = 0.010608320288231112, cost = 122561035.84901689,in iteration =
```

```
7
m = 1.8190054489652439, c = 0.011922800959864957, cost = 122158805.85270806,in iteration =
8
m = 2.0192842926366836, c = 0.013234728435125184, cost = 121758037.14711738,in iteration =
9
m = 2.2191990025377555, c = 0.01454410735608122, cost = 121358724.42341387,in iteration =
10
m = 2.4187502407145165, c = 0.015850942356362568, cost = 120960862.39205372,in iteration =
11
m = 2.617938668009332, c = 0.01715523806117414, cost = 120564445.7827096,in iteration = 12
m = 2.8167649440630638, c = 0.01845699908731158, cost = 120169469.34420152,in iteration =
13
m = 3.0152297273172537, c = 0.01975623004317656, cost = 119775927.84442638,in iteration =
14
m = 3.2133336750163064, c = 0.021052935528792022, cost = 119383816.07028969,in iteration =
15
m = 3.4110774432096624, c = 0.022347120135817432, cost = 118993128.82763575,in iteration =
16
m = 3.608461686753975, c = 0.023638788447563976, cost = 118603860.94117904,in iteration =
17
m = 3.8054870593152748, c = 0.02492794503900974, cost = 118216007.25443557,in iteration =
 18
m = 4.002154213371136, c = 0.02621459447681486, cost = 117829562.62965527,in iteration = 1
9
m = 4.198463800212839, c = 0.027498741319336648, cost = 117444521.94775294,in iteration =
 20
m = 4.394416469947526, c = 0.028780390116644683, cost = 117060880.10824096,in iteration =
 21
m = 4.590012871500351, c = 0.030059545410535883, cost = 116678632.02916156,in iteration =
 22
m = 4.785253652616634, c = 0.03133621173454955, cost = 116297772.6470198,in iteration = 23
m = 4.9801394598640005, c = 0.03261039361398236, cost = 115918296.91671616,in iteration =
 24
m = 5.17467093863453, c = 0.03388209556590339, cost = 115540199.81147988,in iteration = 25
m = 5.368848733146886, c = 0.03515132209916905, cost = 115163476.32280238,in iteration = 2
6
m = 5.562673486448453, c = 0.036418077714438, cost = 114788121.46037057,in iteration = 27
m = 5.756145840417467, c = 0.0376823669041861, cost = 114414130.25200152,in iteration = 28
m = 5.9492664357651375, c = 0.038944194152721254, cost = 114041497.74357557,in iteration =
 29
m = 6.142035912037772, c = 0.04020356393619825, cost = 113670218.99897169,in iteration = 3
0
m = 6.334454907618896, c = 0.04146048072263362, cost = 113300289.10000144,in iteration = 3
1
m = 6.5265240597313605, c = 0.042714948971920415, cost = 112931703.14634395,in iteration =
 32
m = 6.71824400443946, c = 0.043966973135842975, cost = 112564456.25548147,in iteration = 3
3
m = 6.909615376651033, c = 0.045216557658091676, cost = 112198543.56263366,in iteration =
 34
m = 7.100638810119567, c = 0.04646370697427764, cost = 111833960.22069453,in iteration = 3
5
m = 7.291314937446298, c = 0.04770842551194742, cost = 111470701.40016699,in iteration = 3
6
m = 7.481644390082305, c = 0.0489507176905977, cost = 111108762.28909957,in iteration = 37
m = 7.6716277983306, c = 0.05019058792168988, cost = 110748138.0930224,in iteration = 38
m = 7.861265791348215, c = 0.05142804060866471, cost = 110388824.03488392,in iteration = 3
9
m = 8.05055899714829, c = 0.052663080146956864, cost = 110030815.35498746,in iteration = 4
0
m = 8.239508042602145, c = 0.053895710924009514, cost = 109674107.31092802,in iteration =
 41
m = 8.428113553441362, c = 0.05512593731928884, cost = 109318695.17752992,in iteration = 4
2
m = 8.616376154259859, c = 0.05635376370429854, cost = 108964574.24678369,in iteration = 4
3
```

