Window size:1024

Stride: 512

Raw data with detrend(lambda:300)

Use all channels

No scale on raw signal. Shuffle and split data to 20% for test. Shuffle and split the rest to 80% for training and 20% for validation.

model = keras.models.Sequential()

model.add(layers.InputLayer(input\_shape=X[:,:,:].shape[1:]))

model.add(layers.Bidirectional(layers.LSTM(32,return\_sequences=True,

recurrent\_regularizer=reg)))

model.add(layers.Conv1D(filters=32, kernel\_size=kernel\_size,strides=1,padding='same',kernel\_regularizer=reg))

model.add(layers.BatchNormalization(momentum=0.8))

model.add(layers.ELU())

model.add(layers.AveragePooling1D(2))

model.add(layers.Dropout(0.5))

model.add(layers.Conv1D(filters=16, kernel\_size=kernel\_size,strides=1,padding='same',kernel\_regularizer=reg))

model.add(layers.BatchNormalization(momentum=0.8))

model.add(layers.ELU())

model.add(layers.AveragePooling1D(2))

model.add(layers.Dropout(0.5))

model.add(layers.Conv1D(filters=8, kernel\_size=kernel\_size,strides=1,padding='same',kernel\_regularizer=reg))

model.add(layers.BatchNormalization(momentum=0.8))

model.add(layers.ELU())

model.add(layers.AveragePooling1D(2))

model.add(layers.Dropout(0.5))

model.add(layers.Conv1D(filters=4, kernel\_size=kernel\_size,strides=1,padding='same',kernel\_regularizer=reg))

model.add(layers.BatchNormalization(momentum=0.8))

model.add(layers.ELU())

model.add(layers.GlobalAveragePooling1D())

model.add(layers.Dropout(0.5))

model.add(layers.Dense(3,activation='softmax',kernel\_regularizer=reg))

kernel\_size=7

reg=regularizers.l2(0)

Train (acc 1.000)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Predicted 1 | Predicted 2 | Predicted 6 | acc |
| Actual 1 | 117 | 0 | 0 | 1.000 |
| Actual 2 | 0 | 324 | 0 | 1.000 |
| Actual 6 | 0 | 0 | 183 | 1.000 |

Validation (acc 0.885)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Predicted 1 | Predicted 2 | Predicted 6 | acc |
| Actual 1 | 38 | 11 | 2 | 0.745 |
| Actual 2 | 5 | 85 | 0 | 0.944 |
| Actual 6 | 5 | 1 | 62 | 0.911 |

Test 20% (acc 0.856)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Predicted 1 | Predicted 2 | Predicted 6 | acc |
| Actual 1 | 31 | 9 | 9 | 0.632 |
| Actual 2 | 5 | 92 | 2 | 0.929 |
| Actual 6 | 4 | 1 | 56 | 0.918 |

kernel\_size=7

Reg = regularizers.l2(1e-4)

Train (acc 1.000)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Predicted 1 | Predicted 2 | Predicted 6 | acc |
| Actual 1 | 117 | 0 | 0 | 1.000 |
| Actual 2 | 0 | 324 | 0 | 1.000 |
| Actual 6 | 0 | 0 | 183 | 1.000 |

Validation (acc 0.889)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Predicted 1 | Predicted 2 | Predicted 6 | acc |
| Actual 1 | 41 | 6 | 4 | 0.803 |
| Actual 2 | 5 | 85 | 0 | 0.944 |
| Actual 6 | 7 | 1 | 60 | 0.882 |

Test 20% (acc 0.866)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Predicted 1 | Predicted 2 | Predicted 6 | acc |
| Actual 1 | 32 | 10 | 7 | 0.653 |
| Actual 2 | 6 | 93 | 0 | 0.939 |
| Actual 6 | 4 | 1 | 56 | 0.918 |

kernel\_size=9

reg=regularizers.l2(0)

Train (acc 1.000)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Predicted 1 | Predicted 2 | Predicted 6 | acc |
| Actual 1 | 117 | 0 | 0 | 1.000 |
| Actual 2 | 0 | 324 | 0 | 1.000 |
| Actual 6 | 0 | 0 | 183 | 1.000 |

Validation (acc 0.870)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Predicted 1 | Predicted 2 | Predicted 6 | acc |
| Actual 1 | 35 | 11 | 5 | 0.686 |
| Actual 2 | 5 | 84 | 1 | 0.933 |
| Actual 6 | 4 | 1 | 63 | 0.926 |

Test 20% (acc 0.889)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Predicted 1 | Predicted 2 | Predicted 6 | acc |
| Actual 1 | 34 | 7 | 8 | 0.693 |
| Actual 2 | 2 | 95 | 2 | 0.959 |
| Actual 6 | 3 | 1 | 57 | 0.934 |

kernel\_size=9

reg=regularizers.l2(1e-4)

Train (acc 1.000)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Predicted 1 | Predicted 2 | Predicted 6 | acc |
| Actual 1 | 117 | 0 | 0 | 1.000 |
| Actual 2 | 0 | 324 | 0 | 1.000 |
| Actual 6 | 0 | 0 | 183 | 1.000 |

Validation (acc 0.894)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Predicted 1 | Predicted 2 | Predicted 6 | acc |
| Actual 1 | 39 | 9 | 3 | 0.764 |
| Actual 2 | 4 | 85 | 1 | 0.944 |
| Actual 6 | 4 | 1 | 63 | 0.926 |

Test 20% (acc 0.880)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Predicted 1 | Predicted 2 | Predicted 6 | acc |
| Actual 1 | 34 | 9 | 6 | 0.693 |
| Actual 2 | 5 | 91 | 3 | 0.919 |
| Actual 6 | 1 | 1 | 59 | 0.967 |

kernel\_size=9

reg=regularizers.l2(1e-4)

class weights: 1:5, 2:1, 6:1

Train (acc 0.996)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Predicted 1 | Predicted 2 | Predicted 6 | acc |
| Actual 1 | 117 | 0 | 0 | 1.000 |
| Actual 2 | 0 | 324 | 0 | 1.000 |
| Actual 6 | 1 | 0 | 182 | 0.994 |

Validation (acc 0.904)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Predicted 1 | Predicted 2 | Predicted 6 | acc |
| Actual 1 | 41 | 7 | 1 | 0.803 |
| Actual 2 | 6 | 83 | 1 | 0.922 |
| Actual 6 | 5 | 0 | 63 | 0.926 |

Test 20% (acc 0.894)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Predicted 1 | Predicted 2 | Predicted 6 | acc |
| Actual 1 | 41 | 5 | 3 | 0.836 |
| Actual 2 | 5 | 92 | 2 | 0.929 |
| Actual 6 | 4 | 3 | 54 | 0.885 |

kernel\_size=9

reg=regularizers.l2(1e-4)

class weights: 1:10, 2:1, 6:1

Train (acc 0.982)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Predicted 1 | Predicted 2 | Predicted 6 | acc |
| Actual 1 | 117 | 0 | 0 | 1.000 |
| Actual 2 | 0 | 324 | 0 | 1.000 |
| Actual 6 | 1 | 10 | 172 | 0.939 |

Validation (acc 0.861)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Predicted 1 | Predicted 2 | Predicted 6 | acc |
| Actual 1 | 43 | 5 | 3 | 0.843 |
| Actual 2 | 3 | 85 | 2 | 0.944 |
| Actual 6 | 4 | 5 | 59 | 0.867 |

Test 20% (acc 0.885)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Predicted 1 | Predicted 2 | Predicted 6 | acc |
| Actual 1 | 44 | 2 | 3 | 0.897 |
| Actual 2 | 5 | 92 | 2 | 0.929 |
| Actual 6 | 6 | 5 | 50 | 0.819 |

kernel\_size=9

reg=regularizers.l2(1e-4)

cost\_matrix = ([[0, 3., 1.5],

[1, 0, 1],

[1., 1., 0]])

Train (acc 1.000)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Predicted 1 | Predicted 2 | Predicted 6 | acc |
| Actual 1 | 117 | 0 | 0 | 1.000 |
| Actual 2 | 0 | 324 | 0 | 1.000 |
| Actual 6 | 0 | 0 | 183 | 1.000 |

Validation (acc 0.904)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Predicted 1 | Predicted 2 | Predicted 6 | acc |
| Actual 1 | 44 | 4 | 3 | 0.862 |
| Actual 2 | 7 | 81 | 2 | 0.900 |
| Actual 6 | 4 | 0 | 64 | 0.941 |

Test 20% (acc 0.875)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Predicted 1 | Predicted 2 | Predicted 6 | acc |
| Actual 1 | 39 | 3 | 7 | 0.795 |
| Actual 2 | 7 | 89 | 3 | 0.898 |
| Actual 6 | 5 | 1 | 55 | 0.901 |

input\_ = layers.Input(shape=X[:,:,:].shape[1:],name='input')

lstm = layers.Bidirectional(layers.LSTM(32,return\_sequences=True,

name = 'lstm',

recurrent\_regularizer=reg))(input\_)

cnn11 = layers.Conv1D(filters=32, kernel\_size=kernel\_size1,strides=1,padding='same',kernel\_regularizer=reg)(lstm)

cnn11 = layers.BatchNormalization(momentum=0.8,name='BN\_11')(cnn11)

cnn11 = layers.ELU(name='Act\_11')(cnn11)

cnn11 = layers.AveragePooling1D(2,name='pooling\_11')(cnn11)

cnn11 = layers.Dropout(0.5,name='dropout\_11')(cnn11)

cnn12 = layers.Conv1D(filters=32, kernel\_size=kernel\_size2,strides=1,padding='same',kernel\_regularizer=reg)(lstm)

cnn12 = layers.BatchNormalization(momentum=0.8,name='BN\_12')(cnn12)

cnn12 = layers.ELU(name='Act\_12')(cnn12)

cnn12 = layers.AveragePooling1D(2,name='pooling\_12')(cnn12)

cnn12 = layers.Dropout(0.5,name='dropout\_12')(cnn12)

cnn21 = layers.Conv1D(filters=16, kernel\_size=kernel\_size1,strides=1,padding='same',kernel\_regularizer=reg)(cnn11)

cnn21 = layers.BatchNormalization(momentum=0.8,name='BN\_21')(cnn21)

cnn21 = layers.ELU(name='Act\_21')(cnn21)

cnn21 = layers.AveragePooling1D(2,name='pooling\_21')(cnn21)

cnn21 = layers.Dropout(0.5,name='dropout\_21')(cnn21)

cnn22 = layers.Conv1D(filters=16, kernel\_size=kernel\_size2,strides=1,padding='same',kernel\_regularizer=reg)(cnn12)

cnn22 = layers.BatchNormalization(momentum=0.8,name='BN\_22')(cnn22)

cnn22 = layers.ELU(name='Act\_22')(cnn22)

cnn22 = layers.AveragePooling1D(2,name='pooling\_22')(cnn22)

cnn22 = layers.Dropout(0.5,name='dropout\_22')(cnn22)

cnn31 = layers.Conv1D(filters=8, kernel\_size=kernel\_size1,strides=1,padding='same',kernel\_regularizer=reg)(cnn21)

cnn31 = layers.BatchNormalization(momentum=0.8,name='BN\_31')(cnn31)

cnn31 = layers.ELU(name='Act\_31')(cnn31)

cnn31 = layers.AveragePooling1D(2,name='pooling\_31')(cnn31)

cnn31 = layers.Dropout(0.5,name='dropout\_31')(cnn31)

cnn32 = layers.Conv1D(filters=8, kernel\_size=kernel\_size2,strides=1,padding='same',kernel\_regularizer=reg)(cnn22)

cnn32 = layers.BatchNormalization(momentum=0.8,name='BN\_32')(cnn32)

cnn32 = layers.ELU(name='Act\_32')(cnn32)

cnn32 = layers.AveragePooling1D(2,name='pooling\_32')(cnn32)

cnn32 = layers.Dropout(0.5,name='dropout\_32')(cnn32)

cnn41 = layers.Conv1D(filters=4, kernel\_size=kernel\_size1,strides=1,padding='same',kernel\_regularizer=reg)(cnn31)

cnn41 = layers.BatchNormalization(momentum=0.8,name='BN\_41')(cnn41)

cnn41 = layers.ELU(name='Act\_41')(cnn41)

cnn42 = layers.Conv1D(filters=4, kernel\_size=kernel\_size1,strides=1,padding='same',kernel\_regularizer=reg)(cnn32)

cnn42 = layers.BatchNormalization(momentum=0.8,name='BN\_42')(cnn42)

cnn42 = layers.ELU(name='Act\_42')(cnn42)

cnn4 = layers.concatenate([cnn41,cnn42],axis=2)

cnn4 = layers.GlobalAveragePooling1D(name='global\_average')(cnn4)

cnn4 = layers.Dropout(0.5,name='dropout\_4')(cnn4)

output = layers.Dense(3,activation='softmax',kernel\_regularizer=reg,name='output')(cnn4)

model = Model(input\_, output)

kernel\_size1=11

kernel\_size2=7

reg=regularizers.l2(1e-4)

Train (acc 1.000)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Predicted 1 | Predicted 2 | Predicted 6 | acc |
| Actual 1 | 117 | 0 | 0 | 1.000 |
| Actual 2 | 0 | 324 | 0 | 1.000 |
| Actual 6 | 0 | 0 | 183 | 1.000 |

Validation (acc 0.875)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Predicted 1 | Predicted 2 | Predicted 6 | acc |
| Actual 1 | 35 | 8 | 6 | 0.714 |
| Actual 2 | 7 | 82 | 1 | 0.911 |
| Actual 6 | 4 | 0 | 64 | 0.941 |

Test 20% (acc 0.870)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Predicted 1 | Predicted 2 | Predicted 6 | acc |
| Actual 1 | 35 | 8 | 6 | 0.714 |
| Actual 2 | 6 | 91 | 2 | 0.919 |
| Actual 6 | 3 | 2 | 56 | 0.918 |

kernel\_size1=11

kernel\_size2=7

reg=regularizers.l2(1e-4)

class weights: 1:5, 2:1, 6:1

Train (acc 0.996)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Predicted 1 | Predicted 2 | Predicted 6 | acc |
| Actual 1 | 117 | 0 | 0 | 1.000 |
| Actual 2 | 0 | 324 | 0 | 1.000 |
| Actual 6 | 0 | 2 | 181 | 0.989 |

Validation (acc 0.856)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Predicted 1 | Predicted 2 | Predicted 6 | acc |
| Actual 1 | 41 | 7 | 3 | 0.803 |
| Actual 2 | 5 | 83 | 2 | 0.922 |
| Actual 6 | 9 | 4 | 55 | 0.808 |

Test 20% (acc 0.889)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Predicted 1 | Predicted 2 | Predicted 6 | acc |
| Actual 1 | 43 | 3 | 3 | 0.877 |
| Actual 2 | 6 | 91 | 2 | 0.919 |
| Actual 6 | 5 | 4 | 52 | 0.852 |

kernel\_size1=11

kernel\_size2=7

reg=regularizers.l2(1e-4)

class weights: 1:10, 2:1, 6:1

Train (acc 0.988)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Predicted 1 | Predicted 2 | Predicted 6 | acc |
| Actual 1 | 117 | 0 | 0 | 1.000 |
| Actual 2 | 0 | 323 | 1 | 0.996 |
| Actual 6 | 0 | 6 | 177 | 0.967 |

Validation (acc 0.870)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Predicted 1 | Predicted 2 | Predicted 6 | acc |
| Actual 1 | 43 | 6 | 2 | 0.843 |
| Actual 2 | 8 | 81 | 1 | 0.900 |
| Actual 6 | 5 | 5 | 58 | 0.852 |

Test 20% (acc 0.870)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Predicted 1 | Predicted 2 | Predicted 6 | acc |
| Actual 1 | 41 | 4 | 4 | 0.836 |
| Actual 2 | 8 | 88 | 3 | 0.888 |
| Actual 6 | 3 | 5 | 53 | 0.868 |

def inception\_module(input\_,filters,reg):

x1 = layers.Conv1D(filters=filters[0], kernel\_size=3, strides=1, activation=None,padding='same',kernel\_regularizer=reg)(input\_)

x2 = layers.Conv1D(filters=filters[1], kernel\_size=7, strides=1, activation=None, padding='same',kernel\_regularizer=reg)(input\_)

x3 = layers.Conv1D(filters=filters[2], kernel\_size=11, strides=1, activation=None, padding='same',kernel\_regularizer=reg)(input\_)

x4 = layers.Conv1D(filters=filters[3], kernel\_size=15, strides=1, activation=None, padding='same',kernel\_regularizer=reg)(input\_)

merge = layers.concatenate([x1,x2,x3,x4],axis=2)

return merge

reg=regularizers.l2(1e-3)

input\_ = layers.Input(shape=X[:,:,:].shape[1:],name='input')

lstm = layers.Bidirectional(layers.LSTM(32,return\_sequences=True,

name = 'lstm',

recurrent\_regularizer=reg))(input\_)

cnn1 = inception\_module(lstm,[32,16,8,8],reg)

cnn1 = layers.BatchNormalization(momentum=0.8,name='BN\_1')(cnn1)

cnn1 = layers.ELU(name='Act\_1')(cnn1)

cnn1 = layers.AveragePooling1D(2,name='pooling\_1')(cnn1)

cnn1 = layers.Dropout(0.5,name='dropout\_1')(cnn1)

cnn2 = inception\_module(cnn1,[16,8,4,4],reg)

cnn2 = layers.BatchNormalization(momentum=0.8,name='BN\_2')(cnn2)

cnn2 = layers.ELU(name='Act\_2')(cnn2)

cnn2 = layers.AveragePooling1D(2,name='pooling\_2')(cnn2)

cnn2 = layers.Dropout(0.5,name='dropout\_2')(cnn2)

cnn3 = inception\_module(cnn2,[8,4,2,2],reg)

cnn3 = layers.BatchNormalization(momentum=0.8,name='BN\_3')(cnn3)

cnn3 = layers.ELU(name='Act\_3')(cnn3)

cnn3 = layers.AveragePooling1D(2,name='pooling\_3')(cnn3)

cnn3 = layers.Dropout(0.5,name='dropout\_3')(cnn3)

cnn4 = inception\_module(cnn3,[4,2,1,1],reg)

cnn4 = layers.BatchNormalization(momentum=0.8,name='BN\_4')(cnn4)

cnn4 = layers.ELU(name='Act\_4')(cnn4)

cnn4 = layers.GlobalAveragePooling1D(name='global\_average')(cnn4)

cnn4 = layers.Dropout(0.5,name='dropout\_4')(cnn4)

output = layers.Dense(3,activation='softmax',kernel\_regularizer=reg,name='output')(cnn4)

model = Model(input\_, output)

Train (acc 1.000)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Predicted 1 | Predicted 2 | Predicted 6 | acc |
| Actual 1 | 117 | 0 | 0 | 1.000 |
| Actual 2 | 0 | 324 | 0 | 1.000 |
| Actual 6 | 0 | 0 | 183 | 1.000 |

Validation (acc 0.904)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Predicted 1 | Predicted 2 | Predicted 6 | acc |
| Actual 1 | 41 | 6 | 4 | 0.803 |
| Actual 2 | 5 | 82 | 3 | 0.911 |
| Actual 6 | 2 | 0 | 66 | 0.970 |

Test 20% (acc 0.842)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Predicted 1 | Predicted 2 | Predicted 6 | acc |
| Actual 1 | 30 | 10 | 9 | 0.625 |
| Actual 2 | 3 | 89 | 7 | 0.898 |
| Actual 6 | 3 | 1 | 57 | 0.934 |

class weights: 1:5, 2:1, 6:1

Train (acc 0.998)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Predicted 1 | Predicted 2 | Predicted 6 | acc |
| Actual 1 | 117 | 0 | 0 | 1.000 |
| Actual 2 | 0 | 323 | 1 | 0.996 |
| Actual 6 | 0 | 0 | 183 | 1.000 |

Validation (acc 0.827)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Predicted 1 | Predicted 2 | Predicted 6 | acc |
| Actual 1 | 36 | 9 | 6 | 0.705 |
| Actual 2 | 10 | 76 | 4 | 0.844 |
| Actual 6 | 5 | 2 | 61 | 0.897 |

Test 20% (acc 0.827)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Predicted 1 | Predicted 2 | Predicted 6 | acc |
| Actual 1 | 37 | 6 | 6 | 0.755 |
| Actual 2 | 14 | 82 | 3 | 0.828 |
| Actual 6 | 3 | 4 | 54 | 0.885 |