breast_cancer_prediction

April 30, 2022

0.1 Objective

Malignant tumors that occur in the glandular epithelium of the breast are called breast cancers, which are cancers that develop from breast tissue. Breast cancer has now become a relatively common tumor that threatens women's physical and mental health.
Although breast cancer is the most common gynecological cancer, most breast lumps are not cancer. In fact, more than 80 percent of breast lumps end up being benign. However, can we identify breast cancer from a breast lump?
I developed an analysis and prediction algorithm to predict breast cancer using data obtained from: https://archive.ics.uci.edu/ml/datasets/Breast+Cancer+Wisconsin+%28Diagnostic%29
Data can be viewed through Streamlit dashboard: https://share.streamlit.io/liyiliang999/breast_cancer_prediction/main/app.py
I found out that some features can greatly help us distinguish malignant tumors.

0.2 Data Processing

First of all, data needs to be processed in order to further analyze. Let's take a look at our data.

[56]:
```
#import packages
import warnings
warnings.filterwarnings("ignore")
```

[57]:
```
import numpy as np
import pandas as pd
import seaborn as sns
import matplotlib.pyplot as plt
from sklearn.linear_model import LogisticRegression
```

[2]:
```
#read data
data = pd.read_csv("data.csv")
```

[3]:
```
data
```

[3]:
```
         id diagnosis  radius_mean  texture_mean  perimeter_mean  area_mean  \
0    842302         M        17.99         10.38          122.80     1001.0
1    842517         M        20.57         17.77          132.90     1326.0
2  84300903         M        19.69         21.25          130.00     1203.0
```

```
3    84348301         M        11.42          20.38            77.58      386.1
4    84358402         M        20.29          14.34           135.10     1297.0
..        ...       ...          ...            ...              ...        ...
564    926424         M        21.56          22.39           142.00     1479.0
565    926682         M        20.13          28.25           131.20     1261.0
566    926954         M        16.60          28.08           108.30      858.1
567    927241         M        20.60          29.33           140.10     1265.0
568     92751         B         7.76          24.54            47.92      181.0

     smoothness_mean  compactness_mean  concavity_mean  concave points_mean  \
0            0.11840           0.27760         0.30010              0.14710
1            0.08474           0.07864         0.08690              0.07017
2            0.10960           0.15990         0.19740              0.12790
3            0.14250           0.28390         0.24140              0.10520
4            0.10030           0.13280         0.19800              0.10430
..               ...               ...             ...                  ...
564          0.11100           0.11590         0.24390              0.13890
565          0.09780           0.10340         0.14400              0.09791
566          0.08455           0.10230         0.09251              0.05302
567          0.11780           0.27700         0.35140              0.15200
568          0.05263           0.04362         0.00000              0.00000

     ...  texture_worst  perimeter_worst  area_worst  smoothness_worst  \
0    ...          17.33           184.60      2019.0           0.16220
1    ...          23.41           158.80      1956.0           0.12380
2    ...          25.53           152.50      1709.0           0.14440
3    ...          26.50            98.87       567.7           0.20980
4    ...          16.67           152.20      1575.0           0.13740
..   ...            ...              ...         ...               ...
564  ...          26.40           166.10      2027.0           0.14100
565  ...          38.25           155.00      1731.0           0.11660
566  ...          34.12           126.70      1124.0           0.11390
567  ...          39.42           184.60      1821.0           0.16500
568  ...          30.37            59.16       268.6           0.08996

     compactness_worst  concavity_worst  concave points_worst  symmetry_worst  \
0              0.66560           0.7119                0.2654          0.4601
1              0.18660           0.2416                0.1860          0.2750
2              0.42450           0.4504                0.2430          0.3613
3              0.86630           0.6869                0.2575          0.6638
4              0.20500           0.4000                0.1625          0.2364
..                 ...              ...                   ...             ...
564            0.21130           0.4107                0.2216          0.2060
565            0.19220           0.3215                0.1628          0.2572
566            0.30940           0.3403                0.1418          0.2218
567            0.86810           0.9387                0.2650          0.4087
568            0.06444           0.0000                0.0000          0.2871
```

```
     fractal_dimension_worst  Unnamed: 32
0                    0.11890          NaN
1                    0.08902          NaN
2                    0.08758          NaN
3                    0.17300          NaN
4                    0.07678          NaN
..                       ...          ...
564                  0.07115          NaN
565                  0.06637          NaN
566                  0.07820          NaN
567                  0.12400          NaN
568                  0.07039          NaN

[569 rows x 33 columns]
```

I printed out our data, there are 569 rows and 33 columns in the data. I found out that the last column is meaningless, I decided to remove the last column.

[4]:
```
data = data.iloc[:,0:-1] #removing the last column
```

[5]:
```
data
```

[5]:
```
           id diagnosis  radius_mean  texture_mean  perimeter_mean  area_mean  \
0      842302         M        17.99         10.38          122.80     1001.0
1      842517         M        20.57         17.77          132.90     1326.0
2    84300903         M        19.69         21.25          130.00     1203.0
3    84348301         M        11.42         20.38           77.58      386.1
4    84358402         M        20.29         14.34          135.10     1297.0
..        ...       ...          ...           ...             ...        ...
564    926424         M        21.56         22.39          142.00     1479.0
565    926682         M        20.13         28.25          131.20     1261.0
566    926954         M        16.60         28.08          108.30      858.1
567    927241         M        20.60         29.33          140.10     1265.0
568     92751         B         7.76         24.54           47.92      181.0

     smoothness_mean  compactness_mean  concavity_mean  concave points_mean  \
0            0.11840           0.27760         0.30010              0.14710
1            0.08474           0.07864         0.08690              0.07017
2            0.10960           0.15990         0.19740              0.12790
3            0.14250           0.28390         0.24140              0.10520
4            0.10030           0.13280         0.19800              0.10430
..               ...               ...             ...                  ...
564          0.11100           0.11590         0.24390              0.13890
565          0.09780           0.10340         0.14400              0.09791
566          0.08455           0.10230         0.09251              0.05302
567          0.11780           0.27700         0.35140              0.15200
568          0.05263           0.04362         0.00000              0.00000
```

```
     ...  radius_worst  texture_worst  perimeter_worst  area_worst  \
0    ...        25.380          17.33           184.60      2019.0
1    ...        24.990          23.41           158.80      1956.0
2    ...        23.570          25.53           152.50      1709.0
3    ...        14.910          26.50            98.87       567.7
4    ...        22.540          16.67           152.20      1575.0
..   ...           ...            ...              ...         ...
564  ...        25.450          26.40           166.10      2027.0
565  ...        23.690          38.25           155.00      1731.0
566  ...        18.980          34.12           126.70      1124.0
567  ...        25.740          39.42           184.60      1821.0
568  ...         9.456          30.37            59.16       268.6

     smoothness_worst  compactness_worst  concavity_worst  \
0             0.16220            0.66560           0.7119
1             0.12380            0.18660           0.2416
2             0.14440            0.42450           0.4504
3             0.20980            0.86630           0.6869
4             0.13740            0.20500           0.4000
..                ...                ...              ...
564           0.14100            0.21130           0.4107
565           0.11660            0.19220           0.3215
566           0.11390            0.30940           0.3403
567           0.16500            0.86810           0.9387
568           0.08996            0.06444           0.0000

     concave points_worst  symmetry_worst  fractal_dimension_worst
0                  0.2654          0.4601                  0.11890
1                  0.1860          0.2750                  0.08902
2                  0.2430          0.3613                  0.08758
3                  0.2575          0.6638                  0.17300
4                  0.1625          0.2364                  0.07678
..                    ...             ...                      ...
564                0.2216          0.2060                  0.07115
565                0.1628          0.2572                  0.06637
566                0.1418          0.2218                  0.07820
567                0.2650          0.4087                  0.12400
568                0.0000          0.2871                  0.07039

[569 rows x 32 columns]
```

Now the last column is gone.

The first 5 rows of data

[6]:
```
data.head(5)
```

[6]:
```
         id diagnosis  radius_mean  texture_mean  perimeter_mean  area_mean  \
0    842302         M        17.99         10.38          122.80     1001.0
1    842517         M        20.57         17.77          132.90     1326.0
```

```
2  84300903         M        19.69         21.25          130.00     1203.0
3  84348301         M        11.42         20.38           77.58      386.1
4  84358402         M        20.29         14.34          135.10     1297.0

   smoothness_mean  compactness_mean  concavity_mean  concave points_mean  \
0          0.11840           0.27760          0.3001              0.14710
1          0.08474           0.07864          0.0869              0.07017
2          0.10960           0.15990          0.1974              0.12790
3          0.14250           0.28390          0.2414              0.10520
4          0.10030           0.13280          0.1980              0.10430

   ...  radius_worst  texture_worst  perimeter_worst  area_worst  \
0  ...         25.38          17.33           184.60      2019.0
1  ...         24.99          23.41           158.80      1956.0
2  ...         23.57          25.53           152.50      1709.0
3  ...         14.91          26.50            98.87       567.7
4  ...         22.54          16.67           152.20      1575.0

   smoothness_worst  compactness_worst  concavity_worst  concave points_worst  \
0            0.1622             0.6656           0.7119                0.2654
1            0.1238             0.1866           0.2416                0.1860
2            0.1444             0.4245           0.4504                0.2430
3            0.2098             0.8663           0.6869                0.2575
4            0.1374             0.2050           0.4000                0.1625

   symmetry_worst  fractal_dimension_worst
0          0.4601                  0.11890
1          0.2750                  0.08902
2          0.3613                  0.08758
3          0.6638                  0.17300
4          0.2364                  0.07678

[5 rows x 32 columns]
```

The summary of data

[7]:
```
data.describe()
```

[7]:
```
                 id  radius_mean  texture_mean  perimeter_mean    area_mean  \
count  5.690000e+02   569.000000    569.000000      569.000000   569.000000
mean   3.037183e+07    14.127292     19.289649       91.969033   654.889104
std    1.250206e+08     3.524049      4.301036       24.298981   351.914129
min    8.670000e+03     6.981000      9.710000       43.790000   143.500000
25%    8.692180e+05    11.700000     16.170000       75.170000   420.300000
50%    9.060240e+05    13.370000     18.840000       86.240000   551.100000
75%    8.813129e+06    15.780000     21.800000      104.100000   782.700000
max    9.113205e+08    28.110000     39.280000      188.500000  2501.000000

       smoothness_mean  compactness_mean  concavity_mean  concave points_mean  \
count       569.000000        569.000000       569.000000           569.000000
mean          0.096360          0.104341         0.088799             0.048919
std           0.014064          0.052813         0.079720             0.038803
min           0.052630          0.019380         0.000000             0.000000
25%           0.086370          0.064920         0.029560             0.020310
50%           0.095870          0.092630         0.061540             0.033500
75%           0.105300          0.130400         0.130700             0.074000
max           0.163400          0.345400         0.426800             0.201200

       symmetry_mean  ...  radius_worst  texture_worst  perimeter_worst  \
count     569.000000  ...    569.000000     569.000000       569.000000
mean        0.181162  ...     16.269190      25.677223       107.261213
std         0.027414  ...      4.833242       6.146258        33.602542
min         0.106000  ...      7.930000      12.020000        50.410000
25%         0.161900  ...     13.010000      21.080000        84.110000
50%         0.179200  ...     14.970000      25.410000        97.660000
75%         0.195700  ...     18.790000      29.720000       125.400000
max         0.304000  ...     36.040000      49.540000       251.200000

        area_worst  smoothness_worst  compactness_worst  concavity_worst  \
count   569.000000        569.000000         569.000000       569.000000
mean    880.583128          0.132369           0.254265         0.272188
std     569.356993          0.022832           0.157336         0.208624
min     185.200000          0.071170           0.027290         0.000000
25%     515.300000          0.116600           0.147200         0.114500
50%     686.500000          0.131300           0.211900         0.226700
75%    1084.000000          0.146000           0.339100         0.382900
max    4254.000000          0.222600           1.058000         1.252000

       concave points_worst  symmetry_worst  fractal_dimension_worst
count            569.000000      569.000000               569.000000
mean               0.114606        0.290076                 0.083946
std                0.065732        0.061867                 0.018061
min                0.000000        0.156500                 0.055040
25%                0.064930        0.250400                 0.071460
50%                0.099930        0.282200                 0.080040
75%                0.161400        0.317900                 0.092080
max                0.291000        0.663800                 0.207500

[8 rows x 31 columns]
```

Based on the output above, we can easily see the mean value, standard deviation, minimum, maximum and quantiles of each numeric features.

Data Info

[8]:
```
data.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 569 entries, 0 to 568
```

```
Data columns (total 32 columns):
 #   Column                   Non-Null Count  Dtype  
---  ------                   --------------  -----  
 0   id                       569 non-null    int64  
 1   diagnosis                569 non-null    object 
 2   radius_mean              569 non-null    float64
 3   texture_mean             569 non-null    float64
 4   perimeter_mean           569 non-null    float64
 5   area_mean                569 non-null    float64
 6   smoothness_mean          569 non-null    float64
 7   compactness_mean         569 non-null    float64
 8   concavity_mean           569 non-null    float64
 9   concave points_mean      569 non-null    float64
 10  symmetry_mean            569 non-null    float64
 11  fractal_dimension_mean   569 non-null    float64
 12  radius_se                569 non-null    float64
 13  texture_se               569 non-null    float64
 14  perimeter_se             569 non-null    float64
 15  area_se                  569 non-null    float64
 16  smoothness_se            569 non-null    float64
 17  compactness_se           569 non-null    float64
 18  concavity_se             569 non-null    float64
 19  concave points_se        569 non-null    float64
 20  symmetry_se              569 non-null    float64
 21  fractal_dimension_se     569 non-null    float64
 22  radius_worst             569 non-null    float64
 23  texture_worst            569 non-null    float64
 24  perimeter_worst          569 non-null    float64
 25  area_worst               569 non-null    float64
 26  smoothness_worst         569 non-null    float64
 27  compactness_worst        569 non-null    float64
 28  concavity_worst          569 non-null    float64
 29  concave points_worst     569 non-null    float64
 30  symmetry_worst           569 non-null    float64
 31  fractal_dimension_worst  569 non-null    float64
dtypes: float64(30), int64(1), object(1)
memory usage: 142.4+ KB
```

Based on the information above, we can see that there are currently still 32 columns in the data.

‘id’ is integer. ‘diagnosis’ is ‘B’ or ‘M’ which means the tumor is benign or malignant. ‘radius_mean’, ‘texture_mean’, ‘perimeter_mean’, ‘area_mean’, ‘smoothness_mean’, ‘compactness_mean’, ‘concavity_mean’, ‘concave points_mean’, ‘symmetry_mean’, ‘fractal_dimension_mean’, ‘radius_se’, ‘texture_se’, ‘perimeter_se’, ‘area_se’, ‘smoothness_se’, ‘compactness_se’, ‘concavity_se’, ‘concave points_se’, ‘symmetry_se’, ‘fractal_dimension_se’, ‘radius_worst’, ‘texture_worst’, ‘perimeter_worst’, ‘area_worst’, ‘smoothness_worst’, ‘compactness_worst’, ‘concavity_worst’, ‘concave points_worst’, ‘symmetry_worst’, ‘fractal_dimension_worst’ are features.

Ten real-valued features are computed for each cell nucleus:

- radius (mean of distances from center to points on the perimeter)
- texture (standard deviation of gray-scale values)
- perimeter
- area
- smoothness (local variation in radius lengths)
- compactness (perimeter^2 / area - 1.0)
- concavity (severity of concave portions of the contour)
- concave points (number of concave portions of the contour)
- symmetry
- fractal dimension ("coastline approximation" - 1)

The mean, standard error and "worst" or largest (mean of the three largest values) of these features were computed for each image.

Check Missing Values

[9]:
```
pd.isna(data)
```

[9]:
```
        id  diagnosis  radius_mean  texture_mean  perimeter_mean  area_mean  \
0    False      False        False         False           False      False
1    False      False        False         False           False      False
2    False      False        False         False           False      False
3    False      False        False         False           False      False
4    False      False        False         False           False      False
..     ...        ...          ...           ...             ...        ...
564  False      False        False         False           False      False
565  False      False        False         False           False      False
566  False      False        False         False           False      False
567  False      False        False         False           False      False
568  False      False        False         False           False      False

     smoothness_mean  compactness_mean  concavity_mean  concave points_mean  \
0              False             False           False                False
1              False             False           False                False
2              False             False           False                False
3              False             False           False                False
4              False             False           False                False
..               ...               ...             ...                  ...
564            False             False           False                False
565            False             False           False                False
566            False             False           False                False
567            False             False           False                False
568            False             False           False                False

     ...  radius_worst  texture_worst  perimeter_worst  area_worst  \
0    ...         False          False            False       False
1    ...         False          False            False       False
2    ...         False          False            False       False
3    ...         False          False            False       False
4    ...         False          False            False       False
```

```
..   ...          ...          ...              ...          ...
564  ...        False        False            False        False
565  ...        False        False            False        False
566  ...        False        False            False        False
567  ...        False        False            False        False
568  ...        False        False            False        False

     smoothness_worst  compactness_worst  concavity_worst  \
0               False              False            False
1               False              False            False
2               False              False            False
3               False              False            False
4               False              False            False
..                ...                ...              ...
564             False              False            False
565             False              False            False
566             False              False            False
567             False              False            False
568             False              False            False

     concave points_worst  symmetry_worst  fractal_dimension_worst
0                   False           False                    False
1                   False           False                    False
2                   False           False                    False
3                   False           False                    False
4                   False           False                    False
..                    ...             ...                      ...
564                 False           False                    False
565                 False           False                    False
566                 False           False                    False
567                 False           False                    False
568                 False           False                    False

[569 rows x 32 columns]
```

[10]:
```
pd.isna(data).sum()
```

[10]:
```
id                         0
diagnosis                  0
radius_mean                0
texture_mean               0
perimeter_mean             0
area_mean                  0
smoothness_mean            0
compactness_mean           0
concavity_mean             0
concave points_mean        0
symmetry_mean              0
```

```
fractal_dimension_mean     0
radius_se                  0
texture_se                 0
perimeter_se               0
area_se                    0
smoothness_se              0
compactness_se             0
concavity_se               0
concave points_se          0
symmetry_se                0
fractal_dimension_se       0
radius_worst               0
texture_worst              0
perimeter_worst            0
area_worst                 0
smoothness_worst           0
compactness_worst          0
concavity_worst            0
concave points_worst       0
symmetry_worst             0
fractal_dimension_worst    0
dtype: int64
```

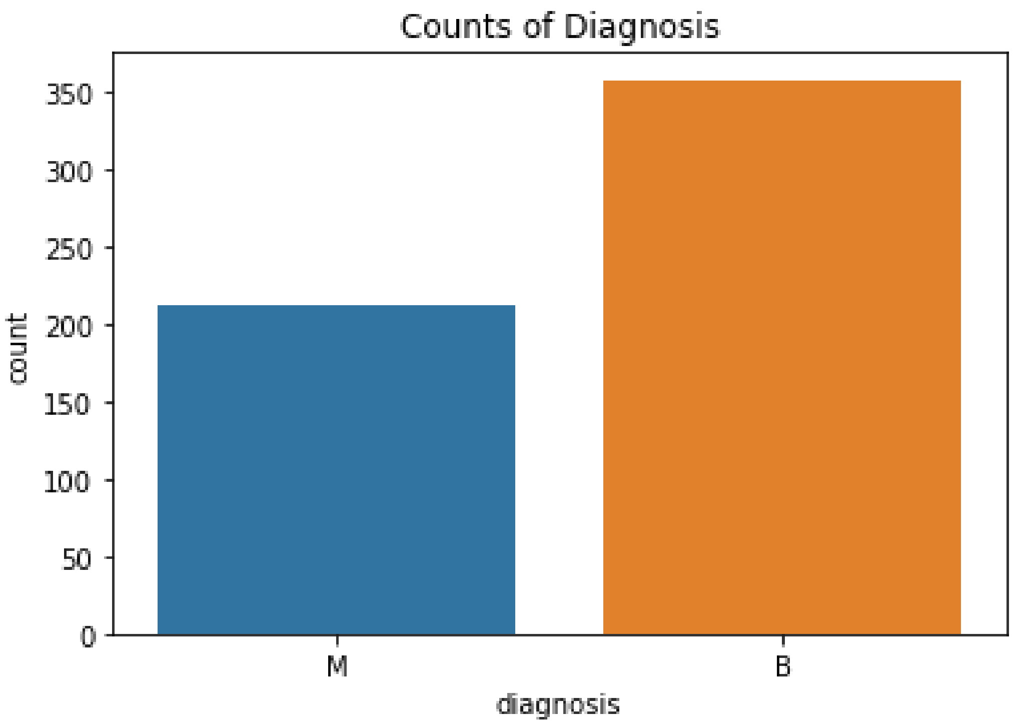
There are no missing values in this dataset.

0.3 Data Exploration

[11]:
```
data2 = data.iloc[:,1:] #data2 dropped id
```

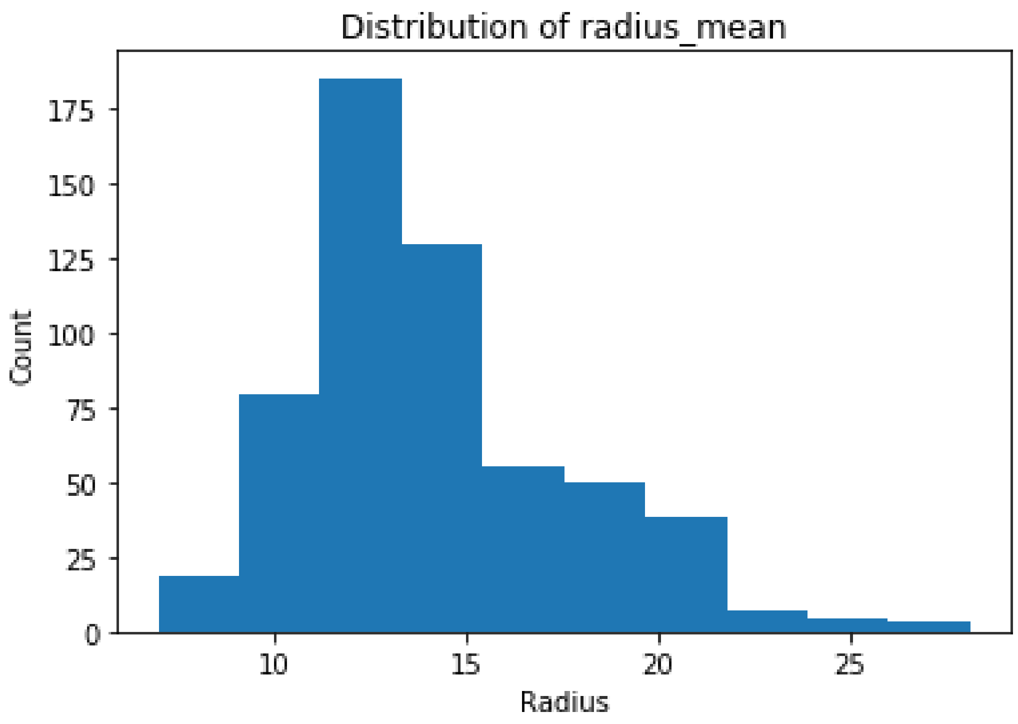
[12]:
```
sns.countplot(x='diagnosis', data = data)
plt.title( 'Counts of Diagnosis' )
```

[12]:
```
Text(0.5, 1.0, 'Counts of Diagnosis')
```



Class distribution: 357 benign, 212 malignant.
There are 357 benign cases and 212 malignant cases in the dataset.

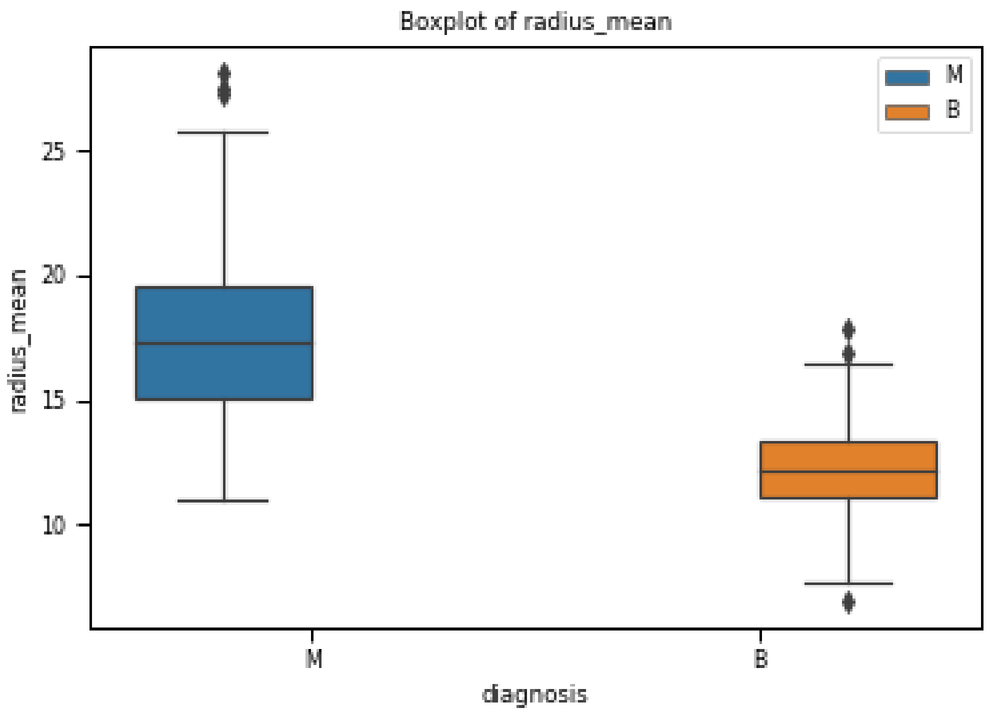
[13]:
```
plt.hist( data['radius_mean'])
plt.xlabel('Radius')
plt.ylabel('Count')
plt.title( 'Distribution of radius_mean' )
plt.show()
```



radius_mean is mostly distributed between 10-15.

[14]:
```
sns.set_context('paper', font_scale=0.9)
sns.boxplot(x='diagnosis',y='radius_mean', data=data, hue='diagnosis')
plt.legend(loc=0)
plt.title( 'Boxplot of radius_mean' )
```

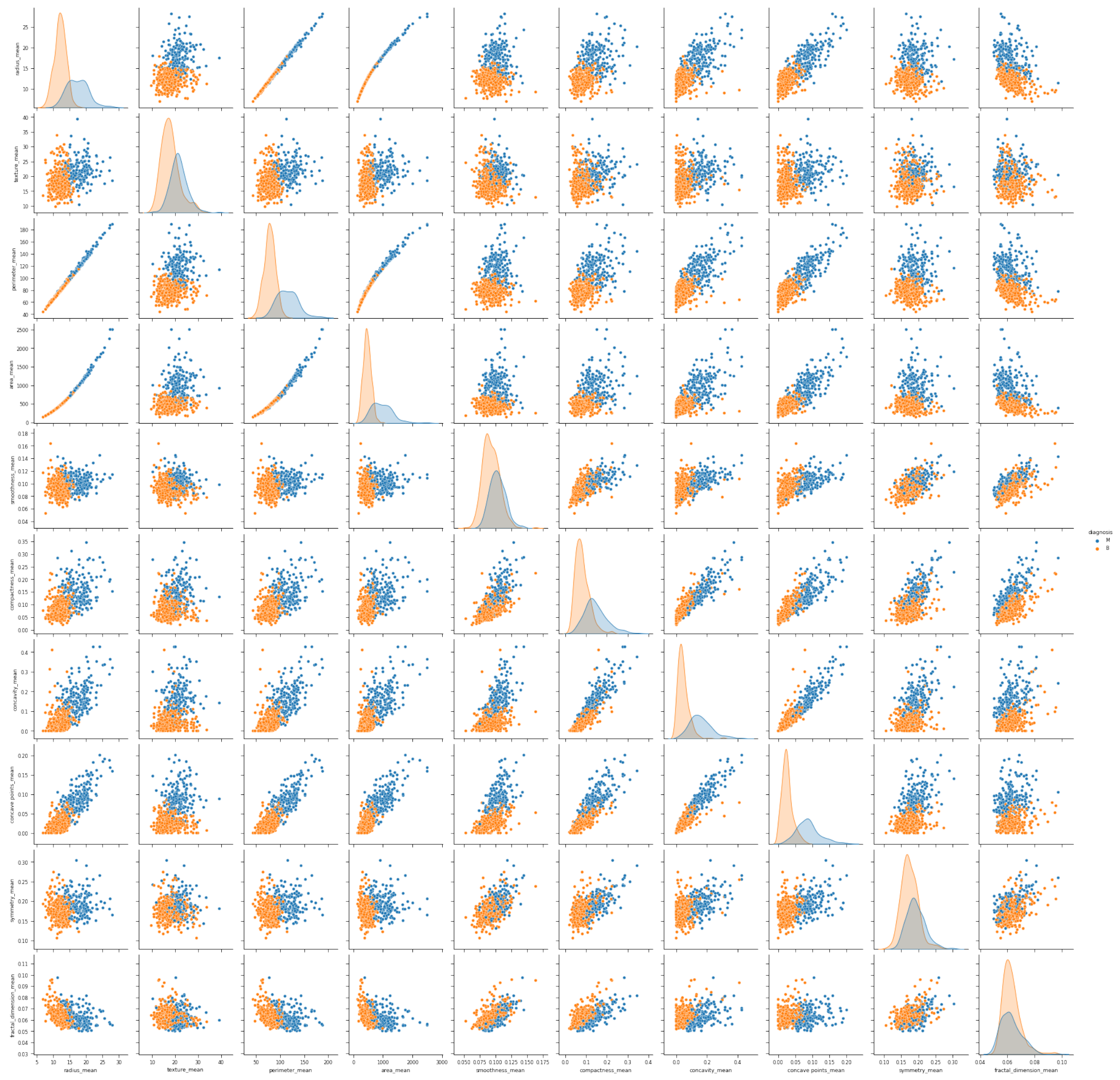
[14]:
```
Text(0.5, 1.0, 'Boxplot of radius_mean')
```



From the boxplot above, we can easily tell that malignant tumors tend to have larger radius_mean.

