Homework 1: Applied Machine Learning - Linear | Logisitc | SVM

In [1]:
```
print("Name --> Davit Barblishvili")
print("UNI --> db3230")
```

```
Name --> Davit Barblishvili
UNI --> db3230
```

In [2]:
```
import numpy as np
import pandas as pd
import seaborn as sns
import matplotlib.pyplot as plt
from numpy.linalg import inv
%matplotlib inline
from sklearn.model_selection import train_test_split
from sklearn.preprocessing import StandardScaler, MinMaxScaler
from sklearn.preprocessing import OrdinalEncoder
from sklearn.svm import LinearSVC, SVC
from sklearn.metrics import accuracy_score
from sklearn.preprocessing import StandardScaler, OneHotEncoder, OrdinalEncoder
from category_encoders import TargetEncoder
from sklearn.compose import make_column_transformer
```

In [3]:
```
import warnings

def fxn():
    warnings.warn("deprecated", DeprecationWarning)

with warnings.catch_warnings():
    warnings.simplefilter("ignore")
    fxn()
```

In [4]:
```
pd.options.mode.chained_assignment = None
```

Part 1: Linear Regression

In part 1, we will use **two datasets** to train and evaluate our linear regression model.

The first dataset will be a synthetic dataset sampled from the following equations:

ϵ ~ Normal(0,3)

z = 3x + 10y + 10 + ϵ

In [5]:
```
np.random.seed(0)
epsilon = np.random.normal(0, 3, 100)
x = np.linspace(0, 10, 100)
y = np.linspace(0, 5, 100)
z = 3 * x + 10 * y + 10 + epsilon
```

To apply linear regression, we need to first check if the assumptions of linear regression are not violated.

Assumptions of Linear Regression:

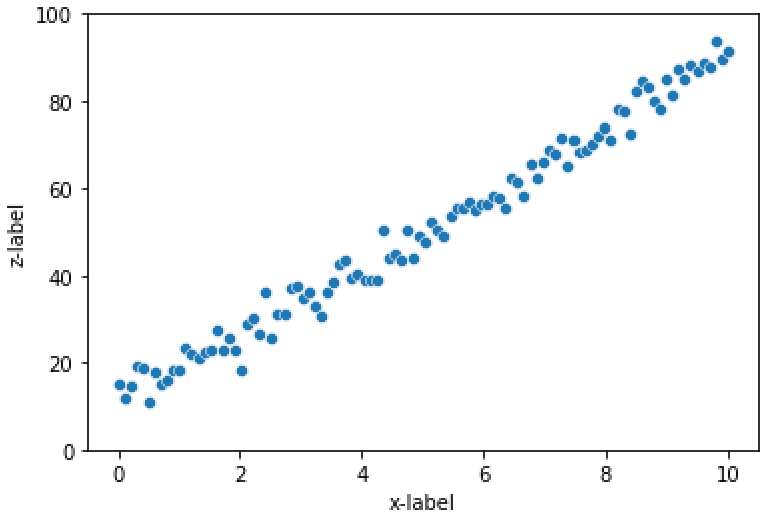
- Linearity: y is a linear (technically affine) function of x.
- Independence: the x's are independently drawn, and not dependent on each other.
- Homoscedasticity: the ϵ's, and thus the y's, have constant variance.
- Normality: the ϵ's are drawn from a Normal distribution (i.e. Normally-distributed errors)

These properties, as well as the simplicity of this dataset, will make it a good test case to check if our linear regression model is working properly.

1.1. Plot z vs x and z vs y in the synthetic dataset as scatter plots. Label your axes and make sure your y-axis starts from 0. Do the independent and dependent features have linear relationship?

In [6]:
```
### Your code here
plt.ylim(0, 100)
plt.xlabel("x-label")
plt.ylabel("z-label")
sns.scatterplot(x = x, y = z)
```

Out[6]: <AxesSubplot:xlabel='x-label', ylabel='z-label'>

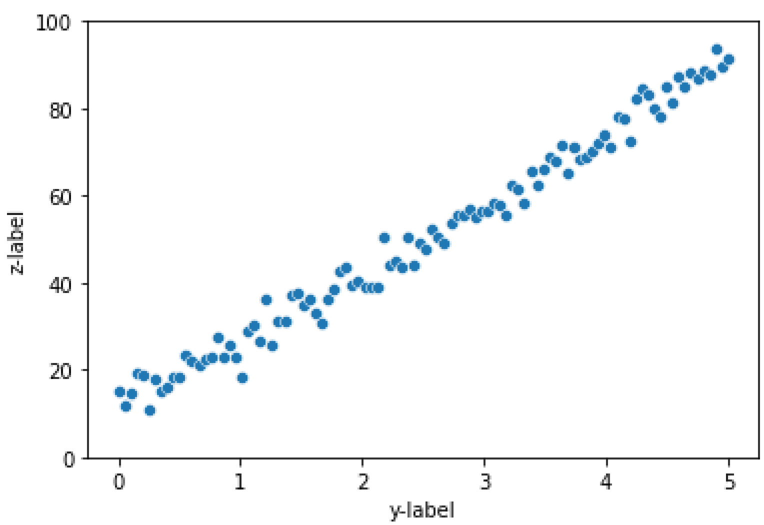


In [7]:

```
### Your code here
plt.ylim(0, 100)
plt.xlabel("y-label")
plt.ylabel("z-label")
sns.scatterplot(x = y, y = z)
```

Out[7]:

```
<AxesSubplot:xlabel='y-label', ylabel='z-label'>
```



1.2. Are the independent variables correlated? Use pearson correlation to verify? What would be the problem if linear

regression is applied to correlated features?

In [8]:

```
### Your code here
pearson_correlation = np.corrcoef(x, y)
print(pearson_correlation)

# Yes they are highly correlated and that is not a good result.
# For a linear regression, highly correlated features might will result in highly unstable parameter estimates.
```

```
[[1. 1.]
 [1. 1.]]
```

The second dataset we will be using is an auto MPG dataset. This dataset contains various characteristics for around 8128 cars. We will use linear regression to predict the selling_price label

In [9]:

```
auto_mpg_df = pd.read_csv('Car details v3.csv')
# Dropping Torque column, there is information in this column but it will take some preprocessing.
# The idea of the exercise is to familarize yourself with the basics of Linear regression.
auto_mpg_df = auto_mpg_df.drop(['torque'], axis = 1)
```

In [10]:

```
auto_mpg_df
```

Out[10]:

	name	year	selling_price	km_driven	fuel	seller_type	transmission	owner	mileage	engine	max_power	seats
0	Maruti Swift Dzire VDI	2014	450000	145500	Diesel	Individual	Manual	First Owner	23.4 kmpl	1248 CC	74 bhp	5.0
1	Skoda Rapid 1.5 TDI Ambition	2014	370000	120000	Diesel	Individual	Manual	Second Owner	21.14 kmpl	1498 CC	103.52 bhp	5.0
2	Honda City 2017-2020 EXi	2006	158000	140000	Petrol	Individual	Manual	Third Owner	17.7 kmpl	1497 CC	78 bhp	5.0
3	Hyundai i20 Sportz Diesel	2010	225000	127000	Diesel	Individual	Manual	First Owner	23.0 kmpl	1396 CC	90 bhp	5.0
4	Maruti Swift VXI BSIII	2007	130000	120000	Petrol	Individual	Manual	First Owner	16.1 kmpl	1298 CC	88.2 bhp	5.0
...	...	...	...	...	...	...	...	...	...	...	...	...

	name	year	selling_price	km_driven	fuel	seller_type	transmission	owner	mileage	engine	max_power	seats
8123	Hyundai i20 Magna	2013	320000	110000	Petrol	Individual	Manual	First Owner	18.5 kmpl	1197 CC	82.85 bhp	5.0
8124	Hyundai Verna CRDi SX	2007	135000	119000	Diesel	Individual	Manual	Fourth & Above Owner	16.8 kmpl	1493 CC	110 bhp	5.0
8125	Maruti Swift Dzire ZDi	2009	382000	120000	Diesel	Individual	Manual	First Owner	19.3 kmpl	1248 CC	73.9 bhp	5.0
8126	Tata Indigo CR4	2013	290000	25000	Diesel	Individual	Manual	First Owner	23.57 kmpl	1396 CC	70 bhp	5.0
8127	Tata Indigo CR4	2013	290000	25000	Diesel	Individual	Manual	First Owner	23.57 kmpl	1396 CC	70 bhp	5.0

8128 rows × 12 columns

1.3. Missing Value analysis - Auto mpg dataset.

Are there any missing values in the dataset? If so, what can be done about it? Jusify your approach.

In [11]:

```
### Your code here
print(" \nCount total NaN at each column in a DataFrame : \n\n",
      auto_mpg_df.isnull().sum())

# considering we have 8128 rows, I believe it would be a good idea to remove the rows that have the NaN values.
# There are some other methods to deal with NaN values such as column removal, but in this case it is not going
# work because out of 8128 only 2xx rows do not have data in a several columns so deleting the entire column fo
# that is not useful. One more way is to interpolate the values meaning averaging based on the neighboring
# values, but after looking at the data, I do not think there is a good correlation between let's say
# selling price and mileage, so removing the rows that include NaN values remains the best option.
```

```
Count total NaN at each column in a DataFrame :

 name             0
year             0
selling_price    0
km_driven        0
fuel             0
seller_type      0
transmission     0
```

```
owner              0
mileage          221
engine           221
max_power        215
seats            221
dtype: int64
```

In [12]:

```python
auto_mpg_df = auto_mpg_df.dropna(axis=0)

print(" \nCount total NaN at each column in a DataFrame : \n\n",
      auto_mpg_df.isnull().sum())

auto_mpg_df
```

```
Count total NaN at each column in a DataFrame :

 name              0
year             0
selling_price    0
km_driven        0
fuel             0
seller_type      0
transmission     0
owner            0
mileage          0
engine           0
max_power        0
seats            0
dtype: int64
```

Out[12]:

	name	year	selling_price	km_driven	fuel	seller_type	transmission	owner	mileage	engine	max_power	seats
0	Maruti Swift Dzire VDI	2014	450000	145500	Diesel	Individual	Manual	First Owner	23.4 kmpl	1248 CC	74 bhp	5.0
1	Skoda Rapid 1.5 TDI Ambition	2014	370000	120000	Diesel	Individual	Manual	Second Owner	21.14 kmpl	1498 CC	103.52 bhp	5.0
2	Honda City 2017-2020 EXi	2006	158000	140000	Petrol	Individual	Manual	Third Owner	17.7 kmpl	1497 CC	78 bhp	5.0
3	Hyundai i20 Sportz Diesel	2010	225000	127000	Diesel	Individual	Manual	First Owner	23.0 kmpl	1396 CC	90 bhp	5.0

	name	year	selling_price	km_driven	fuel	seller_type	transmission	owner	mileage	engine	max_power	seats
4	Maruti Swift VXI BSIII	2007	130000	120000	Petrol	Individual	Manual	First Owner	16.1 kmpl	1298 CC	88.2 bhp	5.0
...	...	...	...	...	...	...	...	...	...	...	...	...
8123	Hyundai i20 Magna	2013	320000	110000	Petrol	Individual	Manual	First Owner	18.5 kmpl	1197 CC	82.85 bhp	5.0
8124	Hyundai Verna CRDi SX	2007	135000	119000	Diesel	Individual	Manual	Fourth & Above Owner	16.8 kmpl	1493 CC	110 bhp	5.0
8125	Maruti Swift Dzire ZDi	2009	382000	120000	Diesel	Individual	Manual	First Owner	19.3 kmpl	1248 CC	73.9 bhp	5.0
8126	Tata Indigo CR4	2013	290000	25000	Diesel	Individual	Manual	First Owner	23.57 kmpl	1396 CC	70 bhp	5.0
8127	Tata Indigo CR4	2013	290000	25000	Diesel	Individual	Manual	First Owner	23.57 kmpl	1396 CC	70 bhp	5.0

7907 rows × 12 columns

In [13]:

```
# checking individual features

print(auto_mpg_df['name'].isna().sum())
print(auto_mpg_df['year'].isna().sum())
print(auto_mpg_df['selling_price'].isna().sum())
print(auto_mpg_df['km_driven'].isna().sum())
print(auto_mpg_df['seller_type'].isna().sum())
print(auto_mpg_df['transmission'].isna().sum())
print(auto_mpg_df['owner'].isna().sum())
print(auto_mpg_df['mileage'].isna().sum())
print(auto_mpg_df['engine'].isna().sum())
print(auto_mpg_df['max_power'].isna().sum())
print(auto_mpg_df['seats'].isna().sum())
```

```
0
0
0
0
0
0
0
```

```
0
0
0
0
```

1.4. The features engine, max_power and mileage have units in the dataset. In the real world if we have such datasets, we generally remove the units from each feature. After doing so, convert the datatype of these columns to float. For example: 1248 CC engine is 1248, 23.4 kmpl is 23.4 and so on.

Hint: Check for distinct units in each of these features. A feature might have multiple units as well. Also, a feature could have no value but have unit. For example 'CC' without any value. Remove such rows.

In [14]:

```
auto_mpg_df["engine"].unique()
```

Out[14]:

```
array(['1248 CC', '1498 CC', '1497 CC', '1396 CC', '1298 CC', '1197 CC',
       '1061 CC', '796 CC', '1364 CC', '1399 CC', '1461 CC', '993 CC',
       '1198 CC', '1199 CC', '998 CC', '1591 CC', '2179 CC', '1368 CC',
       '2982 CC', '2494 CC', '2143 CC', '2477 CC', '1462 CC', '2755 CC',
       '1968 CC', '1798 CC', '1196 CC', '1373 CC', '1598 CC', '1998 CC',
       '1086 CC', '1194 CC', '1172 CC', '1405 CC', '1582 CC', '999 CC',
       '2487 CC', '1999 CC', '3604 CC', '2987 CC', '1995 CC', '1451 CC',
       '1969 CC', '2967 CC', '2497 CC', '1797 CC', '1991 CC', '2362 CC',
       '1493 CC', '1599 CC', '1341 CC', '1794 CC', '799 CC', '1193 CC',
       '2696 CC', '1495 CC', '1186 CC', '1047 CC', '2498 CC', '2956 CC',
       '2523 CC', '1120 CC', '624 CC', '1496 CC', '1984 CC', '2354 CC',
       '814 CC', '793 CC', '1799 CC', '936 CC', '1956 CC', '1997 CC',
       '1499 CC', '1948 CC', '2997 CC', '2489 CC', '2499 CC', '2609 CC',
       '2953 CC', '1150 CC', '1994 CC', '1388 CC', '1527 CC', '2199 CC',
       '995 CC', '2993 CC', '1586 CC', '1390 CC', '909 CC', '2393 CC',
       '3198 CC', '1339 CC', '2835 CC', '2092 CC', '1595 CC', '2496 CC',
       '1596 CC', '1597 CC', '2596 CC', '2148 CC', '1299 CC', '1590 CC',
       '2231 CC', '2694 CC', '2200 CC', '1795 CC', '1896 CC', '1796 CC',
       '1422 CC', '1489 CC', '2359 CC', '2197 CC', '2999 CC', '1781 CC',
       '2650 CC', '1343 CC', '2446 CC', '3498 CC', '2198 CC', '2776 CC',
       '1950 CC'], dtype=object)
```

In [15]:

```
### Your code here
### cleaning column --> engine
auto_mpg_df["engine"] = auto_mpg_df["engine"].map(lambda x: x.rstrip('CC'))
auto_mpg_df["engine"] = auto_mpg_df["engine"].str.strip()
auto_mpg_df["engine"]= auto_mpg_df["engine"].astype(float)
```

In [16]:
```
kmkg = 0
kmpl = 0
for i in auto_mpg_df.mileage:
    if str(i).endswith("km/kg"):
        kmkg+=1
    elif str(i).endswith("kmpl"):
        kmpl+=1
print('The number of rows with Km/Kg : {} '.format(kmkg))
print('The number of rows with Kmpl : {} '.format(kmpl))

# since there are 88 rows it is not going to make a big difference overal how we deal with these 88 rows that
# do not align with kmpl.
```

```
The number of rows with Km/Kg : 88
The number of rows with Kmpl : 7819
```

In [17]:
```
Correct_Mileage= []
for i in auto_mpg_df.mileage:
    if str(i).endswith('km/kg'):
        i = i[:-5]
        # conversion
        i = float(i)*1.40
        auto_mpg_df["mileage"] = auto_mpg_df["mileage"].str.strip()
        Correct_Mileage.append(float(i))
    elif str(i).endswith('kmpl'):
        i = i[:-4]
        auto_mpg_df["mileage"] = auto_mpg_df["mileage"].str.strip()
        Correct_Mileage.append(float(i))
auto_mpg_df['mileage']=Correct_Mileage
```

In [18]:
```
auto_mpg_df["max_power"].unique()
```

Out[18]:
```
array(['74 bhp', '103.52 bhp', '78 bhp', '90 bhp', '88.2 bhp',
       '81.86 bhp', '57.5 bhp', '37 bhp', '67.1 bhp', '68.1 bhp',
       '108.45 bhp', '60 bhp', '73.9 bhp', '67 bhp', '82 bhp', '88.5 bhp',
       '46.3 bhp', '88.73 bhp', '64.1 bhp', '98.6 bhp', '88.8 bhp',
       '83.81 bhp', '83.1 bhp', '47.3 bhp', '73.8 bhp', '34.2 bhp',
       '35 bhp', '81.83 bhp', '40.3 bhp', '121.3 bhp', '138.03 bhp',
       '160.77 bhp', '117.3 bhp', '116.3 bhp', '83.14 bhp', '67.05 bhp',
       '168.5 bhp', '100 bhp', '120.7 bhp', '98.63 bhp', '175.56 bhp',
       '103.25 bhp', '171.5 bhp', '100.6 bhp', '174.33 bhp', '187.74 bhp',
       '170 bhp', '78.9 bhp', '88.76 bhp', '86.8 bhp', '108.495 bhp',
       '108.62 bhp', '93.7 bhp', '103.6 bhp', '98.59 bhp', '189 bhp',
```

```
'67.04 bhp', '68.05 bhp', '58.2 bhp', '82.85 bhp', '81.80 bhp',
'73 bhp', '120 bhp', '94.68 bhp', '160 bhp', '65 bhp', '155 bhp',
'69.01 bhp', '126.32 bhp', '138.1 bhp', '83.8 bhp', '126.2 bhp',
'98.96 bhp', '62.1 bhp', '86.7 bhp', '188 bhp', '214.56 bhp',
'177 bhp', '280 bhp', '148.31 bhp', '254.79 bhp', '190 bhp',
'177.46 bhp', '204 bhp', '141 bhp', '117.6 bhp', '241.4 bhp',
'282 bhp', '150 bhp', '147.5 bhp', '108.5 bhp', '103.5 bhp',
'183 bhp', '181.04 bhp', '157.7 bhp', '164.7 bhp', '91.1 bhp',
'400 bhp', '68 bhp', '75 bhp', '85.8 bhp', '87.2 bhp', '53 bhp',
'118 bhp', '103.2 bhp', '83 bhp', '84 bhp', '58.16 bhp',
'147.94 bhp', '74.02 bhp', '53.3 bhp', '80 bhp', '88.7 bhp',
'97.7 bhp', '121.36 bhp', '162 bhp', '140 bhp', '94 bhp',
'100.57 bhp', '82.9 bhp', '83.11 bhp', '70 bhp', '153.86 bhp',
'121 bhp', '126.3 bhp', '73.97 bhp', '171 bhp', '69 bhp',
'99.6 bhp', '102 bhp', '105 bhp', '63 bhp', '79.4 bhp', '97.9 bhp',
'63.1 bhp', '66.1 bhp', '110 bhp', '174.5 bhp', '53.26 bhp',
'73.75 bhp', '67.06 bhp', '64.08 bhp', '37.5 bhp', '189.3 bhp',
'158.8 bhp', '61.7 bhp', '55.2 bhp', '71.01 bhp', '73.74 bhp',
'147.9 bhp', '71 bhp', '77 bhp', '121.4 bhp', '113.4 bhp',
'47 bhp', '130 bhp', '57.6 bhp', '138 bhp', '52.8 bhp',
'53.64 bhp', '53.5 bhp', '76.8 bhp', '82.4 bhp', '113.42 bhp',
'76 bhp', '84.8 bhp', '56.3 bhp', '218 bhp', '112 bhp', '92 bhp',
'105.5 bhp', '169 bhp', '95 bhp', '72.4 bhp', '115 bhp', '152 bhp',
'91.2 bhp', '156 bhp', '74.9 bhp', '62 bhp', '105.3 bhp',
'73.94 bhp', '85.80 bhp', '85 bhp', '118.3 bhp', '72 bhp',
'147.51 bhp', '58 bhp', '64 bhp', '126.24 bhp', '76.9 bhp',
'194.3 bhp', '99.23 bhp', '89.84 bhp', '123.7 bhp', '118.35 bhp',
'99 bhp', '241 bhp', '136 bhp', '261.4 bhp', '104.68 bhp',
'37.48 bhp', '104 bhp', '88.50 bhp', '63.12 bhp', '91.7 bhp',
'102.5 bhp', '177.6 bhp', '45 bhp', '123.37 bhp', '147.8 bhp',
'184 bhp', '84.48 bhp', '68.07 bhp', '74.96 bhp', '167.6 bhp',
'152.87 bhp', '112.2 bhp', '83.83 bhp', '197 bhp', '110.4 bhp',
'104.55 bhp', '103 bhp', '103.3 bhp', '66 bhp', '108.6 bhp',
'165 bhp', '163.7 bhp', '116.9 bhp', '94.93 bhp', '127 bhp',
'198.5 bhp', '179.5 bhp', '120.69 bhp', '121.31 bhp', '138.08 bhp',
'187.7 bhp', '80.8 bhp', '86.79 bhp', '93.87 bhp', '116.6 bhp',
'143 bhp', '92.7 bhp', '88 bhp', '58.33 bhp', '78.8 bhp',
'64.4 bhp', '125 bhp', '139.01 bhp', '254.8 bhp', '181 bhp',
'258 bhp', '55.23 bhp', '270.9 bhp', '265 bhp', '157.75 bhp',
'101 bhp', '186 bhp', '187.4 bhp', '224 bhp', '64.9 bhp',
'148 bhp', '35.5 bhp', '89.75 bhp', '32.8 bhp', '91.72 bhp',
'106 bhp', '98.97 bhp', '66.6 bhp', '86 bhp', '65.3 bhp',
'98.82 bhp', '198.25 bhp', '38 bhp', '142 bhp', '132 bhp',
'174.57 bhp', '178 bhp', '163.2 bhp', '203.2 bhp', '177.5 bhp',
'175 bhp', '57 bhp', '80.84 bhp', '68.4 bhp', '167.67 bhp',
```

```
       '170.63 bhp', '52 bhp', '149.5 bhp', '48.21 bhp', ' bhp',
       '201.1 bhp', '100.5 bhp', '144 bhp', '194.4 bhp', '168.7 bhp',
       '104.5 bhp', '103.26 bhp', '116.4 bhp', '98.79 bhp', '80.9 bhp',
       '58.3 bhp', '272 bhp', '235 bhp', '167.62 bhp', '170.30 bhp',
       '139.46 bhp', '158 bhp', '110.5 bhp', '82.5 bhp', '141.1 bhp',
       '38.4 bhp', '197.2 bhp', '161 bhp', '194 bhp', '122.4 bhp',
       '134.10 bhp', '60.2 bhp', '134 bhp', '203 bhp', '135.1 bhp'],
      dtype=object)
```

In [19]:

```
### cleaning column --> max_power
auto_mpg_df["max_power"] = auto_mpg_df["max_power"].map(lambda x: x.rstrip('bhp'))
auto_mpg_df["max_power"] = auto_mpg_df["max_power"].str.strip()
```

In [20]:

```
auto_mpg_df['max_power'] = auto_mpg_df['max_power'].replace('', float('NaN'))
auto_mpg_df = auto_mpg_df.dropna()
auto_mpg_df["max_power"]= auto_mpg_df["max_power"].astype(float)
```

In [21]:

```
auto_mpg_X = auto_mpg_df.drop(columns=['selling_price'])
auto_mpg_y = auto_mpg_df['selling_price']
```

1.5. Plot the distribution of the label (selling_price) using a histogram. Make multiple plots with different binwidths. Make sure to label your axes while plotting.

In [22]:

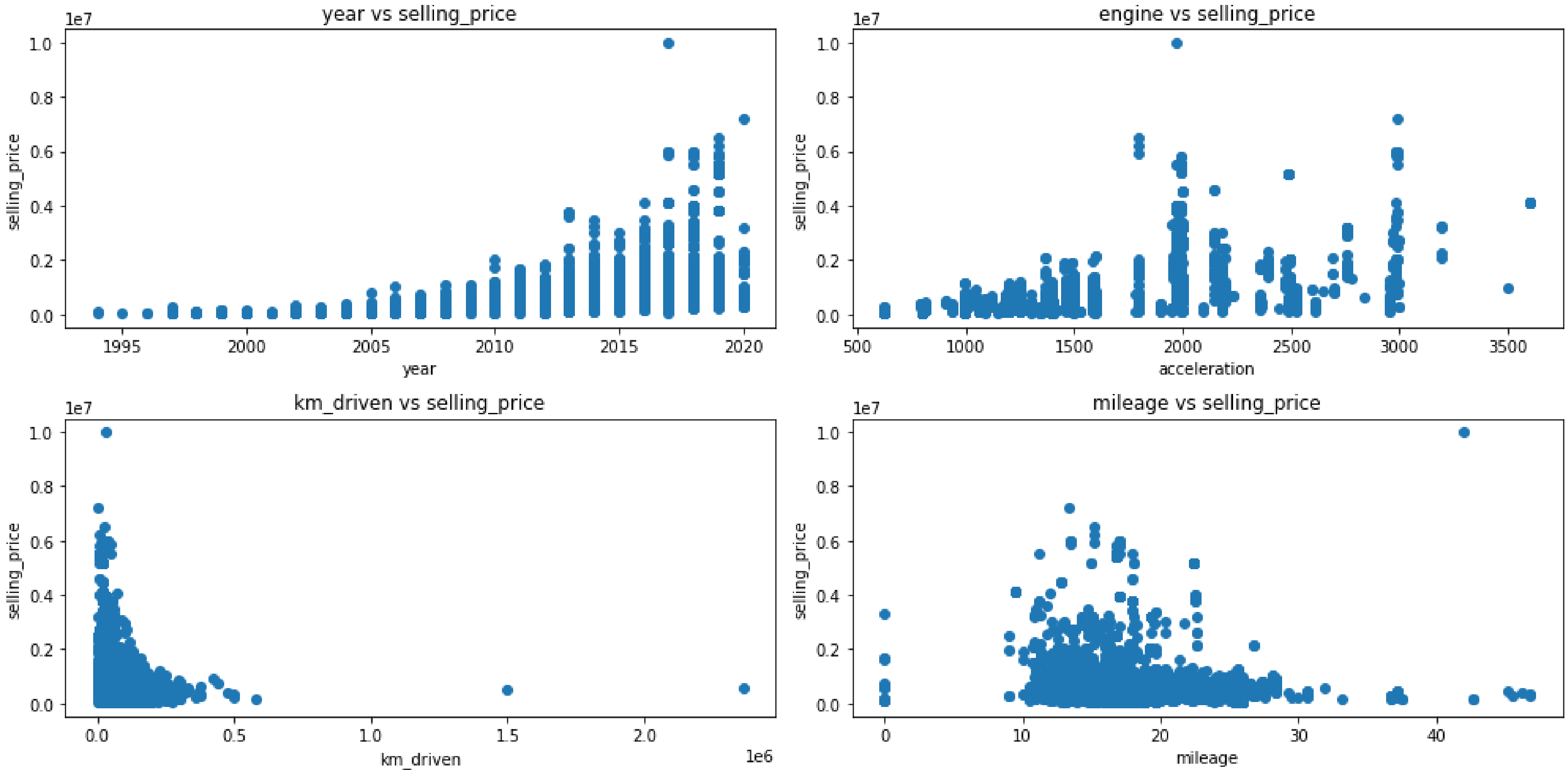
```
### Your code here

fig, ax = plt.subplots(2,2, figsize=(14,7))
ax[0][0].scatter(auto_mpg_X['year'], auto_mpg_y)
ax[0][0].set_xlabel('year')
ax[0][0].set_ylabel('selling_price')
ax[0][0].set_title('year vs selling_price')
ax[1][0].scatter(auto_mpg_X['km_driven'], auto_mpg_y)
ax[1][0].set_ylabel('selling_price')
ax[1][0].set_xlabel('km_driven')
ax[1][0].set_title('km_driven vs selling_price')
ax[1][1].scatter(auto_mpg_X['mileage'], auto_mpg_y)
ax[1][1].set_ylabel('selling_price')
ax[1][1].set_xlabel('mileage')
ax[1][1].set_title('mileage vs selling_price')
ax[0][1].scatter(auto_mpg_X['engine'], auto_mpg_y)
ax[0][1].set_ylabel('selling_price')
```

```
ax[0][1].set_xlabel('acceleration')
ax[0][1].set_title('engine vs selling_price')

fig.tight_layout()
fig.show()
```

```
/var/folders/hc/1s53gb2x4170pxgm9cmzd3s00000gn/T/ipykernel_39795/2357932289.py:22: UserWarning: Matplotlib is c
urrently using module://matplotlib_inline.backend_inline, which is a non-GUI backend, so cannot show the figur
e.
  fig.show()
```

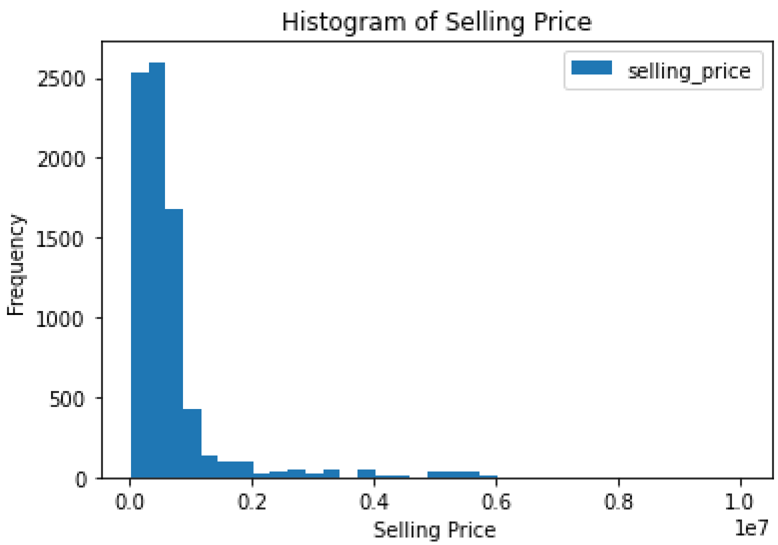


In [23]:

```
maxAmount = max(auto_mpg_y)
plt.xlabel('Selling Price')
plt.ylabel("Number of Vehicles");
auto_mpg_y.plot.hist(bins=35, legend=True, title='Histogram of Selling Price',)
```

Out[23]:

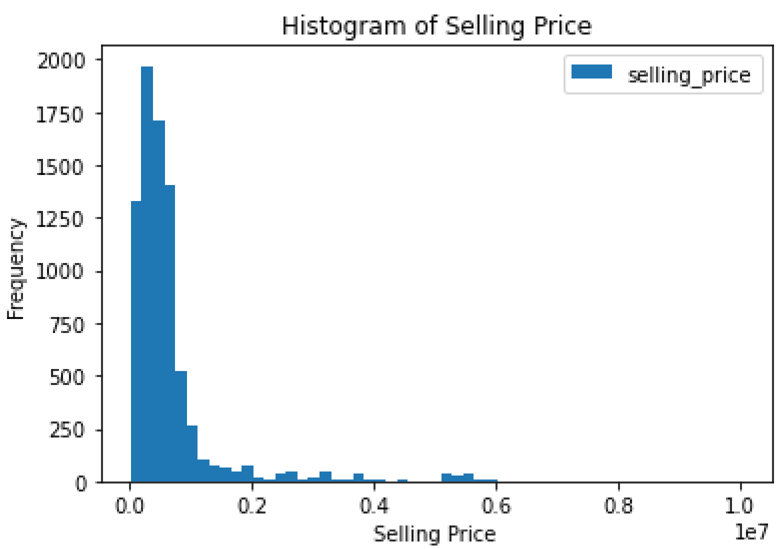
```
<AxesSubplot:title={'center':'Histogram of Selling Price'}, xlabel='Selling Price', ylabel='Frequency'>
```



In [24]:

```
maxAmount = max(auto_mpg_y)
plt.xlabel('Selling Price')
plt.ylabel("Number of Vehicles");
auto_mpg_y.plot.hist(bins=55, legend=True, title='Histogram of Selling Price',)
```

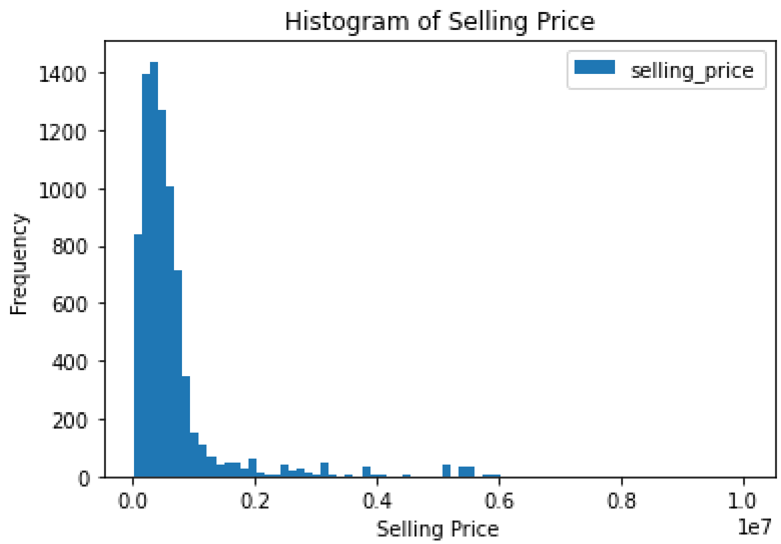
Out[24]: <AxesSubplot:title={'center':'Histogram of Selling Price'}, xlabel='Selling Price', ylabel='Frequency'>



In [25]:

```python
maxAmount = max(auto_mpg_y)
plt.xlabel('Selling Price')
plt.ylabel("Number of Vehicles");
auto_mpg_y.plot.hist(bins=75, legend=True, title='Histogram of Selling Price',)
```

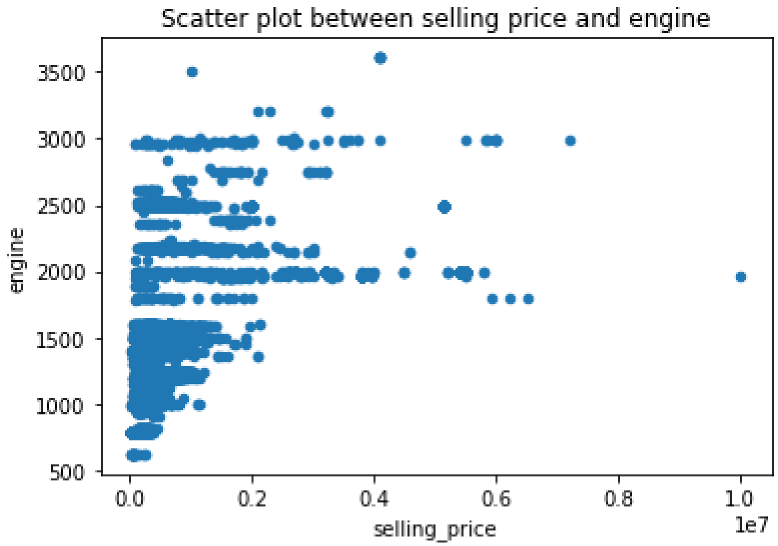
Out[25]: <AxesSubplot:title={'center':'Histogram of Selling Price'}, xlabel='Selling Price', ylabel='Frequency'>



1.6. Plot the relationships between the label (Selling Price) and the continuous features (Mileage, km driven, engine, max power) using a small multiple of scatter plots. Make sure to label the axes. Do you see something interesting about the distributions of these features.

In [26]:

```python
### Your code here
auto_mpg_df.plot.scatter(x='selling_price', y='engine', title= "Scatter plot between selling price and engine")
```



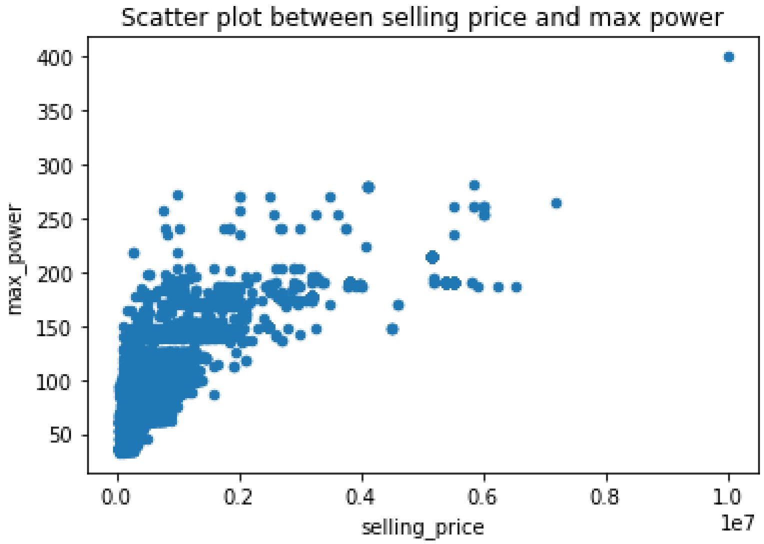
In [27]:

```
auto_mpg_df.plot.scatter(x='selling_price', y='mileage',
                         title= "Scatter plot between selling price and mileage");
```

In [28]:

```
auto_mpg_df.plot.scatter(x='selling_price', y='max_power',
                         title= "Scatter plot between selling price and max power");
```

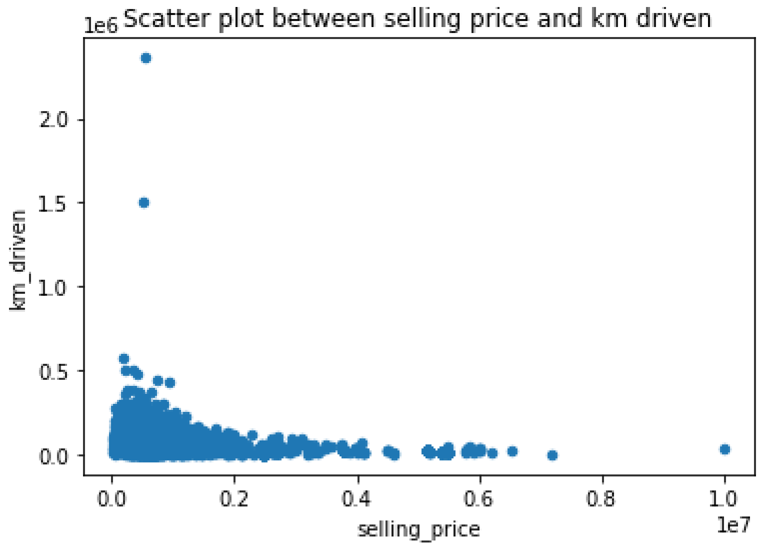
```
### max power is not that popular determiner of the car's popularity. Same signs are appearing here.
### The average power car cost the average price
```



In [29]:
```
auto_mpg_df.plot.scatter(x='selling_price', y='km_driven', title=
                         "Scatter plot between selling price and km driven")

### lower the km driver the higher the concentration of points
```

Out[29]:
```
<AxesSubplot:title={'center':'Scatter plot between selling price and km driven'}, xlabel='selling_price', ylabe
l='km_driven'>
```



1.7. Plot the relationships between the label (Selling Price) and the discrete features (fuel type, Seller type, transmission) using a small multiple of box plots. Make sure to label the axes.

