```
from pyspark.sql import SparkSession
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
from mpl_toolkits.mplot3d import axes3d
import seaborn as sns
import sklearn
from sklearn.preprocessing import scale
import sklearn.linear_model as skl_lm
from sklearn.metrics import mean_squared_error, r2_score
import statsmodels.api as sm
import statsmodels.formula.api as smf

df1 =
spark.read.format("csv").load("dbfs:/FileStore/shared_uploads/MichaelRocchio2023@u.northwestern.ed
u/boston.csv", header=True)

df=df1.toPandas()
train_var_fin=df

del train_var_fin['neighborhood']
for i in list(train_var_fin.columns):
  train_var_fin[i]=pd.to_numeric(train_var_fin[i])
y=train_var_fin['mv'].to_numpy()
del train_var_fin['mv']
X = train_var_fin.to_numpy()
X

Out[36]: array([[6.3200e-03, 1.8000e+01, 2.3100e+00, ..., 2.9600e+02, 1.5300e+01,
        4.9800e+00],
       [2.7310e-02, 0.0000e+00, 7.0700e+00, ..., 2.4200e+02, 1.7800e+01,
        9.1400e+00],
       [2.7290e-02, 0.0000e+00, 7.0700e+00, ..., 2.4200e+02, 1.7800e+01,
        4.0300e+00],
       ...,
       [6.0760e-02, 0.0000e+00, 1.1930e+01, ..., 2.7300e+02, 2.1000e+01,
        5.6400e+00],
       [1.0959e-01, 0.0000e+00, 1.1930e+01, ..., 2.7300e+02, 2.1000e+01,
        6.4800e+00],
       [4.7410e-02, 0.0000e+00, 1.1930e+01, ..., 2.7300e+02, 2.1000e+01,
        7.8800e+00]])

train_var_fin

Out[39]:
```

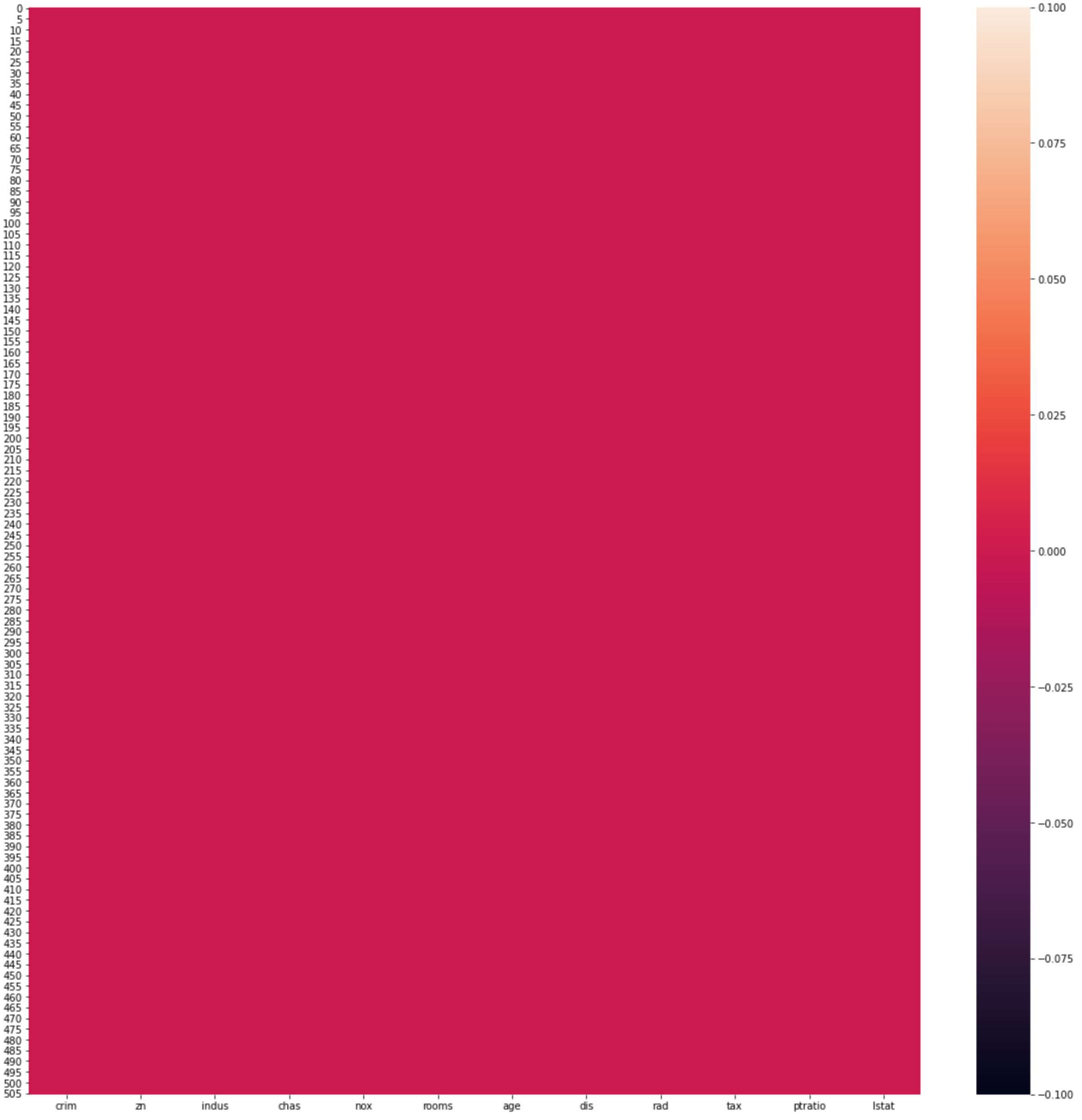
	crim	zn	indus	chas	nox	rooms	age	dis	rad	tax	ptratio	lstat
0	0.00632	18.0	2.31	0	0.538	6.575	65.2	4.0900	1	296	15.3	4.98
1	0.02731	0.0	7.07	0	0.469	6.421	78.9	4.9671	2	242	17.8	9.14
2	0.02729	0.0	7.07	0	0.469	7.185	61.1	4.9671	2	242	17.8	4.03
3	0.03237	0.0	2.18	0	0.458	6.998	45.8	6.0622	3	222	18.7	2.94
4	0.06905	0.0	2.18	0	0.458	7.147	54.2	6.0622	3	222	18.7	5.33
...	...	...	...	...	...	...	...	...	...	...	...	...
501	0.06263	0.0	11.93	0	0.573	6.593	69.1	2.4786	1	273	21.0	9.67
502	0.04527	0.0	11.93	0	0.573	6.120	76.7	2.2875	1	273	21.0	9.08
503	0.06076	0.0	11.93	0	0.573	6.976	91.0	2.1675	1	273	21.0	5.64
504	0.10959	0.0	11.93	0	0.573	6.794	89.3	2.3889	1	273	21.0	6.48
505	0.04741	0.0	11.93	0	0.573	6.030	80.8	2.5050	1	273	21.0	7.88