[15]:
```
sns.pairplot(data2.iloc[:,0:11],hue='diagnosis')
```

[15]:
```
<seaborn.axisgrid.PairGrid at 0x7f95e9107f60>
```



From this pairplot, we can easily identify some patterns from the data.

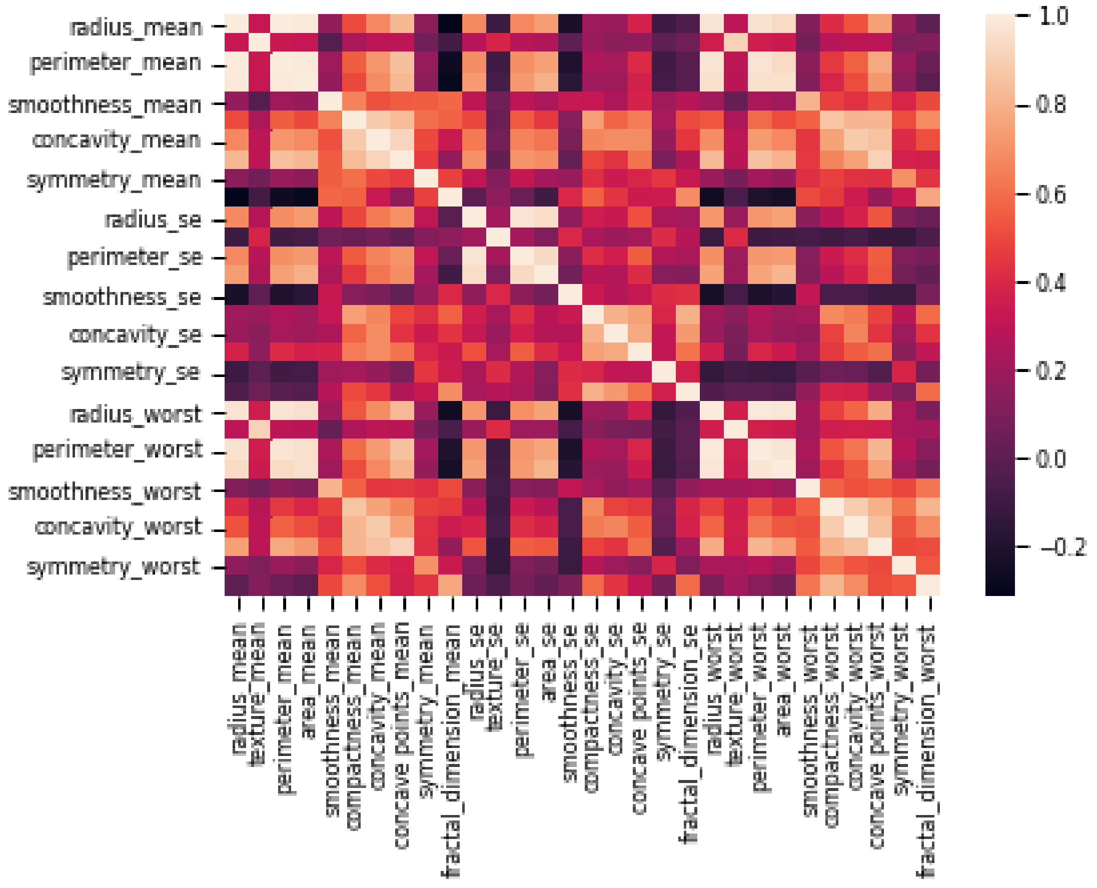
perimeter_mean and radius_mean are highly correlated. There is a strong positive linear relationship between them.

perimeter_mean and area_mean, perimeter_mean and concavity_mean, concavity_mean and concave points_mean are highly correlated too.

There is a huge difference between between benign cases and malignant cases in radius_mean, perimeter_mean, area_mean, concavity_mean, concave points_mean. But not so much in fractal_dimension_mean. fractal_dimension_mean might be a bad indicator to distinguish benign cases and malignant cases.

[16]:
```
sns.heatmap(data2.corr())
```

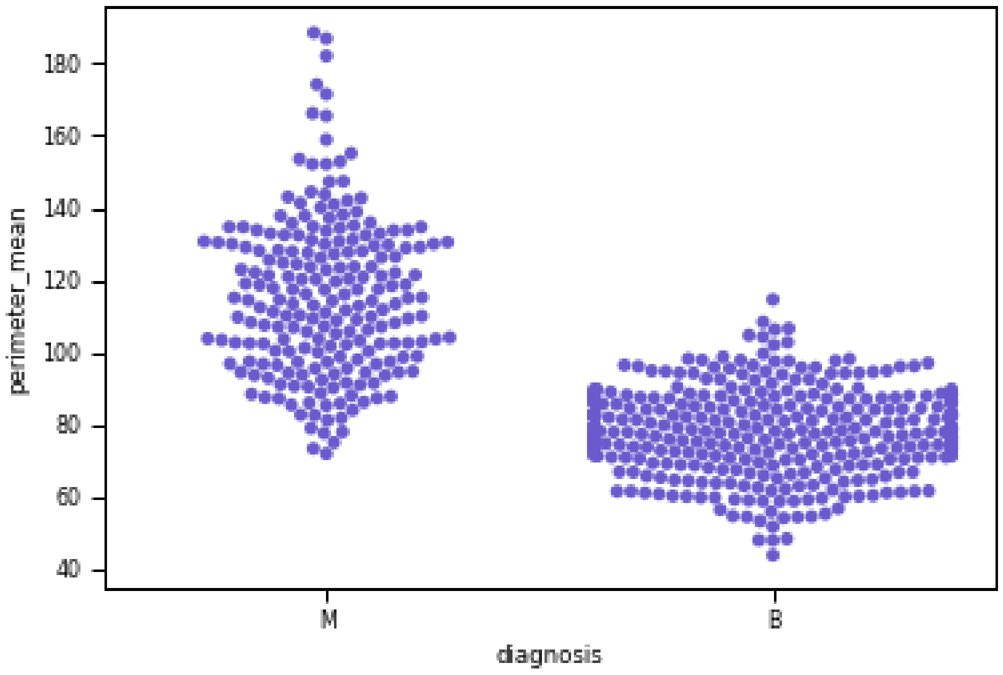
[16]:
```
<matplotlib.axes._subplots.AxesSubplot at 0x7f95e90fef28>
```



The lighter the color means the more the two features are correlated.
We can easily tell that features like perimeter_mean and radius_mean are highly correlated.

[17]:
```
sns.swarmplot(x='diagnosis', y='perimeter_mean',data=data,color='slateblue')
```

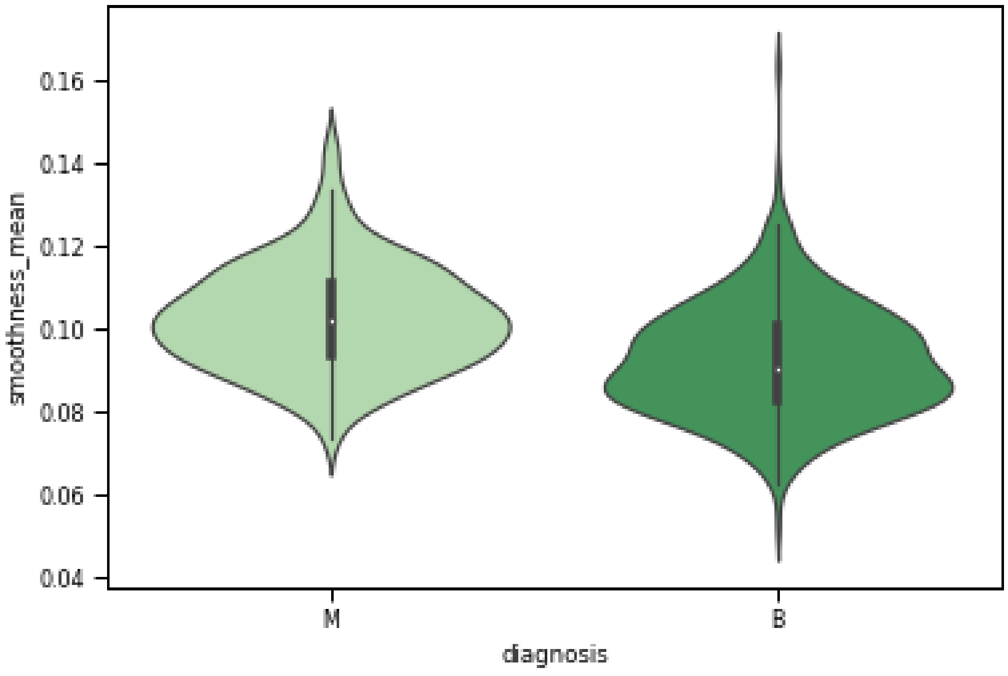
[17]:
```
<matplotlib.axes._subplots.AxesSubplot at 0x7f95e9bc5668>
```



perimeter_mean is higher in malignant tumors.

[18]:
```
sns.violinplot(x='diagnosis', y='smoothness_mean',data=data,palette='Greens')
```

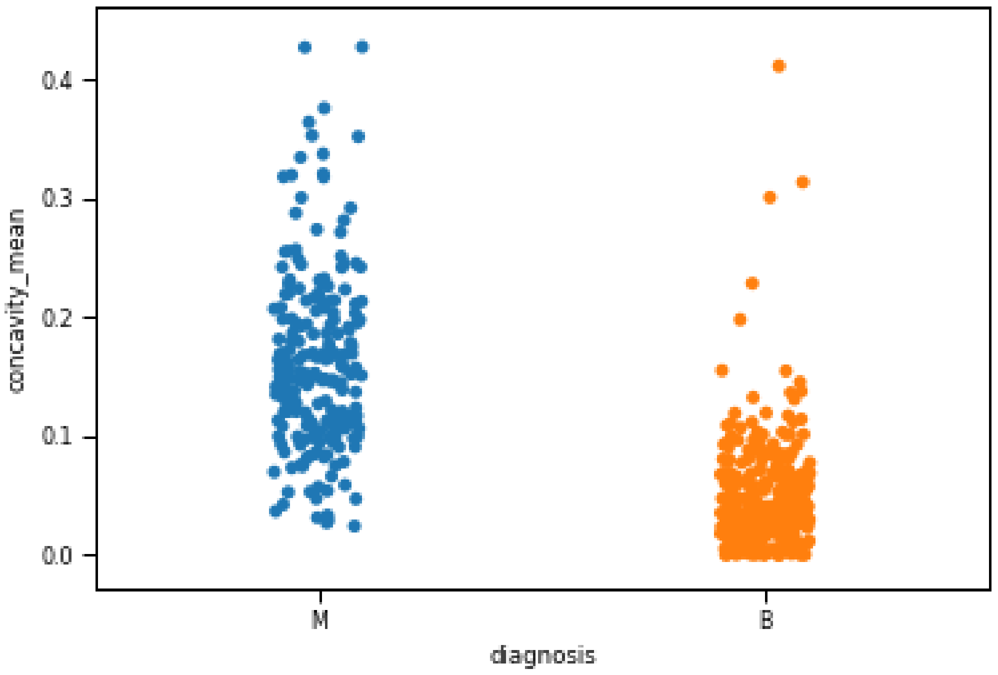
[18]:
```
<matplotlib.axes._subplots.AxesSubplot at 0x7f95d93504e0>
```



smoothness_mean is higher in malignant tumors, but not by a huge margin compared to other features.

[19]:
```
sns.stripplot(x='diagnosis', y='concavity_mean',data=data,jitter=True)
```

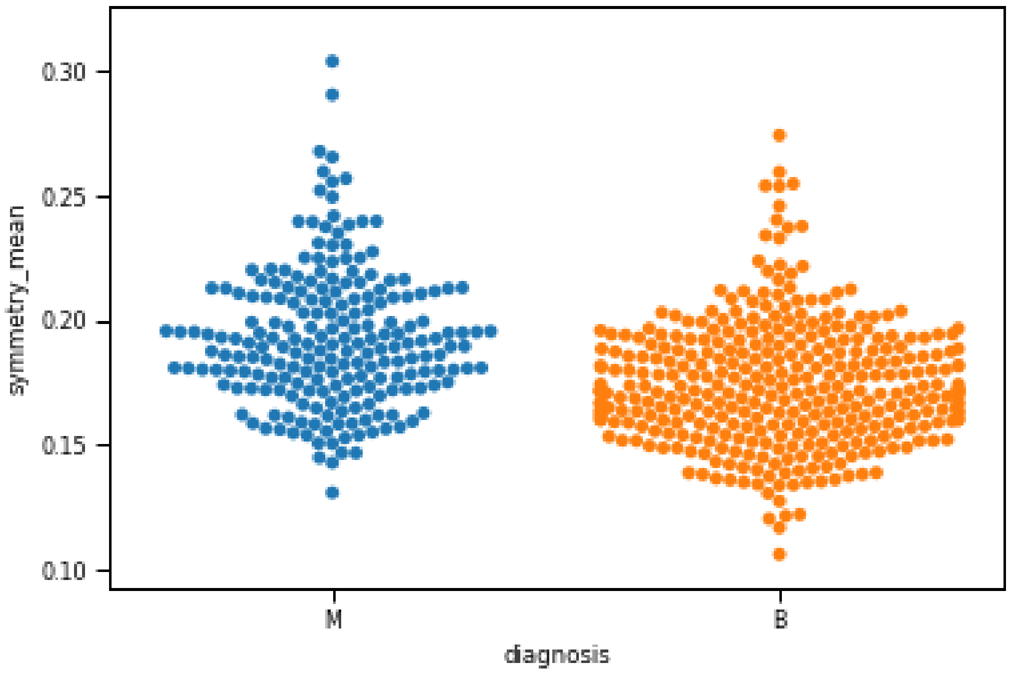
[19]:
```
<matplotlib.axes._subplots.AxesSubplot at 0x7f95cbfc9390>
```



concavity_mean is higher in malignant tumors.