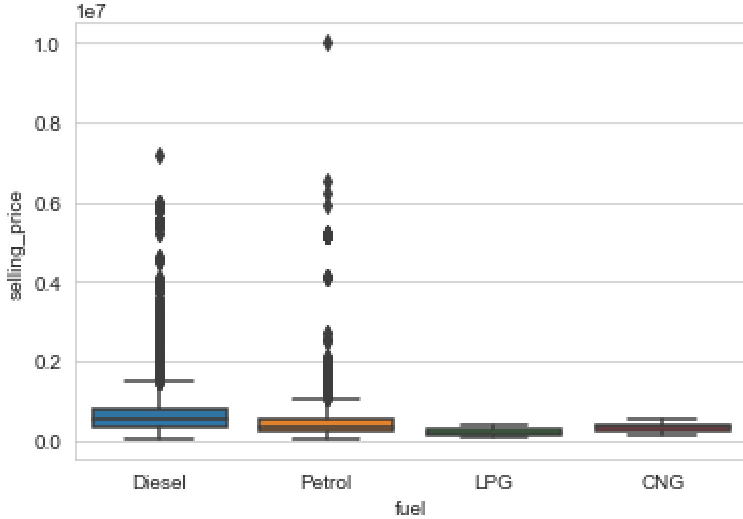
In [30]:

```
### Your code here

sns.set_style("whitegrid")
sns.boxplot(x = 'fuel', y = 'selling_price', data = auto_mpg_df)
```

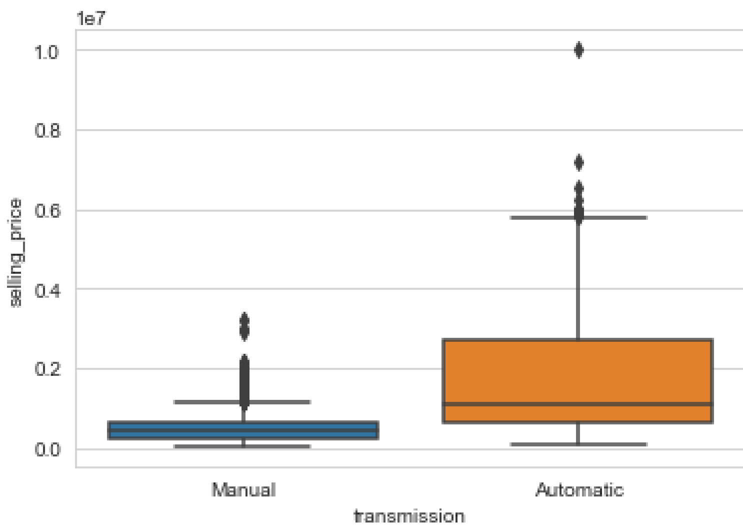
Out[30]:

```
<AxesSubplot:xlabel='fuel', ylabel='selling_price'>
```



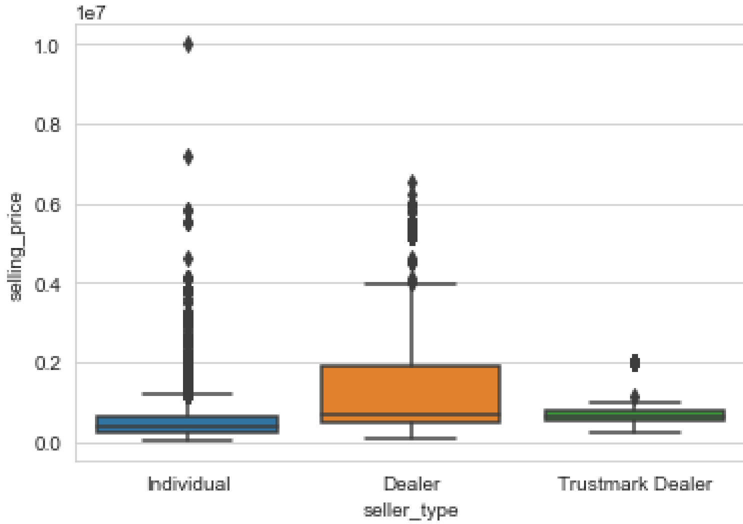
In [31]:
```
sns.set_style("whitegrid")
sns.boxplot(x = 'transmission', y = 'selling_price', data = auto_mpg_df)
```

Out[31]: <AxesSubplot:xlabel='transmission', ylabel='selling_price'>



In [32]:
```
sns.set_style("whitegrid")
sns.boxplot(x = 'seller_type', y = 'selling_price', data = auto_mpg_df)
```

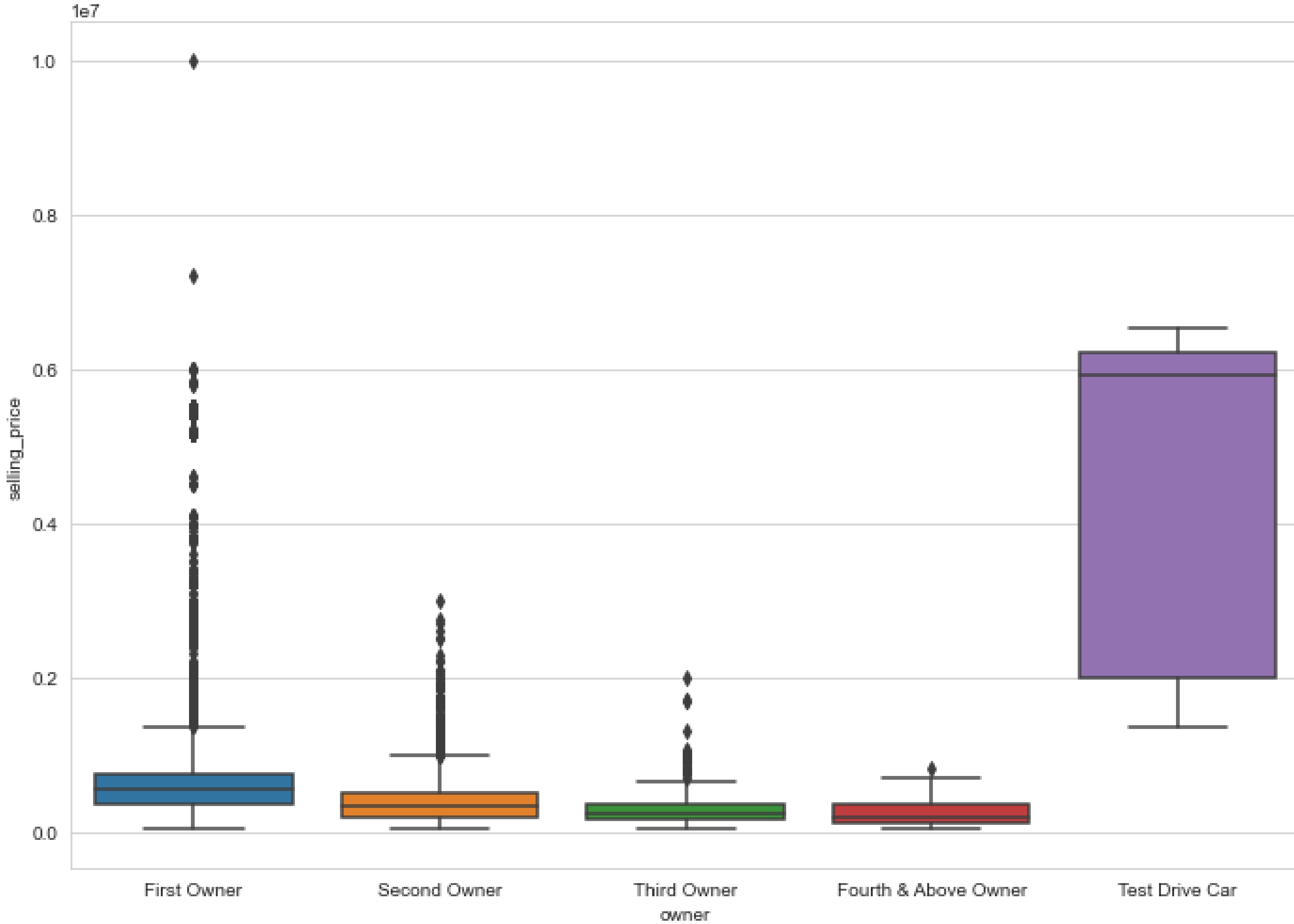
Out[32]: <AxesSubplot:xlabel='seller_type', ylabel='selling_price'>



In [33]:

```
from matplotlib import rcParams
rcParams['figure.figsize'] = 11.7,8.27
sns.set_style("whitegrid")
sns.boxplot(x = 'owner', y = 'selling_price', data = auto_mpg_df)
```

Out[33]: <AxesSubplot:xlabel='owner', ylabel='selling_price'>



1.8. From the visualizations above, do you think linear regression is a good model for this problem? Why and/or why not?

In [34]:
```
### Your answer here
### I think linear regression is a good model for this problem since we need to find the best model
### to fit the data which seems equally distributed around the mean and does not have that many outliers. addit
### from the above, it appears many variables do have a linear relationship and are correlated to price which a
### us to ise linear regression to uncover different relationships.
### once we have the model, predicting selling price of the vehicle given let's say fuel type is just finding
### the 'y' value.
```

In [35]:
```
auto_mpg_X['year'] =  2020 - auto_mpg_X['year']
```

In [36]:
```
#dropping the car name as it is irrelevant.
auto_mpg_X.drop(['name'],axis = 1,inplace=True)

#check out the dataset with new changes
auto_mpg_X.head()
```

Out[36]:

	year	km_driven	fuel	seller_type	transmission	owner	mileage	engine	max_power	seats
0	6	145500	Diesel	Individual	Manual	First Owner	23.40	1248.0	74.00	5.0
1	6	120000	Diesel	Individual	Manual	Second Owner	21.14	1498.0	103.52	5.0
2	14	140000	Petrol	Individual	Manual	Third Owner	17.70	1497.0	78.00	5.0
3	10	127000	Diesel	Individual	Manual	First Owner	23.00	1396.0	90.00	5.0
4	13	120000	Petrol	Individual	Manual	First Owner	16.10	1298.0	88.20	5.0

Data Pre-processing

1.9. Before we can fit a linear regression model, there are several pre-processing steps we should apply to the datasets:

1. Encode categorial features appropriately.
2. Split the dataset into training (60%), validation (20%), and test (20%) sets.
3. Standardize the columns in the feature matrices X_train, X_val, and X_test to have zero mean and unit variance. To avoid information leakage, learn the standardization parameters (mean, variance) from X_train, and apply it to X_train, X_val, and X_test.
4. Add a column of ones to the feature matrices X_train, X_val, and X_test. This is a common trick so that we can learn a coefficient for the bias term of a linear model.

In [37]:
```
print(" \nCount total NaN at each column in a DataFrame : \n\n",
      auto_mpg_X.isnull().sum())

# dataset does not have nan values
```

```
Count total NaN at each column in a DataFrame :

 year            0
km_driven       0
fuel            0
```

```
seller_type     0
transmission    0
owner           0
mileage         0
engine          0
max_power       0
seats           0
dtype: int64
```

In [38]:

```
X = x.reshape((100, 1))   # Turn the x vector into a feature matrix X

# 1. No categorical features in the synthetic dataset (skip this step)

# 2. Split the dataset into training (60%), validation (20%), and test (20%) sets
X_dev, X_test, y_dev, y_test = train_test_split(X, z, test_size=0.2, random_state=0)
X_train, X_val, y_train, y_val = train_test_split(X_dev, y_dev, test_size=0.25, random_state=0)

# 3. Standardize the columns in the feature matrices
scaler = StandardScaler()
X_train = scaler.fit_transform(X_train)   # Fit and transform scalar on X_train
X_val = scaler.transform(X_val)           # Transform X_val
X_test = scaler.transform(X_test)         # Transform X_test

# 4. Add a column of ones to the feature matrices
X_train = np.hstack([np.ones((X_train.shape[0], 1)), X_train])
X_val = np.hstack([np.ones((X_val.shape[0], 1)), X_val])
X_test = np.hstack([np.ones((X_test.shape[0], 1)), X_test])

print(X_train[:5])
print(y_train[:5])
```

```
[[ 1.          0.53651502]
 [ 1.         -1.00836082]
 [ 1.         -0.72094206]
 [ 1.         -0.25388657]
 [ 1.          0.64429705]]
[58.44273829 26.35936352 36.18499261 44.02659901 65.91341194]
```

In [39]:

```
print(X_train.mean(axis=0), X_train.std(axis=0))
print(X_val.mean(axis=0), X_val.std(axis=0))
print(X_test.mean(axis=0), X_test.std(axis=0))
```

```
[ 1.00000000e+00 -4.81096644e-17] [0. 1.]
[ 1.        -0.1263445] [0.         1.03471221]
```

```
[ 1.         -0.15508637] [0.         1.13264481]
```

In [40]:

```
auto_mpg_y
```

Out[40]:

```
0       450000
1       370000
2       158000
3       225000
4       130000
         ...
8123    320000
8124    135000
8125    382000
8126    290000
8127    290000
Name: selling_price, Length: 7906, dtype: int64
```

In [41]:

```
# 1. No categorical features in the synthetic dataset (skip this step)

num_features = ['year', 'km_driven', 'mileage', 'engine', 'max_power', 'seats']
cat_features = ['fuel', 'seller_type', 'transmission', 'owner']
all_features_mpg = cat_features + num_features + ['Bias']
auto_mpg_X['Bias'] = 1

# 2. Split the dataset into training (60%), validation (20%), and test (20%) sets
auto_mpg_X_dev, auto_mpg_X_test, auto_mpg_y_dev, auto_mpg_y_test = train_test_split(auto_mpg_X, auto_mpg_y, tes
auto_mpg_X_train, auto_mpg_X_val, auto_mpg_y_train, auto_mpg_y_val = train_test_split(auto_mpg_X_dev, auto_mpg_

column_transformer = make_column_transformer((StandardScaler(), num_features),
                                           (TargetEncoder(), cat_features),
                                            remainder='passthrough')
# 3. Standardize the columns in the feature matrices
auto_mpg_X_train = column_transformer.fit_transform(auto_mpg_X_train,auto_mpg_y_train)
auto_mpg_X_val = column_transformer.transform(auto_mpg_X_val)
auto_mpg_X_test = column_transformer.transform(auto_mpg_X_test)
```

In [42]:

```
print(auto_mpg_X_train.mean(axis=0), auto_mpg_X_train.std(axis=0))
print(auto_mpg_X_val.mean(axis=0), auto_mpg_X_val.std(axis=0))
print(auto_mpg_X_test.mean(axis=0), auto_mpg_X_test.std(axis=0))
```

```
[ 9.06342726e-17 -4.04483531e-17 -1.55801064e-16  9.58775777e-17
  1.28835495e-16 -2.24713073e-17  6.38882799e+05  6.38882799e+05
  6.38882799e+05  6.38811413e+05  1.00000000e+00] [1.00000000e+00 1.00000000e+00 1.00000000e+00 1.00000000e+00
```

```
 1.00000000e+00 1.00000000e+00 1.54633592e+05 3.14277330e+05
 4.61658942e+05 2.25336091e+05 0.00000000e+00]
[ 1.59727079e-02 -2.80115549e-02 -3.04962880e-02 -2.41315526e-02
  2.30409922e-02 -1.47826034e-02  6.33904099e+05  6.35561683e+05
  6.61820554e+05  6.31908703e+05  1.00000000e+00] [1.04392030e+00 7.44488269e-01 1.02048637e+00 9.81783397e-01
 1.03471675e+00 1.01082503e+00 1.55466660e+05 3.10655294e+05
 4.86397686e+05 1.91164234e+05 0.00000000e+00]
[-1.97506832e-02 -2.51129173e-02  9.41304364e-03 -4.02800489e-03
 -5.56405257e-03 -1.82101300e-03  6.31320826e+05  6.43982731e+05
  6.60813974e+05  6.31750582e+05  1.00000000e+00] [9.83789131e-01 7.86338547e-01 1.03779420e+00 1.00878538e+00
 1.00590351e+00 1.00766001e+00 1.56472960e+05 3.18099866e+05
 4.85361269e+05 1.91419114e+05 0.00000000e+00]
```

At the end of this pre-processing, you should have the following vectors and matrices:

- Auto MPG dataset: auto_mpg_X_train, auto_mpg_X_val, auto_mpg_X_test, auto_mpg_y_train, auto_mpg_y_val, auto_mpg_y_test

Implement Linear Regression

Now, we can implement our linear regression model! Specifically, we will be implementing ridge regression, which is linear regression with L2 regularization. Given an (m x n) feature matrix X, an (m x 1) label vector y, and an (n x 1) weight vector w, the hypothesis function for linear regression is:

$$y = Xw$$

Note that we can omit the bias term here because we have included a column of ones in our X matrix, so the bias term is learned implicitly as a part of w. This will make our implementation easier.

Our objective in linear regression is to learn the weights w which best fit the data. This notion can be formalized as finding the optimal w which minimizes the following loss function:

$$\min_{w} \|Xw - y\|_2^2 + \alpha\|w\|_2^2$$

This is the ridge regression loss function. The $\|Xw - y\|_2^2$ term penalizes predictions Xw which are not close to the label y. And the $\alpha\|w\|_2^2$ penalizes large weight values, to favor a simpler, more generalizable model. The α hyperparameter, known as the regularization parameter, is used to tune the complexity of the model - a higher α results in smaller weights and lower complexity, and vice versa. Setting $\alpha = 0$ gives us vanilla linear regression.

Conveniently, ridge regression has a closed-form solution which gives us the optimal w without having to do iterative methods such as gradient descent. The closed-form solution, known as the Normal Equations, is given by:

$$w = (X^T X + \alpha I)^{-1} X^T y$$

1.10. Implement a `LinearRegression` class with two methods: `train` and `predict` . You may NOT use sklearn for this implementation. You may, however, use `np.linalg.solve` to find the closed-form solution. It is highly recommended that you vectorize your code.

In [43]:

```
class LinearRegression():
    '''
    Linear regression model with L2-regularization (i.e. ridge regression).

    Attributes
    ----------
    alpha: regularization parameter
    w: (n x 1) weight vector
    '''

    def __init__(self, alpha=0):
        self.alpha = alpha
        self.w = None

    def train(self, X, y):
        '''Trains model using ridge regression closed-form solution
        (sets w to its optimal value).

        Parameters
        ----------
        X : (m x n) feature matrix
        y: (m x 1) label vector

        Returns
        -------
        None
        '''

        num_rows, num_cols = X.shape

        LHS = inv(np.matmul(X.T,X) + self.alpha*np.identity(num_cols))
        RHS = np.matmul(X.T,y)
        w = np.matmul(LHS,RHS)
        self.w = w
```

```
    def predict(self, X):
        '''Predicts on X using trained model.

        Parameters
        ----------
        X : (m x n) feature matrix

        Returns
        -------
        y_pred: (m x 1) prediction vector
        '''
        ### Your code here

        y_pred = np.matmul(X, self.w)
        return y_pred
```

Train, Evaluate, and Interpret Linear Regression Model

1.11. A) Train a linear regression model ($\alpha = 0$) on the auto MPG training data. Make predictions and report the mean-squared error (MSE) on the training, validation, and test sets. Report the first 5 predictions on the test set, along with the actual labels.

In [44]:

```
### Your code here
from sklearn.metrics import mean_squared_error
ridge_reg = LinearRegression(alpha=0)
ridge_reg.train(auto_mpg_X_train,auto_mpg_y_train)
ridge_reg_predictions = ridge_reg.predict(auto_mpg_X_test)
print('predictions for first 5 values from test set: ')
print(ridge_reg_predictions[:5])
print('actual first 5 values from test set: ')
print(auto_mpg_y_train[:5])

train_est = ridge_reg.predict(auto_mpg_X_train)
print('MSE using predicted from model on train set: ')
print(mean_squared_error(auto_mpg_y_train, train_est))

val_est = ridge_reg.predict(auto_mpg_X_val)
print('MSE using predicted from model on val set: ')
print(mean_squared_error(auto_mpg_y_val, val_est))

test_est = ridge_reg.predict(auto_mpg_X_test)
```

```
print('MSE using predicted from model on test set: ')
print(mean_squared_error(auto_mpg_y_test, test_est))
```

```
predictions for first 5 values from test set:
[ 514637.90476326 1245392.54660809   94540.98040576  921886.11058349
  660311.36247431]
actual first 5 values from test set:
5464    300000
2774    185000
5012    400000
3524    550000
918     700000
Name: selling_price, dtype: int64
MSE using predicted from model on train set:
197293544752.44693
MSE using predicted from model on val set:
253557239371.69687
MSE using predicted from model on test set:
217717666389.34482
```

B) As a baseline model, use the mean of the training labels (auto_mpg_y_train) as the prediction for all instances. Report the mean-squared error (MSE) on the training, validation, and test sets using this baseline. This is a common baseline used in regression problems and tells you if your model is any good. Your linear regression MSEs should be much lower than these baseline MSEs.