```
m = 8.80429646851595, c = 0.05757919444259431, cost = 108611739.82778393,in iteration = 44
m = 8.991875118534418, c = 0.05880223388979829, cost = 108260187.2466675,in iteration = 45
m = 9.17911272550857, c = 0.0600228863936135, cost = 107909911.84655076,in iteration = 46
m = 9.3660099095023, c = 0.06124156293838216, cost = 107560908.98746884,in iteration = 47
m = 9.552567289452135, c = 0.06245704792238036, cost = 107213174.04631357,in iteration = 4
8
m = 9.738785483169293, c = 0.06367056560327185, cost = 106866702.41677232,in iteration = 4
9
m = 9.924665107341724, c = 0.06488171365268289, cost = 106521489.5092675,in iteration = 50
m = 10.11020677753615, c = 0.0660904963789363, cost = 106177530.75089464,in iteration = 51
m = 10.295411108200112, c = 0.06729691808252175, cost = 105834821.58536306,in iteration =
 52
m = 10.480278712663994, c = 0.06850098305611003, cost = 105493357.47293475,in iteration =
 53
m = 10.664810203143064, c = 0.06970269558456728, cost = 105153133.89036463,in iteration =
 54
m = 10.849006190739496, c = 0.0709020599449691, cost = 104814146.33083999,in iteration = 5
5
m = 11.032867285444395, c = 0.07209908040661482, cost = 104476390.30392194,in iteration =
 56
m = 11.216394096139814, c = 0.07329376123104156, cost = 104139861.33548473,in iteration =
 57
m = 11.399587230600778, c = 0.07448610667203837, cost = 103804554.96765698,in iteration =
 58
m = 11.582447295497289, c = 0.07567612097566033, cost = 103470466.75876296,in iteration =
 59
m = 11.764974896396339, c = 0.0768638083802426, cost = 103137592.28326322,in iteration = 6
0
m = 11.947170637763914, c = 0.07804917311641442, cost = 102805927.13169622,in iteration =
 61
m = 12.129035122966998, c = 0.07923221940711321, cost = 102475466.91061987,in iteration =
 62
m = 12.310568954275569, c = 0.08041295146759847, cost = 102146207.24255331,in iteration =
 63
m = 12.491772732864593, c = 0.08159137350546576, cost = 101818143.76591909,in iteration =
 64
m = 12.672647058816018, c = 0.08276748972066067, cost = 101491272.13498515,in iteration =
 65
m = 12.853192531120756, c = 0.08394130430549268, cost = 101165588.01980722,in iteration =
 66
m = 13.033409747680674, c = 0.08511282144464907, cost = 100841087.10617185,in iteration =
 67
m = 13.213299305310564, c = 0.08628204531520879, cost = 100517765.09553894,in iteration =
 68
m = 13.392861799740132, c = 0.08744898008665625, cost = 100195617.70498486,in iteration =
 69
m = 13.572097825615959, c = 0.08861362992089516, cost = 99874640.66714564,in iteration = 7
0
m = 13.751007976503479, c = 0.08977599897226235, cost = 99554829.73016068,in iteration = 7
1
m = 13.929592844888939, c = 0.09093609138754143, cost = 99236180.65761614,in iteration = 7
2
m = 14.107853022181365, c = 0.0920939113059766, cost = 98918689.22848904,in iteration = 73
m = 14.285789098714517, c = 0.09324946285928636, cost = 98602351.23709135,in iteration = 7
4
m = 14.463401663748847, c = 0.09440275017167711, cost = 98287162.49301393,in iteration = 7
5
m = 14.640691305473448, c = 0.09555377735985693, cost = 97973118.8210715,in iteration = 76
m = 14.817658611008005, c = 0.0967025485330491, cost = 97660216.06124735,in iteration = 77
m = 14.994304166404733, c = 0.09784906779300581, cost = 97348450.06863725,in iteration = 7
8
m = 15.170628556650328, c = 0.09899333923402164, cost = 97037816.71339616,in iteration = 7
9
m = 15.346632365667897, c = 0.10013536694294718, cost = 96728311.88068204,in iteration = 8
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m = 15.52231617631889, c = 0.10127515499920259, cost = 96419931.4706023,in iteration = 81
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m = 15.697680570405035, c = 0.10241270747479105, cost = 96112671.39815897,in iteration = 8
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m = 15.872726128670266, c = 0.10354802843431225, cost = 95806527.59319493,in iteration = 8
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m = 16.047453430802637, c = 0.10468112193497592, cost = 95501496.00033978,in iteration = 8
4
m = 16.221863055436256, c = 0.10581199202661516, cost = 95197572.57895601,in iteration = 8
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m = 16.39595558015319, c = 0.10694064275169994, cost = 94894753.30308585,in iteration = 86
m = 16.569731581485378, c = 0.10806707814535045, cost = 94593034.16139759,in iteration = 8
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m = 16.74319163491655, c = 0.10919130223535048, cost = 94292411.15713277,in iteration = 88
m = 16.916336314884116, c = 0.11031331904216071, cost = 93992880.30805287,in iteration = 8
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m = 17.089166194781093, c = 0.1114331325789321, cost = 93694437.64638668,in iteration = 90
m = 17.261681846957977, c = 0.11255074685151913, cost = 93397079.21877801,in iteration = 9
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m = 17.433883842724654, c = 0.11366616585849305, cost = 93100801.08623305,in iteration = 9
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m = 17.60577275235229, c = 0.1147793935911552, cost = 92805599.32406819,in iteration = 93
m = 17.777349145075224, c = 0.11589043403355014, cost = 92511470.02185792,in iteration = 9
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m = 17.948613589092837, c = 0.11699929116247887, cost = 92218409.28338373,in iteration = 9
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m = 18.119566651571446, c = 0.11810596894751203, cost = 91926413.22658135,in iteration = 9
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m = 18.29020889864619, c = 0.11921047135100304, cost = 91635477.98349035,in iteration = 97
m = 18.460540895422884, c = 0.1203128023281012, cost = 91345599.7002024,in iteration = 98
m = 18.630563205979907, c = 0.12141296582676477, cost = 91056774.53681032,in iteration = 9
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m = 18.800276393370066, c = 0.1225109657877741, cost = 90768998.6673571,in iteration = 100
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m = 19.812095333410877, c = 0.12905375104565328, cost = 89064166.11476988,in iteration = 1
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m = 19.979660338354087, c = 0.1301367159847201, cost = 88783629.33732226,in iteration = 10
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m = 20.48052963514913, c = 0.13337283269238773, cost = 87948119.30248144,in iteration = 11
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m = 21.144115968931324, c = 0.1376579836530803, cost = 86848202.59355569,in iteration = 11
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m = 21.30925918344213, c = 0.13872399860164977, cost = 86575716.3510289,in iteration = 115
m = 21.47410214566420, c = 0.1397879120994276, cost = 86304220.04357062,in iteration = 11
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m = 21.638645401498156, c = 0.14084972796714665, cost = 86033710.0747729,in iteration = 11
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m = 21.802889495852053, c = 0.1419094500185931, cost = 85764182.86129314,in iteration = 1
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m = 21.966834972643255, c = 0.1429670820606194, cost = 85495634.83280723,in iteration = 11
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m = 22.456885121991302, c = 0.1461274760949532 5, cost = 84695830.34835045,in iteration = 1
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m = 22.619641547953908, c = 0.1471767860295815, cost = 84431163.61530906,in iteration = 12
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m = 23.106137500264033, c = 0.1503123044162972 8, cost = 83642918.61804268,in iteration = 1
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m = 23.267713499285215, c = 0.15135335260171193, cost = 83382077.0844882,in iteration = 12
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m = 23.4289957317137, c = 0.1523923447294192, cost = 83122183.18108049,in iteration = 128
m = 23.589984731658195, c = 0.153429284537621, cost = 82863233.46510424,in iteration = 129
m = 23.75068103225631, c = 0.15446417575772264, cost = 82605224.50635107,in iteration = 13
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m = 26.126361202166546, c = 0.16974423018841445, cost = 78845686.19871353,in iteration = 1
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m = 27.36712276680779, c = 0.177709745118863, cost = 76922961.33404367,in iteration = 153
m = 27.520951730286704, c = 0.1786965721901326, cost = 76686533.22087474,in iteration = 15
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m = 28.892887564854185, c = 0.1874903551271894, cost = 74596960.27074508,in iteration = 16
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m = 29.64542078248647, c = 0.1923082267300151, cost = 73465323.53027217,in iteration = 168
m = 29.795107499077492, c = 0.19326606242312327, cost = 73241456.92002589,in iteration = 1
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m = 31.862369672756316, c = 0.206477328892967, cost = 70191391.15143918,in iteration = 183
m = 32.008025683738815, c = 0.20740695388012934, cost = 69979418.64713226,in iteration = 1
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m = 32.44340671075904, c = 0.2101847214669965, cost = 69348110.49498793,in iteration = 187
m = 32.588006319817204, c = 0.21110695275025912, cost = 69139201.60598294,in iteration = 1
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m = 33.020229651220006, c = 0.21386261978446974, cost = 68517017.68113472,in iteration = 1
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m = 33.59286905793079, c = 0.21751123775993964, cost = 67697936.56026343,in iteration = 19
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m = 34.01962142991087, c = 0.220228613824784, cost = 67091403.86494875,in iteration = 198
m = 34.16135527301149, c = 0.2211307877564904, cost = 66890693.528629735,in iteration = 19
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m = 34.86616848437864, c = 0.22561466943654052, cost = 65898026.636006765,in iteration = 2
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m = 35.0063631935436, c = 0.22650607104746515, cost = 65701651.80605544,in iteration = 205
m = 35.14630301028741, c = 0.22739568867919718, cost = 65505990.40041003,in iteration = 20
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m = 36.6689500351827, c = 0.23706466344701205, cost = 63400066.36161657,in iteration = 217
m = 36.80586705052846, c = 0.23793312464444177, cost = 63212766.55191779,in iteration = 21
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m = 37.35105030259089, c = 0.24138957837936748, cost = 62470347.18720149,in iteration = 22
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m = 37.48672717008734, c = 0.2422493598447156, cost = 62286425.021377,in iteration = 223
m = 37.62215735922986, c = 0.24310741482074474, cost = 62103171.039656796,in iteration = 2
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m = 37.75734131851415, c = 0.2439637464464554, cost = 61920582.814545564,in iteration = 22
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m = 37.89227949562049, c = 0.244818357855141, cost = 61738657.92736697,in iteration = 226
m = 38.02697233741521, c = 0.24567125217439814, cost = 61557393.96823185,in iteration = 22
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m = 38.16142028995217 6, c = 0.24652243252613704, cost = 61376788.53600589,in iteration = 2
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m = 38.29562379847426, c = 0.24737190202659182, cost = 61196839.23827812,in iteration = 22
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m = 38.42958330741483, c = 0.2482196637863309, cost = 61017543.691329196,in iteration = 23
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m = 39.492528460032204, c = 0.25494065060513, cost = 59606431.14076183,in iteration = 238
m = 39.62431183939717, c = 0.2557731817442413, cost = 59432913.50201809,in iteration = 239