[20]:
```
sns.swarmplot(y='symmetry_mean',data=data,x='diagnosis')
```

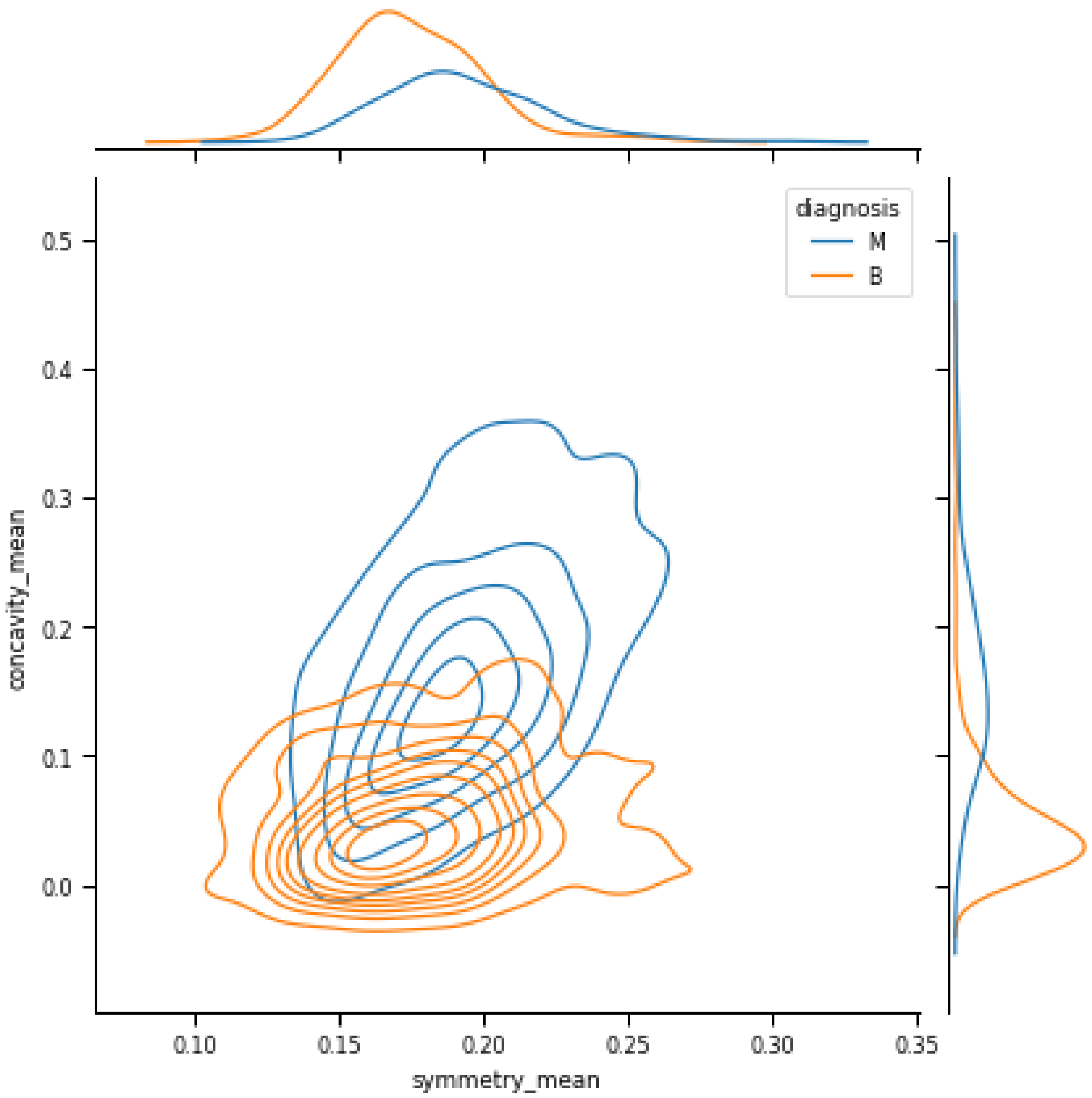
[20]:
```
<matplotlib.axes._subplots.AxesSubplot at 0x7f95b8c062e8>
```



The difference in symmetry_mean between benign and malignant tumors is not very huge, but malignant tumors tend to have higher symmetry_mean.

[21]:
```
sns.jointplot(x='symmetry_mean',y='concavity_mean', data=data,␣
↪kind='kde',hue='diagnosis')
```

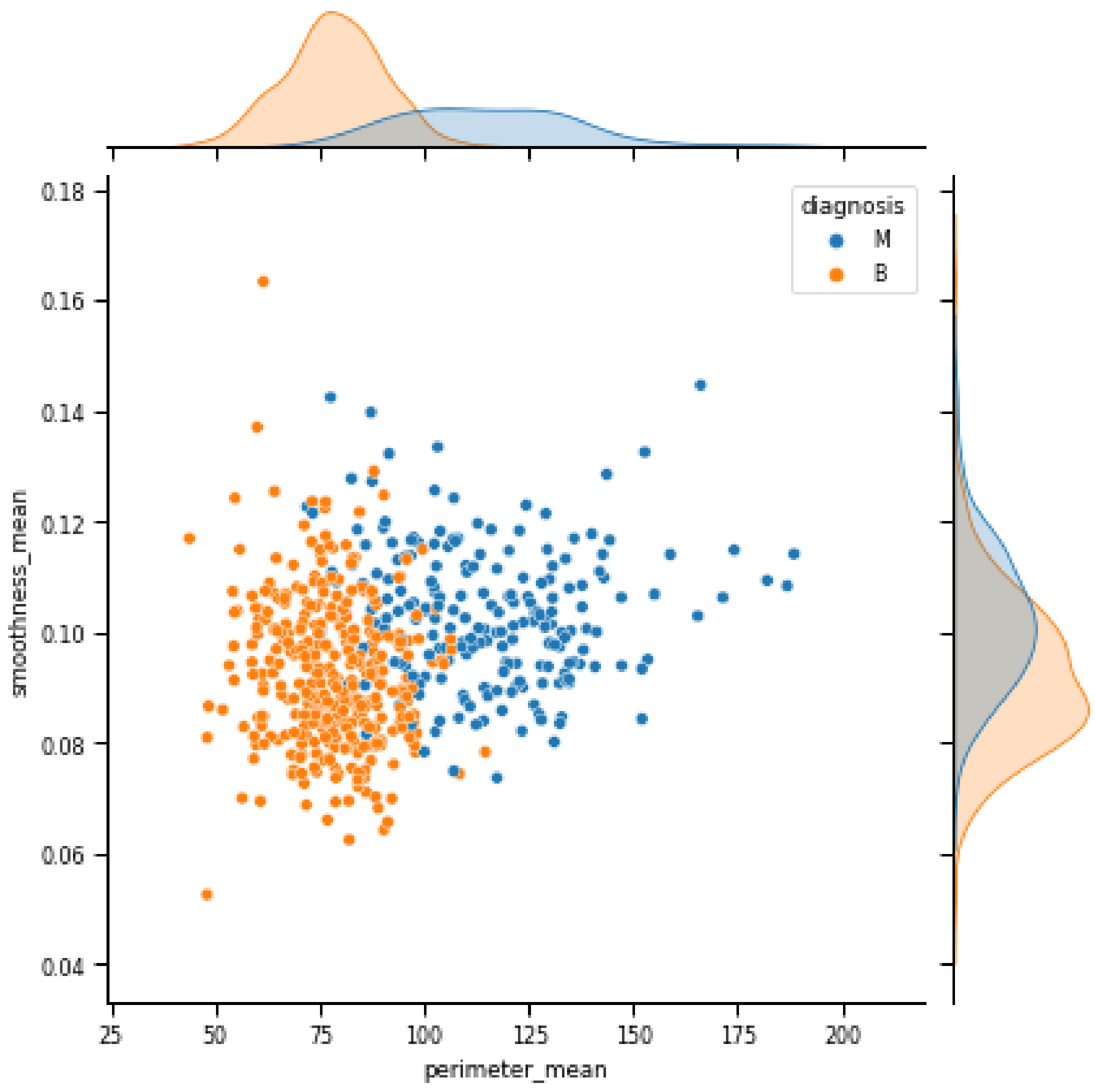
[21]:
```
<seaborn.axisgrid.JointGrid at 0x7f95d9428198>
```



Malignant tumors seem to have higher symmetry_mean and concavity_mean.

[22]:
```
sns.jointplot(x='perimeter_mean',y='smoothness_mean', data=data,hue='diagnosis')
```

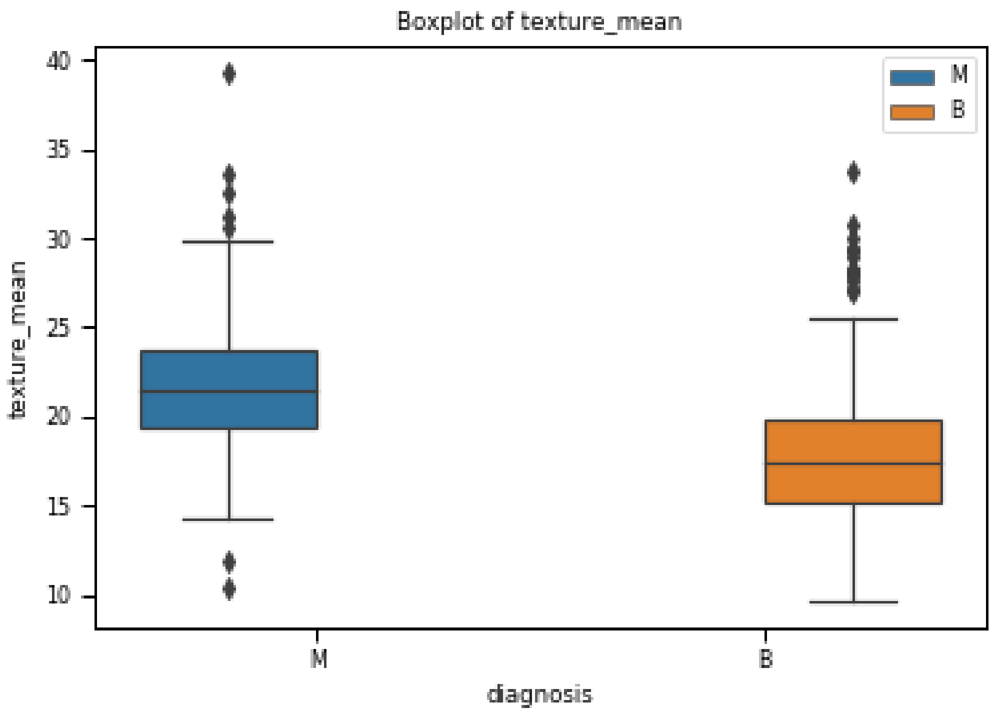
[22]:
```
<seaborn.axisgrid.JointGrid at 0x7f95cc332c50>
```



Malignant tumors seem to have higher perimeter_mean and smoothness_mean. And they don't seem to be correlated.

[23]:
```
sns.set_context('paper', font_scale=0.9)
sns.boxplot(x='diagnosis',y='texture_mean', data=data, hue='diagnosis')
plt.legend(loc=0)
plt.title( 'Boxplot of texture_mean' )
```

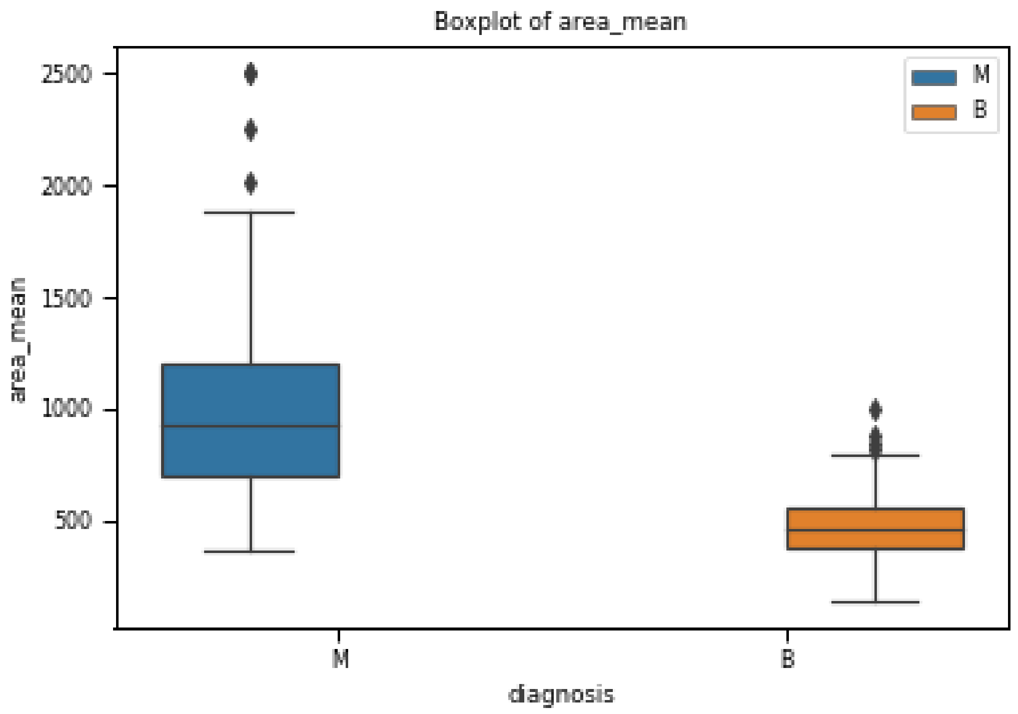
[23]:
```
Text(0.5, 1.0, 'Boxplot of texture_mean')
```



Malignant tumors have higher texture_mean.

[24]:
```
sns.set_context('paper', font_scale=0.9)
sns.boxplot(x='diagnosis',y='area_mean', data=data, hue='diagnosis')
plt.legend(loc=0)
plt.title( 'Boxplot of area_mean' )
```

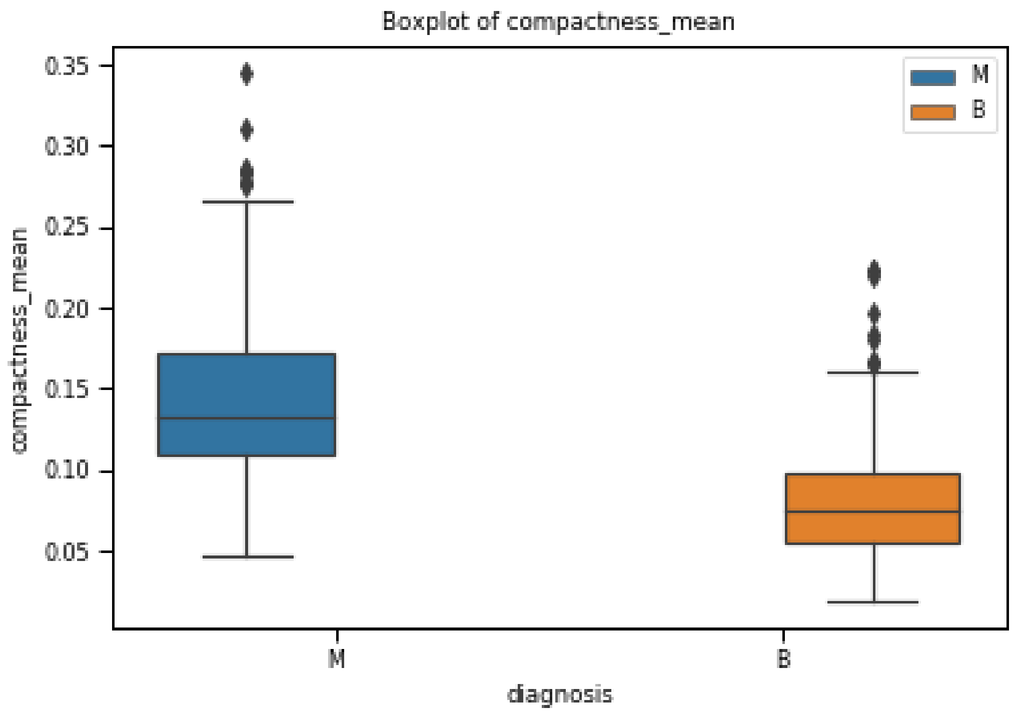
[24]:
```
Text(0.5, 1.0, 'Boxplot of area_mean')
```



Malignant tumors have higher area_mean.

[25]:
```
sns.set_context('paper', font_scale=0.9)
sns.boxplot(x='diagnosis',y='compactness_mean', data=data, hue='diagnosis')
plt.legend(loc=0)
plt.title( 'Boxplot of compactness_mean' )
```

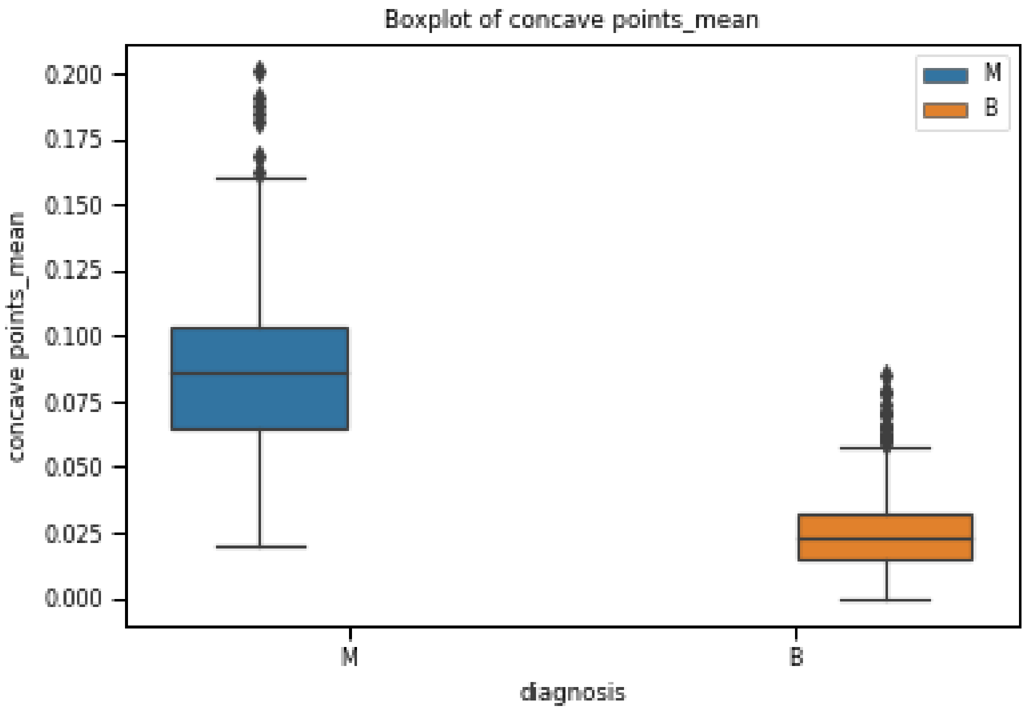
[25]:
```
Text(0.5, 1.0, 'Boxplot of compactness_mean')
```



Malignant tumors have higher compactness_mean.

[26]:
```
sns.set_context('paper', font_scale=0.9)
sns.boxplot(x='diagnosis',y='concave points_mean', data=data, hue='diagnosis')
plt.legend(loc=0)
plt.title( 'Boxplot of concave points_mean' )
```

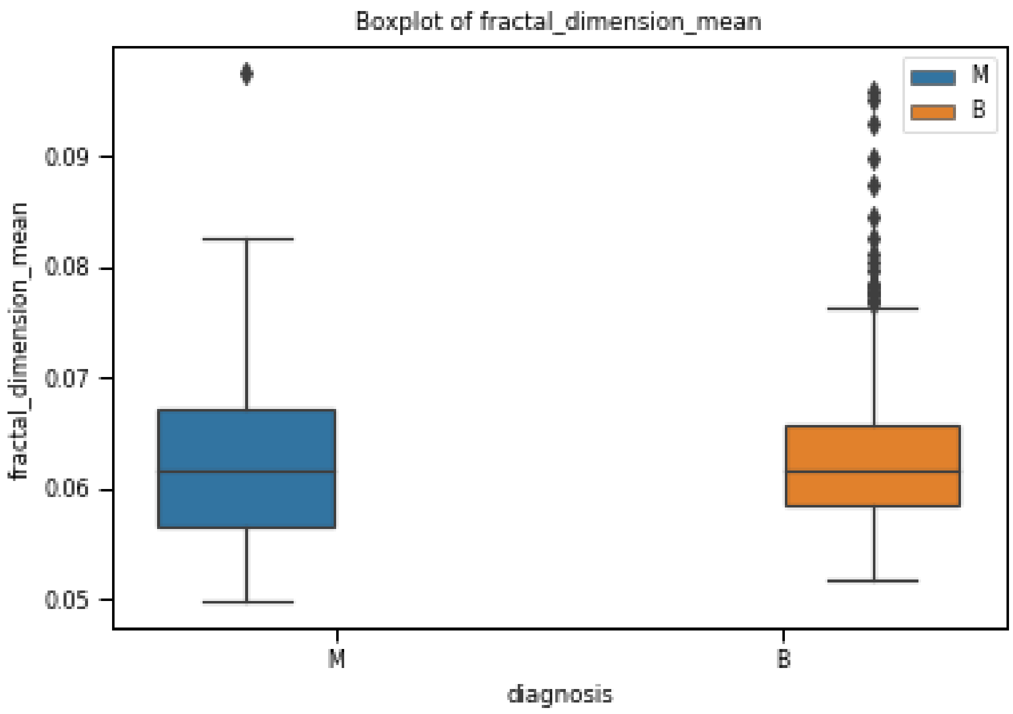
[26]:
```
Text(0.5, 1.0, 'Boxplot of concave points_mean')
```



Malignant tumors have higher concave points_mean.

[27]:
```
sns.set_context('paper', font_scale=0.9)
sns.boxplot(x='diagnosis',y='fractal_dimension_mean', data=data,␣
 ↪hue='diagnosis')
plt.legend(loc=0)
plt.title( 'Boxplot of fractal_dimension_mean' )
```

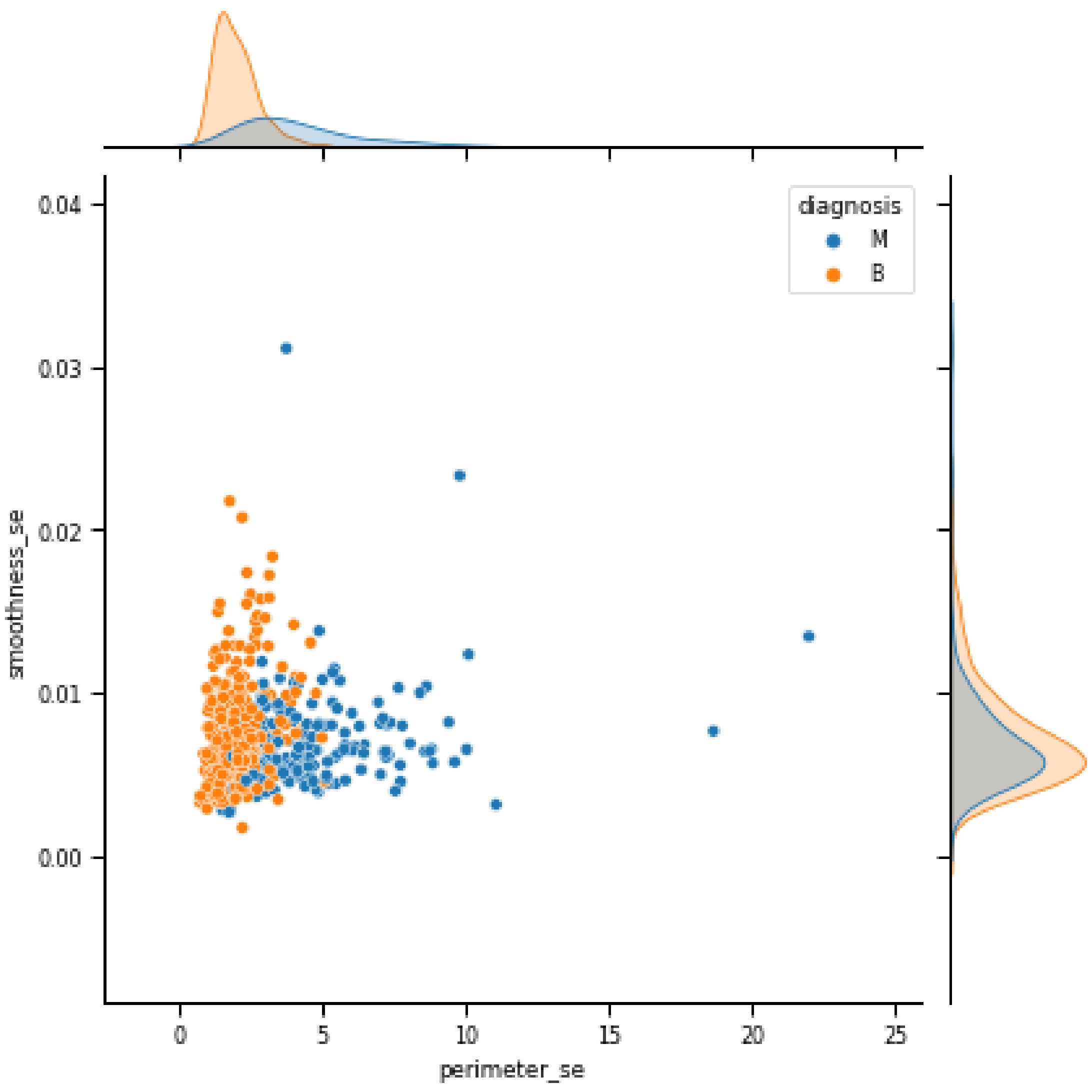
[27]:
```
Text(0.5, 1.0, 'Boxplot of fractal_dimension_mean')
```



There is no noticeable difference in fractal_dimension_mean between benign and malignant tumors.

[28]:
```
sns.jointplot(x='perimeter_se',y='smoothness_se', data=data,hue='diagnosis')
```

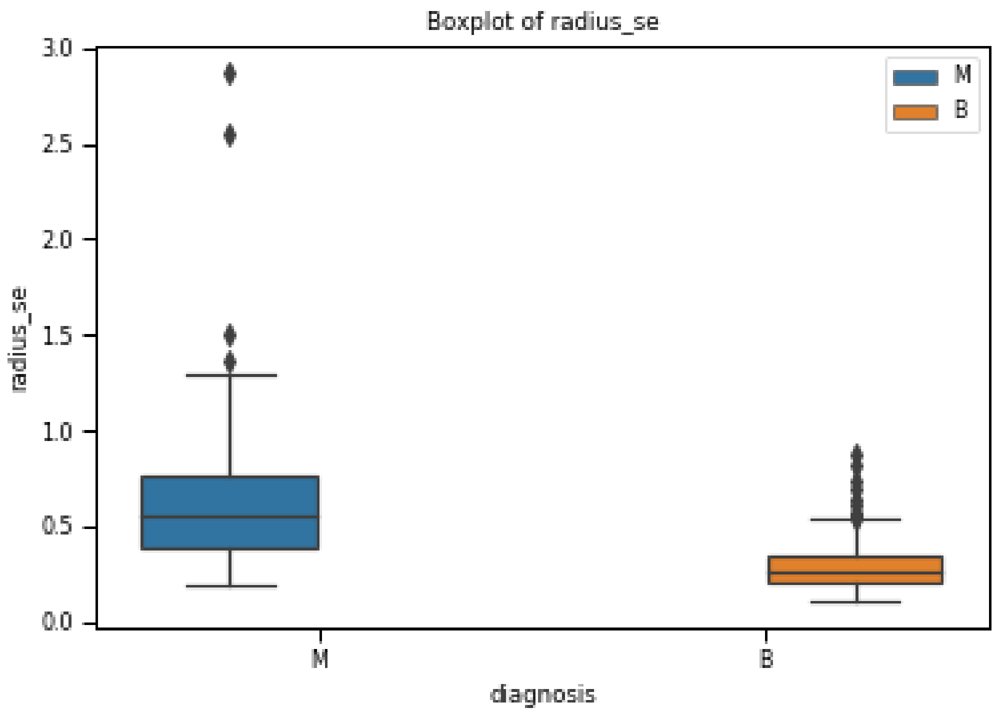
[28]:
```
<seaborn.axisgrid.JointGrid at 0x7f95e9f43b70>
```



Malignant tumors tend to have higher perimeter_se, but no noticeable difference in smoothness_se.

[29]:
```
sns.set_context('paper', font_scale=0.9)
sns.boxplot(x='diagnosis',y='radius_se', data=data, hue='diagnosis')
plt.legend(loc=0)
plt.title( 'Boxplot of radius_se' )
```

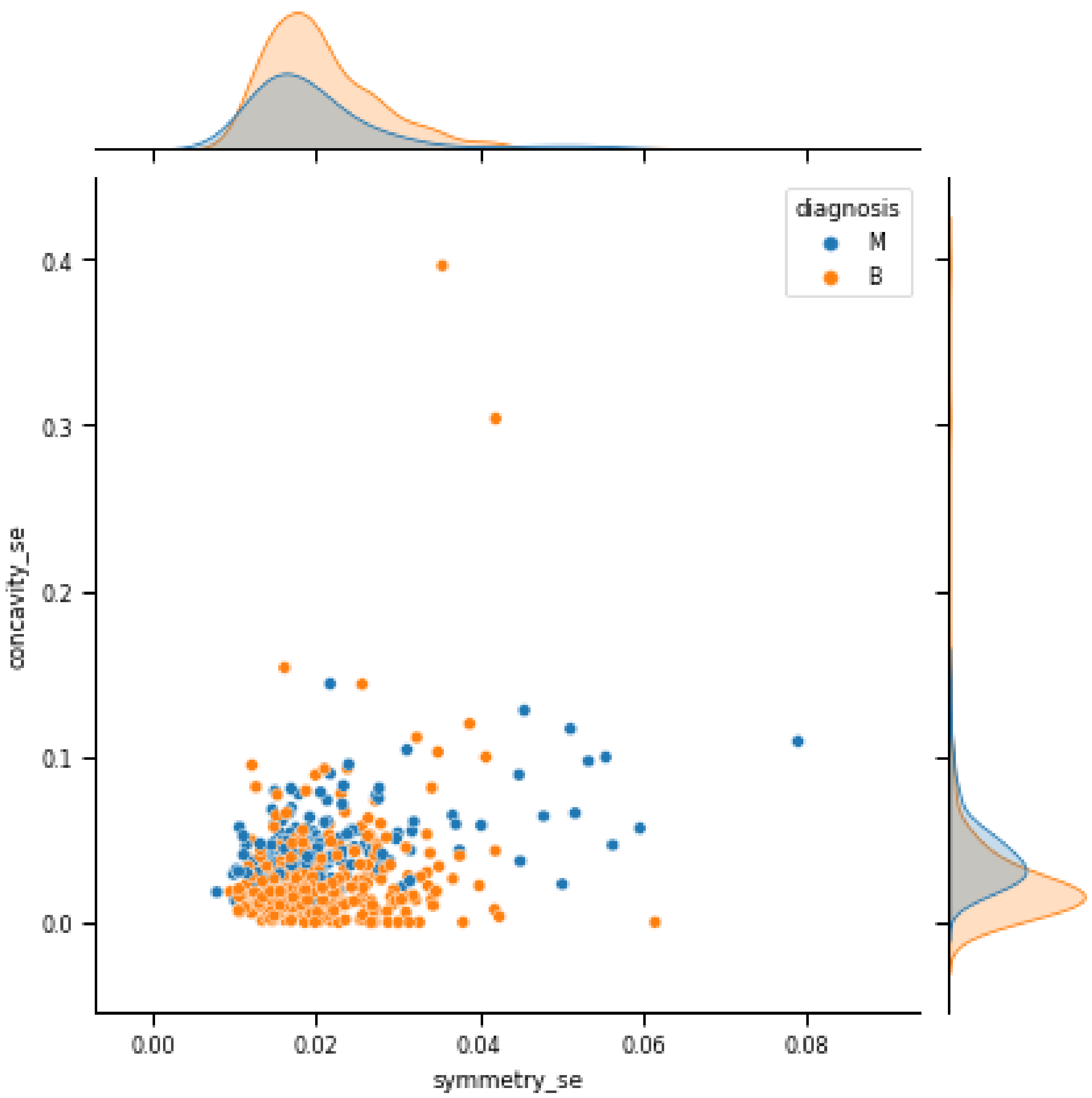
[29]:
```
Text(0.5, 1.0, 'Boxplot of radius_se')
```



Malignant tumors have higher radius_se.

[30]:
```
sns.jointplot(x='symmetry_se',y='concavity_se', data=data,hue='diagnosis')
```

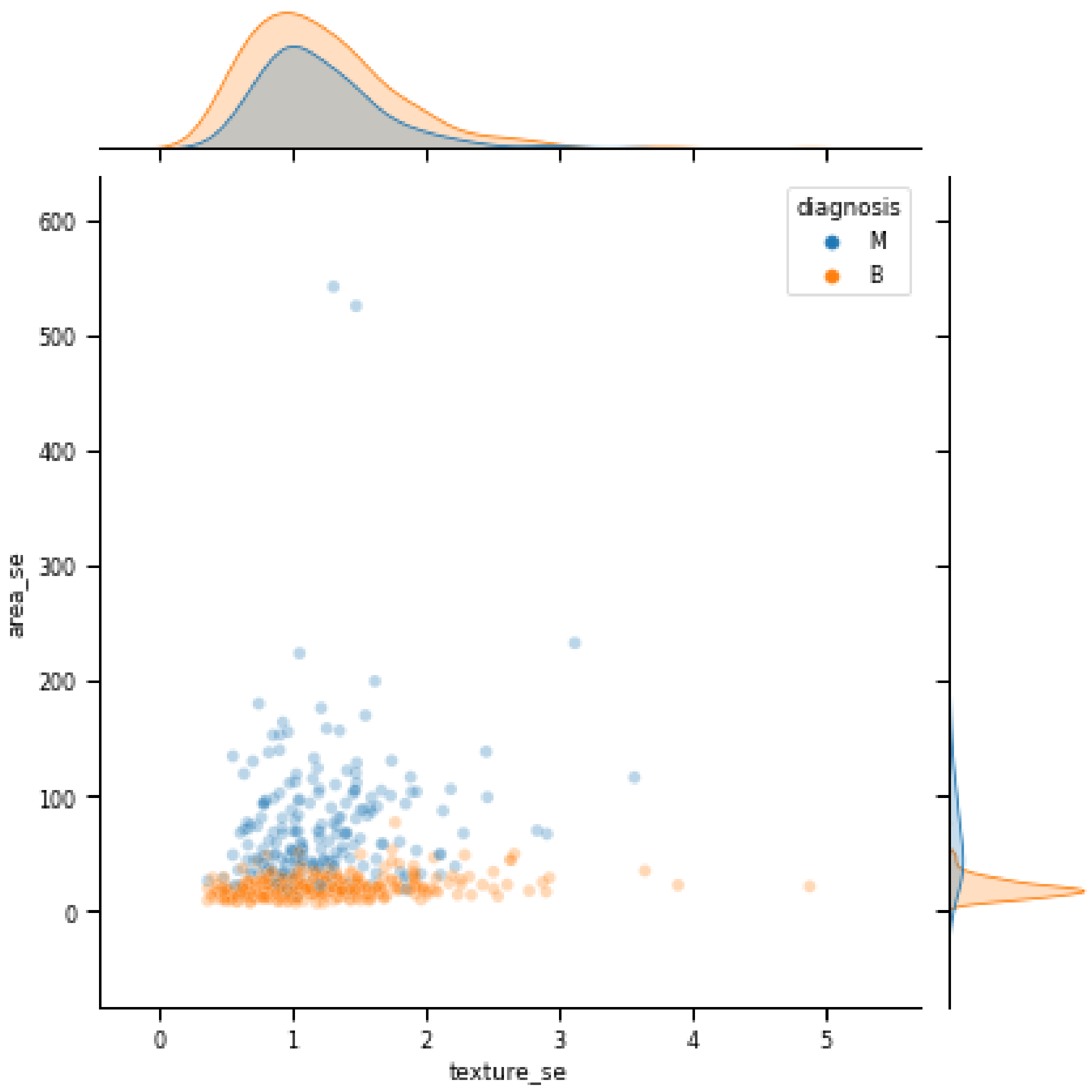
[30]:
```
<seaborn.axisgrid.JointGrid at 0x7f95d99419e8>
```



There is no big difference between benign and malignant tumors in symmetry_se. Malignant tumors may have higher concavity_se.

[31]:
```
sns.jointplot(x='texture_se',y='area_se', data=data, alpha=0.3,hue='diagnosis')
```

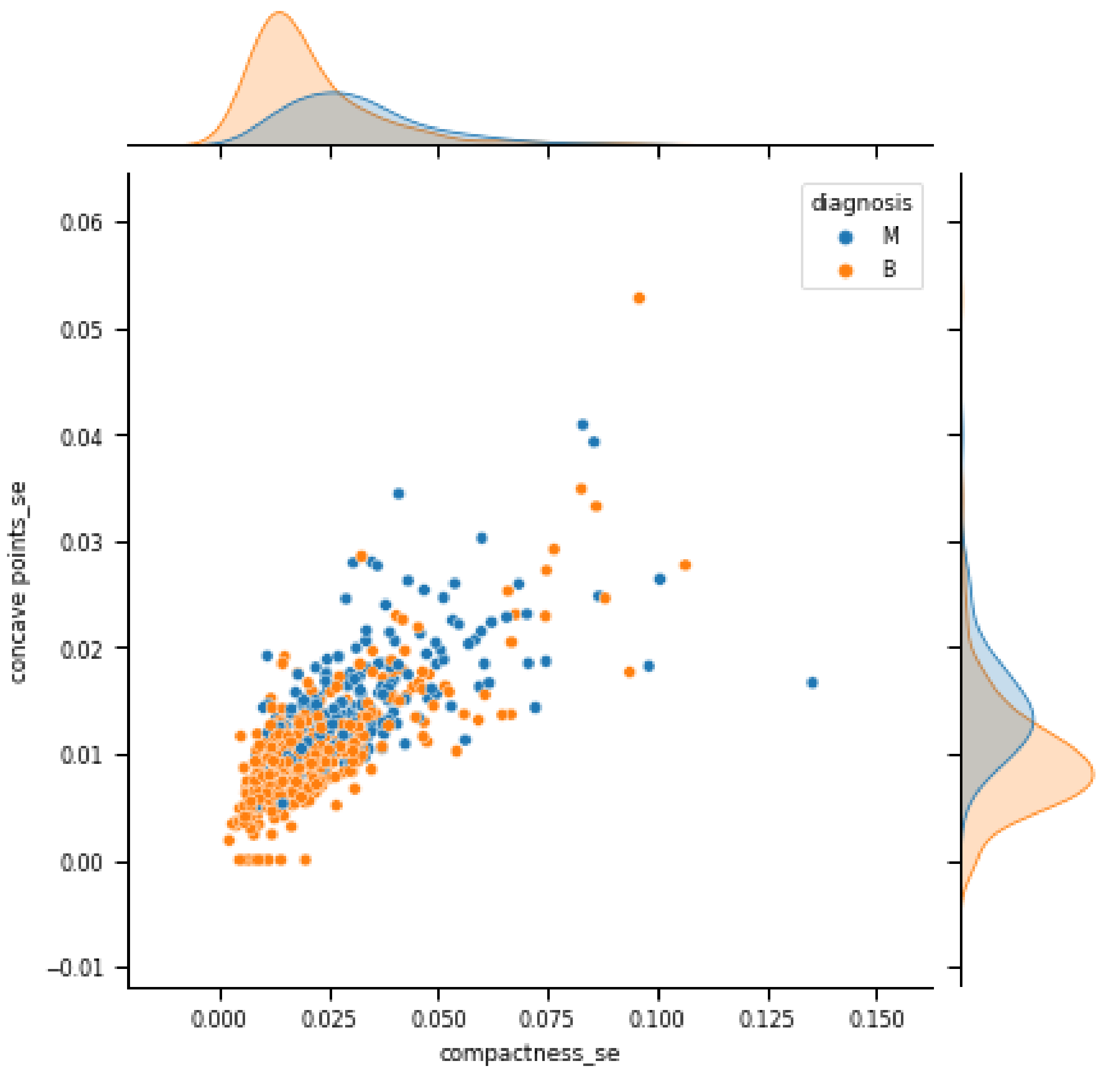
[31]:
```
<seaborn.axisgrid.JointGrid at 0x7f95cc452eb8>
```



Malignant tumors have higher area_se, but no noticeable texture_se difference.

[32]:
```
sns.jointplot(data=data, x="compactness_se", y="concave points_se",␣
 ↪hue='diagnosis')
```

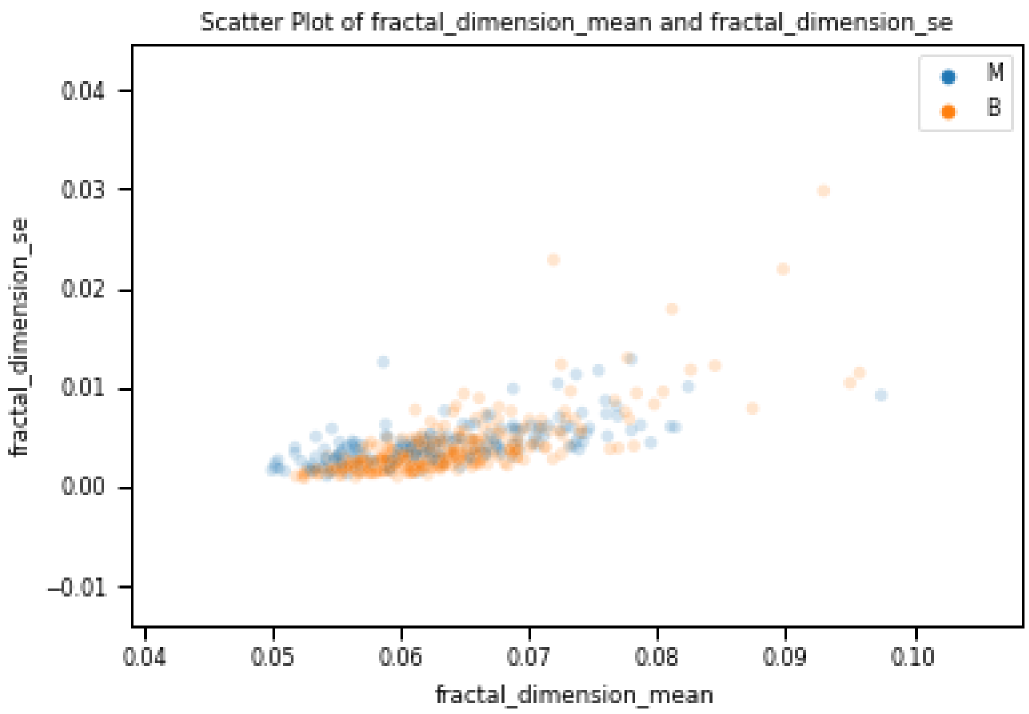
[32]:
```
<seaborn.axisgrid.JointGrid at 0x7f95d9a8a7b8>
```



Malignant tumors have higher compactness_se and concave points_se. And these two features are highly correlated.

[33]:
```
sns.set_context('paper', font_scale=0.9)
sns.scatterplot( x='fractal_dimension_mean',y='fractal_dimension_se',␣
 ↪data=data, hue='diagnosis', alpha=0.2)
plt.legend(loc=0)
plt.title( 'Scatter Plot of fractal_dimension_mean and fractal_dimension_se' )
```

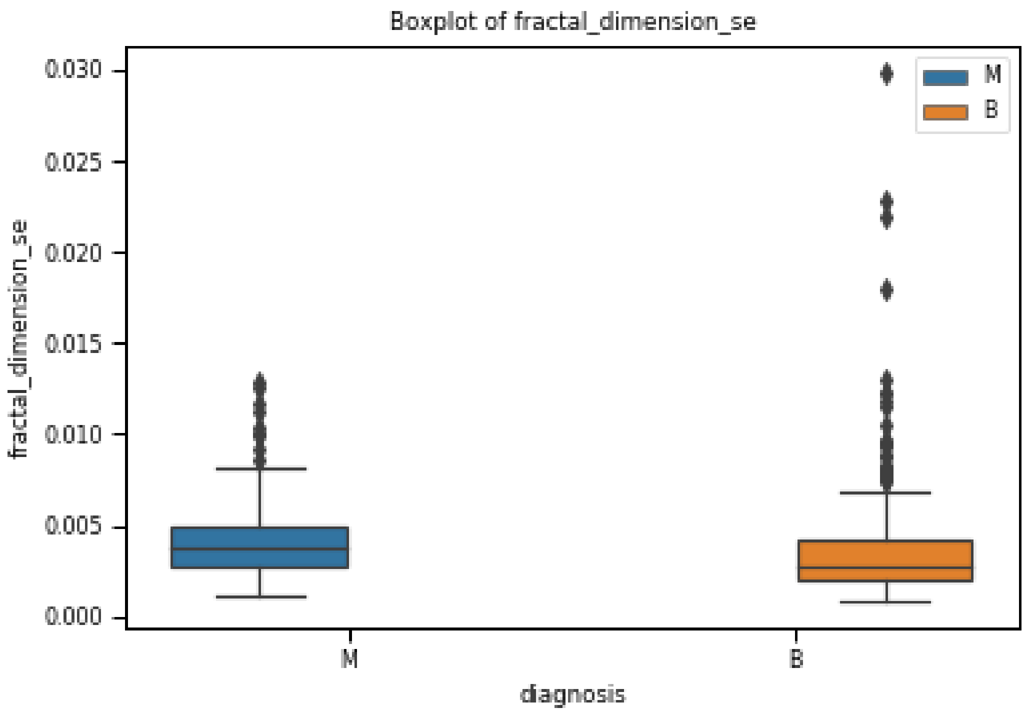
[33]:
```
Text(0.5, 1.0, 'Scatter Plot of fractal_dimension_mean and
fractal_dimension_se')
```



fractal_dimension_mean and fractal_dimension_se are highly correlated. But there is no big fractal_dimension_mean or fractal_dimension_se difference between benign and malignant tumors.