506 rows × 12 columns

```
train_var_fin.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 506 entries, 0 to 505
Data columns (total 12 columns):
 #   Column   Non-Null Count  Dtype  
---  ------   --------------  -----  
 0   crim     506 non-null    float64
 1   zn       506 non-null    float64
 2   indus    506 non-null    float64
 3   chas     506 non-null    int64  
 4   nox      506 non-null    float64
 5   rooms    506 non-null    float64
 6   age      506 non-null    float64
 7   dis      506 non-null    float64
 8   rad      506 non-null    int64  
 9   tax      506 non-null    int64  
 10  ptratio  506 non-null    float64
 11  lstat    506 non-null    float64
dtypes: float64(9), int64(3)
memory usage: 47.6 KB
```

```
plt.figure(figsize=(20, 20))
sns.heatmap(train_var_fin.isnull())
plt.show()
```


0
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475
480
485
490
495
500
505
crim
zn
indus
chas
nox
rooms
age
dis
rad
tax
ptratio
lstat
0.100
0.075
0.050
0.025
0.000
−0.025
−0.050
−0.075
−0.100

```
from sklearn.linear_model import ElasticNet
elastic_net = ElasticNet()
elastic_net.fit(X, y)

elastic_net.coef_
resulte = train_var_fin.mul(elastic_net.coef_, axis='columns')
resulte['beta_zero']=elastic_net.intercept_
resulte['elastic_house_price']=resulte.sum(axis=1)
resulte=resulte.reset_index()
resulte=resulte[['index', 'elastic_house_price']]
final_result=resulte
final_result['actual_house_price']=y
final_result
```

Out[49]:

	index	elastic_house_price	actual_house_price
0	0	31.054209	24.0
1	1	25.679992	21.6
2	2	29.966521	34.7
3	3	29.543117	33.4
4	4	27.984297	36.2
...	...	...	...
501	501	23.986619	22.4
502	502	24.346976	20.6
503	503	28.202926	23.9
504	504	27.170687	22.0
505	505	25.127949	19.0

506 rows × 3 columns

```
from sklearn.linear_model import Lasso

lasso_reg = Lasso(alpha=0.1)
lasso_reg.fit(X, y)

resultl = train_var_fin.mul(lasso_reg.coef_, axis='columns')
resultl['beta_zero']=lasso_reg.intercept_
resultl['lasso_house_price']=resultl.sum(axis=1)
resultl=resultl.reset_index()
resultl=resultl[['index', 'lasso_house_price']]
final_result=pd.merge(final_result, resultl, how='inner')
final_result=final_result[['index', 'elastic_house_price', 'lasso_house_price',
'actual_house_price']]
display(final_result)
```

	index	elastic_house_price	lasso_house_price	actual_house_price
1	0	31.05420939247718	30.772545131622906	24

2	1	25.679992347229245	24.715345884143503	21.6
3	2	29.966520774492583	30.645558644708444	34.7
4	3	29.543116990271223	29.609866327085072	33.4
5	4	27.984296993785424	28.61745690572944	36.2
6	5	27.54651435351851	26.12989097073054	28.7
7	6	24.157543272087274	22.816065345482013	22.9

Showing all 506 rows.

```
lasso_reg = Lasso(alpha=0.1)
lasso_reg.fit(X, y)

resultl = train_var_fin.mul(lasso_reg.coef_, axis='columns')
resultl['beta_zero']=lasso_reg.intercept_
resultl['lasso_house_price']=resultl.sum(axis=1)
resultl=resultl.reset_index()
resultl=resultl[['index', 'lasso_house_price']]
final_result=pd.merge(final_result, resultl, how='inner')
final_result=final_result[['index', 'elastic_house_price', 'lasso_house_price',
'actual_house_price']]
display(final_result)


lasso_mse = sklearn.metrics.mean_squared_error(final_result['actual_house_price'].to_numpy(),
final_result['lasso_house_price'].to_numpy())
elastic_mse = sklearn.metrics.mean_squared_error(final_result['actual_house_price'].to_numpy(),
final_result['elastic_house_price'].to_numpy())
print('lasso_mse: ', lasso_mse)
print('elastic_mse: ', elastic_mse)

lasso_mse:  23.29498433612626
elastic_mse:  26.617920352737336

X

Out[57]: array([[6.3200e-03, 1.8000e+01, 2.3100e+00, ..., 2.9600e+02, 1.5300e+01,
         4.9800e+00],
        [2.7310e-02, 0.0000e+00, 7.0700e+00, ..., 2.4200e+02, 1.7800e+01,
         9.1400e+00],
        [2.7290e-02, 0.0000e+00, 7.0700e+00, ..., 2.4200e+02, 1.7800e+01,
         4.0300e+00],
        ...,
        [6.0760e-02, 0.0000e+00, 1.1930e+01, ..., 2.7300e+02, 2.1000e+01,
         5.6400e+00],
        [1.0959e-01, 0.0000e+00, 1.1930e+01, ..., 2.7300e+02, 2.1000e+01,
         6.4800e+00],
        [4.7410e-02, 0.0000e+00, 1.1930e+01, ..., 2.7300e+02, 2.1000e+01,
         7.8800e+00]])
```

```
from sklearn.datasets import load_iris
from sklearn.tree import DecisionTreeRegressor
from sklearn.model_selection import cross_val_score

tree_reg = DecisionTreeRegressor()
tree_reg.fit(X, y)
regressor = DecisionTreeRegressor(random_state=0)
cross_val_score(regressor, X, y)

Out[77]: array([ 0.62968671,  0.42436098,  0.62503004,  0.35857816, -1.45998688])

from sklearn.metrics import accuracy_score
y_pred = tree_reg.predict(X)

def reg_metrics(y, y_pred, X):
    from sklearn.metrics import mean_squared_error, r2_score
    rmse = np.sqrt(mean_squared_error(y,y_pred))
    r2 = r2_score(y,y_pred)
    n = y_pred.shape[0]
    k = X.shape[1]
    adj_r_sq = 1 - (1 - r2)*(n-1)/(n-1-k)
    print('RMSE: ', rmse)
    print('R2: ',r2)
    print('ADJUSTED R_SQR: ', adj_r_sq)
    return rmse, r2, adj_r_sq
reg_metrics(y, y_pred, X)

###OVER FITTED

RMSE:  0.0
R2:  1.0
ADJUSTED R_SQR:  1.0
Out[91]: (0.0, 1.0, 1.0)

predict=pd.DataFrame(
{
  'y': y,
  'y_pred': y_pred
})
predict

Out[74]:
```

	y	y_pred
0	24.0	24.0
1	21.6	21.6
2	34.7	34.7
3	33.4	33.4
4	36.2	36.2
...	...	...
501	22.4	22.4
502	20.6	20.6
503	23.9	23.9
504	22.0	22.0
505	19.0	19.0

506 rows × 2 columns

```
from sklearn import tree
text_representation = tree.export_text(tree_reg)
print(text_representation)
```

```
|--- feature_5 <= 6.84
|   |--- feature_11 <= 14.40
|   |   |--- feature_7 <= 1.38
|   |   |   |--- feature_0 <= 10.59
|   |   |   |   |--- value: [50.00]
|   |   |   |--- feature_0 >  10.59
|   |   |   |   |--- value: [27.90]
|   |   |--- feature_7 >  1.38
|   |   |   |--- feature_5 <= 6.54
|   |   |   |   |--- feature_11 <= 7.57
|   |   |   |   |   |--- feature_9 <= 222.50
|   |   |   |   |   |   |--- value: [28.70]
|   |   |   |   |   |--- feature_9 >  222.50
|   |   |   |   |   |   |--- feature_2 <= 5.48
|   |   |   |   |   |   |   |--- feature_10 <= 19.95
|   |   |   |   |   |   |   |   |--- feature_0 <= 0.04
|   |   |   |   |   |   |   |   |   |--- feature_11 <= 7.47
|   |   |   |   |   |   |   |   |   |   |--- feature_6 <= 29.95
|   |   |   |   |   |   |   |   |   |   |   |--- truncated branch of depth 2
|   |   |   |   |   |   |   |   |   |   |--- feature_6 >  29.95
|   |   |   |   |   |   |   |   |   |   |   |--- truncated branch of depth 3
```

```
from sklearn.datasets import load_iris
from sklearn.tree import DecisionTreeRegressor
from sklearn.model_selection import cross_val_score
from sklearn.metrics import accuracy_score
import numpy as np
def createList(r1, r2):
    return np.arange(r1, r2+1, 1)

depth_tries = createList(1,20)

for i in depth_tries:
  tree_reg2 = DecisionTreeRegressor(random_state=42, max_depth=i)
  tree_reg2.fit(X, y)
  y_pred = tree_reg2.predict(X)
  print('depth = ',i)
  reg_metrics(y, y_pred, X)
  print('')
```

```
depth =  1
RMSE:  6.781452485868371
R2:  0.45347079983071137
ADJUSTED R_SQR:  0.4401678578387611

depth =  2
RMSE:  4.9601852791465255
R2:  0.7076091873459209
ADJUSTED R_SQR:  0.7004921695936919

depth =  3
RMSE:  3.7808197781187625
R2:  0.8301209293555389
ADJUSTED R_SQR:  0.8259859418347812

depth =  4
RMSE:  3.05461079325196
R2:  0.8891132415208693
ADJUSTED R_SQR:  0.8864141723489636

depth =  5
```

```
tree_regfin = DecisionTreeRegressor(random_state=42, max_depth=5)
tree_regfin.fit(X, y)

final=pd.DataFrame({
  'tree_predict': tree_regfin.predict(X),
  'actual': y
})
final
```

Out[113]:

	tree_predict	actual
0	26.012500	24.0
1	21.011184	21.6
2	34.286364	34.7
3	30.290323	33.4
4	34.286364	36.2
...	...	...
501	26.012500	22.4
502	21.011184	20.6
503	30.290323	23.9
504	26.012500	22.0
505	21.011184	19.0

506 rows × 2 columns

```
from sklearn import tree
text_representation = tree.export_text(tree_regfin)
print(text_representation)
```

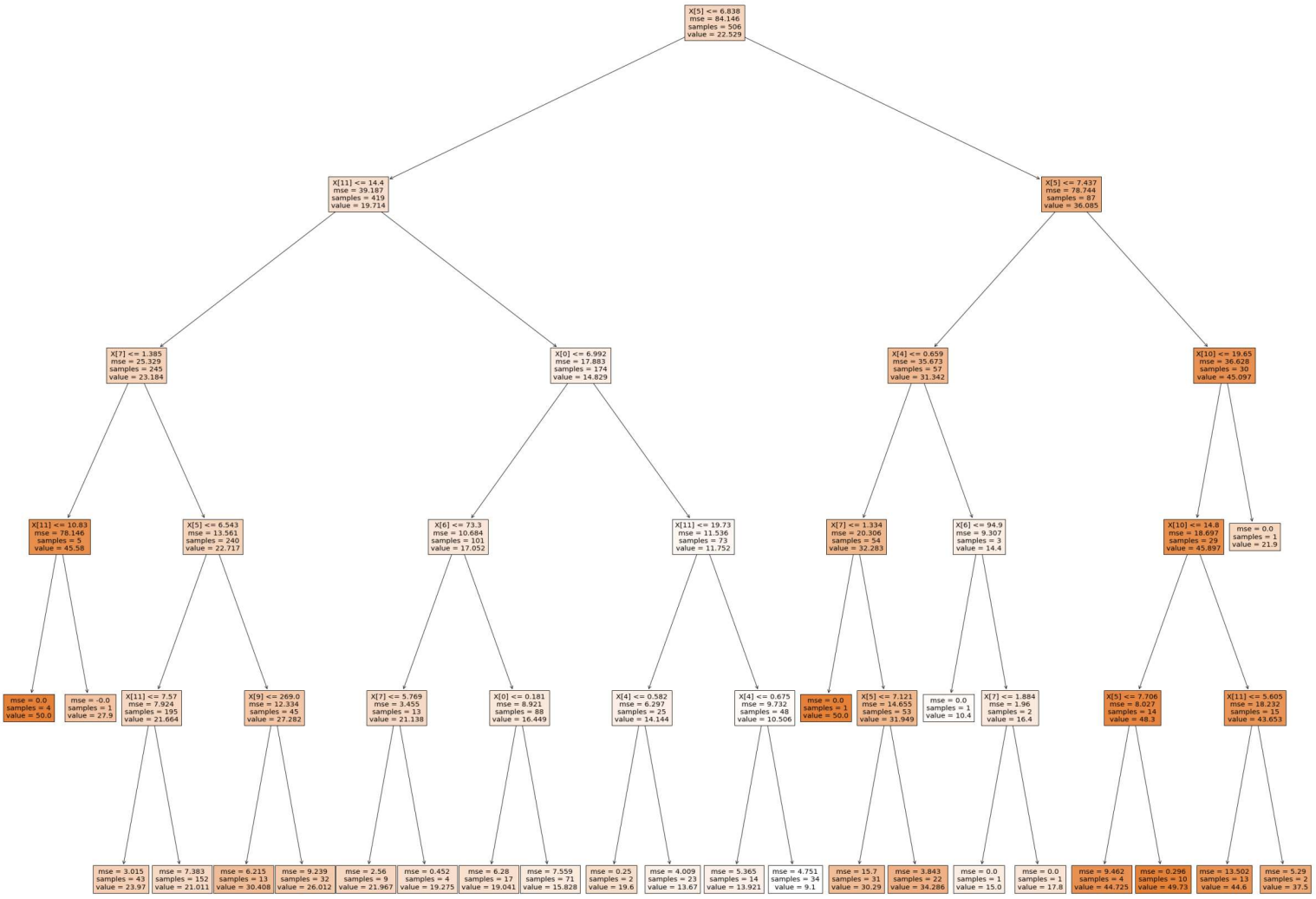
```
|--- feature_5 <= 6.84
|   |--- feature_11 <= 14.40
|   |   |--- feature_7 <= 1.38
|   |   |   |--- feature_11 <= 10.83
|   |   |   |   |--- value: [50.00]
|   |   |   |--- feature_11 >  10.83
|   |   |   |   |--- value: [27.90]
|   |   |--- feature_7 >  1.38
|   |   |   |--- feature_5 <= 6.54
|   |   |   |   |--- feature_11 <= 7.57
|   |   |   |   |   |--- value: [23.97]
|   |   |   |   |--- feature_11 >  7.57
|   |   |   |   |   |--- value: [21.01]
|   |   |   |--- feature_5 >  6.54
|   |   |   |   |--- feature_9 <= 269.00
|   |   |   |   |   |--- value: [30.41]
|   |   |   |   |--- feature_9 >  269.00
|   |   |   |   |   |--- value: [26.01]
|   |--- feature_11 >  14.40
|   |   |--- feature_0 <= 6.99
|   |   |   |--- feature_6 <= 73.30
```

```
print(tree_regfin.n_features_)
```

```
12
```

```
fig = plt.figure(figsize=(50,40))
_ = tree.plot_tree(tree_regfin,
                   filled=True)

### I AM SEEING SAMPLING ISSUES TOWARDS THE BOTTOM OF THE TREE AFTER THIS ASSESMENT I WOULD REDUCE THE DEPTH TO EITHER 3 OR 4
```



Show cell