P3

November 15, 2021

[1]:
```
import os
import pandas as pd

print("Loadind Dataset: gestures")
path = 'gestures-dataset'

dataset = None
dataset_idx = None
samples = 0
for subject in os.listdir(path):
    if os.path.isfile(os.path.join(path, subject)):
        continue
    if subject in ('U01', 'U02', 'U03', 'U04', 'U05', 'U06', 'U07', 'U08'):
        for gesture in os.listdir(os.path.join(path, subject)):
            if os.path.isfile(os.path.join(path, subject, gesture)):
                continue
            gesture = str(gesture)
            #if gesture not in gesture_subset:
            #    continue
            for samplefile in os.listdir(os.path.join(path, subject, gesture)):
                if os.path.isfile(os.path.join(path, subject, gesture,␣
 ↪samplefile)):
                    df = pd.read_csv(os.path.join(path, subject, gesture,␣
 ↪samplefile), \
                        sep = ' ', \
                        names = ['System.currentTimeMillis()', \
                        'System.nanoTime()', \
                        'sample.timestamp', \
                        'X', \
                        'Y', \
                        'Z' \
                        ])
                    df = df[["sample.timestamp", "X", "Y", "Z"]]

                    start = df["sample.timestamp"][0]
                    df["sample.timestamp"] -= start
                    df["sample.timestamp"] /= 10000000
```

```
                    df["subject"] = subject
                    df["gesture"] = gesture
                    df["sample"] = str(samplefile[:-4])
                    #print(df)
                    if dataset is None:
                        dataset = df.copy()
                    else:
                        dataset = pd.concat([dataset, df])

                    df_idx_sample = pd.DataFrame()
                    df_idx_sample = df_idx_sample.append({'subject':subject,␣
 ↪'gesture': gesture, 'sample': str(samplefile[:-4])}, ignore_index = True)
                    if dataset_idx is None:
                        dataset_idx = df_idx_sample.copy()
                    else:
                        dataset_idx = pd.concat([dataset_idx, df_idx_sample])
                    samples += 1

dataset = dataset.sort_values(by=['gesture','subject','sample','sample.
 ↪timestamp'])
dataset_idx = dataset_idx.sort_values(by=['gesture','subject','sample'])
data = dataset
print(str(samples) + " samples loaded")

print("Scaling Dataset: gestures")
from sklearn.preprocessing import StandardScaler

scaler = StandardScaler()
dataset_scaled = None
samples = 0
#for i, gesture in enumerate(gesture_subset):
for i, gesture in enumerate(['01', '02', '03', '04', '05', '06', '07', '08',␣
 ↪'09', '10', '11', '12', '13', '14', '15', '16', '17', '18', '19', '20']):
    df_gesture=data[data['gesture']==gesture]
    for j, subject in enumerate(df_gesture['subject'].unique()):
        df_subject=df_gesture[df_gesture['subject']==subject]
        for k, sample in enumerate(df_subject['sample'].unique()):
            df_sample=df_subject[df_subject['sample']==sample].copy()
            df_sample.sort_values(by=['sample.timestamp'])

            sc = scaler
            sc = sc.fit_transform(df_sample[["X", "Y", "Z"]])
            sc = pd.DataFrame(data=sc, columns=["X", "Y", "Z"])
            df_sample['X'] = sc['X']
            df_sample['Y'] = sc['Y']
            df_sample['Z'] = sc['Z']
            if dataset_scaled is None:
```

```
                dataset_scaled = df_sample.copy()
            else:
                dataset_scaled = pd.concat([dataset_scaled, df_sample])
            samples += 1
print(str(samples) + " samples scaled")
data = dataset_scaled
```

```
Loadind Dataset: gestures
3251 samples loaded
Scaling Dataset: gestures
3251 samples scaled
```

[2]:
```
import tsfel

cfg_file = tsfel.get_features_by_domain(domain=None, json_path="features.json")
#cfg_file = tsfel.get_features_by_domain("statistical")
#cfg_file = tsfel.get_features_by_domain("temporal")
#cgf_file = tsfel.get_features_by_domain("spectral")
curr = 127
print("Extracting All Features as describe in features.json, total of 381, 127␣
 ↪per axis: dataset_scaled")
data = dataset_scaled
print("Set: " + str(len(data.index)) + " measurements")
dataset_features = None
samples = 0
for i, gesture in enumerate(data['gesture'].unique()):
    df_gesture = data[data['gesture']==gesture]
    for j, subject in enumerate(df_gesture['subject'].unique()):
        df_subject = df_gesture[df_gesture['subject']==subject]
        for k, sample in enumerate(df_subject['sample'].unique()):
            df_sample = df_subject[df_subject['sample']==sample]
            df_sample.sort_values(by=['sample.timestamp'])

            df_feature = pd.DataFrame(columns = ["gesture","subject", "sample",␣
 ↪"features"])
            #print(df_sample["Y"].size)
            features = {}
            features['X'] =  tsfel.time_series_features_extractor(cfg_file,␣
 ↪df_sample["X"], fs=209, verbose=0)
            features['Y'] =  tsfel.time_series_features_extractor(cfg_file,␣
 ↪df_sample["Y"], fs=209, verbose=0)
            features['Z'] =  tsfel.time_series_features_extractor(cfg_file,␣
 ↪df_sample["Z"], fs=209, verbose=0)
            adj = features['X'].columns.size - 127
            if adj > 0:
                for a in range(adj):
```

```
                    features['X'] = features['X'].drop(labels = ["0_FFT mean␣
↪coefficient_" + str(6+a)], axis = 1)
            if features['X'].columns.size != curr:
                curr = features['X'].columns.size
                print(curr)
                for tmp in features['X'].columns:
                    print(tmp)
            adj = features['Y'].columns.size - 127
            if adj > 0:
                for a in range(adj):
                    features['Y'] = features['Y'].drop(labels = ["0_FFT mean␣
↪coefficient_" + str(6+a)], axis = 1)
            if features['Y'].columns.size != curr:
                curr = features['Y'].columns.size
                print(curr)
                for tmp in features['Y'].columns:
                    print(tmp)
            adj = features['Z'].columns.size - 127
            if adj > 0:
                for a in range(adj):
                    features['Z'] = features['Z'].drop(labels = ["0_FFT mean␣
↪coefficient_" + str(6+a)], axis = 1)
            if features['Z'].columns.size != curr:
                curr = features['Z'].columns.size
                print(curr)
                for tmp in features['Z'].columns:
                    print(tmp)
            df_feature = df_feature.append({ \
                                        'gesture' : gesture, 'subject' :␣
↪subject, 'sample' : sample, \
                                        'features': features
                                       }, \
                                       ignore_index=True)
            if dataset_features is None:
                dataset_features = df_feature.copy()
            else:
                dataset_features = pd.concat([dataset_features, df_feature],␣
↪ignore_index=True)
            samples += 1
#print(dataset_features.head(10))
#print(dataset_features.tail(10))
print("Features extracted from " + str(samples) + " samples")
dataset_scaled_features = dataset_features
```

```
Extracting All Features as describe in features.json, total of 381, 127 per
axis: dataset_scaled
Set: 64070 measurements
```

```
Features extracted from 3251 samples
```

[3]:
```
list = dataset_scaled_features['features'][0]['X'].values.
 ↪tolist()[0]+dataset_scaled_features['features'][0]['Y'].values.
 ↪tolist()[0]+dataset_scaled_features['features'][0]['Z'].values.tolist()[0]
print(type(list))
print(len(list))
```

```
<class 'list'>
381
```

[4]:
```
print("Segregating outliers for testing separately: gestures")
data = dataset_scaled
dataset_outliers = None
dataset_outliers_idx = None
dataset_cleaned = None
dataset_cleaned_idx = None

samples = 0
outliers = 0
#for i, gesture in enumerate(gesture_subset):
for i, gesture in enumerate(['01', '02', '03', '04', '05', '06', '07', '08',␣
 ↪'09', '10', '11', '12', '13', '14', '15', '16', '17', '18', '19', '20']):
    df_gesture = data[data['gesture']==gesture]
    for j, subject in enumerate(df_gesture['subject'].unique()):
        df_subject = df_gesture[df_gesture['subject']==subject]

        time_mean = df_subject.groupby(["gesture","subject", "sample"]).count().
 ↪groupby(["gesture","subject"]).agg({'sample.timestamp': ['mean']})
        time_std = df_subject.groupby(["gesture","subject", "sample"]).count().
 ↪groupby(["gesture","subject"]).agg({'sample.timestamp': ['std']})
        time_max = time_mean['sample.timestamp'].iloc[0]['mean'] + 1.0 *␣
 ↪time_std['sample.timestamp'].iloc[0]['std']
        time_min = time_mean['sample.timestamp'].iloc[0]['mean'] - 1.0 *␣
 ↪time_std['sample.timestamp'].iloc[0]['std']
        for k, sample in enumerate(df_subject['sample'].unique()):
            df_sample=df_subject[df_subject['sample']==sample]
            df_sample_count = df_sample.count()['sample.timestamp']
            if df_sample_count < time_min or df_sample_count > time_max:
                if dataset_outliers is None:
                    dataset_outliers = df_sample.copy()
                else:
                    dataset_outliers = pd.concat([dataset_outliers, df_sample])
                df_idx_sample = pd.DataFrame()
                df_idx_sample = df_idx_sample.append({'subject':subject,␣
 ↪'gesture': gesture, 'sample': sample}, ignore_index = True)
                if dataset_outliers_idx is None:
```

```
                    dataset_outliers_idx = df_idx_sample.copy()
                else:
                    dataset_outliers_idx = pd.concat([dataset_outliers_idx,␣
↪df_idx_sample])
                outliers += 1
            else:
                if dataset_cleaned is None:
                    dataset_cleaned = df_sample.copy()
                else:
                    dataset_cleaned = pd.concat([dataset_cleaned, df_sample])
                df_idx_sample = pd.DataFrame()
                df_idx_sample = df_idx_sample.append({'subject':subject,␣
↪'gesture': gesture, 'sample': sample}, ignore_index = True)
                if dataset_cleaned_idx is None:
                    dataset_cleaned_idx = df_idx_sample.copy()
                else:
                    dataset_cleaned_idx = pd.concat([dataset_cleaned_idx,␣
↪df_idx_sample])
                samples += 1
print(str(samples) + " samples cleaned")
print(str(outliers) + " samples outliers")
data = dataset_cleaned
```

```
Segregating outliers for testing separately: gestures
2479 samples cleaned
772 samples outliers
```

[5]:
```
print("Segregating a stratified test set in addition to outliers: gestures")
from sklearn.model_selection import train_test_split
data = dataset_cleaned_idx
train, test = train_test_split(data, test_size=0.15, train_size=0.85,␣
↪random_state=1000, shuffle=True, stratify=data['gesture'])
print("Training set: " + str(len(train.index)) + " samples")
print("Test set: " + str(len(test.index)) + " samples")
```

```
Segregating a stratified test set in addition to outliers: gestures
Training set: 2107 samples
Test set: 372 samples
```

[6]:
```
print("Filling training samples with measurement data")
data = dataset_cleaned
dataset_cleaned_train = None
samples = 0
for tmp in train.iterrows():
    df = data[data['gesture'] == tmp[1]['gesture']]
    df = df[df['subject'] == tmp[1]['subject']]
    df = df[df['sample'] == tmp[1]['sample']]
    if dataset_cleaned_train is None:
```

```
        dataset_cleaned_train = df.copy()
    else:
        dataset_cleaned_train = pd.concat([dataset_cleaned_train, df])
    samples += 1
print(str(samples) + " training samples filled")

print("Filling test samples with measurement data")
data = dataset_cleaned
dataset_cleaned_test = None
samples = 0
for tmp in test.iterrows():
    df = data[data['gesture'] == tmp[1]['gesture']]
    df = df[df['subject'] == tmp[1]['subject']]
    df = df[df['sample'] == tmp[1]['sample']]
    if dataset_cleaned_test is None:
        dataset_cleaned_test = df.copy()
    else:
        dataset_cleaned_test = pd.concat([dataset_cleaned_test, df])
    samples += 1
print(str(samples) + " test samples filled")
```

```
Filling training samples with measurement data
2107 training samples filled
Filling test samples with measurement data
372 test samples filled
```

[7]:
```
print("Filling training samples with features data")
data = dataset_scaled_features
dataset_cleaned_train_features = None
samples = 0
for tmp in train.iterrows():
    df = data[data['gesture'] == tmp[1]['gesture']]
    df = df[df['subject'] == tmp[1]['subject']]
    df = df[df['sample'] == tmp[1]['sample']]
    if dataset_cleaned_train_features is None:
        dataset_cleaned_train_features = df.copy()
    else:
        dataset_cleaned_train_features = pd.
 ↪concat([dataset_cleaned_train_features, df])
    samples += 1
print(str(samples) + " training samples filled")

print("Filling test samples with feature data")
data = dataset_scaled_features
dataset_cleaned_test_features = None
samples = 0
for tmp in test.iterrows():
```

```
    df = data[data['gesture'] == tmp[1]['gesture']]
    df = df[df['subject'] == tmp[1]['subject']]
    df = df[df['sample'] == tmp[1]['sample']]
    if dataset_cleaned_test_features is None:
        dataset_cleaned_test_features = df.copy()
    else:
        dataset_cleaned_test_features = pd.
 ↪concat([dataset_cleaned_test_features, df])
    samples += 1
print(str(samples) + " test samples filled")

print("Filling outliers samples with feature data")
data = dataset_scaled_features
dataset_outliers_features = None
samples = 0
for tmp in dataset_outliers_idx.iterrows():
    df = data[data['gesture'] == tmp[1]['gesture']]
    df = df[df['subject'] == tmp[1]['subject']]
    df = df[df['sample'] == tmp[1]['sample']]
    if dataset_cleaned_test_features is None:
        dataset_outliers_features = df.copy()
    else:
        dataset_outliers_features = pd.concat([dataset_outliers_features, df])
    samples += 1
print(str(samples) + " outliers samples filled")
```

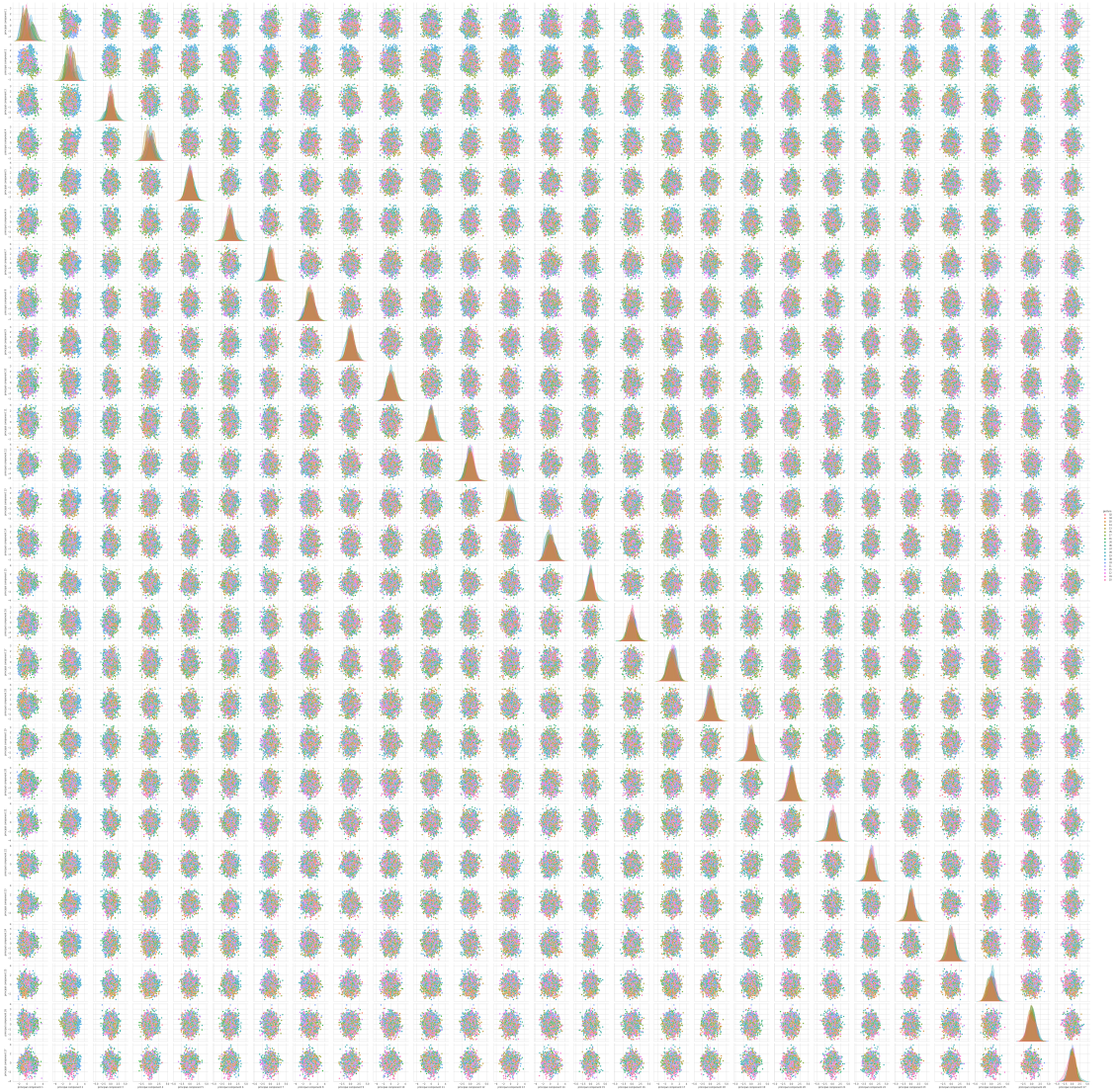
```
Filling training samples with features data
2107 training samples filled
Filling test samples with feature data
372 test samples filled
Filling outliers samples with feature data
772 outliers samples filled
```

[8]:
```
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
from sklearn.decomposition import PCA
%matplotlib inline


data = dataset_cleaned_train_features
work = data.copy()
train_targets = pd.DataFrame(work[["gesture","subject","sample"]],␣
 ↪columns=["gesture","subject","sample"])
train_targets.reset_index(inplace=True, drop=True)
target_for_plot = pd.DataFrame(work[["gesture"]], columns=["gesture"])
target_for_plot.reset_index(inplace=True, drop=True)
```

```
work = work.drop(labels = ["gesture","subject", "sample"], axis = 1)
work = work.reset_index(inplace=False, drop=True)
workArray = []
for tmp in work.values:
    tmpList = tmp[0]['X'].values.tolist()[0]+tmp[0]['Y'].values.
 ↪tolist()[0]+tmp[0]['Z'].values.tolist()[0]
    workArray.append(tmpList)

#pca = PCA(n_components=3)
pca = PCA(.95, svd_solver='full', whiten=True)
principalComponents = pca.fit_transform(np.array(workArray))
print(pca.n_features_)
print(pca.n_samples_)
print(pca.n_components_)
print(pca.noise_variance_)

columns = []
for i in range(pca.n_components_):
    columns.append("principal component "+str(i+1))
train_features_pca = pd.DataFrame(data = principalComponents, columns = columns)
train_features_pca = pd.concat([train_features_pca, train_targets], axis = 1)
features_pca_for_plot = pd.DataFrame(data = principalComponents, columns =␣
 ↪columns)
features_pca_for_plot = pd.concat([features_pca_for_plot, target_for_plot],␣
 ↪axis = 1)

fig = plt.figure(figsize = (70,70))
import seaborn as sns

sns.set_style("whitegrid");
#sns.pairplot(iris, hue = "species", size = 3);
#plt.show()
# NOTE: the diagonal elements are PDFs for each feature.import seaborn as sns
sns.pairplot(features_pca_for_plot, hue='gesture')
plt.show()
```

```
381
2107
27
61.699079627611795
```

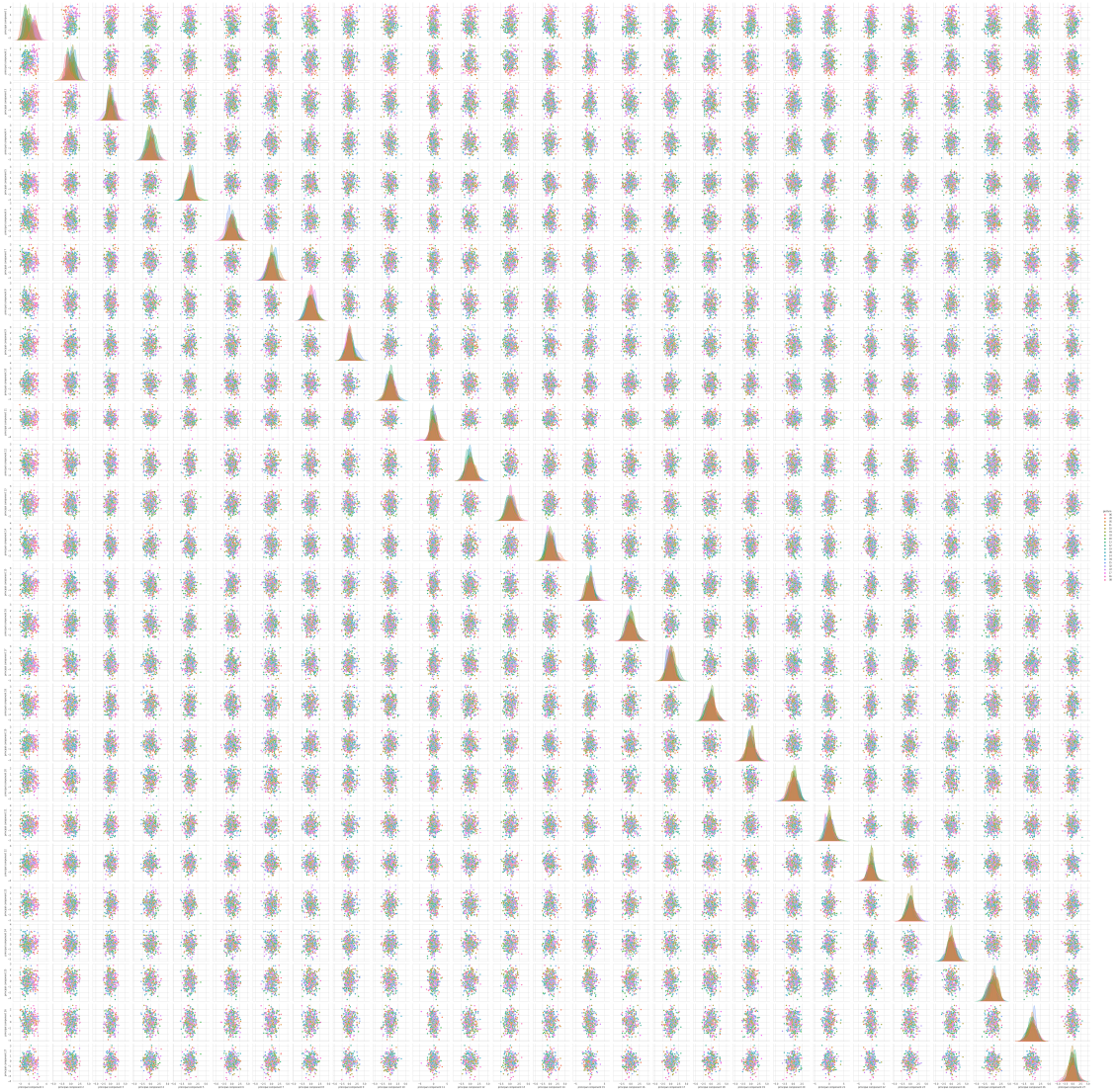
```
<Figure size 5040x5040 with 0 Axes>
```



[9]:
```
data = dataset_cleaned_test_features
work = data.copy()
test_targets = pd.DataFrame(work[["gesture","subject","sample"]],␣
 ↪columns=["gesture","subject","sample"])
test_targets.reset_index(inplace=True, drop=True)
target_for_plot = pd.DataFrame(work[["gesture"]], columns=["gesture"])
target_for_plot.reset_index(inplace=True, drop=True)
work = work.drop(labels = ["gesture","subject", "sample"], axis = 1)
work = work.reset_index(inplace=False, drop=True)
workArray = []
for tmp in work.values:
    tmpList = tmp[0]['X'].values.tolist()[0]+tmp[0]['Y'].values.
 ↪tolist()[0]+tmp[0]['Z'].values.tolist()[0]
```

```
    workArray.append(tmpList)

#pca = PCA(n_components=3)
#pca = PCA(.90)
principalComponents = pca.transform(np.array(workArray))

columns = []
for i in range(pca.n_components_):
    columns.append("principal component "+str(i+1))
test_features_pca = pd.DataFrame(data = principalComponents, columns = columns)
test_features_pca = pd.concat([test_features_pca, test_targets], axis = 1)
features_pca_for_plot = pd.DataFrame(data = principalComponents, columns =␣
 ↪columns)
features_pca_for_plot = pd.concat([features_pca_for_plot, target_for_plot],␣
 ↪axis = 1)

fig = plt.figure(figsize = (70,70))
import seaborn as sns

sns.set_style("whitegrid");
#sns.pairplot(iris, hue = "species", size = 3);
#plt.show()
# NOTE: the diagonal elements are PDFs for each feature.import seaborn as sns
sns.pairplot(features_pca_for_plot, hue='gesture')
plt.show()
```

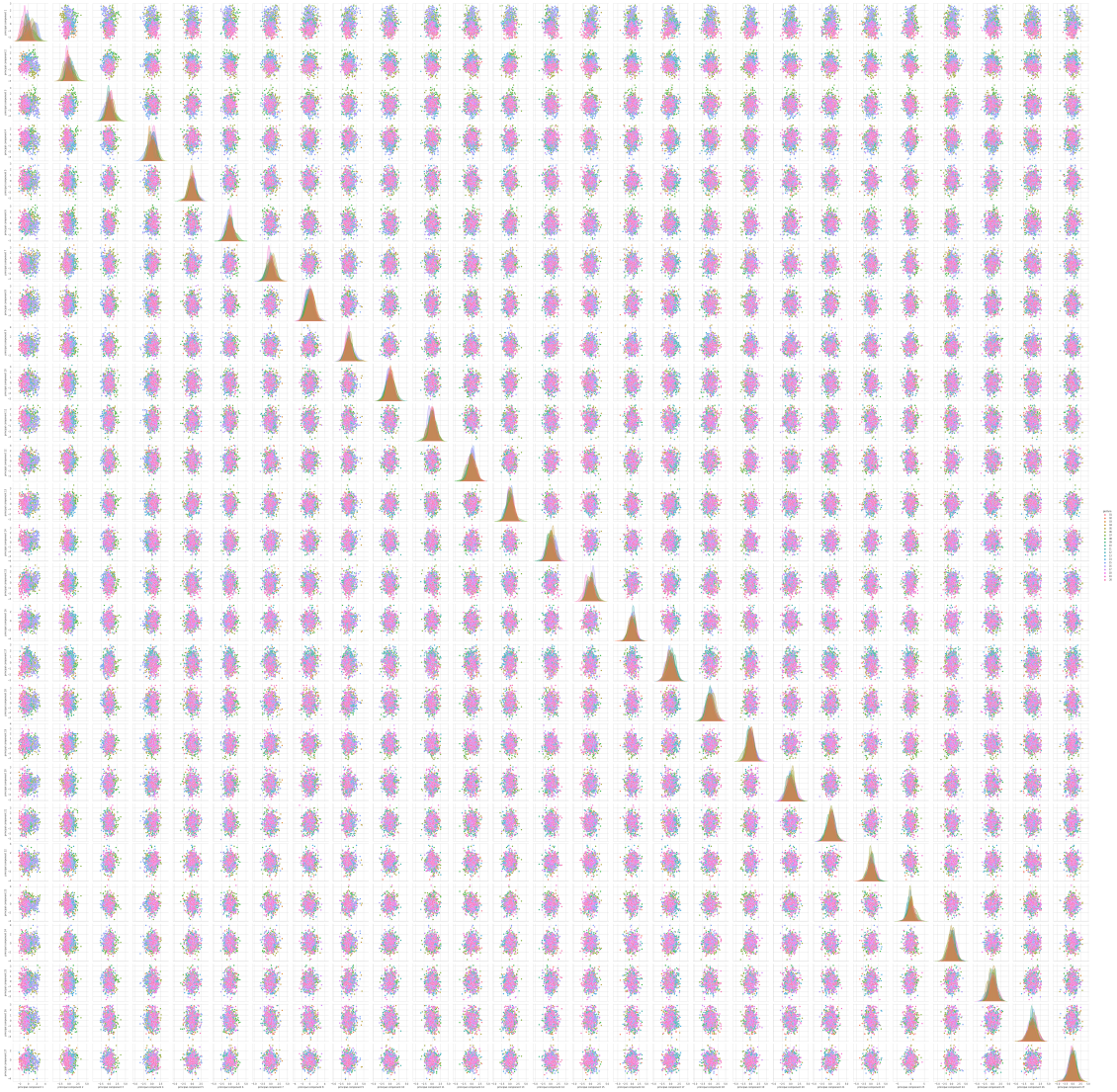
```
<Figure size 5040x5040 with 0 Axes>
```



[10]:
```
data = dataset_outliers_features
work = data.copy()
outliers_targets = pd.DataFrame(work[["gesture","subject","sample"]],␣
 ↪columns=["gesture","subject","sample"])
outliers_targets.reset_index(inplace=True, drop=True)
target_for_plot = pd.DataFrame(work[["gesture"]], columns=["gesture"])
target_for_plot.reset_index(inplace=True, drop=True)
work = work.drop(labels = ["gesture","subject", "sample"], axis = 1)
work = work.reset_index(inplace=False, drop=True)
workArray = []
for tmp in work.values:
    tmpList = tmp[0]['X'].values.tolist()[0]+tmp[0]['Y'].values.
 ↪tolist()[0]+tmp[0]['Z'].values.tolist()[0]
```

```
    workArray.append(tmpList)

#pca = PCA(n_components=3)
#pca = PCA(.90)
principalComponents = pca.transform(np.array(workArray))

columns = []
for i in range(pca.n_components_):
    columns.append("principal component "+str(i+1))
outliers_features_pca = pd.DataFrame(data = principalComponents, columns =␣
 ↪columns)
outliers_features_pca = pd.concat([outliers_features_pca, outliers_targets],␣
 ↪axis = 1)
features_pca_for_plot = pd.DataFrame(data = principalComponents, columns =␣
 ↪columns)
features_pca_for_plot = pd.concat([features_pca_for_plot, target_for_plot],␣
 ↪axis = 1)

fig = plt.figure(figsize = (70,70))
import seaborn as sns

sns.set_style("whitegrid");
#sns.pairplot(iris, hue = "species", size = 3);
#plt.show()
# NOTE: the diagonal elements are PDFs for each feature.import seaborn as sns
sns.pairplot(features_pca_for_plot, hue='gesture')
plt.show()
```

```
<Figure size 5040x5040 with 0 Axes>
```



[13]:
```
from keras.models import Sequential
from keras.layers import Bidirectional
from keras.layers import LSTM
from keras.layers import Dense
from keras.layers import Dropout
from keras.models import Model
from keras.layers import Input
from keras.layers import LeakyReLU
from keras.layers import BatchNormalization
from keras.layers import Conv1D
from keras.layers import MaxPooling1D
from keras.layers import Flatten
from keras.layers import concatenate
```

```
from keras.optimizers import adam_v2
from keras.wrappers.scikit_learn import KerasClassifier
from sklearn.model_selection import StratifiedGroupKFold
from sklearn.model_selection import cross_val_score
from sklearn.model_selection import GridSearchCV
from keras.utils import np_utils
from keras.utils.vis_utils import plot_model
from sklearn.preprocessing import LabelEncoder
from sklearn.pipeline import Pipeline
import numpy as np

# fix random seed for reproducibility
seed = 1000
np.random.seed(seed)
```

[12]:
```
# create the dataset
def get_dataset_features(data):
    X_train = []
    Y_train = []
    groups = []
    for i, gesture in enumerate(data['gesture'].unique()):
        df_gesture = data[data['gesture']==gesture]
        for j, subject in enumerate(df_gesture['subject'].unique()):
            df_subject = df_gesture[df_gesture['subject']==subject]
            for k, sample in enumerate(df_subject['sample'].unique()):
                df_sample = df_subject[df_subject['sample']==sample]
                df_sample = df_sample.drop(labels = ["gesture","subject",␣
↪"sample"], axis = 1)
                df_sample = df_sample.reset_index(inplace=False, drop=True)
                workArray = []
                for tmp in df_sample.values:
                    tmpList = tmp[0]['X'].values.tolist()[0]+tmp[0]['Y'].values.
↪tolist()[0]+tmp[0]['Z'].values.tolist()[0]
                    #print(tmpList)
                    workArray.append(tmpList)
                #print(df_sample.values[0])
                X_train.append(np.asarray(workArray[0]))
                Y_train.append(gesture)
                groups.append(subject)
    X_train = np.asarray(X_train)
    Y_train = LabelEncoder().fit_transform(Y_train)
    return X_train, Y_train, groups
```

[13]:
```
X, y, g = get_dataset_features(dataset_cleaned_train_features)
#print(X[1])
```

[14]:
```
# Function to create model, required for KerasClassifier
def create_model(n_inputs=24, dropout_rate=0.8, units=128, optimizer=adam_v2.
 ↪Adam(learning_rate=0.001)):

    model = Sequential()
    model.add(Input(shape=(n_inputs,)))
    # encoder level 1
    model.add(Dense(2*n_inputs))
    model.add(BatchNormalization())
    model.add(LeakyReLU())
    # encoder level 2
    model.add(Dense(n_inputs))
    model.add(BatchNormalization())
    model.add(LeakyReLU())
    # bottleneck
    n_bottleneck = round(float(n_inputs) / dropout_rate)
    bottleneck = Dense(n_bottleneck)
    model.add(bottleneck)
    # define decoder, level 1
    model.add(Dense(n_inputs))
    model.add(BatchNormalization())
    model.add(LeakyReLU())
    # decoder level 2
    model.add(Dense(2*n_inputs))
    model.add(BatchNormalization())
    model.add(LeakyReLU())
    # output layer
    model.add(Dense(20, activation='softmax'))
    model.compile(loss='sparse_categorical_crossentropy', optimizer=optimizer,␣
 ↪metrics=['accuracy'])
    #model.build((n_inputs,))
    #print(model.summary())
    return model
```

[15]:
```
print("Training an autoencoder model with the 381 direct statistical features,␣
 ↪gridsearch over bottleneck")
data=dataset_cleaned_train_features
X, y, g = get_dataset_features(data)
#n_inputs = X.shape[0]
#print(n_inputs)
n_inputs = X.shape[1]
n_inputs = [n_inputs]
#print(n_inputs)
model = KerasClassifier(build_fn=create_model, verbose=0)
cv = StratifiedGroupKFold(n_splits=5, shuffle=True, random_state=1000)
# get the dataset
X, y, g = get_dataset_features(data)
```

```
#cv = cv.split(X, y, g)
batch_size = [19]
#epochs = [64, 128]
epochs = [128]
#units = [32,64,128]
units = [128]
#dropout_rate = [0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9]
dropout_rate = [1.0, 2.0, 3.0, 6.0, 9.0]
param_grid = dict(n_inputs=n_inputs,epochs=epochs, units=units,␣
 ↪batch_size=batch_size, dropout_rate=dropout_rate)
#print("Hyperparameter tunning started for Dataset for gestures: ",␣
 ↪gesture_subset)
grid = GridSearchCV(estimator=model, param_grid=param_grid, n_jobs=1, cv=cv,␣
 ↪verbose=1, error_score='raise')
grid_result = grid.fit(X, y, groups=g)
# summarize results
print("Best: %f using %s" % (grid_result.best_score_, grid_result.best_params_))
means = grid_result.cv_results_['mean_test_score']
stds = grid_result.cv_results_['std_test_score']
train_mean = grid_result.cv_results_['mean_fit_time']
train_std = grid_result.cv_results_['std_fit_time']
score_mean = grid_result.cv_results_['mean_score_time']
score_std = grid_result.cv_results_['std_score_time']
params = grid_result.cv_results_['params']
for mean, stdev, train_mean, train_std, score_mean, score_std, param in␣
 ↪zip(means, stds, train_mean, train_std, score_mean, score_std, params):
    print("accuracy: %f (%f) train time: %f (%f) score time: %f (%f) with: %r"␣
 ↪% (mean, stdev, train_mean, train_std, score_mean, score_std, param))
print("Training and tunning completed for Dataset: gestures")
```

```
Training an autoencoder model with the 381 direct statistical features,
gridsearch over bottleneck
Fitting 5 folds for each of 5 candidates, totalling 25 fits

2021-11-15 11:34:39.767270: I tensorflow/core/platform/cpu_feature_guard.cc:142]
This TensorFlow binary is optimized with oneAPI Deep Neural Network Library
(oneDNN) to use the following CPU instructions in performance-critical
operations:  AVX2 AVX512F FMA
To enable them in other operations, rebuild TensorFlow with the appropriate
compiler flags.
2021-11-15 11:34:39.927065: I
tensorflow/compiler/mlir/mlir_graph_optimization_pass.cc:185] None of the MLIR
Optimization Passes are enabled (registered 2)

Best: 0.634647 using {'batch_size': 19, 'dropout_rate': 3.0, 'epochs': 128,
'n_inputs': 381, 'units': 128}
accuracy: 0.597801 (0.082041) train time: 49.041778 (4.735642) score time:
0.281400 (0.134938) with: {'batch_size': 19, 'dropout_rate': 1.0, 'epochs': 128,
```

```
'n_inputs': 381, 'units': 128}
accuracy: 0.582342 (0.072800) train time: 46.159583 (4.153968) score time:
0.212230 (0.010722) with: {'batch_size': 19, 'dropout_rate': 2.0, 'epochs': 128,
'n_inputs': 381, 'units': 128}
accuracy: 0.634647 (0.054616) train time: 44.944802 (4.009744) score time:
0.209278 (0.011437) with: {'batch_size': 19, 'dropout_rate': 3.0, 'epochs': 128,
'n_inputs': 381, 'units': 128}
accuracy: 0.600170 (0.061464) train time: 41.966161 (4.056529) score time:
0.203042 (0.008784) with: {'batch_size': 19, 'dropout_rate': 6.0, 'epochs': 128,
'n_inputs': 381, 'units': 128}
accuracy: 0.595186 (0.074417) train time: 39.929319 (3.596336) score time:
0.265362 (0.127604) with: {'batch_size': 19, 'dropout_rate': 9.0, 'epochs': 128,
'n_inputs': 381, 'units': 128}
Training and tunning completed for Dataset: gestures
```

[16]:
```
model = grid_result.best_estimator_
import pickle

def save_model(model, gesture_subset):
    gesture_subset.sort()
    name = '-'.join(gesture_subset)
    # saving model
    pickle.dump(model.classes_, open(name + '_model_classes.pkl','wb'))
    model.model.save(name + '_auto')
print("Saving model to disk started for Dataset: gestures")
save_model(model, ["Autoencoder","Features"])
print("Saving model to disk completed for Dataset: gestures")

import tensorflow as tf
def load_model(gesture_subset):
    gesture_subset.sort()
    name = '-'.join(gesture_subset)
    # loading model
    build_model = lambda: tf.keras.models.load_model(name + '_auto')
    classifier = KerasClassifier(build_fn=build_model, epochs=1, batch_size=10,␣
 ↪verbose=0)
    classifier.classes_ = pickle.load(open(name + '_model_classes.pkl','rb'))
    classifier.model = build_model()
    return classifier
print("Loading model to disk started for Dataset: gestures")
model = load_model(["Autoencoder","Features"])
print(model.model.summary())
print("Loading model to disk completed for Dataset: gestures")
```

```
Saving model to disk started for Dataset: gestures
```

```
2021-11-15 11:54:09.566412: W tensorflow/python/util/util.cc:348] Sets are not
currently considered sequences, but this may change in the future, so consider
```

```
avoiding using them.

INFO:tensorflow:Assets written to: Autoencoder-Features_auto/assets
Saving model to disk completed for Dataset: gestures
Loading model to disk started for Dataset: gestures
Model: "sequential_25"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
dense_150 (Dense)            (None, 762)               291084
_________________________________________________________________
batch_normalization_100 (Bat (None, 762)               3048
_________________________________________________________________
leaky_re_lu_100 (LeakyReLU)  (None, 762)               0
_________________________________________________________________
dense_151 (Dense)            (None, 381)               290703
_________________________________________________________________
batch_normalization_101 (Bat (None, 381)               1524
_________________________________________________________________
leaky_re_lu_101 (LeakyReLU)  (None, 381)               0
_________________________________________________________________
dense_152 (Dense)            (None, 127)               48514
_________________________________________________________________
dense_153 (Dense)            (None, 381)               48768
_________________________________________________________________
batch_normalization_102 (Bat (None, 381)               1524
_________________________________________________________________
leaky_re_lu_102 (LeakyReLU)  (None, 381)               0
_________________________________________________________________
dense_154 (Dense)            (None, 762)               291084
_________________________________________________________________
batch_normalization_103 (Bat (None, 762)               3048
_________________________________________________________________
leaky_re_lu_103 (LeakyReLU)  (None, 762)               0
_________________________________________________________________
dense_155 (Dense)            (None, 20)                15260
=================================================================
Total params: 994,557
Trainable params: 989,985
Non-trainable params: 4,572
_________________________________________________________________
None
Loading model to disk completed for Dataset: gestures
```

[17]:
```
print("Testing model against test set for Dataset: gestures")
data = dataset_cleaned_test_features
X, y, g = get_dataset_features(data)
y_pred = model.predict(X.tolist())
```

```
from sklearn.metrics import classification_report
print(classification_report(y, y_pred))

#from sklearn.metrics import confusion_matrix
#cf_matrix = confusion_matrix(y, y_pred)
#make_confusion_matrix(cf_matrix, categories=gesture_subset, figsize=[8,8])
```

```
Testing model against test set for Dataset: gestures
              precision    recall  f1-score   support

           0       0.71      0.83      0.77        18
           1       0.80      0.63      0.71        19
           2       0.90      0.90      0.90        20
           3       1.00      0.95      0.97        19
           4       0.83      0.88      0.86        17
           5       0.84      0.89      0.86        18
           6       1.00      0.89      0.94        18
           7       0.90      0.95      0.92        19
           8       0.86      0.95      0.90        19
           9       0.86      0.95      0.90        19
          10       0.84      0.89      0.86        18
          11       0.93      0.78      0.85        18
          12       0.73      0.80      0.76        20
          13       0.82      0.70      0.76        20
          14       0.71      0.94      0.81        18
          15       0.91      0.56      0.69        18
          16       0.90      1.00      0.95        18
          17       0.95      0.95      0.95        20
          18       0.88      0.88      0.88        17
          19       0.94      0.89      0.92        19

    accuracy                           0.86       372
   macro avg       0.87      0.86      0.86       372
weighted avg       0.87      0.86      0.86       372
```

[18]:
```
print("Testing model against outliers set for Dataset: gestures")
data = dataset_outliers_features
X, y, g = get_dataset_features(data)
y_pred = model.predict(X.tolist())
from sklearn.metrics import classification_report
print(classification_report(y, y_pred))

#from sklearn.metrics import confusion_matrix
#cf_matrix = confusion_matrix(y, y_pred)
#make_confusion_matrix(cf_matrix, categories=gesture_subset, figsize=[8,8])
```

```
Testing model against outliers set for Dataset: gestures
```

	precision	recall	f1-score	support
0	0.66	0.64	0.65	39
1	0.68	0.42	0.52	36
2	0.91	0.59	0.71	34
3	0.88	0.88	0.88	42
4	0.81	0.68	0.74	44
5	0.81	0.77	0.79	44
6	0.88	0.73	0.80	41
7	0.46	0.97	0.63	38
8	0.71	0.94	0.81	32
9	0.79	0.95	0.86	39
10	0.70	0.71	0.71	42
11	0.71	0.62	0.67	40
12	0.64	0.62	0.63	26
13	0.79	0.72	0.75	32
14	0.78	0.91	0.84	44
15	0.76	0.66	0.71	44
16	0.97	0.68	0.80	41
17	0.81	0.72	0.76	29
18	0.76	0.81	0.78	47
19	0.78	0.82	0.79	38
accuracy			0.75	772
macro avg	0.76	0.74	0.74	772
weighted avg	0.77	0.75	0.75	772

[19]:
```
# create the dataset
def get_dataset_features_pca(data):
    X_train = []
    Y_train = []
    groups = []
    for i, gesture in enumerate(data['gesture'].unique()):
        df_gesture = data[data['gesture']==gesture]
        for j, subject in enumerate(df_gesture['subject'].unique()):
            df_subject = df_gesture[df_gesture['subject']==subject]
            for k, sample in enumerate(df_subject['sample'].unique()):
                df_sample = df_subject[df_subject['sample']==sample]
                df_sample = df_sample.drop(labels = ["gesture","subject",␣
 ↪"sample"], axis = 1)
                #print(df_sample.values[0])
                X_train.append(np.asarray(df_sample.values[0]))
                Y_train.append(gesture)
                groups.append(subject)
    X_train = np.asarray(X_train)
    #print(X_train)
```

```
    Y_train = LabelEncoder().fit_transform(Y_train)
    return X_train, Y_train, groups
```

[20]:
```
X, y, g = get_dataset_features_pca(train_features_pca)
#print(X)
```

[21]:
```
print("Training an autoencoder model with the PCA features, 1x girth because␣
 ↪PCA is already compressed")
data=train_features_pca
X, y, g = get_dataset_features_pca(data)
n_inputs = X.shape[1]
n_inputs = [n_inputs]
#print(n_inputs)
model = KerasClassifier(build_fn=create_model, verbose=0)
cv = StratifiedGroupKFold(n_splits=5, shuffle=True, random_state=1000)
# get the dataset
X, y, g = get_dataset_features_pca(data)
#cv = cv.split(X, y, g)
batch_size = [19]
#epochs = [64, 128]
epochs = [128]
#units = [32,64,128]
units = [128]
#dropout_rate = [0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9]
dropout_rate = [1.0]
param_grid = dict(n_inputs=n_inputs,epochs=epochs, units=units,␣
 ↪batch_size=batch_size, dropout_rate=dropout_rate)
#print("Hyperparameter tunning started for Dataset for gestures: ",␣
 ↪gesture_subset)
grid = GridSearchCV(estimator=model, param_grid=param_grid, n_jobs=1, cv=cv,␣
 ↪verbose=1)
grid_result = grid.fit(X, y, groups=g)
# summarize results
print("Best: %f using %s" % (grid_result.best_score_, grid_result.best_params_))
means = grid_result.cv_results_['mean_test_score']
stds = grid_result.cv_results_['std_test_score']
train_mean = grid_result.cv_results_['mean_fit_time']
train_std = grid_result.cv_results_['std_fit_time']
score_mean = grid_result.cv_results_['mean_score_time']
score_std = grid_result.cv_results_['std_score_time']
params = grid_result.cv_results_['params']
for mean, stdev, train_mean, train_std, score_mean, score_std, param in␣
 ↪zip(means, stds, train_mean, train_std, score_mean, score_std, params):
    print("accuracy: %f (%f) train time: %f (%f) score time: %f (%f) with: %r"␣
 ↪% (mean, stdev, train_mean, train_std, score_mean, score_std, param))
print("Training and tunning completed for Dataset: gestures")
```

```
Training an autoencoder model with the PCA features, 1x girth because PCA is
already compressed
Fitting 5 folds for each of 1 candidates, totalling 5 fits
Best: 0.408233 using {'batch_size': 19, 'dropout_rate': 1.0, 'epochs': 128,
'n_inputs': 27, 'units': 128}
accuracy: 0.408233 (0.056236) train time: 16.722026 (1.331812) score time:
0.260476 (0.159935) with: {'batch_size': 19, 'dropout_rate': 1.0, 'epochs': 128,
'n_inputs': 27, 'units': 128}
Training and tunning completed for Dataset: gestures
```

[22]:
```
model = grid_result.best_estimator_
import pickle

def save_model(model, gesture_subset):
    gesture_subset.sort()
    name = '-'.join(gesture_subset)
    # saving model
    pickle.dump(model.classes_, open(name + '_model_classes.pkl','wb'))
    model.model.save(name + '_auto')
print("Saving model to disk started for Dataset: gestures")
save_model(model, ["Autoencoder","Features", "PCA"])
print("Saving model to disk completed for Dataset: gestures")

import tensorflow as tf
def load_model(gesture_subset):
    gesture_subset.sort()
    name = '-'.join(gesture_subset)
    # loading model
    build_model = lambda: tf.keras.models.load_model(name + '_auto')
    classifier = KerasClassifier(build_fn=build_model, epochs=1, batch_size=10,␣
 ↪verbose=0)
    classifier.classes_ = pickle.load(open(name + '_model_classes.pkl','rb'))
    classifier.model = build_model()
    return classifier
print("Loading model to disk started for Dataset: gestures")
model = load_model(["Autoencoder","Features", "PCA"])
print(model.model.summary())
print("Loading model to disk completed for Dataset: gestures")
```

```
Saving model to disk started for Dataset: gestures
INFO:tensorflow:Assets written to: Autoencoder-Features-PCA_auto/assets
Saving model to disk completed for Dataset: gestures
Loading model to disk started for Dataset: gestures
Model: "sequential_31"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
dense_186 (Dense)            (None, 54)                1512
```

```
_________________________________________________________________
batch_normalization_124 (Bat (None, 54)                216
_________________________________________________________________
leaky_re_lu_124 (LeakyReLU)  (None, 54)                0
_________________________________________________________________
dense_187 (Dense)            (None, 27)                1485
_________________________________________________________________
batch_normalization_125 (Bat (None, 27)                108
_________________________________________________________________
leaky_re_lu_125 (LeakyReLU)  (None, 27)                0
_________________________________________________________________
dense_188 (Dense)            (None, 27)                756
_________________________________________________________________
dense_189 (Dense)            (None, 27)                756
_________________________________________________________________
batch_normalization_126 (Bat (None, 27)                108
_________________________________________________________________
leaky_re_lu_126 (LeakyReLU)  (None, 27)                0
_________________________________________________________________
dense_190 (Dense)            (None, 54)                1512
_________________________________________________________________
batch_normalization_127 (Bat (None, 54)                216
_________________________________________________________________
leaky_re_lu_127 (LeakyReLU)  (None, 54)                0
_________________________________________________________________
dense_191 (Dense)            (None, 20)                1100
=================================================================
Total params: 7,769
Trainable params: 7,445
Non-trainable params: 324
_________________________________________________________________
None
Loading model to disk completed for Dataset: gestures
```

[23]:
```
print("Testing model against test set for Dataset: gestures")
data = test_features_pca
X, y, g = get_dataset_features_pca(data)
y_pred = model.predict(X.tolist())
from sklearn.metrics import classification_report
print(classification_report(y, y_pred))

#from sklearn.metrics import confusion_matrix
#cf_matrix = confusion_matrix(y, y_pred)
#make_confusion_matrix(cf_matrix, categories=gesture_subset, figsize=[8,8])
```

```
Testing model against test set for Dataset: gestures
              precision    recall  f1-score   support
```

```
              0       0.29      0.22      0.25        18
              1       0.47      0.37      0.41        19
              2       0.70      0.70      0.70        20
              3       0.57      0.68      0.62        19
              4       0.84      0.94      0.89        17
              5       0.78      0.78      0.78        18
              6       0.88      0.83      0.86        18
              7       0.84      0.84      0.84        19
              8       0.61      0.74      0.67        19
              9       0.84      0.84      0.84        19
             10       0.79      0.61      0.69        18
             11       0.56      0.50      0.53        18
             12       0.75      0.75      0.75        20
             13       0.65      0.55      0.59        20
             14       0.75      0.83      0.79        18
             15       0.68      0.72      0.70        18
             16       0.77      0.56      0.65        18
             17       0.68      0.85      0.76        20
             18       0.65      0.65      0.65        17
             19       0.71      0.89      0.79        19

    accuracy                           0.69       372
   macro avg       0.69      0.69      0.69       372
weighted avg       0.69      0.69      0.69       372
```

[24]:
```
print("Testing model against outliers set for Dataset: gestures")
data = outliers_features_pca
X, y, g = get_dataset_features_pca(data)
y_pred = model.predict(X.tolist())
from sklearn.metrics import classification_report
print(classification_report(y, y_pred))

#from sklearn.metrics import confusion_matrix
#cf_matrix = confusion_matrix(y, y_pred)
#make_confusion_matrix(cf_matrix, categories=gesture_subset, figsize=[8,8])
```

```
Testing model against outliers set for Dataset: gestures
              precision    recall  f1-score   support

           0       0.37      0.38      0.37        39
           1       0.32      0.33      0.33        36
           2       0.72      0.68      0.70        34
           3       0.55      0.43      0.48        42
           4       0.71      0.55      0.62        44
           5       0.54      0.73      0.62        44
           6       0.73      0.78      0.75        41
           7       0.74      0.68      0.71        38
```

```
           8       0.62      0.56      0.59        32
           9       0.68      0.72      0.70        39
          10       0.65      0.71      0.68        42
          11       0.56      0.45      0.50        40
          12       0.46      0.50      0.48        26
          13       0.57      0.53      0.55        32
          14       0.65      0.73      0.69        44
          15       0.65      0.55      0.59        44
          16       0.54      0.51      0.53        41
          17       0.46      0.62      0.53        29
          18       0.62      0.62      0.62        47
          19       0.62      0.66      0.64        38

    accuracy                           0.59       772
   macro avg       0.59      0.59      0.58       772
weighted avg       0.59      0.59      0.59       772
```

[8]:
```
print("Time slicing Cleaned Dataset for gestures: dataset_cleaned_train")
data=dataset_cleaned_train
dataset_timecut = None
samples = 0
damaged = 0
for i, gesture in enumerate(data['gesture'].unique()):
    df_gesture = data[data['gesture']==gesture]
    for j, subject in enumerate(df_gesture['subject'].unique()):
        df_subject = df_gesture[df_gesture['subject']==subject]
        time_max = 19 # 18 * 11 = 198
        for i, sample in enumerate(df_subject['sample'].unique()):
            df_sample = df_subject[df_subject['sample']==sample]
            df_sample_count = df_sample.count()['sample.timestamp']
            #print(df_sample_count)
            if df_sample_count >= time_max:
                df_sample = df_sample[df_sample['sample.timestamp'] <= (11 *␣
↪(time_max-1))]
                df_sample_count = df_sample.count()['sample.timestamp']
            #print(df_sample_count)
            elif df_sample_count < time_max:
                for tmp in range(df_sample_count * 11, (time_max) * 11, 11):
                    df = pd.DataFrame([[tmp, 0.0, 0.0, 0.0, gesture, subject,␣
↪sample]], columns=['sample.timestamp', 'X', 'Y', 'Z', 'gesture', 'subject',␣
↪'sample'])
                    df_sample = df_sample.append(df, ignore_index=True)
            #print(df_sample)
            df_sample_count = df_sample.count()['sample.timestamp']
            #print(df_sample_count)
            if df_sample_count != time_max:
```

```
                damaged += 1
                continue
            if dataset_timecut is None:
                dataset_timecut = df_sample.copy()
            else:
                dataset_timecut = pd.concat([dataset_timecut, df_sample])
            samples += 1

dataset_cleaned_train_timecut = dataset_timecut
print(str(samples) + " cleaned samples sliced")
print(str(damaged) + " cleaned samples damaged")
```

```
Time slicing Cleaned Dataset for gestures: dataset_cleaned_train
2106 cleaned samples sliced
1 cleaned samples damaged
```

[9]:
```
print("Time slicing Cleaned Dataset for gestures: dataset_cleaned_test")
data=dataset_cleaned_test
dataset_timecut = None
samples = 0
damaged = 0
for i, gesture in enumerate(data['gesture'].unique()):
    df_gesture = data[data['gesture']==gesture]
    for j, subject in enumerate(df_gesture['subject'].unique()):
        df_subject = df_gesture[df_gesture['subject']==subject]
        time_max = 19 # 18 * 11 = 198
        for i, sample in enumerate(df_subject['sample'].unique()):
            df_sample = df_subject[df_subject['sample']==sample]
            df_sample_count = df_sample.count()['sample.timestamp']
            #print(df_sample_count)
            if df_sample_count >= time_max:
                df_sample = df_sample[df_sample['sample.timestamp'] <= (11 *␣
↪(time_max-1))]
                df_sample_count = df_sample.count()['sample.timestamp']
            #print(df_sample_count)
            elif df_sample_count < time_max:
                for tmp in range(df_sample_count * 11, (time_max) * 11, 11):
                    df = pd.DataFrame([[tmp, 0.0, 0.0, 0.0, gesture, subject,␣
↪sample]], columns=['sample.timestamp', 'X', 'Y', 'Z', 'gesture', 'subject',␣
↪'sample'])
                    df_sample = df_sample.append(df, ignore_index=True)
            #print(df_sample)
            df_sample_count = df_sample.count()['sample.timestamp']
            #print(df_sample_count)
            if df_sample_count != time_max:
                damaged += 1
                continue
```

```
            if dataset_timecut is None:
                dataset_timecut = df_sample.copy()
            else:
                dataset_timecut = pd.concat([dataset_timecut, df_sample])
            samples += 1

dataset_cleaned_test_timecut = dataset_timecut
print(str(samples) + " cleaned samples sliced")
print(str(damaged) + " cleaned samples damaged")
```

```
Time slicing Cleaned Dataset for gestures: dataset_cleaned_test
372 cleaned samples sliced
0 cleaned samples damaged
```

[10]:
```
print("Time slicing Cleaned Dataset for gestures: dataset_outliers")
data=dataset_outliers
dataset_timecut = None
samples = 0
damaged = 0
for i, gesture in enumerate(data['gesture'].unique()):
    df_gesture = data[data['gesture']==gesture]
    for j, subject in enumerate(df_gesture['subject'].unique()):
        df_subject = df_gesture[df_gesture['subject']==subject]
        time_max = 19 # 18 * 11 = 198
        for i, sample in enumerate(df_subject['sample'].unique()):
            df_sample = df_subject[df_subject['sample']==sample]
            df_sample_count = df_sample.count()['sample.timestamp']
            #print(df_sample_count)
            if df_sample_count >= time_max:
                df_sample = df_sample[df_sample['sample.timestamp'] <= (11 *␣
↪(time_max-1))]
                df_sample_count = df_sample.count()['sample.timestamp']
            #print(df_sample_count)
            elif df_sample_count < time_max:
                for tmp in range(df_sample_count * 11, (time_max) * 11, 11):
                    df = pd.DataFrame([[tmp, 0.0, 0.0, 0.0, gesture, subject,␣
↪sample]], columns=['sample.timestamp', 'X', 'Y', 'Z', 'gesture', 'subject',␣
↪'sample'])
                    df_sample = df_sample.append(df, ignore_index=True)
            #print(df_sample)
            df_sample_count = df_sample.count()['sample.timestamp']
            #print(df_sample_count)
            if df_sample_count != time_max:
                damaged += 1
                continue
            if dataset_timecut is None:
                dataset_timecut = df_sample.copy()
```

```
            else:
                dataset_timecut = pd.concat([dataset_timecut, df_sample])
            samples += 1

dataset_outliers_timecut = dataset_timecut
print(str(samples) + " outliers samples sliced")
print(str(damaged) + " outliers samples damaged")
```

```
Time slicing Cleaned Dataset for gestures: dataset_outliers
769 outliers samples sliced
3 outliers samples damaged
```

[16]:
```
# create the dataset
def get_dataset(data):
    X_train = []
    Y_train = []
    groups = []
    for i, gesture in enumerate(data['gesture'].unique()):
        df_gesture = data[data['gesture']==gesture]
        for j, subject in enumerate(df_gesture['subject'].unique()):
            df_subject = df_gesture[df_gesture['subject']==subject]
            for k, sample in enumerate(df_subject['sample'].unique()):
                df_sample = df_subject[df_subject['sample']==sample]
                accel_vector = []
                for index, row in df_sample.sort_values(by='sample.timestamp').
 ↪iterrows():
                    accel_vector.append(np.
 ↪asarray([row['X'],row['Y'],row['Z']]))
                accel_vector = np.asarray(accel_vector)
                X_train.append(accel_vector)
                Y_train.append(gesture)
                groups.append(subject)
    X_train = np.asarray(X_train)
    Y_train = LabelEncoder().fit_transform(Y_train)
    #print(Y_train)
    return X_train, Y_train, groups
```

[14]:
```
# Function to create model, required for KerasClassifier
def create_model(dropout_rate=0.8, units=128, optimizer=adam_v2.
 ↪Adam(learning_rate=0.001)):
    model = Sequential()
    model.add(
        Bidirectional(
            LSTM(
                units=units,
                input_shape=[19, 3]
            )
```

```
        )
    )
    model.add(Dropout(rate=dropout_rate))
    model.add(Dense(units=units, activation='relu'))
    model.add(Dense(20, activation='softmax'))
    model.compile(loss='sparse_categorical_crossentropy', optimizer=optimizer,␣
 ↪metrics=['accuracy'])
    #print(model.summary())
    return model
```

[33]:
```
data = dataset_cleaned_train_timecut
print("Training a LSTM model from measurement data for comparison")

model = KerasClassifier(build_fn=create_model, verbose=0)
cv = StratifiedGroupKFold(n_splits=5, shuffle=True, random_state=1000)
# get the dataset
X, y, g = get_dataset(data)
#cv = cv.split(X, y, g)
batch_size = [19]
#epochs = [64, 128]
epochs = [128]
#units = [32,64,128]
units = [128]
#dropout_rate = [0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9]
dropout_rate = [0.5]
param_grid = dict(epochs=epochs, units=units, batch_size=batch_size,␣
 ↪dropout_rate=dropout_rate)
#print("Hyperparameter tunning started for Dataset for gestures: ",␣
 ↪gesture_subset)
grid = GridSearchCV(estimator=model, param_grid=param_grid, n_jobs=1, cv=cv,␣
 ↪verbose=1)
grid_result = grid.fit(X, y, groups=g)
# summarize results
print("Best: %f using %s" % (grid_result.best_score_, grid_result.best_params_))
means = grid_result.cv_results_['mean_test_score']
stds = grid_result.cv_results_['std_test_score']
train_mean = grid_result.cv_results_['mean_fit_time']
train_std = grid_result.cv_results_['std_fit_time']
score_mean = grid_result.cv_results_['mean_score_time']
score_std = grid_result.cv_results_['std_score_time']
params = grid_result.cv_results_['params']
for mean, stdev, train_mean, train_std, score_mean, score_std, param in␣
 ↪zip(means, stds, train_mean, train_std, score_mean, score_std, params):
    print("accuracy: %f (%f) train time: %f (%f) score time: %f (%f) with: %r"␣
 ↪% (mean, stdev, train_mean, train_std, score_mean, score_std, param))
print("Training and tunning completed for Dataset: gestures")
```

```
Training a LSTM model from measurement data for comparison
Fitting 5 folds for each of 1 candidates, totalling 5 fits
Best: 0.934965 using {'batch_size': 19, 'dropout_rate': 0.5, 'epochs': 128,
'units': 128}
accuracy: 0.934965 (0.039706) train time: 131.592410 (12.340437) score time:
0.799166 (0.150575) with: {'batch_size': 19, 'dropout_rate': 0.5, 'epochs': 128,
'units': 128}
Training and tunning completed for Dataset: gestures
```

[34]:
```
model = grid_result.best_estimator_
import pickle

def save_model(model, gesture_subset):
    gesture_subset.sort()
    name = '-'.join(gesture_subset)
    # saving model
    pickle.dump(model.classes_, open(name + '_model_classes.pkl','wb'))
    model.model.save(name + '_lstm')
print("Saving model to disk started for Dataset: gestures")
save_model(model, ["LSTM","Measurements"])
print("Saving model to disk completed for Dataset: gestures")

import tensorflow as tf
def load_model(gesture_subset):
    gesture_subset.sort()
    name = '-'.join(gesture_subset)
    # loading model
    build_model = lambda: tf.keras.models.load_model(name + '_lstm')
    classifier = KerasClassifier(build_fn=build_model, epochs=1, batch_size=10,␣
 ↪verbose=0)
    classifier.classes_ = pickle.load(open(name + '_model_classes.pkl','rb'))
    classifier.model = build_model()
    return classifier
print("Loading model to disk started for Dataset: gestures")
model = load_model(["LSTM","Measurements"])
print(model.model.summary())
print("Loading model to disk completed for Dataset: gestures")
```

```
Saving model to disk started for Dataset: gestures

WARNING:absl:Found untraced functions such as lstm_cell_34_layer_call_fn,
lstm_cell_34_layer_call_and_return_conditional_losses,
lstm_cell_35_layer_call_fn,
lstm_cell_35_layer_call_and_return_conditional_losses,
lstm_cell_34_layer_call_fn while saving (showing 5 of 10). These functions will
not be directly callable after loading.

INFO:tensorflow:Assets written to: LSTM-Measurements_lstm/assets
```

```
INFO:tensorflow:Assets written to: LSTM-Measurements_lstm/assets

Saving model to disk completed for Dataset: gestures
Loading model to disk started for Dataset: gestures
Model: "sequential_43"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
bidirectional_11 (Bidirectio (None, 256)               135168
_________________________________________________________________
dropout_11 (Dropout)         (None, 256)               0
_________________________________________________________________
dense_214 (Dense)            (None, 128)               32896
_________________________________________________________________
dense_215 (Dense)            (None, 20)                2580
=================================================================
Total params: 170,644
Trainable params: 170,644
Non-trainable params: 0
_________________________________________________________________
None
Loading model to disk completed for Dataset: gestures
```

[35]:
```
print("Testing model against test set for Dataset: gestures")
data = dataset_cleaned_test_timecut
X, y, g = get_dataset(data)
y_pred = model.predict(X.tolist())
from sklearn.metrics import classification_report
print(classification_report(y, y_pred))

#from sklearn.metrics import confusion_matrix
#cf_matrix = confusion_matrix(y, y_pred)
#make_confusion_matrix(cf_matrix, categories=gesture_subset, figsize=[8,8])
```

```
Testing model against test set for Dataset: gestures
              precision    recall  f1-score   support

           0       1.00      1.00      1.00        18
           1       1.00      0.95      0.97        19
           2       1.00      1.00      1.00        20
           3       1.00      1.00      1.00        19
           4       1.00      1.00      1.00        17
           5       1.00      0.94      0.97        18
           6       1.00      1.00      1.00        18
           7       1.00      1.00      1.00        19
           8       0.95      1.00      0.97        19
           9       1.00      1.00      1.00        19
          10       1.00      1.00      1.00        18
          11       1.00      1.00      1.00        18
```

```
           12       1.00      0.95      0.97        20
           13       0.95      1.00      0.98        20
           14       1.00      1.00      1.00        18
           15       1.00      1.00      1.00        18
           16       1.00      1.00      1.00        18
           17       1.00      1.00      1.00        20
           18       0.94      0.88      0.91        17
           19       0.90      1.00      0.95        19

     accuracy                           0.99       372
    macro avg       0.99      0.99      0.99       372
 weighted avg       0.99      0.99      0.99       372
```

[36]:
```
print("Testing model against outliers set for Dataset: gestures")
data = dataset_outliers_timecut
X, y, g = get_dataset(data)
y_pred = model.predict(X.tolist())
from sklearn.metrics import classification_report
print(classification_report(y, y_pred))

#from sklearn.metrics import confusion_matrix
#cf_matrix = confusion_matrix(y, y_pred)
#make_confusion_matrix(cf_matrix, categories=gesture_subset, figsize=[8,8])
```

```
Testing model against outliers set for Dataset: gestures
              precision    recall  f1-score   support

           0       0.97      0.97      0.97        39
           1       1.00      1.00      1.00        34
           2       0.97      0.91      0.94        34
           3       1.00      0.98      0.99        42
           4       1.00      0.95      0.98        43
           5       1.00      1.00      1.00        44
           6       1.00      0.98      0.99        41
           7       1.00      0.97      0.99        38
           8       1.00      0.97      0.98        32
           9       1.00      1.00      1.00        39
          10       0.95      1.00      0.98        42
          11       1.00      0.97      0.99        40
          12       1.00      1.00      1.00        26
          13       0.97      1.00      0.98        32
          14       0.98      1.00      0.99        44
          15       0.98      1.00      0.99        44
          16       1.00      1.00      1.00        41
          17       0.93      0.97      0.95        29
          18       0.98      0.98      0.98        47
          19       0.93      1.00      0.96        38
```

```
    accuracy                           0.98       769
   macro avg       0.98      0.98      0.98       769
weighted avg       0.98      0.98      0.98       769
```

[15]:
```
# Function to create model, required for KerasClassifier
def create_model(n_timesteps=19, n_features=3, dropout_rate=0.8, units=128,␣
↪filters=64, kernel_size=[3,5,11], pool_size=2, optimizer=adam_v2.
↪Adam(learning_rate=0.001)):
        # head 1
       inputs1 = Input(shape=(n_timesteps,n_features))
       conv1 = Conv1D(filters=filters, kernel_size=kernel_size[0],␣
↪activation='relu')(inputs1)
       drop1 = Dropout(dropout_rate)(conv1)
       pool1 = MaxPooling1D(pool_size=pool_size)(drop1)
       flat1 = Flatten()(pool1)
       # head 2
       inputs2 = Input(shape=(n_timesteps,n_features))
       conv2 = Conv1D(filters=filters, kernel_size=kernel_size[1],␣
↪activation='relu')(inputs2)
       drop2 = Dropout(dropout_rate)(conv2)
       pool2 = MaxPooling1D(pool_size=pool_size)(drop2)
       flat2 = Flatten()(pool2)
       # head 3
       inputs3 = Input(shape=(n_timesteps,n_features))
       conv3 = Conv1D(filters=filters, kernel_size=kernel_size[2],␣
↪activation='relu')(inputs3)
       drop3 = Dropout(dropout_rate)(conv3)
       pool3 = MaxPooling1D(pool_size=pool_size)(drop3)
       flat3 = Flatten()(pool3)
       # merge
       merged = concatenate([flat1, flat2, flat3])
       # interpretation
       dense1 = Dense(units, activation='relu')(merged)
       outputs = Dense(20, activation='softmax')(dense1)
       model = Model(inputs=[inputs1, inputs2, inputs3], outputs=outputs)
       model.compile(loss='sparse_categorical_crossentropy',␣
↪optimizer=optimizer, metrics=['accuracy'])
   #print(model.summary())
       return model
```

[27]:
```
# Function to create model, required for KerasClassifier
def create_model(n_timesteps=19, n_features=3, dropout_rate=0.8, units=128,␣
↪filters=64, kernel_size=[3,5,11], pool_size=2, optimizer=adam_v2.
↪Adam(learning_rate=0.001)):
        # head 1
```

```
        inputs = Input(shape=(n_timesteps,n_features))
        conv1 = Conv1D(filters=filters, kernel_size=kernel_size[0],␣
 ↪activation='relu')(inputs)
        conv2 = Conv1D(filters=filters, kernel_size=kernel_size[0],␣
 ↪activation='relu')(conv1)
        drop1 = Dropout(dropout_rate)(conv2)
        pool1 = MaxPooling1D(pool_size=pool_size)(drop1)
        flat1 = Flatten()(pool1)

        # interpretation
        dense1 = Dense(units, activation='relu')(flat1)
        outputs = Dense(20, activation='softmax')(dense1)
        model = Model(inputs=inputs, outputs=outputs)
        model.compile(loss='sparse_categorical_crossentropy',␣
 ↪optimizer=optimizer, metrics=['accuracy'])
        print(model.summary())
        return model
```

[28]:
```
data = dataset_cleaned_train_timecut
print("Training a CNN model from measurement data for comparison")

model = KerasClassifier(build_fn=create_model, verbose=0)
cv = StratifiedGroupKFold(n_splits=5, shuffle=True, random_state=1000)
# get the dataset
X, y, g = get_dataset(data)
#cv = cv.split(X, y, g)
batch_size = [19]
#epochs = [64, 128]
epochs = [128]
#units = [32,64,128]
units = [128]
#dropout_rate = [0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9]
dropout_rate = [0.5]
filters = [8, 16, 32, 64, 128]
pool_size = [2, 3]
kernel_size = [[3, 5, 7], [3, 5, 11]]
param_grid = dict(filters=filters, kernel_size=kernel_size,␣
 ↪pool_size=pool_size, epochs=epochs, units=units, batch_size=batch_size,␣
 ↪dropout_rate=dropout_rate)
#print("Hyperparameter tunning started for Dataset for gestures: ",␣
 ↪gesture_subset)
grid = GridSearchCV(estimator=model, param_grid=param_grid, n_jobs=2, cv=cv,␣
 ↪verbose=1)
grid_result = grid.fit(X, y, groups=g)
# summarize results
print("Best: %f using %s" % (grid_result.best_score_, grid_result.best_params_))
means = grid_result.cv_results_['mean_test_score']
```

```
stds = grid_result.cv_results_['std_test_score']
train_mean = grid_result.cv_results_['mean_fit_time']
train_std = grid_result.cv_results_['std_fit_time']
score_mean = grid_result.cv_results_['mean_score_time']
score_std = grid_result.cv_results_['std_score_time']
params = grid_result.cv_results_['params']
for mean, stdev, train_mean, train_std, score_mean, score_std, param in␣
 ↪zip(means, stds, train_mean, train_std, score_mean, score_std, params):
    print("accuracy: %f (%f) train time: %f (%f) score time: %f (%f) with: %r"␣
 ↪% (mean, stdev, train_mean, train_std, score_mean, score_std, param))
print("Training and tunning completed for Dataset: gestures")
```

```
Training a CNN model from measurement data for comparison
Fitting 5 folds for each of 20 candidates, totalling 100 fits
```

```
2021-11-15 22:18:29.027821: I
tensorflow/compiler/mlir/mlir_graph_optimization_pass.cc:185] None of the MLIR
Optimization Passes are enabled (registered 2)
2021-11-15 22:18:29.028150: I
tensorflow/compiler/mlir/mlir_graph_optimization_pass.cc:185] None of the MLIR
Optimization Passes are enabled (registered 2)
```

```
Model: "model"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_102 (InputLayer)       [(None, 19, 3)]           0
_________________________________________________________________
conv1d_202 (Conv1D)          (None, 17, 8)             80
_________________________________________________________________
conv1d_203 (Conv1D)          (None, 15, 8)             200
_________________________________________________________________
dropout_101 (Dropout)        (None, 15, 8)             0
_________________________________________________________________
max_pooling1d_101 (MaxPoolin (None, 7, 8)              0
_________________________________________________________________
flatten_101 (Flatten)        (None, 56)                0
_________________________________________________________________
dense (Dense)                (None, 128)               7296
_________________________________________________________________
dense_1 (Dense)              (None, 20)                2580
=================================================================
Total params: 10,156
Trainable params: 10,156
Non-trainable params: 0
_________________________________________________________________
None
Model: "model_1"
```

```
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_103 (InputLayer)       [(None, 19, 3)]           0
_________________________________________________________________
conv1d_204 (Conv1D)          (None, 17, 8)             80
_________________________________________________________________
conv1d_205 (Conv1D)          (None, 15, 8)             200
_________________________________________________________________
dropout_102 (Dropout)        (None, 15, 8)             0
_________________________________________________________________
max_pooling1d_102 (MaxPoolin (None, 7, 8)              0
_________________________________________________________________
flatten_102 (Flatten)        (None, 56)                0
_________________________________________________________________
dense_2 (Dense)              (None, 128)               7296
_________________________________________________________________
dense_3 (Dense)              (None, 20)                2580
=================================================================
Total params: 10,156
Trainable params: 10,156
Non-trainable params: 0
_________________________________________________________________
None
Model: "model_2"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_104 (InputLayer)       [(None, 19, 3)]           0
_________________________________________________________________
conv1d_206 (Conv1D)          (None, 17, 8)             80
_________________________________________________________________
conv1d_207 (Conv1D)          (None, 15, 8)             200
_________________________________________________________________
dropout_103 (Dropout)        (None, 15, 8)             0
_________________________________________________________________
max_pooling1d_103 (MaxPoolin (None, 7, 8)              0
_________________________________________________________________
flatten_103 (Flatten)        (None, 56)                0
_________________________________________________________________
dense_4 (Dense)              (None, 128)               7296
_________________________________________________________________
dense_5 (Dense)              (None, 20)                2580
=================================================================
Total params: 10,156
Trainable params: 10,156
Non-trainable params: 0
_________________________________________________________________
```

```
None
Model: "model_3"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_105 (InputLayer)       [(None, 19, 3)]           0
_________________________________________________________________
conv1d_208 (Conv1D)          (None, 17, 8)             80
_________________________________________________________________
conv1d_209 (Conv1D)          (None, 15, 8)             200
_________________________________________________________________
dropout_104 (Dropout)        (None, 15, 8)             0
_________________________________________________________________
max_pooling1d_104 (MaxPoolin (None, 5, 8)              0
_________________________________________________________________
flatten_104 (Flatten)        (None, 40)                0
_________________________________________________________________
dense_6 (Dense)              (None, 128)               5248
_________________________________________________________________
dense_7 (Dense)              (None, 20)                2580
=================================================================
Total params: 8,108
Trainable params: 8,108
Non-trainable params: 0
_________________________________________________________________
None
Model: "model_4"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_106 (InputLayer)       [(None, 19, 3)]           0
_________________________________________________________________
conv1d_210 (Conv1D)          (None, 17, 8)             80
_________________________________________________________________
conv1d_211 (Conv1D)          (None, 15, 8)             200
_________________________________________________________________
dropout_105 (Dropout)        (None, 15, 8)             0
_________________________________________________________________
max_pooling1d_105 (MaxPoolin (None, 5, 8)              0
_________________________________________________________________
flatten_105 (Flatten)        (None, 40)                0
_________________________________________________________________
dense_8 (Dense)              (None, 128)               5248
_________________________________________________________________
dense_9 (Dense)              (None, 20)                2580
=================================================================
Total params: 8,108
Trainable params: 8,108
```

```
Non-trainable params: 0
_________________________________________________________________
None
Model: "model_5"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_107 (InputLayer)       [(None, 19, 3)]           0
_________________________________________________________________
conv1d_212 (Conv1D)          (None, 17, 8)             80
_________________________________________________________________
conv1d_213 (Conv1D)          (None, 15, 8)             200
_________________________________________________________________
dropout_106 (Dropout)        (None, 15, 8)             0
_________________________________________________________________
max_pooling1d_106 (MaxPoolin (None, 7, 8)              0
_________________________________________________________________
flatten_106 (Flatten)        (None, 56)                0
_________________________________________________________________
dense_10 (Dense)             (None, 128)               7296
_________________________________________________________________Model: "model"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_100 (InputLayer)       [(None, 19, 3)]           0
_________________________________________________________________
conv1d_198 (Conv1D)          (None, 17, 8)             80
_________________________________________________________________
conv1d_199 (Conv1D)          (None, 15, 8)             200
_________________________________________________________________
dropout_99 (Dropout)         (None, 15, 8)             0
_________________________________________________________________
max_pooling1d_99 (MaxPooling (None, 7, 8)              0
_________________________________________________________________
flatten_99 (Flatten)         (None, 56)                0
_________________________________________________________________
dense (Dense)                (None, 128)               7296
_________________________________________________________________
dense_1 (Dense)              (None, 20)                2580
=================================================================
Total params: 10,156
Trainable params: 10,156
Non-trainable params: 0
_________________________________________________________________
None
Model: "model_1"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
```

```
=================================================================
input_101 (InputLayer)       [(None, 19, 3)]           0
_________________________________________________________________
conv1d_200 (Conv1D)          (None, 17, 8)             80
_________________________________________________________________
conv1d_201 (Conv1D)          (None, 15, 8)             200
_________________________________________________________________
dropout_100 (Dropout)        (None, 15, 8)             0
_________________________________________________________________
max_pooling1d_100 (MaxPoolin (None, 7, 8)              0
_________________________________________________________________
flatten_100 (Flatten)        (None, 56)                0
_________________________________________________________________
dense_2 (Dense)              (None, 128)               7296
_________________________________________________________________
dense_3 (Dense)              (None, 20)                2580
=================================================================
Total params: 10,156
Trainable params: 10,156
Non-trainable params: 0
_________________________________________________________________
None
Model: "model_2"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_102 (InputLayer)       [(None, 19, 3)]           0
_________________________________________________________________
conv1d_202 (Conv1D)          (None, 17, 8)             80
_________________________________________________________________
conv1d_203 (Conv1D)          (None, 15, 8)             200
_________________________________________________________________
dropout_101 (Dropout)        (None, 15, 8)             0
_________________________________________________________________
max_pooling1d_101 (MaxPoolin (None, 5, 8)              0
_________________________________________________________________
flatten_101 (Flatten)        (None, 40)                0
_________________________________________________________________
dense_4 (Dense)              (None, 128)               5248
_________________________________________________________________
dense_5 (Dense)              (None, 20)                2580
=================================================================
Total params: 8,108
Trainable params: 8,108
Non-trainable params: 0
_________________________________________________________________
None
Model: "model_3"
```

```
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_103 (InputLayer)       [(None, 19, 3)]           0
_________________________________________________________________
conv1d_204 (Conv1D)          (None, 17, 8)             80
_________________________________________________________________
conv1d_205 (Conv1D)          (None, 15, 8)             200
_________________________________________________________________
dropout_102 (Dropout)        (None, 15, 8)             0
_________________________________________________________________
max_pooling1d_102 (MaxPoolin (None, 5, 8)              0
_________________________________________________________________
flatten_102 (Flatten)        (None, 40)                0
_________________________________________________________________
dense_6 (Dense)              (None, 128)               5248
_________________________________________________________________
dense_7 (Dense)              (None, 20)                2580
=================================================================
Total params: 8,108
Trainable params: 8,108
Non-trainable params: 0
_________________________________________________________________
None
Model: "model_4"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_104 (InputLayer)       [(None, 19, 3)]           0
_________________________________________________________________
conv1d_206 (Conv1D)          (None, 17, 8)             80
_________________________________________________________________
conv1d_207 (Conv1D)          (None, 15, 8)             200
_________________________________________________________________
dropout_103 (Dropout)        (None, 15, 8)             0
_________________________________________________________________
max_pooling1d_103 (MaxPoolin (None, 5, 8)              0
_________________________________________________________________
flatten_103 (Flatten)        (None, 40)                0
_________________________________________________________________
dense_8 (Dense)              (None, 128)               5248
_________________________________________________________________
dense_9 (Dense)              (None, 20)                2580
=================================================================
Total params: 8,108
Trainable params: 8,108
Non-trainable params: 0
_________________________________________________________________
```

```
None
Model: "model_5"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_105 (InputLayer)       [(None, 19, 3)]           0
_________________________________________________________________
conv1d_208 (Conv1D)          (None, 17, 8)             80
_________________________________________________________________
conv1d_209 (Conv1D)          (None, 15, 8)             200
_________________________________________________________________
dropout_104 (Dropout)        (None, 15, 8)             0
_________________________________________________________________
max_pooling1d_104 (MaxPoolin (None, 7, 8)              0
_________________________________________________________________
flatten_104 (Flatten)        (None, 56)                0
_________________________________________________________________
dense_10 (Dense)             (None, 128)               7296
_________________________________________________________________

dense_11 (Dense)             (None, 20)                2580
=================================================================
Total params: 10,156
Trainable params: 10,156
Non-trainable params: 0
_________________________________________________________________
None
Model: "model_6"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_108 (InputLayer)       [(None, 19, 3)]           0
_________________________________________________________________
conv1d_214 (Conv1D)          (None, 17, 8)             80
_________________________________________________________________
conv1d_215 (Conv1D)          (None, 15, 8)             200
_________________________________________________________________
dropout_107 (Dropout)        (None, 15, 8)             0
_________________________________________________________________
max_pooling1d_107 (MaxPoolin (None, 7, 8)              0
_________________________________________________________________
flatten_107 (Flatten)        (None, 56)                0
_________________________________________________________________
dense_12 (Dense)             (None, 128)               7296
_________________________________________________________________
dense_13 (Dense)             (None, 20)                2580
=================================================================
Total params: 10,156
```

```
Trainable params: 10,156
Non-trainable params: 0
_________________________________________________________________
None
Model: "model_7"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_109 (InputLayer)       [(None, 19, 3)]           0
_________________________________________________________________
conv1d_216 (Conv1D)          (None, 17, 8)             80
_________________________________________________________________
conv1d_217 (Conv1D)          (None, 15, 8)             200
_________________________________________________________________
dropout_108 (Dropout)        (None, 15, 8)             0
_________________________________________________________________
max_pooling1d_108 (MaxPoolin (None, 7, 8)              0
_________________________________________________________________
flatten_108 (Flatten)        (None, 56)                0
_________________________________________________________________
dense_14 (Dense)             (None, 128)               7296
_________________________________________________________________
dense_15 (Dense)             (None, 20)                2580
=================================================================
Total params: 10,156
Trainable params: 10,156
Non-trainable params: 0
_________________________________________________________________
None
Model: "model_8"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_110 (InputLayer)       [(None, 19, 3)]           0
_________________________________________________________________
conv1d_218 (Conv1D)          (None, 17, 8)             80
_________________________________________________________________
conv1d_219 (Conv1D)          (None, 15, 8)             200
_________________________________________________________________
dropout_109 (Dropout)        (None, 15, 8)             0
_________________________________________________________________
max_pooling1d_109 (MaxPoolin (None, 5, 8)              0
_________________________________________________________________
flatten_109 (Flatten)        (None, 40)                0
_________________________________________________________________
dense_16 (Dense)             (None, 128)               5248
_________________________________________________________________
dense_17 (Dense)             (None, 20)                2580
```

```
=================================================================
Total params: 8,108
Trainable params: 8,108
Non-trainable params: 0
_________________________________________________________________
None
Model: "model_9"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_111 (InputLayer)       [(None, 19, 3)]           0
_________________________________________________________________
conv1d_220 (Conv1D)          (None, 17, 8)             80
_________________________________________________________________
conv1d_221 (Conv1D)          (None, 15, 8)             200
_________________________________________________________________
dropout_110 (Dropout)        (None, 15, 8)             0
_________________________________________________________________
max_pooling1d_110 (MaxPoolin (None, 5, 8)              0
_________________________________________________________________
flatten_110 (Flatten)        (None, 40)                0
_________________________________________________________________
dense_18 (Dense)             (None, 128)               5248
_________________________________________________________________
dense_19 (Dense)             (None, 20)                2580
=================================================================
Total params: 8,108
Trainable params: 8,108
Non-trainable params: 0
_________________________________________________________________
None
Model: "model_10"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_112 (InputLayer)       [(None, 19, 3)]           0
_________________________________________________________________
conv1d_222 (Conv1D)          (None, 17, 16)            160
_________________________________________________________________
conv1d_223 (Conv1D)          (None, 15, 16)            784
_________________________________________________________________
dropout_111 (Dropout)        (None, 15, 16)            0
_________________________________________________________________
max_pooling1d_111 (MaxPoolin (None, 7, 16)             0
_________________________________________________________________
flatten_111 (Flatten)        (None, 112)               0
_________________________________________________________________
dense_20 (Dense)             (None, 128)               14464
```

```
_________________________________________________________________
dense_21 (Dense)             (None, 20)                2580
=================================================================
Total params: 17,988
Trainable params: 17,988
Non-trainable params: 0
_________________________________________________________________
None
Model: "model_11"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_113 (InputLayer)       [(None, 19, 3)]           0
_________________________________________________________________
conv1d_224 (Conv1D)          (None, 17, 16)            160
_________________________________________________________________
conv1d_225 (Conv1D)          (None, 15, 16)            784
_________________________________________________________________
dropout_112 (Dropout)        (None, 15, 16)            0
_________________________________________________________________
max_pooling1d_112 (MaxPoolin (None, 7, 16)             0
dense_11 (Dense)             (None, 20)                2580
=================================================================
Total params: 10,156
Trainable params: 10,156
Non-trainable params: 0
_________________________________________________________________
None
Model: "model_6"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_106 (InputLayer)       [(None, 19, 3)]           0
_________________________________________________________________
conv1d_210 (Conv1D)          (None, 17, 8)             80
_________________________________________________________________
conv1d_211 (Conv1D)          (None, 15, 8)             200
_________________________________________________________________
dropout_105 (Dropout)        (None, 15, 8)             0
_________________________________________________________________
max_pooling1d_105 (MaxPoolin (None, 7, 8)              0
_________________________________________________________________
flatten_105 (Flatten)        (None, 56)                0
_________________________________________________________________
dense_12 (Dense)             (None, 128)               7296
_________________________________________________________________
dense_13 (Dense)             (None, 20)                2580
=================================================================
```

```
Total params: 10,156
Trainable params: 10,156
Non-trainable params: 0
_________________________________________________________________
None
Model: "model_7"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_107 (InputLayer)       [(None, 19, 3)]           0
_________________________________________________________________
conv1d_212 (Conv1D)          (None, 17, 8)             80
_________________________________________________________________
conv1d_213 (Conv1D)          (None, 15, 8)             200
_________________________________________________________________
dropout_106 (Dropout)        (None, 15, 8)             0
_________________________________________________________________
max_pooling1d_106 (MaxPoolin (None, 5, 8)              0
_________________________________________________________________
flatten_106 (Flatten)        (None, 40)                0
_________________________________________________________________
dense_14 (Dense)             (None, 128)               5248
_________________________________________________________________
dense_15 (Dense)             (None, 20)                2580
=================================================================
Total params: 8,108
Trainable params: 8,108
Non-trainable params: 0
_________________________________________________________________
None
Model: "model_8"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_108 (InputLayer)       [(None, 19, 3)]           0
_________________________________________________________________
conv1d_214 (Conv1D)          (None, 17, 8)             80
_________________________________________________________________
conv1d_215 (Conv1D)          (None, 15, 8)             200
_________________________________________________________________
dropout_107 (Dropout)        (None, 15, 8)             0
_________________________________________________________________
max_pooling1d_107 (MaxPoolin (None, 5, 8)              0
_________________________________________________________________
flatten_107 (Flatten)        (None, 40)                0
_________________________________________________________________
dense_16 (Dense)             (None, 128)               5248
_________________________________________________________________
```

```
dense_17 (Dense)             (None, 20)                2580
=================================================================
Total params: 8,108
Trainable params: 8,108
Non-trainable params: 0
_________________________________________________________________
None
Model: "model_9"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_109 (InputLayer)       [(None, 19, 3)]           0
_________________________________________________________________
conv1d_216 (Conv1D)          (None, 17, 8)             80
_________________________________________________________________
conv1d_217 (Conv1D)          (None, 15, 8)             200
_________________________________________________________________
dropout_108 (Dropout)        (None, 15, 8)             0
_________________________________________________________________
max_pooling1d_108 (MaxPoolin (None, 5, 8)              0
_________________________________________________________________
flatten_108 (Flatten)        (None, 40)                0
_________________________________________________________________
dense_18 (Dense)             (None, 128)               5248
_________________________________________________________________
dense_19 (Dense)             (None, 20)                2580
=================================================================
Total params: 8,108
Trainable params: 8,108
Non-trainable params: 0
_________________________________________________________________
None
Model: "model_10"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_110 (InputLayer)       [(None, 19, 3)]           0
_________________________________________________________________
conv1d_218 (Conv1D)          (None, 17, 16)            160
_________________________________________________________________
conv1d_219 (Conv1D)          (None, 15, 16)            784
_________________________________________________________________
dropout_109 (Dropout)        (None, 15, 16)            0
_________________________________________________________________
max_pooling1d_109 (MaxPoolin (None, 7, 16)             0
_________________________________________________________________
flatten_109 (Flatten)        (None, 112)               0
_________________________________________________________________
```

```
dense_20 (Dense)             (None, 128)               14464
_________________________________________________________________
dense_21 (Dense)             (None, 20)                2580
=================================================================
Total params: 17,988
Trainable params: 17,988
Non-trainable params: 0
_________________________________________________________________
None
Model: "model_11"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_111 (InputLayer)       [(None, 19, 3)]           0
_________________________________________________________________
conv1d_220 (Conv1D)          (None, 17, 16)            160
_________________________________________________________________
conv1d_221 (Conv1D)          (None, 15, 16)            784
_________________________________________________________________
dropout_110 (Dropout)        (None, 15, 16)            0
_________________________________________________________________
max_pooling1d_110 (MaxPoolin (None, 7, 16)             0
_________________________________________________________________
flatten_112 (Flatten)        (None, 112)               0
_________________________________________________________________
dense_22 (Dense)             (None, 128)               14464
_________________________________________________________________
dense_23 (Dense)             (None, 20)                2580
=================================================================
Total params: 17,988
Trainable params: 17,988
Non-trainable params: 0
_________________________________________________________________
None
Model: "model_12"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_114 (InputLayer)       [(None, 19, 3)]           0
_________________________________________________________________
conv1d_226 (Conv1D)          (None, 17, 16)            160
_________________________________________________________________
conv1d_227 (Conv1D)          (None, 15, 16)            784
_________________________________________________________________
dropout_113 (Dropout)        (None, 15, 16)            0
_________________________________________________________________
max_pooling1d_113 (MaxPoolin (None, 7, 16)             0
_________________________________________________________________
```

```
flatten_113 (Flatten)        (None, 112)               0
_________________________________________________________________
dense_24 (Dense)             (None, 128)               14464
_________________________________________________________________
dense_25 (Dense)             (None, 20)                2580
=================================================================
Total params: 17,988
Trainable params: 17,988
Non-trainable params: 0
_________________________________________________________________
None
Model: "model_13"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_115 (InputLayer)       [(None, 19, 3)]           0
_________________________________________________________________
conv1d_228 (Conv1D)          (None, 17, 16)            160
_________________________________________________________________
conv1d_229 (Conv1D)          (None, 15, 16)            784
_________________________________________________________________
dropout_114 (Dropout)        (None, 15, 16)            0
_________________________________________________________________
max_pooling1d_114 (MaxPoolin (None, 5, 16)             0
_________________________________________________________________
flatten_114 (Flatten)        (None, 80)                0
_________________________________________________________________
dense_26 (Dense)             (None, 128)               10368
_________________________________________________________________
dense_27 (Dense)             (None, 20)                2580
=================================================================
Total params: 13,892
Trainable params: 13,892
Non-trainable params: 0
_________________________________________________________________
None
Model: "model_14"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_116 (InputLayer)       [(None, 19, 3)]           0
_________________________________________________________________
conv1d_230 (Conv1D)          (None, 17, 16)            160
_________________________________________________________________
conv1d_231 (Conv1D)          (None, 15, 16)            784
_________________________________________________________________
dropout_115 (Dropout)        (None, 15, 16)            0
_________________________________________________________________
```

```
max_pooling1d_115 (MaxPoolin (None, 5, 16)             0
_________________________________________________________________
flatten_115 (Flatten)        (None, 80)                0
_________________________________________________________________
dense_28 (Dense)             (None, 128)               10368
_________________________________________________________________
dense_29 (Dense)             (None, 20)                2580
=================================================================
Total params: 13,892
Trainable params: 13,892
Non-trainable params: 0
_________________________________________________________________
None
Model: "model_15"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_117 (InputLayer)       [(None, 19, 3)]           0
_________________________________________________________________
conv1d_232 (Conv1D)          (None, 17, 16)            160
_________________________________________________________________
conv1d_233 (Conv1D)          (None, 15, 16)            784
_________________________________________________________________
dropout_116 (Dropout)        (None, 15, 16)            0
_________________________________________________________________
max_pooling1d_116 (MaxPoolin (None, 7, 16)             0
_________________________________________________________________
flatten_116 (Flatten)        (None, 112)               0
_________________________________________________________________
dense_30 (Dense)             (None, 128)               14464
_________________________________________________________________
dense_31 (Dense)             (None, 20)                2580
=================================================================
Total params: 17,988
Trainable params: 17,988
Non-trainable params: 0
_________________________________________________________________
None
Model: "model_16"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_118 (InputLayer)       [(None, 19, 3)]           0
_________________________________________________________________
conv1d_234 (Conv1D)          (None, 17, 16)            160
_________________________________________________________________
conv1d_235 (Conv1D)          (None, 15, 16)            784
_________________________________________________________________
```

```
dropout_117 (Dropout)        (None, 15, 16)            0
_________________________________________________________________
max_pooling1d_117 (MaxPoolin (None, 7, 16)             0
_________________________________________________________________
flatten_117 (Flatten)        (None, 112)               0
_________________________________________________________________
dense_32 (Dense)             (None, 128)               14464
_________________________________________________________________
dense_33 (Dense)             (None, 20)                2580
=================================================================
Total params: 17,988
Trainable params: 17,988
Non-trainable params: 0
_________________________________________________________________
None
Model: "model_17"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_119 (InputLayer)       [(None, 19, 3)]           0
_________________________________________________________________
conv1d_236 (Conv1D)          (None, 17, 16)            160
_________________________________________________________________
_________________________________________________________________
flatten_110 (Flatten)        (None, 112)               0
_________________________________________________________________
dense_22 (Dense)             (None, 128)               14464
_________________________________________________________________
dense_23 (Dense)             (None, 20)                2580
=================================================================
Total params: 17,988
Trainable params: 17,988
Non-trainable params: 0
_________________________________________________________________
None
Model: "model_12"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_112 (InputLayer)       [(None, 19, 3)]           0
_________________________________________________________________
conv1d_222 (Conv1D)          (None, 17, 16)            160
_________________________________________________________________
conv1d_223 (Conv1D)          (None, 15, 16)            784
_________________________________________________________________
dropout_111 (Dropout)        (None, 15, 16)            0
_________________________________________________________________
max_pooling1d_111 (MaxPoolin (None, 5, 16)             0
```

```
_________________________________________________________________
flatten_111 (Flatten)        (None, 80)                0
_________________________________________________________________
dense_24 (Dense)             (None, 128)               10368
_________________________________________________________________
dense_25 (Dense)             (None, 20)                2580
=================================================================
Total params: 13,892
Trainable params: 13,892
Non-trainable params: 0
_________________________________________________________________
None
Model: "model_13"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_113 (InputLayer)       [(None, 19, 3)]           0
_________________________________________________________________
conv1d_224 (Conv1D)          (None, 17, 16)            160
_________________________________________________________________
conv1d_225 (Conv1D)          (None, 15, 16)            784
_________________________________________________________________
dropout_112 (Dropout)        (None, 15, 16)            0
_________________________________________________________________
max_pooling1d_112 (MaxPoolin (None, 5, 16)             0
_________________________________________________________________
flatten_112 (Flatten)        (None, 80)                0
_________________________________________________________________
dense_26 (Dense)             (None, 128)               10368
_________________________________________________________________
dense_27 (Dense)             (None, 20)                2580
=================================================================
Total params: 13,892
Trainable params: 13,892
Non-trainable params: 0
_________________________________________________________________
None
Model: "model_14"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_114 (InputLayer)       [(None, 19, 3)]           0
_________________________________________________________________
conv1d_226 (Conv1D)          (None, 17, 16)            160
_________________________________________________________________
conv1d_227 (Conv1D)          (None, 15, 16)            784
_________________________________________________________________
dropout_113 (Dropout)        (None, 15, 16)            0
```

```
_________________________________________________________________
max_pooling1d_113 (MaxPoolin (None, 5, 16)             0
_________________________________________________________________
flatten_113 (Flatten)        (None, 80)                0
_________________________________________________________________
dense_28 (Dense)             (None, 128)               10368
_________________________________________________________________
dense_29 (Dense)             (None, 20)                2580
=================================================================
Total params: 13,892
Trainable params: 13,892
Non-trainable params: 0
_________________________________________________________________
None
Model: "model_15"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_115 (InputLayer)       [(None, 19, 3)]           0
_________________________________________________________________
conv1d_228 (Conv1D)          (None, 17, 16)            160
_________________________________________________________________
conv1d_229 (Conv1D)          (None, 15, 16)            784
_________________________________________________________________
dropout_114 (Dropout)        (None, 15, 16)            0
_________________________________________________________________
max_pooling1d_114 (MaxPoolin (None, 7, 16)             0
_________________________________________________________________
flatten_114 (Flatten)        (None, 112)               0
_________________________________________________________________
dense_30 (Dense)             (None, 128)               14464
_________________________________________________________________
dense_31 (Dense)             (None, 20)                2580
=================================================================
Total params: 17,988
Trainable params: 17,988
Non-trainable params: 0
_________________________________________________________________
None
Model: "model_16"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_116 (InputLayer)       [(None, 19, 3)]           0
_________________________________________________________________
conv1d_230 (Conv1D)          (None, 17, 16)            160
_________________________________________________________________
conv1d_231 (Conv1D)          (None, 15, 16)            784
```

```
_________________________________________________________________
dropout_115 (Dropout)        (None, 15, 16)            0
_________________________________________________________________
max_pooling1d_115 (MaxPoolin (None, 7, 16)             0
_________________________________________________________________
flatten_115 (Flatten)        (None, 112)               0
_________________________________________________________________
dense_32 (Dense)             (None, 128)               14464
_________________________________________________________________
dense_33 (Dense)             (None, 20)                2580
=================================================================
Total params: 17,988
Trainable params: 17,988
Non-trainable params: 0
_________________________________________________________________
None
Model: "model_17"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_117 (InputLayer)       [(None, 19, 3)]           0
_________________________________________________________________
conv1d_232 (Conv1D)          (None, 17, 16)            160
_________________________________________________________________
conv1d_237 (Conv1D)          (None, 15, 16)            784
_________________________________________________________________
dropout_118 (Dropout)        (None, 15, 16)            0
_________________________________________________________________
max_pooling1d_118 (MaxPoolin (None, 7, 16)             0
_________________________________________________________________
flatten_118 (Flatten)        (None, 112)               0
_________________________________________________________________
dense_34 (Dense)             (None, 128)               14464
_________________________________________________________________
dense_35 (Dense)             (None, 20)                2580
=================================================================
Total params: 17,988
Trainable params: 17,988
Non-trainable params: 0
_________________________________________________________________
None
Model: "model_18"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_120 (InputLayer)       [(None, 19, 3)]           0
_________________________________________________________________
conv1d_238 (Conv1D)          (None, 17, 16)            160
```

```
_________________________________________________________________
conv1d_239 (Conv1D)          (None, 15, 16)            784
_________________________________________________________________
dropout_119 (Dropout)        (None, 15, 16)            0
_________________________________________________________________
max_pooling1d_119 (MaxPoolin (None, 5, 16)             0
_________________________________________________________________
flatten_119 (Flatten)        (None, 80)                0
_________________________________________________________________
dense_36 (Dense)             (None, 128)               10368
_________________________________________________________________
dense_37 (Dense)             (None, 20)                2580
=================================================================
Total params: 13,892
Trainable params: 13,892
Non-trainable params: 0
_________________________________________________________________
None
Model: "model_19"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_121 (InputLayer)       [(None, 19, 3)]           0
_________________________________________________________________
conv1d_240 (Conv1D)          (None, 17, 16)            160
_________________________________________________________________
conv1d_241 (Conv1D)          (None, 15, 16)            784
_________________________________________________________________
dropout_120 (Dropout)        (None, 15, 16)            0
_________________________________________________________________
max_pooling1d_120 (MaxPoolin (None, 5, 16)             0
_________________________________________________________________
flatten_120 (Flatten)        (None, 80)                0
_________________________________________________________________
dense_38 (Dense)             (None, 128)               10368
_________________________________________________________________
dense_39 (Dense)             (None, 20)                2580
=================================================================
Total params: 13,892
Trainable params: 13,892
Non-trainable params: 0
_________________________________________________________________
None
Model: "model_20"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_122 (InputLayer)       [(None, 19, 3)]           0
```

```
_________________________________________________________________
conv1d_242 (Conv1D)          (None, 17, 32)            320
_________________________________________________________________
conv1d_243 (Conv1D)          (None, 15, 32)            3104
_________________________________________________________________
dropout_121 (Dropout)        (None, 15, 32)            0
_________________________________________________________________
max_pooling1d_121 (MaxPoolin (None, 7, 32)             0
_________________________________________________________________
flatten_121 (Flatten)        (None, 224)               0
_________________________________________________________________
dense_40 (Dense)             (None, 128)               28800
_________________________________________________________________
dense_41 (Dense)             (None, 20)                2580
=================================================================
Total params: 34,804
Trainable params: 34,804
Non-trainable params: 0
_________________________________________________________________
None
Model: "model_21"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_123 (InputLayer)       [(None, 19, 3)]           0
_________________________________________________________________
conv1d_244 (Conv1D)          (None, 17, 32)            320
_________________________________________________________________
conv1d_245 (Conv1D)          (None, 15, 32)            3104
_________________________________________________________________
dropout_122 (Dropout)        (None, 15, 32)            0
_________________________________________________________________
max_pooling1d_122 (MaxPoolin (None, 7, 32)             0
_________________________________________________________________
flatten_122 (Flatten)        (None, 224)               0
_________________________________________________________________
dense_42 (Dense)             (None, 128)               28800
_________________________________________________________________
dense_43 (Dense)             (None, 20)                2580
=================================================================
Total params: 34,804
Trainable params: 34,804
Non-trainable params: 0
_________________________________________________________________
None
Model: "model_22"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
```

```
=================================================================
input_124 (InputLayer)       [(None, 19, 3)]           0
_________________________________________________________________
conv1d_246 (Conv1D)          (None, 17, 32)            320
_________________________________________________________________
conv1d_247 (Conv1D)          (None, 15, 32)            3104
_________________________________________________________________
dropout_123 (Dropout)        (None, 15, 32)            0
_________________________________________________________________
max_pooling1d_123 (MaxPoolin (None, 7, 32)             0
_________________________________________________________________
flatten_123 (Flatten)        (None, 224)               0
_________________________________________________________________
dense_44 (Dense)             (None, 128)               28800
_________________________________________________________________
dense_45 (Dense)             (None, 20)                2580
=================================================================
Total params: 34,804
Trainable params: 34,804
Non-trainable params: 0
_________________________________________________________________
None
Model: "model_23"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
conv1d_233 (Conv1D)          (None, 15, 16)            784
_________________________________________________________________
dropout_116 (Dropout)        (None, 15, 16)            0
_________________________________________________________________
max_pooling1d_116 (MaxPoolin (None, 5, 16)             0
_________________________________________________________________
flatten_116 (Flatten)        (None, 80)                0
_________________________________________________________________
dense_34 (Dense)             (None, 128)               10368
_________________________________________________________________
dense_35 (Dense)             (None, 20)                2580
=================================================================
Total params: 13,892
Trainable params: 13,892
Non-trainable params: 0
_________________________________________________________________
None
Model: "model_18"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_118 (InputLayer)       [(None, 19, 3)]           0
_________________________________________________________________
```

```
conv1d_234 (Conv1D)          (None, 17, 16)            160
_________________________________________________________________
conv1d_235 (Conv1D)          (None, 15, 16)            784
_________________________________________________________________
dropout_117 (Dropout)        (None, 15, 16)            0
_________________________________________________________________
max_pooling1d_117 (MaxPoolin (None, 5, 16)             0
_________________________________________________________________
flatten_117 (Flatten)        (None, 80)                0
_________________________________________________________________
dense_36 (Dense)             (None, 128)               10368
_________________________________________________________________
dense_37 (Dense)             (None, 20)                2580
=================================================================
Total params: 13,892
Trainable params: 13,892
Non-trainable params: 0
_________________________________________________________________
None
Model: "model_19"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_119 (InputLayer)       [(None, 19, 3)]           0
_________________________________________________________________
conv1d_236 (Conv1D)          (None, 17, 16)            160
_________________________________________________________________
conv1d_237 (Conv1D)          (None, 15, 16)            784
_________________________________________________________________
dropout_118 (Dropout)        (None, 15, 16)            0
_________________________________________________________________
max_pooling1d_118 (MaxPoolin (None, 5, 16)             0
_________________________________________________________________
flatten_118 (Flatten)        (None, 80)                0
_________________________________________________________________
dense_38 (Dense)             (None, 128)               10368
_________________________________________________________________
dense_39 (Dense)             (None, 20)                2580
=================================================================
Total params: 13,892
Trainable params: 13,892
Non-trainable params: 0
_________________________________________________________________
None
Model: "model_20"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
```

```
input_120 (InputLayer)       [(None, 19, 3)]           0
_________________________________________________________________
conv1d_238 (Conv1D)          (None, 17, 32)            320
_________________________________________________________________
conv1d_239 (Conv1D)          (None, 15, 32)            3104
_________________________________________________________________
dropout_119 (Dropout)        (None, 15, 32)            0
_________________________________________________________________
max_pooling1d_119 (MaxPoolin (None, 7, 32)             0
_________________________________________________________________
flatten_119 (Flatten)        (None, 224)               0
_________________________________________________________________
dense_40 (Dense)             (None, 128)               28800
_________________________________________________________________
dense_41 (Dense)             (None, 20)                2580
=================================================================
Total params: 34,804
Trainable params: 34,804
Non-trainable params: 0
_________________________________________________________________
None
Model: "model_21"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_121 (InputLayer)       [(None, 19, 3)]           0
_________________________________________________________________
conv1d_240 (Conv1D)          (None, 17, 32)            320
_________________________________________________________________
conv1d_241 (Conv1D)          (None, 15, 32)            3104
_________________________________________________________________
dropout_120 (Dropout)        (None, 15, 32)            0
_________________________________________________________________
max_pooling1d_120 (MaxPoolin (None, 7, 32)             0
_________________________________________________________________
flatten_120 (Flatten)        (None, 224)               0
_________________________________________________________________
dense_42 (Dense)             (None, 128)               28800
_________________________________________________________________
dense_43 (Dense)             (None, 20)                2580
=================================================================
Total params: 34,804
Trainable params: 34,804
Non-trainable params: 0
_________________________________________________________________
None
Model: "model_22"
_________________________________________________________________
```

```
Layer (type)                 Output Shape              Param #
=================================================================
input_122 (InputLayer)       [(None, 19, 3)]           0
_________________________________________________________________
conv1d_242 (Conv1D)          (None, 17, 32)            320
_________________________________________________________________
conv1d_243 (Conv1D)          (None, 15, 32)            3104
_________________________________________________________________
dropout_121 (Dropout)        (None, 15, 32)            0
_________________________________________________________________
max_pooling1d_121 (MaxPoolin (None, 5, 32)             0
_________________________________________________________________
flatten_121 (Flatten)        (None, 160)               0
_________________________________________________________________
dense_44 (Dense)             (None, 128)               20608
_________________________________________________________________
dense_45 (Dense)             (None, 20)                2580
=================================================================
Total params: 26,612
Trainable params: 26,612
Non-trainable params: 0
_________________________________________________________________
None
Model: "model_23"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_125 (InputLayer)       [(None, 19, 3)]           0
_________________________________________________________________
conv1d_248 (Conv1D)          (None, 17, 32)            320
_________________________________________________________________
conv1d_249 (Conv1D)          (None, 15, 32)            3104
_________________________________________________________________
dropout_124 (Dropout)        (None, 15, 32)            0
_________________________________________________________________
max_pooling1d_124 (MaxPoolin (None, 5, 32)             0
_________________________________________________________________
flatten_124 (Flatten)        (None, 160)               0
_________________________________________________________________
dense_46 (Dense)             (None, 128)               20608
_________________________________________________________________
dense_47 (Dense)             (None, 20)                2580
=================================================================
Total params: 26,612
Trainable params: 26,612
Non-trainable params: 0
_________________________________________________________________
None
```

```
Model: "model_24"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_126 (InputLayer)       [(None, 19, 3)]           0
_________________________________________________________________
conv1d_250 (Conv1D)          (None, 17, 32)            320
_________________________________________________________________
conv1d_251 (Conv1D)          (None, 15, 32)            3104
_________________________________________________________________
dropout_125 (Dropout)        (None, 15, 32)            0
_________________________________________________________________
max_pooling1d_125 (MaxPoolin (None, 5, 32)             0
_________________________________________________________________
flatten_125 (Flatten)        (None, 160)               0
_________________________________________________________________
dense_48 (Dense)             (None, 128)               20608
_________________________________________________________________
dense_49 (Dense)             (None, 20)                2580
=================================================================
Total params: 26,612
Trainable params: 26,612
Non-trainable params: 0
_________________________________________________________________
None
Model: "model_25"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_127 (InputLayer)       [(None, 19, 3)]           0
_________________________________________________________________
conv1d_252 (Conv1D)          (None, 17, 32)            320
_________________________________________________________________
conv1d_253 (Conv1D)          (None, 15, 32)            3104
_________________________________________________________________
dropout_126 (Dropout)        (None, 15, 32)            0
_________________________________________________________________
max_pooling1d_126 (MaxPoolin (None, 7, 32)             0
_________________________________________________________________
flatten_126 (Flatten)        (None, 224)               0
_________________________________________________________________
dense_50 (Dense)             (None, 128)               28800
_________________________________________________________________
dense_51 (Dense)             (None, 20)                2580
=================================================================
Total params: 34,804
Trainable params: 34,804
Non-trainable params: 0
```

```
_________________________________________________________________
None
Model: "model_26"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_128 (InputLayer)       [(None, 19, 3)]           0
_________________________________________________________________
conv1d_254 (Conv1D)          (None, 17, 32)            320
_________________________________________________________________
conv1d_255 (Conv1D)          (None, 15, 32)            3104
_________________________________________________________________
dropout_127 (Dropout)        (None, 15, 32)            0
_________________________________________________________________
max_pooling1d_127 (MaxPoolin (None, 7, 32)             0
_________________________________________________________________
flatten_127 (Flatten)        (None, 224)               0
_________________________________________________________________
dense_52 (Dense)             (None, 128)               28800
_________________________________________________________________
dense_53 (Dense)             (None, 20)                2580
=================================================================
Total params: 34,804
Trainable params: 34,804
Non-trainable params: 0
_________________________________________________________________
None
Model: "model_27"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_129 (InputLayer)       [(None, 19, 3)]           0
_________________________________________________________________
conv1d_256 (Conv1D)          (None, 17, 32)            320
_________________________________________________________________
conv1d_257 (Conv1D)          (None, 15, 32)            3104
_________________________________________________________________
dropout_128 (Dropout)        (None, 15, 32)            0
_________________________________________________________________
max_pooling1d_128 (MaxPoolin (None, 7, 32)             0
_________________________________________________________________
flatten_128 (Flatten)        (None, 224)               0
_________________________________________________________________
dense_54 (Dense)             (None, 128)               28800
_________________________________________________________________
dense_55 (Dense)             (None, 20)                2580
=================================================================
Total params: 34,804
```

```
Trainable params: 34,804
Non-trainable params: 0
_________________________________________________________________
None
Model: "model_28"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_130 (InputLayer)       [(None, 19, 3)]           0
_________________________________________________________________
conv1d_258 (Conv1D)          (None, 17, 32)            320
_________________________________________________________________
conv1d_259 (Conv1D)          (None, 15, 32)            3104
_________________________________________________________________
dropout_129 (Dropout)        (None, 15, 32)            0
_________________________________________________________________
max_pooling1d_129 (MaxPoolin (None, 5, 32)             0
_________________________________________________________________
flatten_129 (Flatten)        (None, 160)               0
_________________________________________________________________
dense_56 (Dense)             (None, 128)               20608
_________________________________________________________________
dense_57 (Dense)             (None, 20)                2580
=================================================================
=================================================================
input_123 (InputLayer)       [(None, 19, 3)]           0
_________________________________________________________________
conv1d_244 (Conv1D)          (None, 17, 32)            320
_________________________________________________________________
conv1d_245 (Conv1D)          (None, 15, 32)            3104
_________________________________________________________________
dropout_122 (Dropout)        (None, 15, 32)            0
_________________________________________________________________
max_pooling1d_122 (MaxPoolin (None, 5, 32)             0
_________________________________________________________________
flatten_122 (Flatten)        (None, 160)               0
_________________________________________________________________
dense_46 (Dense)             (None, 128)               20608
_________________________________________________________________
dense_47 (Dense)             (None, 20)                2580
=================================================================
Total params: 26,612
Trainable params: 26,612
Non-trainable params: 0
_________________________________________________________________
None
Model: "model_24"
_________________________________________________________________
```

```
Layer (type)                 Output Shape              Param #
=================================================================
input_124 (InputLayer)       [(None, 19, 3)]           0
_________________________________________________________________
conv1d_246 (Conv1D)          (None, 17, 32)            320
_________________________________________________________________
conv1d_247 (Conv1D)          (None, 15, 32)            3104
_________________________________________________________________
dropout_123 (Dropout)        (None, 15, 32)            0
_________________________________________________________________
max_pooling1d_123 (MaxPoolin (None, 5, 32)             0
_________________________________________________________________
flatten_123 (Flatten)        (None, 160)               0
_________________________________________________________________
dense_48 (Dense)             (None, 128)               20608
_________________________________________________________________
dense_49 (Dense)             (None, 20)                2580
=================================================================
Total params: 26,612
Trainable params: 26,612
Non-trainable params: 0
_________________________________________________________________
None
Model: "model_25"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_125 (InputLayer)       [(None, 19, 3)]           0
_________________________________________________________________
conv1d_248 (Conv1D)          (None, 17, 32)            320
_________________________________________________________________
conv1d_249 (Conv1D)          (None, 15, 32)            3104
_________________________________________________________________
dropout_124 (Dropout)        (None, 15, 32)            0
_________________________________________________________________
max_pooling1d_124 (MaxPoolin (None, 7, 32)             0
_________________________________________________________________
flatten_124 (Flatten)        (None, 224)               0
_________________________________________________________________
dense_50 (Dense)             (None, 128)               28800
_________________________________________________________________
dense_51 (Dense)             (None, 20)                2580
=================================================================
Total params: 34,804
Trainable params: 34,804
Non-trainable params: 0
_________________________________________________________________
None
```

```
Model: "model_26"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_126 (InputLayer)       [(None, 19, 3)]           0
_________________________________________________________________
conv1d_250 (Conv1D)          (None, 17, 32)            320
_________________________________________________________________
conv1d_251 (Conv1D)          (None, 15, 32)            3104
_________________________________________________________________
dropout_125 (Dropout)        (None, 15, 32)            0
_________________________________________________________________
max_pooling1d_125 (MaxPoolin (None, 7, 32)             0
_________________________________________________________________
flatten_125 (Flatten)        (None, 224)               0
_________________________________________________________________
dense_52 (Dense)             (None, 128)               28800
_________________________________________________________________
dense_53 (Dense)             (None, 20)                2580
=================================================================
Total params: 34,804
Trainable params: 34,804
Non-trainable params: 0
_________________________________________________________________
None
Model: "model_27"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_127 (InputLayer)       [(None, 19, 3)]           0
_________________________________________________________________
conv1d_252 (Conv1D)          (None, 17, 32)            320
_________________________________________________________________
conv1d_253 (Conv1D)          (None, 15, 32)            3104
_________________________________________________________________
dropout_126 (Dropout)        (None, 15, 32)            0
_________________________________________________________________
max_pooling1d_126 (MaxPoolin (None, 5, 32)             0
_________________________________________________________________
flatten_126 (Flatten)        (None, 160)               0
_________________________________________________________________
dense_54 (Dense)             (None, 128)               20608
_________________________________________________________________
dense_55 (Dense)             (None, 20)                2580
=================================================================
Total params: 26,612
Trainable params: 26,612
Non-trainable params: 0
```

```
_________________________________________________________________
None
Model: "model_28"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_128 (InputLayer)       [(None, 19, 3)]           0
_________________________________________________________________
conv1d_254 (Conv1D)          (None, 17, 32)            320
_________________________________________________________________
conv1d_255 (Conv1D)          (None, 15, 32)            3104
_________________________________________________________________
dropout_127 (Dropout)        (None, 15, 32)            0
_________________________________________________________________
max_pooling1d_127 (MaxPoolin (None, 5, 32)             0
_________________________________________________________________
flatten_127 (Flatten)        (None, 160)               0
_________________________________________________________________
dense_56 (Dense)             (None, 128)               20608
_________________________________________________________________
dense_57 (Dense)             (None, 20)                2580
=================================================================
Total params: 26,612
Trainable params: 26,612
Non-trainable params: 0
_________________________________________________________________
None
Model: "model_29"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_131 (InputLayer)       [(None, 19, 3)]           0
_________________________________________________________________
conv1d_260 (Conv1D)          (None, 17, 32)            320
_________________________________________________________________
conv1d_261 (Conv1D)          (None, 15, 32)            3104
_________________________________________________________________
dropout_130 (Dropout)        (None, 15, 32)            0
_________________________________________________________________
max_pooling1d_130 (MaxPoolin (None, 5, 32)             0
_________________________________________________________________
flatten_130 (Flatten)        (None, 160)               0
_________________________________________________________________
dense_58 (Dense)             (None, 128)               20608
_________________________________________________________________
dense_59 (Dense)             (None, 20)                2580
=================================================================
Total params: 26,612
```

```
Trainable params: 26,612
Non-trainable params: 0
_________________________________________________________________
None
Model: "model_30"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_132 (InputLayer)       [(None, 19, 3)]           0
_________________________________________________________________
conv1d_262 (Conv1D)          (None, 17, 64)            640
_________________________________________________________________
conv1d_263 (Conv1D)          (None, 15, 64)            12352
_________________________________________________________________
dropout_131 (Dropout)        (None, 15, 64)            0
_________________________________________________________________
max_pooling1d_131 (MaxPoolin (None, 7, 64)             0
_________________________________________________________________
flatten_131 (Flatten)        (None, 448)               0
_________________________________________________________________
dense_60 (Dense)             (None, 128)               57472
_________________________________________________________________
dense_61 (Dense)             (None, 20)                2580
=================================================================
Total params: 73,044
Trainable params: 73,044
Non-trainable params: 0
_________________________________________________________________
None
Model: "model_31"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_133 (InputLayer)       [(None, 19, 3)]           0
_________________________________________________________________
conv1d_264 (Conv1D)          (None, 17, 64)            640
_________________________________________________________________
conv1d_265 (Conv1D)          (None, 15, 64)            12352
_________________________________________________________________
dropout_132 (Dropout)        (None, 15, 64)            0
_________________________________________________________________
max_pooling1d_132 (MaxPoolin (None, 7, 64)             0
_________________________________________________________________
flatten_132 (Flatten)        (None, 448)               0
_________________________________________________________________
dense_62 (Dense)             (None, 128)               57472
_________________________________________________________________
dense_63 (Dense)             (None, 20)                2580
```

```
=================================================================
Total params: 73,044
Trainable params: 73,044
Non-trainable params: 0
_________________________________________________________________
None
Model: "model_32"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_134 (InputLayer)       [(None, 19, 3)]           0
_________________________________________________________________
conv1d_266 (Conv1D)          (None, 17, 64)            640
_________________________________________________________________
conv1d_267 (Conv1D)          (None, 15, 64)            12352
_________________________________________________________________
dropout_133 (Dropout)        (None, 15, 64)            0
_________________________________________________________________
max_pooling1d_133 (MaxPoolin (None, 7, 64)             0
_________________________________________________________________
flatten_133 (Flatten)        (None, 448)               0
_________________________________________________________________
dense_64 (Dense)             (None, 128)               57472
_________________________________________________________________
dense_65 (Dense)             (None, 20)                2580
=================================================================
Total params: 73,044
Trainable params: 73,044
Non-trainable params: 0
_________________________________________________________________
None

/usr/local/lib/python3.8/site-
packages/joblib/externals/loky/process_executor.py:688: UserWarning: A worker
stopped while some jobs were given to the executor. This can be caused by a too
short worker timeout or by a memory leak.
  warnings.warn(
2021-11-15 22:27:22.791997: I tensorflow/core/platform/cpu_feature_guard.cc:142]
This TensorFlow binary is optimized with oneAPI Deep Neural Network Library
(oneDNN) to use the following CPU instructions in performance-critical
operations:  AVX2 AVX512F FMA
To enable them in other operations, rebuild TensorFlow with the appropriate
compiler flags.
2021-11-15 22:27:23.105732: I
tensorflow/compiler/mlir/mlir_graph_optimization_pass.cc:185] None of the MLIR
Optimization Passes are enabled (registered 2)

Total params: 26,612
Trainable params: 26,612
```

```
Non-trainable params: 0
_________________________________________________________________
None
Model: "model_29"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_129 (InputLayer)       [(None, 19, 3)]           0
_________________________________________________________________
conv1d_256 (Conv1D)          (None, 17, 32)            320
_________________________________________________________________
conv1d_257 (Conv1D)          (None, 15, 32)            3104
_________________________________________________________________
dropout_128 (Dropout)        (None, 15, 32)            0
_________________________________________________________________
max_pooling1d_128 (MaxPoolin (None, 5, 32)             0
_________________________________________________________________
flatten_128 (Flatten)        (None, 160)               0
_________________________________________________________________
dense_58 (Dense)             (None, 128)               20608
_________________________________________________________________
dense_59 (Dense)             (None, 20)                2580
=================================================================
Total params: 26,612
Trainable params: 26,612
Non-trainable params: 0
_________________________________________________________________
None
Model: "model_30"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_130 (InputLayer)       [(None, 19, 3)]           0
_________________________________________________________________
conv1d_258 (Conv1D)          (None, 17, 64)            640
_________________________________________________________________
conv1d_259 (Conv1D)          (None, 15, 64)            12352
_________________________________________________________________
dropout_129 (Dropout)        (None, 15, 64)            0
_________________________________________________________________
max_pooling1d_129 (MaxPoolin (None, 7, 64)             0
_________________________________________________________________
flatten_129 (Flatten)        (None, 448)               0
_________________________________________________________________
dense_60 (Dense)             (None, 128)               57472
_________________________________________________________________
dense_61 (Dense)             (None, 20)                2580
=================================================================
```

```
Total params: 73,044
Trainable params: 73,044
Non-trainable params: 0
_________________________________________________________________
None
Model: "model_31"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_131 (InputLayer)       [(None, 19, 3)]           0
_________________________________________________________________
conv1d_260 (Conv1D)          (None, 17, 64)            640
_________________________________________________________________
conv1d_261 (Conv1D)          (None, 15, 64)            12352
_________________________________________________________________
dropout_130 (Dropout)        (None, 15, 64)            0
_________________________________________________________________
max_pooling1d_130 (MaxPoolin (None, 7, 64)             0
_________________________________________________________________
flatten_130 (Flatten)        (None, 448)               0
_________________________________________________________________
dense_62 (Dense)             (None, 128)               57472
_________________________________________________________________
dense_63 (Dense)             (None, 20)                2580
=================================================================
Total params: 73,044
Trainable params: 73,044
Non-trainable params: 0
_________________________________________________________________
None
Model: "model_32"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_132 (InputLayer)       [(None, 19, 3)]           0
_________________________________________________________________
conv1d_262 (Conv1D)          (None, 17, 64)            640
_________________________________________________________________
conv1d_263 (Conv1D)          (None, 15, 64)            12352
_________________________________________________________________
dropout_131 (Dropout)        (None, 15, 64)            0
_________________________________________________________________
max_pooling1d_131 (MaxPoolin (None, 5, 64)             0
_________________________________________________________________
flatten_131 (Flatten)        (None, 320)               0
_________________________________________________________________
dense_64 (Dense)             (None, 128)               41088
_________________________________________________________________
```

```
dense_65 (Dense)             (None, 20)                2580
=================================================================
Total params: 56,660
Trainable params: 56,660
Non-trainable params: 0
_________________________________________________________________
None
Model: "model_33"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_133 (InputLayer)       [(None, 19, 3)]           0
_________________________________________________________________
conv1d_264 (Conv1D)          (None, 17, 64)            640
_________________________________________________________________
conv1d_265 (Conv1D)          (None, 15, 64)            12352
_________________________________________________________________
dropout_132 (Dropout)        (None, 15, 64)            0
_________________________________________________________________
max_pooling1d_132 (MaxPoolin (None, 5, 64)             0
_________________________________________________________________
flatten_132 (Flatten)        (None, 320)               0
_________________________________________________________________
dense_66 (Dense)             (None, 128)               41088
_________________________________________________________________
dense_67 (Dense)             (None, 20)                2580
=================================================================
Total params: 56,660
Trainable params: 56,660
Non-trainable params: 0
_________________________________________________________________
None
Model: "model_34"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_134 (InputLayer)       [(None, 19, 3)]           0
_________________________________________________________________
conv1d_266 (Conv1D)          (None, 17, 64)            640
_________________________________________________________________
conv1d_267 (Conv1D)          (None, 15, 64)            12352
_________________________________________________________________
dropout_133 (Dropout)        (None, 15, 64)            0
_________________________________________________________________
max_pooling1d_133 (MaxPoolin (None, 5, 64)             0
_________________________________________________________________
flatten_133 (Flatten)        (None, 320)               0
Model: "model"
```

```
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_1 (InputLayer)         [(None, 19, 3)]           0
_________________________________________________________________
conv1d (Conv1D)              (None, 17, 64)            640
_________________________________________________________________
conv1d_1 (Conv1D)            (None, 15, 64)            12352
_________________________________________________________________
dropout (Dropout)            (None, 15, 64)            0
_________________________________________________________________
max_pooling1d (MaxPooling1D) (None, 5, 64)             0
_________________________________________________________________
flatten (Flatten)            (None, 320)               0
_________________________________________________________________
dense (Dense)                (None, 128)               41088
_________________________________________________________________
dense_1 (Dense)              (None, 20)                2580
=================================================================
Total params: 56,660
Trainable params: 56,660
Non-trainable params: 0
_________________________________________________________________
None
Model: "model_1"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_2 (InputLayer)         [(None, 19, 3)]           0
_________________________________________________________________
conv1d_2 (Conv1D)            (None, 17, 64)            640
_________________________________________________________________
conv1d_3 (Conv1D)            (None, 15, 64)            12352
_________________________________________________________________
dropout_1 (Dropout)          (None, 15, 64)            0
_________________________________________________________________
max_pooling1d_1 (MaxPooling1 (None, 5, 64)             0
_________________________________________________________________
flatten_1 (Flatten)          (None, 320)               0
_________________________________________________________________
dense_2 (Dense)              (None, 128)               41088
_________________________________________________________________
dense_3 (Dense)              (None, 20)                2580
=================================================================
Total params: 56,660
Trainable params: 56,660
Non-trainable params: 0
_________________________________________________________________
```

```
None
Model: "model_2"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_3 (InputLayer)         [(None, 19, 3)]           0
_________________________________________________________________
conv1d_4 (Conv1D)            (None, 17, 64)            640
_________________________________________________________________
conv1d_5 (Conv1D)            (None, 15, 64)            12352
_________________________________________________________________
dropout_2 (Dropout)          (None, 15, 64)            0
_________________________________________________________________
max_pooling1d_2 (MaxPooling1 (None, 7, 64)             0
_________________________________________________________________
flatten_2 (Flatten)          (None, 448)               0
_________________________________________________________________
dense_4 (Dense)              (None, 128)               57472
_________________________________________________________________
dense_5 (Dense)              (None, 20)                2580
=================================================================
Total params: 73,044
Trainable params: 73,044
Non-trainable params: 0
_________________________________________________________________
None
Model: "model_3"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_4 (InputLayer)         [(None, 19, 3)]           0
_________________________________________________________________
conv1d_6 (Conv1D)            (None, 17, 64)            640
_________________________________________________________________
conv1d_7 (Conv1D)            (None, 15, 64)            12352
_________________________________________________________________
dropout_3 (Dropout)          (None, 15, 64)            0
_________________________________________________________________
max_pooling1d_3 (MaxPooling1 (None, 7, 64)             0
_________________________________________________________________
flatten_3 (Flatten)          (None, 448)               0
_________________________________________________________________
dense_6 (Dense)              (None, 128)               57472
_________________________________________________________________
dense_7 (Dense)              (None, 20)                2580
=================================================================
Total params: 73,044
Trainable params: 73,044
```

```
Non-trainable params: 0
_________________________________________________________________
None
Model: "model_4"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_5 (InputLayer)         [(None, 19, 3)]           0
_________________________________________________________________
conv1d_8 (Conv1D)            (None, 17, 64)            640
_________________________________________________________________
conv1d_9 (Conv1D)            (None, 15, 64)            12352
_________________________________________________________________
dropout_4 (Dropout)          (None, 15, 64)            0
_________________________________________________________________
max_pooling1d_4 (MaxPooling1 (None, 5, 64)             0
_________________________________________________________________
flatten_4 (Flatten)          (None, 320)               0
_________________________________________________________________
dense_8 (Dense)              (None, 128)               41088
_________________________________________________________________
dense_9 (Dense)              (None, 20)                2580
=================================================================
Total params: 56,660
Trainable params: 56,660
Non-trainable params: 0
_________________________________________________________________
None
Model: "model_5"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_6 (InputLayer)         [(None, 19, 3)]           0
_________________________________________________________________
conv1d_10 (Conv1D)           (None, 17, 64)            640
_________________________________________________________________
conv1d_11 (Conv1D)           (None, 15, 64)            12352
_________________________________________________________________
dropout_5 (Dropout)          (None, 15, 64)            0
_________________________________________________________________
max_pooling1d_5 (MaxPooling1 (None, 5, 64)             0
_________________________________________________________________
flatten_5 (Flatten)          (None, 320)               0
_________________________________________________________________
dense_10 (Dense)             (None, 128)               41088
_________________________________________________________________
dense_68 (Dense)             (None, 128)               41088
_________________________________________________________________
```

```
dense_69 (Dense)             (None, 20)                2580
=================================================================
Total params: 56,660
Trainable params: 56,660
Non-trainable params: 0
_________________________________________________________________
None
Model: "model_35"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_135 (InputLayer)       [(None, 19, 3)]           0
_________________________________________________________________
conv1d_268 (Conv1D)          (None, 17, 64)            640
_________________________________________________________________
conv1d_269 (Conv1D)          (None, 15, 64)            12352
_________________________________________________________________
dropout_134 (Dropout)        (None, 15, 64)            0
_________________________________________________________________
max_pooling1d_134 (MaxPoolin (None, 7, 64)             0
_________________________________________________________________
flatten_134 (Flatten)        (None, 448)               0
_________________________________________________________________
dense_70 (Dense)             (None, 128)               57472
_________________________________________________________________
dense_71 (Dense)             (None, 20)                2580
=================================================================
Total params: 73,044
Trainable params: 73,044
Non-trainable params: 0
_________________________________________________________________
None
Model: "model_36"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_136 (InputLayer)       [(None, 19, 3)]           0
_________________________________________________________________
conv1d_270 (Conv1D)          (None, 17, 64)            640
_________________________________________________________________
conv1d_271 (Conv1D)          (None, 15, 64)            12352
_________________________________________________________________
dropout_135 (Dropout)        (None, 15, 64)            0
_________________________________________________________________
max_pooling1d_135 (MaxPoolin (None, 7, 64)             0
_________________________________________________________________
flatten_135 (Flatten)        (None, 448)               0
_________________________________________________________________
```

```
dense_72 (Dense)             (None, 128)               57472
_________________________________________________________________
dense_73 (Dense)             (None, 20)                2580
=================================================================
Total params: 73,044
Trainable params: 73,044
Non-trainable params: 0
_________________________________________________________________
None
Model: "model_37"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_137 (InputLayer)       [(None, 19, 3)]           0
_________________________________________________________________
conv1d_272 (Conv1D)          (None, 17, 64)            640
_________________________________________________________________
conv1d_273 (Conv1D)          (None, 15, 64)            12352
_________________________________________________________________
dropout_136 (Dropout)        (None, 15, 64)            0
_________________________________________________________________
max_pooling1d_136 (MaxPoolin (None, 7, 64)             0
_________________________________________________________________
flatten_136 (Flatten)        (None, 448)               0
_________________________________________________________________
dense_74 (Dense)             (None, 128)               57472
_________________________________________________________________
dense_75 (Dense)             (None, 20)                2580
=================================================================
Total params: 73,044
Trainable params: 73,044
Non-trainable params: 0
_________________________________________________________________
None
Model: "model_38"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_138 (InputLayer)       [(None, 19, 3)]           0
_________________________________________________________________
conv1d_274 (Conv1D)          (None, 17, 64)            640
_________________________________________________________________
conv1d_275 (Conv1D)          (None, 15, 64)            12352
_________________________________________________________________
dropout_137 (Dropout)        (None, 15, 64)            0
_________________________________________________________________
max_pooling1d_137 (MaxPoolin (None, 5, 64)             0
_________________________________________________________________
```

```
flatten_137 (Flatten)        (None, 320)               0
_________________________________________________________________
dense_76 (Dense)             (None, 128)               41088
_________________________________________________________________
dense_77 (Dense)             (None, 20)                2580
=================================================================
Total params: 56,660
Trainable params: 56,660
Non-trainable params: 0
_________________________________________________________________
None
Model: "model_39"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_139 (InputLayer)       [(None, 19, 3)]           0
_________________________________________________________________
conv1d_276 (Conv1D)          (None, 17, 64)            640
_________________________________________________________________
conv1d_277 (Conv1D)          (None, 15, 64)            12352
_________________________________________________________________
dropout_138 (Dropout)        (None, 15, 64)            0
_________________________________________________________________
max_pooling1d_138 (MaxPoolin (None, 5, 64)             0
_________________________________________________________________
flatten_138 (Flatten)        (None, 320)               0
_________________________________________________________________
dense_78 (Dense)             (None, 128)               41088
_________________________________________________________________
dense_79 (Dense)             (None, 20)                2580
=================================================================
Total params: 56,660
Trainable params: 56,660
Non-trainable params: 0
_________________________________________________________________
None
Model: "model_40"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_140 (InputLayer)       [(None, 19, 3)]           0
_________________________________________________________________
conv1d_278 (Conv1D)          (None, 17, 128)           1280
_________________________________________________________________
conv1d_279 (Conv1D)          (None, 15, 128)           49280
_________________________________________________________________
_________________________________________________________________
dense_11 (Dense)             (None, 20)                2580
```

```
=================================================================
Total params: 56,660
Trainable params: 56,660
Non-trainable params: 0
_________________________________________________________________
None
Model: "model_6"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_7 (InputLayer)         [(None, 19, 3)]           0
_________________________________________________________________
conv1d_12 (Conv1D)           (None, 17, 64)            640
_________________________________________________________________
conv1d_13 (Conv1D)           (None, 15, 64)            12352
_________________________________________________________________
dropout_6 (Dropout)          (None, 15, 64)            0
_________________________________________________________________
max_pooling1d_6 (MaxPooling1 (None, 5, 64)             0
_________________________________________________________________
flatten_6 (Flatten)          (None, 320)               0
_________________________________________________________________
dense_12 (Dense)             (None, 128)               41088
_________________________________________________________________
dense_13 (Dense)             (None, 20)                2580
=================================================================
Total params: 56,660
Trainable params: 56,660
Non-trainable params: 0
_________________________________________________________________
None
Model: "model_7"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_8 (InputLayer)         [(None, 19, 3)]           0
_________________________________________________________________
conv1d_14 (Conv1D)           (None, 17, 128)           1280
_________________________________________________________________
conv1d_15 (Conv1D)           (None, 15, 128)           49280
_________________________________________________________________
dropout_7 (Dropout)          (None, 15, 128)           0
_________________________________________________________________
max_pooling1d_7 (MaxPooling1 (None, 7, 128)            0
_________________________________________________________________
flatten_7 (Flatten)          (None, 896)               0
_________________________________________________________________
dense_14 (Dense)             (None, 128)               114816
```

```
_________________________________________________________________
dense_15 (Dense)             (None, 20)                2580
=================================================================
Total params: 167,956
Trainable params: 167,956
Non-trainable params: 0
_________________________________________________________________
None
Model: "model_8"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_9 (InputLayer)         [(None, 19, 3)]           0
_________________________________________________________________
conv1d_16 (Conv1D)           (None, 17, 128)           1280
_________________________________________________________________
conv1d_17 (Conv1D)           (None, 15, 128)           49280
_________________________________________________________________
dropout_8 (Dropout)          (None, 15, 128)           0
_________________________________________________________________
max_pooling1d_8 (MaxPooling1 (None, 7, 128)            0
_________________________________________________________________
flatten_8 (Flatten)          (None, 896)               0
_________________________________________________________________
dense_16 (Dense)             (None, 128)               114816
_________________________________________________________________
dense_17 (Dense)             (None, 20)                2580
=================================================================
Total params: 167,956
Trainable params: 167,956
Non-trainable params: 0
_________________________________________________________________
None
Model: "model_9"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_10 (InputLayer)        [(None, 19, 3)]           0
_________________________________________________________________
conv1d_18 (Conv1D)           (None, 17, 128)           1280
_________________________________________________________________
conv1d_19 (Conv1D)           (None, 15, 128)           49280
_________________________________________________________________
dropout_9 (Dropout)          (None, 15, 128)           0
_________________________________________________________________
max_pooling1d_9 (MaxPooling1 (None, 5, 128)            0
_________________________________________________________________
flatten_9 (Flatten)          (None, 640)               0
```

```
_________________________________________________________________
dense_18 (Dense)             (None, 128)               82048
_________________________________________________________________
dense_19 (Dense)             (None, 20)                2580
=================================================================
Total params: 135,188
Trainable params: 135,188
Non-trainable params: 0
_________________________________________________________________
None
Model: "model_10"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_11 (InputLayer)        [(None, 19, 3)]           0
_________________________________________________________________
conv1d_20 (Conv1D)           (None, 17, 128)           1280
_________________________________________________________________
conv1d_21 (Conv1D)           (None, 15, 128)           49280
_________________________________________________________________
dropout_10 (Dropout)         (None, 15, 128)           0
_________________________________________________________________
max_pooling1d_10 (MaxPooling (None, 5, 128)            0
_________________________________________________________________
flatten_10 (Flatten)         (None, 640)               0
_________________________________________________________________
dense_20 (Dense)             (None, 128)               82048
_________________________________________________________________
dense_21 (Dense)             (None, 20)                2580
=================================================================
Total params: 135,188
Trainable params: 135,188
Non-trainable params: 0
_________________________________________________________________
None
Model: "model_11"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_12 (InputLayer)        [(None, 19, 3)]           0
_________________________________________________________________
conv1d_22 (Conv1D)           (None, 17, 128)           1280
_________________________________________________________________
conv1d_23 (Conv1D)           (None, 15, 128)           49280
_________________________________________________________________
dropout_11 (Dropout)         (None, 15, 128)           0
_________________________________________________________________
dropout_139 (Dropout)        (None, 15, 128)           0
```

```
_________________________________________________________________
max_pooling1d_139 (MaxPoolin (None, 7, 128)            0
_________________________________________________________________
flatten_139 (Flatten)        (None, 896)               0
_________________________________________________________________
dense_80 (Dense)             (None, 128)               114816
_________________________________________________________________
dense_81 (Dense)             (None, 20)                2580
=================================================================
Total params: 167,956
Trainable params: 167,956
Non-trainable params: 0
_________________________________________________________________
None
Model: "model_41"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_141 (InputLayer)       [(None, 19, 3)]           0
_________________________________________________________________
conv1d_280 (Conv1D)          (None, 17, 128)           1280
_________________________________________________________________
conv1d_281 (Conv1D)          (None, 15, 128)           49280
_________________________________________________________________
dropout_140 (Dropout)        (None, 15, 128)           0
_________________________________________________________________
max_pooling1d_140 (MaxPoolin (None, 7, 128)            0
_________________________________________________________________
flatten_140 (Flatten)        (None, 896)               0
_________________________________________________________________
dense_82 (Dense)             (None, 128)               114816
_________________________________________________________________
dense_83 (Dense)             (None, 20)                2580
=================================================================
Total params: 167,956
Trainable params: 167,956
Non-trainable params: 0
_________________________________________________________________
None
Model: "model_42"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_142 (InputLayer)       [(None, 19, 3)]           0
_________________________________________________________________
conv1d_282 (Conv1D)          (None, 17, 128)           1280
_________________________________________________________________
conv1d_283 (Conv1D)          (None, 15, 128)           49280
```

```
_________________________________________________________________
dropout_141 (Dropout)        (None, 15, 128)           0
_________________________________________________________________
max_pooling1d_141 (MaxPoolin (None, 7, 128)            0
_________________________________________________________________
flatten_141 (Flatten)        (None, 896)               0
_________________________________________________________________
dense_84 (Dense)             (None, 128)               114816
_________________________________________________________________
dense_85 (Dense)             (None, 20)                2580
=================================================================
Total params: 167,956
Trainable params: 167,956
Non-trainable params: 0
_________________________________________________________________
None
Model: "model_43"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_143 (InputLayer)       [(None, 19, 3)]           0
_________________________________________________________________
conv1d_284 (Conv1D)          (None, 17, 128)           1280
_________________________________________________________________
conv1d_285 (Conv1D)          (None, 15, 128)           49280
_________________________________________________________________
dropout_142 (Dropout)        (None, 15, 128)           0
_________________________________________________________________
max_pooling1d_142 (MaxPoolin (None, 5, 128)            0
_________________________________________________________________
flatten_142 (Flatten)        (None, 640)               0
_________________________________________________________________
dense_86 (Dense)             (None, 128)               82048
_________________________________________________________________
dense_87 (Dense)             (None, 20)                2580
=================================================================
Total params: 135,188
Trainable params: 135,188
Non-trainable params: 0
_________________________________________________________________
None
Model: "model_44"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_144 (InputLayer)       [(None, 19, 3)]           0
_________________________________________________________________
conv1d_286 (Conv1D)          (None, 17, 128)           1280
```

```
_________________________________________________________________
conv1d_287 (Conv1D)          (None, 15, 128)           49280
_________________________________________________________________
dropout_143 (Dropout)        (None, 15, 128)           0
_________________________________________________________________
max_pooling1d_143 (MaxPoolin (None, 5, 128)            0
_________________________________________________________________
flatten_143 (Flatten)        (None, 640)               0
_________________________________________________________________
dense_88 (Dense)             (None, 128)               82048
_________________________________________________________________
dense_89 (Dense)             (None, 20)                2580
=================================================================
Total params: 135,188
Trainable params: 135,188
Non-trainable params: 0
_________________________________________________________________
None
Model: "model_45"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_145 (InputLayer)       [(None, 19, 3)]           0
_________________________________________________________________
conv1d_288 (Conv1D)          (None, 17, 128)           1280
_________________________________________________________________
conv1d_289 (Conv1D)          (None, 15, 128)           49280
_________________________________________________________________
dropout_144 (Dropout)        (None, 15, 128)           0
_________________________________________________________________
max_pooling1d_144 (MaxPoolin (None, 7, 128)            0
_________________________________________________________________
flatten_144 (Flatten)        (None, 896)               0
_________________________________________________________________
dense_90 (Dense)             (None, 128)               114816
_________________________________________________________________
dense_91 (Dense)             (None, 20)                2580
=================================================================
Total params: 167,956
Trainable params: 167,956
Non-trainable params: 0
_________________________________________________________________
None
Model: "model_46"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_146 (InputLayer)       [(None, 19, 3)]           0
```

```
Model: "model"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_3 (InputLayer)         [(None, 19, 3)]           0
_________________________________________________________________
conv1d_4 (Conv1D)            (None, 17, 64)            640
_________________________________________________________________
conv1d_5 (Conv1D)            (None, 15, 64)            12352
_________________________________________________________________
dropout_2 (Dropout)          (None, 15, 64)            0
_________________________________________________________________
max_pooling1d_2 (MaxPooling1 (None, 5, 64)             0
_________________________________________________________________
flatten_2 (Flatten)          (None, 320)               0
_________________________________________________________________
dense (Dense)                (None, 128)               41088
_________________________________________________________________
dense_1 (Dense)              (None, 20)                2580
=================================================================
Total params: 56,660
Trainable params: 56,660
Non-trainable params: 0
_________________________________________________________________
None

2021-11-15 22:35:57.779725: I
tensorflow/compiler/mlir/mlir_graph_optimization_pass.cc:185] None of the MLIR
Optimization Passes are enabled (registered 2)

Best: 0.923892 using {'batch_size': 19, 'dropout_rate': 0.5, 'epochs': 128,
'filters': 64, 'kernel_size': [3, 5, 7], 'pool_size': 3, 'units': 128}
accuracy: 0.865617 (0.067927) train time: 13.102384 (1.098246) score time:
0.253009 (0.077575) with: {'batch_size': 19, 'dropout_rate': 0.5, 'epochs': 128,
'filters': 8, 'kernel_size': [3, 5, 7], 'pool_size': 2, 'units': 128}
accuracy: 0.884282 (0.041610) train time: 12.853946 (1.051627) score time:
0.268014 (0.101953) with: {'batch_size': 19, 'dropout_rate': 0.5, 'epochs': 128,
'filters': 8, 'kernel_size': [3, 5, 7], 'pool_size': 3, 'units': 128}
accuracy: 0.888071 (0.043372) train time: 13.104415 (1.116149) score time:
0.190640 (0.007689) with: {'batch_size': 19, 'dropout_rate': 0.5, 'epochs': 128,
'filters': 8, 'kernel_size': [3, 5, 11], 'pool_size': 2, 'units': 128}
accuracy: 0.865317 (0.059250) train time: 13.475104 (0.981933) score time:
0.195375 (0.010975) with: {'batch_size': 19, 'dropout_rate': 0.5, 'epochs': 128,
'filters': 8, 'kernel_size': [3, 5, 11], 'pool_size': 3, 'units': 128}
accuracy: 0.903793 (0.057140) train time: 15.309269 (1.362194) score time:
0.198080 (0.010809) with: {'batch_size': 19, 'dropout_rate': 0.5, 'epochs': 128,
'filters': 16, 'kernel_size': [3, 5, 7], 'pool_size': 2, 'units': 128}
accuracy: 0.890175 (0.050085) train time: 15.208556 (1.295592) score time:
0.200384 (0.013522) with: {'batch_size': 19, 'dropout_rate': 0.5, 'epochs': 128,
```

```
'filters': 16, 'kernel_size': [3, 5, 7], 'pool_size': 3, 'units': 128}
accuracy: 0.899480 (0.064419) train time: 15.410845 (1.290705) score time:
0.198778 (0.008156) with: {'batch_size': 19, 'dropout_rate': 0.5, 'epochs': 128,
'filters': 16, 'kernel_size': [3, 5, 11], 'pool_size': 2, 'units': 128}
accuracy: 0.913517 (0.049196) train time: 14.820899 (1.180213) score time:
0.195375 (0.006359) with: {'batch_size': 19, 'dropout_rate': 0.5, 'epochs': 128,
'filters': 16, 'kernel_size': [3, 5, 11], 'pool_size': 3, 'units': 128}
accuracy: 0.900143 (0.048561) train time: 17.577573 (1.558564) score time:
0.197343 (0.008872) with: {'batch_size': 19, 'dropout_rate': 0.5, 'epochs': 128,
'filters': 32, 'kernel_size': [3, 5, 7], 'pool_size': 2, 'units': 128}
accuracy: 0.913837 (0.035133) train time: 17.361521 (1.544264) score time:
0.195536 (0.008865) with: {'batch_size': 19, 'dropout_rate': 0.5, 'epochs': 128,
'filters': 32, 'kernel_size': [3, 5, 7], 'pool_size': 3, 'units': 128}
accuracy: 0.900021 (0.051851) train time: 17.706992 (1.338181) score time:
0.197460 (0.008661) with: {'batch_size': 19, 'dropout_rate': 0.5, 'epochs': 128,
'filters': 32, 'kernel_size': [3, 5, 11], 'pool_size': 2, 'units': 128}
accuracy: 0.915802 (0.043137) train time: 17.433552 (1.599566) score time:
0.201199 (0.014107) with: {'batch_size': 19, 'dropout_rate': 0.5, 'epochs': 128,
'filters': 32, 'kernel_size': [3, 5, 11], 'pool_size': 3, 'units': 128}
accuracy: 0.892407 (0.054467) train time: 22.918142 (1.936891) score time:
0.219524 (0.014982) with: {'batch_size': 19, 'dropout_rate': 0.5, 'epochs': 128,
'filters': 64, 'kernel_size': [3, 5, 7], 'pool_size': 2, 'units': 128}
accuracy: 0.923892 (0.020173) train time: 23.716686 (1.588873) score time:
0.227306 (0.038413) with: {'batch_size': 19, 'dropout_rate': 0.5, 'epochs': 128,
'filters': 64, 'kernel_size': [3, 5, 7], 'pool_size': 3, 'units': 128}
accuracy: 0.899176 (0.046497) train time: 23.803486 (1.982897) score time:
0.217766 (0.005575) with: {'batch_size': 19, 'dropout_rate': 0.5, 'epochs': 128,
'filters': 64, 'kernel_size': [3, 5, 11], 'pool_size': 2, 'units': 128}
accuracy: 0.898707 (0.041247) train time: 23.459208 (1.964822) score time:
0.224141 (0.015370) with: {'batch_size': 19, 'dropout_rate': 0.5, 'epochs': 128,
'filters': 64, 'kernel_size': [3, 5, 11], 'pool_size': 3, 'units': 128}
accuracy: 0.894030 (0.051734) train time: 34.587926 (2.950544) score time:
0.241238 (0.020339) with: {'batch_size': 19, 'dropout_rate': 0.5, 'epochs': 128,
'filters': 128, 'kernel_size': [3, 5, 7], 'pool_size': 2, 'units': 128}
accuracy: 0.888426 (0.054633) train time: 33.898856 (3.234556) score time:
0.233456 (0.010207) with: {'batch_size': 19, 'dropout_rate': 0.5, 'epochs': 128,
'filters': 128, 'kernel_size': [3, 5, 7], 'pool_size': 3, 'units': 128}
accuracy: 0.886415 (0.049428) train time: 35.910100 (3.714762) score time:
0.223555 (0.035946) with: {'batch_size': 19, 'dropout_rate': 0.5, 'epochs': 128,
'filters': 128, 'kernel_size': [3, 5, 11], 'pool_size': 2, 'units': 128}
accuracy: 0.910470 (0.037032) train time: 32.477444 (3.343270) score time:
0.214732 (0.026509) with: {'batch_size': 19, 'dropout_rate': 0.5, 'epochs': 128,
'filters': 128, 'kernel_size': [3, 5, 11], 'pool_size': 3, 'units': 128}
Training and tunning completed for Dataset: gestures
```

[29]:
```
model = grid_result.best_estimator_
import pickle
```

```
def save_model(model, gesture_subset):
    gesture_subset.sort()
    name = '-'.join(gesture_subset)
    # saving model
    pickle.dump(model.classes_, open(name + '_model_classes.pkl','wb'))
    model.model.save(name + '_cnn')
print("Saving model to disk started for Dataset: gestures")
save_model(model, ["CNN","Measurements"])
print("Saving model to disk completed for Dataset: gestures")

import tensorflow as tf
def load_model(gesture_subset):
    gesture_subset.sort()
    name = '-'.join(gesture_subset)
    # loading model
    build_model = lambda: tf.keras.models.load_model(name + '_cnn')
    classifier = KerasClassifier(build_fn=build_model, epochs=1, batch_size=10,␣
 ↪verbose=0)
    classifier.classes_ = pickle.load(open(name + '_model_classes.pkl','rb'))
    classifier.model = build_model()
    return classifier
print("Loading model to disk started for Dataset: gestures")
model = load_model(["CNN","Measurements"])
print(model.model.summary())
print("Loading model to disk completed for Dataset: gestures")
```

```
Saving model to disk started for Dataset: gestures
```

```
2021-11-15 22:40:27.715042: W tensorflow/python/util/util.cc:348] Sets are not
currently considered sequences, but this may change in the future, so consider
avoiding using them.
```

```
INFO:tensorflow:Assets written to: CNN-Measurements_cnn/assets
Saving model to disk completed for Dataset: gestures
Loading model to disk started for Dataset: gestures
Model: "model"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_3 (InputLayer)         [(None, 19, 3)]           0
_________________________________________________________________
conv1d_4 (Conv1D)            (None, 17, 64)            640
_________________________________________________________________
conv1d_5 (Conv1D)            (None, 15, 64)            12352
_________________________________________________________________
dropout_2 (Dropout)          (None, 15, 64)            0
_________________________________________________________________
max_pooling1d_2 (MaxPooling1 (None, 5, 64)             0
```

```
_________________________________________________________________
flatten_2 (Flatten)          (None, 320)               0
_________________________________________________________________
dense (Dense)                (None, 128)               41088
_________________________________________________________________
dense_1 (Dense)              (None, 20)                2580
=================================================================
Total params: 56,660
Trainable params: 56,660
Non-trainable params: 0
_________________________________________________________________
None
Loading model to disk completed for Dataset: gestures
```

[30]:
```
print("Testing model against test set for Dataset: gestures")
data = dataset_cleaned_test_timecut
X, y, g = get_dataset(data)
y_pred = model.predict(X.tolist())
from sklearn.metrics import classification_report
print(classification_report(y, y_pred))

#from sklearn.metrics import confusion_matrix
#cf_matrix = confusion_matrix(y, y_pred)
#make_confusion_matrix(cf_matrix, categories=gesture_subset, figsize=[8,8])
```

```
Testing model against test set for Dataset: gestures
              precision    recall  f1-score   support

           0       1.00      1.00      1.00        18
           1       1.00      1.00      1.00        19
           2       1.00      1.00      1.00        20
           3       1.00      0.95      0.97        19
           4       1.00      1.00      1.00        17
           5       1.00      1.00      1.00        18
           6       1.00      1.00      1.00        18
           7       1.00      1.00      1.00        19
           8       0.95      1.00      0.97        19
           9       1.00      1.00      1.00        19
          10       0.95      1.00      0.97        18
          11       1.00      1.00      1.00        18
          12       1.00      0.95      0.97        20
          13       0.95      1.00      0.98        20
          14       1.00      1.00      1.00        18
          15       1.00      1.00      1.00        18
          16       1.00      1.00      1.00        18
          17       1.00      1.00      1.00        20
          18       1.00      0.88      0.94        17
          19       0.95      1.00      0.97        19
```

```
    accuracy                           0.99       372
   macro avg       0.99      0.99      0.99       372
weighted avg       0.99      0.99      0.99       372
```

[31]:
```
print("Testing model against outliers set for Dataset: gestures")
data = dataset_outliers_timecut
X, y, g = get_dataset(data)
y_pred = model.predict(X.tolist())
from sklearn.metrics import classification_report
print(classification_report(y, y_pred))

#from sklearn.metrics import confusion_matrix
#cf_matrix = confusion_matrix(y, y_pred)
#make_confusion_matrix(cf_matrix, categories=gesture_subset, figsize=[8,8])
```

```
Testing model against outliers set for Dataset: gestures
              precision    recall  f1-score   support

           0       0.95      0.95      0.95        39
           1       1.00      0.94      0.97        34
           2       0.97      0.91      0.94        34
           3       0.98      0.95      0.96        42
           4       0.98      0.95      0.96        43
           5       1.00      1.00      1.00        44
           6       0.97      0.95      0.96        41
           7       0.90      1.00      0.95        38
           8       1.00      0.94      0.97        32
           9       0.97      1.00      0.99        39
          10       0.98      0.98      0.98        42
          11       0.97      0.93      0.95        40
          12       1.00      0.96      0.98        26
          13       0.91      1.00      0.96        32
          14       0.98      1.00      0.99        44
          15       0.98      0.98      0.98        44
          16       0.95      0.93      0.94        41
          17       0.90      0.93      0.92        29
          18       1.00      1.00      1.00        47
          19       0.93      1.00      0.96        38

    accuracy                           0.97       769
   macro avg       0.97      0.96      0.96       769
weighted avg       0.97      0.97      0.97       769

max_pooling1d_11 (MaxPooling (None, 5, 128)            0
_________________________________________________________________
flatten_11 (Flatten)         (None, 640)               0
```

```
_________________________________________________________________
dense_22 (Dense)             (None, 128)               82048
_________________________________________________________________
dense_23 (Dense)             (None, 20)                2580
=================================================================
Total params: 135,188
Trainable params: 135,188
Non-trainable params: 0
_________________________________________________________________
None
Model: "model_12"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_13 (InputLayer)        [(None, 19, 3)]           0
_________________________________________________________________
conv1d_24 (Conv1D)           (None, 17, 128)           1280
_________________________________________________________________
conv1d_25 (Conv1D)           (None, 15, 128)           49280
_________________________________________________________________
dropout_12 (Dropout)         (None, 15, 128)           0
_________________________________________________________________
max_pooling1d_12 (MaxPooling (None, 7, 128)            0
_________________________________________________________________
flatten_12 (Flatten)         (None, 896)               0
_________________________________________________________________
dense_24 (Dense)             (None, 128)               114816
_________________________________________________________________
dense_25 (Dense)             (None, 20)                2580
=================================================================
Total params: 167,956
Trainable params: 167,956
Non-trainable params: 0
_________________________________________________________________
None
Model: "model_13"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_14 (InputLayer)        [(None, 19, 3)]           0
_________________________________________________________________
conv1d_26 (Conv1D)           (None, 17, 128)           1280
_________________________________________________________________
conv1d_27 (Conv1D)           (None, 15, 128)           49280
_________________________________________________________________
dropout_13 (Dropout)         (None, 15, 128)           0
_________________________________________________________________
max_pooling1d_13 (MaxPooling (None, 7, 128)            0
```

```
_________________________________________________________________
flatten_13 (Flatten)         (None, 896)               0
_________________________________________________________________
dense_26 (Dense)             (None, 128)               114816
_________________________________________________________________
dense_27 (Dense)             (None, 20)                2580
=================================================================
Total params: 167,956
Trainable params: 167,956
Non-trainable params: 0
_________________________________________________________________
None
Model: "model_14"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_15 (InputLayer)        [(None, 19, 3)]           0
_________________________________________________________________
conv1d_28 (Conv1D)           (None, 17, 128)           1280
_________________________________________________________________
conv1d_29 (Conv1D)           (None, 15, 128)           49280
_________________________________________________________________
dropout_14 (Dropout)         (None, 15, 128)           0
_________________________________________________________________
max_pooling1d_14 (MaxPooling (None, 7, 128)            0
_________________________________________________________________
flatten_14 (Flatten)         (None, 896)               0
_________________________________________________________________
dense_28 (Dense)             (None, 128)               114816
_________________________________________________________________
dense_29 (Dense)             (None, 20)                2580
=================================================================
Total params: 167,956
Trainable params: 167,956
Non-trainable params: 0
_________________________________________________________________
None
Model: "model_15"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_16 (InputLayer)        [(None, 19, 3)]           0
_________________________________________________________________
conv1d_30 (Conv1D)           (None, 17, 128)           1280
_________________________________________________________________
conv1d_31 (Conv1D)           (None, 15, 128)           49280
_________________________________________________________________
dropout_15 (Dropout)         (None, 15, 128)           0
```

```
_________________________________________________________________
max_pooling1d_15 (MaxPooling (None, 5, 128)            0
_________________________________________________________________
flatten_15 (Flatten)         (None, 640)               0
_________________________________________________________________
dense_30 (Dense)             (None, 128)               82048
_________________________________________________________________
dense_31 (Dense)             (None, 20)                2580
=================================================================
Total params: 135,188
Trainable params: 135,188
Non-trainable params: 0
_________________________________________________________________
None
Model: "model_16"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_17 (InputLayer)        [(None, 19, 3)]           0
_________________________________________________________________
conv1d_32 (Conv1D)           (None, 17, 128)           1280
_________________________________________________________________
conv1d_33 (Conv1D)           (None, 15, 128)           49280
_________________________________________________________________
dropout_16 (Dropout)         (None, 15, 128)           0
_________________________________________________________________
max_pooling1d_16 (MaxPooling (None, 5, 128)            0
_________________________________________________________________
flatten_16 (Flatten)         (None, 640)               0
_________________________________________________________________
dense_32 (Dense)             (None, 128)               82048
_________________________________________________________________
dense_33 (Dense)             (None, 20)                2580
=================================================================
Total params: 135,188
Trainable params: 135,188
Non-trainable params: 0
_________________________________________________________________
None
_________________________________________________________________
conv1d_290 (Conv1D)          (None, 17, 128)           1280
_________________________________________________________________
conv1d_291 (Conv1D)          (None, 15, 128)           49280
_________________________________________________________________
dropout_145 (Dropout)        (None, 15, 128)           0
_________________________________________________________________
max_pooling1d_145 (MaxPoolin (None, 7, 128)            0
_________________________________________________________________
```

```
flatten_145 (Flatten)        (None, 896)               0
_________________________________________________________________
dense_92 (Dense)             (None, 128)               114816
_________________________________________________________________
dense_93 (Dense)             (None, 20)                2580
=================================================================
Total params: 167,956
Trainable params: 167,956
Non-trainable params: 0
_________________________________________________________________
None
Model: "model_47"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_147 (InputLayer)       [(None, 19, 3)]           0
_________________________________________________________________
conv1d_292 (Conv1D)          (None, 17, 128)           1280
_________________________________________________________________
conv1d_293 (Conv1D)          (None, 15, 128)           49280
_________________________________________________________________
dropout_146 (Dropout)        (None, 15, 128)           0
_________________________________________________________________
max_pooling1d_146 (MaxPoolin (None, 5, 128)            0
_________________________________________________________________
flatten_146 (Flatten)        (None, 640)               0
_________________________________________________________________
dense_94 (Dense)             (None, 128)               82048
_________________________________________________________________
dense_95 (Dense)             (None, 20)                2580
=================================================================
Total params: 135,188
Trainable params: 135,188
Non-trainable params: 0
_________________________________________________________________
None
Model: "model_48"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_148 (InputLayer)       [(None, 19, 3)]           0
_________________________________________________________________
conv1d_294 (Conv1D)          (None, 17, 128)           1280
_________________________________________________________________
conv1d_295 (Conv1D)          (None, 15, 128)           49280
_________________________________________________________________
dropout_147 (Dropout)        (None, 15, 128)           0
_________________________________________________________________
```

```
max_pooling1d_147 (MaxPoolin (None, 5, 128)           0
_________________________________________________________________
flatten_147 (Flatten)        (None, 640)              0
_________________________________________________________________
dense_96 (Dense)             (None, 128)              82048
_________________________________________________________________
dense_97 (Dense)             (None, 20)               2580
=================================================================
Total params: 135,188
Trainable params: 135,188
Non-trainable params: 0
_________________________________________________________________
None
Model: "model_49"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_149 (InputLayer)       [(None, 19, 3)]           0
_________________________________________________________________
conv1d_296 (Conv1D)          (None, 17, 128)           1280
_________________________________________________________________
conv1d_297 (Conv1D)          (None, 15, 128)           49280
_________________________________________________________________
dropout_148 (Dropout)        (None, 15, 128)           0
_________________________________________________________________
max_pooling1d_148 (MaxPoolin (None, 5, 128)           0
_________________________________________________________________
flatten_148 (Flatten)        (None, 640)              0
_________________________________________________________________
dense_98 (Dense)             (None, 128)              82048
_________________________________________________________________
dense_99 (Dense)             (None, 20)               2580
=================================================================
Total params: 135,188
Trainable params: 135,188
Non-trainable params: 0
_________________________________________________________________
None
```

[ ]: