

# FCN-FCT-20E-16L-03

March 24, 2021

## 1 Are Relations Relevant in CNNs? *A Study Based on a Facial Dataset*

### 1.1 FCN with Features Closer Together (*20 Epochs - 16 Layers*)

#### 1.1.1 Imports, Seed, GPU integration

```
[1]: import numpy as np
import random
import tensorflow as tf
```

```
[2]: # Seeds for better reproducibility
seed = 42
np.random.seed(seed)
random.seed(seed)
tf.random.set_seed(seed)
```

```
[3]: from tensorflow.keras.layers import Dropout, Conv2D, GlobalMaxPooling2D,
↳BatchNormalization, Activation, MaxPool2D
from tensorflow.keras.optimizers import Adam
from tensorflow.keras.models import load_model
from tensorflow.keras.preprocessing.image import ImageDataGenerator
from tensorflow.python.keras.models import Sequential
from sklearn.metrics import confusion_matrix
import itertools
import matplotlib.pyplot as plt
import warnings
warnings.simplefilter(action='ignore', category=FutureWarning)
%matplotlib inline
```

```
[4]: physical_devices = tf.config.experimental.list_physical_devices('GPU')
print("Num GPUs Available: ", len(physical_devices))
tf.config.experimental.set_memory_growth(physical_devices[0], True)
```

Num GPUs Available: 1

### 1.1.2 Data preparation

```
[5]: train_path = '../..//picasso_dataset/FCT-data/middle/train'
      valid_path = '../..//picasso_dataset/FCT-data/middle/valid'
      test_path = '../..//picasso_dataset/FCT-data/middle/test'

[6]: train_batches = ImageDataGenerator(preprocessing_function=tf.keras.applications.
      ↪vgg16.preprocess_input) \
      .flow_from_directory(directory=train_path, target_size=(224,224),
      ↪classes=['no_face', 'face'], batch_size=20)

      valid_batches = ImageDataGenerator(preprocessing_function=tf.keras.applications.
      ↪vgg16.preprocess_input) \
      .flow_from_directory(directory=valid_path, target_size=(224,224),
      ↪classes=['no_face', 'face'], batch_size=10)

      test_batches = ImageDataGenerator(preprocessing_function=tf.keras.applications.
      ↪vgg16.preprocess_input) \
      .flow_from_directory(directory=test_path, target_size=(224,224),
      ↪classes=['no_face', 'face'], batch_size=10, shuffle=False)
```

Found 16002 images belonging to 2 classes.

Found 998 images belonging to 2 classes.

Found 3000 images belonging to 2 classes.

```
[7]: assert train_batches.n == 16002
      assert valid_batches.n == 998
      assert test_batches.n == 3000
      assert train_batches.num_classes == valid_batches.num_classes == test_batches.
      ↪num_classes == 2
```

### 1.1.3 Building and training the FCN

```
[8]: dropout_rate=0.2

[9]: model = Sequential(name = "FCN-FCT")

      model.add(Conv2D(filters=32, kernel_size=(3, 3), activation='relu', padding =
      ↪'same', input_shape=(224,224,3), name = "Conv_1"))
      model.add(MaxPool2D(pool_size=(2, 2), name = "Max_1"))
      model.add(Dropout(rate=dropout_rate, name = "DO_1"))
      model.add(BatchNormalization(name = "BN_1"))

      model.add(Conv2D(filters=64, kernel_size=(3, 3), activation='relu', padding =
      ↪'same', name = "Conv_2"))
      model.add(MaxPool2D(pool_size=(2, 2), name = "Max_2"))
```

```

model.add(Conv2D(filters=128, kernel_size=(3, 3), activation='relu', padding =
↳ 'same', name = "Conv_3"))
model.add(MaxPool2D(pool_size=(2, 2), name = "Max_3"))
model.add(Dropout(rate=dropout_rate, name = "DO_3"))

model.add(Conv2D(filters=256, kernel_size=(3, 3), activation='relu', padding =
↳ 'same', name = "Conv_4"))
model.add(MaxPool2D(pool_size=(2, 2), name = "Max_4"))

model.add(Conv2D(filters=512, kernel_size=(3, 3), activation='relu', padding =
↳ 'same', name = "Conv_5"))
model.add(MaxPool2D(pool_size=(2, 2), name = "Max_5"))

# Fully connected layer
model.add(Conv2D(filters=2, kernel_size=(1,1), name = "Conv_con"))
model.add(GlobalMaxPooling2D(name = "GMax_con"))
model.add(Activation('softmax', name = "Act_con"))

model.summary()
untrained_weights = list(model.get_weights()[0][0][0][0])

```

Model: "FCN-FCT"

| Layer (type)              | Output Shape         | Param # |
|---------------------------|----------------------|---------|
| Conv_1 (Conv2D)           | (None, 224, 224, 32) | 896     |
| Max_1 (MaxPooling2D)      | (None, 112, 112, 32) | 0       |
| DO_1 (Dropout)            | (None, 112, 112, 32) | 0       |
| BN_1 (BatchNormalization) | (None, 112, 112, 32) | 128     |
| Conv_2 (Conv2D)           | (None, 112, 112, 64) | 18496   |
| Max_2 (MaxPooling2D)      | (None, 56, 56, 64)   | 0       |
| Conv_3 (Conv2D)           | (None, 56, 56, 128)  | 73856   |
| Max_3 (MaxPooling2D)      | (None, 28, 28, 128)  | 0       |
| DO_3 (Dropout)            | (None, 28, 28, 128)  | 0       |
| Conv_4 (Conv2D)           | (None, 28, 28, 256)  | 295168  |
| Max_4 (MaxPooling2D)      | (None, 14, 14, 256)  | 0       |

|                               |                     |         |
|-------------------------------|---------------------|---------|
| Conv_5 (Conv2D)               | (None, 14, 14, 512) | 1180160 |
| -----                         |                     |         |
| Max_5 (MaxPooling2D)          | (None, 7, 7, 512)   | 0       |
| -----                         |                     |         |
| Conv_con (Conv2D)             | (None, 7, 7, 2)     | 1026    |
| -----                         |                     |         |
| GMax_con (GlobalMaxPooling2D) | (None, 2)           | 0       |
| -----                         |                     |         |
| Act_con (Activation)          | (None, 2)           | 0       |
| =====                         |                     |         |
| Total params: 1,569,730       |                     |         |
| Trainable params: 1,569,666   |                     |         |
| Non-trainable params: 64      |                     |         |
| -----                         |                     |         |

```
[10]: model.compile(optimizer=Adam(learning_rate=0.0001),
                loss='categorical_crossentropy',
                metrics=['accuracy'] )
```

```
[11]: history = model.fit(x=train_batches,
                steps_per_epoch=len(train_batches),
                validation_data=valid_batches,
                validation_steps=len(valid_batches),
                epochs=20,
                verbose=2 )
```

Epoch 1/20

WARNING:tensorflow:Callbacks method `on\_train\_batch\_end` is slow compared to the batch time (batch time: 0.0153s vs `on\_train\_batch\_end` time: 0.0246s). Check your callbacks.

801/801 - 42s - loss: 0.3582 - accuracy: 0.8025 - val\_loss: 0.0693 - val\_accuracy: 0.9760

Epoch 2/20

801/801 - 42s - loss: 0.0255 - accuracy: 0.9919 - val\_loss: 0.0191 - val\_accuracy: 0.9960

Epoch 3/20

801/801 - 42s - loss: 0.0103 - accuracy: 0.9963 - val\_loss: 0.0044 - val\_accuracy: 0.9990

Epoch 4/20

801/801 - 41s - loss: 0.0064 - accuracy: 0.9981 - val\_loss: 0.0017 - val\_accuracy: 1.0000

Epoch 5/20

801/801 - 42s - loss: 0.0051 - accuracy: 0.9983 - val\_loss: 0.0019 - val\_accuracy: 0.9990

Epoch 6/20

801/801 - 42s - loss: 0.0025 - accuracy: 0.9993 - val\_loss: 0.0013 - val\_accuracy: 0.9990

Epoch 7/20

```

801/801 - 42s - loss: 0.0018 - accuracy: 0.9996 - val_loss: 0.0037 -
val_accuracy: 1.0000
Epoch 8/20
801/801 - 42s - loss: 0.0046 - accuracy: 0.9987 - val_loss: 0.0018 -
val_accuracy: 1.0000
Epoch 9/20
801/801 - 42s - loss: 0.0016 - accuracy: 0.9995 - val_loss: 8.9828e-04 -
val_accuracy: 1.0000
Epoch 10/20
801/801 - 41s - loss: 1.3692e-04 - accuracy: 1.0000 - val_loss: 4.0088e-05 -
val_accuracy: 1.0000
Epoch 11/20
801/801 - 41s - loss: 4.9611e-05 - accuracy: 1.0000 - val_loss: 1.4407e-04 -
val_accuracy: 1.0000
Epoch 12/20
801/801 - 42s - loss: 0.0068 - accuracy: 0.9976 - val_loss: 0.0016 -
val_accuracy: 0.9990
Epoch 13/20
801/801 - 42s - loss: 0.0018 - accuracy: 0.9992 - val_loss: 0.0036 -
val_accuracy: 0.9990
Epoch 14/20
801/801 - 42s - loss: 8.7512e-05 - accuracy: 1.0000 - val_loss: 0.0037 -
val_accuracy: 0.9990
Epoch 15/20
801/801 - 41s - loss: 0.0035 - accuracy: 0.9989 - val_loss: 1.1012e-04 -
val_accuracy: 1.0000
Epoch 16/20
801/801 - 42s - loss: 8.4101e-05 - accuracy: 1.0000 - val_loss: 2.5089e-05 -
val_accuracy: 1.0000
Epoch 17/20
801/801 - 42s - loss: 2.3583e-05 - accuracy: 1.0000 - val_loss: 1.6129e-05 -
val_accuracy: 1.0000
Epoch 18/20
801/801 - 42s - loss: 6.3399e-06 - accuracy: 1.0000 - val_loss: 1.0588e-05 -
val_accuracy: 1.0000
Epoch 19/20
801/801 - 42s - loss: 4.9552e-06 - accuracy: 1.0000 - val_loss: 7.6632e-06 -
val_accuracy: 1.0000
Epoch 20/20
801/801 - 42s - loss: 3.0087e-06 - accuracy: 1.0000 - val_loss: 6.2418e-06 -
val_accuracy: 1.0000

```

#### 1.1.4 Saving the model

```
[12]: filename='models/FCN-FCT-20E-16L-03.h5'
```

```
[13]: model.save(filename)
      saved_weights = list(model.get_weights()[0][0][0][0])
```

### 1.1.5 Loading the saved model

```
[14]: loaded_model = load_model(filename)
      loaded_weights = list(loaded_model.get_weights()[0][0][0][0])
```

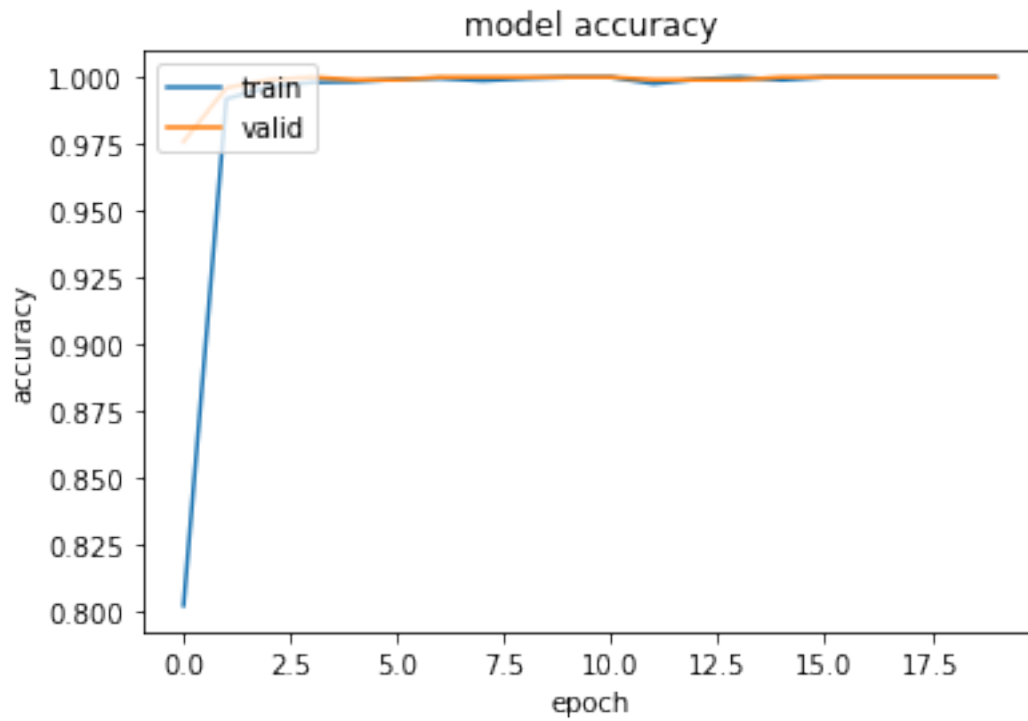
```
[15]: # Assertion that the model was saved and loaded successfully
      assert untrained_weights != saved_weights
      assert saved_weights == loaded_weights
```

### 1.1.6 Accuracy and loss of the trained model

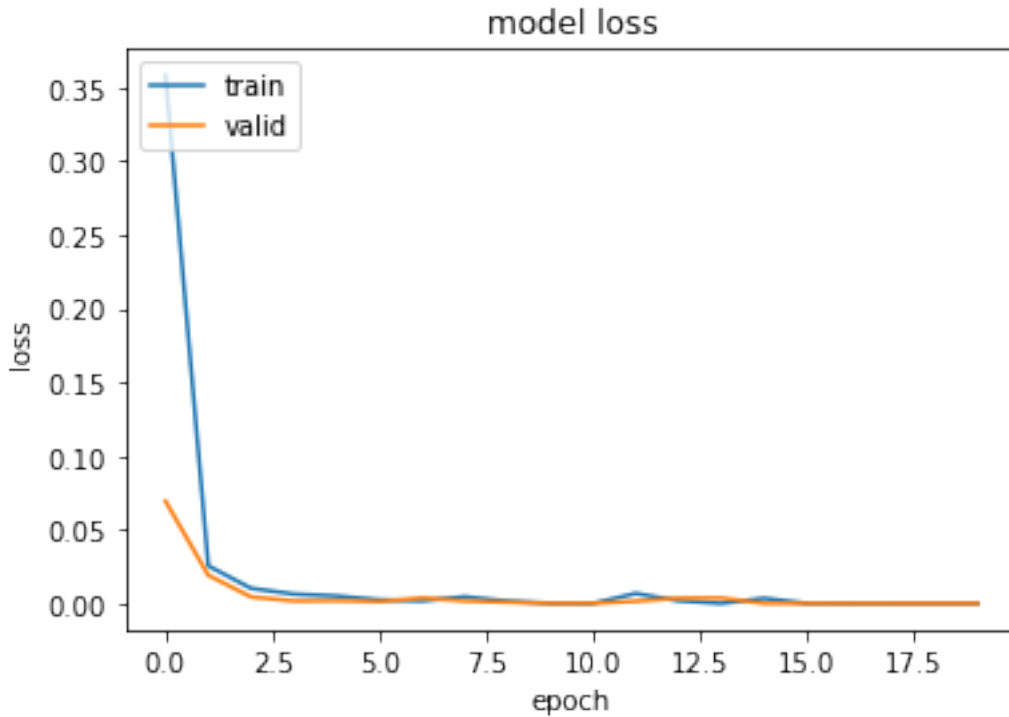
```
[16]: scores = loaded_model.evaluate(test_batches, verbose=2)
      print("Accuracy: %.2f%%" % (scores[1]*100))
      print("Loss: %.2f%%" % (scores[0]*100))
```

```
300/300 - 7s - loss: 1.1726e-04 - accuracy: 1.0000
Accuracy: 100.00%
Loss: 0.01%
```

```
[17]: #Course of accuracy
      plt.plot(history.history['accuracy'])
      plt.plot(history.history['val_accuracy'])
      plt.title('model accuracy')
      plt.ylabel('accuracy')
      plt.xlabel('epoch')
      plt.legend(['train', 'valid'], loc='upper left')
      plt.show()
```



```
[18]: #Course of loss
plt.plot(history.history['loss'])
plt.plot(history.history['val_loss'])
plt.title('model loss')
plt.ylabel('loss')
plt.xlabel('epoch')
plt.legend(['train', 'valid'], loc='upper left')
plt.show()
```



### 1.1.7 Testing the CNN

```
[19]: predictions = loaded_model.predict(x=test_batches, steps=len(test_batches),
    ↪ verbose=0)
```

### 1.1.8 Index of wrongly predicted pictures

```
[20]: y_true=test_batches.classes
y_pred=np.argmax(predictions, axis=-1)
cm = confusion_matrix(y_true = y_true, y_pred = y_pred)
```

```
[21]: face_but_predicted_no_face=[]
no_face_but_predicted_face=[]

for i in range(len(predictions)):
    if y_true[i] != y_pred[i]:
        if y_true[i] == 1:
            face_but_predicted_no_face.append(i+8001-1500) #Index of file
    ↪ on disk
        else:
            no_face_but_predicted_face.append(i+8001) #Index of file on disk
```



```

print("Data from class 'face', that was wrongly predicted as 'no-face' [",
      ↪len(face_but_predicted_no_face), "] :")
print(face_but_predicted_no_face)
print("-----")
print("Data from class 'no-face', that was wrongly predicted as 'face' [",
      ↪len(no_face_but_predicted_face), "] :")
print(no_face_but_predicted_face)

```

Data from class 'face', that was wrongly predicted as 'no-face' [ 0 ] :

[]

-----

Data from class 'no-face', that was wrongly predicted as 'face' [ 0 ] :

[]

### 1.1.9 Confusion matrix

```

[22]: def plot_confusion_matrix(cm, classes,
                                normalize=False,
                                title='Confusion matrix',
                                cmap=plt.cm.Blues):

    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')

```

```
[23]: test_batches.class_indices
```

```
[23]: {'no_face': 0, 'face': 1}
```

```
[24]: cm_plot_labels = ['no_face', 'face']  
plot_confusion_matrix(cm=cm, classes=cm_plot_labels, title='Confusion Matrix')
```

Confusion matrix, without normalization

```
[[1500   0]  
 [   0 1500]]
```



```
[ ]:
```