DATA1030 Project

December 6, 2021

1 Import Data

[25]:
```
import pandas as pd
import numpy as np

df = pd.read_csv("../data/dataset-of-10s.csv")

df.drop(['uri'], axis=1).head()
```

[25]:
```
                                 track                           artist  \
0                          Wild Things                     Alessia Cara
1                            Surfboard                        Esquivel!
2                         Love Someone                     Lukas Graham
3  Music To My Ears (feat. Tory Lanez)                    Keys N Krates
4        Juju On That Beat (TZ Anthem)  Zay Hilfigerrr & Zayion McCall

   danceability  energy  key  loudness  mode  speechiness  acousticness  \
0         0.741   0.626    1    -4.826     0       0.0886       0.02000
1         0.447   0.247    5   -14.661     0       0.0346       0.87100
2         0.550   0.415    9    -6.557     0       0.0520       0.16100
3         0.502   0.648    0    -5.698     0       0.0527       0.00513
4         0.807   0.887    1    -3.892     1       0.2750       0.00381

   instrumentalness  liveness  valence    tempo  duration_ms  time_signature  \
0             0.000    0.0828    0.706  108.029       188493               4
1             0.814    0.0946    0.250  155.489       176880               3
2             0.000    0.1080    0.274  172.065       205463               4
3             0.000    0.2040    0.291   91.837       193043               4
4             0.000    0.3910    0.780  160.517       144244               4

   chorus_hit  sections  target
0    41.18681        10       1
1    33.18083         9       0
2    44.89147         9       1
3    29.52521         7       0
4    24.99199         8       1
```

[26]:
```
df.shape
```

[26]:
```
(6398, 19)
```

[27]:
```
print(df.dtypes)
df2= df.drop(['track','uri','artist'], axis=1)
```

```
track                  object
artist                 object
uri                    object
danceability          float64
energy                float64
key                     int64
loudness              float64
mode                    int64
speechiness           float64
acousticness          float64
instrumentalness      float64
liveness              float64
valence               float64
tempo                 float64
duration_ms             int64
time_signature          int64
chorus_hit            float64
sections                int64
target                  int64
dtype: object
```

[28]:
```
df2.head()
```

[28]:
```
   danceability  energy  key  loudness  mode  speechiness  acousticness  \
0         0.741   0.626    1    -4.826     0       0.0886       0.02000
1         0.447   0.247    5   -14.661     0       0.0346       0.87100
2         0.550   0.415    9    -6.557     0       0.0520       0.16100
3         0.502   0.648    0    -5.698     0       0.0527       0.00513
4         0.807   0.887    1    -3.892     1       0.2750       0.00381

   instrumentalness  liveness  valence    tempo  duration_ms  time_signature  \
0             0.000    0.0828    0.706  108.029       188493               4
1             0.814    0.0946    0.250  155.489       176880               3
2             0.000    0.1080    0.274  172.065       205463               4
3             0.000    0.2040    0.291   91.837       193043               4
4             0.000    0.3910    0.780  160.517       144244               4

   chorus_hit  sections  target
0    41.18681        10       1
1    33.18083         9       0
2    44.89147         9       1
```

```
3    29.52521          7       0
4    24.99199          8       1
```

[29]:
```
df['target'].unique().shape[0]
```

[29]:
```
2
```

[30]:
```
unique_value=df.select_dtypes(exclude=['object']).nunique().sort_values()
unique_value
```

[30]:
```
mode                   2
target                 2
time_signature         5
key                   12
sections              40
danceability         882
energy              1066
speechiness         1114
liveness            1206
valence             1219
instrumentalness    2302
acousticness        2668
loudness            4704
tempo               5531
duration_ms         5591
chorus_hit          6241
dtype: int64
```

[31]:
```
df.isnull().values.any()
```

[31]:
```
False
```

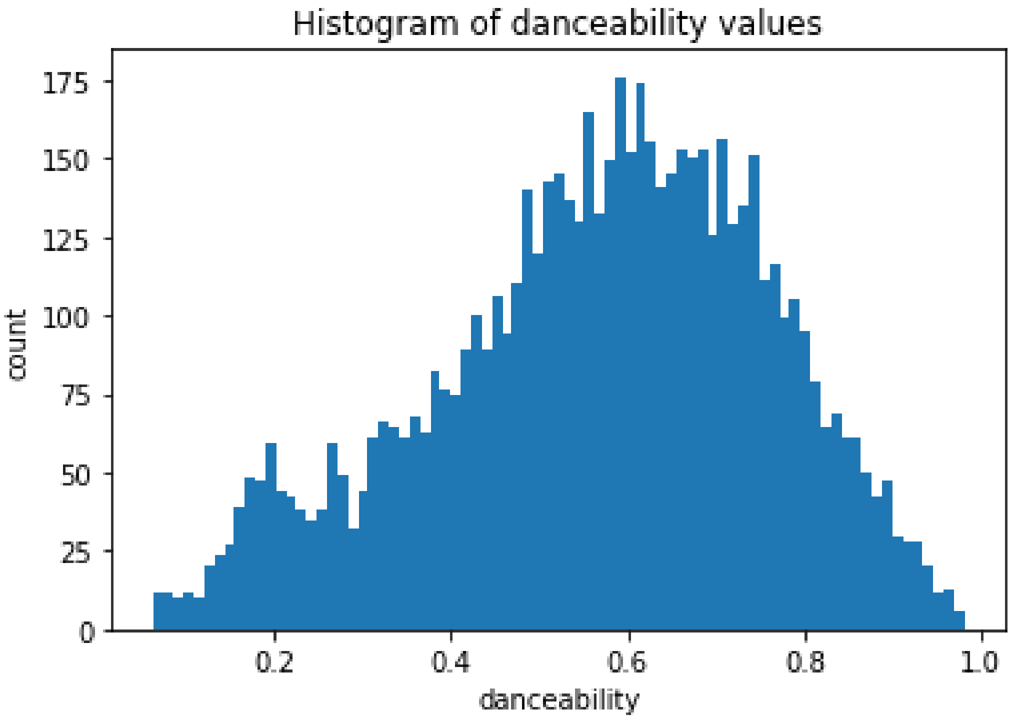
[32]:
```
columns = list(df2.columns)
```

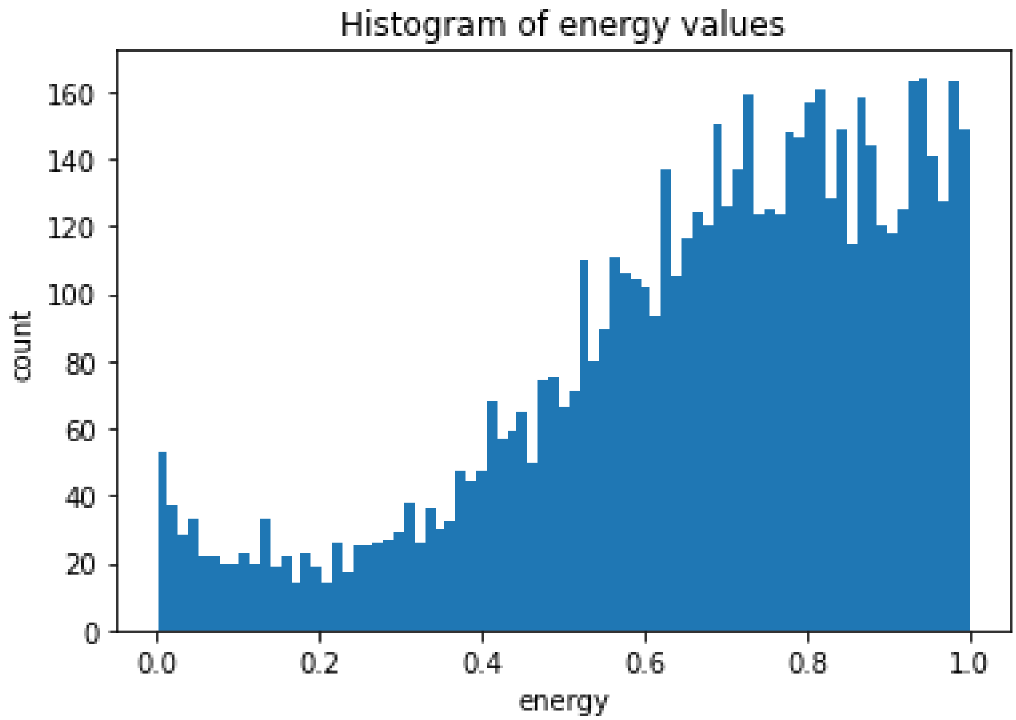
---

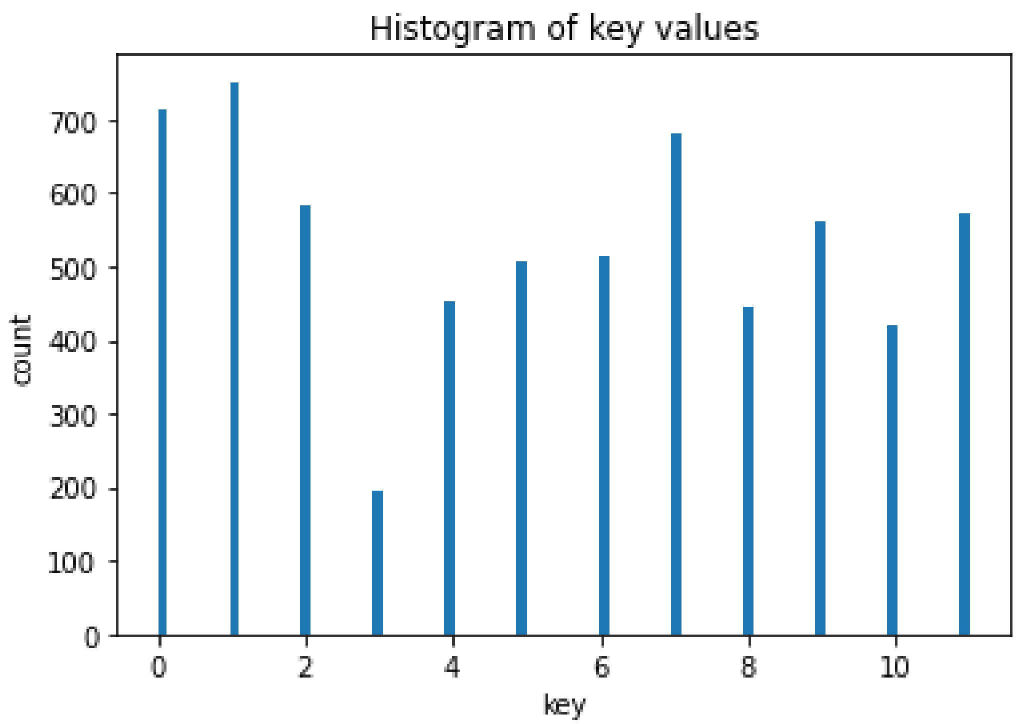
2 Plots

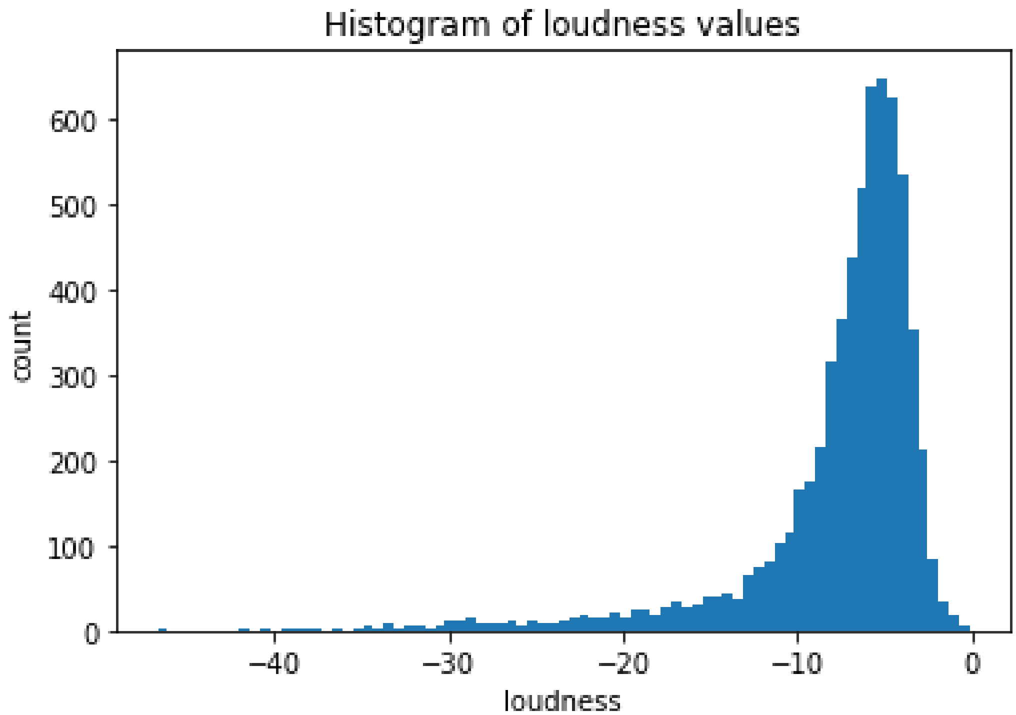
[33]:
```
from matplotlib import pylab as plt
for column in columns:
    if column == "target":
        pd.value_counts(df[column]).plot.bar()
        figtitle = '../figures/barplot_target.png'
        plt.title('Barplot of Target Variable ')
        figtitle = f'../figures/barplot_{column}.png'
    else:
        df[column].plot.hist(bins = int(np.sqrt(df.shape[0])))
        plt.title(f'Histogram of {column} values')
```

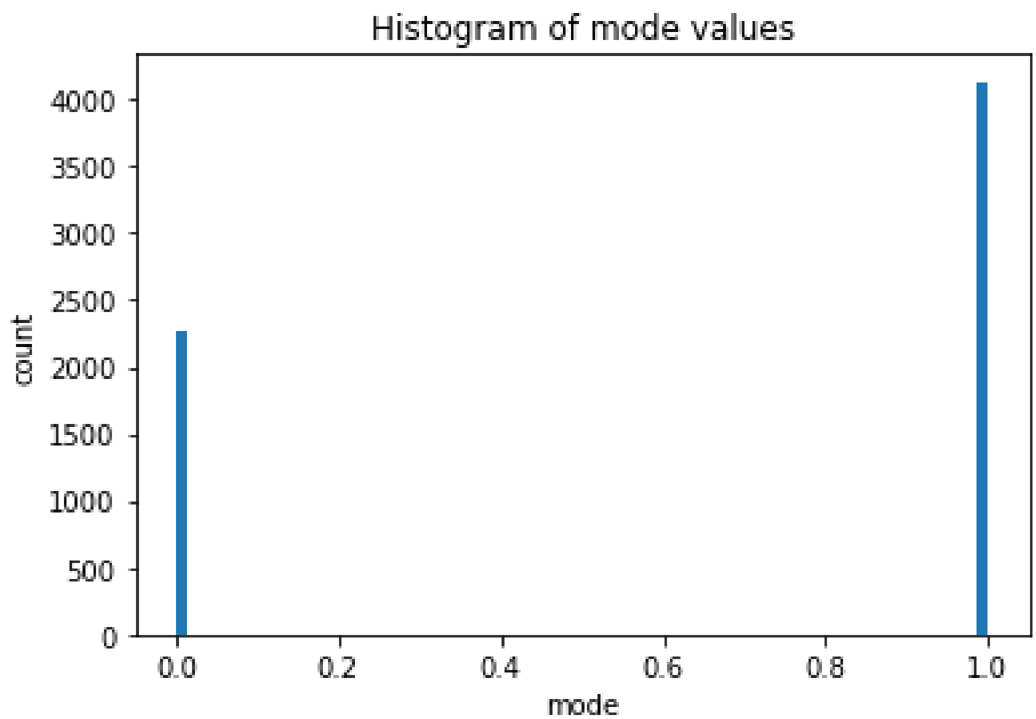
```
        figtitle = f'../figures/histogram_{column}.png'
    plt.xlabel(column)
    plt.ylabel('count')

    plt.savefig(figtitle, dpi=300, format='png')
    plt.show()
```

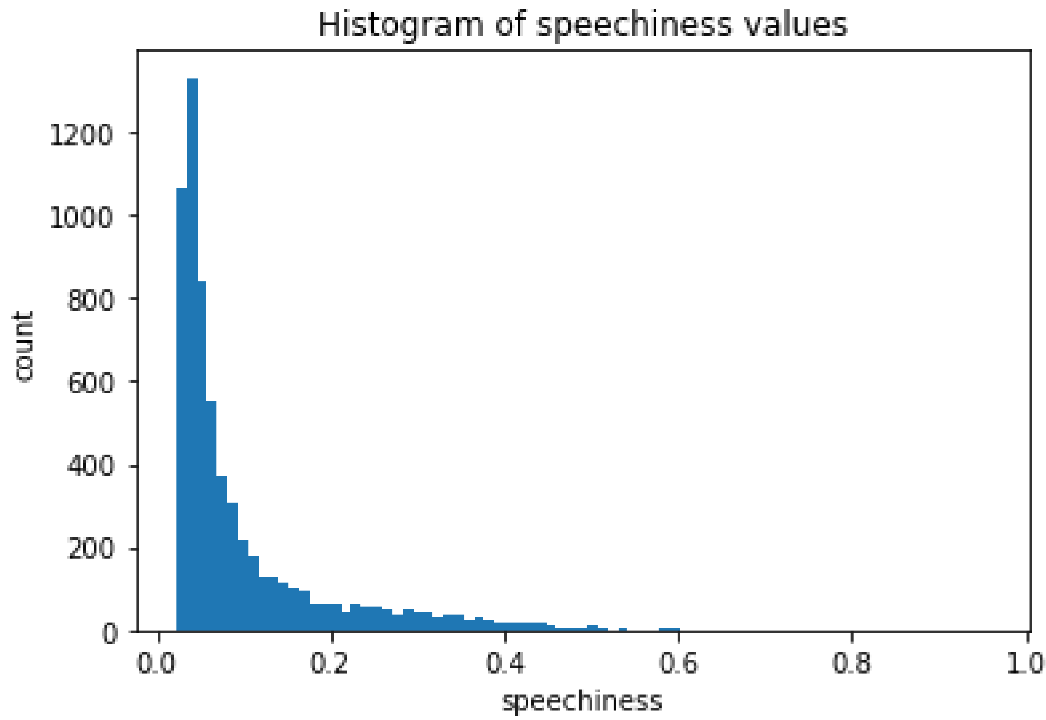


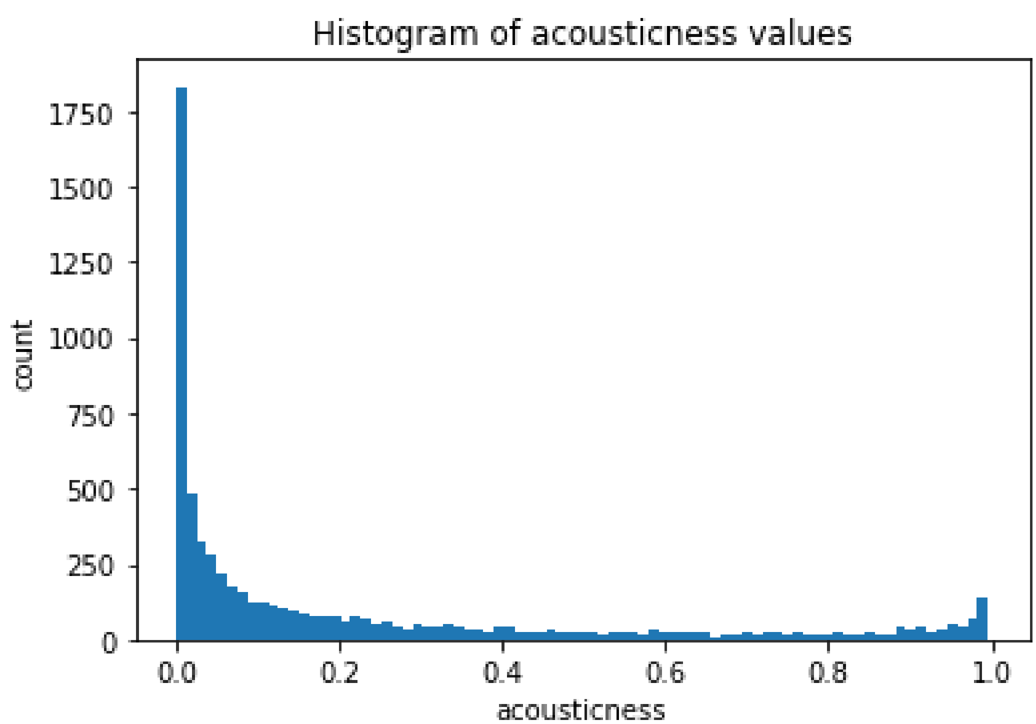

Histogram of energy values
count
energy
0
20
40
60
80
100
120
140
160
0.0
0.2
0.4
0.6
0.8
1.0

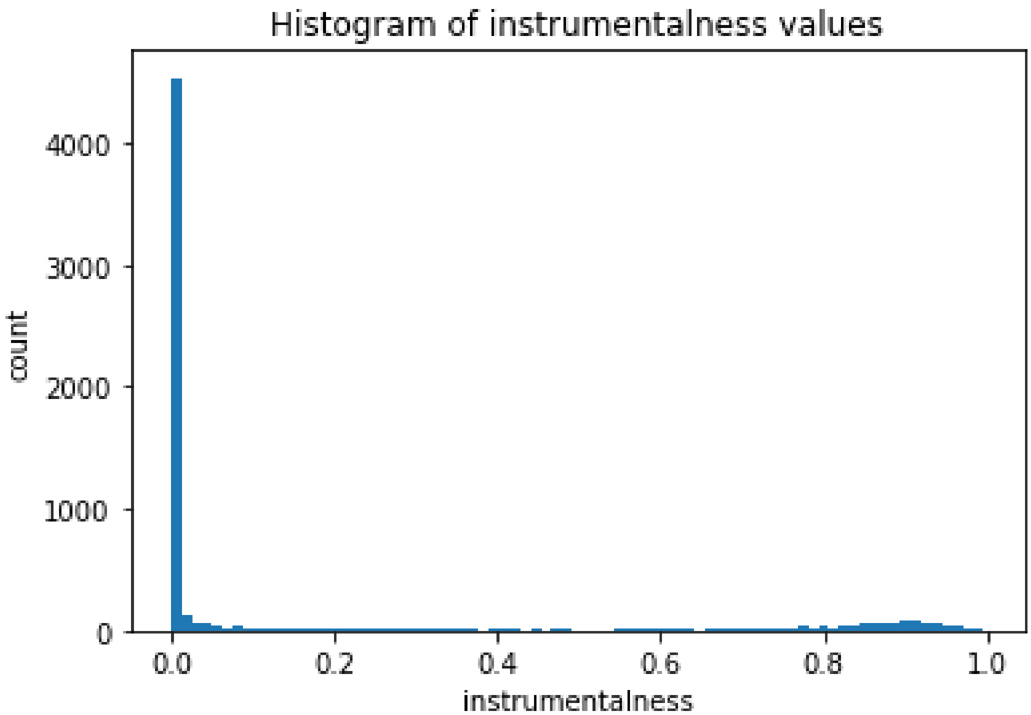

Histogram of key values
count
key
0
100
200
300
400
500
600
700
0
2
4
6
8
10

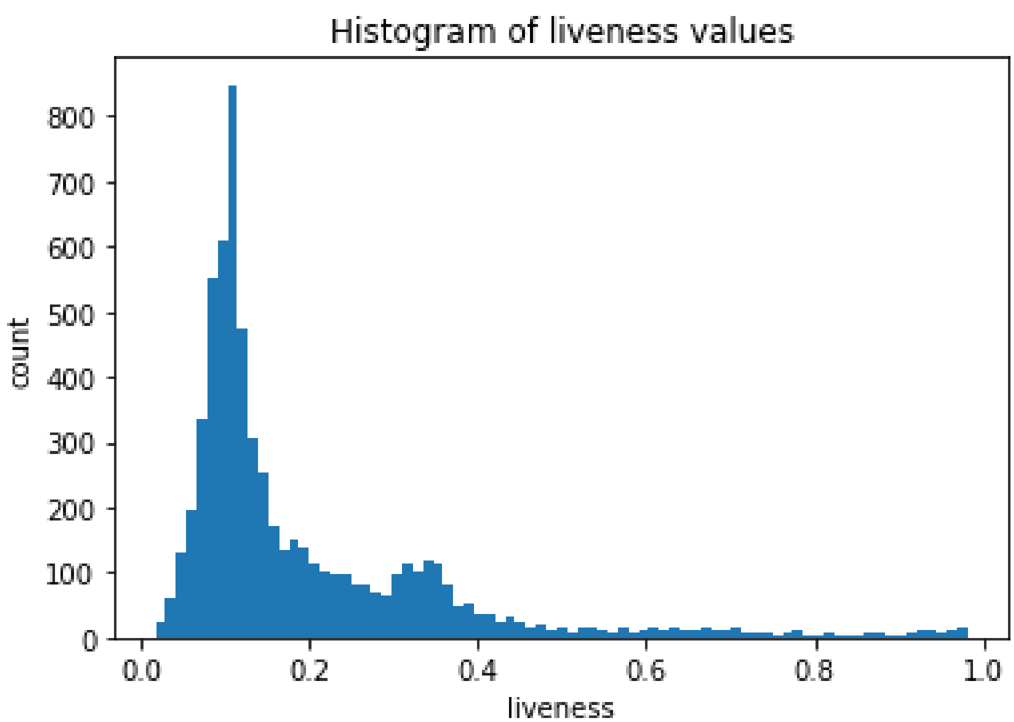

Histogram of loudness values
count
loudness
600
500
400
300
200
100
0
−40
−30
−20
−10
0

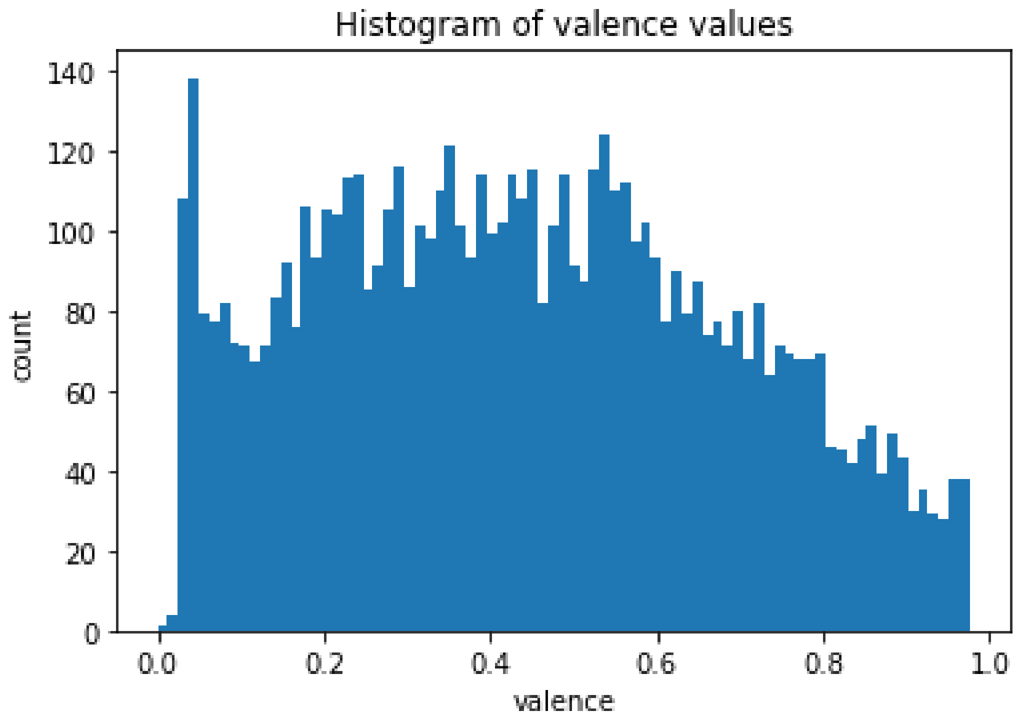

Histogram of mode values
count
mode
4000
3500
3000
2500
2000
1500
1000
500
0
0.0
0.2
0.4
0.6
0.8
1.0

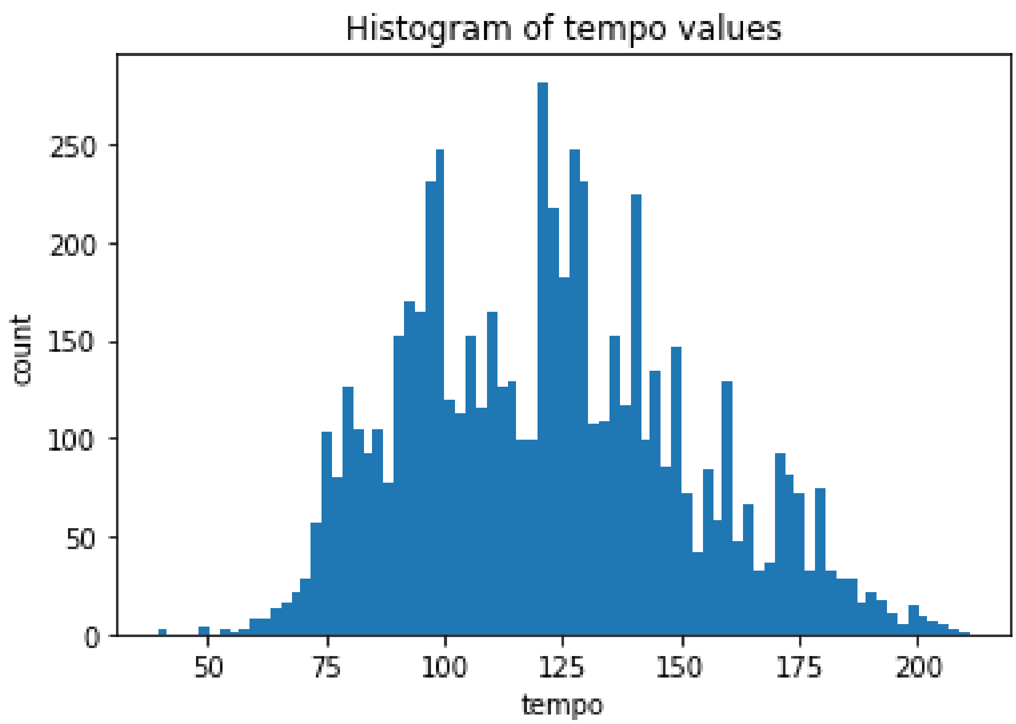

Histogram of speechiness values
count
1200
1000
800
600
400
200
0
0.0
0.2
0.4
0.6
0.8
1.0
speechiness

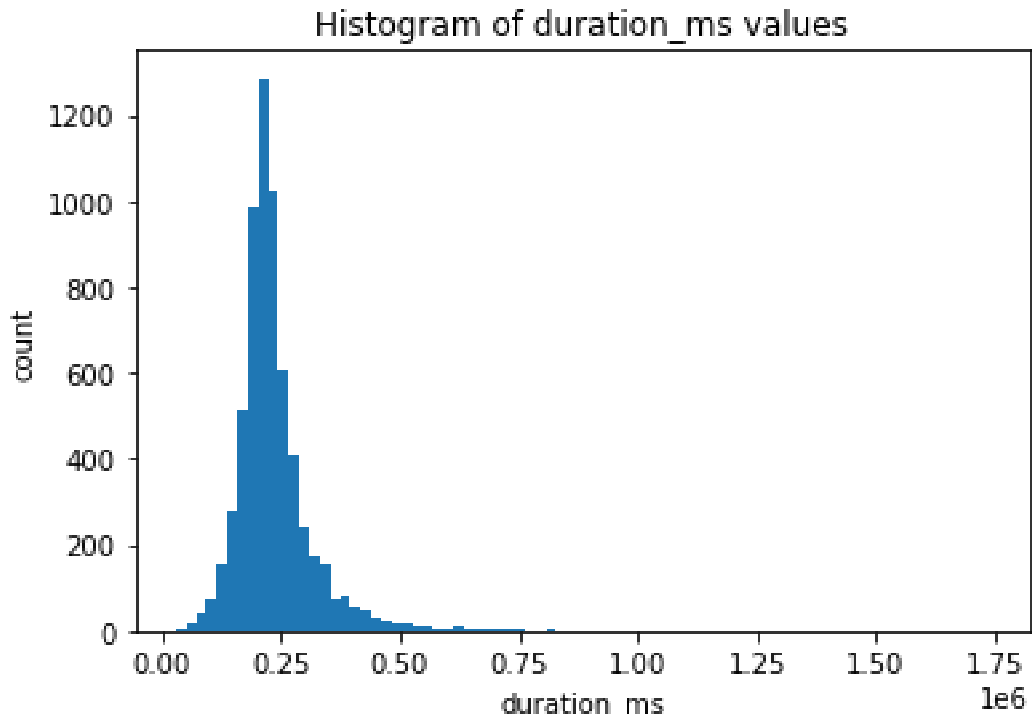

Histogram of acousticness values
count
1750
1500
1250
1000
750
500
250
0
0.0
0.2
0.4
0.6
0.8
1.0
acousticness

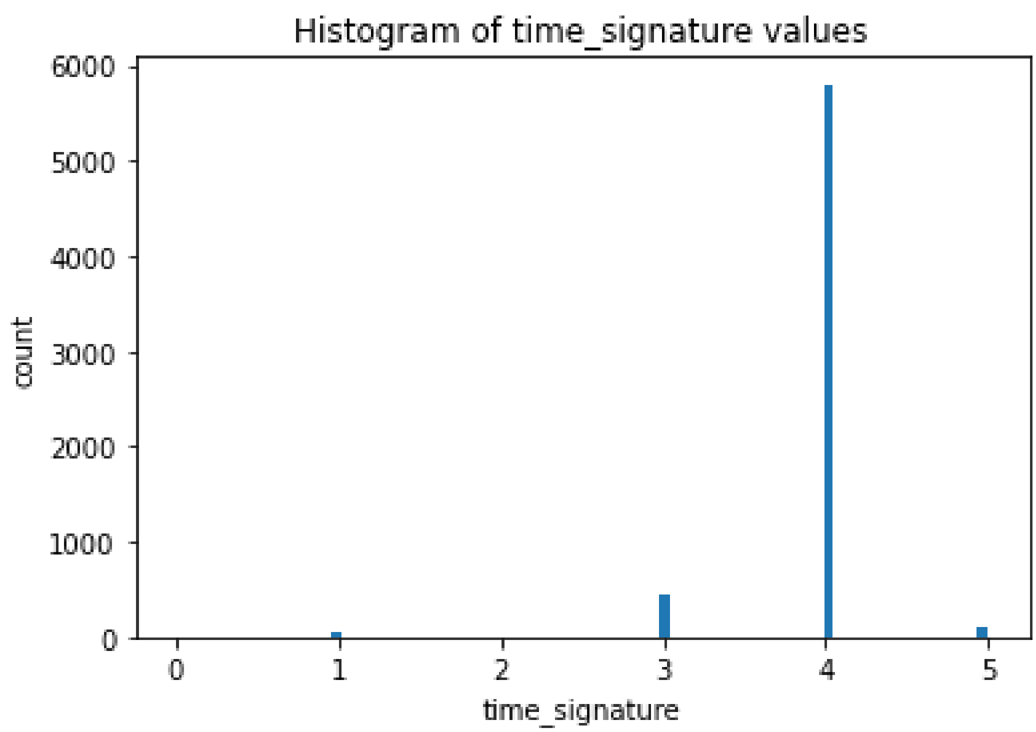

Histogram of instrumentalness values
count
4000
3000
2000
1000
0
0.0
0.2
0.4
0.6
0.8
1.0
instrumentalness

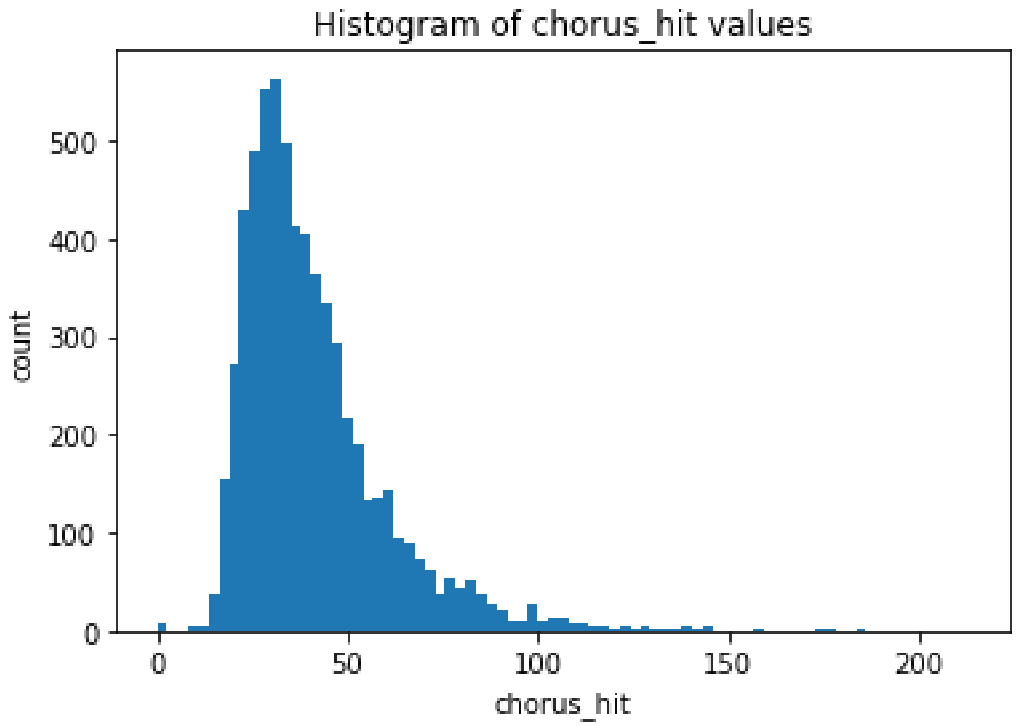

Histogram of liveness values
count
800
700
600
500
400
300
200
100
0
0.0
0.2
0.4
0.6
0.8
1.0
liveness

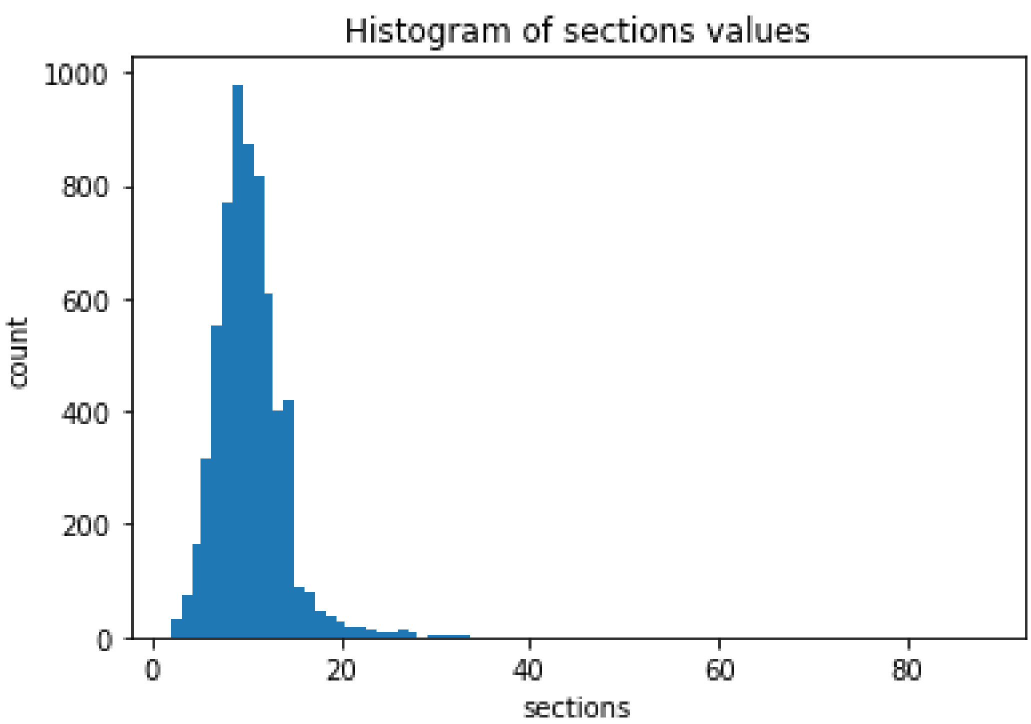

Histogram of valence values
count
valence
0
20
40
60
80
100
120
140
0.0
0.2
0.4
0.6
0.8
1.0

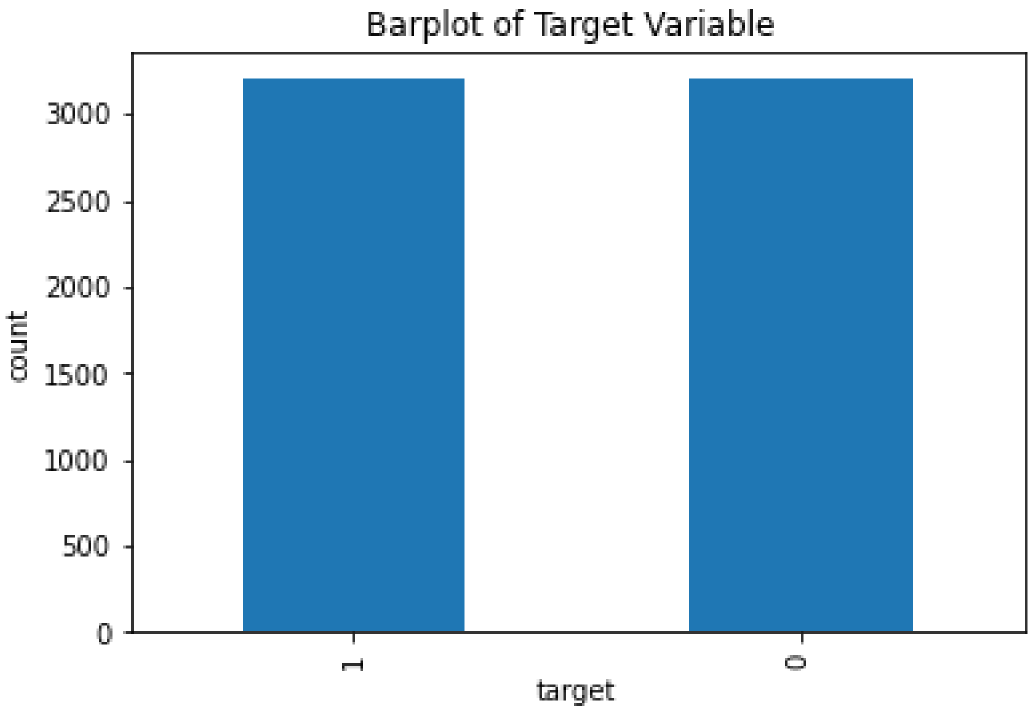

Histogram of tempo values
count
tempo
0
50
100
150
200
250
50
75
100
125
150
175
200


Histogram of duration_ms values
count
1200
1000
800
600
400
200
0
0.00
0.25
0.50
0.75
1.00
1.25
1.50
1.75
duration_ms
1e6


Histogram of time_signature values
count
6000
5000
4000
3000
2000
1000
0
0
1
2
3
4
5
time_signature

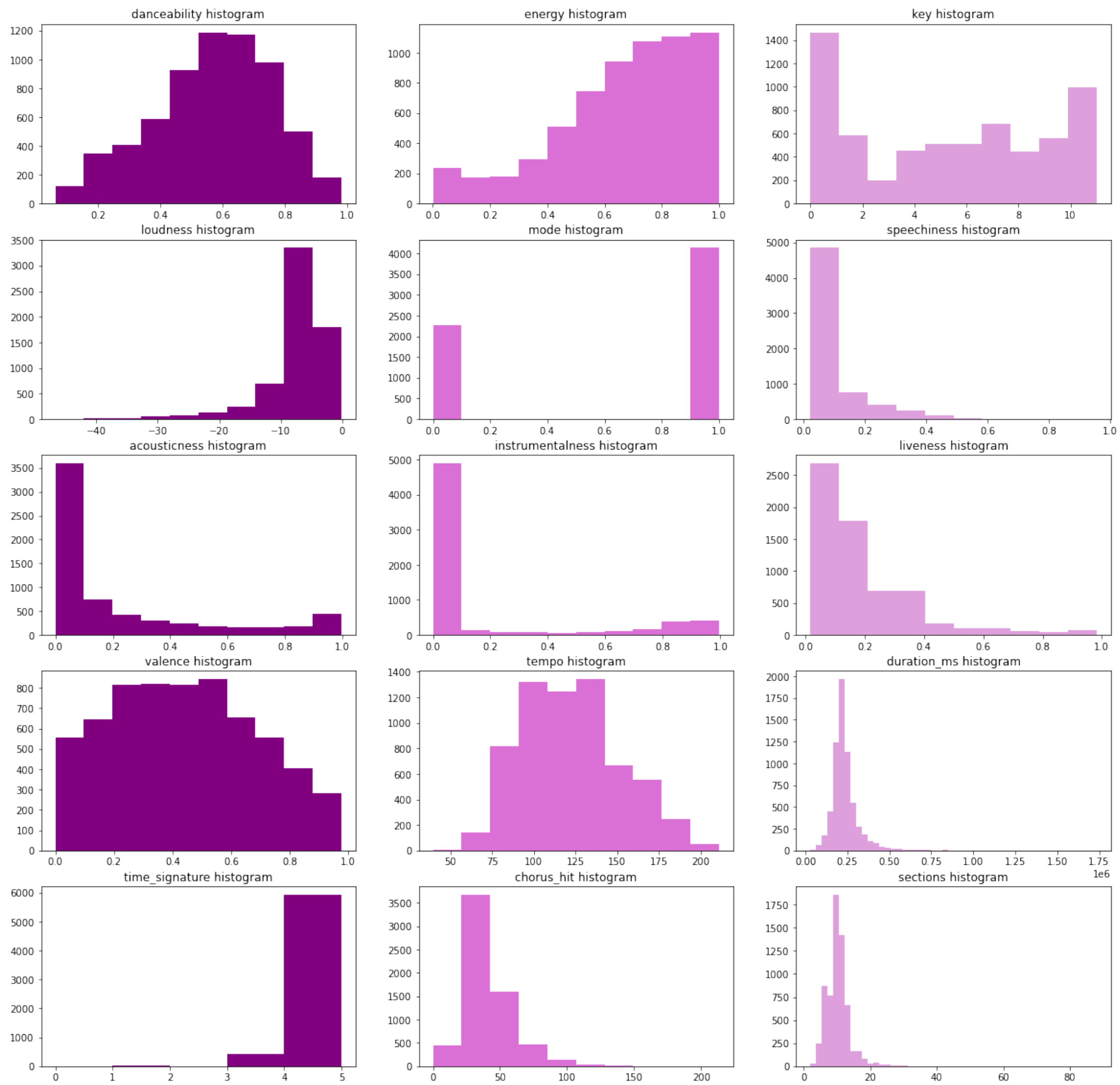

Histogram of chorus_hit values
count
0
100
200
300
400
500
0
50
100
150
200
chorus_hit


Histogram of sections values
count
0
200
400
600
800
1000
0
20
40
60
80
sections

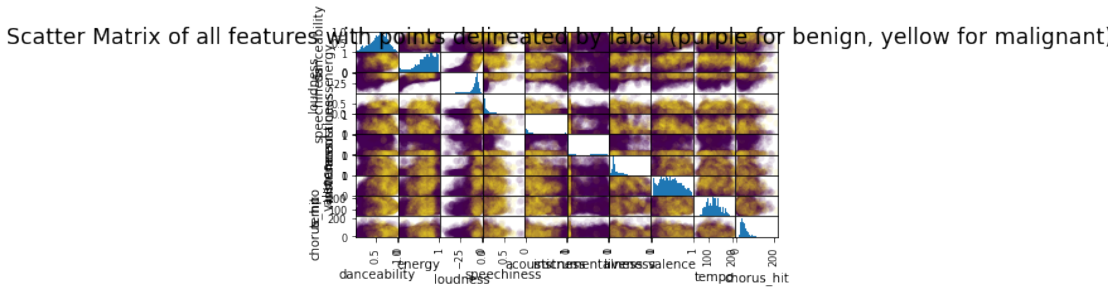


[34]:
```
#create histograpms of all the variables to see distributions
fig, ax = plt.subplots(5,3, figsize=(20,20))

def hist_plot(row, column, variable, binsnum, color):
    ax[row, column].hist(df[variable], bins = binsnum, color = color)
    ax[row, column].set_title(variable + ' histogram')

hist_plot(0, 0, 'danceability', 10, 'purple')
hist_plot(0, 1, 'energy', 10, 'orchid')
hist_plot(0, 2, 'key', 10, 'plum')
hist_plot(1,0, 'loudness', 10, 'purple')
hist_plot(1,1, 'mode', 10, 'orchid')
hist_plot(1,2, 'speechiness', 10, 'plum')
hist_plot(2,0, 'acousticness', 10, 'purple')
hist_plot(2,1, 'instrumentalness', 10, 'orchid')
hist_plot(2,2, 'liveness', 10, 'plum')
hist_plot(3,0, 'valence', 10, 'purple')
hist_plot(3,1, 'tempo', 10, 'orchid')
hist_plot(3,2, 'duration_ms', 50, 'plum')
hist_plot(4,0, 'time_signature', 5, 'purple')
hist_plot(4,1, 'chorus_hit', 10, 'orchid')
hist_plot(4,2, 'sections', 50, 'plum')
```

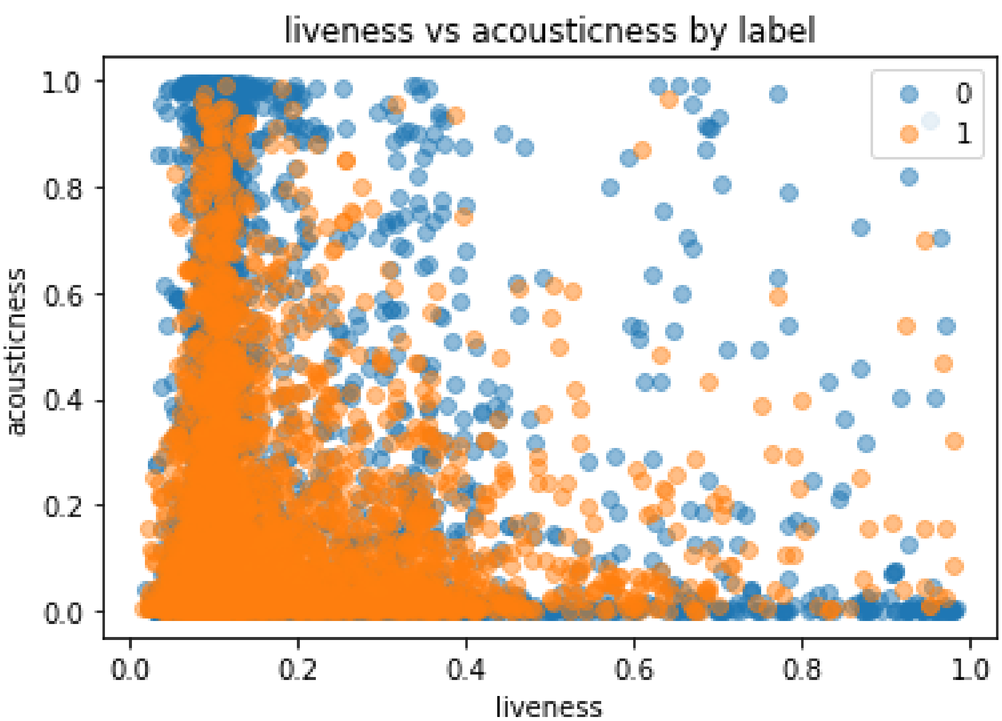
```
figtitle = f'../figures/histogram_all.png'
plt.savefig(figtitle, dpi=300, format='png')
plt.show()
```



[35]:
```
pd.plotting.scatter_matrix(df2.select_dtypes(float), figsize=(6, 3),c = pd.
 ↪get_dummies(df['target']).iloc[:,1],
                              marker='o',hist_kwds={'bins': 50}, s=30, alpha=.1)
plt.suptitle('Scatter Matrix of all features with points delineated by label␣
 ↪(purple for benign, yellow for malignant)',
             y = 0.90, fontsize='xx-large')
figtitle = f'../figures/scattermatrix_all_.png'
plt.savefig(figtitle, dpi=300, format='png')
plt.show()
```



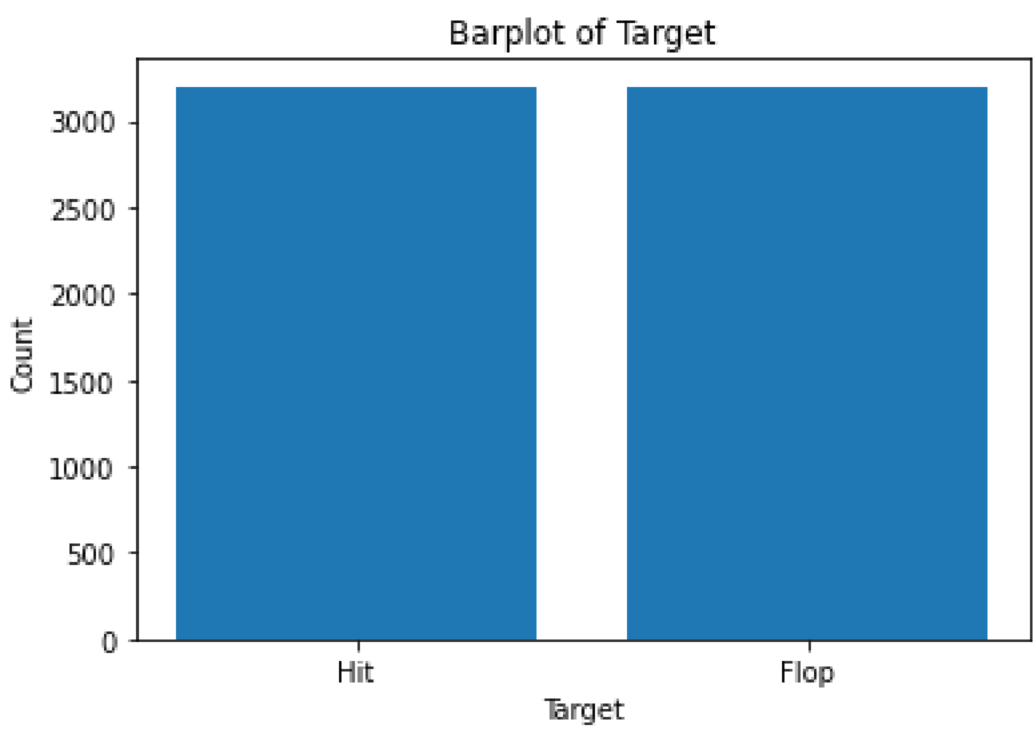

```
[36]: groups = df.groupby("target")
for name, group in groups:
    plt.plot(group['liveness'], group['acousticness'], marker="o",␣
 ↪linestyle="", label=name,alpha=0.5)
plt.title("liveness vs acousticness by label")
plt.xlabel('liveness')
plt.ylabel('acousticness')
figtitle = f'../figures/scattermatrix_liveness_acouticness_.png'
plt.savefig(figtitle, dpi=300, format='png')
plt.legend()
plt.show()
```



[37]:

```python
# Make a random dataset:
height = [df[df['target']==1].shape[0], df[df['target']==0].shape[0]]
bars = ('Hit', 'Flop')
y_pos = np.arange(len(bars))

print(df.target.value_counts())
# Create bars
plt.bar(y_pos, height)

# Create names on the x-axis
plt.xticks(y_pos, bars)

plt.title('Barplot of Target')
plt.ylabel('Count')
plt.xlabel('Target')

figtitle = f'../figures/scatterplot_target_.png'
plt.savefig(figtitle, dpi=300, format='png')
# Show graphic
plt.show()
```

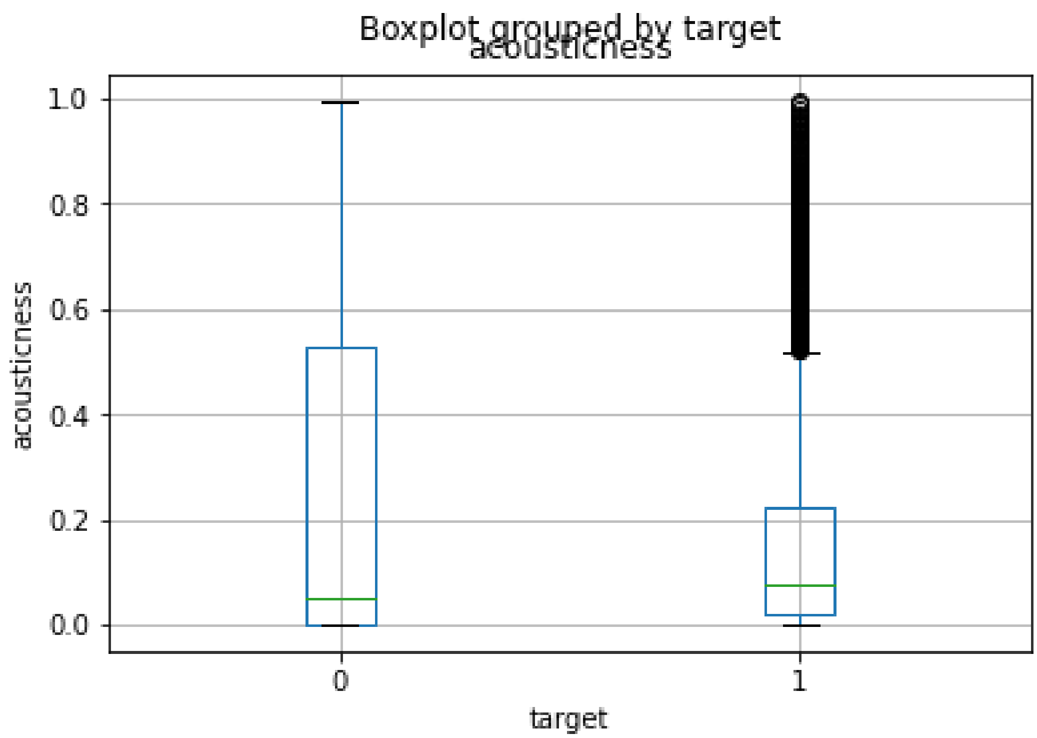
```
1    3199
0    3199
Name: target, dtype: int64
```



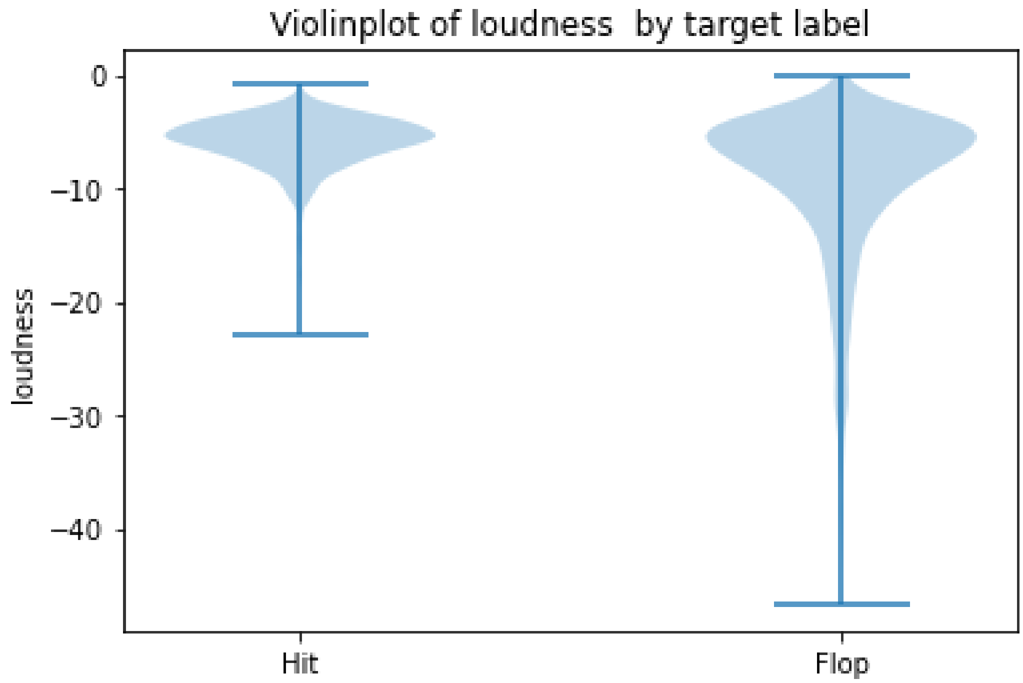
[38]:
```
df[df['target']==1].shape[0]
```

[38]: 3199

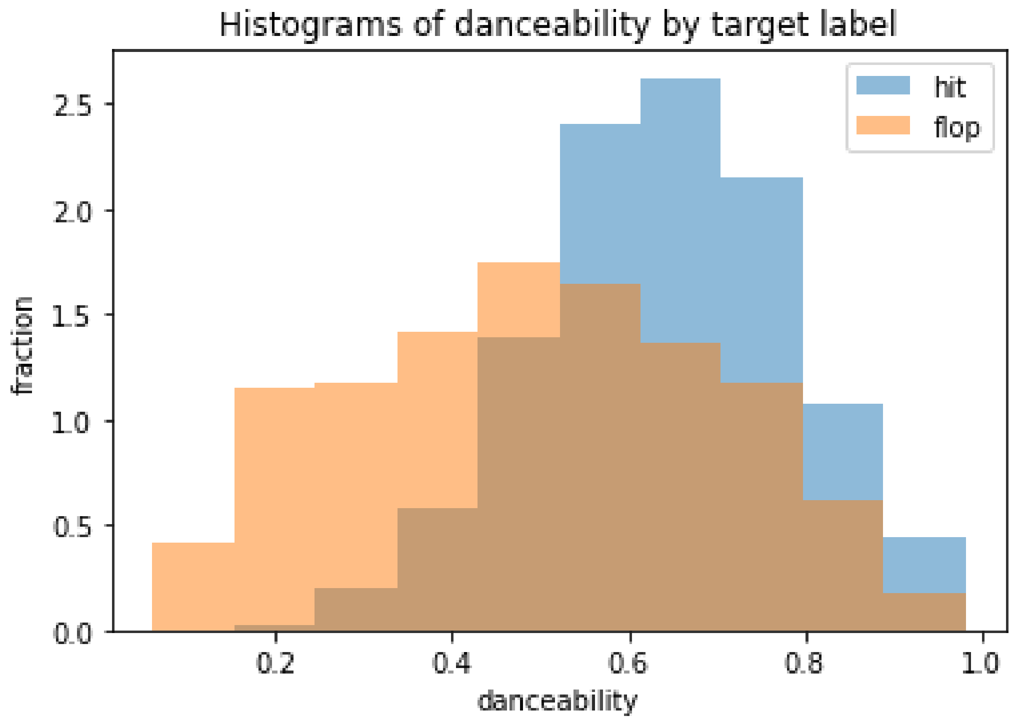
[39]:
```
from matplotlib import pylab as plt
df[['target','acousticness']].boxplot(by='target')
plt.ylabel('acousticness')
plt.xlabel('target')

figtitle = f'../figures/boxplot_accousticness_target.png'
plt.savefig(figtitle, dpi=300, format='png')

plt.show()
```



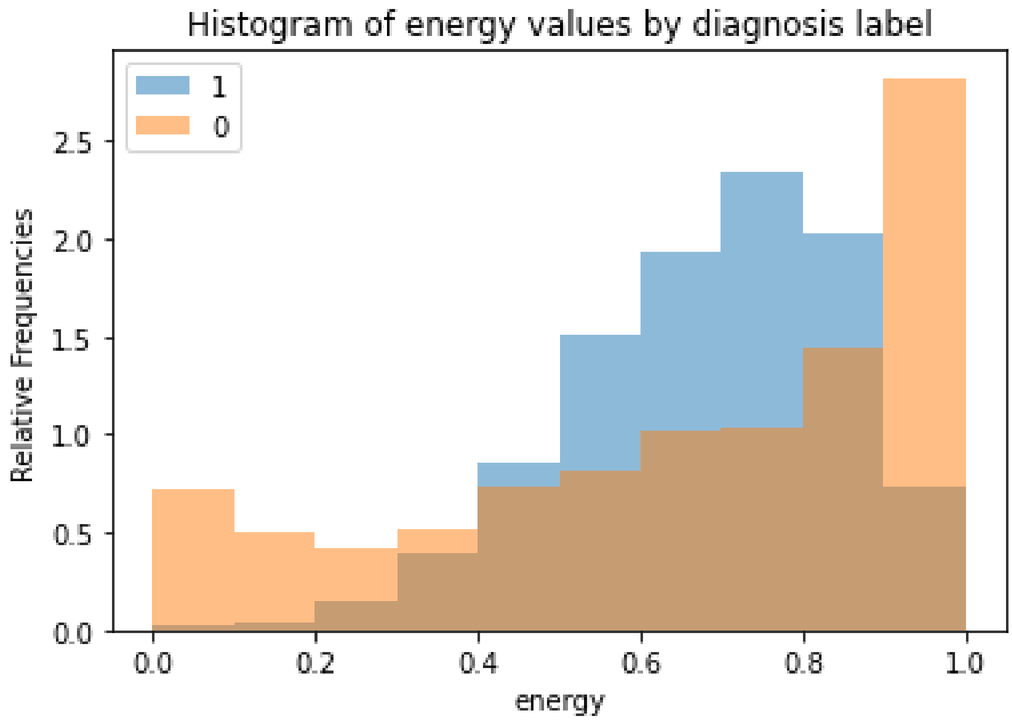
[40]:
```
from matplotlib import pylab as plt
dataset = [df[df['target']==1]['loudness'].values,
           df[df['target']==0]['loudness'].values]

plt.violinplot(dataset = dataset)
plt.title('Violinplot of loudness  by target label')
plt.xticks([1,2],['Hit','Flop'])
plt.ylabel('loudness')
plt.show()
```

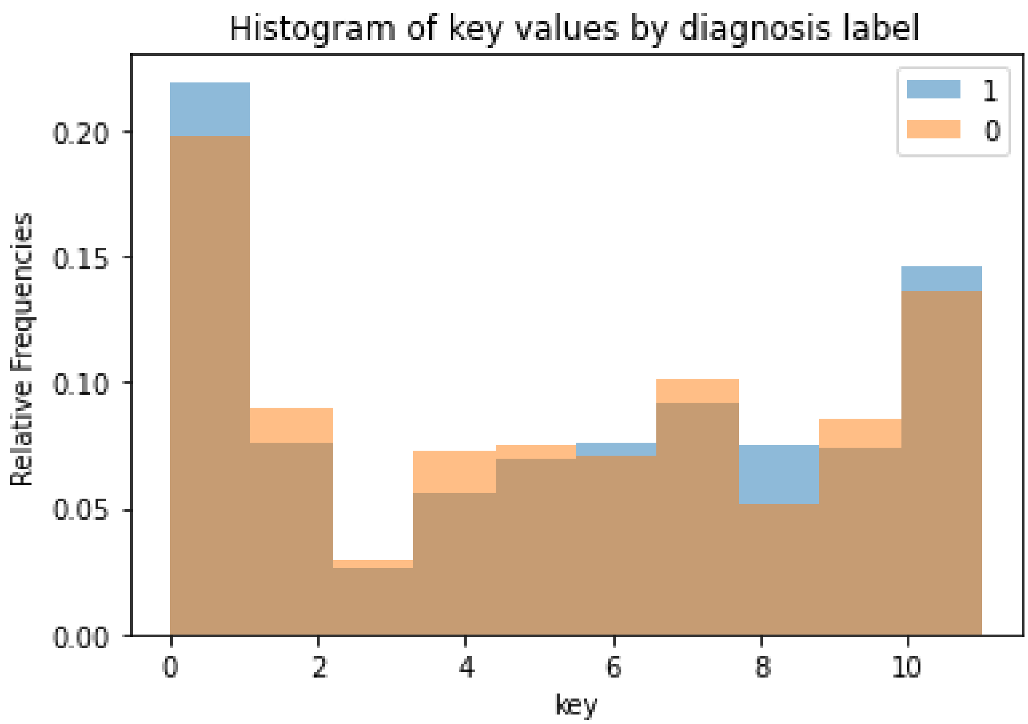


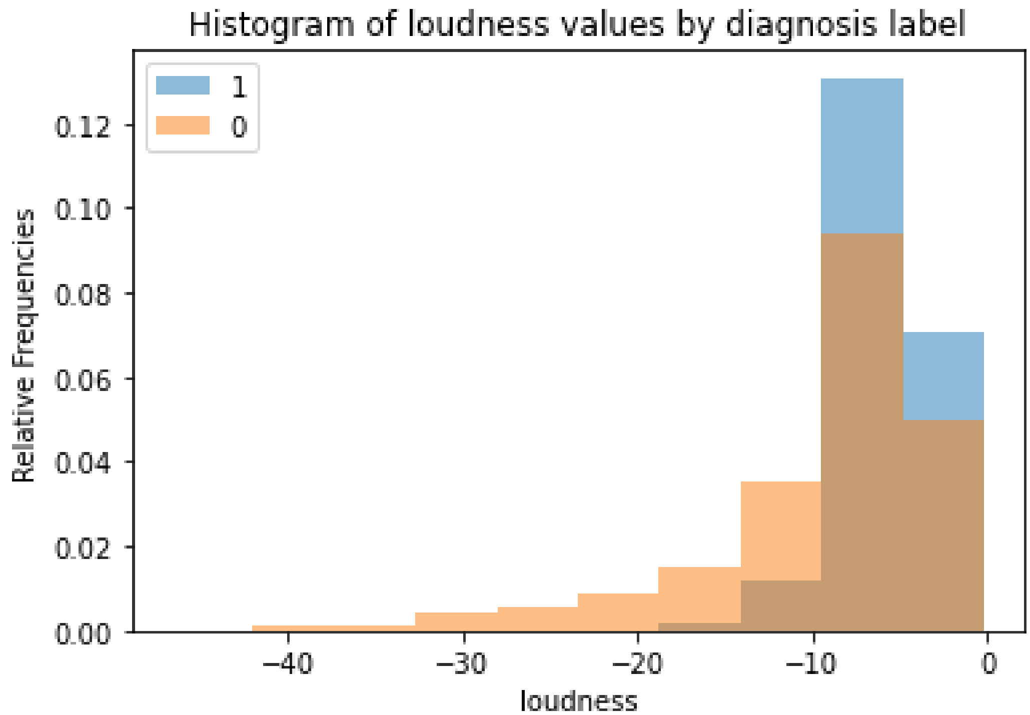
[41]:
```
categories = df['target'].unique()
bin_range = (df['danceability'].min(),df['danceability'].max())
label=['flop','hit']
for c in categories:
    plt.hist(df[df['target']==c]['danceability'],alpha=0.
 ↪5,label=label[c],range=bin_range,bins=10,density=True)
plt.legend()
plt.title('Histograms of danceability by target label')
plt.ylabel('fraction')
plt.xlabel('danceability')
plt.show()
```

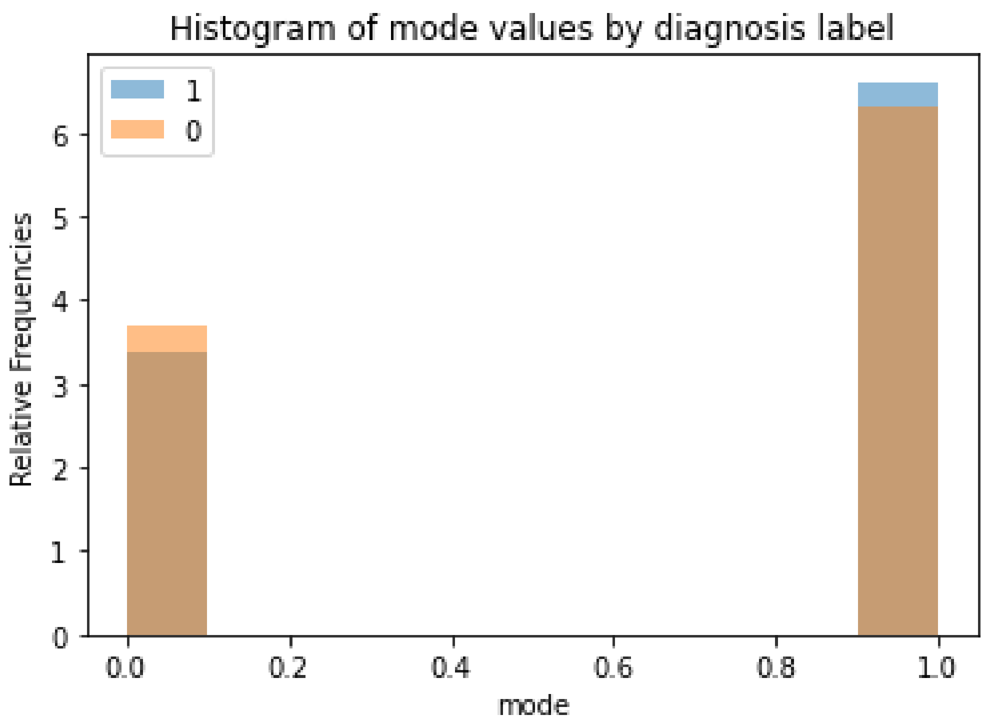


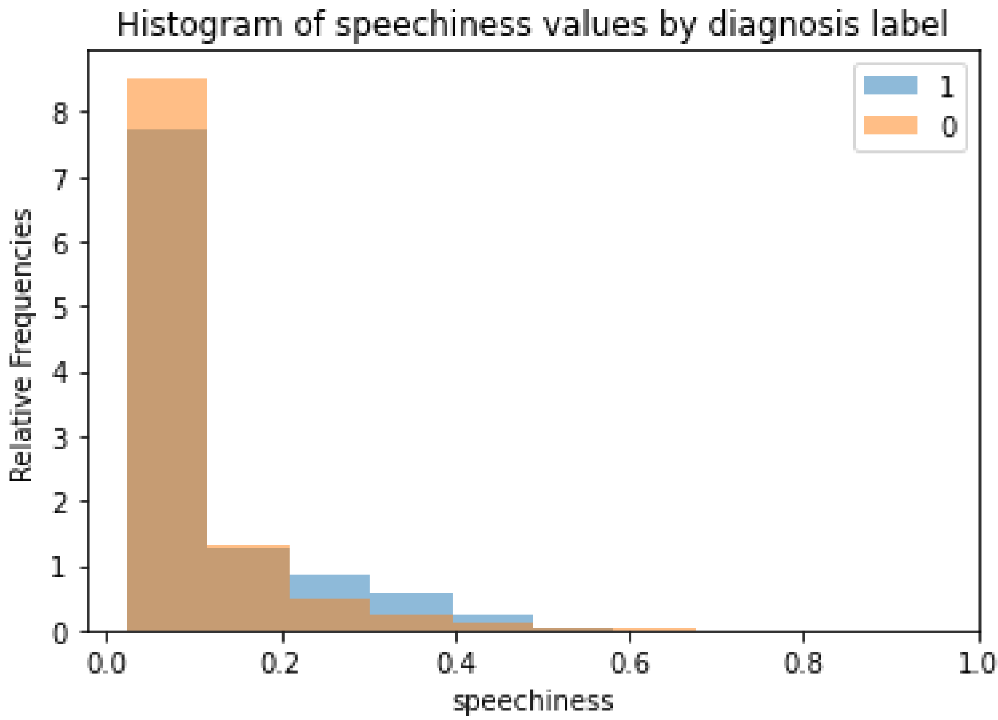
[42]:
```
df2.columns[1:]

categories = df2['target'].unique()

for column in df2.columns[1:]:

    bin_range = (df2[column].min(),df2[column].max())

    for c in categories:
        plt.hist(df2[df2['target']==c][column],alpha=0.
↪5,label=c,range=bin_range,bins=10,density=True)
    plt.legend()
    plt.ylabel('Relative Frequencies')
    plt.xlabel(column)
    plt.title(f'Histogram of {column} values by diagnosis label')

    figtitle = f'../figures/histogram_categories_{column}.png'
    plt.savefig(figtitle, dpi=300, format='png')
    plt.show()
```

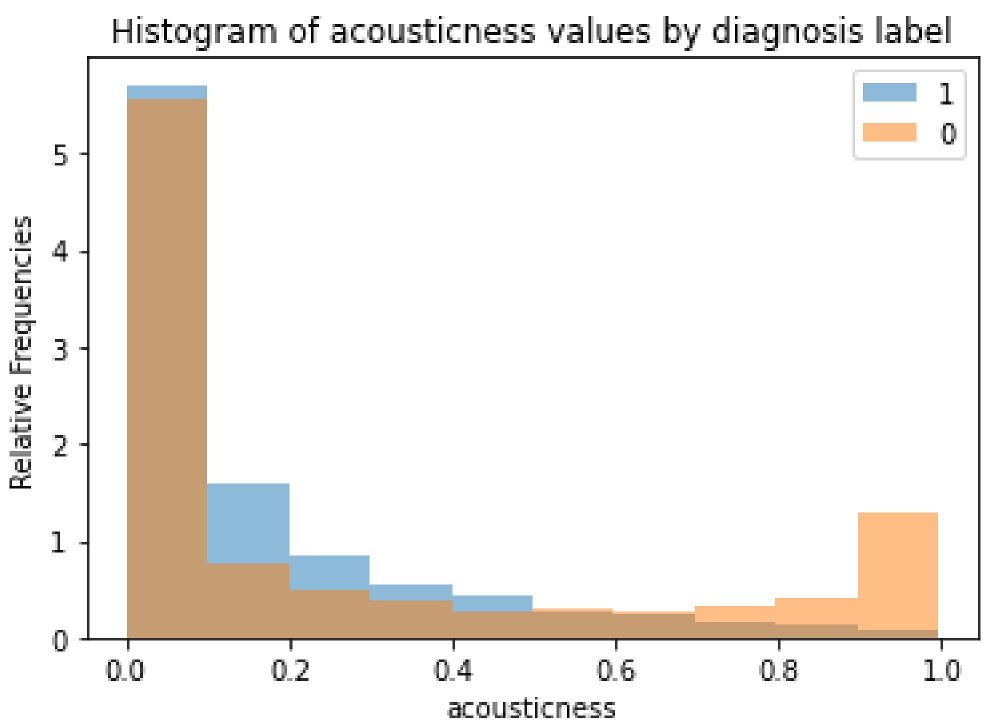

Histogram of energy values by diagnosis label
1
0
Relative Frequencies
0.0
0.5
1.0
1.5
2.0
2.5
0.0
0.2
0.4
0.6
0.8
1.0
energy

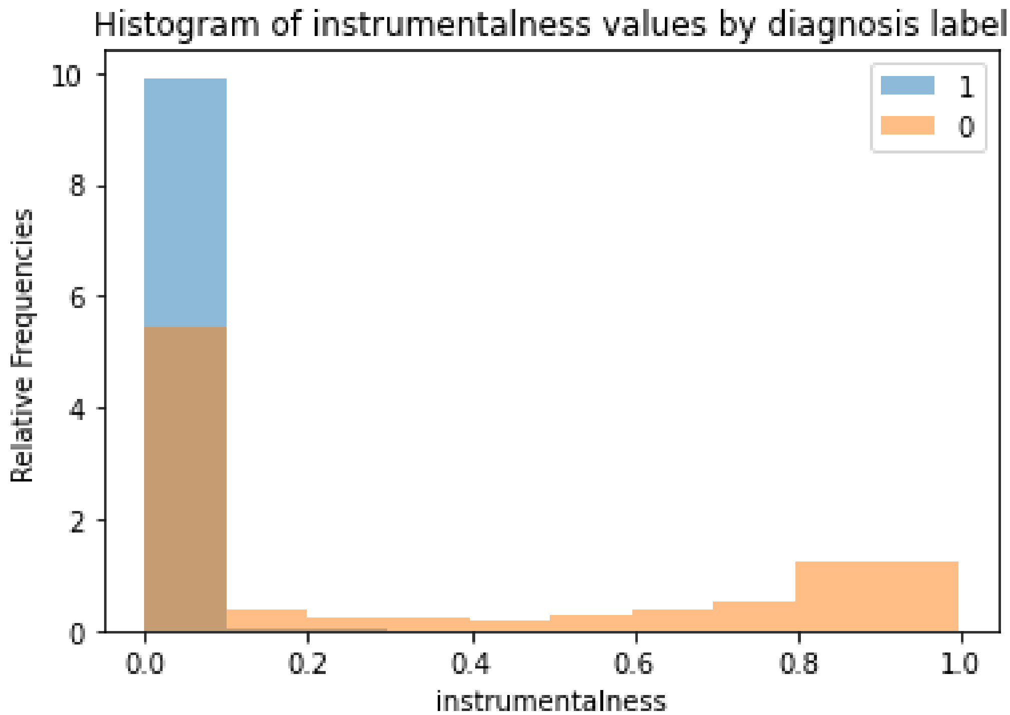

Histogram of key values by diagnosis label
1
0
Relative Frequencies
0.00
0.05
0.10
0.15
0.20
0
2
4
6
8
10
key

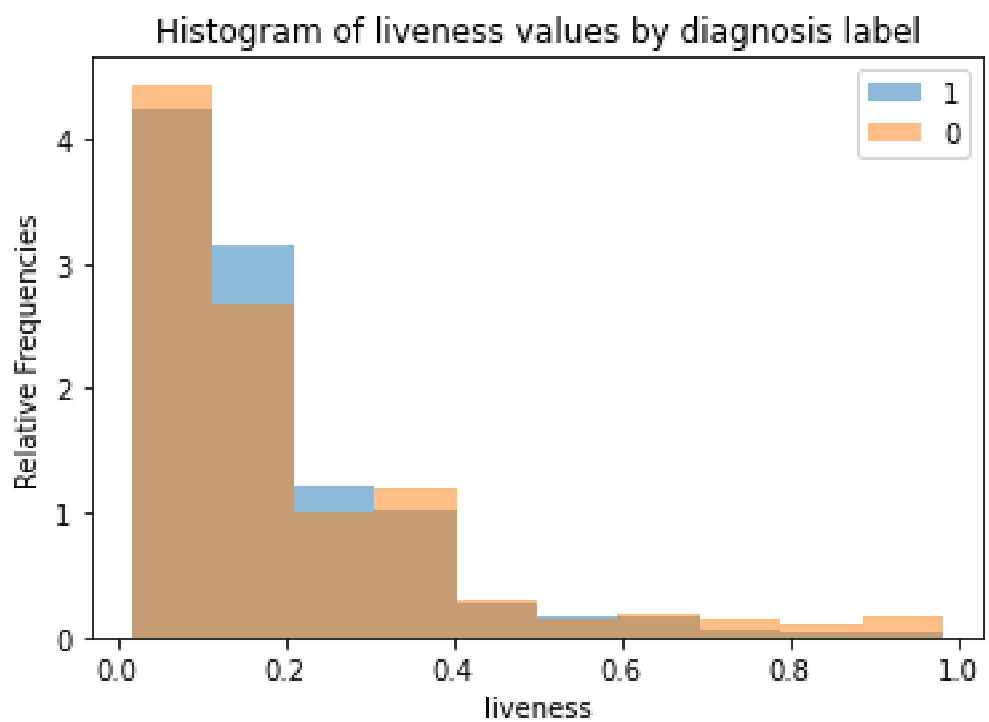

Histogram of loudness values by diagnosis label
1
0
0.12
0.10
0.08
0.06
0.04
0.02
0.00
Relative Frequencies
−40
−30
−20
−10
0
loudness

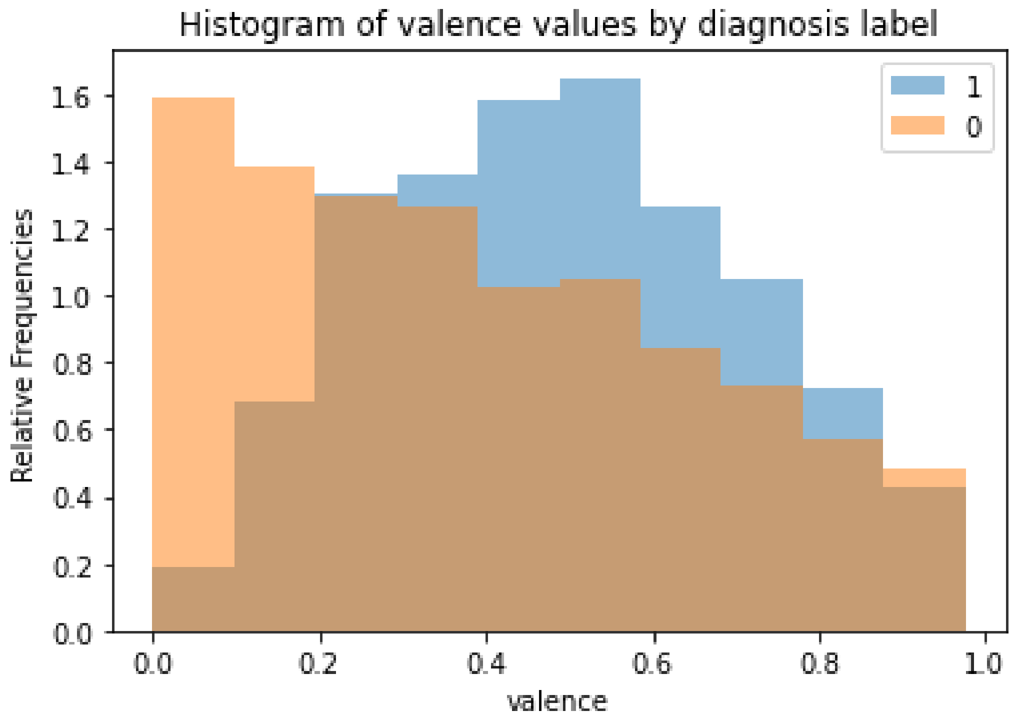

Histogram of mode values by diagnosis label
1
0
6
5
4
3
2
1
0
Relative Frequencies
0.0
0.2
0.4
0.6
0.8
1.0
mode

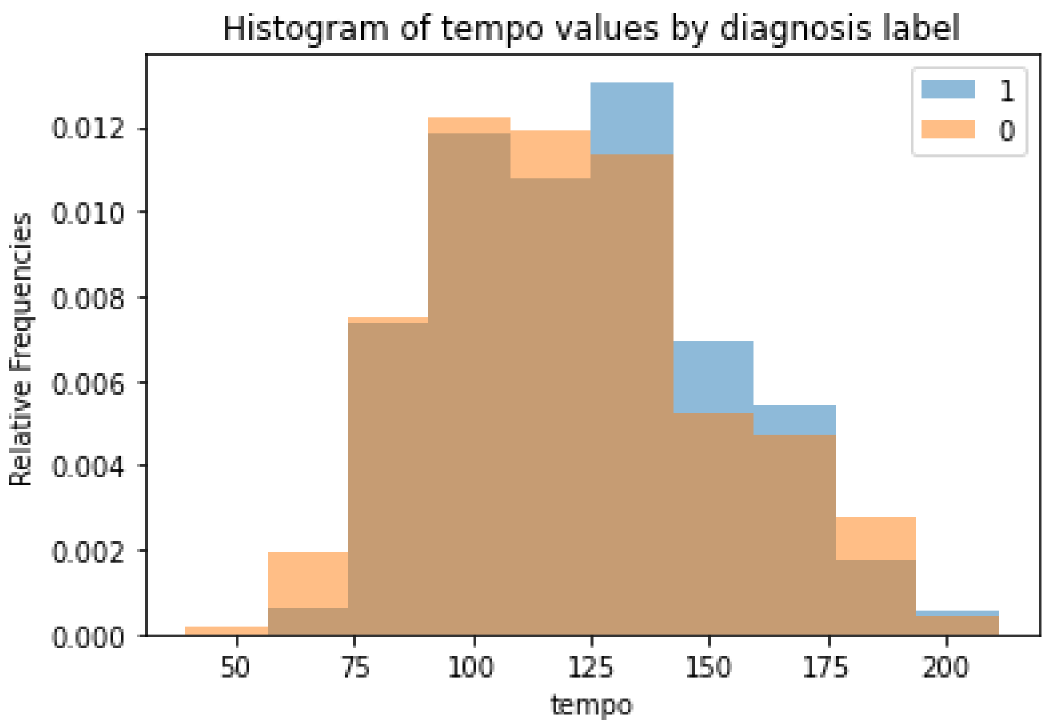

Histogram of speechiness values by diagnosis label
1
0
Relative Frequencies
speechiness
0
1
2
3
4
5
6
7
8
0.0
0.2
0.4
0.6
0.8
1.0

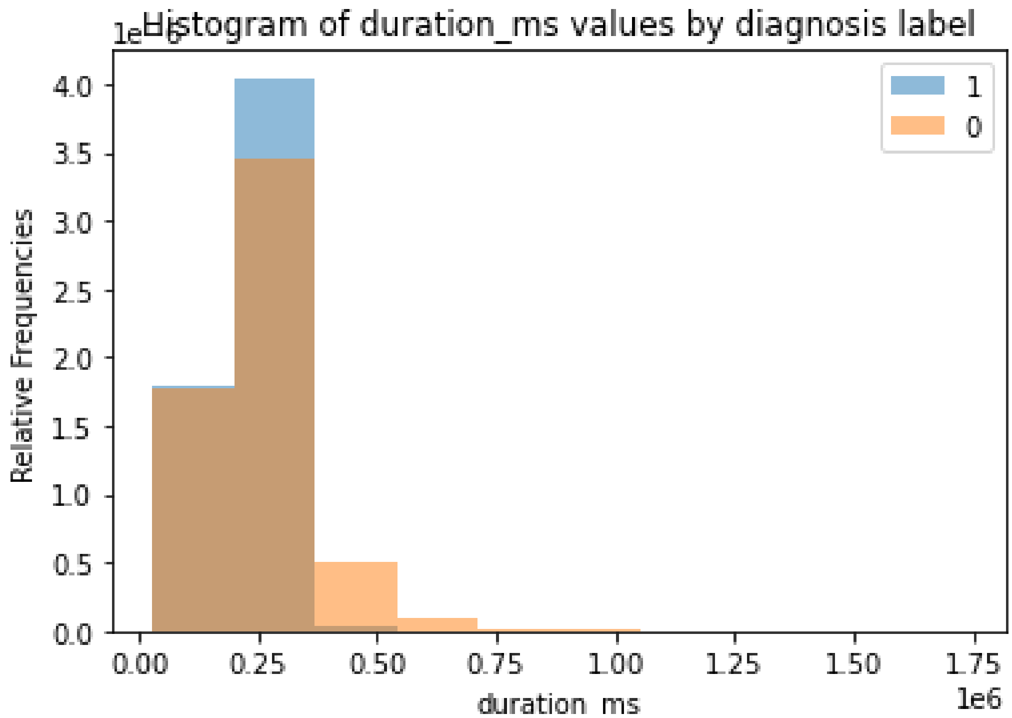

Histogram of acousticness values by diagnosis label
1
0
Relative Frequencies
acousticness
0
1
2
3
4
5
0.0
0.2
0.4
0.6
0.8
1.0

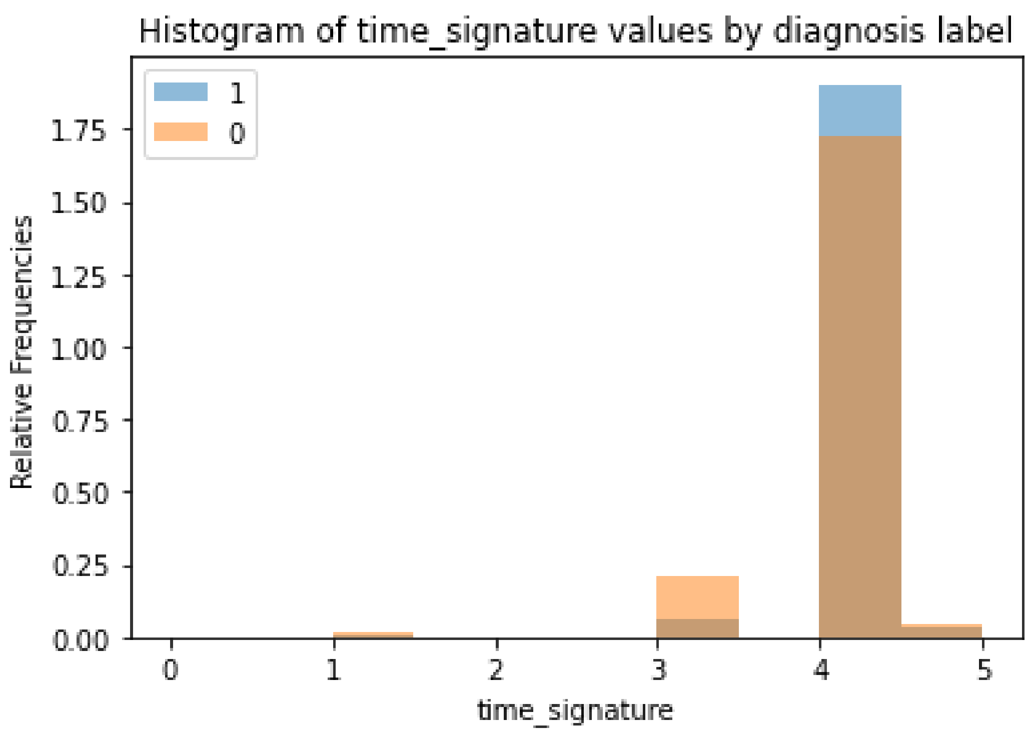

Histogram of instrumentalness values by diagnosis label
Relative Frequencies
instrumentalness
1
0
0
2
4
6
8
10
0.0
0.2
0.4
0.6
0.8
1.0

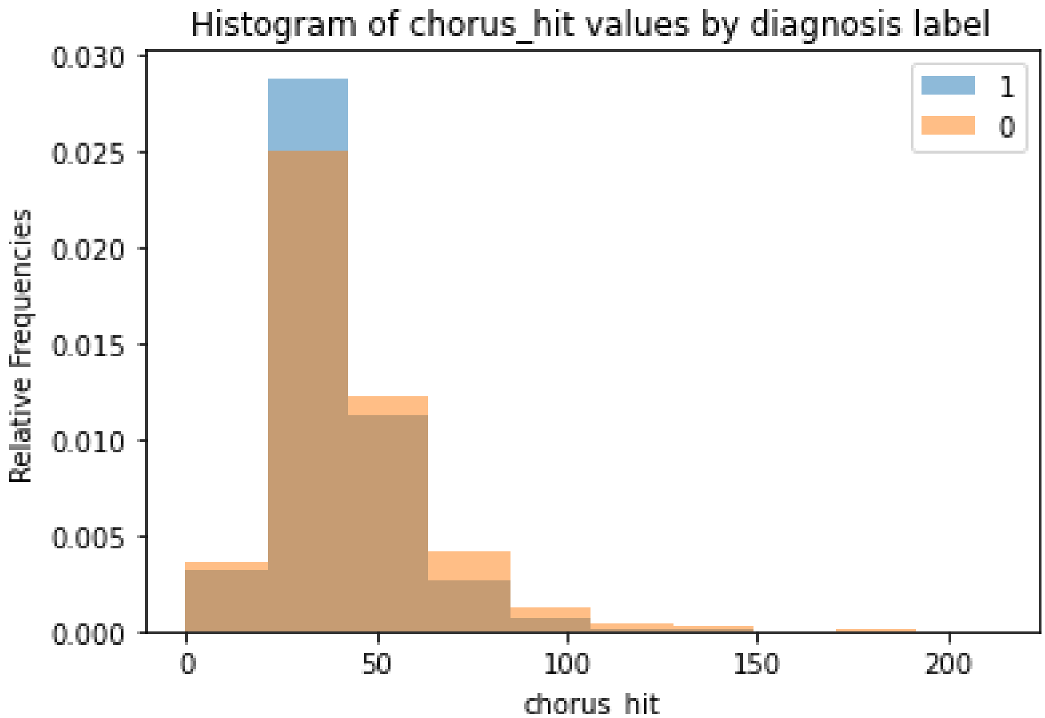

Histogram of liveness values by diagnosis label
Relative Frequencies
liveness
1
0
0
1
2
3
4
0.0
0.2
0.4
0.6
0.8
1.0


Histogram of valence values by diagnosis label
Relative Frequencies
valence
1
0
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6

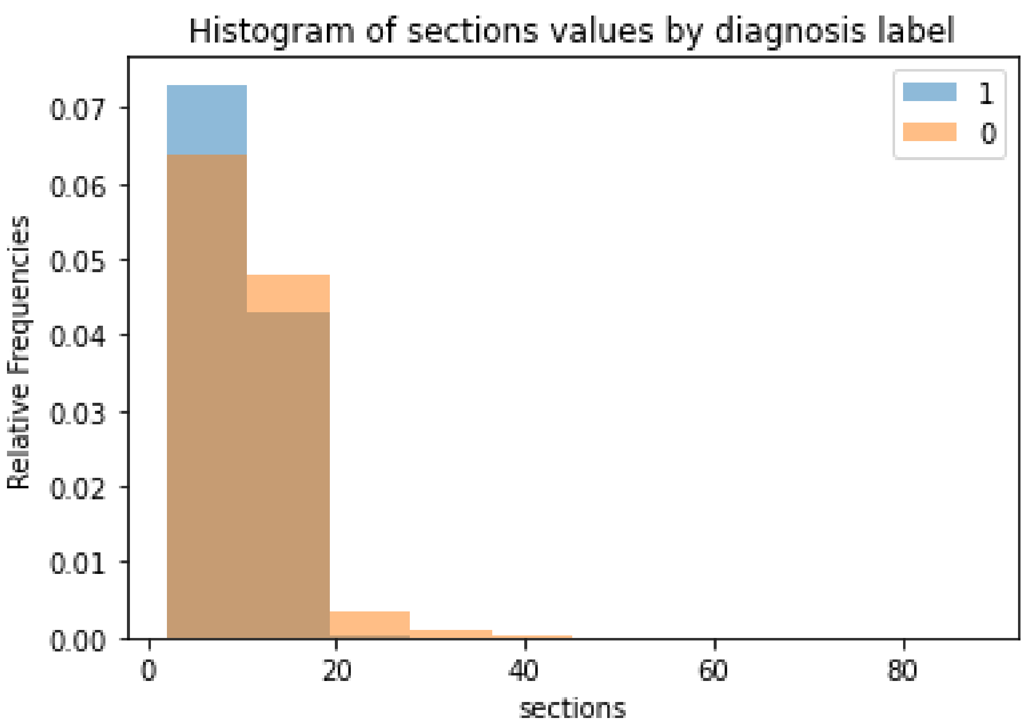

Histogram of tempo values by diagnosis label
Relative Frequencies
tempo
1
0
0.000
0.002
0.004
0.006
0.008
0.010
0.012
50
75
100
125
150
175
200


Histogram of duration_ms values by diagnosis label
1e-6
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Relative Frequencies
1
0
0.00
0.25
0.50
0.75
1.00
1.25
1.50
1.75
1e6
duration_ms

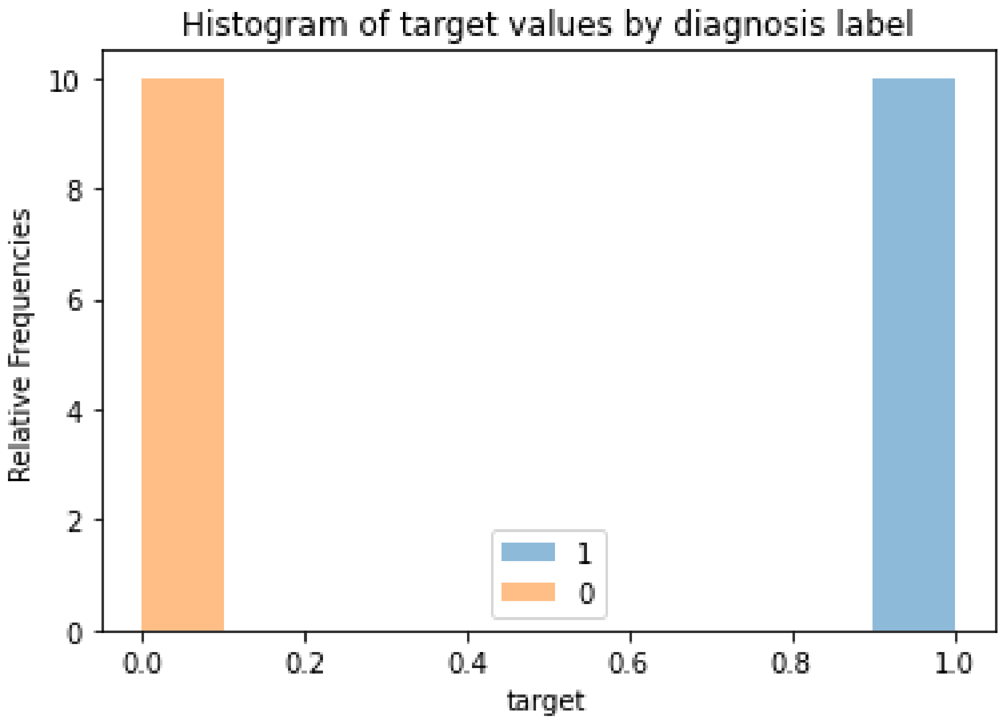

Histogram of time_signature values by diagnosis label
1
0
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
Relative Frequencies
0
1
2
3
4
5
time_signature



Histogram of chorus_hit values by diagnosis label
Relative Frequencies
0.000
0.005
0.010
0.015
0.020
0.025
0.030
0
50
100
150
200
chorus_hit
1
0



Histogram of sections values by diagnosis label
Relative Frequencies
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0
20
40
60
80
sections
1
0



---

3 Data Preprocessing

4 Model Selection

[43]:
```
#import packages
import pandas as pd
import numpy as np
from sklearn.model_selection import train_test_split, KFold,GridSearchCV
from sklearn.preprocessing import OneHotEncoder, StandardScaler,␣
↪OrdinalEncoder,MinMaxScaler
from sklearn.metrics import make_scorer,accuracy_score,classification_report

from sklearn.pipeline import make_pipeline, Pipeline
from sklearn.compose import ColumnTransformer
from sklearn.svm import SVC
from sklearn.linear_model import Lasso, Ridge, ElasticNet,LogisticRegression
from sklearn.ensemble import RandomForestClassifier
from sklearn.neighbors import KNeighborsClassifier
from xgboost import XGBClassifier
```

[59]:
```
y = df2['target']
X = df2.loc[:, df2.columns != 'target']
ftr_names = X.columns
#preprocess data
cat_ftrs  = ['key', 'mode','time_signature', 'sections']
cont_ftrs = ['danceability', 'energy',  'loudness', 'speechiness',␣
↪'acousticness',
            'instrumentalness', 'liveness', 'valence', 'tempo', 'duration_ms',
            'chorus_hit']
# ordinal encoder
categorical_transformer = Pipeline(steps=[
    ('onehot', OneHotEncoder(sparse=False,handle_unknown='ignore'))])
# standard scaler
numeric_transformer = Pipeline(steps=[
    ('scaler', StandardScaler())])

# collect all the encoders
preprocessor = ColumnTransformer(
    transformers=[
            ('num', numeric_transformer, cont_ftrs),
            ('cat', categorical_transformer, cat_ftrs)])
```

[45]:
```
def MLpipe_KFold_acc(X, y, preprocessor, ML_algo, param_grid):
    '''
    This function splits the data to other/test (80/20) and then applies KFold␣
↪with 4 folds to other.
    The acc is minimized in cross-validation.
    '''

    test_scores = []
    best_models = []
    grids = []
    X_tests_cv = []
    y_tests_cv = []

    for i in range(10):
        #splits the data to other/test (80/20)
        X_other, X_test, y_other, y_test = train_test_split(X, y, test_size=0.
↪2, random_state=42*i)
        #applies KFold with 4 folds to other
        kf = KFold(n_splits=4,shuffle=True,random_state=42*i)


        pipe = Pipeline(steps=[('preprocessor', preprocessor),
                               ('classifier', ML_algo)])
        # use GridSearchCV
```

```
        # GridSearchCV loops through all parameter combinations and collects␣
↪the results
        #use acc as score
        grid = GridSearchCV(pipe, param_grid=param_grid,scoring =␣
↪make_scorer(accuracy_score, greater_is_better=True),
                            cv=kf, return_train_score = True, n_jobs=-1,␣
↪verbose=False)

        # this line actually fits the model on other
        grid.fit(X_other, y_other)

        #best_param = grid.best_params_
        y_predict = grid.predict(X_test)

        test_score = accuracy_score(y_test,  y_predict)
        # append the test score and the best model
        best_models.append(grid.best_estimator_)
        grids.append(grid)
        test_scores.append(test_score)
        X_tests_cv.append(X_test)
        y_tests_cv.append(y_test)
        #best_parameter.append(grid.best_params_)

    return grids, best_models, test_scores, X_tests_cv, y_tests_cv
```

4.1 Logistic l1

[70]:
```
param_grid_l1 = {'classifier__C': [1e-3, 1e-2, 1e-1, 1e0, 1e1, 1e2, 1e3],
              'classifier__max_iter': [100000]}

l1_grids, l1_models, l1_scores ,l1_X_tests ,l1_y_tests =␣
↪MLpipe_KFold_acc(X,y,preprocessor,LogisticRegression(penalty='l1',␣
↪solver='saga'),param_grid_l1)
print(max(l1_scores))
```

```
0.81640625
```

[71]:
```
#l1_grids[0].score(l1_X_tests[0],l1_y_tests[0])
```

4.2 Logistic l2

[72]:
```
param_grid_l2 = {'classifier__C': [ 1e-3, 1e-2, 1e-1, 1e0, 1e1, 1e2, 1e3],
              'classifier__max_iter': [100000]}

l2_grids, l2_models, l2_scores ,_ ,_ =␣
↪MLpipe_KFold_acc(X,y,preprocessor,LogisticRegression(penalty='l2',␣
↪solver='saga'),param_grid_l2)
```

```
print(max(l2_scores))
```

```
0.8109375
```

4.3 Logistic Elatic

[73]:
```
param_grid = {'classifier__C': [ 1e-3, 1e-2, 1e-1, 1e0, 1e1, 1e2, 1e3],
                  'classifier__l1_ratio': [0.01, 0.25, 0.5, 0.75],
                  'classifier__max_iter': [100000]}

elastic_grids, elstic_models,elastic_scores,_ ,_ =␣
 ↪MLpipe_KFold_acc(X,y,preprocessor,LogisticRegression(penalty='elasticnet',␣
 ↪solver='saga'),param_grid)
print(max(elastic_scores))
```

```
0.815625
```

4.4 Rando Forest

[74]:
```
param_grid_RF ={'classifier__max_features': [1, 3, 5, 10, 12, None],
                  'classifier__max_depth': [1, 3, 5, 10, None]}

RF_grids, RF_models, RF_scores, X_tests_cv, y_tests_cv=␣
 ↪MLpipe_KFold_acc(X,y,preprocessor,RandomForestClassifier(),param_grid_RF)
print(max(RF_scores))
```

```
0.85078125
```

4.5 SVC

[75]:
```
param_grid_SVC ={'classifier__gamma': [1e-2, 1e-1, 1e0, 1e1, 1e2, 'auto',␣
 ↪'scale'],
                  'classifier__C': np.logspace(-1, 1, 5)}

SVC_grids, SVC_models, SVC_scores ,_ ,_ =␣
 ↪MLpipe_KFold_acc(X,y,preprocessor,SVC(),param_grid_SVC)
print(max(SVC_scores))
```

```
0.84140625
```

4.6 KNN

[76]:
```
param_grid_KNN ={'classifier__n_neighbors': [1, 5, 10, 30, 100],
                  'classifier__weights': ['uniform', 'distance']}
KNN_grids, KNN_models, KNN_scores,_ ,_  =␣
 ↪MLpipe_KFold_acc(X,y,preprocessor,KNeighborsClassifier(),param_grid_KNN)
print(max(KNN_scores))
```

```
0.80703125
```

4.7 XGB

[77]:
```
param_grid_XGB = {'classifier__max_depth': [1, 3, 5, 10, 30],
                  'classifier__eval_metric':['mlogloss']}
XGB_grids, XGB_models, XGB_scores,_ ,_  =␣
 ↪MLpipe_KFold_acc(X,y,preprocessor,XGBClassifier(use_label_encoder=False),param_grid_XGB)
print(max(XGB_scores))
```

```
0.8484375
```

[78]:
```
RF_models
```

[78]:
```
[Pipeline(steps=[('preprocessor',
                  ColumnTransformer(transformers=[('num',
                                                   Pipeline(steps=[('scaler',
StandardScaler())]),
                                                   ['danceability', 'energy',
                                                    'loudness', 'speechiness',
                                                    'acousticness',
                                                    'instrumentalness',
                                                    'liveness', 'valence',
                                                    'tempo', 'duration_ms',
                                                    'chorus_hit']),
                                                  ('cat',
                                                   Pipeline(steps=[('onehot',
OneHotEncoder(handle_unknown='ignore',
  sparse=False))]),
                                                   ['key', 'mode',
                                                    'time_signature',
                                                    'sections'])])),
                 ('classifier', RandomForestClassifier(max_features=10))]),
 Pipeline(steps=[('preprocessor',
                  ColumnTransformer(transformers=[('num',
                                                   Pipeline(steps=[('scaler',
StandardScaler())]),
                                                   ['danceability', 'energy',
                                                    'loudness', 'speechiness',
                                                    'acousticness',
                                                    'instrumentalness',
                                                    'liveness', 'valence',
                                                    'tempo', 'duration_ms',
                                                    'chorus_hit']),
                                                  ('cat',
                                                   Pipeline(steps=[('onehot',
OneHotEncoder(handle_unknown='ignore',
  sparse=False))]),
                                                   ['key', 'mode',
                                                    'time_signature',
```

```
                                                   'sections'])])),
                 ('classifier', RandomForestClassifier(max_features=12))]),
 Pipeline(steps=[('preprocessor',
                  ColumnTransformer(transformers=[('num',
                                                  Pipeline(steps=[('scaler',
StandardScaler())]),
                                                  ['danceability', 'energy',
                                                   'loudness', 'speechiness',
                                                   'acousticness',
                                                   'instrumentalness',
                                                   'liveness', 'valence',
                                                   'tempo', 'duration_ms',
                                                   'chorus_hit']),
                                                 ('cat',
                                                  Pipeline(steps=[('onehot',
OneHotEncoder(handle_unknown='ignore',
  sparse=False))]),
                                                  ['key', 'mode',
                                                   'time_signature',
                                                   'sections'])])),
                 ('classifier', RandomForestClassifier(max_features=12))]),
 Pipeline(steps=[('preprocessor',
                  ColumnTransformer(transformers=[('num',
                                                  Pipeline(steps=[('scaler',
StandardScaler())]),
                                                  ['danceability', 'energy',
                                                   'loudness', 'speechiness',
                                                   'acousticness',
                                                   'instrumentalness',
                                                   'liveness', 'valence',
                                                   'tempo', 'duration_ms',
                                                   'chorus_hit']),
                                                 ('cat',
                                                  Pipeline(steps=[('onehot',
OneHotEncoder(handle_unknown='ignore',
  sparse=False))]),
                                                  ['key', 'mode',
                                                   'time_signature',
                                                   'sections'])])),
                 ('classifier', RandomForestClassifier(max_features=None))]),
 Pipeline(steps=[('preprocessor',
                  ColumnTransformer(transformers=[('num',
                                                  Pipeline(steps=[('scaler',
StandardScaler())]),
                                                  ['danceability', 'energy',
                                                   'loudness', 'speechiness',
                                                   'acousticness',
```

```
                                                    'instrumentalness',
                                                    'liveness', 'valence',
                                                    'tempo', 'duration_ms',
                                                    'chorus_hit']),
                                                  ('cat',
                                                   Pipeline(steps=[('onehot',
OneHotEncoder(handle_unknown='ignore',
  sparse=False))]),
                                                   ['key', 'mode',
                                                    'time_signature',
                                                    'sections'])])),
                 ('classifier', RandomForestClassifier(max_features=12))]),
 Pipeline(steps=[('preprocessor',
                  ColumnTransformer(transformers=[('num',
                                                   Pipeline(steps=[('scaler',
StandardScaler())]),
                                                   ['danceability', 'energy',
                                                    'loudness', 'speechiness',
                                                    'acousticness',
                                                    'instrumentalness',
                                                    'liveness', 'valence',
                                                    'tempo', 'duration_ms',
                                                    'chorus_hit']),
                                                  ('cat',
                                                   Pipeline(steps=[('onehot',
OneHotEncoder(handle_unknown='ignore',
  sparse=False))]),
                                                   ['key', 'mode',
                                                    'time_signature',
                                                    'sections'])])),
                 ('classifier', RandomForestClassifier(max_features=None))]),
 Pipeline(steps=[('preprocessor',
                  ColumnTransformer(transformers=[('num',
                                                   Pipeline(steps=[('scaler',
StandardScaler())]),
                                                   ['danceability', 'energy',
                                                    'loudness', 'speechiness',
                                                    'acousticness',
                                                    'instrumentalness',
                                                    'liveness', 'valence',
                                                    'tempo', 'duration_ms',
                                                    'chorus_hit']),
                                                  ('cat',
                                                   Pipeline(steps=[('onehot',
OneHotEncoder(handle_unknown='ignore',
  sparse=False))]),
                                                   ['key', 'mode',
```

```
                                                    'time_signature',
                                                    'sections'])])),
                 ('classifier', RandomForestClassifier(max_features=10))]),
 Pipeline(steps=[('preprocessor',
                  ColumnTransformer(transformers=[('num',
                                                   Pipeline(steps=[('scaler',
StandardScaler())]),
                                                   ['danceability', 'energy',
                                                    'loudness', 'speechiness',
                                                    'acousticness',
                                                    'instrumentalness',
                                                    'liveness', 'valence',
                                                    'tempo', 'duration_ms',
                                                    'chorus_hit']),
                                                  ('cat',
                                                   Pipeline(steps=[('onehot',
OneHotEncoder(handle_unknown='ignore',
  sparse=False))]),
                                                   ['key', 'mode',
                                                    'time_signature',
                                                    'sections'])])),
                 ('classifier', RandomForestClassifier(max_features=10))]),
 Pipeline(steps=[('preprocessor',
                  ColumnTransformer(transformers=[('num',
                                                   Pipeline(steps=[('scaler',
StandardScaler())]),
                                                   ['danceability', 'energy',
                                                    'loudness', 'speechiness',
                                                    'acousticness',
                                                    'instrumentalness',
                                                    'liveness', 'valence',
                                                    'tempo', 'duration_ms',
                                                    'chorus_hit']),
                                                  ('cat',
                                                   Pipeline(steps=[('onehot',
OneHotEncoder(handle_unknown='ignore',
  sparse=False))]),
                                                   ['key', 'mode',
                                                    'time_signature',
                                                    'sections'])])),
                 ('classifier', RandomForestClassifier(max_features=10))]),
 Pipeline(steps=[('preprocessor',
                  ColumnTransformer(transformers=[('num',
                                                   Pipeline(steps=[('scaler',
StandardScaler())]),
                                                   ['danceability', 'energy',
                                                    'loudness', 'speechiness',
```

```
                                                      'acousticness',
                                                      'instrumentalness',
                                                      'liveness', 'valence',
                                                      'tempo', 'duration_ms',
                                                      'chorus_hit']),
                                                    ('cat',
                                                     Pipeline(steps=[('onehot',
OneHotEncoder(handle_unknown='ignore',
  sparse=False))]),
                                                     ['key', 'mode',
                                                      'time_signature',
                                                      'sections'])])),
                 ('classifier', RandomForestClassifier(max_features=10))])]
```

[236]:
```
import pickle
file = open('../results/l1_models_tuned.save', 'wb')
pickle.dump(l1_models, file)
file.close()

file = open('../results/l2_models_tuned.save', 'wb')
pickle.dump(l2_models, file)
file.close()

file = open('../results/elastic_models_tuned.save', 'wb')
pickle.dump(elstic_models, file)
file.close()

file = open('../results/RF_models_tuned.save', 'wb')
pickle.dump(RF_models, file)
file.close()

file = open('../results/SVC_models_tuned.save', 'wb')
pickle.dump(SVC_models, file)
file.close()

file = open('../results/KNN_models_tuned.save', 'wb')
pickle.dump(KNN_models, file)
file.close()

file = open('../results/XGB_models_tuned.save', 'wb')
pickle.dump(XGB_models, file)
file.close()
```

[237]:
```
file = open('../results/Best_model.save', 'wb')
pickle.dump(RF_grids[9], file)
file.close()
```

5 Result

[79]:
```
#repeat the split process and apply the best model
# to have a better understanding of its performance
def optimal_acc(X, y,preprocessor):
    X_tests = []
    y_tests = []
    y_predicts = []
    y_test_probs = []
    for i in range(10):
        #splits the data to other/test (80/20)
        X_other, X_test, y_other, y_test = train_test_split(X, y, test_size=0.
 ↪2, random_state=42*i)

        pipe = Pipeline(steps=[('preprocessor', preprocessor)])

        X_other = pipe.fit_transform(X_other)
        X_test = pipe.transform(X_test)

        clf = RandomForestClassifier(max_features = None,max_depth = 5)
        clf.fit(X_other, y_other)
        y_predict =clf.predict(X_test)
        y_test_prob = clf.predict_proba(X_test)

        X_tests.append(X_test)
        y_tests.append(y_test)
        y_predicts.append(y_predict)
        y_test_probs.append(y_test_prob)
    return X_tests, y_tests ,y_test_probs, y_predicts
```

[80]:
```
X_tests, y_tests,y_test_probs, y_predicts = optimal_acc(X, y,preprocessor)
```

[240]:
```
file = open('../results/prediction.save', 'wb')
pickle.dump((X_tests, y_tests,y_test_probs, y_predicts),file)
file.close()
```

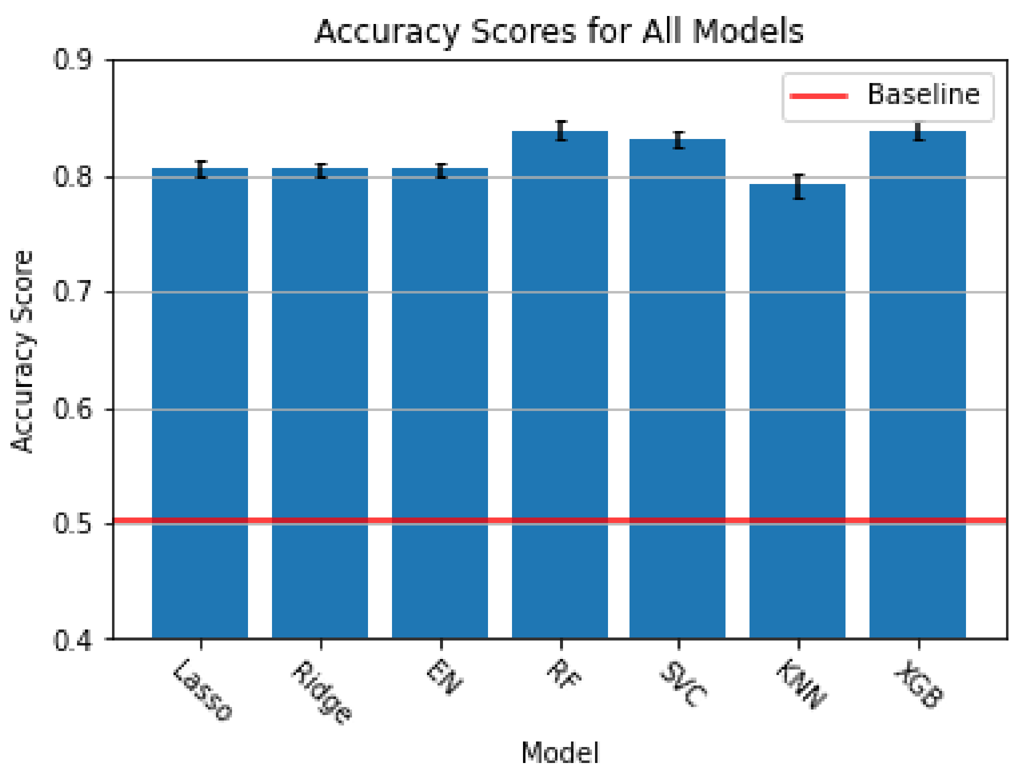
[81]:
```
baseline_scores = [len([y for y in Y if y ==0])/len(Y) for Y in y_tests]
baseline_scores
```

[81]:
```
[0.48046875,
 0.51171875,
 0.5125,
 0.50390625,
 0.5046875,
 0.51328125,
 0.5046875,
 0.5046875,
```

```
 0.48984375,
 0.48828125]
```

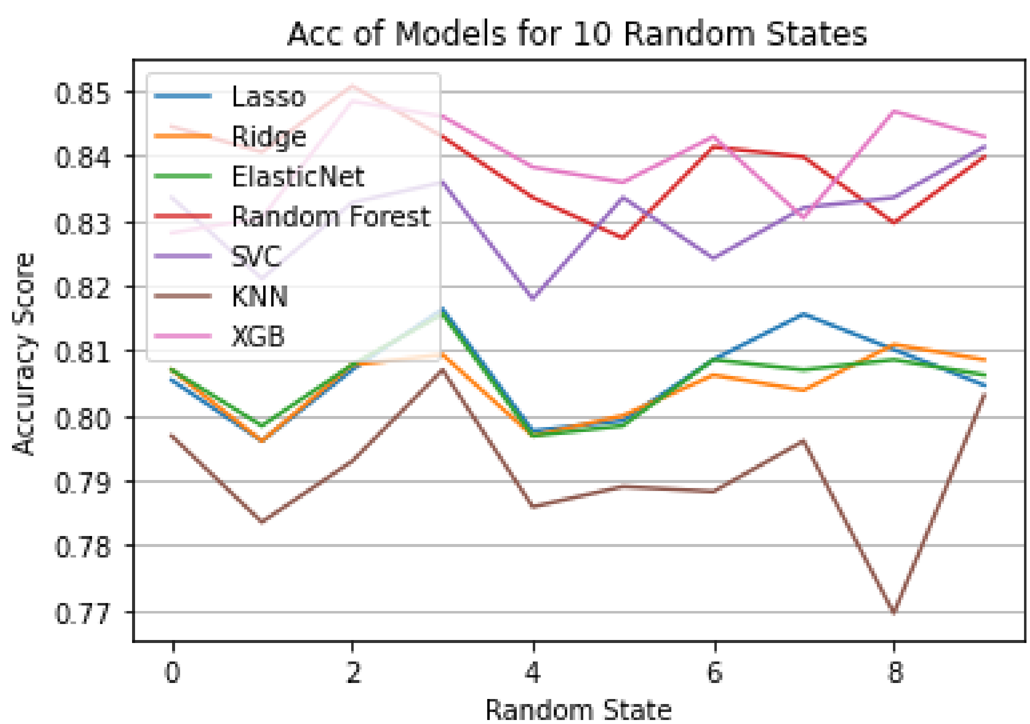
5.1 Comparison Models

[82]:
```python
from statistics import mean, stdev

labels = [ "Lasso", "Ridge", "EN", "RF", "SVC", "KNN", "XGB"]
scores = [ l1_scores, l2_scores, elastic_scores, RF_scores, SVC_scores,␣
 ↪KNN_scores, XGB_scores]
mean_scores = [mean(score) for score in scores]
stdev_scores = [stdev(score) for score in scores]

plt.bar(labels, mean_scores, yerr=stdev_scores, capsize=2)
plt.axhline(mean(baseline_scores),label='Baseline',color="red")
plt.ylim([0.4,0.9])
plt.xticks(rotation=-45)
plt.grid(axis='y')
plt.xlabel("Model")
plt.ylabel("Accuracy Score")
plt.legend()
plt.title("Accuracy Scores for All Models")
plt.savefig('../figures/acc_bar_plot.png', dpi=300, format='png')
plt.show()
```



[83]:

```
import matplotlib.pyplot as plt

plt.plot(l1_scores, label="Lasso")
plt.plot(l2_scores, label="Ridge")
plt.plot(elastic_scores, label="ElasticNet")
plt.plot(RF_scores, label="Random Forest")
plt.plot(SVC_scores, label="SVC")
plt.plot(KNN_scores, label="KNN")
plt.plot(XGB_scores, label="XGB")
plt.grid(axis='y')
plt.xlabel("Random State")
plt.ylabel("Accuracy Score")
plt.title("Acc of Models for 10 Random States")
plt.legend()
plt.savefig('../figures/acc_chart_plot.png', dpi=300, format='png')
plt.show()
```



[84]:

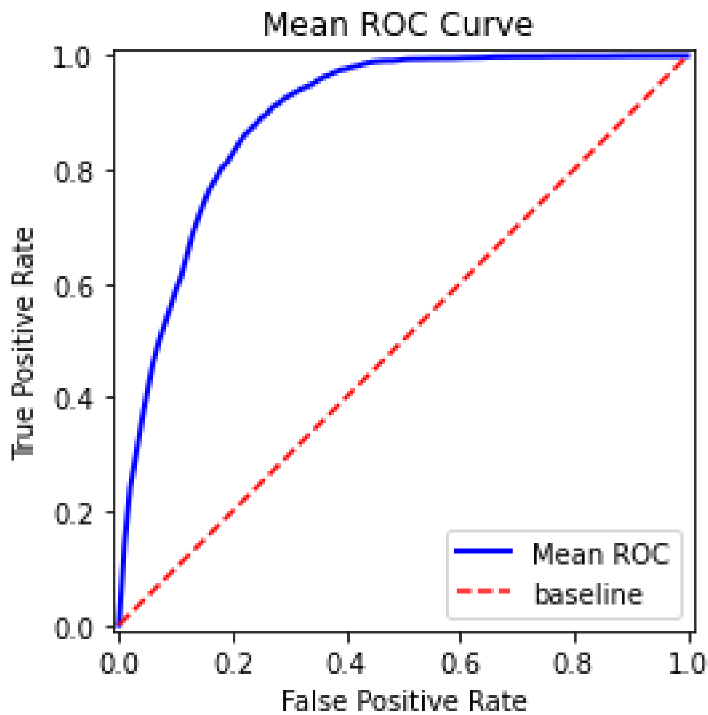
```
print(mean(RF_scores),stdev(RF_scores))
print(mean(baseline_scores), stdev(baseline_scores))
```

```
0.8390625 0.007045702738785766
```

0.5014062499999999 0.011320189989080956

5.2 ROC curve

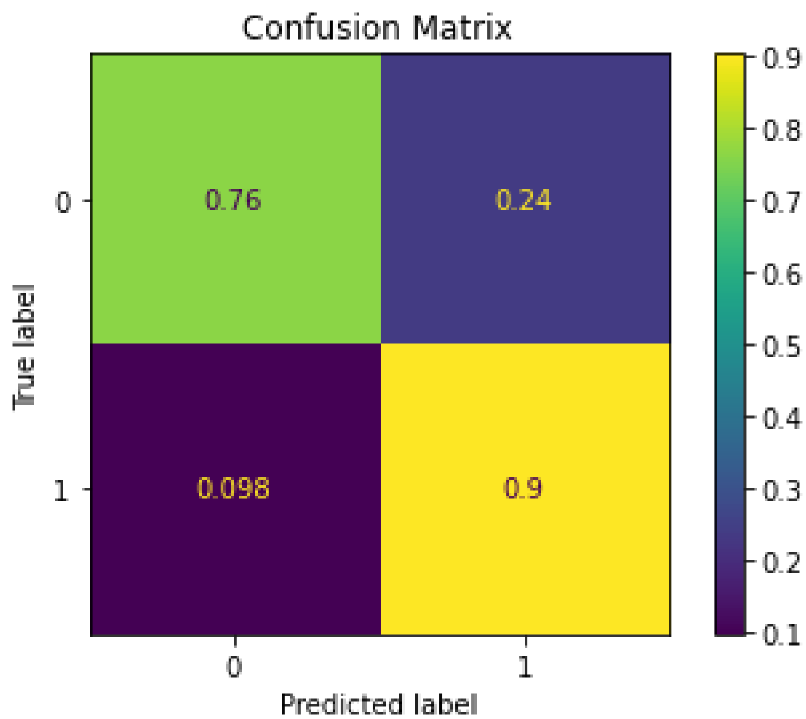
[85]:
```
from sklearn.metrics import roc_curve
from sklearn.metrics import plot_roc_curve
import numpy as np

tprs = []
aucs = []
base_fpr = np.linspace(0, 1, 101)

for y_test, y_test_prob in zip(y_tests, y_test_probs):

    fpr, tpr, _ = roc_curve(y_test, y_test_prob[:, 1])


    tpr = np.interp(base_fpr, fpr, tpr)
    tpr[0] = 0.0
    tprs.append(tpr)

tprs = np.array(tprs)
mean_tprs = tprs.mean(axis=0)
std = tprs.std(axis=0)

tprs_upper = np.minimum(mean_tprs + std, 1)
tprs_lower = np.maximum(mean_tprs - std, 0)

plt.plot(base_fpr, mean_tprs, 'b', label="Mean ROC", lw=2)
plt.plot([0, 1], [0, 1],'r--',label='baseline')
plt.ylabel('True Positive Rate')
plt.xlabel('False Positive Rate')
plt.gca().set_aspect('equal', adjustable='box')
plt.legend()
plt.xlim([-0.01, 1.01])
plt.ylim([-0.01, 1.01])
plt.title("Mean ROC Curve ")
plt.savefig('../figures/ROC_curves.png', dpi=300, format='png')
plt.show()
```



5.3 Confusion Matrix

[86]:
```
import numpy as np
import matplotlib.pyplot as plt
from sklearn.metrics import confusion_matrix
from sklearn.metrics import ConfusionMatrixDisplay

cms = [confusion_matrix(y_tests[0], y_predicts[0]) for i in range(len(y_tests))]

tn = sum([a[0,0] for a in cms]) / len([a[0,0] for a in cms])
fp = sum([a[0,1] for a in cms]) / len([a[0,1] for a in cms])
fn = sum([a[1,0] for a in cms]) / len([a[1,0] for a in cms])
tp = sum([a[1,1] for a in cms]) / len([a[1,1] for a in cms])

mean_confusion_matrix = np.array([[tn, fp], [fn, tp]])
cm = mean_confusion_matrix.astype('float') / mean_confusion_matrix.sum(axis=1)[:
 ↪, np.newaxis]
cm

disp = ConfusionMatrixDisplay(confusion_matrix=cm)
disp.plot()
plt.title("Confusion Matrix")
#plt.set_xticklabels('flop','hit')
```

```
#plt.set_yticklabels('flop','hit')
plt.savefig('../figures/confusion_matrixs.png', dpi=300, format='png')
plt.show()
```



5.4 Global Importance

[214]:
```
nr_runs = 10
np.random.seed(42)
scores = np.zeros([len(feature_names),nr_runs])
grid = RF_grids[9]#the best model

X_test = X_tests_cv[9]
y_test = y_tests_cv[9]

X_test_transformed = grid.best_estimator_[0].transform(X_test)

test_score = grid.score(X_test,y_test)
print('test score = ',test_score)
print('test baseline = ',np.sum(y_test == 0)/len(y_test))
# loop through the features
for i in range(len(feature_names)):
    print('shuffling '+str(feature_names[i]))
    acc_scores = []
```

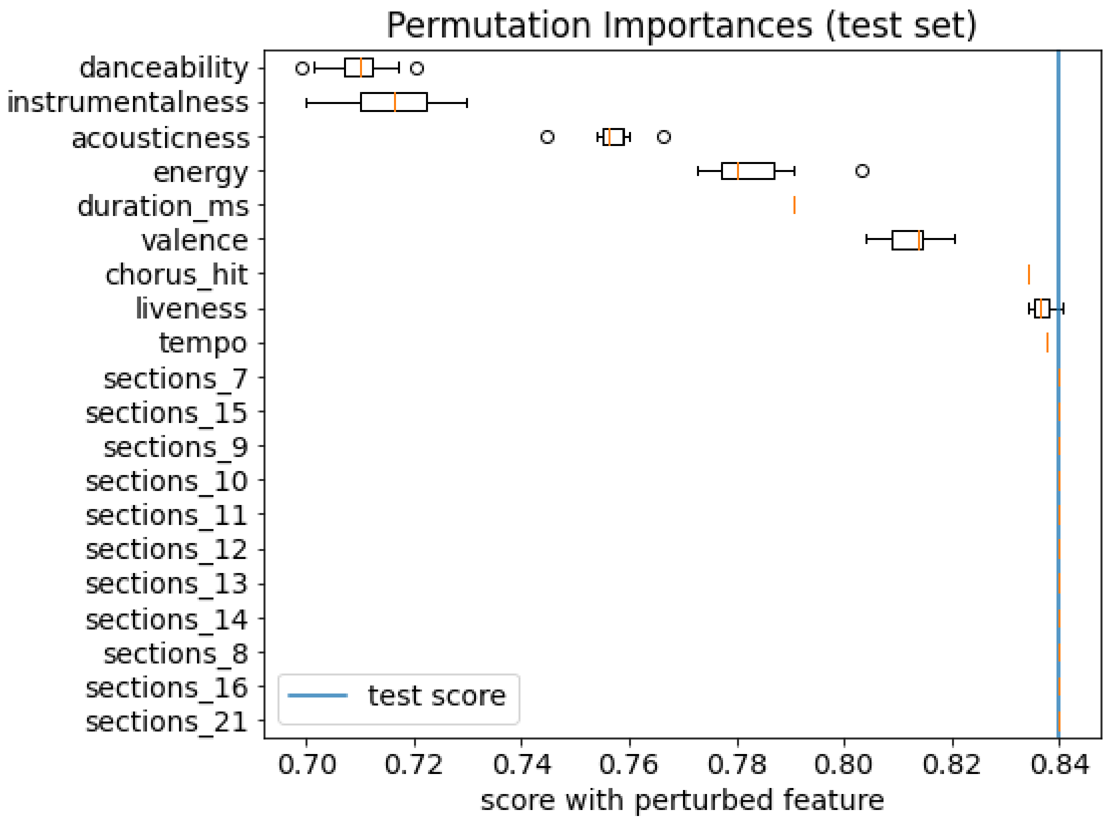
```
    for j in range(nr_runs):
        X_test_shuffled = X_test.copy()
        X_test_shuffled[feature_names[i]] = np.random.
↪permutation(X_test_transformed[:,i])
        acc_scores.append(grid.score(X_test_shuffled,y_test))
    print('   shuffled test score:',np.around(np.mean(acc_scores),3),'+/-',np.
↪around(np.std(acc_scores),3))
    scores[i] = acc_scores
```

```
test score =  0.83984375
test baseline =  0.48828125
shuffling danceability
   shuffled test score: 0.71 +/- 0.006
shuffling energy
   shuffled test score: 0.783 +/- 0.009
shuffling loudness
   shuffled test score: 0.841 +/- 0.001
shuffling speechiness
   shuffled test score: 0.844 +/- 0.004
shuffling acousticness
   shuffled test score: 0.757 +/- 0.005
shuffling instrumentalness
   shuffled test score: 0.716 +/- 0.009
shuffling liveness
   shuffled test score: 0.837 +/- 0.002
shuffling valence
   shuffled test score: 0.812 +/- 0.005
shuffling tempo
   shuffled test score: 0.838 +/- 0.0
shuffling duration_ms
   shuffled test score: 0.791 +/- 0.0
shuffling chorus_hit
   shuffled test score: 0.834 +/- 0.0
shuffling key_0
   shuffled test score: 0.84 +/- 0.0
shuffling key_1
   shuffled test score: 0.84 +/- 0.0
shuffling key_2
   shuffled test score: 0.84 +/- 0.0
shuffling key_3
   shuffled test score: 0.84 +/- 0.0
shuffling key_4
   shuffled test score: 0.84 +/- 0.0
shuffling key_5
   shuffled test score: 0.84 +/- 0.0
shuffling key_6
   shuffled test score: 0.84 +/- 0.0
```

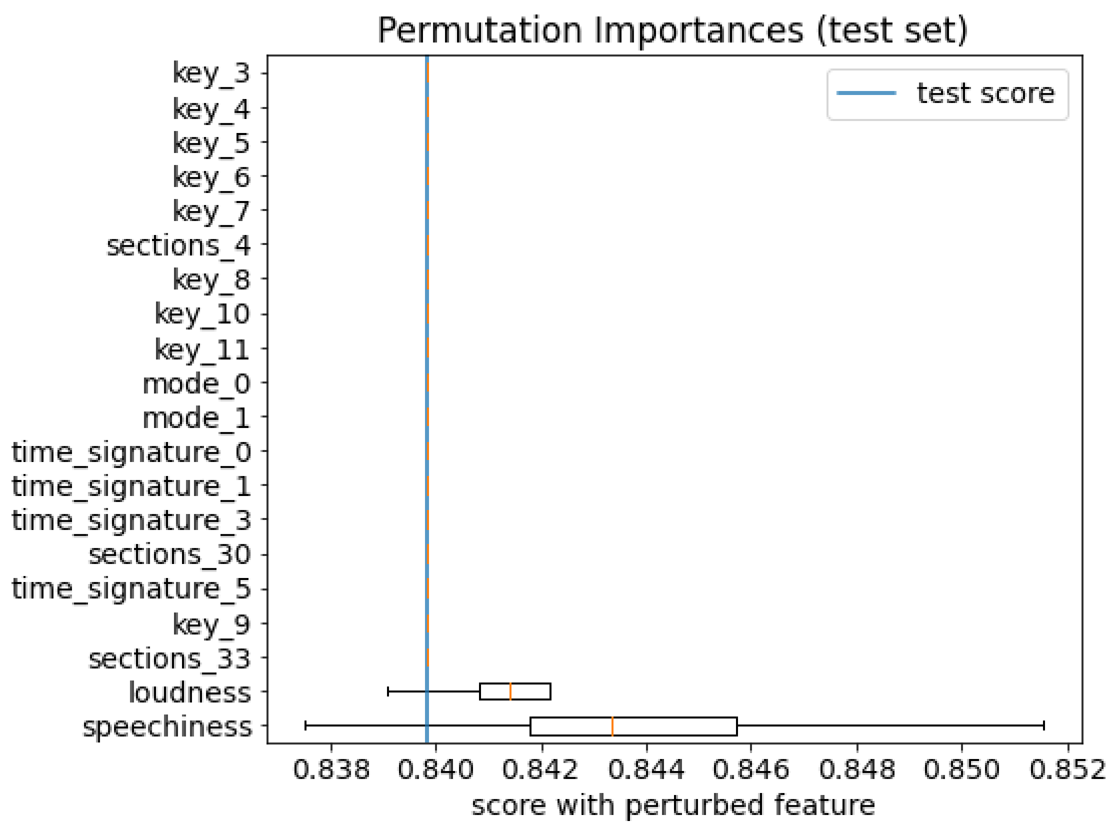
```
shuffling key_7
   shuffled test score: 0.84 +/- 0.0
shuffling key_8
   shuffled test score: 0.84 +/- 0.0
shuffling key_9
   shuffled test score: 0.84 +/- 0.0
shuffling key_10
   shuffled test score: 0.84 +/- 0.0
shuffling key_11
   shuffled test score: 0.84 +/- 0.0
shuffling mode_0
   shuffled test score: 0.84 +/- 0.0
shuffling mode_1
   shuffled test score: 0.84 +/- 0.0
shuffling time_signature_0
   shuffled test score: 0.84 +/- 0.0
shuffling time_signature_1
   shuffled test score: 0.84 +/- 0.0
shuffling time_signature_3
   shuffled test score: 0.84 +/- 0.0
shuffling time_signature_4
   shuffled test score: 0.84 +/- 0.0
shuffling time_signature_5
   shuffled test score: 0.84 +/- 0.0
shuffling sections_3
   shuffled test score: 0.84 +/- 0.0
shuffling sections_4
   shuffled test score: 0.84 +/- 0.0
shuffling sections_5
   shuffled test score: 0.84 +/- 0.0
shuffling sections_6
   shuffled test score: 0.84 +/- 0.0
shuffling sections_7
   shuffled test score: 0.84 +/- 0.0
shuffling sections_8
   shuffled test score: 0.84 +/- 0.0
shuffling sections_9
   shuffled test score: 0.84 +/- 0.0
shuffling sections_10
   shuffled test score: 0.84 +/- 0.0
shuffling sections_11
   shuffled test score: 0.84 +/- 0.0
shuffling sections_12
   shuffled test score: 0.84 +/- 0.0
shuffling sections_13
   shuffled test score: 0.84 +/- 0.0
shuffling sections_14
   shuffled test score: 0.84 +/- 0.0
```

```
shuffling sections_15
   shuffled test score: 0.84 +/- 0.0
shuffling sections_16
   shuffled test score: 0.84 +/- 0.0
shuffling sections_17
   shuffled test score: 0.84 +/- 0.0
shuffling sections_18
   shuffled test score: 0.84 +/- 0.0
shuffling sections_19
   shuffled test score: 0.84 +/- 0.0
shuffling sections_20
   shuffled test score: 0.84 +/- 0.0
shuffling sections_21
   shuffled test score: 0.84 +/- 0.0
shuffling sections_22
   shuffled test score: 0.84 +/- 0.0
shuffling sections_23
   shuffled test score: 0.84 +/- 0.0
shuffling sections_25
   shuffled test score: 0.84 +/- 0.0
shuffling sections_26
   shuffled test score: 0.84 +/- 0.0
shuffling sections_27
   shuffled test score: 0.84 +/- 0.0
shuffling sections_28
   shuffled test score: 0.84 +/- 0.0
shuffling sections_30
   shuffled test score: 0.84 +/- 0.0
shuffling sections_33
   shuffled test score: 0.84 +/- 0.0
```

[223]:
```
sorted_indcs = np.argsort(np.mean(scores,axis=1))[::-1]
sorted_indcs = sorted_indcs[-20:]
plt.rcParams.update({'font.size': 14})
plt.figure(figsize=(8,6))
plt.boxplot(scores[sorted_indcs].
 ↪T,labels=feature_names[sorted_indcs],vert=False)
plt.axvline(test_score,label='test score')
plt.title("Permutation Importances (test set)")
plt.xlabel('score with perturbed feature')
plt.legend()
plt.tight_layout()
plt.savefig('../figures/global_importance.png', dpi=300, format='png')
plt.show()
```



[229]:
```
sorted_indcs = np.argsort(np.mean(scores,axis=1))[::-1]
sorted_indcs = sorted_indcs[:20]
plt.rcParams.update({'font.size': 14})
plt.figure(figsize=(8,6))
plt.boxplot(scores[sorted_indcs].
 ↪T,labels=feature_names[sorted_indcs],vert=False)
plt.axvline(test_score,label='test score')
plt.title("Permutation Importances (test set)")
plt.xlabel('score with perturbed feature')
plt.legend()
plt.tight_layout()
plt.savefig('../figures/global_importance_least.png', dpi=300, format='png')
plt.show()
```



5.5 SHAP

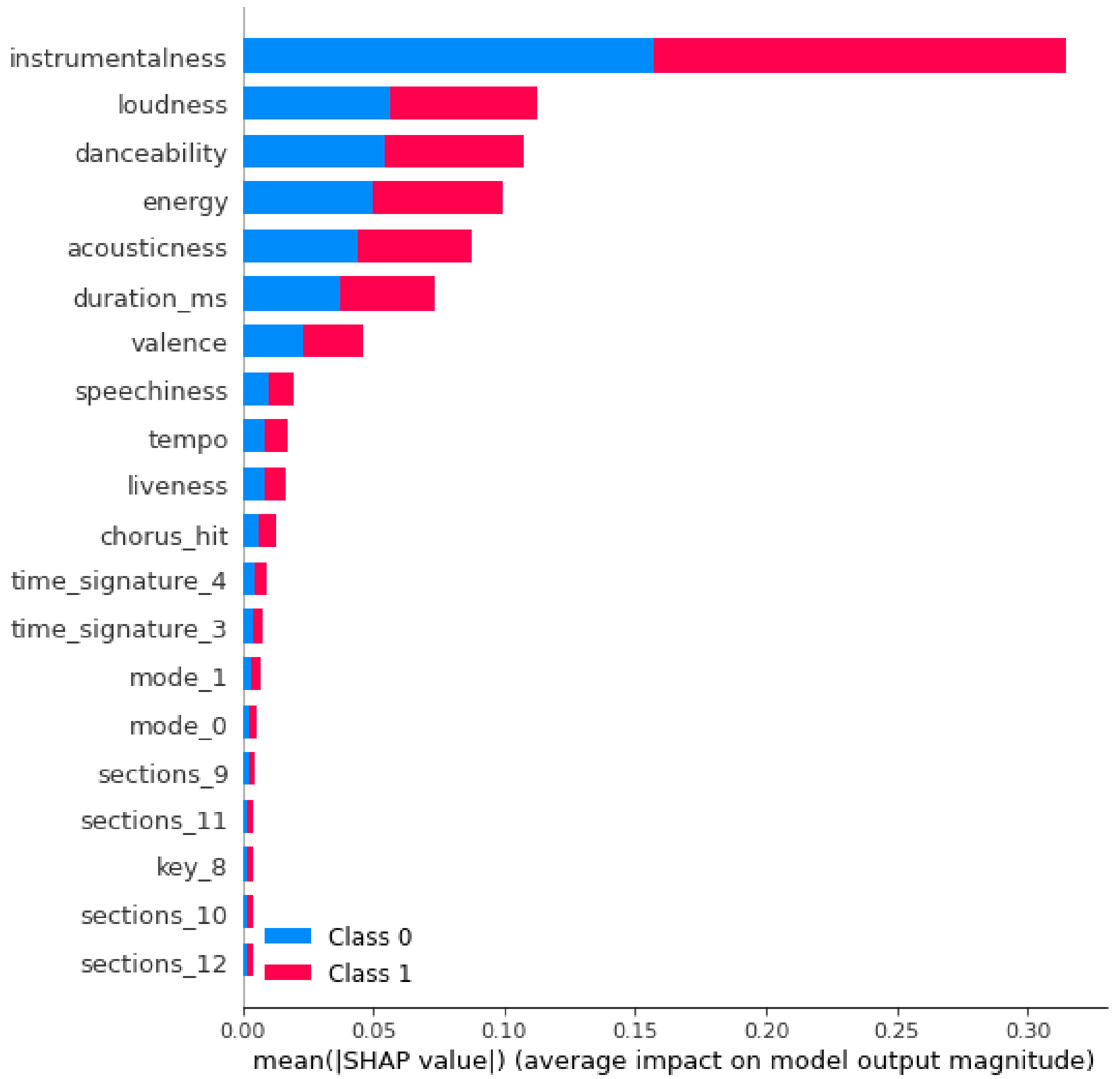
[105]:
```
import shap
shap.initjs() # required for visualizations later on
# create the explainer object with the random forest model
grid = RF_grids[9]
X_test = X_tests_cv[9]
y_test = y_tests_cv[9]

# create the explainer object with the random forest model
explainer = shap.TreeExplainer(grid.best_estimator_[1])
# transform the test set
X_test_transformed = grid.best_estimator_[0].transform(X_test)
print(np.shape(X_test_transformed))
# calculate shap values on all points in the test
shap_values = explainer.shap_values(X_test_transformed)
print(np.shape(shap_values))
```

```
<IPython.core.display.HTML object>
```

```
(1280, 69)
(2, 1280, 69)
```

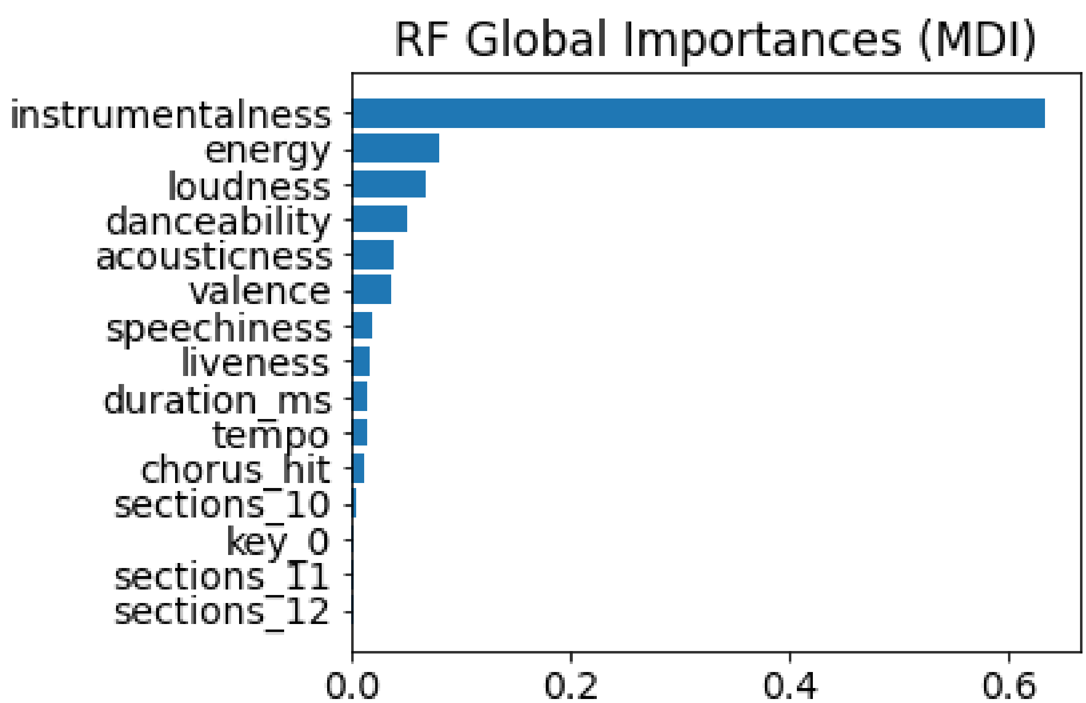
[197]:
```
feature_names = cont_ftrs + \
                list(grid.best_estimator_[0].named_transformers_['cat'][0].
 ↪get_feature_names_out(cat_ftrs))
```

[106]:
```
shap.summary_plot(shap_values, X_test_transformed,feature_names = feature_names)
```



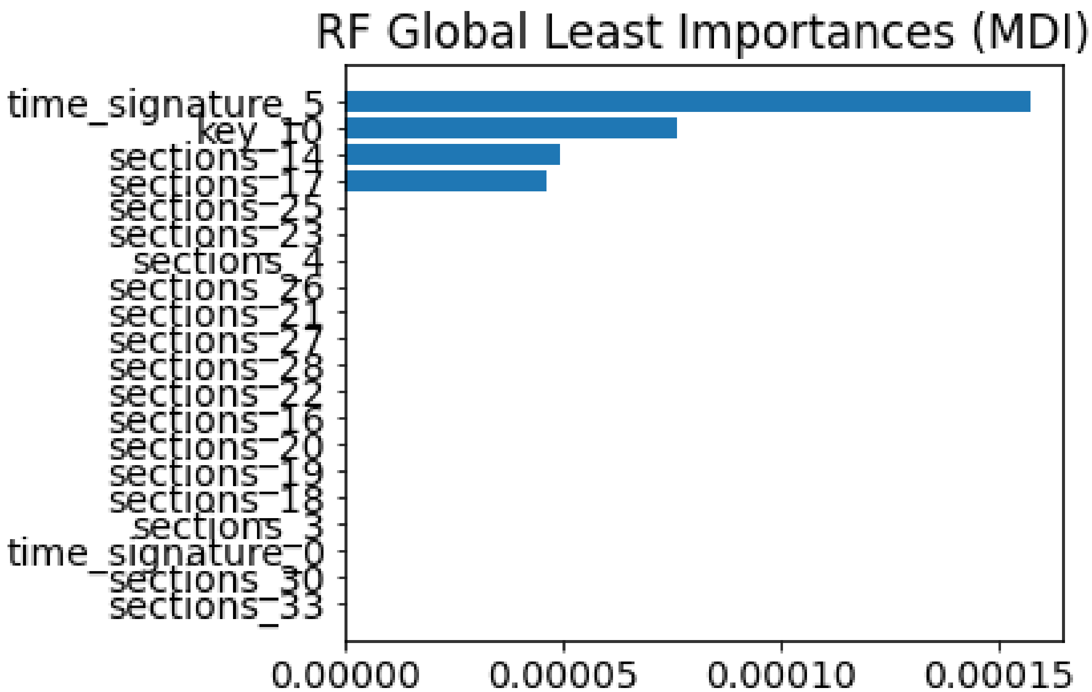
[227]:
```
# collect all the encoders

rf = Pipeline(
     [
        ('preprocess', preprocessor),
        ('classifier', RandomForestClassifier(max_features = None ,max_depth =␣
 ↪5,random_state=42))
```

```
    ]
)
rf.fit(X_test, y_test)

ohe = rf.named_steps["preprocess"].named_transformers_["cat"]
feature_names = ohe.get_feature_names_out(cat_ftrs)
feature_names = np.r_[cont_ftrs, feature_names]

tree_feature_importances = rf.named_steps["classifier"].feature_importances_
sorted_idx = tree_feature_importances.argsort()

y_ticks = np.arange(15)
fig, ax = plt.subplots()
ax.barh(y_ticks, tree_feature_importances[sorted_idx][-15:])
ax.set_yticks(y_ticks)
ax.set_yticklabels(feature_names[sorted_idx][-15:])
ax.set_title("RF Global Importances (MDI)")
fig.tight_layout()
plt.savefig('../figures/MDI_importance.png', dpi=300, format='png')
plt.show()
```



[232]:
```
y_ticks = np.arange(20)
fig, ax = plt.subplots()
ax.barh(y_ticks, tree_feature_importances[sorted_idx][:20])
```

```
ax.set_yticks(y_ticks)
ax.set_yticklabels(feature_names[sorted_idx][:20])
ax.set_title("RF Global Least Importances (MDI)")
fig.tight_layout()
plt.savefig('../figures/MDI_importance_least.png', dpi=300, format='png')
plt.show()
```



5.6 Local Importance

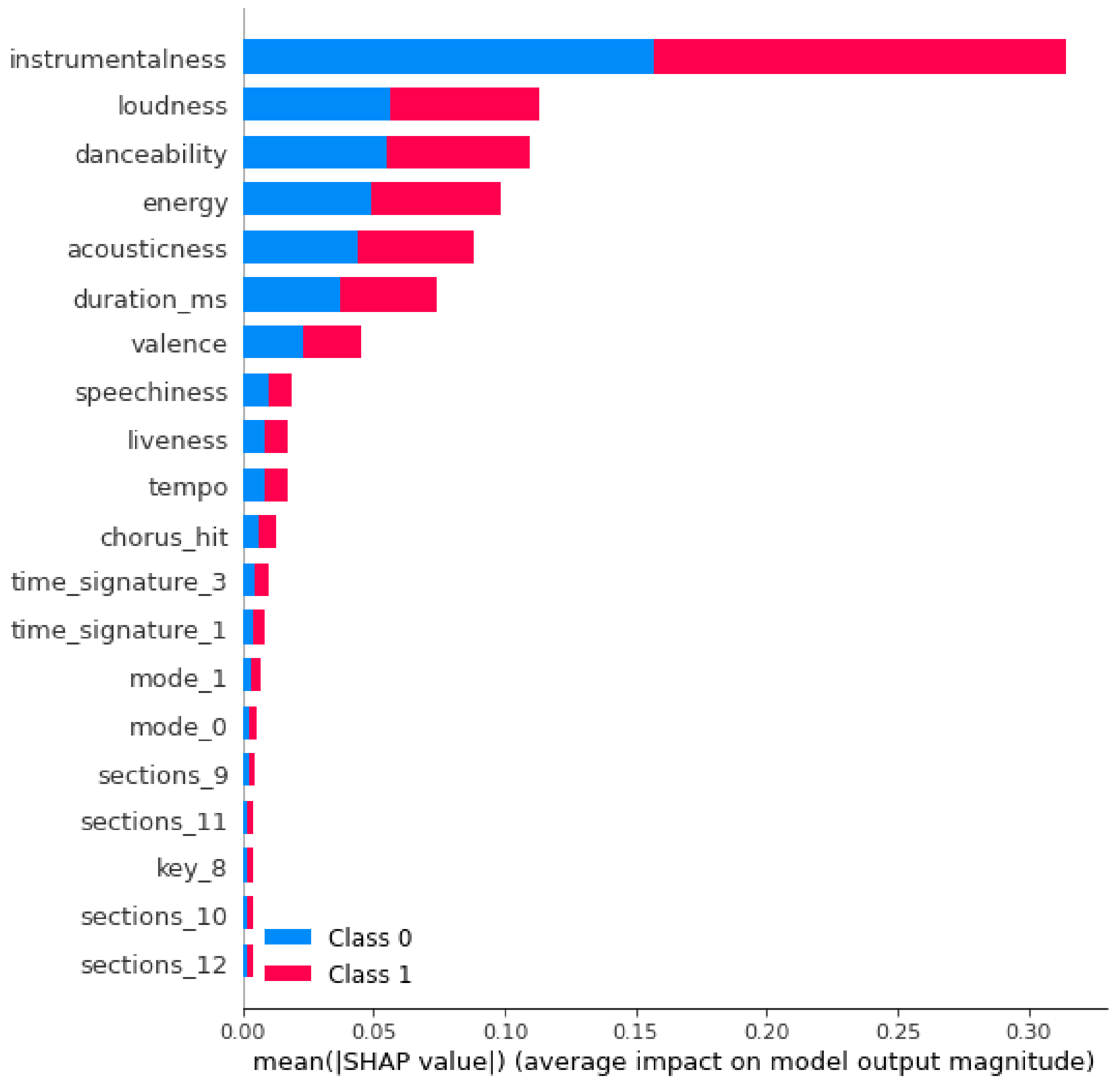
[207]:
```
import shap
shap.initjs() # required for visualizations later on
# create the explainer object with the random forest model
grid = RF_grids[9]
X_test = X_tests_cv[9]
y_test = y_tests_cv[9]

# create the explainer object with the random forest model
explainer = shap.TreeExplainer(grid.best_estimator_[1])
# transform the test set
X_test_transformed = grid.best_estimator_[0].transform(X_test)
print(np.shape(X_test_transformed))
# calculate shap values on the first 1000 points in the test
```

```
shap_values1 = explainer.shap_values(X_test_transformed[:1000])
print(np.shape(shap_values1))
```

<IPython.core.display.HTML object>

```
(1280, 69)
(2, 1000, 69)
```

[208]:
```
shap.summary_plot(shap_values1,X_test_transformed[:1000], feature_names =␣
↪feature_names,
                  title="SHAP Summary Plot for Second Random State")
plt.savefig('../figures/shap_values1.png', dpi=300, format='png')
```



<Figure size 432x288 with 0 Axes>

[225]:
```python
index = 250
shap.force_plot(explainer.expected_value[0], shap_values1[0][index,:], features␣
↪= X_test_transformed[index,:],feature_names = feature_names)
```

[225]:
```
<shap.plots._force.AdditiveForceVisualizer at 0x16773f910>
```

[ ]:
```

```