[34]:
```
sns.set_context('paper', font_scale=0.9)
sns.boxplot(x='diagnosis', y='fractal_dimension_se', data=data, hue='diagnosis')
plt.legend(loc=0)
plt.title( 'Boxplot of fractal_dimension_se' )
```

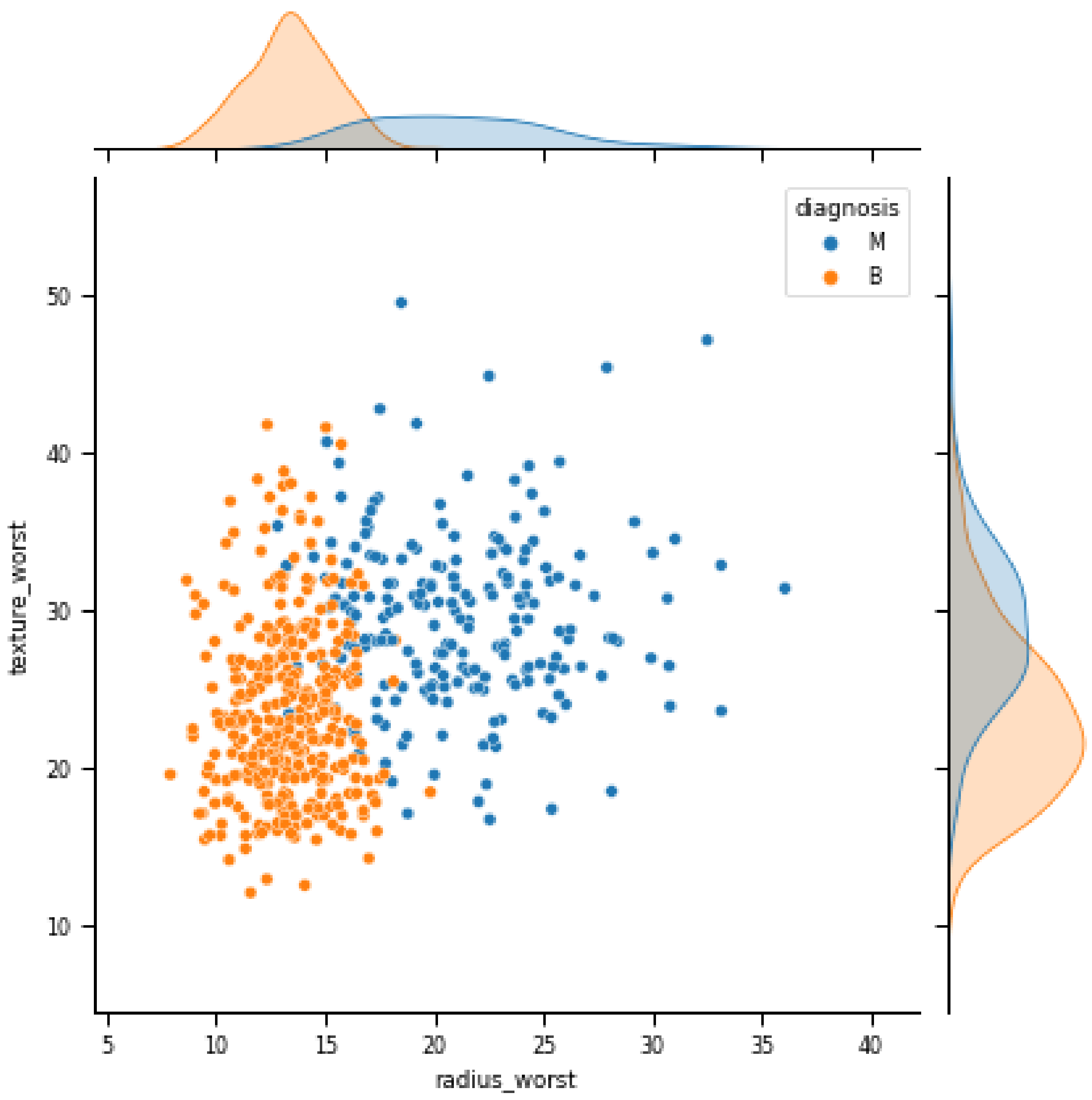
[34]:
```
Text(0.5, 1.0, 'Boxplot of fractal_dimension_se')
```



fractal_dimension_se doesn't vary much between benign tumors and malignant tumors.

[35]:
```
sns.jointplot(x='radius_worst',y='texture_worst', data=data,hue='diagnosis')
```

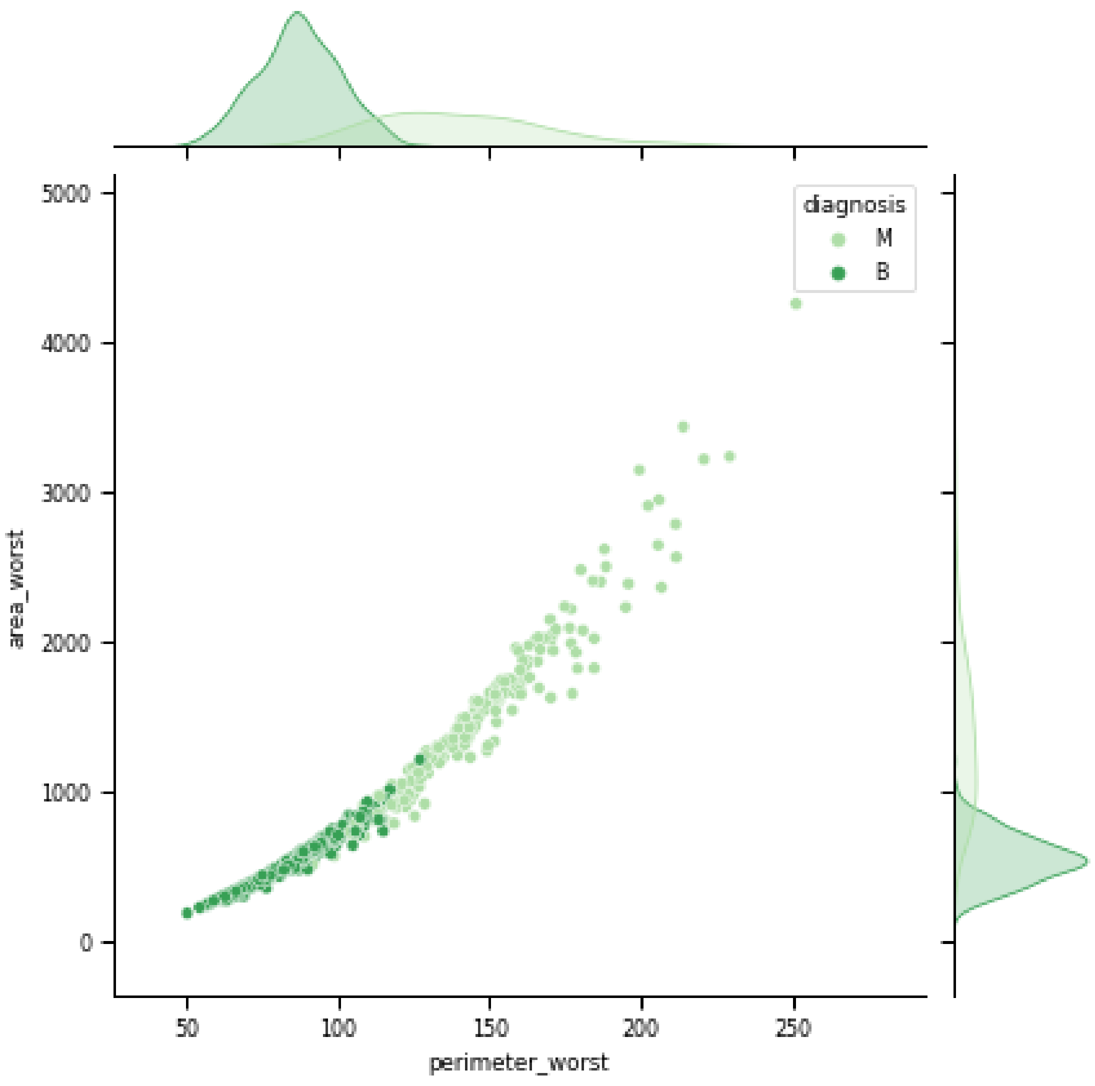
[35]:
```
<seaborn.axisgrid.JointGrid at 0x7f95b8eebeb8>
```



Malignant tumors have higher radius_worst and texture_worst.

[36]:
```
sns.jointplot(x='perimeter_worst',y='area_worst',␣
↪data=data,hue='diagnosis',palette='Greens')
```

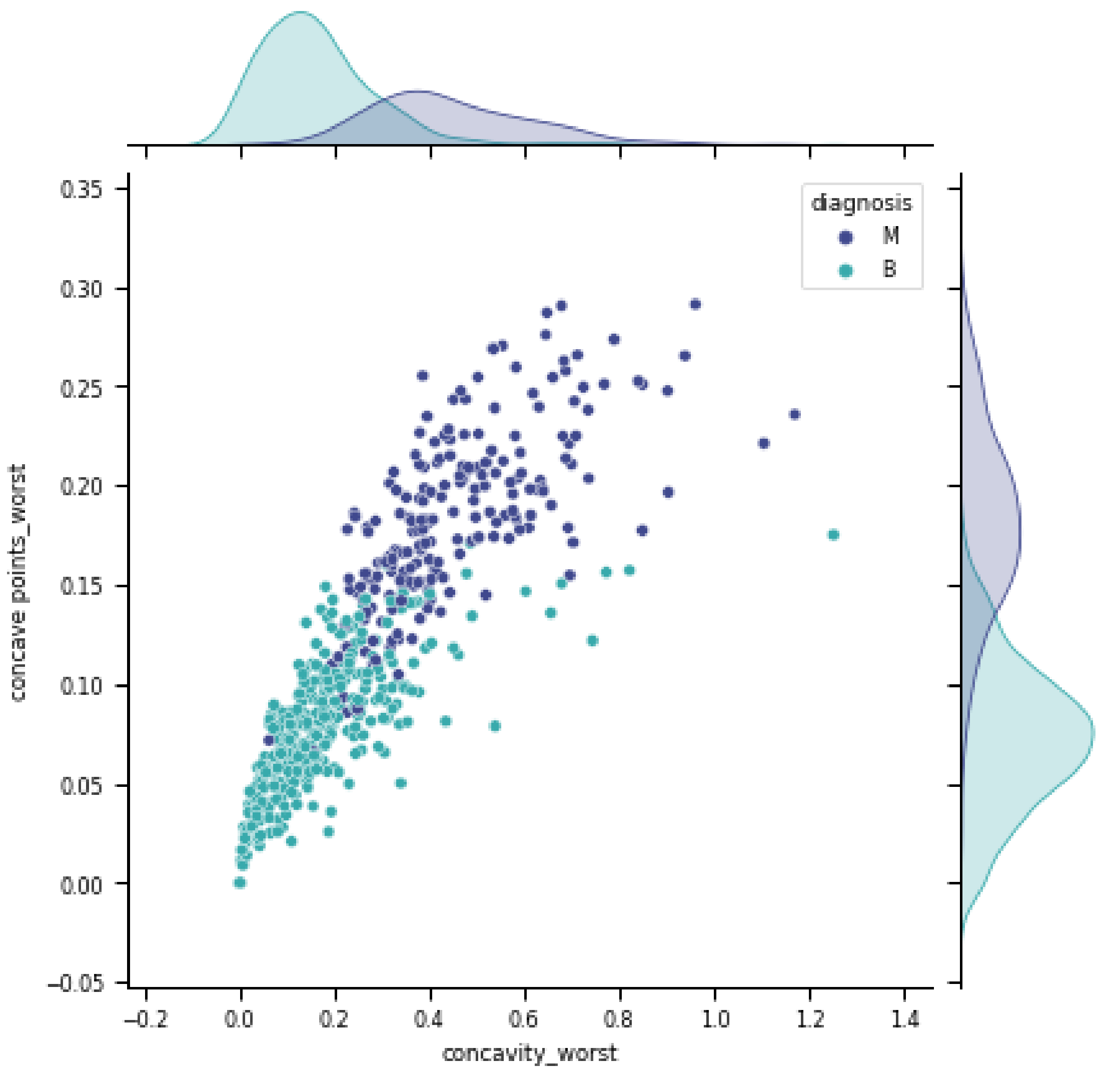
[36]:
```
<seaborn.axisgrid.JointGrid at 0x7f95d9bc4e48>
```



Malignant tumors have higher perimeter_worst and area_worst. These two features are highly correlated.