In [45]:

```
### Your code here
baseline_est = auto_mpg_y_train.mean()
baseline_train_est = np.full((len(auto_mpg_y_train),1), baseline_est)
print('MSE using baseline on train set: ')
print(mean_squared_error(auto_mpg_y_train, baseline_train_est))
baseline_val_est = np.full((len(auto_mpg_y_val),1), baseline_est)
print('MSE using baseline on val set: ')
print(mean_squared_error(auto_mpg_y_val, baseline_val_est))
baseline_test_est = np.full((len(auto_mpg_y_test),1), baseline_est)
print('MSE using baseline on test set: ')
print(mean_squared_error(auto_mpg_y_test, baseline_test_est))
```

```
MSE using baseline on train set:
612322495881.2102
MSE using baseline on val set:
809763045080.3438
MSE using baseline on test set:
663032035101.6919
```

1.12. Interpret your model trained on the auto MPG dataset using a bar chart of the model weights. Make sure to label the bars (x-axis) and don't forget the bias term! Use lecture 3, slide 15 as a reference. According to your model, which features are the greatest contributors to the selling price

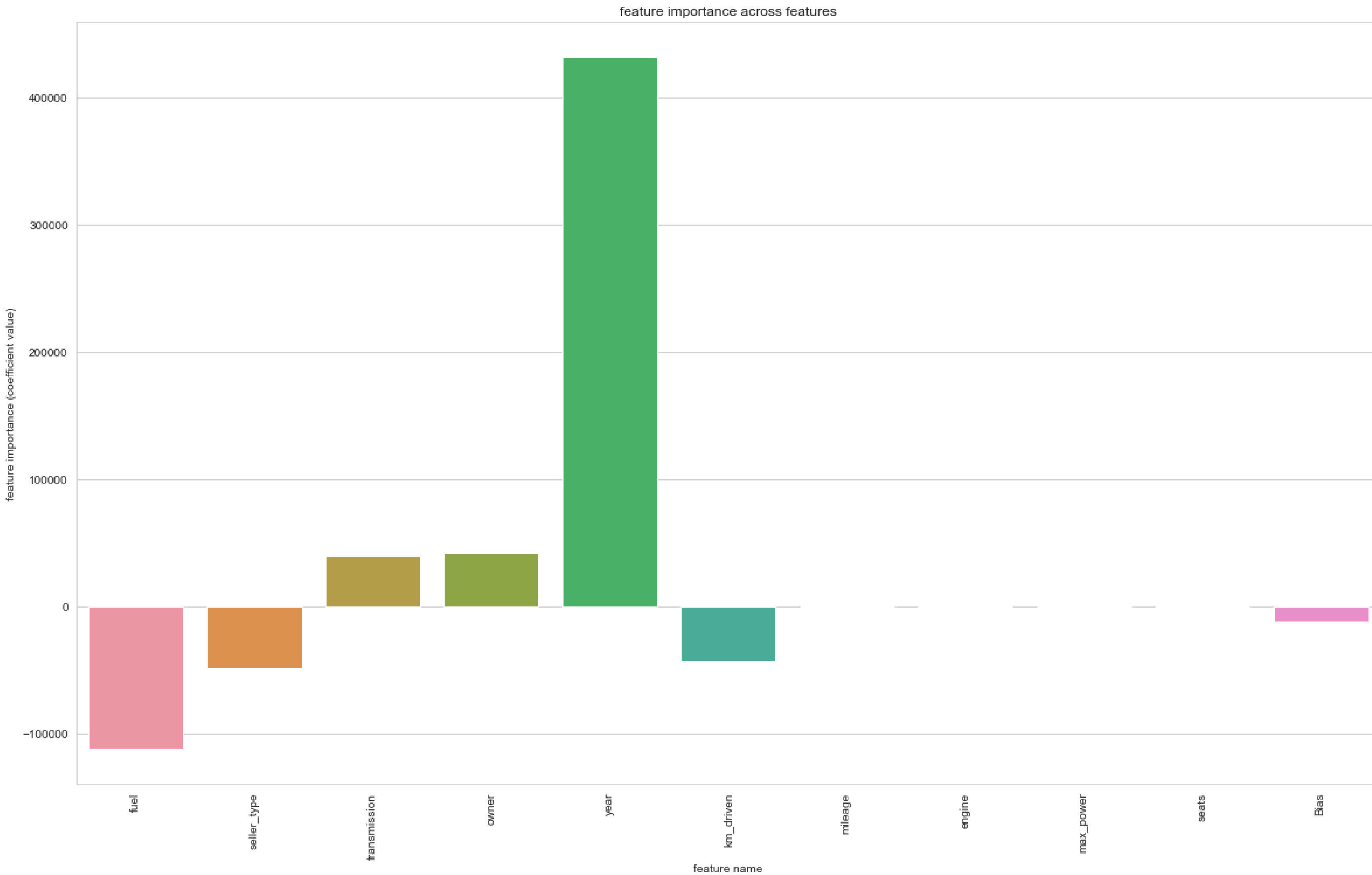
In [46]:
```
all_features_mpg
```

Out[46]:
```
['fuel',
 'seller_type',
 'transmission',
 'owner',
 'year',
 'km_driven',
 'mileage',
 'engine',
 'max_power',
 'seats',
 'Bias']
```

In [47]:
```
ridge_reg.w
```

Out[47]:
```
array([-1.11919226e+05, -4.85942334e+04,  3.95411400e+04,  4.22909397e+04,
        4.31541184e+05, -4.27703212e+04,  1.78939755e-01,  2.40393687e-01,
        3.24473552e-01,  2.74120767e-01, -1.14341698e+04])
```

In [49]:
```
### Your code here
fig = plt.figure(figsize = (20,12))
xval = np.zeros((31))
yval = np.reshape(ridge_reg.w, -1)
ax = sns.barplot(x=all_features_mpg, y=yval)
ax.tick_params(axis='x', rotation=90)
ax.set_xlabel('feature name')
ax.set_ylabel('feature importance (coefficient value)')
ax.set_title('feature importance across features')
plt.show()
```



Tune Regularization Parameter α

Now, let's do ridge regression and tune the α regularization parameter on the auto MPG dataset.

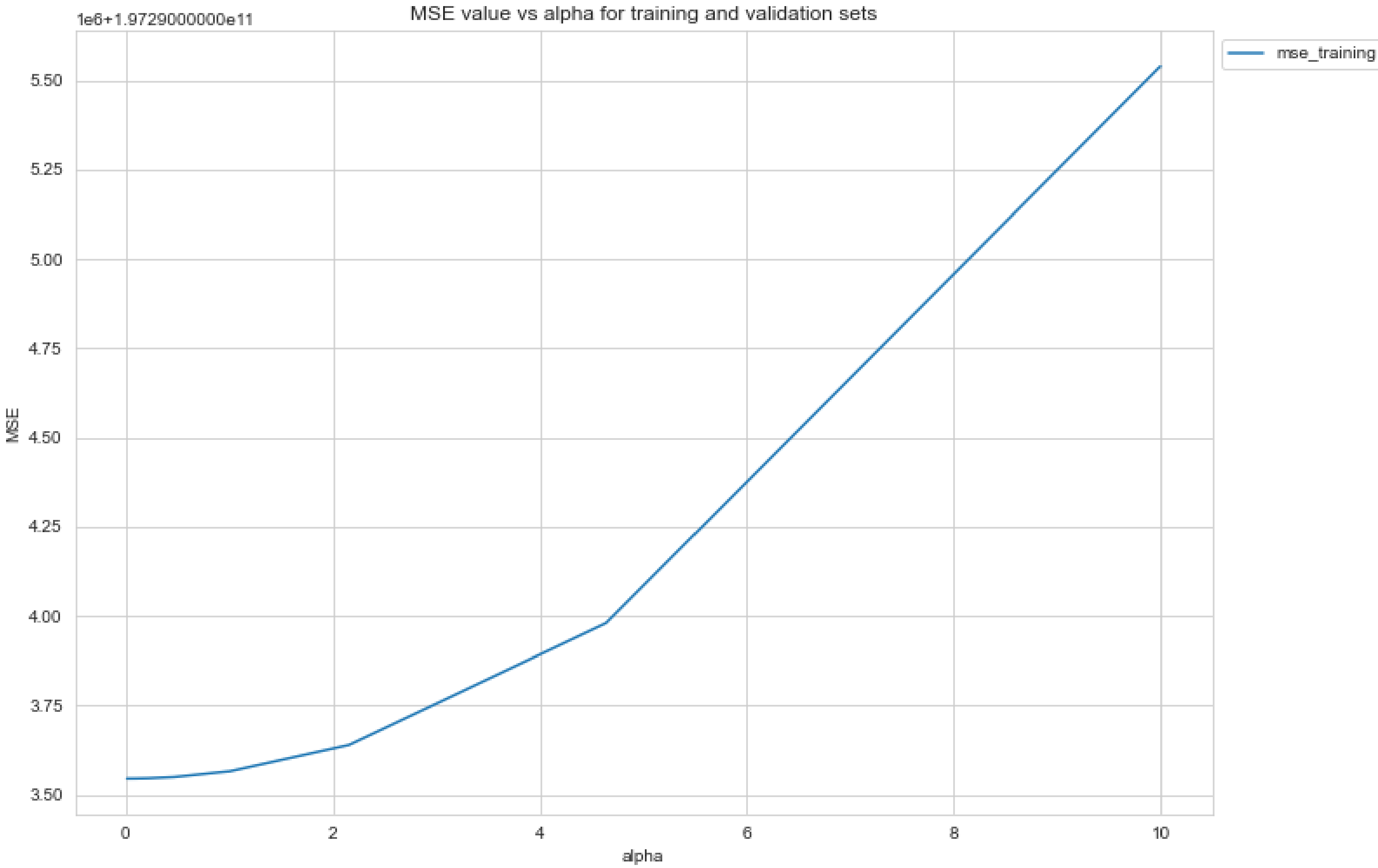
1.13. Sweep out values for α using `alphas = np.logspace(-2, 1, 10)`. Perform a grid search over these α values, recording the training and validation MSEs for each α. A simple grid search is fine, no need for k-fold cross validation. Plot the training and validation MSEs as a function of α on a single figure. Make sure to label the axes and the training and validation MSE curves. Use a log scale for the x-axis.

In [55]:
```
alphas = np.logspace(-2, 1, 10)
df_mses = pd.DataFrame(columns=['alpha', 'mse_training'])
for alpha in alphas:
    model_lin = LinearRegression(alpha=alpha)
    model_lin.train(auto_mpg_X_train,auto_mpg_y_train)
    train_est = model_lin.predict(auto_mpg_X_train)
    train_mse = mean_squared_error(auto_mpg_y_train, train_est)

    val_est = model_lin.predict(auto_mpg_X_val)
    val_mse = mean_squared_error(auto_mpg_y_val, val_est)
    temp_df = pd.DataFrame(columns=['alpha', 'mse_training'], data=[[alpha, train_mse]])
    df_mses = df_mses.append(temp_df)

df_mses.head()
ax = df_mses.set_index('alpha').plot()
ax.legend(bbox_to_anchor=(1.0,1.0))
ax.set_ylabel('MSE')
ax.set_title('MSE value vs alpha for training')
ax.plot()
```

Out[55]:
```
[]
```



In [54]:

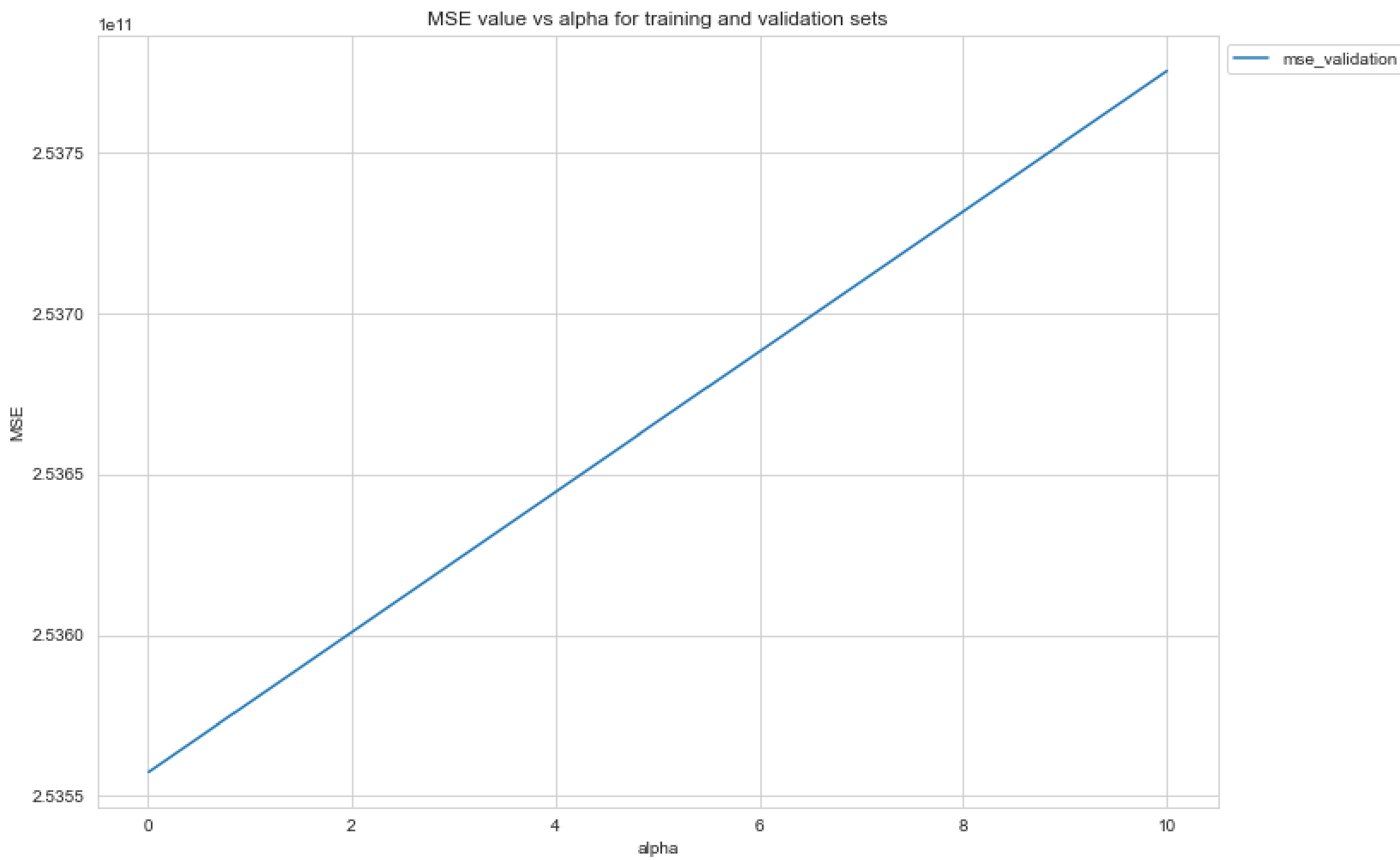
```
### Your code here
alphas = np.logspace(-2, 1, 10)
df_mses = pd.DataFrame(columns=['alpha', 'mse_validation'])
for alpha in alphas:
    model_lin = LinearRegression(alpha=alpha)
    model_lin.train(auto_mpg_X_train,auto_mpg_y_train)
    train_est = model_lin.predict(auto_mpg_X_train)
    train_mse = mean_squared_error(auto_mpg_y_train, train_est)

    val_est = model_lin.predict(auto_mpg_X_val)
    val_mse = mean_squared_error(auto_mpg_y_val, val_est)
    temp_df = pd.DataFrame(columns=['alpha', 'mse_validation'], data=[[alpha,  val_mse]])
```

```
    df_mses = df_mses.append(temp_df)

df_mses.head()
ax = df_mses.set_index('alpha').plot()
ax.legend(bbox_to_anchor=(1.0,1.0))
ax.set_ylabel('MSE')
ax.set_title('MSE value vs alpha for validation set')
ax.plot()
```

Out[54]: []



Explain your plot above. How do training and validation MSE behave with decreasing model complexity (increasing α)?

In [ ]:
```
### Your answer here
# As alpha increases both MSE for the training and validation increase as well.
```

1.14. Using the α which gave the best validation MSE above, train a model on the training set. Report the value of α and its training, validation, and test MSE. This is the final tuned model which you would deploy in production.

In [56]:
```
### Your code here
print(df_mses)

prod_model = LinearRegression(alpha=.046416)
prod_model.train(auto_mpg_X_train, auto_mpg_y_train)
train_est = prod_model.predict(auto_mpg_X_train)
print('MSE using predicted from model on train set: ')
print(mean_squared_error(auto_mpg_y_train, train_est))

val_est = prod_model.predict(auto_mpg_X_val)
print('MSE using predicted from model on val set: ')
print(mean_squared_error(auto_mpg_y_val, val_est))

test_est = prod_model.predict(auto_mpg_X_test)
print('MSE using predicted from model on test set: ')
print(mean_squared_error(auto_mpg_y_test, test_est))
```

```
       alpha  mse_training
0   0.010000  1.972935e+11
0   0.021544  1.972935e+11
0   0.046416  1.972935e+11
0   0.100000  1.972935e+11
0   0.215443  1.972935e+11
0   0.464159  1.972935e+11
0   1.000000  1.972936e+11
0   2.154435  1.972936e+11
0   4.641589  1.972940e+11
0  10.000000  1.972955e+11
MSE using predicted from model on train set: 
197293544796.42923
MSE using predicted from model on val set: 
253558252544.48474
MSE using predicted from model on test set: 
217717789256.16647
```

Part 2: Logistic Regression

Gender Recognition by Voice and Speech Analysis

This dataset is used to identify a voice as male or female, based upon acoustic properties of the voice and speech.

In [57]:
```
voice_df = pd.read_csv("voice-classification.csv")
voice_df.head()
```

Out[57]:

	meanfreq	sd	median	Q25	Q75	IQR	skew	kurt	sp.ent	sfm	...	centroid	meanfu
0	0.059781	0.064241	0.032027	0.015071	0.090193	0.075122	12.863462	274.402906	0.893369	0.491918	...	0.059781	0.08427
1	0.066009	0.067310	0.040229	0.019414	0.092666	0.073252	22.423285	634.613855	0.892193	0.513724	...	0.066009	0.10793
2	0.077316	0.083829	0.036718	0.008701	0.131908	0.123207	30.757155	1024.927705	0.846389	0.478905	...	0.077316	0.09870
3	0.151228	0.072111	0.158011	0.096582	0.207955	0.111374	1.232831	4.177296	0.963322	0.727232	...	0.151228	0.08896
4	0.135120	0.079146	0.124656	0.078720	0.206045	0.127325	1.101174	4.333713	0.971955	0.783568	...	0.135120	0.10639

5 rows × 21 columns

Data - Checking Rows & Columns

In [58]:
```
#Number of Rows & Columns
print(voice_df.shape)
```

```
(3168, 21)
```

2.1 What is the probability of observing different categories in the Label feature of the dataset?

This is mainly to check class imbalance in the dataset, and to apply different techniques to balance the dataset, which we will learn later.

In [59]:
```
voice_df.label.unique()
```

Out[59]:
```
array(['male', 'female'], dtype=object)
```

In [60]:
```
#code here
male_count = len(voice_df[voice_df['label'] == 'male'])
female_count = len(voice_df[voice_df['label'] == 'female'])
```

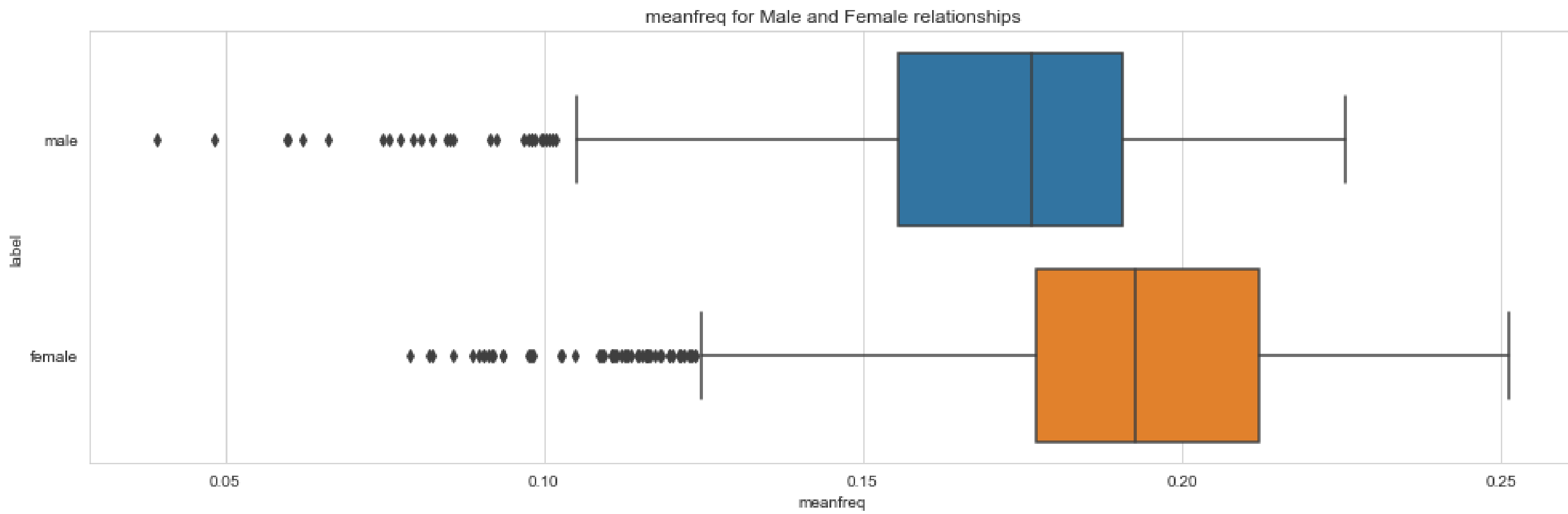
```
female_count / (female_count + male_count)
```

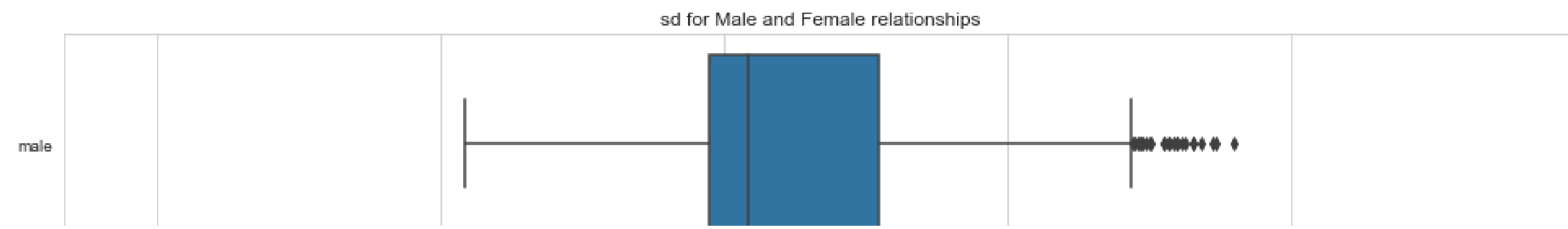
Out[60]: 0.5

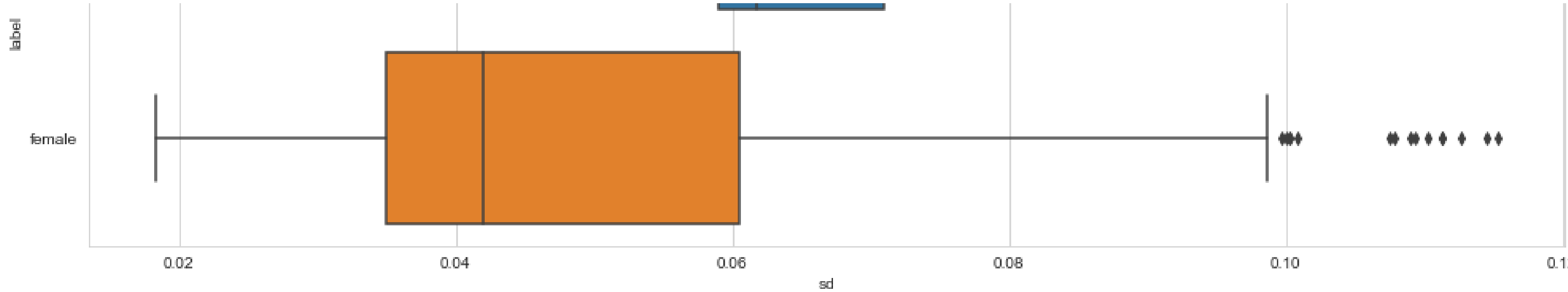
2.2 Plot the relationships between the label and the 20 numerical features using a small multiple of box plots. Make sure to label the axes. What useful information do this plot provide?

In [61]:

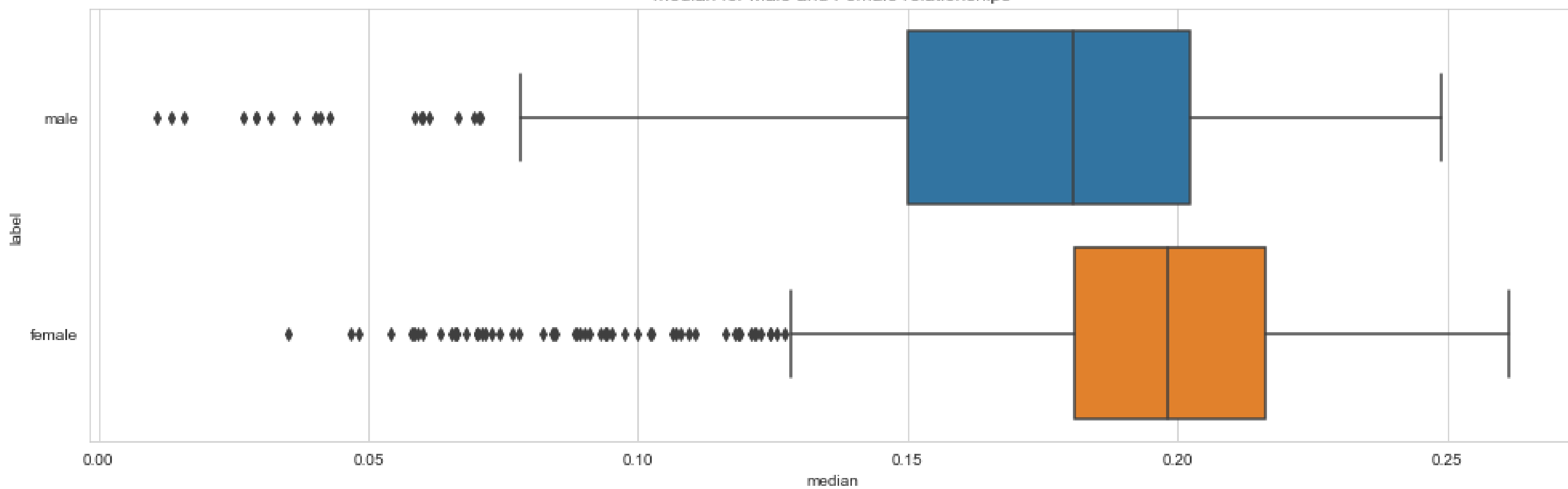
```
#code here
import seaborn as sns
fig, ax = plt.subplots(20,1, figsize=(14,90))
i = 0
for col in voice_df.drop(columns=['label']).columns.values.tolist():
    sns.boxplot(x=voice_df[col],y=voice_df['label'], ax=ax[i])
    ax[i].set_title("% s for Male and Female relationships"% col)
    i = i + 1
fig.tight_layout()
plt.show()
```



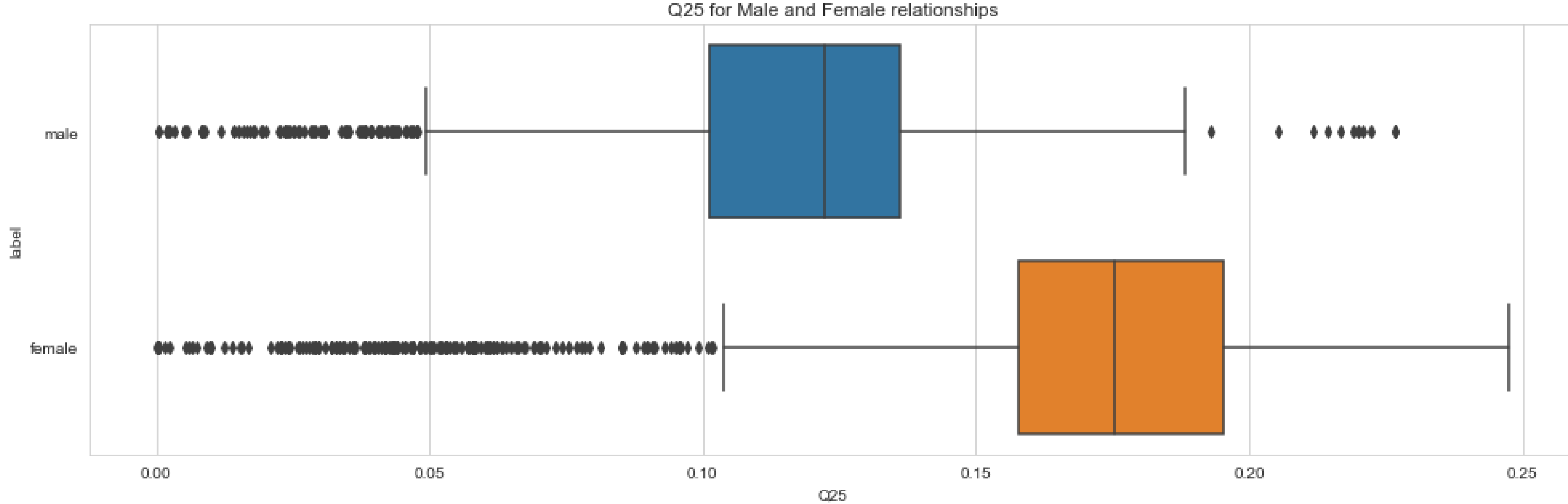




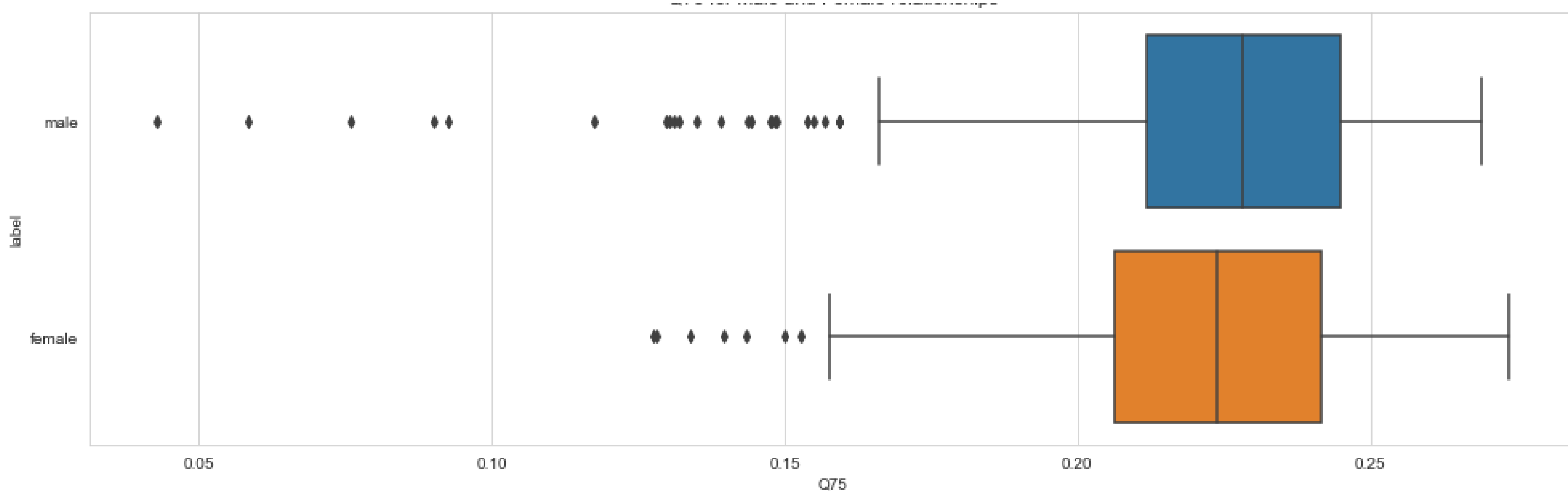
median for Male and Female relationships



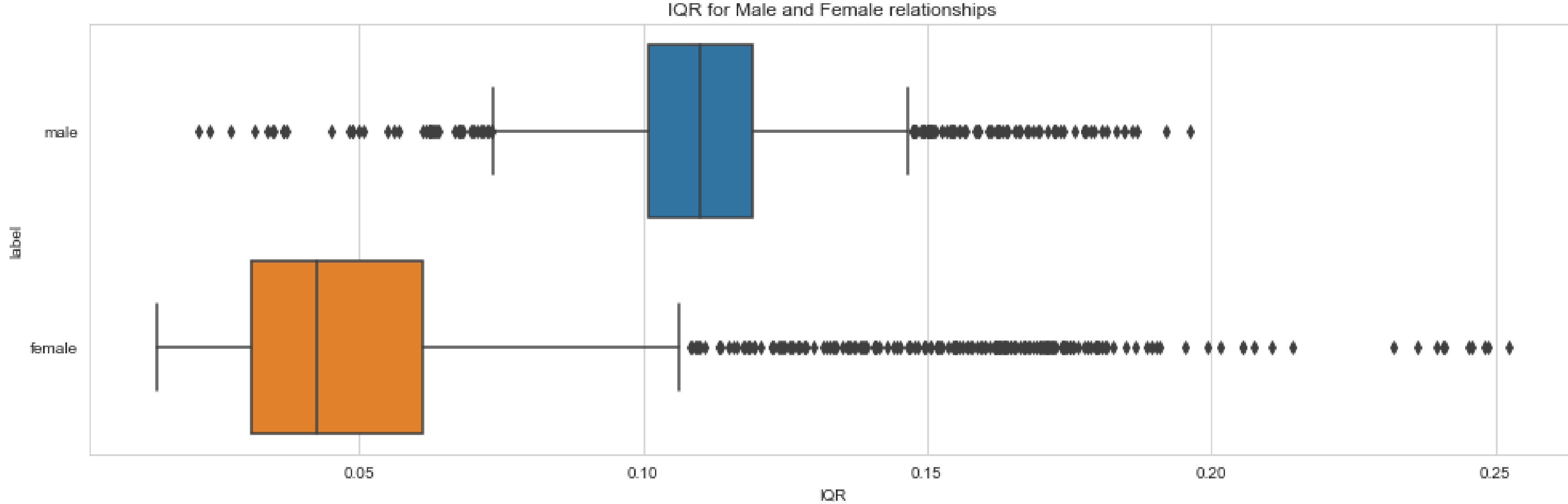
Q25 for Male and Female relationships



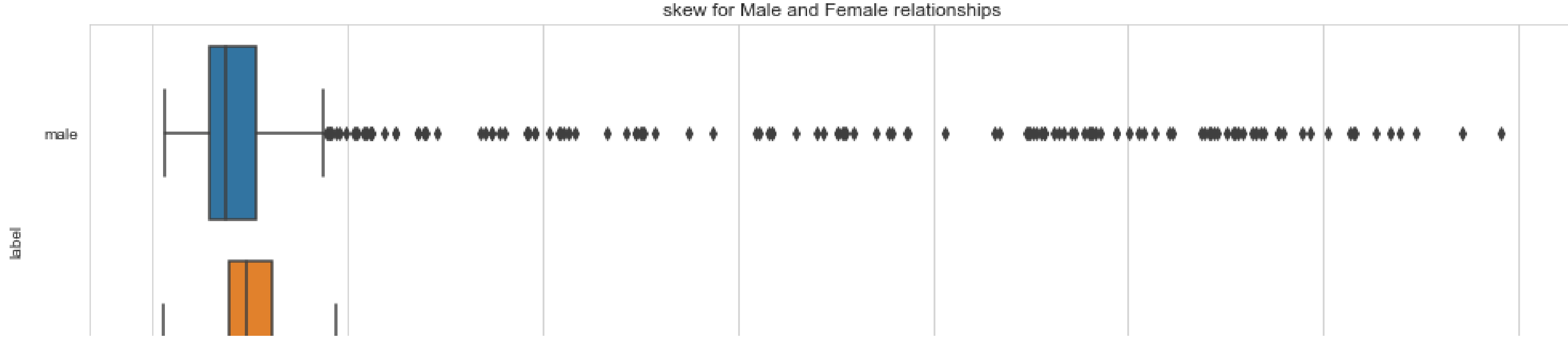
Q75 for Male and Female relationships

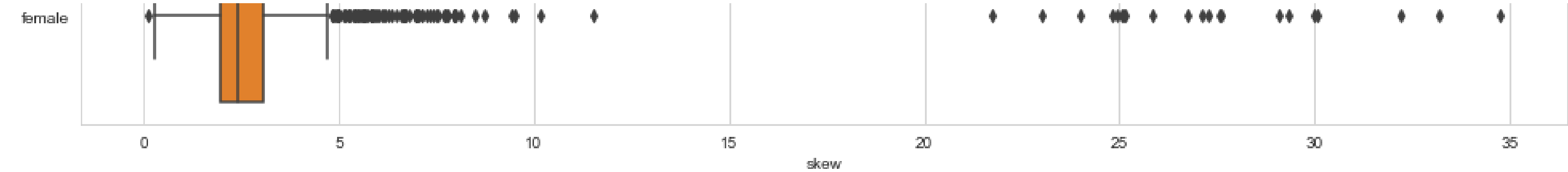


IQR for Male and Female relationships

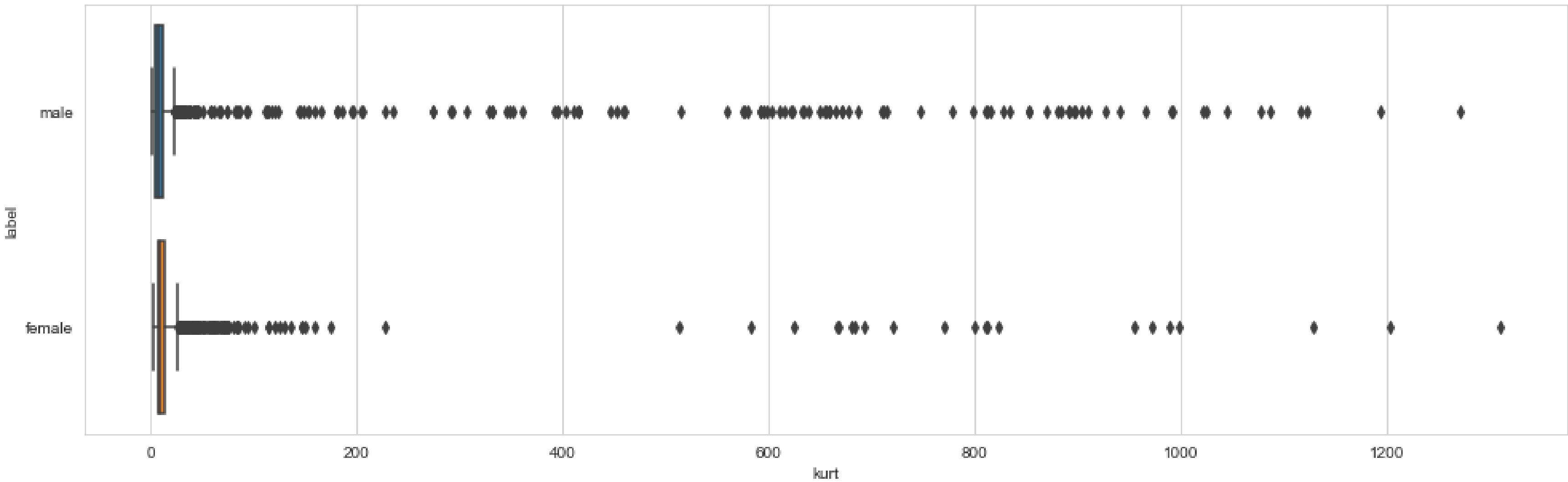


skew for Male and Female relationships

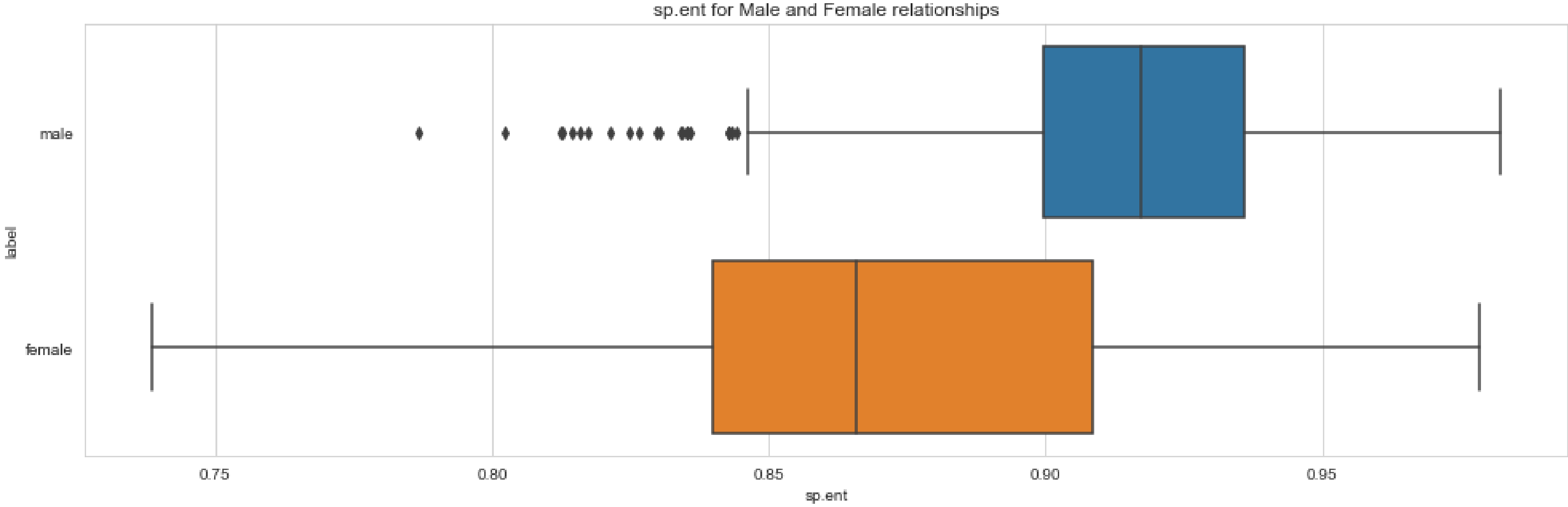




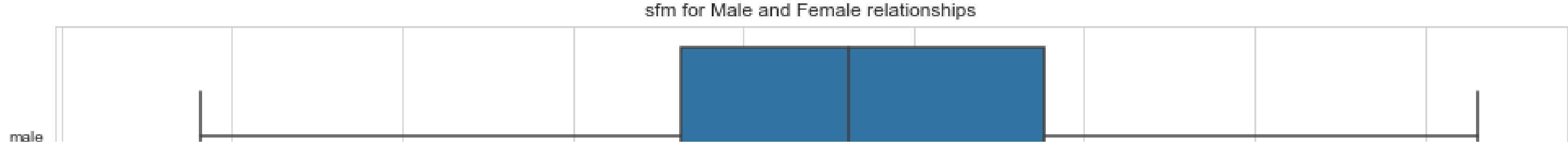
kurt for Male and Female relationships

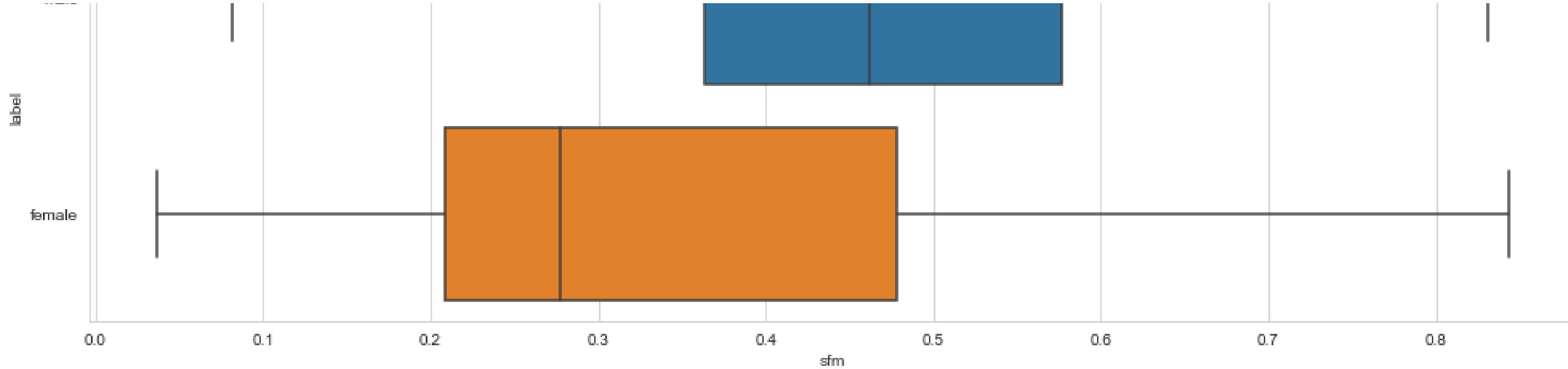


sp.ent for Male and Female relationships

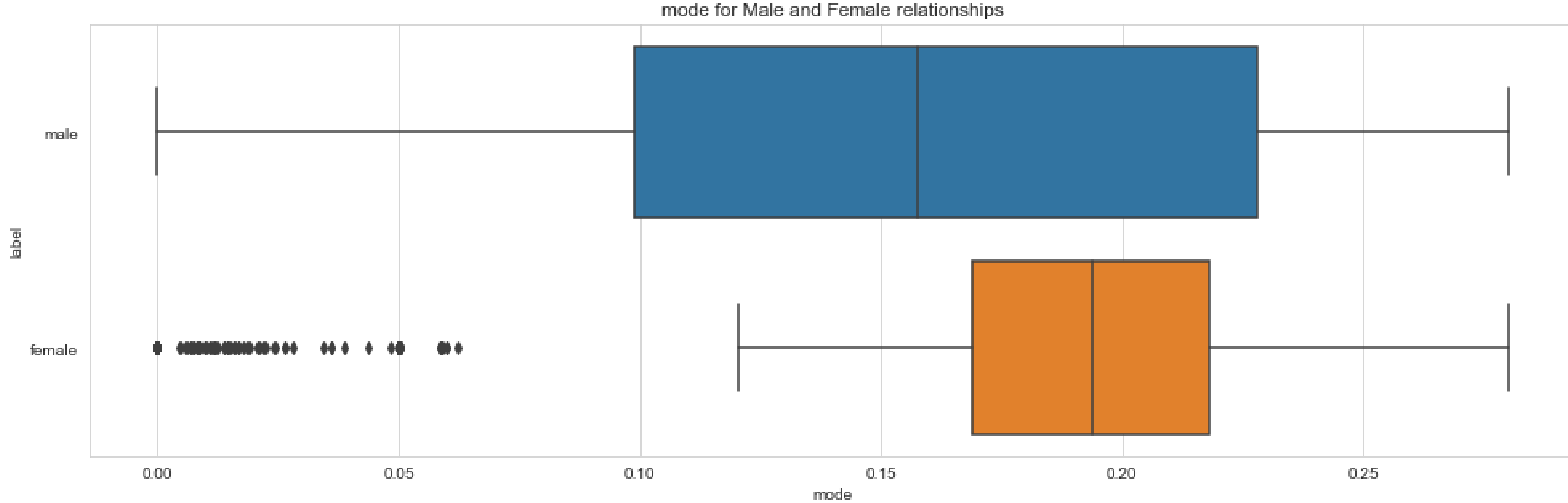


sfm for Male and Female relationships

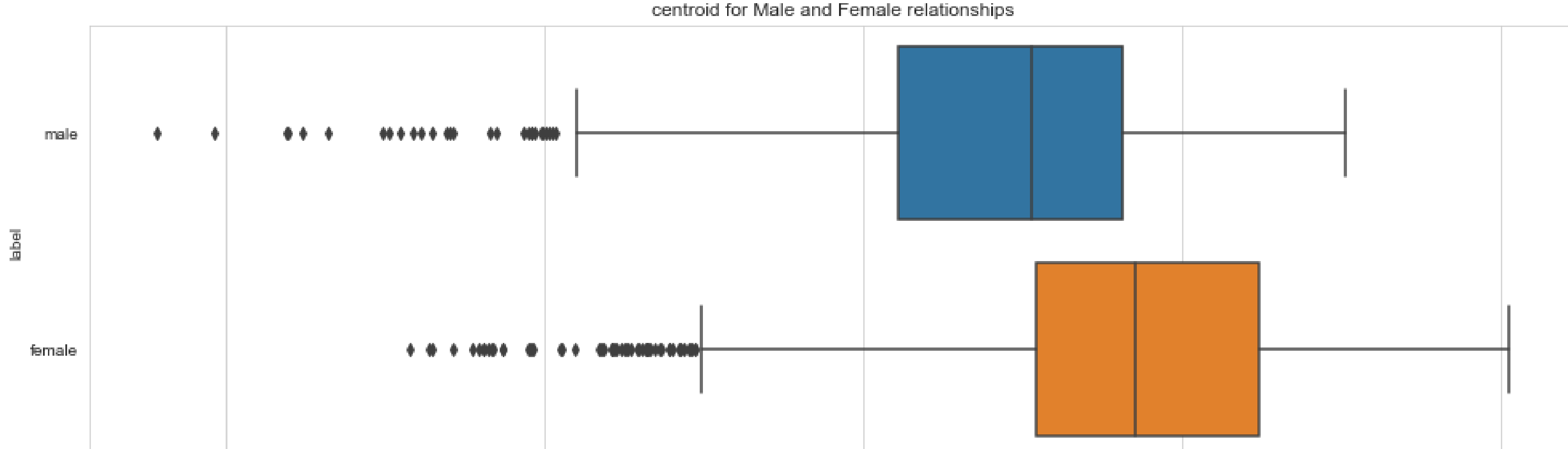




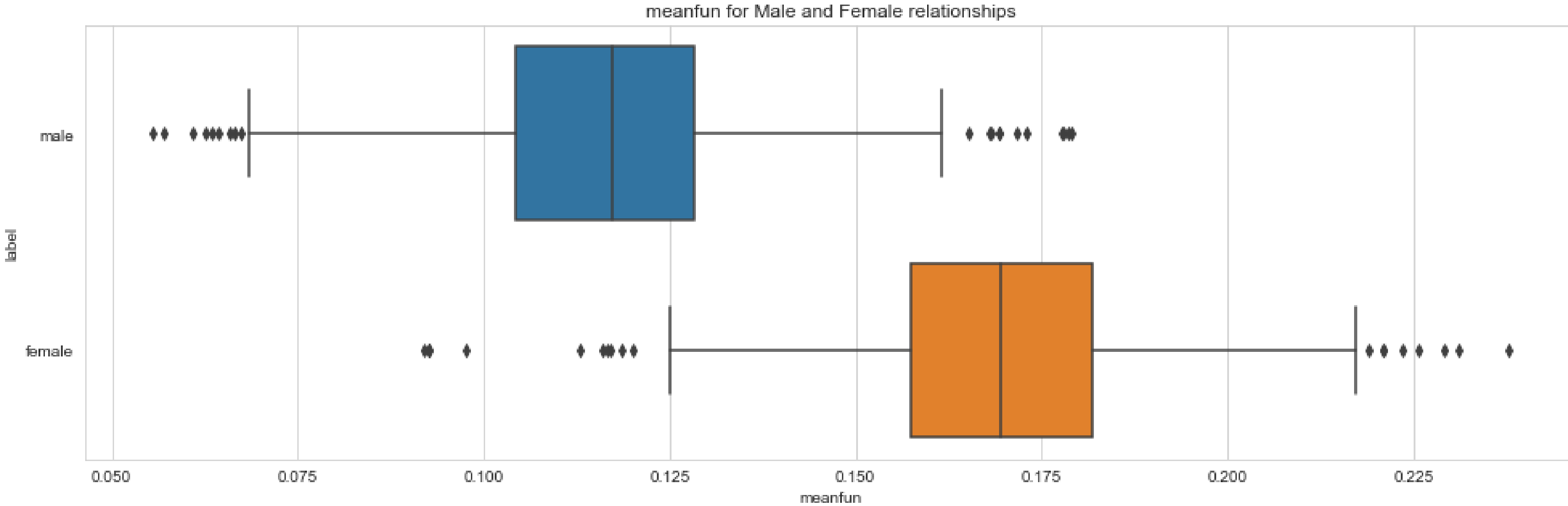
mode for Male and Female relationships

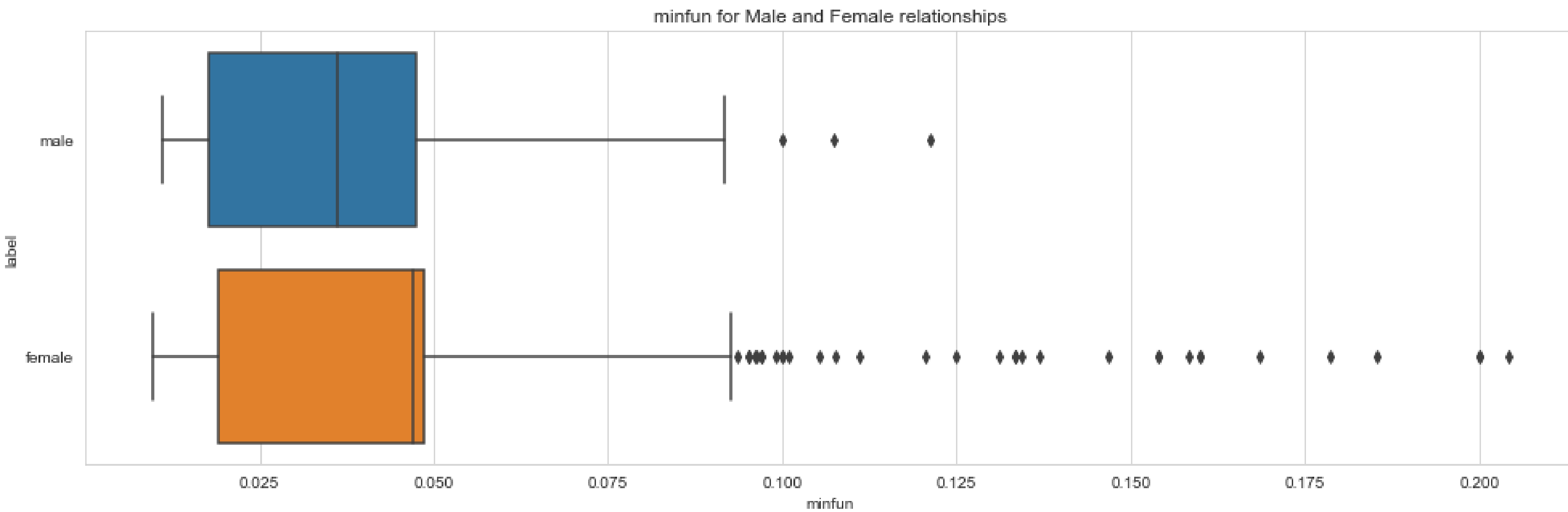


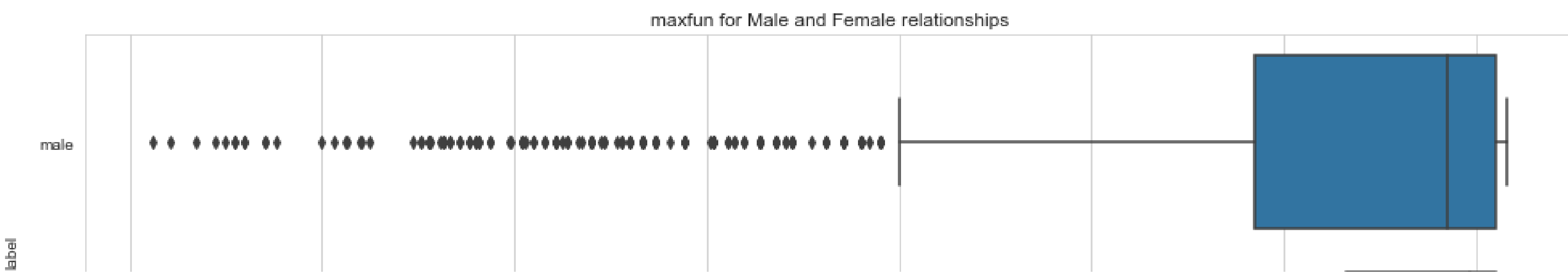
centroid for Male and Female relationships

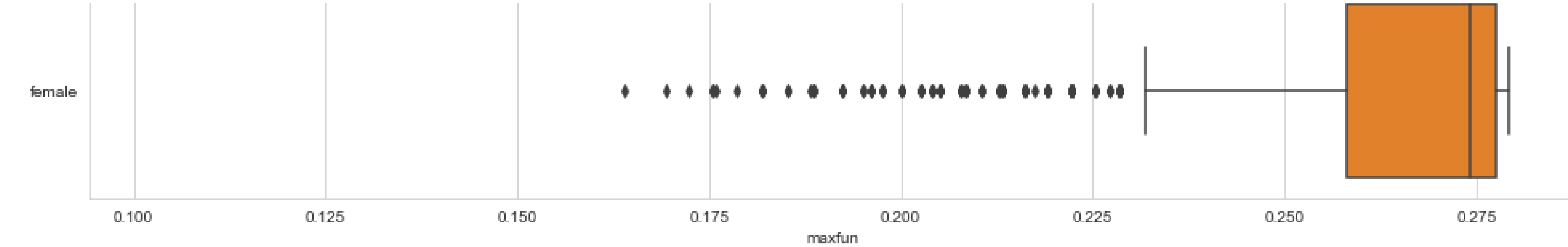


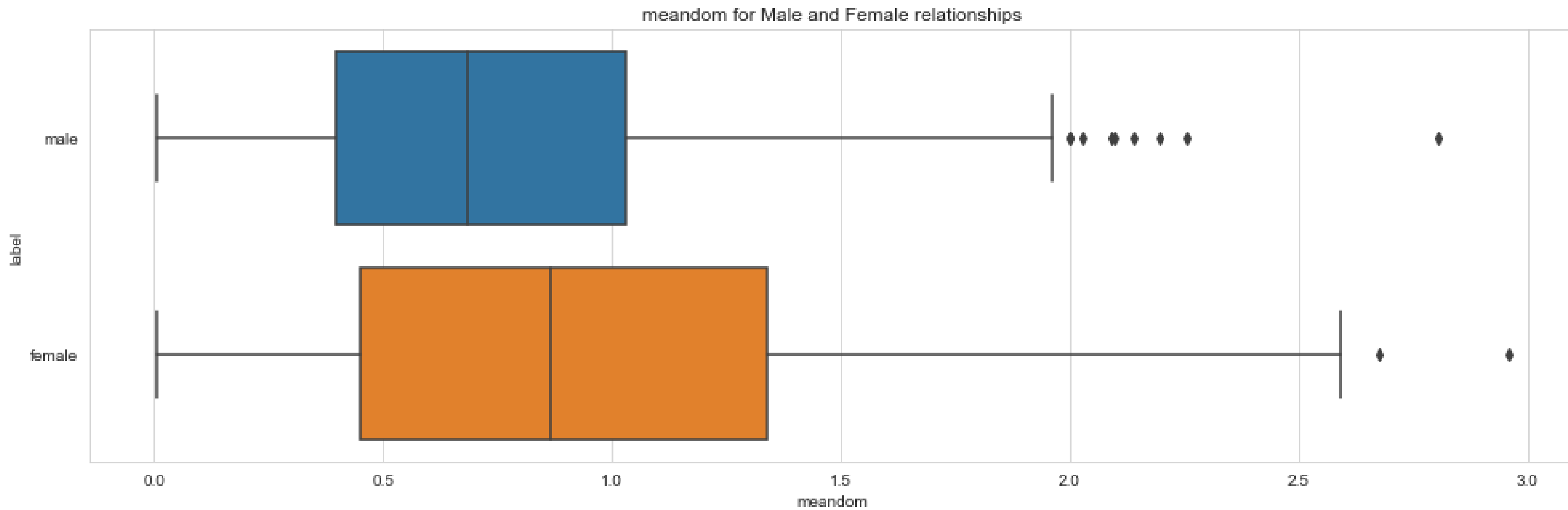

0.05
0.10
0.15
0.20
0.25
centroid

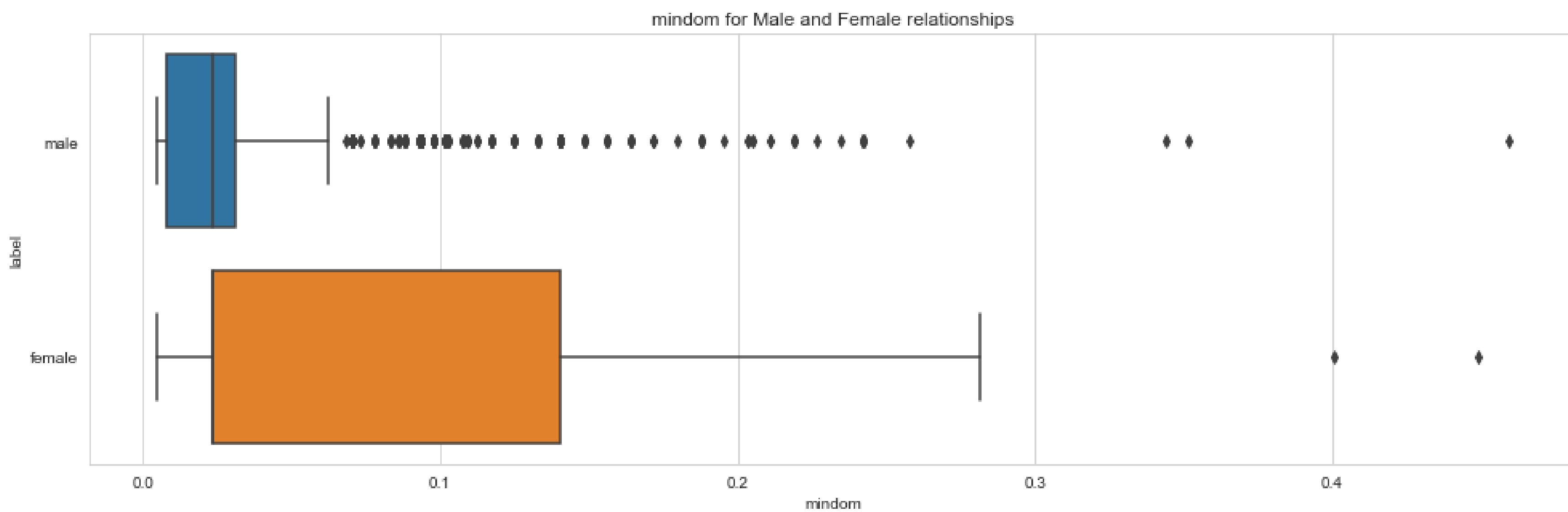

meanfun for Male and Female relationships
label
male
female
0.050
0.075
0.100
0.125
0.150
0.175
0.200
0.225
meanfun