m = 39.75585561931348, c = 0.2566040359389617, cost = 59260026.248005,in iteration = 240
m = 39.8871602354064, c = 0.2574332162382121, cost = 59087767.08855144,in iteration = 241
m = 40.01822612250916, c = 0.25826072568537006, cost = 58916133.74180633,in iteration = 24
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m = 40.27964344512567, c = 0.25991074416926263, cost = 58574735.4004568,in iteration = 244
m = 40.40999574635871, c = 0.26073325926512614, cost = 58404965.88347951,in iteration = 24
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m = 41.700554733252595, c = 0.26886767566802255, cost = 56740825.90531671,in iteration = 2
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m = 42.842147381710134, c = 0.2760492982748705, cost = 55294015.54852741,in iteration = 26
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m = 43.21854221850709, c = 0.27841422450151, cost = 54822181.60580781,in iteration = 267
m = 43.343551217543144, c = 0.2791993420969459, cost = 54666045.01145698,in iteration = 26
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m = 63.84575457265331, c = 0.405179486929326, cost = 32903385.45892553,in iteration = 463
m = 63.93326064236817, c = 0.4057021234630369, cost = 32826879.21779266,in iteration = 464
m = 64.02060761496807, c = 0.4062236464844383, cost = 32750650.92153111,in iteration = 465
m = 64.10779577971378, c = 0.40674405801805297, cost = 32674699.560374558,in iteration = 4
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m = 64.19482542534018, c = 0.4072633600847227, cost = 32599024.128225,in iteration = 467
m = 64.28169684005717, c = 0.40778155470161515, cost = 32523623.622639623,in iteration = 4
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m = 64.36841031155062, c = 0.40829864388223047, cost = 32448497.044817436,in iteration = 4
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m = 64.4549661269834, c = 0.408814629636408, cost = 32373643.399586048,in iteration = 470
m = 64.54136457299623, c = 0.409329513970333, cost = 32299061.695388533,in iteration = 471
m = 64.6276059357087, c = 0.4098432988865431, cost = 32224750.944270268,in iteration = 472
m = 64.7136905007202, c = 0.410355986383935, cost = 32150710.161865838,in iteration = 473
m = 64.79961855311086, c = 0.4108675784577713, cost = 32076938.367386032,in iteration = 47
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m = 64.88539037744248, c = 0.4113780770996867, cost = 32003434.5836047,in iteration = 475
m = 64.97100625775948, c = 0.411887484297695, cost = 31930197.836846072,in iteration = 476
m = 65.05646647758988, c = 0.4123958020361955, cost = 31857227.156971604,in iteration = 47
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m = 65.14177131994617, c = 0.4129030322959795, cost = 31784521.57736735,in iteration = 478
m = 65.22692106732632, c = 0.4134091770542371, cost = 31712080.134931047,in iteration = 47
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m = 65.48144255689066, c = 0.4149211180378678, cost = 31496331.05201371,in iteration = 482
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m = 65.65035323111188, c = 0.41592368727300644, cost = 31353801.51590057,in iteration = 48
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m = 65.73457831239462, c = 0.4164233603422426, cost = 31282924.866375435,in iteration = 48
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m = 65.81865026185766, c = 0.4169219616499928, cost = 31212305.709563244,in iteration = 48
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m = 66.06995010094893, c = 0.41841135447275857, cost = 31001983.857741922,in iteration = 4
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m = 66.2367227587062, c = 0.41939895984407544, cost = 30863039.693636365,in iteration = 49
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m = 66.31988174628214, c = 0.41989117138002663, cost = 30793945.96686923,in iteration = 49
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m = 67.54927637168653, c = 0.42714843204827635, cost = 29787157.20889091,in iteration = 50
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m = 68.03171448387369, c = 0.42998610796578995, cost = 29399581.807711825,in iteration = 5
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m = 68.35042584808107, c = 0.4318574966728972, cost = 29145860.52697968,in iteration = 517
m = 68.42974185790722, c = 0.4323228114122468, cost = 29083005.259400297,in iteration = 51
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m = 68.82416404701071, c = 0.4346342823619816, cost = 28772137.643410236,in iteration = 52
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m = 69.83302295519817, c = 0.44052765287620527, cost = 27989866.184482157,in iteration = 5
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m = 70.44210025405845, c = 0.44407204214667384, cost = 27526545.047526687,in iteration = 5
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m = 71.19108280868849, c = 0.4484159932809374, cost = 26966045.979291745,in iteration = 55
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m = 71.56049379891877, c = 0.4505524121924041, cost = 26693354.204629194,in iteration = 55
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m = 71.78053237383678, c = 0.4518230090995035, cost = 26532105.271778747,in iteration = 56
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m = 71.92655880289979, c = 0.4526654127266344, cost = 26425579.97226504,in iteration = 564
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m = 73.07583304855292, c = 0.4592721013970741, cost = 25600725.571149856,in iteration = 58
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m = 74.32939221591964, c = 0.46642904714865385, cost = 24728407.13246216,in iteration = 59
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m = 76.84471716977723, c = 0.4806207489496001, cost = 23064242.289631438,in iteration = 63
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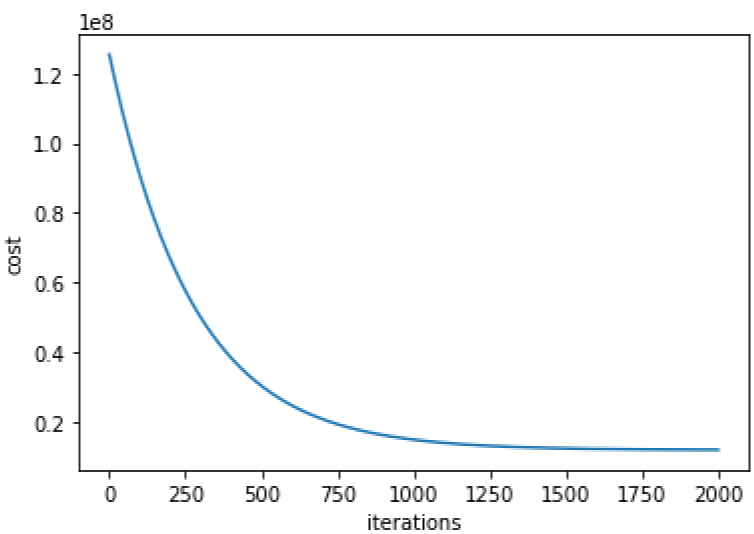
 ...])
```

In [22]:

```
plt.plot(list(range(2000)),x[3])
plt.ylabel('cost')
plt.xlabel('iterations')
plt.show()
```



In [23]:

```
#validating model
```

```
def RMSE(m,c,test_x,test_y):
    y_pred=test_x*m+c
    s_y=y_pred-test_y
    s_y=np.square(s_y)
    res=sum(s_y)
    n=len(x)
    res=res/n
    res=np.sqrt(res)
    return res
```

In [24]:

```
res = RMSE(x[0],x[1],test_x,test_y)
res
```

Out[24]:

```
8892.721526208605
```

UNIVARIATE LINEAR REGRESSION USING CLOSED FORM

In matrix form,

$$\begin{bmatrix} n & \sum_{i=1}^{n} x_i \\ \sum_{i=1}^{n} x_i & \sum_{i=1}^{n} x_i^2 \end{bmatrix} \begin{bmatrix} a \\ b \end{bmatrix} = \begin{bmatrix} \sum_{i=1}^{n} y_i \\ \sum_{i=1}^{n} x_i\, y_i \end{bmatrix},$$

so

$$\begin{bmatrix} a \\ b \end{bmatrix} = \begin{bmatrix} n & \sum_{i=1}^{n} x_i \\ \sum_{i=1}^{n} x_i & \sum_{i=1}^{n} x_i^2 \end{bmatrix}^{-1} \begin{bmatrix} \sum_{i=1}^{n} y_i \\ \sum_{i=1}^{n} x_i\, y_i \end{bmatrix}.$$

In [25]:

```
def closed_form(x,y):
    n=len(x)
    term1=sum(np.square(x))
    term2=sum(x)
    term3=sum(x.T*y)
    term4=sum(y)
    matrix1=np.matrix([term1,term2,term2,n]).reshape(2,2)
    matrix2=np.matrix([term3,term4]).reshape(2,1)
    inverted_matrix1=np.linalg.inv(matrix1)
    res=inverted_matrix1*matrix2
    res=res.tolist()
    m=res[0][0]
    c=res[1][0]
    cost=(1/(2*n))*(sum(np.square(y-m*x-c)))
    return m,c,cost
```

In [26]:

```
m,c,cost=closed_form(train_x,train_y)
```

```
print(m)
print(c)
print(cost)
```

```
169.41737954580628
-8206.5589385817
8158891.979653825
```

In [27]:

```
#validating model
res = RMSE(m,c,test_x,test_y)
res
```

Out[27]:

```
8870.149305866245
```

MULTIVARIATE LINEAR REGRESSION USING CLOSED FORM

In [28]:

```
res_df=main_df[main_df.price!='?']
res_df=res_df[['symboling','wheel-base','length','width','height','curb-weight','engine-si
res_df
```

Out[28]:

	symboling	wheel-base	length	width	height	curb-weight	engine-size	compression-ratio	city-mpg	highway-mpg	price
0	3	88.6	168.8	64.1	48.8	2548	130	9.0	21	27	13495
1	3	88.6	168.8	64.1	48.8	2548	130	9.0	21	27	16500
2	1	94.5	171.2	65.5	52.4	2823	152	9.0	19	26	16500
3	2	99.8	176.6	66.2	54.3	2337	109	10.0	24	30	13950
4	2	99.4	176.6	66.4	54.3	2824	136	8.0	18	22	17450
...	...	...	...	...	...	...	...	...	...	...	...
200	-1	109.1	188.8	68.9	55.5	2952	141	9.5	23	28	16845
201	-1	109.1	188.8	68.8	55.5	3049	141	8.7	19	25	19045
202	-1	109.1	188.8	68.9	55.5	3012	173	8.8	18	23	21485
203	-1	109.1	188.8	68.9	55.5	3217	145	23.0	26	27	22470
204	-1	109.1	188.8	68.9	55.5	3062	141	9.5	19	25	22625

201 rows × 11 columns

In [29]:

```
res_df.describe()
```

Out[29]:

	symboling	wheel-base	length	width	height	curb-weight	engine-size	compression-ratio	city-mp
count	201.000000	201.000000	201.000000	201.000000	201.000000	201.000000	201.000000	201.000000	201.00000
mean	0.840796	98.797015	174.200995	65.889055	53.766667	2555.666667	126.875622	10.164279	25.17910
std	1.254802	6.066366	12.322175	2.101471	2.447822	517.296727	41.546834	4.004965	6.42322
min	-2.000000	86.600000	141.100000	60.300000	47.800000	1488.000000	61.000000	7.000000	13.00000

	symboling	wheel-base	length	width	height	curb-weight	engine-size	compression-ratio	city-mp
25%	0.000000	94.500000	166.800000	64.100000	52.000000	2169.000000	98.000000	8.600000	19.00000
50%	1.000000	97.000000	173.200000	65.500000	54.100000	2414.000000	120.000000	9.000000	24.00000
75%	2.000000	102.400000	183.500000	66.600000	55.500000	2926.000000	141.000000	9.400000	30.00000
max	3.000000	120.900000	208.100000	72.000000	59.800000	4066.000000	326.000000	23.000000	49.00000

In [30]:

```
print(res_df.dtypes)
```

```
symboling              int64
wheel-base           float64
length               float64
width                float64
height               float64
curb-weight            int64
engine-size            int64
compression-ratio    float64
city-mpg               int64
highway-mpg            int64
price                 object
dtype: object
```

In [31]:

```
convert_dict = {'price':float}
res_df = res_df.astype(convert_dict)
print(res_df.dtypes)
```

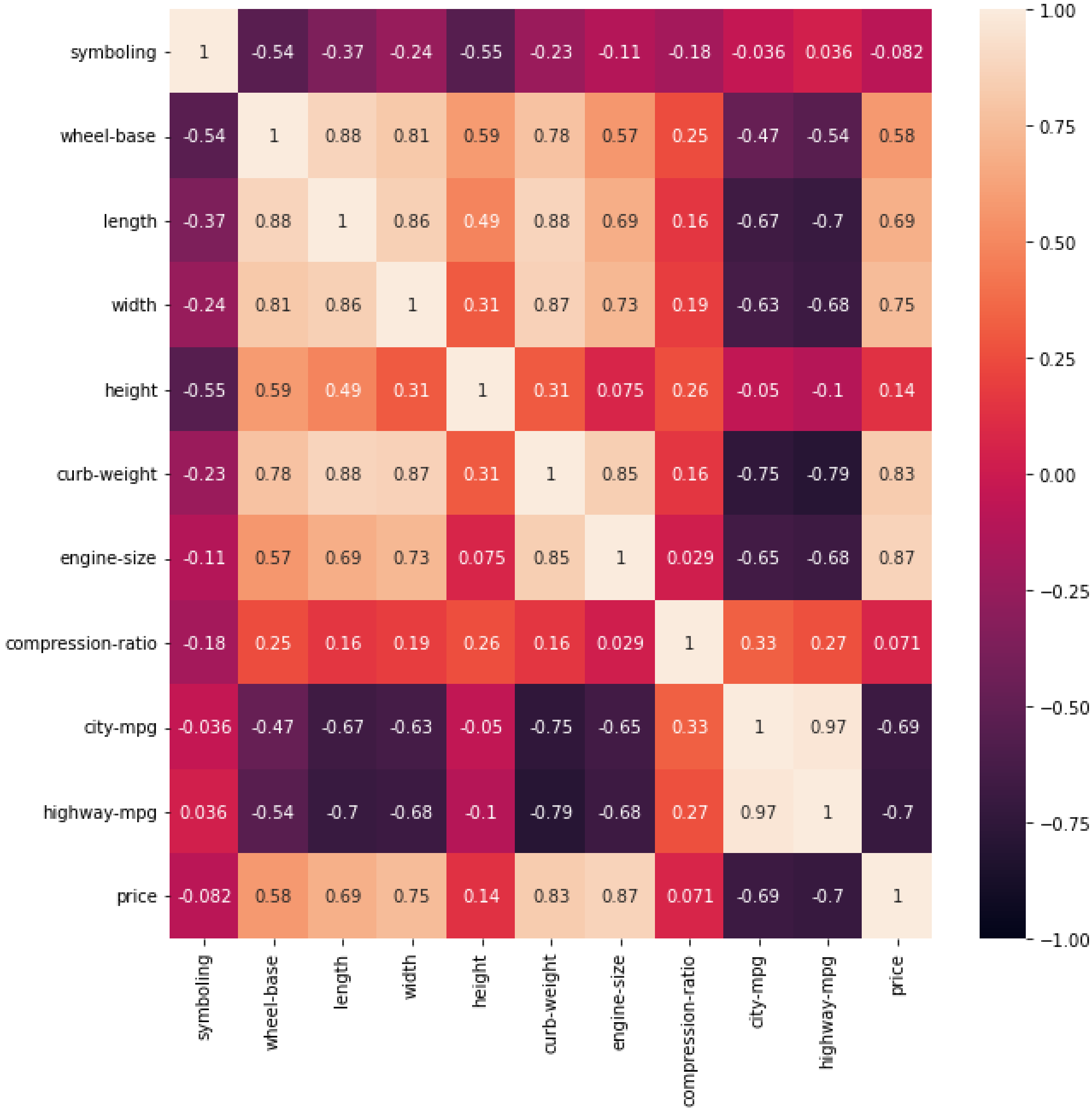
```
symboling              int64
wheel-base           float64
length               float64
width                float64
height               float64
curb-weight            int64
engine-size            int64
compression-ratio    float64
city-mpg               int64
highway-mpg            int64
price                float64
dtype: object
```

In [32]:

```
import seaborn as sns
plt.figure(figsize=(10,10))
sns.heatmap(res_df.corr(), vmin=-1, annot=True)
```

Out[32]:

```
<AxesSubplot:>
```



In [33]:
```
res_df.isna().sum()
```

Out[33]:
```
symboling            0
wheel-base           0
length               0
width                0
height               0
curb-weight          0
engine-size          0
compression-ratio    0
city-mpg             0
highway-mpg          0
price                0
dtype: int64
```

In [34]:
```
(res_df == "?").sum()
```

Out[34]:
```
symboling            0
wheel-base           0
length               0
width                0
height               0
```

```
curb-weight          0
engine-size          0
compression-ratio    0
city-mpg             0
highway-mpg          0
price                0
dtype: int64
```

In [35]:

```
res_df=res_df[['width','curb-weight','engine-size','compression-ratio','price']]
res_df=res_df.drop_duplicates(keep='first')
res_df
```

Out[35]:

	width	curb-weight	engine-size	compression-ratio	price
0	64.1	2548	130	9.0	13495.0
1	64.1	2548	130	9.0	16500.0
2	65.5	2823	152	9.0	16500.0
3	66.2	2337	109	10.0	13950.0
4	66.4	2824	136	8.0	17450.0
...	...	...	...	...	...
200	68.9	2952	141	9.5	16845.0
201	68.8	3049	141	8.7	19045.0
202	68.9	3012	173	8.8	21485.0
203	68.9	3217	145	23.0	22470.0
204	68.9	3062	141	9.5	22625.0

196 rows × 5 columns

In [36]:

```
#train test split
x=res_df[['width','curb-weight','engine-size','compression-ratio']].to_numpy()
y=res_df["price"].to_numpy().reshape(196,1)
x=x.tolist()
for i in x:
    i.insert(0,1)
x=np.array(x)
train_x=x[0:161]
train_y=y[0:161]
test_x=x[161:197]
test_y=y[161:197]
```

In [37]:

```
train_x
```

Out[37]:

```
array([[1.000e+00, 6.410e+01, 2.548e+03, 1.300e+02, 9.000e+00],
       [1.000e+00, 6.410e+01, 2.548e+03, 1.300e+02, 9.000e+00],
       [1.000e+00, 6.550e+01, 2.823e+03, 1.520e+02, 9.000e+00],
       [1.000e+00, 6.620e+01, 2.337e+03, 1.090e+02, 1.000e+01],
       [1.000e+00, 6.640e+01, 2.824e+03, 1.360e+02, 8.000e+00],
       [1.000e+00, 6.630e+01, 2.507e+03, 1.360e+02, 8.500e+00],
       [1.000e+00, 7.140e+01, 2.844e+03, 1.360e+02, 8.500e+00],
       [1.000e+00, 7.140e+01, 2.954e+03, 1.360e+02, 8.500e+00],
       [1.000e+00, 7.140e+01, 3.086e+03, 1.310e+02, 8.300e+00],
       [1.000e+00, 6.480e+01, 2.395e+03, 1.080e+02, 8.800e+00],
       [1.000e+00, 6.480e+01, 2.395e+03, 1.080e+02, 8.800e+00],
       [1.000e+00, 6.480e+01, 2.710e+03, 1.640e+02, 9.000e+00],
```

```
[1.000e+00, 6.480e+01, 2.765e+03, 1.640e+02, 9.000e+00],
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[1.000e+00, 6.690e+01, 3.230e+03, 2.090e+02, 8.000e+00],
[1.000e+00, 6.790e+01, 3.380e+03, 2.090e+02, 8.000e+00],
[1.000e+00, 7.090e+01, 3.505e+03, 2.090e+02, 8.000e+00],
[1.000e+00, 6.030e+01, 1.488e+03, 6.100e+01, 9.500e+00],
[1.000e+00, 6.360e+01, 1.874e+03, 9.000e+01, 9.600e+00],
[1.000e+00, 6.360e+01, 1.909e+03, 9.000e+01, 9.600e+00],
[1.000e+00, 6.380e+01, 1.876e+03, 9.000e+01, 9.410e+00],
[1.000e+00, 6.380e+01, 1.876e+03, 9.000e+01, 9.400e+00],
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[1.000e+00, 6.380e+01, 1.989e+03, 9.000e+01, 9.400e+00],
[1.000e+00, 6.380e+01, 2.191e+03, 9.800e+01, 7.600e+00],
[1.000e+00, 6.460e+01, 2.535e+03, 1.220e+02, 8.500e+00],
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[1.000e+00, 6.390e+01, 1.819e+03, 9.200e+01, 9.200e+00],
[1.000e+00, 6.400e+01, 1.837e+03, 7.900e+01, 1.010e+01],
[1.000e+00, 6.400e+01, 1.940e+03, 9.200e+01, 9.200e+00],
[1.000e+00, 6.400e+01, 1.956e+03, 9.200e+01, 9.200e+00],
[1.000e+00, 6.400e+01, 2.010e+03, 9.200e+01, 9.200e+00],
[1.000e+00, 6.390e+01, 2.024e+03, 9.200e+01, 9.200e+00],
[1.000e+00, 6.520e+01, 2.236e+03, 1.100e+02, 9.000e+00],
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```

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```

In [38]:

```
train_x.shape
```

Out[38]:

```
(161, 5)
```

In [39]:

```
#closed form
def m_closed_form(x,y):
    t_x=(x.transpose())
    inverted_matrix=np.linalg.inv(np.dot(t_x,x))
    w=np.dot(np.dot(inverted_matrix,t_x),y)
    return w
```

In [40]:

```
w=m_closed_form(train_x,train_y)
w
```

Out[40]:

```
array([[-3.94317243e+04],
       [ 4.53967108e+02],
       [ 3.35354427e+00],
       [ 1.17718688e+02],
       [-5.84484941e+01]])
```

In [41]:

```
#prediction
def prediction(x,w):
    l=[]
    for i in x:
        y_sum=0
        for j in range (5):
            y_sum=y_sum+(i[j]*w[j][0])
        l.append(y_sum)
    l=np.array(l)
    return l
```

In [42]:

```
y_pred=prediction(test_x,w)
y_pred
```

Out[42]:

```
array([15976.02048777, 16093.39453714, 16968.66959102, 12410.61034748,
       10707.84269219, 12705.72224304, 12705.72224304, 12853.27819082,
       20868.32125696, 21002.46302767, 20849.20493842, 19739.08894572,
        7959.88220115, 10016.40107058,  7969.94283395, 10026.46170338,
       10237.73499225,  8154.38776868, 10263.12510482,  9606.37756945,
        9404.91718704, 15375.38584842,  9661.86322931, 11839.10969237,
       16883.46053689, 17292.59293756, 16960.59205505, 17319.4212917 ,
```

```
        16151.47334688, 16527.07030486, 17789.34639098, 18116.00226946,
        21798.47100271, 18359.85570253, 18158.23626043])
```

In [43]:
```
test_y.reshape(1,35)
```

Out[43]:
```
array([[11199., 11549., 17669.,  8948., 10698.,  9988., 10898., 11248.,
        16558., 15998., 15690., 15750.,  7775.,  7975.,  7995.,  8195.,
         8495.,  9495.,  9995., 11595.,  9980., 13295., 13845., 12290.,
        12940., 13415., 15985., 16515., 18420., 18950., 16845., 19045.,
        21485., 22470., 22625.]])
```

In [44]:
```
#validating the model
def multi_rmse(test_x,test_y,w):
    b=test_y.flatten();
    y_pred=prediction(test_x,w)
    s_y=np.subtract(y_pred,b)
    s_y=np.square(s_y)
    res=sum(s_y)
    n=len(x)
    res=res/n
    res=np.sqrt(res)
    return res
```

In [45]:
```
multi_rmse(test_x,test_y,w)
```

Out[45]:
```
1186.6923022870083
```

MULTIVARIATE LINEAR REGRESSION USING GRADIENT DESCENT

In [46]:
```
def multi_gradient_descent(x,y):
    k=.00000001       #learning rate
    n=x.shape[1]
    m=len(x)
    w=np.zeros(n)
    cost_val=[]
    for i in range(2000):
        y_pred=[]
        for i in x:
            val=np.dot(w,i)
            y_pred.append(val)
        y_pred=np.array(y_pred).reshape(161,1)
        error=y_pred-y
        cost = 1/(2*m) * np.dot(error.T, error)
        cost_val.append(cost[0][0])
        w=w.reshape(5,1)
        w = w - (k * (1/m) *(np.dot(x.T,error)))
        w=w.reshape(1,5)
    w=w.reshape(5,1)
    return w,cost_val
```

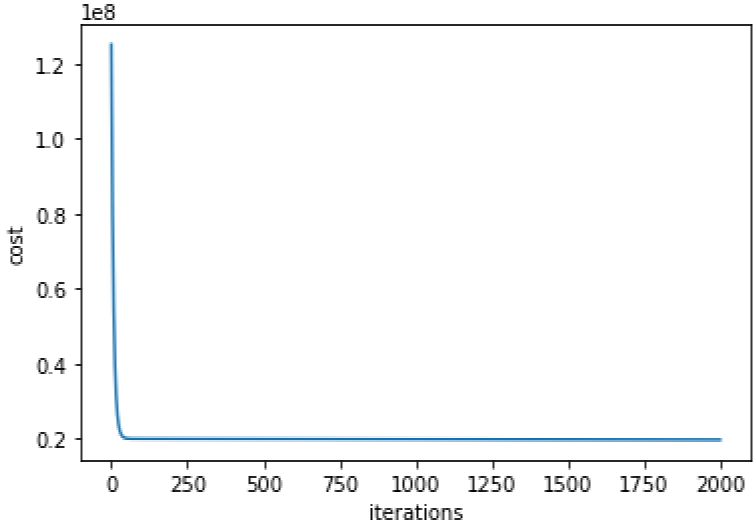
In [47]:
```
w,cost_val=multi_gradient_descent(train_x,train_y)
w
```

Out[47]:
```
array([[-0.01552408],
       [-0.8521628 ],
```

```
       [ 5.48467855],
       [ 2.46295331],
       [-0.13668502]])
```

In [48]:

```
plt.plot(list(range(2000)),cost_val)
plt.ylabel('cost')
plt.xlabel('iterations')
plt.show()
```



In [49]:

```
cost_val
```

Out[49]:

```
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 ...]
```

In [50]:

```
multi_rmse(test_x,test_y,w)
```

Out[50]:

```
1283.958653181554
```

RESULT ANALYSIS

S.No.	Model	RMSE
1	Univariate Closed Form	8870.149305866245
2	Multivariate Closed Form	1186.6923022870083
3	Univariate Gradient Descent	8892.721526208605
4	Multivariate Gradient Descent	1283.958653181554