[37]:
```
sns.jointplot(x='concavity_worst',y='concave points_worst',␣
 ↪data=data,hue='diagnosis',palette='mako')
```

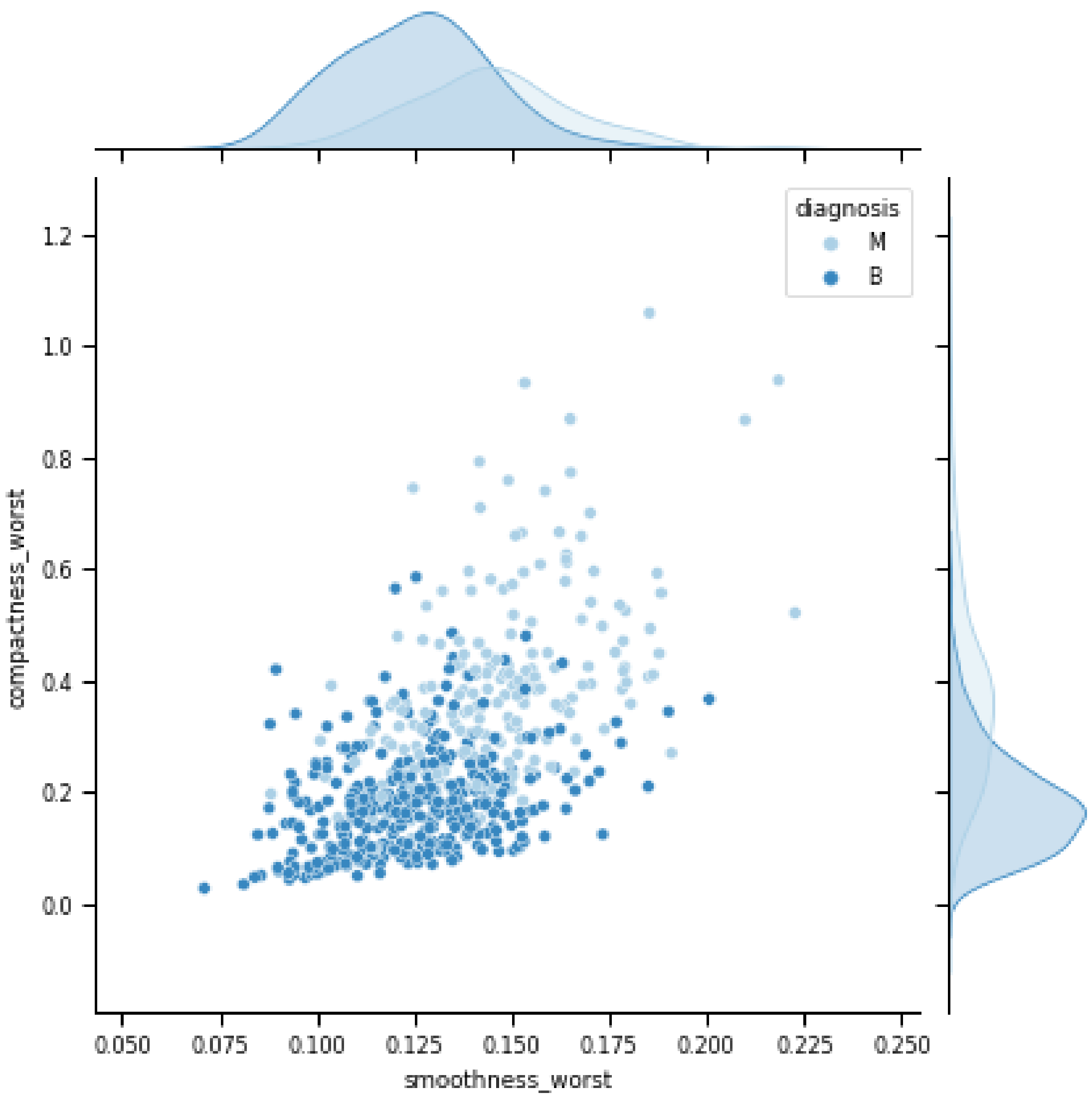
[37]:
```
<seaborn.axisgrid.JointGrid at 0x7f95d9ddeb00>
```



Malignant tumors have higher concavity_worst and concave points_worst. These two features are highly correlated.

[38]:
```
sns.jointplot(x='smoothness_worst',y='compactness_worst',␣
 ↪data=data,hue='diagnosis',palette='Blues')
```

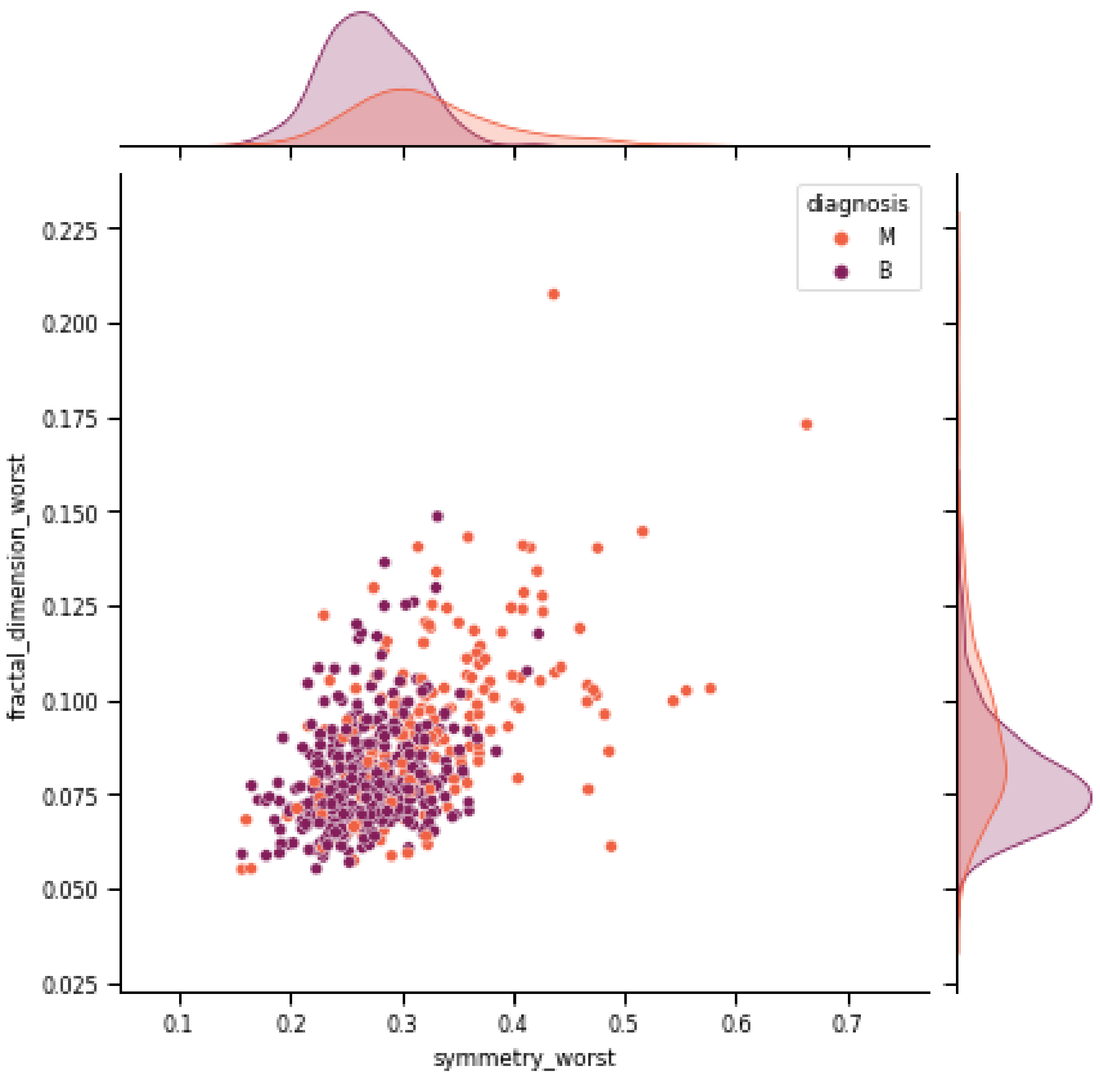
[38]:
```
<seaborn.axisgrid.JointGrid at 0x7f95ea5d5a90>
```



Malignant tumors have higher smoothness_worst and compactness_worst. These two features are somewhat correlated.

[39]:
```
sns.jointplot(x='symmetry_worst',y='fractal_dimension_worst',␣
 ↪data=data,hue='diagnosis',palette='rocket_r')
```

[39]:
```
<seaborn.axisgrid.JointGrid at 0x7f95d9ce6978>
```



Malignant tumors have higher symmetry_worst. Not much difference on fractal_dimension_worst.

0.4 Data Modelling

[58]:
```
data = data2
data.replace('M',1,inplace=True)
```

[59]:
```
data.replace('B',0,inplace=True)
```

0.4.1 Training set and test set split

[60]:
```
seed     = 0                                          # pick a seed to keep it␣
 ↪consistent
df_train = data.sample( frac=0.7, random_state=seed )   # 0.7 means we used 70%␣
 ↪as the training set
df_test  = data.drop( df_train.index )                  # "all the rows not in␣
 ↪df_train"
```

0.4.2 Logistic Regression

[61]:
```
predictors = df_train.iloc[:,1:]
response   = df_train['diagnosis']
```

[62]:
```
# Import the module
from sklearn.linear_model import LogisticRegression

# Create a model and fit it to the data
model = LogisticRegression()
model.fit( predictors, response )
```

[62]:
```
LogisticRegression(C=1.0, class_weight=None, dual=False, fit_intercept=True,
                   intercept_scaling=1, l1_ratio=None, max_iter=100,
                   multi_class='warn', n_jobs=None, penalty='l2',
                   random_state=None, solver='warn', tol=0.0001, verbose=0,
                   warm_start=False)
```

0.4.3 Test the model

[63]:
```
predictors_test = df_test.iloc[:,1:]
response_test   = df_test['diagnosis']
```

[64]:
```
# Use the model to predict the output variable based on the input variables:
df_test['Prediction'] = model.predict( predictors_test )
# Check whether each prediction was correct or not, and show the results:
df_test['Correct'] = df_test['Prediction'] == response_test
df_test
```

[64]:
```
     diagnosis  radius_mean  texture_mean  perimeter_mean  area_mean  \
0            1        17.99         10.38          122.80     1001.0
3            1        11.42         20.38           77.58      386.1
9            1        12.46         24.04           83.97      475.9
11           1        15.78         17.89          103.60      781.0
16           1        14.68         20.13           94.74      684.5
..         ...          ...           ...             ...        ...
551          0        11.13         22.44           71.49      378.4
556          0        10.16         19.59           64.73      311.7
558          0        14.59         22.68           96.39      657.1
```

```
559          0        11.51         23.93            74.52      403.5
568          0         7.76         24.54            47.92      181.0

     smoothness_mean  compactness_mean  concavity_mean  concave points_mean  \
0            0.11840           0.27760        0.300100              0.14710
3            0.14250           0.28390        0.241400              0.10520
9            0.11860           0.23960        0.227300              0.08543
11           0.09710           0.12920        0.099540              0.06606
16           0.09867           0.07200        0.073950              0.05259
..               ...               ...             ...                  ...
551          0.09566           0.08194        0.048240              0.02257
556          0.10030           0.07504        0.005025              0.01116
558          0.08473           0.13300        0.102900              0.03736
559          0.09261           0.10210        0.111200              0.04105
568          0.05263           0.04362        0.000000              0.00000

     symmetry_mean  ...  perimeter_worst  area_worst  smoothness_worst  \
0           0.2419  ...           184.60      2019.0           0.16220
3           0.2597  ...            98.87       567.7           0.20980
9           0.2030  ...            97.65       711.4           0.18530
11          0.1842  ...           136.50      1299.0           0.13960
16          0.1586  ...           123.40      1138.0           0.14640
..             ...  ...              ...         ...               ...
551         0.2030  ...            77.80       436.6           0.10870
556         0.1791  ...            67.88       347.3           0.12650
558         0.1454  ...           105.90       733.5           0.10260
559         0.1388  ...            82.28       474.2           0.12980
568         0.1587  ...            59.16       268.6           0.08996

     compactness_worst  concavity_worst  concave points_worst  symmetry_worst  \
0              0.66560          0.71190               0.26540          0.4601
3              0.86630          0.68690               0.25750          0.6638
9              1.05800          1.10500               0.22100          0.4366
11             0.56090          0.39650               0.18100          0.3792
16             0.18710          0.29140               0.16090          0.3029
..                 ...              ...                   ...             ...
551            0.17820          0.15640               0.06413          0.3169
556            0.12000          0.01005               0.02232          0.2262
558            0.31710          0.36620               0.11050          0.2258
559            0.25170          0.36300               0.09653          0.2112
568            0.06444          0.00000               0.00000          0.2871

     fractal_dimension_worst  Prediction  Correct
0                    0.11890           1     True
3                    0.17300           0    False
9                    0.20750           1     True
11                   0.10480           1     True
```

```
16                        0.08216           1     True
..                            ...         ...      ...
551                       0.08032           0     True
556                       0.06742           0     True
558                       0.08004           0     True
559                       0.08732           0     True
568                       0.07039           0     True

[171 rows x 33 columns]
```

[65]:
```
df_test['Correct'].sum() / len(df_test)
```

[65]:
```
0.9649122807017544
```

The model reached 96.49% accuracy. Our model is pretty accurate.

[66]:
```
# True positive means the answer and the prediction were positive.
TP = ( df_test['diagnosis'] & df_test['Prediction'] ).sum()
# Similarly for the other three.
TN = ( ~df_test['diagnosis'] & ~df_test['Prediction'] ).sum()
FP = ( ~df_test['diagnosis'] & df_test['Prediction'] ).sum()
FN = ( df_test['diagnosis'] & ~df_test['Prediction'] ).sum()

# Precision and recall are defined using the formulas above.
precision = TP / ( TP + FP )
recall = TP / ( TP + FN )

precision, recall
```

[66]:
```
(0.9838709677419355, 0.9242424242424242)
```

The model has a precision as 98.39%, and recall as 92.42%.

0.5 Summary

In this report, I explored a breast cancer dataset with 30 features including 'radius_mean', 'texture_mean', 'perimeter_mean', 'area_mean', 'smoothness_mean', 'compactness_mean', 'concavity_mean', 'concave points_mean', 'symmetry_mean', 'fractal_dimension_mean', 'radius_se', 'texture_se', 'perimeter_se', 'area_se', 'smoothness_se', 'compactness_se', 'concavity_se', 'concave points_se', 'symmetry_se', 'fractal_dimension_se', 'radius_worst', 'texture_worst', 'perimeter_worst', 'area_worst', 'smoothness_worst', 'compactness_worst', 'concavity_worst', 'concave points_worst', 'symmetry_worst', 'fractal_dimension_worst'.

They are computed for each cell nucleus:

- radius (mean of distances from center to points on the perimeter)
- texture (standard deviation of gray-scale values)
- perimeter
- area
- smoothness (local variation in radius lengths)
- compactness (perimeter^2 / area - 1.0)
- concavity (severity of concave portions of the contour)

- concave points (number of concave portions of the contour)
- symmetry
- fractal dimension (“coastline approximation” - 1)

The mean, standard error and “worst” or largest (mean of the three largest values) of these features were computed for each image.

Malignant tumors tend to have higher ‘radius_mean’, ‘texture_mean’, ‘perimeter_mean’, ‘area_mean’, ‘smoothness_mean’, ‘compactness_mean’, ‘concavity_mean’, ‘concave points_mean’, ‘symmetry_mean’, ‘radius_se’, ‘perimeter_se’, ‘area_se’, ‘compactness_se’, ‘concavity_se’, ‘concave points_se’, ‘radius_worst’, ‘texture_worst’, ‘perimeter_worst’, ‘area_worst’, ‘smoothness_worst’, ‘compactness_worst’, ‘concavity_worst’, ‘concave points_worst’, ‘symmetry_worst’. But malignant tumors and benign tumors tend to have similar ‘fractal_dimension_mean’, ‘fractal_dimension_se’, ‘fractal_dimension_worst’, ‘smoothness_se’, ‘symmetry_se’, ‘texture_se’.

Based on our study, these features can help us identify malignant tumors and alert patients.

In the last part of my research, I developed a logistic regression model that reached 96.49% accuracy. We can use this model to predict if someone has breast cancer according to these features of her tumor and further assit modern medicine.