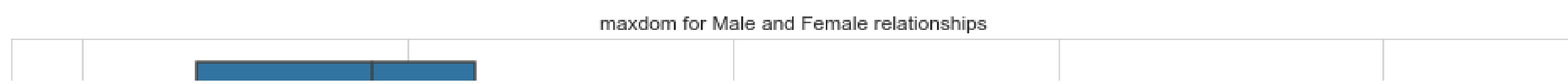

minfun for Male and Female relationships
label
male
female
0.025
0.050
0.075
0.100
0.125
0.150
0.175
0.200
minfun

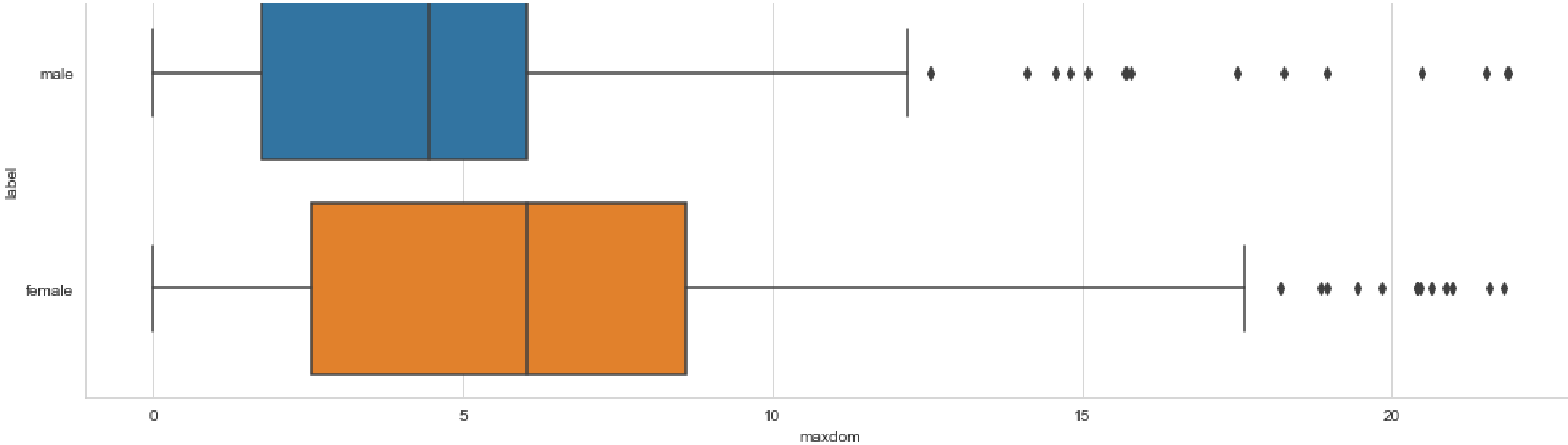

maxfun for Male and Female relationships
label
male


female
0.100
0.125
0.150
0.175
0.200
0.225
0.250
0.275
maxfun

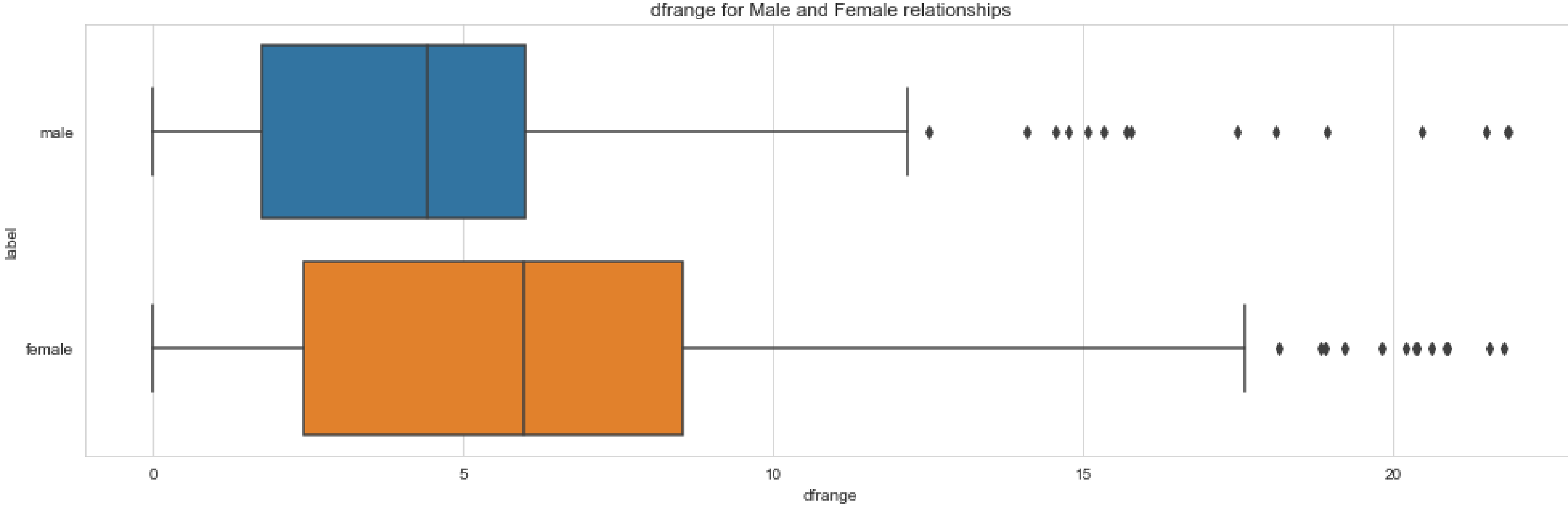

meandom for Male and Female relationships
male
female
label
0.0
0.5
1.0
1.5
2.0
2.5
3.0
meandom


mindom for Male and Female relationships
male
female
label
0.0
0.1
0.2
0.3
0.4
mindom

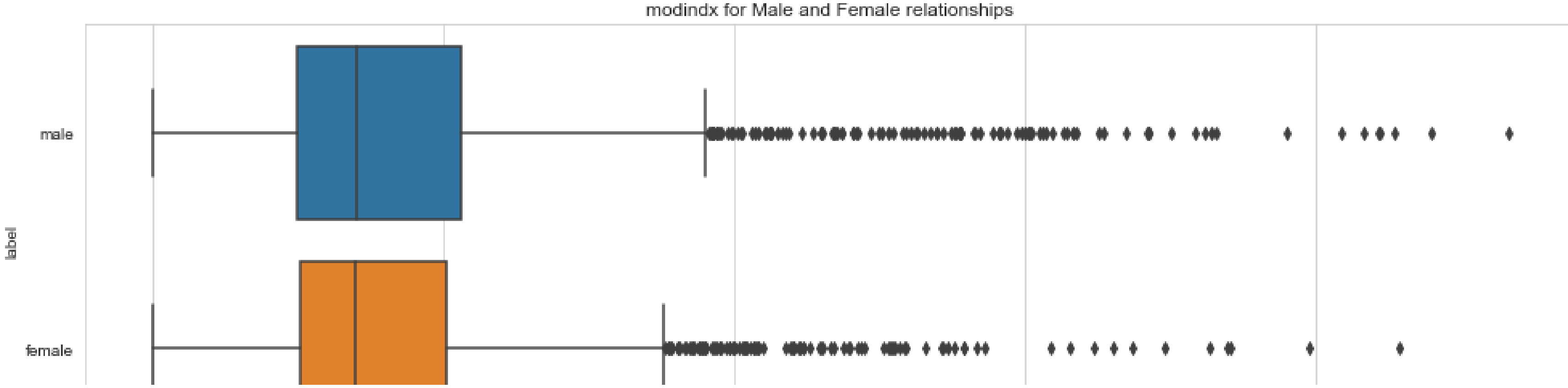

maxdom for Male and Female relationships



dfrange for Male and Female relationships



modindx for Male and Female relationships



In [62]:
```
corr = voice_df.corr()
corr.style.background_gradient(cmap='coolwarm')
```

Out[62]:

	meanfreq	sd	median	Q25	Q75	IQR	skew	kurt	sp.ent	sfm	mode
meanfreq	1.000000	-0.739039	0.925445	0.911416	0.740997	-0.627605	-0.322327	-0.316036	-0.601203	-0.784332	0.687715
sd	-0.739039	1.000000	-0.562603	-0.846931	-0.161076	0.874660	0.314597	0.346241	0.716620	0.838086	-0.529150
median	0.925445	-0.562603	1.000000	0.774922	0.731849	-0.477352	-0.257407	-0.243382	-0.502005	-0.661690	0.677433
Q25	0.911416	-0.846931	0.774922	1.000000	0.477140	-0.874189	-0.319475	-0.350182	-0.648126	-0.766875	0.591277
Q75	0.740997	-0.161076	0.731849	0.477140	1.000000	0.009636	-0.206339	-0.148881	-0.174905	-0.378198	0.486857
IQR	-0.627605	0.874660	-0.477352	-0.874189	0.009636	1.000000	0.249497	0.316185	0.640813	0.663601	-0.403764
skew	-0.322327	0.314597	-0.257407	-0.319475	-0.206339	0.249497	1.000000	0.977020	-0.195459	0.079694	-0.434859
kurt	-0.316036	0.346241	-0.243382	-0.350182	-0.148881	0.316185	0.977020	1.000000	-0.127644	0.109884	-0.406722
sp.ent	-0.601203	0.716620	-0.502005	-0.648126	-0.174905	0.640813	-0.195459	-0.127644	1.000000	0.866411	-0.325298
sfm	-0.784332	0.838086	-0.661690	-0.766875	-0.378198	0.663601	0.079694	0.109884	0.866411	1.000000	-0.485913
mode	0.687715	-0.529150	0.677433	0.591277	0.486857	-0.403764	-0.434859	-0.406722	-0.325298	-0.485913	1.000000
centroid	1.000000	-0.739039	0.925445	0.911416	0.740997	-0.627605	-0.322327	-0.316036	-0.601203	-0.784332	0.687715
meanfun	0.460844	-0.466281	0.414909	0.545035	0.155091	-0.534462	-0.167668	-0.194560	-0.513194	-0.421066	0.324771
minfun	0.383937	-0.345609	0.337602	0.320994	0.258002	-0.222680	-0.216954	-0.203201	-0.305826	-0.362100	0.385467
maxfun	0.274004	-0.129662	0.251328	0.199841	0.285584	-0.069588	-0.080861	-0.045667	-0.120738	-0.192369	0.172329
meandom	0.536666	-0.482726	0.455943	0.467403	0.359181	-0.333362	-0.336848	-0.303234	-0.293562	-0.428442	0.491479
mindom	0.229261	-0.357667	0.191169	0.302255	-0.023750	-0.357037	-0.061608	-0.103313	-0.294869	-0.289593	0.198150
maxdom	0.519528	-0.482278	0.438919	0.459683	0.335114	-0.337877	-0.305651	-0.274500	-0.324253	-0.436649	0.477187
dfrange	0.515570	-0.475999	0.435621	0.454394	0.335648	-0.331563	-0.304640	-0.272729	-0.319054	-0.431580	0.473775
modindx	-0.216979	0.122660	-0.213298	-0.141377	-0.216475	0.041252	-0.169325	-0.205539	0.198074	0.211477	-0.182344

2.3 Plot the correlation matrix, and check if there is high correlation between the given numerical features (Threshold >=0.9). If yes, drop those highly correlated features from the dataframe. Why is necessary to drop those columns before proceeding further?

In [63]:
```
voice_y = voice_df['label']
```

In [64]:
```
def trimm_correlated(df_in, threshold):
    df_corr = df_in.corr(method='pearson', min_periods=1)
    df_not_correlated = ~(df_corr.mask(np.tril(np.ones([len(df_corr)]*2, dtype=bool))).abs() >= threshold).any(
    un_corr_idx = df_not_correlated.loc[df_not_correlated[df_not_correlated.index] == True].index
    df_out = df_in[un_corr_idx]
    return df_out
```

In [65]:
```
voice_df1 = trimm_correlated(voice_df, 0.9)
```

In [66]:
```
voice_df1['label'] = voice_y
```

In [67]:
```
# Split data into features and labels
voice_X = voice_df1.drop(columns=['label']) #replace "voice_df1" with your dataframe from 2.3 to make sure the
voice_y = voice_df1['label']
print(voice_X.columns)
```

```
Index(['meanfreq', 'sd', 'Q75', 'IQR', 'skew', 'sp.ent', 'sfm', 'mode',
       'meanfun', 'minfun', 'maxfun', 'meandom', 'mindom', 'maxdom',
       'modindx'],
      dtype='object')
```

2.4 Apply the following pre-processing steps:

1) Use OrdinalEncoding to encode the label in the dataset (male & female)

2) Convert the label from a Pandas series to a Numpy (m x 1) vector. If you don't do this, it may cause problems when implementing the logistic regression model.

3)Split the dataset into training (60%), validation (20%), and test (20%) sets.

4) Standardize the columns in the feature matrices. To avoid information leakage, learn the standardization parameters from training, and then apply training, validation and test dataset.

5) Add a column of ones to the feature matrices of train, validation and test dataset. This is a common trick so that we can learn a coefficient for the bias term of a linear model.

In [68]:
```
voice_df1
```

Out[68]:

	meanfreq	sd	Q75	IQR	skew	sp.ent	sfm	mode	meanfun	minfun	maxfun	meandom
0	0.059781	0.064241	0.090193	0.075122	12.863462	0.893369	0.491918	0.000000	0.084279	0.015702	0.275862	0.007812
1	0.066009	0.067310	0.092666	0.073252	22.423285	0.892193	0.513724	0.000000	0.107937	0.015826	0.250000	0.009014
2	0.077316	0.083829	0.131908	0.123207	30.757155	0.846389	0.478905	0.000000	0.098706	0.015656	0.271186	0.007990
3	0.151228	0.072111	0.207955	0.111374	1.232831	0.963322	0.727232	0.083878	0.088965	0.017798	0.250000	0.201497
4	0.135120	0.079146	0.206045	0.127325	1.101174	0.971955	0.783568	0.104261	0.106398	0.016931	0.266667	0.712812
...	...	...	...	...	...	...	...	...	...	...	...	...
3163	0.131884	0.084734	0.201144	0.151859	1.762129	0.962934	0.763182	0.200836	0.182790	0.083770	0.262295	0.832899
3164	0.116221	0.089221	0.204911	0.162193	0.693730	0.960716	0.709570	0.013683	0.188980	0.034409	0.275862	0.909856
3165	0.142056	0.095798	0.224360	0.190936	1.876502	0.946854	0.654196	0.008006	0.209918	0.039506	0.275862	0.494271
3166	0.143659	0.090628	0.219943	0.176435	1.591065	0.950436	0.675470	0.212202	0.172375	0.034483	0.250000	0.791360
3167	0.165509	0.092884	0.250827	0.180756	1.705029	0.938829	0.601529	0.267702	0.185607	0.062257	0.271186	0.227022

3168 rows × 16 columns

In [69]:
```
#code here
enc = OrdinalEncoder()

voice_df1['encoded_label'] = np.where(voice_df1['label'] == 'male', 1, 0)
voice_y = voice_df1['encoded_label']
voice_df1.drop('encoded_label', axis=1)
voice_y = voice_y.to_numpy()
voice_y = voice_y.reshape((voice_y.shape[0],1))

voice_X_dev, voice_X_test, voice_y_dev, voice_y_test = train_test_split(
    voice_X, voice_y, test_size=0.2, random_state=0)
```

```
voice_X_train, voice_X_val, voice_y_train, voice_y_val = train_test_split(
    voice_X_dev, voice_y_dev, test_size=0.25, random_state=0)


scaler = StandardScaler()
voice_X_train = scaler.fit_transform(voice_X_train)
voice_X_val = scaler.transform(voice_X_val)
voice_X_test = scaler.transform(voice_X_test)

voice_X_train = np.hstack([np.ones((voice_X_train.shape[0], 1)), voice_X_train])
voice_X_val = np.hstack([np.ones((voice_X_val.shape[0], 1)), voice_X_val])
voice_X_test = np.hstack([np.ones((voice_X_test.shape[0], 1)), voice_X_test])
```

2.5 Implement Logistic Regression

We will now implement logistic regression with L2 regularization. Given an (m x n) feature matrix X, an (m x 1) label vector y, and an (n x 1) weight vector w, the hypothesis function for logistic regression is:

$$y = \sigma(Xw)$$

where $\sigma(x) = \frac{1}{1+e^{-x}}$, i.e. the sigmoid function. This function scales the prediction to be a probability between 0 and 1, and can then be thresholded to get a discrete class prediction.

Just as with linear regression, our objective in logistic regression is to learn the weights w which best fit the data. For L2-regularized logistic regression, we find an optimal w to minimize the following loss function:

$$\min_{w} \ -y^T \log(\sigma(Xw)) \ - \ (\mathbf{1} - y)^T \log(\mathbf{1} - \sigma(Xw)) \ + \ \alpha \|w\|_2^2$$

Unlike linear regression, however, logistic regression has no closed-form solution for the optimal w. So, we will use gradient descent to find the optimal w. The (n x 1) gradient vector g for the loss function above is:

$$g = X^T \Big(\sigma(Xw) - y\Big) + 2\alpha w$$

Below is pseudocode for gradient descent to find the optimal w. You should first initialize w (e.g. to a (n x 1) zero vector). Then, for some number of epochs t, you should update w with $w - \eta g$, where η is the learning rate and g is the gradient. You can learn more about gradient descent here.

> $w = \mathbf{0}$

> for $i = 1, 2, \ldots, t$
>
> $$w = w - \eta g$$

Implement a LogisticRegression class with five methods: train, predict, calculate_loss, calculate_gradient, and calculate_sigmoid. **You may NOT use sklearn for this implementation. It is highly recommended that you vectorize your code.**

In [70]:

```
import math

class LogisticRegression():
    '''
    Logistic regression model with L2 regularization.

    Attributes
    ----------
    alpha: regularization parameter
    t: number of epochs to run gradient descent
    eta: learning rate for gradient descent
    w: (n x 1) weight vector
    '''

    def __init__(self, alpha, t, eta):
        self.alpha = alpha
        self.t = t
        self.eta = eta
        self.w = None

    def train(self, X, y):
        '''Trains logistic regression model using gradient descent
        (sets w to its optimal value).

        Parameters
        ----------
        X : (m x n) feature matrix
        y: (m x 1) label vector

        Returns
        -------
        losses: (t x 1) vector of losses at each epoch of gradient descent
        '''
        ### Your code here
        losses = []
        num_rows, num_cols = X.shape
```

```
        self.w = np.zeros((num_cols,1))
        for i in range(self.t):
            self.w = self.w  - self.eta * self.calculate_gradient(X, y)
            curr_loss = self.calculate_loss(X, y)
            losses.append(curr_loss)
        losses_array = np.array(losses)
        return losses_array

    def predict(self, X):
        '''Predicts on X using trained model. Make sure to threshold
        the predicted probability to return a 0 or 1 prediction.

        Parameters
        ----------
        X : (m x n) feature matrix

        Returns
        -------
        y_pred: (m x 1) 0/1 prediction vector
        '''
        ### Your code here
        values = self.calculate_sigmoid(np.matmul(X, self.w))
        values[values >= .5] = 1
        values[values < 1] = 0
        return values

    def calculate_loss(self, X, y):
        '''Calculates the logistic regression loss using X, y, w,
        and alpha. Useful as a helper function for train().

        Parameters
        ----------
        X : (m x n) feature matrix
        y: (m x 1) label vector

        Returns
        -------
        loss: (scalar) logistic regression loss
        '''
        ### Your code here
        sigma_val = self.calculate_sigmoid(np.matmul(X,self.w))
        LHS = np.matmul(y.T, np.log(sigma_val))
        RHS = np.matmul((1 - y).T, np.log(1 - sigma_val))
        reg_term = self.alpha * np.linalg.norm(self.w,ord=2) * np.linalg.norm(self.w,ord=2)
        output = (-LHS - RHS + reg_term)[0]
```

```
        return output

    def calculate_gradient(self, X, y):
        '''Calculates the gradient of the logistic regression loss
        using X, y, w, and alpha. Useful as a helper function
        for train().

        Parameters
        ----------
        X : (m x n) feature matrix
        y: (m x 1) label vector

        Returns
        -------
        gradient: (n x 1) gradient vector for logistic regression loss
        '''
        ### Your code here
        inside = self.calculate_sigmoid(np.matmul(X, self.w)) - y
        gradient = np.matmul(X.T,inside) + 2*self.alpha*self.w
        return gradient

    def calculate_sigmoid(self, x):
        '''Calculates the sigmoid function on each element in vector x.
        Useful as a helper function for predict(), calculate_loss(),
        and calculate_gradient().

        Parameters
        ----------
        x: (m x 1) vector

        Returns
        -------
        sigmoid_x: (m x 1) vector of sigmoid on each element in x
        '''
        ### Your code here
        sigmoid_x = []
        for curr_x in x:
            val = 1/(1 + pow(math.e, -curr_x[0])) #change if neccesary
            sigmoid_x.append([val],)
        sigmoid_x = np.array(sigmoid_x)
        return sigmoid_x
```

2.6 Plot Loss over Epoch and Search the space randomly to find best hyperparameters.

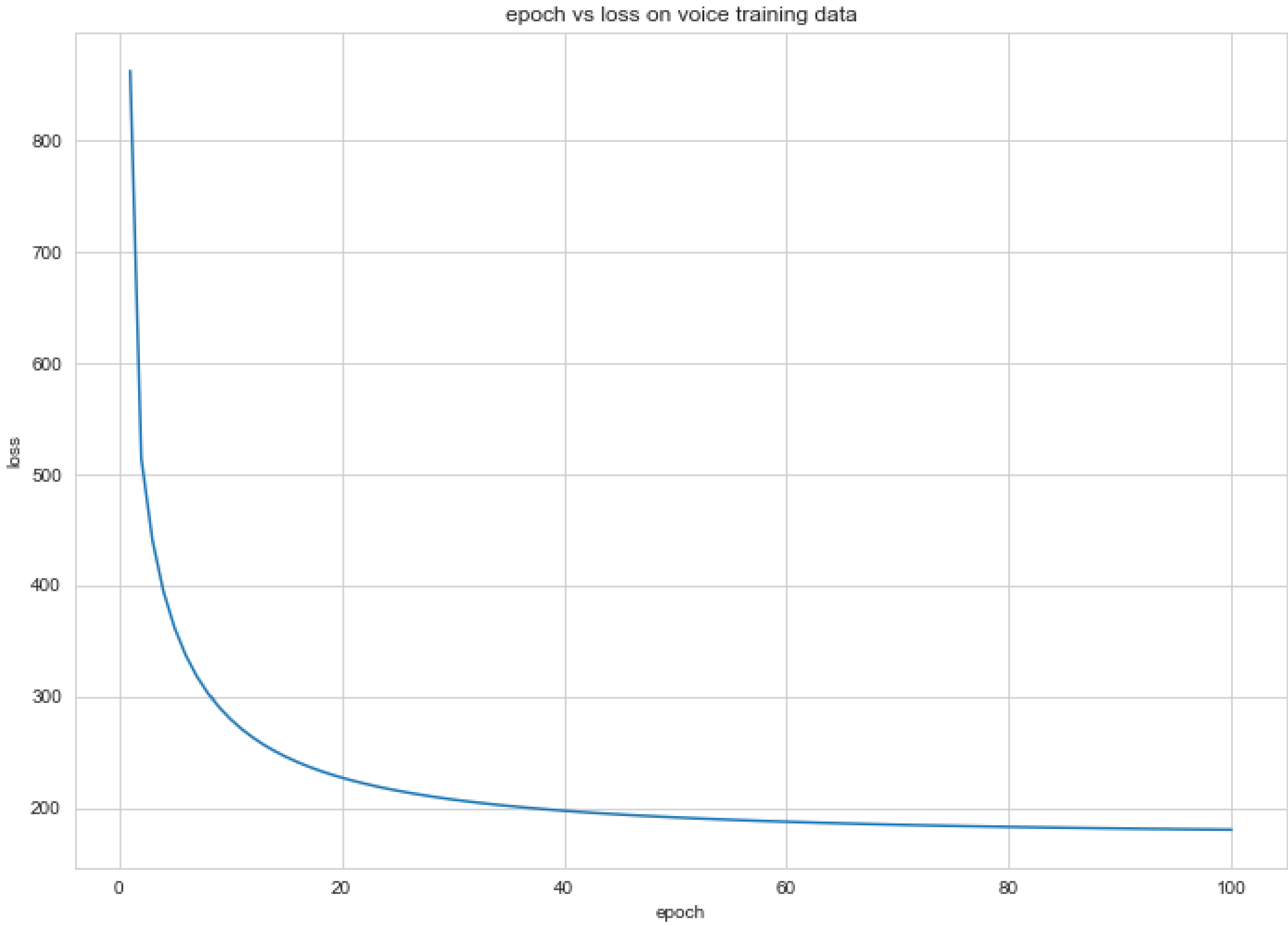
A: Using your implementation above, train a logistic regression model **(alpha=0, t=100, eta=1e-3)** on the voice recognition training data. Plot the training loss over epochs. Make sure to label your axes. You should see the loss decreasing and start to converge.

B: Using **alpha between (0,1), eta between(0, 0.001) and t between (0, 100)**, find the best hyperparameters for LogisticRegression. You can randomly search the space 20 times to find the best hyperparameters.

C. Compare accuracy on the test dataset for both the scenarios.

In [71]:

```
#code here
model = LogisticRegression(0, 100, 1e-3)
losses = model.train(voice_X_train,voice_y_train)
plt.plot(list(range(1,101)), losses)
plt.xlabel('epoch')
plt.ylabel('loss')
plt.title('epoch vs loss on voice training data')
plt.show()
```



In [72]:

```
def print_label(labels):
    toret = []
    for i in labels:
        if i == 1:
            toret.append('male')
        else:
            toret.append('female')
    print(toret)
```

In [80]:

```
best_train = float("-inf")
best_val = float("-inf")
```

```
best_test = float("-inf")
best_hyper = {'alpha' : 0, 't' : 0, 'eta' : 0}
pred_test = []
_actual = []

for i in range(1, 21):

    model = LogisticRegression(i/20, i*5, i/100000 + 0.0008)
    model.train(voice_X_train,voice_y_train)

    y_pred_train = model.predict(voice_X_train)
    y_true_train = voice_y_train
    current_train = accuracy_score(y_true_train, y_pred_train)

    y_pred_val = model.predict(voice_X_val)
    y_true_val = voice_y_val
    current_val = accuracy_score(y_true_val, y_pred_val)

    y_pred_test = model.predict(voice_X_test)
    y_true_test = voice_y_test
    current_test = accuracy_score(y_true_test, y_pred_test)

    if current_train > best_train and current_val > best_val and current_test > best_test:
        best_train = current_train
        best_val = current_val
        best_test = current_test
        best_hyper['alpha'] = i/20
        best_hyper['t'] = i*5
        best_hyper['eta'] = i/100000 + 0.0008
        pred_test = y_pred_test
        _actual = y_true_test
print(best_train)
print(best_val)
print(best_train)
print('best hyperparameters -->' , best_hyper)

print('first five predictions:')
print_label(pred_test[:5])
print('actual: ')
print_label(_actual[:5])
```

```
0.9689473684210527
0.9842271293375394
0.9689473684210527
best hyperparameters --> {'alpha': 0.4, 't': 40, 'eta': 0.00088}
```

```
first five predictions:
['female', 'male', 'female', 'female', 'male']
actual:
['female', 'male', 'female', 'female', 'male']
```

2.7 Feature Importance

Interpret your trained model using a bar chart of the model weights. Make sure to label the bars (x-axis) and don't forget the bias term!

In [81]:
```
num_features_voice = ['meanfreq', 'sd', 'Q75', 'IQR', 'skew', 'sp.ent', 'sfm', 'mode', 'meanfun', 'minfun', 'ma
                      'meandom', 'mindom', 'maxdom', 'modindx']
all_features_voice = num_features_voice + ['Bias']
voice_df1['Bias'] = 1
```

In [82]:
```
len(model.w), len(all_features_voice)
```

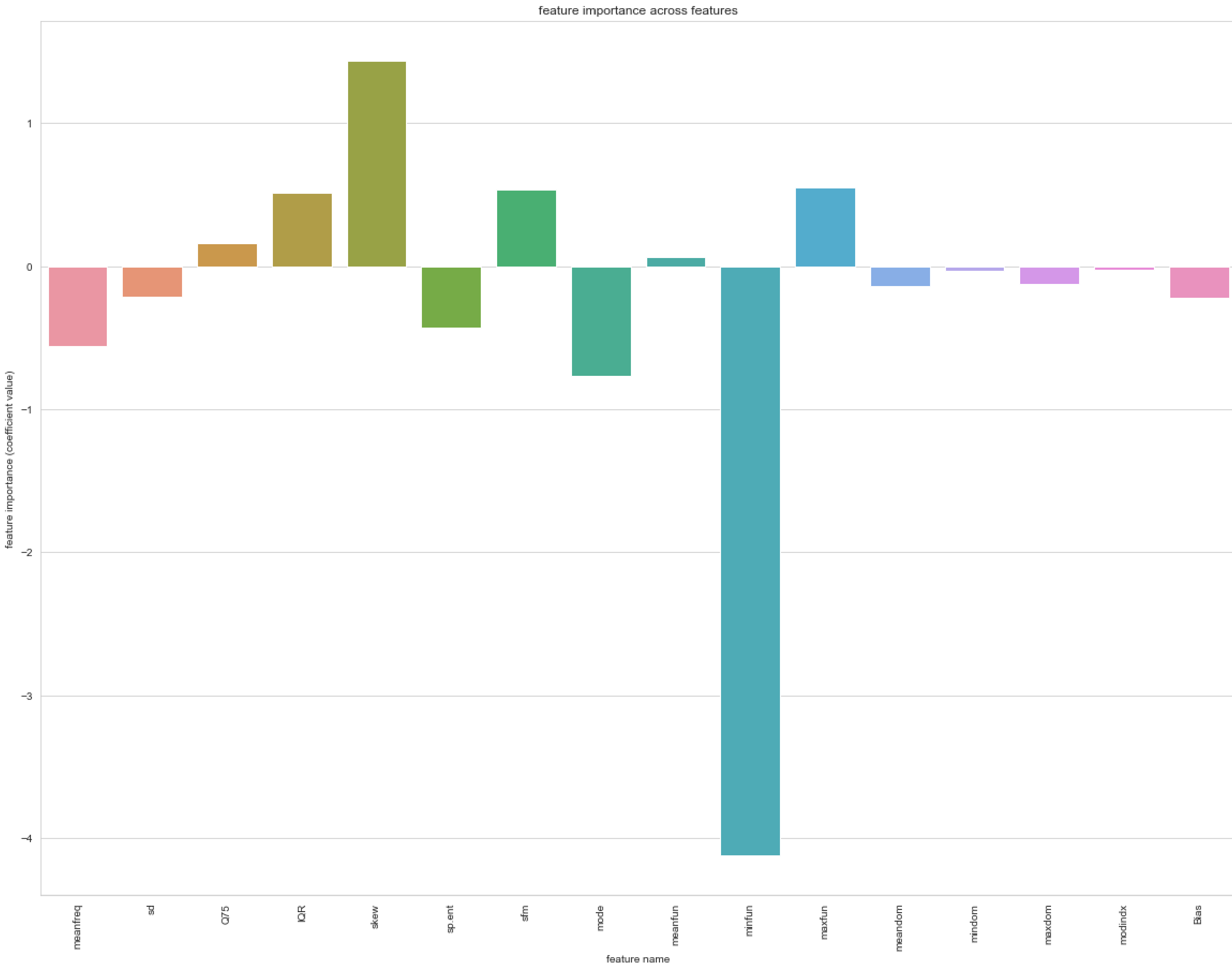
Out[82]:
```
(16, 16)
```

In [83]:
```
model.w
```

Out[83]:
```
array([[-0.55774065],
       [-0.21250378],
       [ 0.16506164],
       [ 0.51191729],
       [ 1.43902154],
       [-0.43196364],
       [ 0.53675256],
       [-0.76813856],
       [ 0.0646603 ],
       [-4.12083387],
       [ 0.55080721],
       [-0.13764874],
       [-0.03262087],
       [-0.12422173],
       [-0.02431183],
       [-0.21985896]])
```

In [84]:
```
#code here
fig = plt.figure(figsize = (20,15))
xval = np.zeros((31))
```

```
yval = np.reshape(model.w, -1)
ax = sns.barplot(x=all_features_voice, y=yval)
ax.tick_params(axis='x', rotation=90)
ax.set_xlabel('feature name')
ax.set_ylabel('feature importance (coefficient value)')
ax.set_title('feature importance across features')
plt.show()
```



Part 3: Support Vector Machines - with the same Dataset

3.1 Dual SVM

A) Train a dual SVM (with default parameters) for both kernel=“linear” and kernel=“rbf”) on the Voice Recognition training data.

B) Make predictions and report the accuracy on the training, validation, and test sets. Which kernel gave better accuracy on test dataset and why do you think that was better?

C) Please report the support vectors in both the cases and what do you observe? Explain

In [85]:

```
#code here
from sklearn import svm
dualModelSVM = svm.SVC(kernel='linear')
dualModelSVM.fit(voice_X_train,voice_y_train)

y_pred_train = dualModelSVM.predict(voice_X_train)
y_true_train = voice_y_train
print('accuracy on train set: ')
print (accuracy_score(y_true_train, y_pred_train))
y_pred_val = dualModelSVM.predict(voice_X_val)
y_true_val = voice_y_val
print('accuracy on val set: ')
print (accuracy_score(y_true_val, y_pred_val))

y_pred_test = dualModelSVM.predict(voice_X_test)
y_true_test = voice_y_test
print('accuracy on test set: ')
print (accuracy_score(y_true_test, y_pred_test))

print('first five predictions:')
print(y_pred_test[:5])
print('actual: ')
print(y_true_test[:5])
```

```
accuracy on train set:
0.9742105263157895
accuracy on val set:
0.9842271293375394
accuracy on test set:
0.9700315457413249
first five predictions:
[0 1 0 0 1]
actual:
```

```
[[0]
 [1]
 [0]
 [0]
 [1]]
/Users/davitbarblishvili/opt/anaconda3/lib/python3.9/site-packages/sklearn/utils/validation.py:63: DataConversionWarning: A column-vector y was passed when a 1d array was expected. Please change the shape of y to (n_samples, ), for example using ravel().
  return f(*args, **kwargs)
```

In [86]:

```
from sklearn import svm
dualModelSVM = svm.SVC(kernel='rbf')
dualModelSVM.fit(voice_X_train,voice_y_train)

y_pred_train = dualModelSVM.predict(voice_X_train)
y_true_train = voice_y_train
print('accuracy on train set: ')
print (accuracy_score(y_true_train, y_pred_train))
y_pred_val = dualModelSVM.predict(voice_X_val)
y_true_val = voice_y_val
print('accuracy on val set: ')
print (accuracy_score(y_true_val, y_pred_val))

y_pred_test = dualModelSVM.predict(voice_X_test)
y_true_test = voice_y_test
print('accuracy on test set: ')
print (accuracy_score(y_true_test, y_pred_test))

print('first five predictions:')
print(y_pred_test[:5])
print('actual: ')
print(y_true_test[:5])
```

```
accuracy on train set:
0.9831578947368421
accuracy on val set:
0.9810725552050473
accuracy on test set:
0.9842271293375394
first five predictions:
[0 1 0 0 1]
actual:
[[0]
 [1]
```

```
 [0]
 [0]
 [1]]
/Users/davitbarblishvili/opt/anaconda3/lib/python3.9/site-packages/sklearn/utils/validation.py:63: DataConversi
onWarning: A column-vector y was passed when a 1d array was expected. Please change the shape of y to (n_sample
s, ), for example using ravel().
  return f(*args, **kwargs)
```

3.2 Using Kernel “rbf”, tune the hyperparameter “C” using the Grid Search & k-fold cross validation. You may take k=5 and assume values in grid between 1 to 100 with interval range of your choice.

In [87]:

```
from sklearn.pipeline import make_pipeline
from sklearn.model_selection import GridSearchCV

pipe = make_pipeline(GridSearchCV(LinearSVC(),
                                 param_grid = {"C":np.logspace(-3,3,20),
                                              "loss":["hinge", "squared_hinge"],
                                              "penalty":["l1","l2"]},
                                 return_train_score=True))
pipe.fit(voice_X_train,voice_y_train)
grid_search_results = pipe.named_steps["gridsearchcv"]
print(f"Best score:", grid_search_results.best_score_)
print(f"Best params:", grid_search_results.best_params_)
print(f"Test score:", pipe.score(voice_X_test,voice_y_test))
```

```
/Users/davitbarblishvili/opt/anaconda3/lib/python3.9/site-packages/sklearn/utils/validation.py:63: DataConversi
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/Users/davitbarblishvili/opt/anaconda3/lib/python3.9/site-packages/sklearn/model_selection/_validation.py:615:
FitFailedWarning: Estimator fit failed. The score on this train-test partition for these parameters will be set
to nan. Details:
Traceback (most recent call last):
  File "/Users/davitbarblishvili/opt/anaconda3/lib/python3.9/site-packages/sklearn/model_selection/_validation.
py", line 598, in _fit_and_score
    estimator.fit(X_train, y_train, **fit_params)
  File "/Users/davitbarblishvili/opt/anaconda3/lib/python3.9/site-packages/sklearn/svm/_classes.py", line 234,
in fit
    self.coef_, self.intercept_, self.n_iter_ = _fit_liblinear(
  File "/Users/davitbarblishvili/opt/anaconda3/lib/python3.9/site-packages/sklearn/svm/_base.py", line 974, in
_fit_liblinear
    solver_type = _get_liblinear_solver_type(multi_class, penalty, loss, dual)
  File "/Users/davitbarblishvili/opt/anaconda3/lib/python3.9/site-packages/sklearn/svm/_base.py", line 830, in
_get_liblinear_solver_type
```

```
    raise ValueError('Unsupported set of arguments: %s, '
ValueError: Unsupported set of arguments: The combination of penalty='l1' and loss='hinge' is not supported, Pa
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```
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```

```
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  File "/Users/davitbarblishvili/opt/anaconda3/lib/python3.9/site-packages/sklearn/svm/_classes.py", line 234,
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```

```
Best score: 0.9705263157894738
Best params: {'C': 0.1623776739188721, 'loss': 'hinge', 'penalty': 'l2'}
Test score: 0.9700315457413249
```

```
/Users/davitbarblishvili/opt/anaconda3/lib/python3.9/site-packages/sklearn/svm/_base.py:985: ConvergenceWarnin
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/Users/davitbarblishvili/opt/anaconda3/lib/python3.9/site-packages/sklearn/model_selection/_search.py:922: User
Warning: One or more of the test scores are non-finite: [       nan 0.91105263        nan 0.96052632        nan
0.95315789
        nan 0.96315789        nan 0.96368421        nan 0.96631579
        nan 0.96631579        nan 0.96684211        nan 0.96736842
        nan 0.96894737        nan 0.96894737        nan 0.96789474
        nan 0.97              nan 0.96947368        nan 0.97052632
        nan 0.96894737        nan 0.97052632        nan 0.96842105
        nan 0.96842105        nan 0.96789474        nan 0.96947368
        nan 0.96789474        nan 0.96894737        nan 0.96789474
        nan 0.97              nan 0.96789474        nan 0.97052632
```

```
        nan 0.96842105        nan 0.97052632        nan 0.96894737
        nan 0.96789474        nan 0.95842105        nan 0.95526316
        nan 0.93              nan 0.95210526        nan 0.95157895
        nan 0.94473684        nan 0.94315789        nan 0.90736842
        nan 0.93947368]
  warnings.warn(
/Users/davitbarblishvili/opt/anaconda3/lib/python3.9/site-packages/sklearn/model_selection/_search.py:922: User
Warning: One or more of the train scores are non-finite: [       nan 0.91434211        nan 0.96355263        na
n 0.95592105
        nan 0.96644737        nan 0.96697368        nan 0.96855263
        nan 0.96815789        nan 0.97026316        nan 0.97092105
        nan 0.97197368        nan 0.97197368        nan 0.97236842
        nan 0.97302632        nan 0.97289474        nan 0.97381579
        nan 0.97302632        nan 0.97394737        nan 0.97302632
        nan 0.97447368        nan 0.97302632        nan 0.97447368
        nan 0.97289474        nan 0.97473684        nan 0.97289474
        nan 0.97447368        nan 0.97368421        nan 0.97421053
        nan 0.97210526        nan 0.97421053        nan 0.97
        nan 0.97263158        nan 0.96184211        nan 0.96157895
        nan 0.93078947        nan 0.95578947        nan 0.94868421
        nan 0.94513158        nan 0.95328947        nan 0.91605263
        nan 0.94223684]
  warnings.warn(
/Users/davitbarblishvili/opt/anaconda3/lib/python3.9/site-packages/sklearn/utils/validation.py:63: DataConversi
onWarning: A column-vector y was passed when a 1d array was expected. Please change the shape of y to (n_sample
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In [88]:

```
'''
Best score: 0.9705263157894738
Best params: {'C': 0.1623776739188721, 'loss': 'hinge', 'penalty': 'l2'}
Test score: 0.9700315457413249
'''
```

Out[88]:

```
"\nBest score: 0.9705263157894738\nBest params: {'C': 0.1623776739188721, 'loss': 'hinge', 'penalty': 'l2'}\nTe
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```

In [ ]: