Final Project Analysis - Evaluating Open Mic Data with MultiClass Classifiers

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Overview

The Open Mic 2018 dataset contains 20,000 examples of Creative Commons-licensed music available on the Free Music Archive (Humphrey, et. al 2018). Open Mic 2018 was made available through a collaboration between Spotify and MARL@NYU. Each example is a 10-second excerpt which has been partially labeled for the presence or absence of 20 instrument classes by annotators on a crowd-sourcing platform. In this project, researchers describe in detail how the instrument taxonomy was constructed, how the dataset was sampled and annotated, and compare its characteristics to similar, previous data-sets. Finally, we present experimental results and baseline model performance to motivate future work in music recognition in music information retrieval.

Task/Problem/Question

Identification of instruments in polyphonic records is an imperative issue in music information retrieval. This is mainly due to a lack of data available for effective predictive and computational models. With the introduction of this Open Mic 2018 data, we are able to effectively build a model with sufficient data that will correctly identify the instruments playing in polyphonic records. Therefore, the goal of this project is to find a classifier that reduces the error rate to either a local or global minimum across each class or instrument. Multi-instrument recognition is the task of predicting the presence or absence of different instruments within an audio clip, this project aims to effectively do so. The implications of succeeding on this project would enable the team to create deliverables that can identify whether a specific instrument is playing, which could be scaled to machine learning deliverables akin to those used by Shazam and other music recognition services.

Data splitting (training, validation, and test sets)

The data is first loaded and mapped based on their respective instrument. The data is then split using the squeeze is true function in Pandas to only have a single array for each instrument rather than parsing through the entire dataframe each runthrough. The testing and training data is split in a 75 to 25 ratio fashion. Then the data was prepared for the baseline model, perceptron, and the following comparative models: Random Forest, Logistic Regression, Neural Network, and Support Vector Machine (SVM). The data was sub-sampled by annotation, and then masked by annotations. Instead of having time-varying features in the original dataset, mean feature vectors were summarized over time. Label likelihood thresholds were at 0.5. This was done for both the test and train datasets and then applied to Perceptron, Random Forest, Logistic Regression, Neural Network, and SVM models for the algorithms.

Validation and testing (model tuning and evaluation)

Across the creation of the models used, several parameters and hyperparameters were imposed on the models to maximize their respective classification rates. After iterating the models several times, the parameters selected were ultimately chosen due to their impact on the precision rates during the classification process.

The parameters selected for the random forest model included the depth of the tree and the number of estimators included at the splits. After iterating the model over several depths, a max depth of eight provided the most significant results. The random forest classified the data at a depth of 2,4,6,8,10… and 20. It was at a parameter selection of eight that resulted in the highest levels of precision for each instrument.

The next model utilizing several different parameters was the logistic regression model. Logistic regression has the ability to implement a penalty within the model. The first penalty used within the model for classification was 'elastic net'. However, the model performance significantly increased with the inclusion of the 'L1' penalty. This penalty was the most successful in limiting the impact of the variables that are less contributive for classification. The 'liblinear' solver was also included as it pairs with the 'L1' penalty.

The SVM model parameters were set with gamma to 'auto,' kernel to 'poly,' and degree to '2' with the rest of the parameters tuned to their defaults within the function. The advantage to using the gamma as auto over scale is that auto uses the value [1 / (number of features)] rather than the value [1 / (number of features * X variance)]. The degree hyperparameter can only be used with a polynomial kernel and this function gave the best results over the default value of degree 3.

The final model parameters were established within the creation of the Neural Network model. Similar to the previous models, several iterations of the model were run and parameters were selected on precision rate. For the neural network, this resulted in five hidden layers. With the inclusion of these parameters, the models were able to increase their classification rates by more than 5% in some cases.

Results and final model selection (performance measures etc.)

The model creation began with establishing the baseline model. The baseline model is to be used to compare future models to determine whether the tuning of the parameters and hyperparameters resulted in a positive change in the precision rates. For the baseline model, a perceptron was used. The creation of the baseline model included the mean average over time for each instrument. As a result, the baseline model for each of the instruments was very high in regards to precision. Additionally, the baseline model seemed to always record a higher precision score with performance on the training set rather than the testing set. For example, The precision rate for false classification for the accordion was 93% on the respective training set. The model performance for the accordion testing set saw a small decrease to 90%. The decrease in precision across training and testing sets is more significant for drums. The train/test precision rates in this case were 98% and 92% respectively. With the validation of the baseline model complete and the precision, recall and F-1 scores documented, additional models were created for comparison.

The models all had high precision and recall scores. Each model had at least one instrument classification where it outperformed each of the other models. For example, the Random Forest model recorded a 99% precision rate for the Cello. This is significantly higher than the 82%, 85%, and 83% rates for the perceptron, logistic regression and neural network models respectively. Alternatively, the Neural Network model had the highest rate for voice; Logistic Regression had the highest recorded rate for piano. As a result, the models all outperformed the baseline model in regards to specific instruments. However, in some cases the models failed to beat the baseline rates entirely. None of the models created had a higher precision rate than the perceptron performance on drums. Overall, the Random Forest model recorde the highest average precision rate while the neural network model recorded the lowest averages.

The recorded 'False' precision rates in the training data for some of the instruments in the models can be found in Table 1 below.

Instrument	Baseline	Random Forest	Logistic Regression	Neural Network	SVM
Accordion	0.93	0.96	0.88	0.84	0.84
Banjo	0.81	0.98	0.87	0.80	0.81
Bass	0.86	0.98	0.86	0.85	0.81
Cello	0.82	0.91	0.85	0.83	0.83
Clarinet	0.89	0.99	0.94	0.80	0.81
Cymbals	0.85	1.00	0.91	0.97	0.99
Drums	0.98	1.00	0.94	0.94	1.00
Flute	0.96	0.97	0.89	0.76	0.80
Guitar	0.92	1.00	0.96	0.95	0.98
Organ	0.88	0.97	0.92	0.84	0.82
Piano	0.97	0.99	0.98	0.95	0.98

Table 1: The recorded precision rates for models on the training sets.

Discussion and conclusions

In conclusion, the creation of the models were successfully able to identify instruments playing in the polyphonic records. The models had significantly reduced error rates to the local and global minimum across each class and instrument. As discussed previously, instruments in polyphonic records is an imperative issue in music information retrieval.

The data was collected and parsed into testing and training sets. The creation of the training set allowed the models to be fit to the data and then utilized on test data. The benefit of the test data is that it represents information never before “seen” by the model. As a result, it allows overfitting and other potential issues to be observed by monitoring the fall-off of classification rates. The data was free of any nulls and the most optimal parameters were selected. This resulted in the tuning of the max depth for the random forest, penalty implementation for logistic regression, the number of hidden layers for the neural network, and the degree of the polynomial kernel for the SVM. These parameters allowed the models to output their optimal performances that resulted in up to 99% precision rates in some cases.

Each of the models outperformed the others in at least one instrument category. As a result, it would be beneficial to split the data even further. An idea of this is to group all the ‘string’ instruments together (Violin, Cello, etc…) since Logistic Regression had higher average rates for string instruments than the other models. This example would optimize results even further and be stronger than using a one-model-fit-all strategy.

The application of this research can be applied to applications across the music industry. The models had high precision outputs and could be utilized to create deliverables that can identify the instrument being played which can be scaled to music recognition services such as Shazam.

References

Eric Humphrey, Simon Durand, & Brian McFee. (2018). OpenMIC-2018: An Open Data-set for Multiple Instrument Recognition. Proceedings of the 19th International Society for Music Information Retrieval Conference, 438–444. https://doi.org/10.5281/zenodo.1492445

ADS504 project

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[2]:
```python
import json
import os
import numpy as np
import pandas as pd

from sklearn.ensemble import RandomForestClassifier
from sklearn.metrics import classification_report
from sklearn.linear_model import Perceptron
from sklearn.linear_model import LogisticRegression
from sklearn.neural_network import MLPClassifier
from sklearn.metrics import confusion_matrix

#DATA_ROOT = 'C:/Users/mzazu/OneDrive/Documents/USD papers/504/Project/
↪openmic-2018-v1.0.0/openmic-2018-v1.0.0/openmic-2018'
DATA_ROOT = 'D:\ADS504OpenMicDataset\openmic-2018-v1.0.0\openmic-2018-v1.0.
↪0\openmic-2018'

if not os.path.exists(DATA_ROOT):
    raise ValueError('Did you forget to set `DATA_ROOT`?')
```

0.0.1 Loading the data

[3]:
```python
OPENMIC = np.load(os.path.join(DATA_ROOT, 'openmic-2018.npz'), ␣
↪allow_pickle=True)
```

[4]:
```python
# What's included?
print(list(OPENMIC.keys()))
```

```
['X', 'Y_true', 'Y_mask', 'sample_key']
```

[5]:
```python
X, Y_true, Y_mask, sample_key = OPENMIC['X'], OPENMIC['Y_true'],␣
↪OPENMIC['Y_mask'], OPENMIC['sample_key']
```

0.0.2 Loading the class map

[6]:
```
with open(os.path.join(DATA_ROOT, 'class-map.json'), 'r') as f:
    class_map = json.load(f)
```

[7]:
```
class_map
```

[7]:
```
{'accordion': 0,
 'banjo': 1,
 'bass': 2,
 'cello': 3,
 'clarinet': 4,
 'cymbals': 5,
 'drums': 6,
 'flute': 7,
 'guitar': 8,
 'mallet_percussion': 9,
 'mandolin': 10,
 'organ': 11,
 'piano': 12,
 'saxophone': 13,
 'synthesizer': 14,
 'trombone': 15,
 'trumpet': 16,
 'ukulele': 17,
 'violin': 18,
 'voice': 19}
```

0.0.3 Loading the train-test splits

[8]:
```
# We use squeeze=True here to return a single array for each, rather than a␣
 ↪full DataFrame

split_train = pd.read_csv(os.path.join(DATA_ROOT, 'partitions/split01_train.
 ↪csv'),
                          header=None, squeeze=True)
split_test = pd.read_csv(os.path.join(DATA_ROOT, 'partitions/split01_test.csv'),
                         header=None, squeeze=True)
```

[9]:
```
# train and test examples are about 75%/25%
print('# Train: {},  # Test: {}'.format(len(split_train), len(split_test)))
```

```
# Train: 14915,  # Test: 5085
```

[10]:
```
# sample key maps are easier to use as sets
train_set = set(split_train)
test_set = set(split_test)
```

0.0.4 Spliting data

[11]:
```
# These loops go through all sample keys, and save their row numbers to either␣
↪idx_train or idx_test
# This will be useful in the next step for slicing the array data
idx_train, idx_test = [], []

for idx, n in enumerate(sample_key):
    if n in train_set:
        idx_train.append(idx)
    elif n in test_set:
        idx_test.append(idx)
    else:
        # This should never happen, but better safe than sorry.
        raise RuntimeError('Unknown sample key={}! Abort!'.
↪format(sample_key[n]))

# Finally, cast the idx_* arrays to numpy structures
idx_train = np.asarray(idx_train)
idx_test = np.asarray(idx_test)
```

[12]:
```
# split indices to partition the features, labels, and masks
X_train = X[idx_train]
X_test = X[idx_test]

Y_true_train = Y_true[idx_train]
Y_true_test = Y_true[idx_test]

Y_mask_train = Y_mask[idx_train]
Y_mask_test = Y_mask[idx_test]
```

0.0.5 Fitting Baseline Model (Perceptron)

[40]:
```
# This dictionary will include the classifiers for each model
models = dict()

# We'll iterate over all istrument classes, and fit a model for each one
# After training, we'll print a classification report for each instrument
for instrument in class_map:

    # Map the instrument name to its column number
    inst_num = class_map[instrument]

    # Step 1: sub-sample the data

    # First, we need to select down to the data for which we have annotations
    # This is what the mask arrays are for
```

```
    train_inst = Y_mask_train[:, inst_num]
    test_inst = Y_mask_test[:, inst_num]

    # Here, we're using the Y_mask_train array to slice out only the training examples
    # for which we have annotations for the given class
    X_train_inst = X_train[train_inst]

    # Step 2: simplify the data by averaging over time

    # Let's arrange the data for a sklearn Perceptron
    # Instead of having time-varying features, we'll summarize each track by its mean feature vector over time
    X_train_inst_sklearn = np.mean(X_train_inst, axis=1)

    # Again, we slice the labels to the annotated examples
    # We thresold the label likelihoods at 0.5 to get binary labels
    Y_true_train_inst = Y_true_train[train_inst, inst_num] >= 0.5


    # Repeat the above slicing and dicing but for the test set
    X_test_inst = X_test[test_inst]
    X_test_inst_sklearn = np.mean(X_test_inst, axis=1)
    Y_true_test_inst = Y_true_test[test_inst, inst_num] >= 0.5

    # Step 3.
    # Initialize a new classifier
    clf = Perceptron(random_state = 0)

    # Step 4.
    clf.fit(X_train_inst_sklearn, Y_true_train_inst)

    # Step 5.
    # Finally, we'll evaluate the model on both train and test
    Y_pred_train = clf.predict(X_train_inst_sklearn)
    Y_pred_test = clf.predict(X_test_inst_sklearn)

    print('-' * 52)
    print(instrument)
    print('\tTRAIN')
    print(classification_report(Y_true_train_inst, Y_pred_train))
    print('\tTEST')
    print(classification_report(Y_true_test_inst, Y_pred_test))
```

```
----------------------------------------------------
accordion
	TRAIN
```

	precision	recall	f1-score	support
False	0.93	0.81	0.86	1159
True	0.58	0.81	0.67	374
accuracy			0.81	1533
macro avg	0.75	0.81	0.77	1533
weighted avg	0.84	0.81	0.82	1533

TEST

	precision	recall	f1-score	support
False	0.90	0.74	0.81	423
True	0.43	0.70	0.53	115
accuracy			0.73	538
macro avg	0.66	0.72	0.67	538
weighted avg	0.80	0.73	0.75	538

----

banjo

TRAIN

	precision	recall	f1-score	support
False	0.81	0.93	0.87	1148
True	0.81	0.58	0.67	592
accuracy			0.81	1740
macro avg	0.81	0.75	0.77	1740
weighted avg	0.81	0.81	0.80	1740

TEST

	precision	recall	f1-score	support
False	0.79	0.89	0.84	338
True	0.62	0.42	0.50	140
accuracy			0.76	478
macro avg	0.70	0.66	0.67	478
weighted avg	0.74	0.76	0.74	478

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bass

TRAIN

	precision	recall	f1-score	support
False	0.86	0.89	0.87	1010
True	0.71	0.64	0.67	415

```
    accuracy                           0.82      1425
   macro avg       0.78      0.77      0.77      1425
weighted avg       0.81      0.82      0.82      1425

        TEST
              precision    recall  f1-score   support

       False       0.85      0.88      0.86       329
        True       0.67      0.61      0.64       134

    accuracy                           0.80       463
   macro avg       0.76      0.75      0.75       463
weighted avg       0.80      0.80      0.80       463

----------------------------------------------------
cello
        TRAIN
              precision    recall  f1-score   support

       False       0.82      0.86      0.84       866
        True       0.78      0.74      0.76       598

    accuracy                           0.81      1464
   macro avg       0.80      0.80      0.80      1464
weighted avg       0.81      0.81      0.81      1464

        TEST
              precision    recall  f1-score   support

       False       0.80      0.81      0.81       259
        True       0.78      0.77      0.77       226

    accuracy                           0.79       485
   macro avg       0.79      0.79      0.79       485
weighted avg       0.79      0.79      0.79       485

----------------------------------------------------
clarinet
        TRAIN
              precision    recall  f1-score   support

       False       0.89      0.73      0.81      1349
        True       0.44      0.70      0.54       396

    accuracy                           0.73      1745
   macro avg       0.67      0.72      0.67      1745
weighted avg       0.79      0.73      0.75      1745
```

TEST

	precision	recall	f1-score	support
False	0.88	0.69	0.77	503
True	0.37	0.66	0.47	137
accuracy			0.68	640
macro avg	0.62	0.67	0.62	640
weighted avg	0.77	0.68	0.71	640

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cymbals

TRAIN

	precision	recall	f1-score	support
False	0.85	0.92	0.88	485
True	0.95	0.91	0.93	814
accuracy			0.91	1299
macro avg	0.90	0.91	0.91	1299
weighted avg	0.91	0.91	0.91	1299

TEST

	precision	recall	f1-score	support
False	0.85	0.91	0.88	139
True	0.96	0.93	0.94	297
accuracy			0.92	436
macro avg	0.91	0.92	0.91	436
weighted avg	0.92	0.92	0.92	436

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drums

TRAIN

	precision	recall	f1-score	support
False	0.98	0.88	0.93	495
True	0.93	0.99	0.96	828
accuracy			0.95	1323
macro avg	0.95	0.93	0.94	1323
weighted avg	0.95	0.95	0.95	1323

TEST

	precision	recall	f1-score	support

```
       False       0.92      0.79      0.85       146
        True       0.90      0.96      0.93       278

    accuracy                           0.91       424
   macro avg       0.91      0.88      0.89       424
weighted avg       0.91      0.91      0.90       424

----------------------------------------------------
flute
        TRAIN
              precision    recall  f1-score   support

       False       0.96      0.50      0.66      1050
        True       0.46      0.95      0.62       472

    accuracy                           0.64      1522
   macro avg       0.71      0.73      0.64      1522
weighted avg       0.80      0.64      0.65      1522

        TEST
              precision    recall  f1-score   support

       False       0.92      0.43      0.58       387
        True       0.42      0.92      0.58       175

    accuracy                           0.58       562
   macro avg       0.67      0.67      0.58       562
weighted avg       0.77      0.58      0.58       562

----------------------------------------------------
guitar
        TRAIN
              precision    recall  f1-score   support

       False       0.92      0.94      0.93       362
        True       0.97      0.97      0.97       852

    accuracy                           0.96      1214
   macro avg       0.95      0.95      0.95      1214
weighted avg       0.96      0.96      0.96      1214

        TEST
              precision    recall  f1-score   support

       False       0.92      0.95      0.93       150
        True       0.97      0.96      0.96       286

    accuracy                           0.95       436
```

```
   macro avg       0.95      0.95      0.95       436
weighted avg       0.95      0.95      0.95       436

----------------------------------------------------
mallet_percussion
        TRAIN
              precision    recall  f1-score   support

       False       0.84      0.90      0.87       802
        True       0.83      0.73      0.78       522

    accuracy                           0.83      1324
   macro avg       0.83      0.82      0.82      1324
weighted avg       0.83      0.83      0.83      1324

        TEST
              precision    recall  f1-score   support

       False       0.75      0.88      0.81       267
        True       0.80      0.64      0.71       211

    accuracy                           0.77       478
   macro avg       0.78      0.76      0.76       478
weighted avg       0.78      0.77      0.77       478

----------------------------------------------------
mandolin
        TRAIN
              precision    recall  f1-score   support

       False       0.99      0.39      0.56      1185
        True       0.47      0.99      0.64       652

    accuracy                           0.60      1837
   macro avg       0.73      0.69      0.60      1837
weighted avg       0.81      0.60      0.59      1837

        TEST
              precision    recall  f1-score   support

       False       0.99      0.35      0.52       434
        True       0.40      0.99      0.57       193

    accuracy                           0.55       627
   macro avg       0.70      0.67      0.55       627
weighted avg       0.81      0.55      0.54       627

----------------------------------------------------
```

```
organ
       TRAIN
              precision    recall  f1-score   support

       False       0.88      0.85      0.87       977
        True       0.72      0.77      0.75       482

    accuracy                           0.83      1459
   macro avg       0.80      0.81      0.81      1459
weighted avg       0.83      0.83      0.83      1459

        TEST
              precision    recall  f1-score   support

       False       0.83      0.85      0.84       310
        True       0.59      0.55      0.57       121

    accuracy                           0.77       431
   macro avg       0.71      0.70      0.70       431
weighted avg       0.76      0.77      0.76       431

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piano
       TRAIN
              precision    recall  f1-score   support

       False       0.97      0.95      0.96       420
        True       0.98      0.99      0.98       885

    accuracy                           0.97      1305
   macro avg       0.97      0.97      0.97      1305
weighted avg       0.97      0.97      0.97      1305

        TEST
              precision    recall  f1-score   support

       False       0.97      0.85      0.91       130
        True       0.94      0.99      0.96       285

    accuracy                           0.95       415
   macro avg       0.96      0.92      0.94       415
weighted avg       0.95      0.95      0.95       415

----------------------------------------------------
saxophone
       TRAIN
              precision    recall  f1-score   support
```

```
       False       0.84      0.75      0.79       906
        True       0.75      0.84      0.79       830

    accuracy                           0.79      1736
   macro avg       0.80      0.79      0.79      1736
weighted avg       0.80      0.79      0.79      1736

        TEST
              precision    recall  f1-score   support

       False       0.86      0.76      0.81       324
        True       0.77      0.87      0.82       305

    accuracy                           0.81       629
   macro avg       0.82      0.81      0.81       629
weighted avg       0.82      0.81      0.81       629

----------------------------------------------------
synthesizer
        TRAIN
              precision    recall  f1-score   support

       False       0.99      0.76      0.86       399
        True       0.90      1.00      0.94       823

    accuracy                           0.92      1222
   macro avg       0.94      0.88      0.90      1222
weighted avg       0.93      0.92      0.92      1222

        TEST
              precision    recall  f1-score   support

       False       0.96      0.73      0.83       112
        True       0.90      0.99      0.94       268

    accuracy                           0.91       380
   macro avg       0.93      0.86      0.89       380
weighted avg       0.92      0.91      0.91       380

----------------------------------------------------
trombone
        TRAIN
              precision    recall  f1-score   support

       False       0.83      0.92      0.87      1405
        True       0.77      0.58      0.66       635

    accuracy                           0.81      2040
```

```
   macro avg       0.80      0.75      0.77      2040
weighted avg       0.81      0.81      0.81      2040

        TEST
              precision    recall  f1-score   support

       False       0.83      0.92      0.87       492
        True       0.77      0.59      0.67       228

    accuracy                           0.81       720
   macro avg       0.80      0.75      0.77       720
weighted avg       0.81      0.81      0.81       720

----------------------------------------------------
trumpet
        TRAIN
              precision    recall  f1-score   support

       False       0.91      0.70      0.79      1303
        True       0.65      0.89      0.76       828

    accuracy                           0.78      2131
   macro avg       0.78      0.80      0.77      2131
weighted avg       0.81      0.78      0.78      2131

        TEST
              precision    recall  f1-score   support

       False       0.88      0.64      0.74       467
        True       0.62      0.87      0.73       318

    accuracy                           0.73       785
   macro avg       0.75      0.76      0.73       785
weighted avg       0.78      0.73      0.73       785

----------------------------------------------------
ukulele
        TRAIN
              precision    recall  f1-score   support

       False       0.92      0.73      0.81      1279
        True       0.58      0.85      0.69       556

    accuracy                           0.77      1835
   macro avg       0.75      0.79      0.75      1835
weighted avg       0.82      0.77      0.78      1835

        TEST
```

```
              precision    recall  f1-score   support

       False       0.89      0.69      0.78       408
        True       0.54      0.82      0.65       182

    accuracy                           0.73       590
   macro avg       0.72      0.75      0.71       590
weighted avg       0.79      0.73      0.74       590

----------------------------------------------------
violin
        TRAIN
              precision    recall  f1-score   support

       False       0.59      0.98      0.74       623
        True       0.97      0.45      0.62       779

    accuracy                           0.69      1402
   macro avg       0.78      0.72      0.68      1402
weighted avg       0.80      0.69      0.67      1402

        TEST
              precision    recall  f1-score   support

       False       0.48      0.97      0.64       237
        True       0.95      0.37      0.53       394

    accuracy                           0.59       631
   macro avg       0.72      0.67      0.59       631
weighted avg       0.78      0.59      0.57       631

----------------------------------------------------
voice
        TRAIN
              precision    recall  f1-score   support

       False       0.90      0.91      0.91       426
        True       0.95      0.94      0.95       764

    accuracy                           0.93      1190
   macro avg       0.93      0.93      0.93      1190
weighted avg       0.93      0.93      0.93      1190

        TEST
              precision    recall  f1-score   support

       False       0.84      0.93      0.89       150
        True       0.95      0.88      0.92       224
```

```
    accuracy                           0.90       374
   macro avg       0.90      0.91      0.90       374
weighted avg       0.91      0.90      0.90       374
```

0.0.6 Random Forest

[77]:
```python
for instrument in class_map:

    inst_num = class_map[instrument]

    train_inst = Y_mask_train[:, inst_num]
    test_inst = Y_mask_test[:, inst_num]

    X_train_inst = X_train[train_inst]

    X_train_inst_sklearn = np.mean(X_train_inst, axis=1)

    Y_true_train_inst = Y_true_train[train_inst, inst_num] >= 0.5

    X_test_inst = X_test[test_inst]
    X_test_inst_sklearn = np.mean(X_test_inst, axis=1)
    Y_true_test_inst = Y_true_test[test_inst, inst_num] >= 0.5

    clf = RandomForestClassifier(max_depth=8, n_estimators=250, random_state=0)

    clf.fit(X_train_inst_sklearn, Y_true_train_inst)

    # Evaluate the model on both train and test
    Y_pred_train = clf.predict(X_train_inst_sklearn)
    Y_pred_test = clf.predict(X_test_inst_sklearn)

    print('-' * 52)
    print(instrument)
    print('\tTRAIN')
    print(classification_report(Y_true_train_inst, Y_pred_train))
    print('\tTEST')
    print(classification_report(Y_true_test_inst, Y_pred_test))
    print('\tConfusion Matrix')
    print(confusion_matrix(Y_true_test_inst, Y_pred_test))
```

```
----------------------------------------------------
accordion
        TRAIN
              precision    recall  f1-score   support

       False       0.96      1.00      0.98      1159
```

```
        True       1.00      0.87      0.93       374

    accuracy                           0.97      1533
   macro avg       0.98      0.93      0.95      1533
weighted avg       0.97      0.97      0.97      1533

        TEST
              precision    recall  f1-score   support

       False       0.84      0.97      0.90       423
        True       0.78      0.33      0.46       115

    accuracy                           0.84       538
   macro avg       0.81      0.65      0.68       538
weighted avg       0.83      0.84      0.81       538

        Confusion Matrix
[[412  11]
 [ 77  38]]
----------------------------------------------------
banjo
        TRAIN
              precision    recall  f1-score   support

       False       0.98      0.99      0.98      1148
        True       0.98      0.96      0.97       592

    accuracy                           0.98      1740
   macro avg       0.98      0.98      0.98      1740
weighted avg       0.98      0.98      0.98      1740

        TEST
              precision    recall  f1-score   support

       False       0.83      0.90      0.86       338
        True       0.68      0.54      0.61       140

    accuracy                           0.79       478
   macro avg       0.76      0.72      0.73       478
weighted avg       0.78      0.79      0.79       478

        Confusion Matrix
[[303  35]
 [ 64  76]]
----------------------------------------------------
bass
        TRAIN
              precision    recall  f1-score   support
```

```
       False       0.98      0.99      0.98      1010
        True       0.97      0.94      0.95       415

    accuracy                           0.97      1425
   macro avg       0.97      0.96      0.97      1425
weighted avg       0.97      0.97      0.97      1425

        TEST
              precision    recall  f1-score   support

       False       0.83      0.96      0.89       329
        True       0.85      0.53      0.65       134

    accuracy                           0.84       463
   macro avg       0.84      0.75      0.77       463
weighted avg       0.84      0.84      0.82       463

        Confusion Matrix
[[316  13]
 [ 63  71]]
----------------------------------------------------
cello
        TRAIN
              precision    recall  f1-score   support

       False       0.99      0.97      0.98       866
        True       0.95      0.99      0.97       598

    accuracy                           0.98      1464
   macro avg       0.97      0.98      0.97      1464
weighted avg       0.98      0.98      0.98      1464

        TEST
              precision    recall  f1-score   support

       False       0.80      0.84      0.82       259
        True       0.80      0.76      0.78       226

    accuracy                           0.80       485
   macro avg       0.80      0.80      0.80       485
weighted avg       0.80      0.80      0.80       485

        Confusion Matrix
[[217  42]
 [ 55 171]]
----------------------------------------------------
clarinet
```

```
        TRAIN
              precision    recall  f1-score   support

       False       0.91      1.00      0.96      1349
        True       1.00      0.68      0.81       396

    accuracy                           0.93      1745
   macro avg       0.96      0.84      0.88      1745
weighted avg       0.93      0.93      0.92      1745

        TEST
              precision    recall  f1-score   support

       False       0.80      0.99      0.88       503
        True       0.67      0.07      0.13       137

    accuracy                           0.79       640
   macro avg       0.73      0.53      0.51       640
weighted avg       0.77      0.79      0.72       640

        Confusion Matrix
[[498   5]
 [127  10]]
----------------------------------------------------
cymbals
        TRAIN
              precision    recall  f1-score   support

       False       1.00      0.89      0.94       485
        True       0.94      1.00      0.97       814

    accuracy                           0.96      1299
   macro avg       0.97      0.95      0.96      1299
weighted avg       0.96      0.96      0.96      1299

        TEST
              precision    recall  f1-score   support

       False       0.96      0.85      0.90       139
        True       0.93      0.98      0.96       297

    accuracy                           0.94       436
   macro avg       0.95      0.92      0.93       436
weighted avg       0.94      0.94      0.94       436

        Confusion Matrix
[[118  21]
 [  5 292]]
```

```
---------------------------------------------------
drums
        TRAIN
              precision    recall  f1-score   support

       False       1.00      0.95      0.97       495
        True       0.97      1.00      0.99       828

    accuracy                           0.98      1323
   macro avg       0.99      0.97      0.98      1323
weighted avg       0.98      0.98      0.98      1323

        TEST
              precision    recall  f1-score   support

       False       0.92      0.79      0.85       146
        True       0.90      0.96      0.93       278

    accuracy                           0.91       424
   macro avg       0.91      0.88      0.89       424
weighted avg       0.91      0.91      0.90       424

        Confusion Matrix
[[116  30]
 [ 10 268]]
---------------------------------------------------
flute
        TRAIN
              precision    recall  f1-score   support

       False       0.97      0.99      0.98      1050
        True       0.98      0.94      0.96       472

    accuracy                           0.98      1522
   macro avg       0.98      0.97      0.97      1522
weighted avg       0.98      0.98      0.98      1522

        TEST
              precision    recall  f1-score   support

       False       0.76      0.92      0.83       387
        True       0.68      0.36      0.47       175

    accuracy                           0.75       562
   macro avg       0.72      0.64      0.65       562
weighted avg       0.74      0.75      0.72       562

        Confusion Matrix
```

```
[[357  30]
 [112  63]]
---------------------------------------------------
guitar
        TRAIN
              precision    recall  f1-score   support

       False       1.00      0.96      0.98       362
        True       0.98      1.00      0.99       852

    accuracy                           0.99      1214
   macro avg       0.99      0.98      0.99      1214
weighted avg       0.99      0.99      0.99      1214

        TEST
              precision    recall  f1-score   support

       False       0.97      0.97      0.97       150
        True       0.98      0.98      0.98       286

    accuracy                           0.98       436
   macro avg       0.97      0.97      0.97       436
weighted avg       0.98      0.98      0.98       436

        Confusion Matrix
[[145   5]
 [  5 281]]
---------------------------------------------------
mallet_percussion
        TRAIN
              precision    recall  f1-score   support

       False       1.00      0.95      0.97       802
        True       0.93      1.00      0.96       522

    accuracy                           0.97      1324
   macro avg       0.96      0.97      0.97      1324
weighted avg       0.97      0.97      0.97      1324

        TEST
              precision    recall  f1-score   support

       False       0.79      0.84      0.82       267
        True       0.78      0.72      0.75       211

    accuracy                           0.79       478
   macro avg       0.79      0.78      0.78       478
weighted avg       0.79      0.79      0.79       478
```

```
        Confusion Matrix
[[225  42]
 [ 60 151]]
---------------------------------------------------
mandolin
        TRAIN
              precision    recall  f1-score   support

       False       0.97      0.97      0.97      1185
        True       0.95      0.95      0.95       652

    accuracy                           0.96      1837
   macro avg       0.96      0.96      0.96      1837
weighted avg       0.96      0.96      0.96      1837

        TEST
              precision    recall  f1-score   support

       False       0.81      0.83      0.82       434
        True       0.60      0.56      0.58       193

    accuracy                           0.75       627
   macro avg       0.71      0.70      0.70       627
weighted avg       0.75      0.75      0.75       627

        Confusion Matrix
[[362  72]
 [ 84 109]]
---------------------------------------------------
organ
        TRAIN
              precision    recall  f1-score   support

       False       0.97      1.00      0.98       977
        True       1.00      0.93      0.96       482

    accuracy                           0.98      1459
   macro avg       0.98      0.96      0.97      1459
weighted avg       0.98      0.98      0.98      1459

        TEST
              precision    recall  f1-score   support

       False       0.77      0.95      0.85       310
        True       0.69      0.27      0.39       121

    accuracy                           0.76       431
```

```
   macro avg       0.73      0.61      0.62       431
weighted avg       0.75      0.76      0.72       431

        Confusion Matrix
[[295  15]
 [ 88  33]]
----------------------------------------------------
piano
        TRAIN
              precision    recall  f1-score   support

       False       1.00      0.96      0.98       420
        True       0.98      1.00      0.99       885

    accuracy                           0.99      1305
   macro avg       0.99      0.98      0.99      1305
weighted avg       0.99      0.99      0.99      1305

        TEST
              precision    recall  f1-score   support

       False       0.96      0.85      0.90       130
        True       0.94      0.98      0.96       285

    accuracy                           0.94       415
   macro avg       0.95      0.92      0.93       415
weighted avg       0.94      0.94      0.94       415

        Confusion Matrix
[[111  19]
 [  5 280]]
----------------------------------------------------
saxophone
        TRAIN
              precision    recall  f1-score   support

       False       1.00      0.94      0.97       906
        True       0.94      1.00      0.97       830

    accuracy                           0.97      1736
   macro avg       0.97      0.97      0.97      1736
weighted avg       0.97      0.97      0.97      1736

        TEST
              precision    recall  f1-score   support

       False       0.84      0.80      0.82       324
        True       0.80      0.84      0.82       305
```

```
    accuracy                           0.82       629
   macro avg       0.82      0.82      0.82       629
weighted avg       0.82      0.82      0.82       629

        Confusion Matrix
[[259  65]
 [ 48 257]]
----------------------------------------------------
synthesizer
        TRAIN
              precision    recall  f1-score   support

       False       0.99      0.96      0.97       399
        True       0.98      1.00      0.99       823

    accuracy                           0.98      1222
   macro avg       0.99      0.98      0.98      1222
weighted avg       0.98      0.98      0.98      1222

        TEST
              precision    recall  f1-score   support

       False       0.93      0.90      0.91       112
        True       0.96      0.97      0.96       268

    accuracy                           0.95       380
   macro avg       0.94      0.94      0.94       380
weighted avg       0.95      0.95      0.95       380

        Confusion Matrix
[[101  11]
 [  8 260]]
----------------------------------------------------
trombone
        TRAIN
              precision    recall  f1-score   support

       False       0.95      0.98      0.97      1405
        True       0.96      0.89      0.92       635

    accuracy                           0.95      2040
   macro avg       0.96      0.94      0.95      2040
weighted avg       0.95      0.95      0.95      2040

        TEST
              precision    recall  f1-score   support
```

```
       False       0.81      0.93      0.87       492
        True       0.78      0.53      0.63       228

    accuracy                           0.80       720
   macro avg       0.79      0.73      0.75       720
weighted avg       0.80      0.80      0.79       720

        Confusion Matrix
[[457  35]
 [107 121]]
----------------------------------------------------
trumpet
        TRAIN
              precision    recall  f1-score   support

       False       0.96      0.97      0.97      1303
        True       0.95      0.94      0.95       828

    accuracy                           0.96      2131
   macro avg       0.96      0.96      0.96      2131
weighted avg       0.96      0.96      0.96      2131

        TEST
              precision    recall  f1-score   support

       False       0.78      0.88      0.83       467
        True       0.78      0.63      0.70       318

    accuracy                           0.78       785
   macro avg       0.78      0.75      0.76       785
weighted avg       0.78      0.78      0.77       785

        Confusion Matrix
[[411  56]
 [118 200]]
----------------------------------------------------
ukulele
        TRAIN
              precision    recall  f1-score   support

       False       0.97      0.99      0.98      1279
        True       0.96      0.94      0.95       556

    accuracy                           0.97      1835
   macro avg       0.97      0.96      0.96      1835
weighted avg       0.97      0.97      0.97      1835

        TEST
```

```
              precision    recall  f1-score   support

       False       0.81      0.89      0.85       408
        True       0.68      0.52      0.59       182

    accuracy                           0.78       590
   macro avg       0.74      0.71      0.72       590
weighted avg       0.77      0.78      0.77       590

        Confusion Matrix
[[363  45]
 [ 87  95]]
----------------------------------------------------
violin
        TRAIN
              precision    recall  f1-score   support

       False       1.00      0.87      0.93       623
        True       0.90      1.00      0.95       779

    accuracy                           0.94      1402
   macro avg       0.95      0.93      0.94      1402
weighted avg       0.95      0.94      0.94      1402

        TEST
              precision    recall  f1-score   support

       False       0.86      0.71      0.78       237
        True       0.84      0.93      0.88       394

    accuracy                           0.85       631
   macro avg       0.85      0.82      0.83       631
weighted avg       0.85      0.85      0.84       631

        Confusion Matrix
[[168  69]
 [ 27 367]]
----------------------------------------------------
voice
        TRAIN
              precision    recall  f1-score   support

       False       1.00      0.91      0.95       426
        True       0.95      1.00      0.98       764

    accuracy                           0.97      1190
   macro avg       0.98      0.96      0.96      1190
weighted avg       0.97      0.97      0.97      1190
```

```
        TEST
              precision    recall  f1-score   support

       False       0.94      0.89      0.91       150
        True       0.93      0.96      0.94       224

    accuracy                           0.93       374
   macro avg       0.93      0.92      0.93       374
weighted avg       0.93      0.93      0.93       374

        Confusion Matrix
[[133  17]
 [  9 215]]
```

0.0.7 Logistic Regression

[43]:
```
for instrument in class_map:

    inst_num = class_map[instrument]

    train_inst = Y_mask_train[:, inst_num]
    test_inst = Y_mask_test[:, inst_num]

    X_train_inst = X_train[train_inst]

    X_train_inst_sklearn = np.mean(X_train_inst, axis=1)

    Y_true_train_inst = Y_true_train[train_inst, inst_num] >= 0.5

    X_test_inst = X_test[test_inst]
    X_test_inst_sklearn = np.mean(X_test_inst, axis=1)
    Y_true_test_inst = Y_true_test[test_inst, inst_num] >= 0.5

    clf = LogisticRegression(random_state=0, penalty='l1', solver = 'liblinear')

    clf.fit(X_train_inst_sklearn, Y_true_train_inst)

    # Evaluate the model on both train and test
    Y_pred_train = clf.predict(X_train_inst_sklearn)
    Y_pred_test = clf.predict(X_test_inst_sklearn)

    print('-' * 52)
    print(instrument)
    print('\tTRAIN')
    print(classification_report(Y_true_train_inst, Y_pred_train))
    print('\tTEST')
```

```python
print(classification_report(Y_true_test_inst, Y_pred_test))
```

```
---------------------------------------------------
accordion
        TRAIN
              precision    recall  f1-score   support

       False       0.88      0.94      0.91      1159
        True       0.75      0.61      0.67       374

    accuracy                           0.86      1533
   macro avg       0.82      0.77      0.79      1533
weighted avg       0.85      0.86      0.85      1533

        TEST
              precision    recall  f1-score   support

       False       0.85      0.89      0.87       423
        True       0.52      0.43      0.47       115

    accuracy                           0.79       538
   macro avg       0.68      0.66      0.67       538
weighted avg       0.78      0.79      0.78       538

---------------------------------------------------
banjo
        TRAIN
              precision    recall  f1-score   support

       False       0.87      0.89      0.88      1148
        True       0.77      0.74      0.75       592

    accuracy                           0.84      1740
   macro avg       0.82      0.81      0.81      1740
weighted avg       0.83      0.84      0.83      1740

        TEST
              precision    recall  f1-score   support

       False       0.83      0.83      0.83       338
        True       0.58      0.59      0.58       140

    accuracy                           0.76       478
   macro avg       0.70      0.71      0.71       478
weighted avg       0.76      0.76      0.76       478

---------------------------------------------------
bass
```

```
        TRAIN
              precision    recall  f1-score   support

       False       0.86      0.90      0.88      1010
        True       0.73      0.65      0.69       415

    accuracy                           0.83      1425
   macro avg       0.80      0.77      0.78      1425
weighted avg       0.82      0.83      0.82      1425

        TEST
              precision    recall  f1-score   support

       False       0.86      0.89      0.88       329
        True       0.71      0.66      0.68       134

    accuracy                           0.82       463
   macro avg       0.79      0.77      0.78       463
weighted avg       0.82      0.82      0.82       463

----------------------------------------------------
cello
        TRAIN
              precision    recall  f1-score   support

       False       0.85      0.85      0.85       866
        True       0.78      0.78      0.78       598

    accuracy                           0.82      1464
   macro avg       0.81      0.81      0.81      1464
weighted avg       0.82      0.82      0.82      1464

        TEST
              precision    recall  f1-score   support

       False       0.78      0.80      0.79       259
        True       0.76      0.75      0.75       226

    accuracy                           0.77       485
   macro avg       0.77      0.77      0.77       485
weighted avg       0.77      0.77      0.77       485

----------------------------------------------------
clarinet
        TRAIN
              precision    recall  f1-score   support

       False       0.83      0.94      0.88      1349
```

```
        True       0.64      0.36      0.46       396

    accuracy                           0.81      1745
   macro avg       0.74      0.65      0.67      1745
weighted avg       0.79      0.81      0.79      1745

        TEST
              precision    recall  f1-score   support

       False       0.83      0.90      0.87       503
        True       0.49      0.34      0.40       137

    accuracy                           0.78       640
   macro avg       0.66      0.62      0.63       640
weighted avg       0.76      0.78      0.77       640

----------------------------------------------------
cymbals
        TRAIN
              precision    recall  f1-score   support

       False       0.93      0.91      0.92       485
        True       0.94      0.96      0.95       814

    accuracy                           0.94      1299
   macro avg       0.94      0.93      0.94      1299
weighted avg       0.94      0.94      0.94      1299

        TEST
              precision    recall  f1-score   support

       False       0.90      0.86      0.88       139
        True       0.93      0.96      0.95       297

    accuracy                           0.92       436
   macro avg       0.92      0.91      0.91       436
weighted avg       0.92      0.92      0.92       436

----------------------------------------------------
drums
        TRAIN
              precision    recall  f1-score   support

       False       0.96      0.94      0.95       495
        True       0.96      0.98      0.97       828

    accuracy                           0.96      1323
   macro avg       0.96      0.96      0.96      1323
```

```
weighted avg       0.96      0.96      0.96      1323

        TEST
              precision    recall  f1-score   support

       False       0.86      0.79      0.82       146
        True       0.89      0.94      0.91       278

    accuracy                           0.88       424
   macro avg       0.88      0.86      0.87       424
weighted avg       0.88      0.88      0.88       424

----------------------------------------------------
flute
        TRAIN
              precision    recall  f1-score   support

       False       0.83      0.89      0.86      1050
        True       0.71      0.59      0.64       472

    accuracy                           0.80      1522
   macro avg       0.77      0.74      0.75      1522
weighted avg       0.79      0.80      0.79      1522

        TEST
              precision    recall  f1-score   support

       False       0.80      0.83      0.82       387
        True       0.59      0.54      0.57       175

    accuracy                           0.74       562
   macro avg       0.70      0.69      0.69       562
weighted avg       0.74      0.74      0.74       562

----------------------------------------------------
guitar
        TRAIN
              precision    recall  f1-score   support

       False       0.97      0.96      0.97       362
        True       0.98      0.99      0.99       852

    accuracy                           0.98      1214
   macro avg       0.98      0.98      0.98      1214
weighted avg       0.98      0.98      0.98      1214

        TEST
              precision    recall  f1-score   support
```

```
       False       0.90      0.85      0.87       150
        True       0.92      0.95      0.94       286

    accuracy                           0.92       436
   macro avg       0.91      0.90      0.90       436
weighted avg       0.91      0.92      0.91       436

----------------------------------------------------
mallet_percussion
        TRAIN
              precision    recall  f1-score   support

       False       0.87      0.87      0.87       802
        True       0.80      0.80      0.80       522

    accuracy                           0.84      1324
   macro avg       0.83      0.83      0.83      1324
weighted avg       0.84      0.84      0.84      1324

        TEST
              precision    recall  f1-score   support

       False       0.79      0.82      0.81       267
        True       0.76      0.72      0.74       211

    accuracy                           0.78       478
   macro avg       0.78      0.77      0.77       478
weighted avg       0.78      0.78      0.78       478

----------------------------------------------------
mandolin
        TRAIN
              precision    recall  f1-score   support

       False       0.83      0.86      0.85      1185
        True       0.73      0.68      0.70       652

    accuracy                           0.80      1837
   macro avg       0.78      0.77      0.77      1837
weighted avg       0.79      0.80      0.79      1837

        TEST
              precision    recall  f1-score   support

       False       0.83      0.81      0.82       434
        True       0.59      0.62      0.60       193
```

```
    accuracy                           0.75       627
   macro avg       0.71      0.71      0.71       627
weighted avg       0.75      0.75      0.75       627

----------------------------------------------------
organ
        TRAIN
              precision    recall  f1-score   support

       False       0.88      0.92      0.90       977
        True       0.83      0.74      0.78       482

    accuracy                           0.86      1459
   macro avg       0.85      0.83      0.84      1459
weighted avg       0.86      0.86      0.86      1459

        TEST
              precision    recall  f1-score   support

       False       0.79      0.88      0.84       310
        True       0.58      0.40      0.48       121

    accuracy                           0.75       431
   macro avg       0.68      0.64      0.66       431
weighted avg       0.73      0.75      0.73       431

----------------------------------------------------
piano
        TRAIN
              precision    recall  f1-score   support

       False       0.99      0.98      0.99       420
        True       0.99      1.00      0.99       885

    accuracy                           0.99      1305
   macro avg       0.99      0.99      0.99      1305
weighted avg       0.99      0.99      0.99      1305

        TEST
              precision    recall  f1-score   support

       False       0.86      0.82      0.84       130
        True       0.92      0.94      0.93       285

    accuracy                           0.90       415
   macro avg       0.89      0.88      0.89       415
weighted avg       0.90      0.90      0.90       415
```

```
----------------------------------------------------
saxophone
        TRAIN
              precision    recall  f1-score   support

       False       0.83      0.80      0.81       906
        True       0.79      0.82      0.80       830

    accuracy                           0.81      1736
   macro avg       0.81      0.81      0.81      1736
weighted avg       0.81      0.81      0.81      1736

        TEST
              precision    recall  f1-score   support

       False       0.83      0.79      0.81       324
        True       0.79      0.82      0.80       305

    accuracy                           0.81       629
   macro avg       0.81      0.81      0.81       629
weighted avg       0.81      0.81      0.81       629

----------------------------------------------------
synthesizer
        TRAIN
              precision    recall  f1-score   support

       False       0.96      0.94      0.95       399
        True       0.97      0.98      0.98       823

    accuracy                           0.97      1222
   macro avg       0.96      0.96      0.96      1222
weighted avg       0.97      0.97      0.97      1222

        TEST
              precision    recall  f1-score   support

       False       0.85      0.86      0.85       112
        True       0.94      0.94      0.94       268

    accuracy                           0.91       380
   macro avg       0.89      0.90      0.90       380
weighted avg       0.91      0.91      0.91       380

----------------------------------------------------
trombone
        TRAIN
              precision    recall  f1-score   support
```

```
       False       0.85      0.91      0.88      1405
        True       0.76      0.64      0.69       635

    accuracy                           0.82      2040
   macro avg       0.80      0.77      0.78      2040
weighted avg       0.82      0.82      0.82      2040

        TEST
              precision    recall  f1-score   support

       False       0.84      0.86      0.85       492
        True       0.69      0.66      0.67       228

    accuracy                           0.80       720
   macro avg       0.77      0.76      0.76       720
weighted avg       0.80      0.80      0.80       720

----------------------------------------------------
trumpet
        TRAIN
              precision    recall  f1-score   support

       False       0.84      0.86      0.85      1303
        True       0.77      0.74      0.76       828

    accuracy                           0.81      2131
   macro avg       0.81      0.80      0.80      2131
weighted avg       0.81      0.81      0.81      2131

        TEST
              precision    recall  f1-score   support

       False       0.81      0.84      0.82       467
        True       0.75      0.70      0.73       318

    accuracy                           0.79       785
   macro avg       0.78      0.77      0.78       785
weighted avg       0.78      0.79      0.78       785

----------------------------------------------------
ukulele
        TRAIN
              precision    recall  f1-score   support

       False       0.85      0.90      0.87      1279
        True       0.73      0.63      0.68       556
```

```
    accuracy                           0.82      1835
   macro avg       0.79      0.76      0.77      1835
weighted avg       0.81      0.82      0.81      1835

        TEST
              precision    recall  f1-score   support

       False       0.83      0.86      0.84       408
        True       0.65      0.59      0.62       182

    accuracy                           0.78       590
   macro avg       0.74      0.73      0.73       590
weighted avg       0.77      0.78      0.77       590

----------------------------------------------------
violin
        TRAIN
              precision    recall  f1-score   support

       False       0.89      0.80      0.84       623
        True       0.85      0.92      0.88       779

    accuracy                           0.87      1402
   macro avg       0.87      0.86      0.86      1402
weighted avg       0.87      0.87      0.87      1402

        TEST
              precision    recall  f1-score   support

       False       0.77      0.79      0.78       237
        True       0.87      0.86      0.86       394

    accuracy                           0.83       631
   macro avg       0.82      0.82      0.82       631
weighted avg       0.83      0.83      0.83       631

----------------------------------------------------
voice
        TRAIN
              precision    recall  f1-score   support

       False       0.96      0.93      0.94       426
        True       0.96      0.98      0.97       764

    accuracy                           0.96      1190
   macro avg       0.96      0.95      0.96      1190
weighted avg       0.96      0.96      0.96      1190
```

```
        TEST
              precision    recall  f1-score   support

       False       0.86      0.89      0.88       150
        True       0.93      0.90      0.91       224

    accuracy                           0.90       374
   macro avg       0.89      0.90      0.89       374
weighted avg       0.90      0.90      0.90       374
```

0.0.8 Neural Network

[72]:
```python
import warnings
warnings.filterwarnings('ignore')

for instrument in class_map:

    inst_num = class_map[instrument]

    train_inst = Y_mask_train[:, inst_num]
    test_inst = Y_mask_test[:, inst_num]

    X_train_inst = X_train[train_inst]

    X_train_inst_sklearn = np.mean(X_train_inst, axis=1)

    Y_true_train_inst = Y_true_train[train_inst, inst_num] >= 0.5

    X_test_inst = X_test[test_inst]
    X_test_inst_sklearn = np.mean(X_test_inst, axis=1)
    Y_true_test_inst = Y_true_test[test_inst, inst_num] >= 0.5

    clf = MLPClassifier(solver='lbfgs', alpha=1e-5, hidden_layer_sizes=(5,2),␣
 ↪max_iter=100, random_state=0)

    clf.fit(X_train_inst_sklearn, Y_true_train_inst)

    # Evaluate the model on both train and test
    Y_pred_train = clf.predict(X_train_inst_sklearn)
    Y_pred_test = clf.predict(X_test_inst_sklearn)

    print('-' * 52)
    print(instrument)
    print('\tTRAIN')
    print(classification_report(Y_true_train_inst, Y_pred_train))
    print('\tTEST')
```

```python
print(classification_report(Y_true_test_inst, Y_pred_test))
```

```
----------------------------------------------------
accordion
        TRAIN
              precision    recall  f1-score   support

       False       0.84      0.90      0.87      1159
        True       0.62      0.48      0.54       374

    accuracy                           0.80      1533
   macro avg       0.73      0.69      0.71      1533
weighted avg       0.79      0.80      0.79      1533

        TEST
              precision    recall  f1-score   support

       False       0.85      0.90      0.87       423
        True       0.53      0.42      0.47       115

    accuracy                           0.80       538
   macro avg       0.69      0.66      0.67       538
weighted avg       0.78      0.80      0.79       538

----------------------------------------------------
banjo
        TRAIN
              precision    recall  f1-score   support

       False       0.80      0.86      0.83      1148
        True       0.69      0.59      0.64       592

    accuracy                           0.77      1740
   macro avg       0.75      0.73      0.73      1740
weighted avg       0.76      0.77      0.76      1740

        TEST
              precision    recall  f1-score   support

       False       0.83      0.86      0.84       338
        True       0.62      0.57      0.60       140

    accuracy                           0.77       478
   macro avg       0.73      0.71      0.72       478
weighted avg       0.77      0.77      0.77       478

----------------------------------------------------
bass
```

```
        TRAIN
              precision    recall  f1-score   support

       False       0.85      0.89      0.87      1010
        True       0.70      0.61      0.65       415

    accuracy                           0.81      1425
   macro avg       0.77      0.75      0.76      1425
weighted avg       0.81      0.81      0.81      1425

        TEST
              precision    recall  f1-score   support

       False       0.84      0.90      0.87       329
        True       0.71      0.59      0.64       134

    accuracy                           0.81       463
   macro avg       0.77      0.74      0.76       463
weighted avg       0.80      0.81      0.80       463

----------------------------------------------------
cello
        TRAIN
              precision    recall  f1-score   support

       False       0.83      0.83      0.83       866
        True       0.75      0.76      0.76       598

    accuracy                           0.80      1464
   macro avg       0.79      0.79      0.79      1464
weighted avg       0.80      0.80      0.80      1464

        TEST
              precision    recall  f1-score   support

       False       0.80      0.80      0.80       259
        True       0.77      0.78      0.77       226

    accuracy                           0.79       485
   macro avg       0.79      0.79      0.79       485
weighted avg       0.79      0.79      0.79       485

----------------------------------------------------
clarinet
        TRAIN
              precision    recall  f1-score   support

       False       0.80      0.95      0.87      1349
```

```
        True       0.52      0.19      0.28       396

    accuracy                           0.78      1745
   macro avg       0.66      0.57      0.57      1745
weighted avg       0.74      0.78      0.73      1745

        TEST
              precision    recall  f1-score   support

       False       0.81      0.94      0.87       503
        True       0.49      0.20      0.28       137

    accuracy                           0.78       640
   macro avg       0.65      0.57      0.58       640
weighted avg       0.74      0.78      0.75       640

----------------------------------------------------
cymbals
        TRAIN
              precision    recall  f1-score   support

       False       0.97      0.83      0.90       485
        True       0.91      0.99      0.94       814

    accuracy                           0.93      1299
   macro avg       0.94      0.91      0.92      1299
weighted avg       0.93      0.93      0.93      1299

        TEST
              precision    recall  f1-score   support

       False       0.97      0.81      0.88       139
        True       0.92      0.99      0.95       297

    accuracy                           0.93       436
   macro avg       0.94      0.90      0.91       436
weighted avg       0.93      0.93      0.93       436

----------------------------------------------------
drums
        TRAIN
              precision    recall  f1-score   support

       False       0.94      0.89      0.91       495
        True       0.94      0.96      0.95       828

    accuracy                           0.94      1323
   macro avg       0.94      0.93      0.93      1323
```

```
weighted avg       0.94      0.94      0.94      1323

        TEST
              precision    recall  f1-score   support

       False       0.89      0.81      0.85       146
        True       0.90      0.95      0.93       278

    accuracy                           0.90       424
   macro avg       0.90      0.88      0.89       424
weighted avg       0.90      0.90      0.90       424

----------------------------------------------------
flute
        TRAIN
              precision    recall  f1-score   support

       False       0.76      0.87      0.81      1050
        True       0.56      0.38      0.45       472

    accuracy                           0.72      1522
   macro avg       0.66      0.62      0.63      1522
weighted avg       0.70      0.72      0.70      1522

        TEST
              precision    recall  f1-score   support

       False       0.76      0.85      0.80       387
        True       0.56      0.42      0.48       175

    accuracy                           0.72       562
   macro avg       0.66      0.63      0.64       562
weighted avg       0.70      0.72      0.70       562

----------------------------------------------------
guitar
        TRAIN
              precision    recall  f1-score   support

       False       0.95      0.92      0.93       362
        True       0.97      0.98      0.97       852

    accuracy                           0.96      1214
   macro avg       0.96      0.95      0.95      1214
weighted avg       0.96      0.96      0.96      1214

        TEST
              precision    recall  f1-score   support
```

	precision	recall	f1-score	support
False	0.95	0.95	0.95	150
True	0.98	0.98	0.98	286
accuracy			0.97	436
macro avg	0.96	0.96	0.96	436
weighted avg	0.97	0.97	0.97	436

----

mallet_percussion

TRAIN

	precision	recall	f1-score	support
False	0.61	1.00	0.75	802
True	0.00	0.00	0.00	522
accuracy			0.61	1324
macro avg	0.30	0.50	0.38	1324
weighted avg	0.37	0.61	0.46	1324

TEST

	precision	recall	f1-score	support
False	0.56	1.00	0.72	267
True	0.00	0.00	0.00	211
accuracy			0.56	478
macro avg	0.28	0.50	0.36	478
weighted avg	0.31	0.56	0.40	478

----

mandolin

TRAIN

	precision	recall	f1-score	support
False	0.80	0.84	0.82	1185
True	0.68	0.63	0.65	652
accuracy			0.76	1837
macro avg	0.74	0.73	0.74	1837
weighted avg	0.76	0.76	0.76	1837

TEST

	precision	recall	f1-score	support
False	0.81	0.82	0.81	434
True	0.58	0.58	0.58	193

```
    accuracy                           0.74       627
   macro avg       0.70      0.70      0.70       627
weighted avg       0.74      0.74      0.74       627

----------------------------------------------------
organ
        TRAIN
              precision    recall  f1-score   support

       False       0.84      0.91      0.88       977
        True       0.79      0.65      0.71       482

    accuracy                           0.83      1459
   macro avg       0.81      0.78      0.79      1459
weighted avg       0.82      0.83      0.82      1459

        TEST
              precision    recall  f1-score   support

       False       0.78      0.92      0.85       310
        True       0.64      0.35      0.45       121

    accuracy                           0.76       431
   macro avg       0.71      0.63      0.65       431
weighted avg       0.74      0.76      0.74       431

----------------------------------------------------
piano
        TRAIN
              precision    recall  f1-score   support

       False       0.95      0.93      0.94       420
        True       0.97      0.98      0.97       885

    accuracy                           0.96      1305
   macro avg       0.96      0.96      0.96      1305
weighted avg       0.96      0.96      0.96      1305

        TEST
              precision    recall  f1-score   support

       False       0.93      0.85      0.89       130
        True       0.94      0.97      0.95       285

    accuracy                           0.93       415
   macro avg       0.93      0.91      0.92       415
weighted avg       0.93      0.93      0.93       415
```

```
---------------------------------------------------
saxophone
        TRAIN
              precision    recall  f1-score   support

       False       0.79      0.78      0.79       906
        True       0.76      0.78      0.77       830

    accuracy                           0.78      1736
   macro avg       0.78      0.78      0.78      1736
weighted avg       0.78      0.78      0.78      1736

        TEST
              precision    recall  f1-score   support

       False       0.82      0.80      0.81       324
        True       0.79      0.82      0.81       305

    accuracy                           0.81       629
   macro avg       0.81      0.81      0.81       629
weighted avg       0.81      0.81      0.81       629

---------------------------------------------------
synthesizer
        TRAIN
              precision    recall  f1-score   support

       False       0.94      0.91      0.92       399
        True       0.96      0.97      0.96       823

    accuracy                           0.95      1222
   macro avg       0.95      0.94      0.94      1222
weighted avg       0.95      0.95      0.95      1222

        TEST
              precision    recall  f1-score   support

       False       0.92      0.88      0.90       112
        True       0.95      0.97      0.96       268

    accuracy                           0.94       380
   macro avg       0.94      0.92      0.93       380
weighted avg       0.94      0.94      0.94       380

---------------------------------------------------
trombone
        TRAIN
              precision    recall  f1-score   support
```

```
       False       0.69      1.00      0.82      1405
        True       0.93      0.02      0.04       635

    accuracy                           0.69      2040
   macro avg       0.81      0.51      0.43      2040
weighted avg       0.77      0.69      0.58      2040

        TEST
              precision    recall  f1-score   support

       False       0.69      1.00      0.82       492
        True       1.00      0.02      0.04       228

    accuracy                           0.69       720
   macro avg       0.84      0.51      0.43       720
weighted avg       0.79      0.69      0.57       720

----------------------------------------------------
trumpet
        TRAIN
              precision    recall  f1-score   support

       False       0.80      0.85      0.83      1303
        True       0.74      0.67      0.70       828

    accuracy                           0.78      2131
   macro avg       0.77      0.76      0.76      2131
weighted avg       0.78      0.78      0.78      2131

        TEST
              precision    recall  f1-score   support

       False       0.78      0.85      0.81       467
        True       0.74      0.64      0.69       318

    accuracy                           0.77       785
   macro avg       0.76      0.75      0.75       785
weighted avg       0.76      0.77      0.76       785

----------------------------------------------------
ukulele
        TRAIN
              precision    recall  f1-score   support

       False       0.81      0.86      0.83      1279
        True       0.62      0.54      0.58       556
```

```
    accuracy                           0.76      1835
   macro avg       0.72      0.70      0.71      1835
weighted avg       0.75      0.76      0.76      1835

        TEST
              precision    recall  f1-score   support

       False       0.81      0.86      0.84       408
        True       0.64      0.54      0.59       182

    accuracy                           0.76       590
   macro avg       0.72      0.70      0.71       590
weighted avg       0.76      0.76      0.76       590

----------------------------------------------------
violin
        TRAIN
              precision    recall  f1-score   support

       False       0.85      0.74      0.79       623
        True       0.81      0.89      0.85       779

    accuracy                           0.83      1402
   macro avg       0.83      0.82      0.82      1402
weighted avg       0.83      0.83      0.83      1402

        TEST
              precision    recall  f1-score   support

       False       0.77      0.76      0.76       237
        True       0.86      0.86      0.86       394

    accuracy                           0.82       631
   macro avg       0.81      0.81      0.81       631
weighted avg       0.82      0.82      0.82       631

----------------------------------------------------
voice
        TRAIN
              precision    recall  f1-score   support

       False       0.96      0.86      0.91       426
        True       0.93      0.98      0.95       764

    accuracy                           0.94      1190
   macro avg       0.94      0.92      0.93      1190
weighted avg       0.94      0.94      0.94      1190
```

```
        TEST
              precision    recall  f1-score   support

       False       0.92      0.88      0.90       150
        True       0.92      0.95      0.93       224

    accuracy                           0.92       374
   macro avg       0.92      0.91      0.92       374
weighted avg       0.92      0.92      0.92       374
```

0.0.9 Support Vector Machine

[13]:
```
from sklearn.pipeline import make_pipeline
from sklearn.preprocessing import StandardScaler
from sklearn.datasets import make_classification
from sklearn.ensemble import RandomForestClassifier
from sklearn.ensemble import VotingClassifier
from sklearn.tree import DecisionTreeClassifier
from sklearn.neighbors import KNeighborsClassifier
from sklearn.svm import SVC
from itertools import product

# This dictionary will include the classifiers for each model
models = dict()

# We'll iterate over all istrument classes, and fit a model for each one
# After training, we'll print a classification report for each instrument
for instrument in class_map:

    # Map the instrument name to its column number
    inst_num = class_map[instrument]

    # Step 1: sub-sample the data

    # First, we need to select down to the data for which we have annotations
    # This is what the mask arrays are for
    train_inst = Y_mask_train[:, inst_num]
    test_inst = Y_mask_test[:, inst_num]

    # Here, we're using the Y_mask_train array to slice out only the training␣
↪examples
    # for which we have annotations for the given class
    X_train_inst = X_train[train_inst]

    # Step 3: simplify the data by averaging over time
```

```python
    # Let's arrange the data for a sklearn Random Forest model
    # Instead of having time-varying features, we'll summarize each track by␣
↪its mean feature vector over time
    X_train_inst_sklearn = np.mean(X_train_inst, axis=1)

    # Again, we slice the labels to the annotated examples
    # We thresold the label likelihoods at 0.5 to get binary labels
    Y_true_train_inst = Y_true_train[train_inst, inst_num] >= 0.5


    # Repeat the above slicing and dicing but for the test set
    X_test_inst = X_test[test_inst]
    X_test_inst_sklearn = np.mean(X_test_inst, axis=1)
    Y_true_test_inst = Y_true_test[test_inst, inst_num] >= 0.5

    # Step 3.
    # Initialize a new classifier
    clf = make_pipeline(StandardScaler(),␣
↪SVC(gamma='auto',kernel='poly',degree=2))

    # Step 4.
    clf.fit(X_train_inst_sklearn, Y_true_train_inst)

    # Step 5.
    # Finally, we'll evaluate the model on both train and test
    Y_pred_train = clf.predict(X_train_inst_sklearn)
    Y_pred_test = clf.predict(X_test_inst_sklearn)

    print('-' * 52)
    print(instrument)
    print('\tTRAIN')
    print(classification_report(Y_true_train_inst, Y_pred_train))
    print('\tTEST')
    print(classification_report(Y_true_test_inst, Y_pred_test))

    # Store the classifier in our dictionary
    models[instrument] = clf
```

```
----------------------------------------------------
accordion
        TRAIN
              precision    recall  f1-score   support

       False       0.84      0.99      0.91      1159
        True       0.91      0.43      0.58       374

    accuracy                           0.85      1533
```

```
   macro avg       0.88      0.71      0.75      1533
weighted avg       0.86      0.85      0.83      1533

        TEST
              precision    recall  f1-score   support

       False       0.83      0.98      0.90       423
        True       0.79      0.27      0.40       115

    accuracy                           0.83       538
   macro avg       0.81      0.63      0.65       538
weighted avg       0.82      0.83      0.79       538

----------------------------------------------------
banjo
        TRAIN
              precision    recall  f1-score   support

       False       0.81      0.96      0.88      1148
        True       0.89      0.57      0.70       592

    accuracy                           0.83      1740
   macro avg       0.85      0.77      0.79      1740
weighted avg       0.84      0.83      0.82      1740

        TEST
              precision    recall  f1-score   support

       False       0.79      0.93      0.85       338
        True       0.70      0.41      0.52       140

    accuracy                           0.78       478
   macro avg       0.75      0.67      0.69       478
weighted avg       0.77      0.78      0.76       478

----------------------------------------------------
bass
        TRAIN
              precision    recall  f1-score   support

       False       0.81      0.98      0.89      1010
        True       0.92      0.45      0.60       415

    accuracy                           0.83      1425
   macro avg       0.87      0.71      0.75      1425
weighted avg       0.84      0.83      0.81      1425

        TEST
```

```
              precision    recall  f1-score   support

       False       0.79      0.97      0.87       329
        True       0.84      0.36      0.50       134

    accuracy                           0.79       463
   macro avg       0.82      0.67      0.69       463
weighted avg       0.80      0.79      0.76       463

----------------------------------------------------
cello
        TRAIN
              precision    recall  f1-score   support

       False       0.83      0.90      0.87       866
        True       0.84      0.74      0.79       598

    accuracy                           0.84      1464
   macro avg       0.84      0.82      0.83      1464
weighted avg       0.84      0.84      0.83      1464

        TEST
              precision    recall  f1-score   support

       False       0.73      0.80      0.76       259
        True       0.74      0.65      0.69       226

    accuracy                           0.73       485
   macro avg       0.73      0.73      0.73       485
weighted avg       0.73      0.73      0.73       485

----------------------------------------------------
clarinet
        TRAIN
              precision    recall  f1-score   support

       False       0.81      1.00      0.89      1349
        True       0.96      0.19      0.31       396

    accuracy                           0.81      1745
   macro avg       0.88      0.59      0.60      1745
weighted avg       0.84      0.81      0.76      1745

        TEST
              precision    recall  f1-score   support

       False       0.79      0.98      0.88       503
        True       0.47      0.07      0.12       137
```

```
    accuracy                           0.78       640
   macro avg       0.63      0.52      0.50       640
weighted avg       0.73      0.78      0.71       640

----------------------------------------------------
cymbals
        TRAIN
              precision    recall  f1-score   support

       False       0.99      0.83      0.90       485
        True       0.91      0.99      0.95       814

    accuracy                           0.93      1299
   macro avg       0.95      0.91      0.93      1299
weighted avg       0.94      0.93      0.93      1299

        TEST
              precision    recall  f1-score   support

       False       0.97      0.81      0.88       139
        True       0.92      0.99      0.95       297

    accuracy                           0.93       436
   macro avg       0.94      0.90      0.92       436
weighted avg       0.93      0.93      0.93       436

----------------------------------------------------
drums
        TRAIN
              precision    recall  f1-score   support

       False       1.00      0.89      0.94       495
        True       0.94      1.00      0.97       828

    accuracy                           0.96      1323
   macro avg       0.97      0.95      0.96      1323
weighted avg       0.96      0.96      0.96      1323

        TEST
              precision    recall  f1-score   support

       False       0.93      0.78      0.85       146
        True       0.89      0.97      0.93       278

    accuracy                           0.90       424
   macro avg       0.91      0.87      0.89       424
weighted avg       0.91      0.90      0.90       424
```

```
----------------------------------------------------
flute
        TRAIN
              precision    recall  f1-score   support

       False       0.80      0.98      0.88      1050
        True       0.91      0.45      0.60       472

    accuracy                           0.82      1522
   macro avg       0.85      0.72      0.74      1522
weighted avg       0.83      0.82      0.79      1522

        TEST
              precision    recall  f1-score   support

       False       0.74      0.93      0.83       387
        True       0.66      0.29      0.40       175

    accuracy                           0.73       562
   macro avg       0.70      0.61      0.61       562
weighted avg       0.72      0.73      0.69       562

----------------------------------------------------
guitar
        TRAIN
              precision    recall  f1-score   support

       False       0.98      0.93      0.95       362
        True       0.97      0.99      0.98       852

    accuracy                           0.97      1214
   macro avg       0.97      0.96      0.97      1214
weighted avg       0.97      0.97      0.97      1214

        TEST
              precision    recall  f1-score   support

       False       0.96      0.89      0.92       150
        True       0.94      0.98      0.96       286

    accuracy                           0.95       436
   macro avg       0.95      0.93      0.94       436
weighted avg       0.95      0.95      0.95       436

----------------------------------------------------
mallet_percussion
        TRAIN
```

```
              precision    recall  f1-score   support

       False       0.92      0.88      0.90       802
        True       0.83      0.89      0.86       522

    accuracy                           0.88      1324
   macro avg       0.87      0.88      0.88      1324
weighted avg       0.88      0.88      0.88      1324

        TEST
              precision    recall  f1-score   support

       False       0.80      0.75      0.77       267
        True       0.70      0.76      0.73       211

    accuracy                           0.75       478
   macro avg       0.75      0.75      0.75       478
weighted avg       0.75      0.75      0.75       478

----------------------------------------------------
mandolin
        TRAIN
              precision    recall  f1-score   support

       False       0.77      0.95      0.85      1185
        True       0.85      0.49      0.62       652

    accuracy                           0.79      1837
   macro avg       0.81      0.72      0.74      1837
weighted avg       0.80      0.79      0.77      1837

        TEST
              precision    recall  f1-score   support

       False       0.77      0.90      0.83       434
        True       0.64      0.40      0.49       193

    accuracy                           0.74       627
   macro avg       0.70      0.65      0.66       627
weighted avg       0.73      0.74      0.73       627

----------------------------------------------------
organ
        TRAIN
              precision    recall  f1-score   support

       False       0.82      0.99      0.89       977
        True       0.95      0.56      0.70       482
```

```
    accuracy                           0.84      1459
   macro avg       0.88      0.77      0.80      1459
weighted avg       0.86      0.84      0.83      1459

        TEST
              precision    recall  f1-score   support

       False       0.75      0.97      0.84       310
        True       0.69      0.15      0.24       121

    accuracy                           0.74       431
   macro avg       0.72      0.56      0.54       431
weighted avg       0.73      0.74      0.68       431

-----------------------------------------------------
piano
        TRAIN
              precision    recall  f1-score   support

       False       0.98      0.94      0.96       420
        True       0.97      0.99      0.98       885

    accuracy                           0.98      1305
   macro avg       0.98      0.97      0.97      1305
weighted avg       0.98      0.98      0.98      1305

        TEST
              precision    recall  f1-score   support

       False       0.97      0.82      0.89       130
        True       0.92      0.99      0.96       285

    accuracy                           0.94       415
   macro avg       0.95      0.91      0.92       415
weighted avg       0.94      0.94      0.94       415

-----------------------------------------------------
saxophone
        TRAIN
              precision    recall  f1-score   support

       False       0.92      0.79      0.85       906
        True       0.80      0.93      0.86       830

    accuracy                           0.85      1736
   macro avg       0.86      0.86      0.85      1736
weighted avg       0.86      0.85      0.85      1736
```

```
        TEST
              precision    recall  f1-score   support

       False       0.86      0.69      0.76       324
        True       0.73      0.89      0.80       305

    accuracy                           0.78       629
   macro avg       0.79      0.79      0.78       629
weighted avg       0.80      0.78      0.78       629

----------------------------------------------------
synthesizer
        TRAIN
              precision    recall  f1-score   support

       False       0.97      0.93      0.95       399
        True       0.97      0.99      0.98       823

    accuracy                           0.97      1222
   macro avg       0.97      0.96      0.96      1222
weighted avg       0.97      0.97      0.97      1222

        TEST
              precision    recall  f1-score   support

       False       0.95      0.88      0.92       112
        True       0.95      0.98      0.97       268

    accuracy                           0.95       380
   macro avg       0.95      0.93      0.94       380
weighted avg       0.95      0.95      0.95       380

----------------------------------------------------
trombone
        TRAIN
              precision    recall  f1-score   support

       False       0.82      0.98      0.89      1405
        True       0.91      0.52      0.67       635

    accuracy                           0.84      2040
   macro avg       0.86      0.75      0.78      2040
weighted avg       0.85      0.84      0.82      2040

        TEST
              precision    recall  f1-score   support
```

```
       False       0.80      0.94      0.87       492
        True       0.79      0.51      0.62       228

    accuracy                           0.80       720
   macro avg       0.80      0.72      0.74       720
weighted avg       0.80      0.80      0.79       720

----------------------------------------------------
trumpet
        TRAIN
              precision    recall  f1-score   support

       False       0.85      0.94      0.89      1303
        True       0.88      0.73      0.80       828

    accuracy                           0.86      2131
   macro avg       0.86      0.83      0.84      2131
weighted avg       0.86      0.86      0.85      2131

        TEST
              precision    recall  f1-score   support

       False       0.75      0.84      0.79       467
        True       0.71      0.58      0.64       318

    accuracy                           0.73       785
   macro avg       0.73      0.71      0.71       785
weighted avg       0.73      0.73      0.73       785

----------------------------------------------------
ukulele
        TRAIN
              precision    recall  f1-score   support

       False       0.80      0.96      0.87      1279
        True       0.84      0.46      0.59       556

    accuracy                           0.81      1835
   macro avg       0.82      0.71      0.73      1835
weighted avg       0.81      0.81      0.79      1835

        TEST
              precision    recall  f1-score   support

       False       0.77      0.95      0.85       408
        True       0.75      0.37      0.49       182

    accuracy                           0.77       590
```

```
   macro avg       0.76      0.66      0.67       590
weighted avg       0.77      0.77      0.74       590

----------------------------------------------------
violin
        TRAIN
              precision    recall  f1-score   support

       False       0.99      0.66      0.79       623
        True       0.79      1.00      0.88       779

    accuracy                           0.85      1402
   macro avg       0.89      0.83      0.84      1402
weighted avg       0.88      0.85      0.84      1402

        TEST
              precision    recall  f1-score   support

       False       0.93      0.62      0.75       237
        True       0.81      0.97      0.88       394

    accuracy                           0.84       631
   macro avg       0.87      0.80      0.82       631
weighted avg       0.86      0.84      0.83       631

----------------------------------------------------
voice
        TRAIN
              precision    recall  f1-score   support

       False       0.99      0.85      0.92       426
        True       0.92      1.00      0.96       764

    accuracy                           0.95      1190
   macro avg       0.96      0.93      0.94      1190
weighted avg       0.95      0.95      0.94      1190

        TEST
              precision    recall  f1-score   support

       False       0.96      0.86      0.91       150
        True       0.91      0.98      0.94       224

    accuracy                           0.93       374
   macro avg       0.94      0.92      0.93       374
weighted avg       0.93      0.93      0.93       374
```

[ ]:

```

```