IE6400 Foundations Data Analytics Engineering

Fall Semester 2023

Project 3:

Topic: EEG Classification Model

Group 9 :

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Importing Libraries

In [78]:
```
import os
import wfdb
import glob
import random
import gc
import mne
import re
import tqdm
import logging
import numpy as np
import pandas as pd
import tensorflow as tf
from sklearn import metrics
from tensorflow import keras
import matplotlib.pyplot as plt
from keras.utils import plot_model
from sklearn import model_selection
from scipy.signal import find_peaks
from tensorflow.keras import layers
from tensorflow.keras.callbacks import ReduceLROnPlateau, EarlyStopping
```

Data Preprocessing

In [3]:
```
ch_labels = ['FP1-F7', 'F7-T7', 'T7-P7', 'P7-O1', 'FP1-F3', 'F3-C3', 'C3-P3','P3-O1',
             'FP2-F4', 'F4-C4', 'C4-P4', 'P4-O2', 'FP2-F8', 'F8-T8', 'T8-P8', 'P8-O2',
             'FZ-CZ', 'CZ-PZ']
```

In [22]:
```
file_path = 'D:/chb-mit-scalp-eeg-database-1.0.0/'

folders = sorted(glob.glob(file_path+'/*/'))
n_patient = [m[-2:] for m in [l.rsplit('\\', 2)[-2] for l in folders]]

print(*n_patient)
```

```
01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
```

In [23]:
```
random.seed(2023)

ratio_train = 0.8
train_patient_str = sorted(random.sample(n_patient, round(ratio_train*len(n_patient))))
test_patient_str = sorted([l for l in n_patient if l not in train_patient_str])
print('Train PT: ', *train_patient_str)
print('Test PT: ', *test_patient_str)
```

```
Train PT:  02 03 04 05 06 09 11 12 13 14 15 16 17 18 19 20 21 23 24
Test PT:  01 07 08 10 22
```

In [24]:
```

files_train = []
for l in train_patient_str:
    files_train = files_train + glob.glob(file_path+'/chb{}/*.edf'.format(l))

files_test = []
for l in test_patient_str:
    files_test = files_test + glob.glob(file_path+'/chb{}/*.edf'.format(l))
```

In [25]:
```
len(files_train), len(files_test)
```

Out[25]: (549, 137)

In [28]:
```
logger = logging.getLogger(__name__)
fh = logging.FileHandler('read_files.log')
logger.addHandler(fh)

time_window = 8
time_step = 4


p = 0.01
counter = 0
for temp_f in files_train:
    temp_edf =  mne.io.read_raw_edf(temp_f)
    temp_labels = temp_edf.ch_names
    if sum([any([0 if re.match(c, l)==None else 1 for l in temp_edf.ch_names]) for c in ch_labels])==len(ch_l
        time_window = 8
        time_step = 4
        fs = int(1/(temp_edf.times[1]-temp_edf.times[0]))
        step_window = time_window*fs
        step = time_step*fs

        temp_is_sz = np.zeros((temp_edf.n_times,))
        if os.path.exists(temp_f+'.seizures'):
            temp_annotation = wfdb.rdann(temp_f, 'seizures')
            for i in range(int(temp_annotation.sample.size/2)):
                temp_is_sz[temp_annotation.sample[i*2]:temp_annotation.sample[i*2+1]]=1
        temp_len = temp_edf.n_times

        temp_is_sz_ind = np.array(
            [temp_is_sz[i*step:i*step+step_window].sum()/step_window for i in range((temp_len-step_window)//s
        )

        temp_0_sample_size = round(p*np.where(temp_is_sz_ind==0)[0].size)
        temp_1_sample_size = np.where(temp_is_sz_ind>0)[0].size

        counter = counter + temp_0_sample_size + temp_1_sample_size
    temp_edf.close()

array_signals = np.zeros((counter, len(ch_labels), step_window), dtype=np.float32)
array_is_sz = np.zeros(counter, dtype=bool)

counter = 0
for n, temp_f in enumerate(tqdm.tqdm(files_train)):
    to_log = 'No. {}: Reading. '.format(n)
```

```
    temp_edf =  mne.io.read_raw_edf(temp_f)
    temp_labels = temp_edf.ch_names
    n_label_match = sum([any([0 if re.match(c, l)==None else 1 for l in temp_edf.ch_names]) for c in ch_label
    if n_label_match==len(ch_labels):
        ch_mapping = {sorted([l for l in temp_edf.ch_names if re.match(c, l)!=None ])[0]:c for c in ch_labels
        temp_edf.rename_channels(ch_mapping)

        temp_is_sz = np.zeros((temp_edf.n_times,))
        temp_signals = temp_edf.get_data(picks=ch_labels)*1e6

        if os.path.exists(temp_f+'.seizures'):
            to_log = to_log+'sz exists.'
            temp_annotation = wfdb.rdann(temp_f, 'seizures')
            for i in range(int(temp_annotation.sample.size/2)):
                temp_is_sz[temp_annotation.sample[i*2]:temp_annotation.sample[i*2+1]]=1
        else:
            to_log = to_log+'No sz.'

        temp_len = temp_edf.n_times

        time_window = 8
        time_step = 4
        fs = int(1/(temp_edf.times[1]-temp_edf.times[0]))
        step_window = time_window*fs
        step = time_step*fs

        temp_is_sz_ind = np.array(
            [temp_is_sz[i*step:i*step+step_window].sum()/step_window for i in range((temp_len-step_window)//s
        )
        del temp_is_sz

        temp_0_sample_size = round(p*np.where(temp_is_sz_ind==0)[0].size)
        temp_1_sample_size = np.where(temp_is_sz_ind>0)[0].size

        # sz data
        temp_ind = list(np.where(temp_is_sz_ind>0)[0])
        for i in temp_ind:
            array_signals[counter, :, :] = temp_signals[:, i*step:i*step+step_window]
            array_is_sz[counter] = True
            counter = counter+1

        # no sz data
        temp_ind = random.sample(list(np.where(temp_is_sz_ind==0)[0]), temp_0_sample_size)
```

```
        for i in temp_ind:
            array_signals[counter, :, :] = temp_signals[:, i*step:i*step+step_window]
            array_is_sz[counter] = False
            counter = counter+1

        to_log += '{} signals added: {} w/o sz, {} w/ sz.'.format(
            temp_0_sample_size+temp_1_sample_size, temp_0_sample_size, temp_1_sample_size
        )

    else:
        to_log += 'Not appropriate channel labels. Reading skipped.'.format(n)

    logger.info(to_log)
    temp_edf.close()

    if n%10==0:
        gc.collect()
gc.collect()

np.save('signal_samples', array_signals)
np.save('is_sz', array_is_sz)
```

```
100%|██████████████████████████████████████████████████████████████████████████| 549/549 [06:10<00:00,
1.48it/s]
```

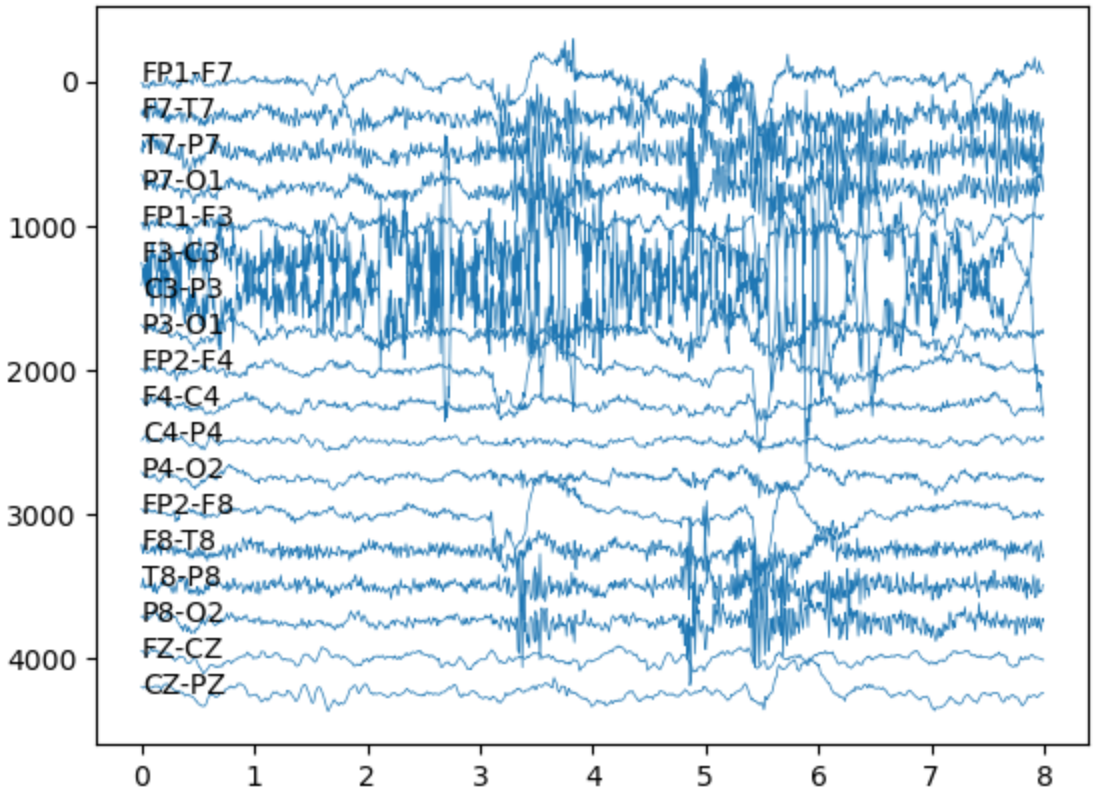
In [29]:
```
array_signals.shape
```

Out[29]:
```
(9505, 18, 2048)
```

In [30]:
```
array_signals = array_signals[:, :, ::2]
```

Feature Extraction

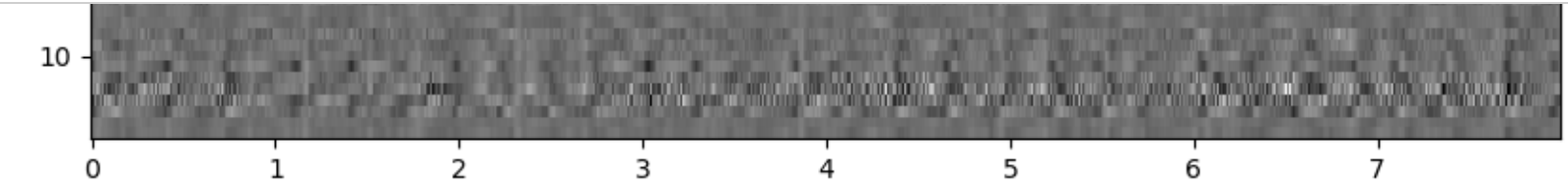
In [31]:
```
# Displaying a sample of extracted features of the EEG signals

vertical_width = 250
signals = array_signals[-1, :, :]
fs = 128

fig, ax = plt.subplots()
for i in range(signals.shape[0]):
    ax.plot(np.arange(signals.shape[-1])/fs, signals[i, :]+i*vertical_width, linewidth=0.5, color='tab:blue')
    ax.annotate(ch_labels[i], xy=(0, i*vertical_width))
ax.invert_yaxis()
plt.show()
```

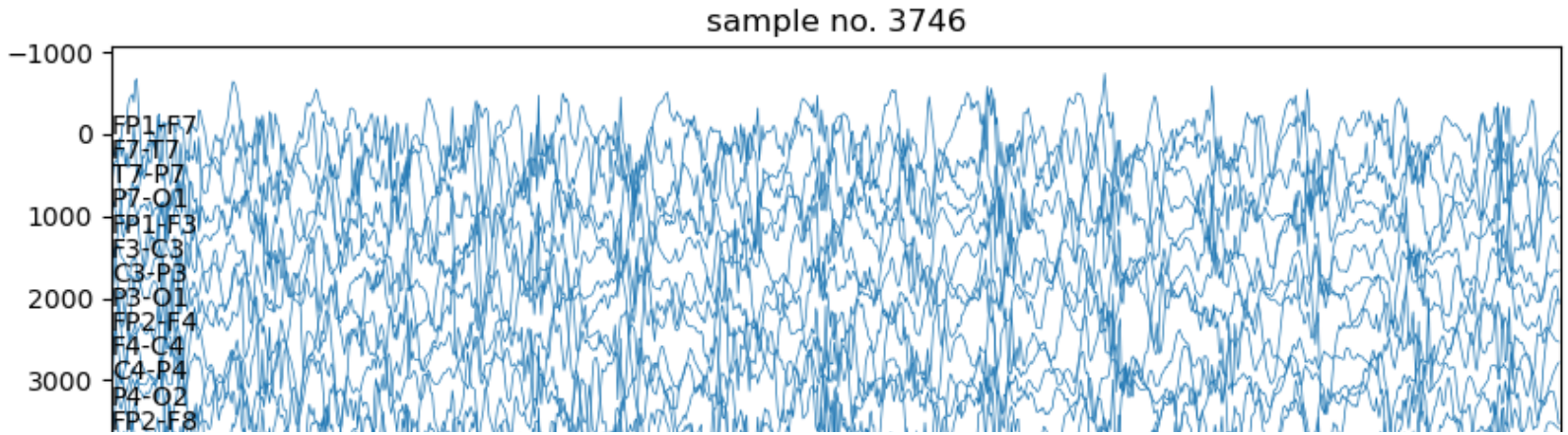


In [32]:
```
array_n = np.where(array_is_sz>.0)[0]
print('Number of all the extracted signals: {}'.format(array_is_sz.size))
print('Number of signals with seizures: {}'.format(array_n.size))
print('Ratio of signals with seizures: {:.3f}'.format(array_n.size/array_is_sz.size))
```

```
Number of all the extracted signals: 9505
Number of signals with seizures: 2581
Ratio of signals with seizures: 0.272
```

In [33]:
```
# Displaying samples with seizures.

for n in random.sample(list(array_n), 10):

    vertical_width = 300
    temp_signals = array_signals[n, :, :]
    fs = 128

    fig, ax = plt.subplots(2, 1, figsize=(10, 6), gridspec_kw={'height_ratios': [3, 1]})
    for i in range(temp_signals.shape[0]):
        ax[0].plot(np.arange(temp_signals.shape[-1])/fs, temp_signals[i, :]+i*vertical_width, linewidth=0.5,
        ax[0].annotate(ch_labels[i], xy=(0, i*vertical_width))
    ax[0].invert_yaxis()
    ax[0].set_xlim(0, 8)
    ax[0].set_title('sample no. {}'.format(n))

    ax[1].pcolormesh(np.arange(temp_signals.shape[-1])/fs, np.arange(len(ch_labels)), temp_signals[:, :], cma
    ax[1].invert_yaxis()

    plt.show()
```





Data Splitting

In [35]:
```
# Channel dimension is added, so that CNN model can be used.
array_signals = array_signals[:, :, :, np.newaxis]

array_signals.shape
```

Out[35]:
```
(9505, 18, 1024, 1)
```

In [36]:
```
# Splitting training data into training & validation data.

X_train, X_val, y_train, y_val = model_selection.train_test_split(
    array_signals, array_is_sz, test_size=0.3,
    stratify=(array_is_sz>0))
```

Model Creation

In [38]:
```
## Creating Deep learning model

model = keras.models.Sequential()

model.add(layers.Conv2D(filters=64, kernel_size=(2, 4), padding='same', activation='relu', input_shape=X_trai
model.add(layers.Conv2D(filters=64, kernel_size=(2, 4), strides=(1, 2),padding='same', activation='relu'))
model.add(layers.MaxPooling2D((1, 2)))

model.add(layers.Conv2D(filters=128, kernel_size=(2, 4), padding='same', activation='relu'))
model.add(layers.Conv2D(filters=128, kernel_size=(2, 4), strides=(1, 2), padding='same', activation='relu'))
model.add(layers.MaxPooling2D((2, 2)))

model.add(layers.Conv2D(filters=256, kernel_size=(4, 4), padding='same', activation='relu'))
model.add(layers.Conv2D(filters=256, kernel_size=(4, 4), strides=(1, 2), padding='same', activation='relu'))
model.add(layers.MaxPooling2D((1, 2)))

model.add(layers.GlobalAveragePooling2D())
#model.add(layers.Flatten())
model.add(layers.Dense(256, activation='relu'))
model.add(layers.Dropout(0.25))
model.add(layers.Dense(128, activation='relu'))
model.add(layers.Dense(64, activation='relu'))
model.add(layers.Dropout(0.25))
model.add(layers.Dense(1, activation='sigmoid'))
```

```
D:\Programfiles\anaconda3\Lib\site-packages\keras\src\layers\convolutional\base_conv.py:99: UserWarning: Do
not pass an `input_shape`/`input_dim` argument to a layer. When using Sequential models, prefer using an `In
put(shape)` object as the first layer in the model instead.
  super().__init__(
```

In [39]:
```
model.summary()
```

Model: "sequential"

Layer (type)	Output Shape	Param #
conv2d (Conv2D)	(None, 18, 1024, 64)	576
conv2d_1 (Conv2D)	(None, 18, 512, 64)	32,832
max_pooling2d (MaxPooling2D)	(None, 18, 256, 64)	0
conv2d_2 (Conv2D)	(None, 18, 256, 128)	65,664
conv2d_3 (Conv2D)	(None, 18, 128, 128)	131,200
max_pooling2d_1 (MaxPooling2D)	(None, 9, 64, 128)	0
conv2d_4 (Conv2D)	(None, 9, 64, 256)	524,544
conv2d_5 (Conv2D)	(None, 9, 32, 256)	1,048,832
max_pooling2d_2 (MaxPooling2D)	(None, 9, 16, 256)	0
global_average_pooling2d (GlobalAveragePooling2D)	(None, 256)	0
dense (Dense)	(None, 256)	65,792
dropout (Dropout)	(None, 256)	0
dense_1 (Dense)	(None, 128)	32,896
dense_2 (Dense)	(None, 64)	8,256
dropout_1 (Dropout)	(None, 64)	0
dense_3 (Dense)	(None, 1)	65

Total params: 1,910,657 (7.29 MB)

Trainable params: 1,910,657 (7.29 MB)

Non-trainable params: 0 (0.00 B)

Model Training

In [45]:
```
LEARNING_RATE = 1e-4
OPTIMIZER = tf.keras.optimizers.Adam(learning_rate=LEARNING_RATE)

model.compile(optimizer=OPTIMIZER, loss='binary_crossentropy', metrics=['accuracy'])

VERBOSE=1
es = EarlyStopping(monitor='val_loss', patience=20, verbose=VERBOSE, mode='auto', restore_best_weights=True)
callbacks = [es]
```

In [47]:
```
X_train.shape, y_train.shape, X_val.shape, y_val.shape
```

Out[47]:
```
((6653, 18, 1024, 1), (6653,), (2852, 18, 1024, 1), (2852,))
```

In [61]:
```
hist = model.fit(
    x=X_train, y=y_train,
    validation_data=(X_val, y_val),
    epochs=5,
    batch_size=256,
    callbacks=callbacks
)
```

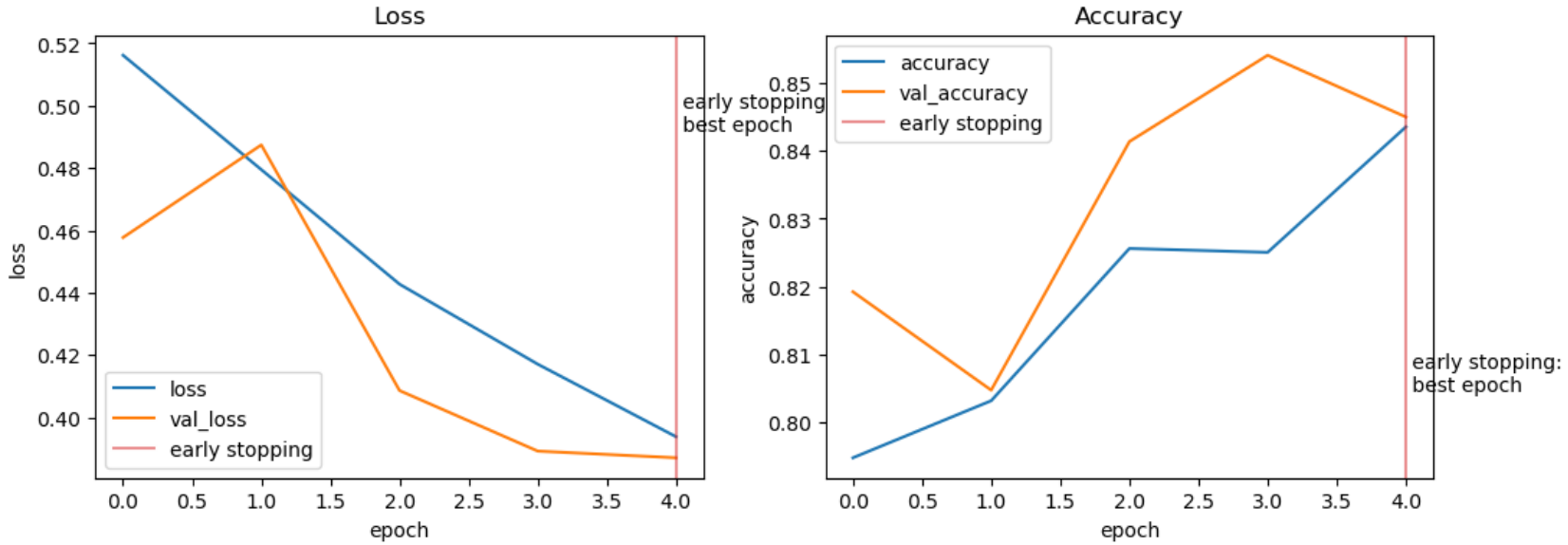
```
Epoch 1/5
26/26 ━━━━━━━━━━━━━━━━━━━━ 478s 18s/step - accuracy: 0.7984 - loss: 0.5036 - val_accuracy: 0.8193 - val_los
s: 0.4577
Epoch 2/5
26/26 ━━━━━━━━━━━━━━━━━━━━ 465s 18s/step - accuracy: 0.7972 - loss: 0.4930 - val_accuracy: 0.8048 - val_los
s: 0.4874
Epoch 3/5
26/26 ━━━━━━━━━━━━━━━━━━━━ 461s 18s/step - accuracy: 0.8268 - loss: 0.4527 - val_accuracy: 0.8414 - val_los
s: 0.4087
Epoch 4/5
26/26 ━━━━━━━━━━━━━━━━━━━━ 461s 18s/step - accuracy: 0.8317 - loss: 0.4078 - val_accuracy: 0.8541 - val_los
s: 0.3892
Epoch 5/5
26/26 ━━━━━━━━━━━━━━━━━━━━ 462s 18s/step - accuracy: 0.8483 - loss: 0.3866 - val_accuracy: 0.8450 - val_los
s: 0.3871
Restoring model weights from the end of the best epoch: 5.
```

In [62]:
```
model.save('CHB_MIT_sz_detec_demo.h5')
```

```
D:\Programfiles\anaconda3\Lib\site-packages\keras\src\models\model.py:342: UserWarning: You are saving your
model as an HDF5 file via `model.save()`. This file format is considered legacy. We recommend using instead
the native Keras format, e.g. `model.save('my_model.keras')`.
  warnings.warn(
```

Model Evaluation and Testing

In [63]:
```
fig, ax = plt.subplots(1, 2, figsize=(12, 4))

ax[0].plot(hist.history['loss'], label='loss')
ax[0].plot(hist.history['val_loss'], label='val_loss')
ax[0].set_xlabel('epoch')
ax[0].set_ylabel('loss')
ax[0].axvline(x=es.best_epoch, label='early stopping', color='tab:red', alpha=0.5)
r = .2
temp_y = r*min(hist.history['loss'])+(1-r)*max(hist.history['loss'])
ax[0].annotate(' early stopping:\n best epoch', xy=(es.best_epoch, temp_y))
ax[0].set_title('Loss')
ax[0].legend()

ax[1].plot(hist.history['accuracy'], label='accuracy')
ax[1].plot(hist.history['val_accuracy'], label='val_accuracy')
ax[1].set_xlabel('epoch')
ax[1].set_ylabel('accuracy')
r = .8
temp_y = r*min(hist.history['accuracy'])+(1-r)*max(hist.history['accuracy'])
ax[1].axvline(x=es.best_epoch, label='early stopping', color='tab:red', alpha=0.5)
ax[1].annotate(' early stopping:\n best epoch', xy=(es.best_epoch, temp_y))
ax[1].set_title('Accuracy')
ax[1].legend()

plt.show()
```


Loss
loss
val_loss
early stopping
early stopping
best epoch
loss
epoch
Accuracy
accuracy
val_accuracy
early stopping
early stopping:
best epoch
accuracy
epoch

In [64]:
```
def sampling_data_pred(f, verbose=True):
    list_signals = []
    list_is_sz = []
    #n_sample = 40
    if verbose==True:
        print('{}: Reading. '.format(f))
    temp_edf =  mne.io.read_raw_edf(f)
    temp_labels = temp_edf.ch_names
    if sum([any([0 if re.match(c, l)==None else 1 for l in temp_edf.ch_names]) for c in ch_labels])==len(ch_l
        ch_mapping = {sorted([l for l in temp_edf.ch_names if re.match(c, l)!=None ])[0]:c for c in ch_labels
        temp_edf.rename_channels(ch_mapping)
        #temp_edf = temp_edf.pick(ch_labels)

        temp_is_sz = np.zeros((temp_edf.n_times,))
        temp_signals = temp_edf.get_data(picks=ch_labels)*1e6

        if os.path.exists(f+'.seizures'):
            if verbose==True:
                print('sz exists.', end=' ')
            temp_annotation = wfdb.rdann(f, 'seizures')
            for i in range(int(temp_annotation.sample.size/2)):
                temp_is_sz[temp_annotation.sample[i*2]:temp_annotation.sample[i*2+1]]=1
        #else:
            #print('No sz.', end=' ')

        temp_len = temp_edf.n_times

        time_window = 8
        time_step = 4
        fs = int(1/(temp_edf.times[1]-temp_edf.times[0]))
        step_window = time_window*fs
        step = time_step*fs

        # sampling all signals
        temp_array_signals = np.array([temp_signals[:, i*step:i*step+step_window] for i in range((temp_len-st
        temp_is_sz_ind = np.array([temp_is_sz[i*step:i*step+step_window].sum()/step_window for i in range((te
    else:
        if verbose==True:
            print('EEG {}: Not appropriate channel labels. Reading skipped.'.format(n))
```

```
    return temp_array_signals, temp_is_sz_ind
```

In [65]:
```
# reading files and prediction

list_pred = []
list_true = []

for f in tqdm.tqdm(files_test):
    array_signals, array_is_sz = sampling_data_pred(f, verbose=False)
    array_signals = array_signals[:, :, ::2, np.newaxis]

    list_pred.append(model.predict(array_signals, verbose=0))
    list_true.append(array_is_sz)
```

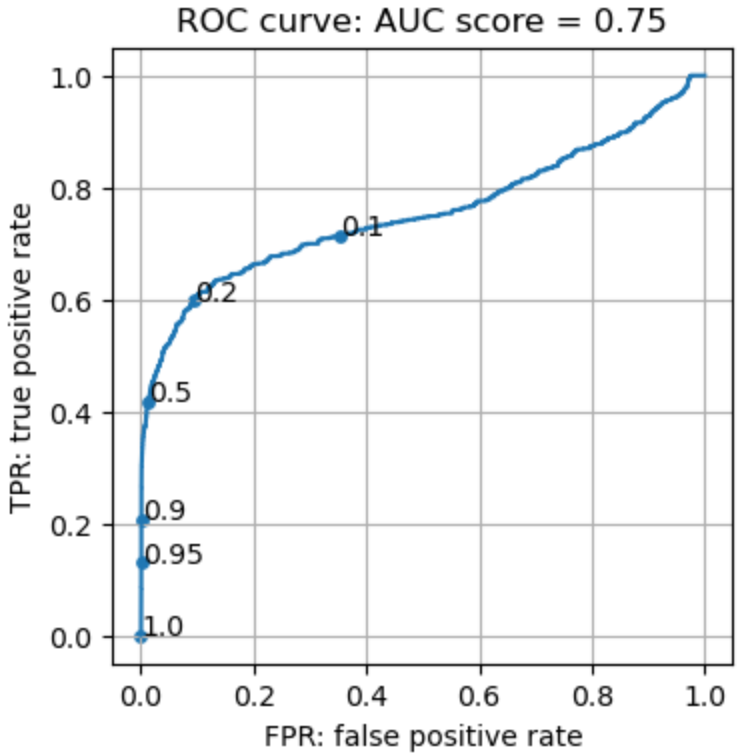
```
100%|██████████| 137/137 [1:03:12<00:00,
27.68s/it]
```

In [76]:
```
# Setting threshold = 0.5
report = metrics.classification_report(np.concatenate(list_true)>0, np.concatenate(list_pred)>.5)
print(report)

# Setting threshold = 0.9
report = metrics.classification_report(np.concatenate(list_true)>0, np.concatenate(list_pred)>.9)
print(report)
```

```
              precision    recall  f1-score   support

       False       1.00      0.99      0.99    186865
        True       0.10      0.42      0.16       629

    accuracy                           0.99    187494
   macro avg       0.55      0.70      0.58    187494
weighted avg       0.99      0.99      0.99    187494

              precision    recall  f1-score   support

       False       1.00      1.00      1.00    186865
        True       0.53      0.21      0.30       629

    accuracy                           1.00    187494
   macro avg       0.77      0.60      0.65    187494
weighted avg       1.00      1.00      1.00    187494
```

In [69]:
```
roc = metrics.roc_curve(np.concatenate(list_true)>0, np.concatenate(list_pred))
auc = metrics.roc_auc_score(np.concatenate(list_true)>0, np.concatenate(list_pred))
```

In [70]:
```
plt.figure(figsize=(4, 4))
plt.plot(roc[0][np.argmin(np.abs(roc[2]-1)):], roc[1][np.argmin(np.abs(roc[2]-1)):])
plt.xlabel('FPR: false positive rate')
plt.ylabel('TPR: true positive rate')
plt.title('ROC curve: AUC score = {:.2f}'.format(auc))

th = [.1, .2, .5, .9, .95, 1.]
ind = [np.argmin(np.abs(roc[2]-l)) for l in th]
plt.scatter(roc[0][ind], roc[1][ind], s=15)
for i, l in enumerate(ind):
    plt.annotate("{}".format(th[i]), xy=(roc[0][l], roc[1][l]))
#plt.plot([0, 1, 1, 0, 0], [0, 0, 1, 1, 0], color='black', linewidth=1)
plt.ylim(-.05, 1.05)
plt.xlim(-.05, 1.05)
plt.grid()
#plt.axis('off')
plt.show()
```



In [71]:
```
for i, f in enumerate(files_test):
    if os.path.exists(f+'.seizures'):
        print('Index = {} has seizures: {}'.format(i, f))
```

```
Index = 2 has seizures: D:/chb-mit-scalp-eeg-database-1.0.0//chb01\chb01_03.edf
Index = 3 has seizures: D:/chb-mit-scalp-eeg-database-1.0.0//chb01\chb01_04.edf
Index = 14 has seizures: D:/chb-mit-scalp-eeg-database-1.0.0//chb01\chb01_15.edf
Index = 15 has seizures: D:/chb-mit-scalp-eeg-database-1.0.0//chb01\chb01_16.edf
Index = 17 has seizures: D:/chb-mit-scalp-eeg-database-1.0.0//chb01\chb01_18.edf
Index = 20 has seizures: D:/chb-mit-scalp-eeg-database-1.0.0//chb01\chb01_21.edf
Index = 25 has seizures: D:/chb-mit-scalp-eeg-database-1.0.0//chb01\chb01_26.edf
Index = 53 has seizures: D:/chb-mit-scalp-eeg-database-1.0.0//chb07\chb07_12.edf
Index = 54 has seizures: D:/chb-mit-scalp-eeg-database-1.0.0//chb07\chb07_13.edf
Index = 60 has seizures: D:/chb-mit-scalp-eeg-database-1.0.0//chb07\chb07_19.edf
Index = 61 has seizures: D:/chb-mit-scalp-eeg-database-1.0.0//chb08\chb08_02.edf
Index = 64 has seizures: D:/chb-mit-scalp-eeg-database-1.0.0//chb08\chb08_05.edf
Index = 66 has seizures: D:/chb-mit-scalp-eeg-database-1.0.0//chb08\chb08_11.edf
Index = 68 has seizures: D:/chb-mit-scalp-eeg-database-1.0.0//chb08\chb08_13.edf
Index = 76 has seizures: D:/chb-mit-scalp-eeg-database-1.0.0//chb08\chb08_21.edf
Index = 89 has seizures: D:/chb-mit-scalp-eeg-database-1.0.0//chb10\chb10_12.edf
Index = 97 has seizures: D:/chb-mit-scalp-eeg-database-1.0.0//chb10\chb10_20.edf
Index = 100 has seizures: D:/chb-mit-scalp-eeg-database-1.0.0//chb10\chb10_27.edf
Index = 102 has seizures: D:/chb-mit-scalp-eeg-database-1.0.0//chb10\chb10_30.edf
Index = 103 has seizures: D:/chb-mit-scalp-eeg-database-1.0.0//chb10\chb10_31.edf
Index = 104 has seizures: D:/chb-mit-scalp-eeg-database-1.0.0//chb10\chb10_38.edf
Index = 105 has seizures: D:/chb-mit-scalp-eeg-database-1.0.0//chb10\chb10_89.edf
Index = 122 has seizures: D:/chb-mit-scalp-eeg-database-1.0.0//chb22\chb22_20.edf
Index = 127 has seizures: D:/chb-mit-scalp-eeg-database-1.0.0//chb22\chb22_25.edf
Index = 133 has seizures: D:/chb-mit-scalp-eeg-database-1.0.0//chb22\chb22_38.edf
```

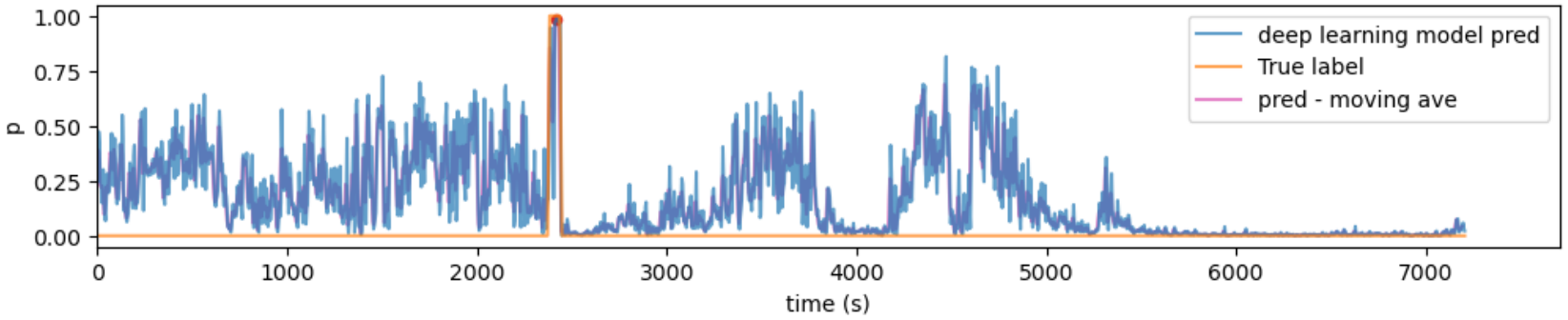
Results and Visualization

In [72]:
```
def moving_ave(a, n):
    if len(a.shape)!=1:
        print('Not 1 dimension array. return nothing.')
        return
    temp = np.zeros(a.size-n)
    for i in range(n):
        temp = temp+a[i:-n+i]
    temp = temp/n

    return temp
```

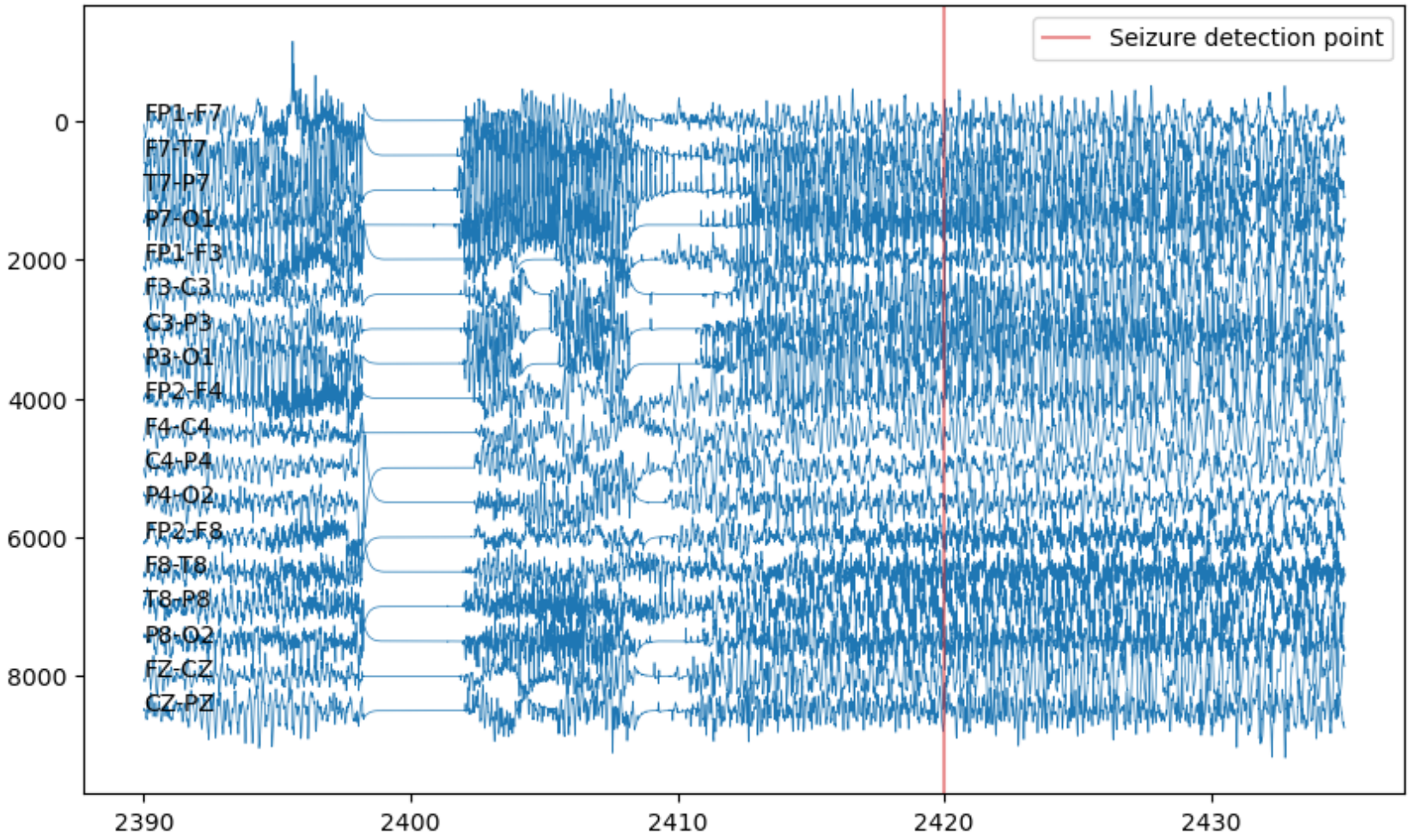
In [73]:
```
# Getting signals and labels from test data.
n=100
array_signals, array_is_sz = sampling_data_pred(files_test[n])

# Preprocessing the Test data
array_signals=array_signals[:, :, ::2, np.newaxis]

# Prediction using the created deep learning model
pred = model.predict(array_signals)
```

```
D:/chb-mit-scalp-eeg-database-1.0.0//chb10\chb10_27.edf: Reading.
57/57 ━━━━━━━━━━━━━━━━━━━━ 35s 606ms/step
```

In [74]:
```
time_window = 8
time_step = 4
mv_win = 3

fig, ax = plt.subplots(figsize=(12, 2))

ax.plot(np.arange(pred.size)*time_step, pred.flatten(), alpha=0.7, label='deep learning model pred')
ax.plot(np.arange(pred.size)*time_step, array_is_sz, alpha=.7, label='True label')

pred_moving_ave = moving_ave(pred.flatten(), mv_win)
pred_peaks, _ = find_peaks(pred_moving_ave, height=.95, distance=6)
ax.plot(np.arange(pred.size-mv_win)*time_step, pred_moving_ave,
        alpha=.9, label='pred - moving ave', color='tab:pink', zorder=0)
ax.scatter(pred_peaks*time_step, pred_moving_ave[pred_peaks], s=20, color='tab:red')

ax.set_xlabel('time (s)')
ax.set_ylabel('p')
ax.set_xlim(0, pred.size*time_step+500)
ax.legend(loc='upper right')
plt.show()
```



In [75]:
```
if pred_peaks.size==0:
    print('No seizure detected.')
else:
    f = files_test[n]
    temp_edf =  mne.io.read_raw_edf(f)
    temp_labels = temp_edf.ch_names
    if sum([any([0 if re.match(c, l)==None else 1 for l in temp_edf.ch_names]) for c in ch_labels])==len(ch_l
        ch_mapping = {sorted([l for l in temp_edf.ch_names if re.match(c, l)!=None ])[0]:c for c in ch_labels
        temp_edf.rename_channels(ch_mapping)
        #temp_edf = temp_edf.pick(ch_labels)

        temp_is_sz = np.zeros((temp_edf.n_times,))
        temp_signals = temp_edf.get_data(picks=ch_labels)*1e6

    fs = int(1/(temp_edf.times[1]-temp_edf.times[0]))
    for n_peak in range(pred_peaks.size):
        ind_peak = pred_peaks[n_peak]*time_step*fs
        backward_steps = 30*fs
        forward_steps = 15*fs
        vertical_width=500

        fig, ax = plt.subplots(figsize=(10, 6))
        for i in range(temp_signals.shape[0]):
            ax.plot(np.arange(ind_peak-backward_steps, ind_peak+forward_steps)/fs,
                    temp_signals[i, ind_peak-backward_steps:ind_peak+forward_steps]+i*vertical_width, linewid
            ax.annotate(ch_labels[i], xy=((ind_peak-backward_steps)/fs, i*vertical_width))
        ax.axvline(x=ind_peak/fs, color='tab:red', alpha=0.5, label='Seizure detection point')
        ax.invert_yaxis()
        ax.legend(loc='upper right')
        plt.show()
    #ax.set_xlim(0, 8)

    temp_edf.close()
```


Seizure detection point
FP1-F7
F7-T7
T7-P7
P7-O1
FP1-F3
F3-C3
C3-P3
P3-O1
FP2-F4
F4-C4
C4-P4
P4-O2
FP2-F8
F8-T8
T8-P8
P8-O2
FZ-CZ
CZ-PZ
0
2000
4000
6000
8000
2390
2400
2410
2420
2430

In [ ]: