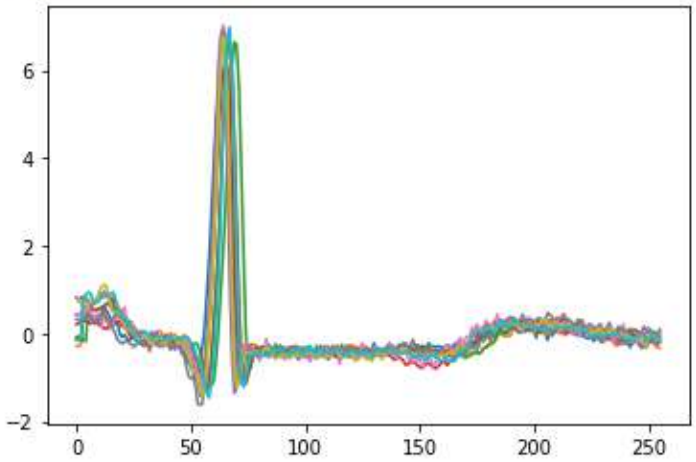
In [ ]:

```
# Load dataset
pickleIn = open('data/ready/pickles/cnn.pickle', 'rb')
people, y, x = pickle.load(pickleIn)
```

In [ ]:

```
why = []
for i in range(10):
  why.append(y[i])
  plt.plot(x[i])
print(why)
plt.show()
```

```
['100', '100', '100', '100', '100', '100', '100', '100', '100', '100']
```



In [ ]:

```
# shuffle data
from collections import Counter

# print(Counter(y))
length = len(y)
print(length)
data = []
for i in range(length):
  data.append([y[i], x[i]])

print(y)
print(y[2])

plt.plot(x[2], linewidth=0.8, color="k")
plt.show()

num = random.randint(0, length)
random.seed(num)
random.shuffle(data)

y, x = [], []
for k in range(length):
  y.append(data[k][0])
  x.append(data[k][1])

data, k, length, num = [], 0, 0, 0 # just for memory management

print(y)
print(y[2])

plt.plot(x[2], linewidth=0.8, color="k")
plt.show()
```

In [ ]:

```
x = np.array(x)

print('Before Normalization\n')
print('Shape:', x.shape)
print('Min:', x.min(), 'Max:', x.max())
print(x.dtype)

print('\nAfter Normalization\n')

x = (x - x.min()) / (x.max() - x.min())
y = np.array(y)

print('Shape:', x.shape)
print('Min:', x.min(), 'Max:', x.max())
print(x.dtype)
```

```
Before Normalization

Shape: (397740, 256)
Min: -7.565526962280273 Max: 8.537934070241493
float64

After Normalization

Shape: (397740, 256)
Min: 0.0 Max: 1.0
float64
```

In [ ]:

```
from sklearn.preprocessing import LabelBinarizer

SIG_DIMS = (x.shape[1], 1)

# binarize the labels
lb = LabelBinarizer()
y = lb.fit_transform(y)

x_train, x_test, y_train, y_test = train_test_split(
    x, y, test_size=0.4, shuffle=True, random_state=42)

x_valid, x_test, y_valid, y_test = train_test_split(
    x_test, y_test, test_size=0.3, shuffle=True, random_state=42)

x, y = [], []  # just for memory management

print(x_train.shape)
x_train = x_train.reshape(x_train.shape[0], SIG_DIMS[0], SIG_DIMS[1])
x_valid = x_valid.reshape(x_valid.shape[0], SIG_DIMS[0], SIG_DIMS[1])
x_test = x_test.reshape(x_test.shape[0], SIG_DIMS[0], SIG_DIMS[1])
print(x_train.shape)
print(x_valid.shape)
print(x_test.shape)
```

```
['100' '101' '102' '103' '104' '105' '106' '107' '108' '109' '111' '112'
 '113' '114' '115' '116' '117' '118' '119' '121' '122' '123' '124' '1975'
 '200' '201' '202' '203' '205' '207' '208' '209' '210' '212' '213' '214'
 '215' '217' '219' '220']
(238644, 256)
(238644, 256, 1)
(111367, 256, 1)
(47729, 256, 1)
```

In [ ]:

```
from keras_preprocessing.image import ImageDataGenerator
from tensorflow.keras.callbacks import ModelCheckpoint
from tensorflow.keras.callbacks import EarlyStopping
from tensorflow.keras.callbacks import TensorBoard
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import BatchNormalization, concatenate, Conv1D, MaxPool1D, Activation, Flatten, Dropout, Dense, Input, Add
from tensorflow.keras.models import Model
from tensorflow.keras import backend as K
from sklearn.preprocessing import LabelBinarizer
from tensorflow.keras.optimizers import Adam
from google.colab.patches import cv2_imshow
from tensorflow.keras.optimizers import Adam
import matplotlib.pyplot as plt
from datetime import datetime
import tensorflow as tf
%load_ext tensorboard
from tensorflow.keras import layers
%matplotlib inline
import numpy as np
import random
import pickle
import time
import cv2
import os
import gc
```

In [ ]:

```
# initialize the number of epochs to train for, initial learning rate,
# batch size, and image dimensions
EPOCHS = 100
BS = 64
SIG_DIMS = (x_train.shape[1], 1)
LR = 0.00001
decay = LR/EPOCHS
adam = Adam(learning_rate=LR,decay=decay)

def block(model, fs, ks, ps):
  model.add(Conv1D(filters=fs, kernel_size=ks, padding="same"))
  model.add(BatchNormalization())
  model.add(Activation('relu'))
  model.add(MaxPool1D(pool_size=ps, padding='same'))
  return model

def SPPLayer(inp, spp_windows):
  p_poolings = []

  for pi in range(len(spp_windows)):
    p_poolings.append(Flatten()(MaxPool1D(pool_size=spp_windows[pi], padding='same')(inp)))
  out = concatenate(p_poolings, axis=-1)

  return out
```

In [ ]:

```
folder = "models/cnn/"
if not os.path.exists(folder):
  os.makedirs(folder)

# save the label binarizer to disk
f = open(folder + "lb.pickle", "wb")
f.write(pickle.dumps(lb))
f.close()

# Model
model = Sequential()

model.add(Conv1D(filters=32, kernel_size=1, padding="same", input_shape=SIG_DIMS))
model.add(BatchNormalization())
model.add(Activation('relu'))

# Blocks
model = block(model, 32 * 2, 15, 2)
model = block(model, 32 * 4, 15, 2)
model = block(model, 32 * 8, 15, 2)
model = block(model, 32 * 16, 15, 2)
last = 1 + 2 + 4 + 8 + 16
model = block(model, 32 * last, 15, 2)

# Fully Connected Layer
model.add(Flatten())
model.add(Dense(32 * last))
model.add(BatchNormalization())
model.add(Activation('relu'))
model.add(Dropout(0.25))

# softmax classifier
model.add(Dense(len(lb.classes_)))
model.add(Activation("softmax"))

print(model.summary())
```

```
model.compile(optimizer=adam, loss="categorical_crossentropy", metrics=["accuracy"])

STEPS_PER_EPOCH = len(x_train) // BS
VAL_STEPS_PER_EPOCH = len(x_valid) // BS

bestmodel = folder + "debbis"
checkpointer = ModelCheckpoint(filepath=bestmodel, verbose=1, save_best_only=True)
early_stopping = EarlyStopping(monitor='val_loss', patience=5)

# Define the Keras TensorBoard callback.
logdir = folder + "logs/fit/" + datetime.now().strftime("%Y%m%d-%H%M%S")
tensorboard_callback = TensorBoard(log_dir=logdir)

# fit network
t = time.time()

H = model.fit(x_train, y_train, batch_size=BS,
              validation_data=(x_valid, y_valid),
              steps_per_epoch=STEPS_PER_EPOCH,
              validation_steps=VAL_STEPS_PER_EPOCH,
              epochs=EPOCHS, verbose=1,
              callbacks=[tensorboard_callback, checkpointer, early_stopping])

print('\nTraining time: ', time.time() - t)

# save the model to disk
model.save(bestmodel)

# evaluate model
_, accuracy = model.evaluate(x_test, y_test, batch_size=BS, verbose=1)
print('\n', 'Test accuracy:', accuracy, '\n')

# plot the training loss and accuracy
acc = H.history['accuracy']
val_acc = H.history['val_accuracy']

loss = H.history['loss']
val_loss = H.history['val_loss']
```

```
plt.figure(figsize=(8, 8))
plt.subplot(2, 1, 1)
plt.plot(acc, label='Training Accuracy')
plt.plot(val_acc, label='Validation Accuracy')
plt.legend(loc='lower right')
plt.ylabel('Accuracy')
plt.ylim([min(plt.ylim()),1])
plt.title('Training and Validation Accuracy')

plt.subplot(2, 1, 2)
plt.plot(loss, label='Training Loss')
plt.plot(val_loss, label='Validation Loss')
plt.legend(loc='upper right')
plt.ylabel('Cross Entropy')
plt.ylim([0,1.0])
plt.title('Training and Validation Loss')
plt.xlabel('epoch')
plt.show()
```

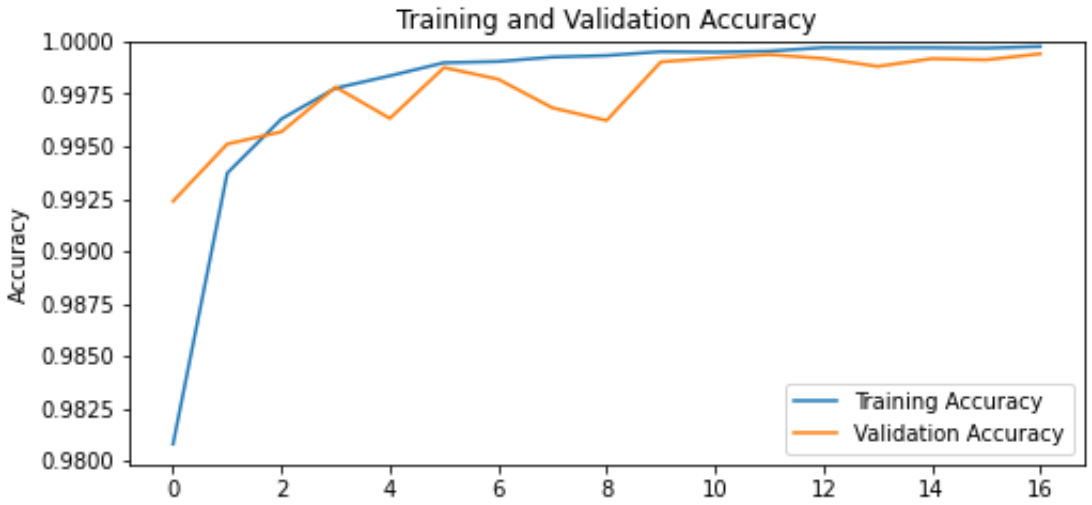
```
Model: "sequential"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv1d (Conv1D)              (None, 256, 128)          256
_________________________________________________________________
batch_normalization (BatchNo (None, 256, 128)          512
_________________________________________________________________
activation (Activation)      (None, 256, 128)          0
_________________________________________________________________
conv1d_1 (Conv1D)            (None, 256, 256)          491776
_________________________________________________________________
batch_normalization_1 (Batch (None, 256, 256)          1024
_________________________________________________________________
activation_1 (Activation)    (None, 256, 256)          0
_________________________________________________________________
max_pooling1d (MaxPooling1D) (None, 128, 256)          0
```

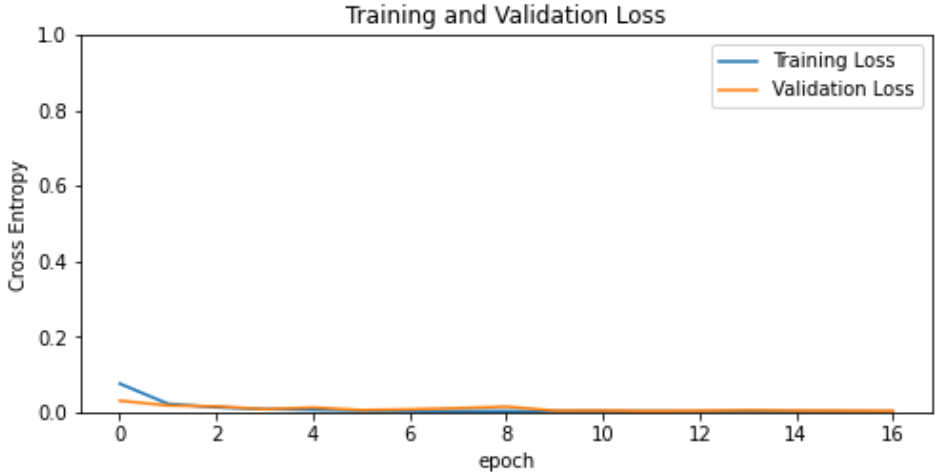
conv1d_2 (Conv1D)	(None, 128, 512)	1966592
batch_normalization_2 (Batch	(None, 128, 512)	2048
activation_2 (Activation)	(None, 128, 512)	0
max_pooling1d_1 (MaxPooling1	(None, 64, 512)	0
conv1d_3 (Conv1D)	(None, 64, 1024)	7865344
batch_normalization_3 (Batch	(None, 64, 1024)	4096
activation_3 (Activation)	(None, 64, 1024)	0
max_pooling1d_2 (MaxPooling1	(None, 32, 1024)	0
conv1d_4 (Conv1D)	(None, 32, 1792)	27526912
batch_normalization_4 (Batch	(None, 32, 1792)	7168
activation_4 (Activation)	(None, 32, 1792)	0
max_pooling1d_3 (MaxPooling1	(None, 16, 1792)	0
flatten (Flatten)	(None, 28672)	0
dense (Dense)	(None, 1792)	51382016
batch_normalization_5 (Batch	(None, 1792)	7168
activation_5 (Activation)	(None, 1792)	0
dropout (Dropout)	(None, 1792)	0
dense_1 (Dense)	(None, 40)	71720
activation_6 (Activation)	(None, 40)	0

```
_________________________________________________________________
dropout (Dropout)            (None, 1792)              0
_________________________________________________________________
dense_1 (Dense)              (None, 40)                71720
_________________________________________________________________
activation_6 (Activation)    (None, 40)                0
=================================================================
Total params: 89,326,632
Trainable params: 89,315,624
Non-trainable params: 11,008
_________________________________________________________________
None
Epoch 1/100
3728/3728 [==============================] - 411s 108ms/step - loss: 0.0754 - accuracy: 0.9808 - val_loss: 0.0300 - val_accuracy: 0.9924

Epoch 00001: val_loss improved from inf to 0.03004, saving model to models/auth/8/debbis
INFO:tensorflow:Assets written to: models/auth/8/debbis/assets
Epoch 2/100
3728/3728 [==============================] - 400s 107ms/step - loss: 0.0218 - accuracy: 0.9937 - val_loss: 0.0174 - val_accuracy: 0.9951

Epoch 00002: val_loss improved from 0.03004 to 0.01742, saving model to models/auth/8/debbis
INFO:tensorflow:Assets written to: models/auth/8/debbis/assets
Epoch 3/100
3728/3728 [==============================] - 399s 107ms/step - loss: 0.0124 - accuracy: 0.9963 - val_loss: 0.0151 - val_accuracy: 0.9957

Epoch 00003: val_loss improved from 0.01742 to 0.01513, saving model to models/auth/8/debbis
INFO:tensorflow:Assets written to: models/auth/8/debbis/assets
Epoch 4/100
3728/3728 [==============================] - 399s 107ms/step - loss: 0.0077 - accuracy: 0.9978 - val_loss: 0.0075 - val_accuracy: 0.9978

Epoch 00004: val_loss improved from 0.01513 to 0.00753, saving model to models/auth/8/debbis
INFO:tensorflow:Assets written to: models/auth/8/debbis/assets
Epoch 5/100
3728/3728 [==============================] - 400s 107ms/step - loss: 0.0056 - accuracy: 0.9984 - val_loss: 0.0120 - val_accuracy: 0.9963

Epoch 00005: val_loss did not improve from 0.00753
Epoch 6/100
3728/3728 [==============================] - 400s 107ms/step - loss: 0.0039 - accuracy: 0.9990 - val_loss: 0.0052 - val_accuracy: 0.9988
```

```
Epoch 00006: val_loss improved from 0.00753 to 0.00524, saving model to models/auth/8/debbis
INFO:tensorflow:Assets written to: models/auth/8/debbis/assets
Epoch 7/100
3728/3728 [==============================] - 399s 107ms/step - loss: 0.0034 - accuracy: 0.9990 - val_loss: 0.0071 - val_accuracy: 0.9982

Epoch 00007: val_loss did not improve from 0.00524
Epoch 8/100
3728/3728 [==============================] - 398s 107ms/step - loss: 0.0028 - accuracy: 0.9992 - val_loss: 0.0103 - val_accuracy: 0.9968

Epoch 00008: val_loss did not improve from 0.00524
Epoch 9/100
3728/3728 [==============================] - 397s 107ms/step - loss: 0.0025 - accuracy: 0.9993 - val_loss: 0.0143 - val_accuracy: 0.9962

Epoch 00009: val_loss did not improve from 0.00524
Epoch 10/100
3728/3728 [==============================] - 397s 106ms/step - loss: 0.0020 - accuracy: 0.9995 - val_loss: 0.0038 - val_accuracy: 0.9990

Epoch 00010: val_loss improved from 0.00524 to 0.00376, saving model to models/auth/8/debbis
INFO:tensorflow:Assets written to: models/auth/8/debbis/assets
Epoch 11/100
3728/3728 [==============================] - 397s 107ms/step - loss: 0.0018 - accuracy: 0.9995 - val_loss: 0.0040 - val_accuracy: 0.9992

Epoch 00011: val_loss did not improve from 0.00376
Epoch 12/100
3728/3728 [==============================] - 397s 107ms/step - loss: 0.0017 - accuracy: 0.9995 - val_loss: 0.0028 - val_accuracy: 0.9994

Epoch 00012: val_loss improved from 0.00376 to 0.00279, saving model to models/auth/8/debbis
INFO:tensorflow:Assets written to: models/auth/8/debbis/assets
Epoch 13/100
3728/3728 [==============================] - 398s 107ms/step - loss: 0.0012 - accuracy: 0.9997 - val_loss: 0.0035 - val_accuracy: 0.9992

Epoch 00013: val_loss did not improve from 0.00279
Epoch 14/100
3728/3728 [==============================] - 397s 107ms/step - loss: 0.0013 - accuracy: 0.9997 - val_loss: 0.0049 - val_accuracy: 0.9988

Epoch 00014: val_loss did not improve from 0.00279
Epoch 15/100
3728/3728 [==============================] - 397s 107ms/step - loss: 0.0013 - accuracy: 0.9997 - val_loss: 0.0039 - val_accuracy: 0.9992
```

```
Epoch 00015: val_loss did not improve from 0.00279
Epoch 16/100
3728/3728 [==============================] - 398s 107ms/step - loss: 0.0013 - accuracy: 0.9997 - val_loss: 0.0034 - val_accuracy: 0.9991

Epoch 00016: val_loss did not improve from 0.00279
Epoch 17/100
3728/3728 [==============================] - 397s 107ms/step - loss: 9.6815e-04 - accuracy: 0.9998 - val_loss: 0.0031 - val_accuracy: 0.9994

Epoch 00017: val_loss did not improve from 0.00279

Training time:  6839.25846529007
INFO:tensorflow:Assets written to: models/auth/8/debbis/assets
746/746 [==============================] - 16s 21ms/step - loss: 0.0023 - accuracy: 0.9994

 Test accuracy: 0.9993923902511597
```





In [ ]:
```
%tensorboard --logdir models/auth/8/logs/fit
```

In [ ]:
```
_, accuracy = model.evaluate(x_test, y_test)
print('\n', 'Test accuracy:', accuracy, '\n')
```

```
375/375 [==============================] - 4s 9ms/step - loss: 0.0058 - accuracy: 0.9987

 Test accuracy: 0.9986666440963745
```

In [ ]:
```
from sklearn.metrics import classification_report

lbb = LabelBinarizer()
predictions = model.predict(x_test, batch_size=BS, verbose=1)
y_pred_bool = np.argmax(predictions, axis=1)
y_pred_bool = lbb.fit_transform(y_pred_bool)
print(classification_report(y_test, y_pred_bool))
```

```
188/188 [==============================] - 2s 11ms/step
```

	precision	recall	f1-score	support
0	1.00	1.00	1.00	303
1	1.00	1.00	1.00	314
2	1.00	1.00	1.00	299
3	1.00	1.00	1.00	328
4	1.00	1.00	1.00	305
5	1.00	1.00	1.00	313
6	1.00	1.00	1.00	318
7	1.00	1.00	1.00	324
8	1.00	1.00	1.00	290
9	1.00	1.00	1.00	303
10	1.00	1.00	1.00	319
11	1.00	1.00	1.00	301
12	1.00	1.00	1.00	297
13	1.00	1.00	1.00	317
14	1.00	1.00	1.00	289
15	0.99	1.00	1.00	281
16	1.00	1.00	1.00	330
17	1.00	1.00	1.00	319
18	1.00	1.00	1.00	284
19	1.00	1.00	1.00	295
20	1.00	1.00	1.00	279
21	1.00	1.00	1.00	279
22	1.00	1.00	1.00	323
23	1.00	1.00	1.00	292
24	1.00	1.00	1.00	309
25	1.00	0.99	1.00	311
26	1.00	1.00	1.00	288
27	1.00	1.00	1.00	268
28	1.00	1.00	1.00	307
29	1.00	1.00	1.00	292
30	1.00	1.00	1.00	261
31	1.00	1.00	1.00	313
32	1.00	1.00	1.00	299
33	1.00	1.00	1.00	269

```
           34       1.00      1.00      1.00       304
           35       1.00      1.00      1.00       282
           36       1.00      1.00      1.00       266
           37       1.00      1.00      1.00       298
           38       1.00      1.00      1.00       338
           39       1.00      1.00      1.00       293

    micro avg       1.00      1.00      1.00     12000
    macro avg       1.00      1.00      1.00     12000
 weighted avg       1.00      1.00      1.00     12000
  samples avg       1.00      1.00      1.00     12000
```

In [ ]:

```
predictions = model.predict(x_test)
print(len(predictions))

up, down = [], []
for i in predictions:
  pred = max(i)
  if pred >= 0.99:
    up.append(pred)
  else:
    down.append(pred)

print("Up:", len(up))
print(up, "\n")
print("Down:", len(down))
print(down, "\n")

fig = plt.figure(figsize=(64, 54))
for i, idx in enumerate(np.random.choice(x_test.shape[0], size=225, replace=False)):
    pred_idx = np.argmax(predictions[idx])
    true_idx = np.argmax(y_test[idx])
    probs = predictions[pred_idx]
    prob = max(predictions[pred_idx])
```

```
    ax = fig.add_subplot(15, 15, i + 1, xticks=[], yticks=[])
    ax.plot(x_test[idx])
    ax.set_title("T: {} P: {} {:.6f}".format(lb.classes_[true_idx], lb.classes_[pred_idx], prob),
                 color=("green" if pred_idx == true_idx else "red"))
    # ax.set_xlabel(probs)
```

In [ ]:

```
def plot_confusion_matrix(cm, classes,
                          normalize=False,
                          title='Confusion matrix',
                          cmap=plt.cm.Blues):
    """
    This function prints and plots the confusion matrix.
    Normalization can be applied by setting `normalize=True`.
    """
    plt.figure(figsize=(20, 20))
    plt.imshow(cm, interpolation='nearest', cmap=cmap)
    plt.title(title)
    plt.colorbar()
    tick_marks = np.arange(len(classes))
    plt.xticks(tick_marks, classes, rotation=45)
    plt.yticks(tick_marks, classes)

    if normalize:
        cm = cm.astype('float') / cm.sum(axis=1)[:, np.newaxis]
        print("Normalized confusion matrix")
    else:
        print('Confusion matrix, without normalization')

    print(cm)

    thresh = cm.max() / 2.
    for i, j in itertools.product(range(cm.shape[0]), range(cm.shape[1])):
        plt.text(j, i, cm[i, j],
            horizontalalignment="center",
            color="white" if cm[i, j] > thresh else "black")

    plt.tight_layout()
```

```
    plt.ylabel('True label')
    plt.xlabel('Predicted label')


%matplotlib inline
from sklearn.metrics import confusion_matrix
import itertools
import matplotlib.pyplot as plt

test = np.argmax(y_test, axis=1)
preds = np.argmax(predictions, axis=1)
cm = confusion_matrix(y_true=test, y_pred=preds)
plot_confusion_matrix(cm=cm, classes=lb.classes_, title='Confusion Matrix')
```

```
Confusion matrix, without normalization
[[1172    0    0 ...    0    0    0]
 [   0 1169    0 ...    0    0    0]
 [   0    0 1261 ...    0    0    0]
 ...
 [   0    0    0 ... 1279    0    0]
 [   0    0    0 ...    0 1168    0]
 [   0    0    0 ...    0    0 1158]]
```