

CNN-FCT-30E-13L-01

March 24, 2021

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

1.1 CNN with Features Closer Together (*30 Epochs - 13 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, BatchNormalization,
↳MaxPool2D, Dense, Flatten
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 CNN

```
[8]: dropout_rate=0.2

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

# Fully connected layer
model.add(Flatten(name = "Flat_con"))
model.add(Dense(units=2, activation='softmax', name = "D_con"))

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

```

Model: "CNN-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
Flat_con (Flatten)	(None, 50176)	0
D_con (Dense)	(None, 2)	100354

Total params: 488,898

Trainable params: 488,834
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=30,  
                        verbose=2 )
```

Epoch 1/30

801/801 - 42s - loss: 0.2375 - accuracy: 0.8891 - val_loss: 0.0382 -
val_accuracy: 0.9900

Epoch 2/30

801/801 - 42s - loss: 0.0430 - accuracy: 0.9860 - val_loss: 0.0276 -
val_accuracy: 0.9870

Epoch 3/30

801/801 - 42s - loss: 0.0173 - accuracy: 0.9947 - val_loss: 0.0048 -
val_accuracy: 0.9980

Epoch 4/30

801/801 - 42s - loss: 0.0094 - accuracy: 0.9969 - val_loss: 0.0026 -
val_accuracy: 1.0000

Epoch 5/30

801/801 - 42s - loss: 0.0054 - accuracy: 0.9983 - val_loss: 0.0024 -
val_accuracy: 0.9990

Epoch 6/30

801/801 - 42s - loss: 0.0043 - accuracy: 0.9984 - val_loss: 0.0033 -
val_accuracy: 0.9990

Epoch 7/30

801/801 - 42s - loss: 0.0019 - accuracy: 0.9993 - val_loss: 0.0016 -
val_accuracy: 0.9990

Epoch 8/30

801/801 - 42s - loss: 0.0024 - accuracy: 0.9994 - val_loss: 6.0324e-04 -
val_accuracy: 1.0000

Epoch 9/30

801/801 - 42s - loss: 2.1771e-04 - accuracy: 1.0000 - val_loss: 3.5284e-04 -
val_accuracy: 1.0000

Epoch 10/30

801/801 - 42s - loss: 0.0021 - accuracy: 0.9993 - val_loss: 0.0025 -
val_accuracy: 0.9990

Epoch 11/30

801/801 - 42s - loss: 0.0023 - accuracy: 0.9991 - val_loss: 4.7460e-04 -
val_accuracy: 1.0000

Epoch 12/30
801/801 - 42s - loss: 2.5510e-04 - accuracy: 0.9999 - val_loss: 8.4614e-05 -
val_accuracy: 1.0000

Epoch 13/30
801/801 - 42s - loss: 0.0018 - accuracy: 0.9991 - val_loss: 5.4947e-05 -
val_accuracy: 1.0000

Epoch 14/30
801/801 - 42s - loss: 9.5593e-05 - accuracy: 1.0000 - val_loss: 1.8568e-05 -
val_accuracy: 1.0000

Epoch 15/30
801/801 - 42s - loss: 1.4126e-04 - accuracy: 0.9999 - val_loss: 9.1683e-06 -
val_accuracy: 1.0000

Epoch 16/30
801/801 - 42s - loss: 1.3605e-05 - accuracy: 1.0000 - val_loss: 7.4994e-06 -
val_accuracy: 1.0000

Epoch 17/30
801/801 - 42s - loss: 1.2192e-05 - accuracy: 1.0000 - val_loss: 1.5874e-05 -
val_accuracy: 1.0000

Epoch 18/30
801/801 - 42s - loss: 0.0016 - accuracy: 0.9996 - val_loss: 0.0015 -
val_accuracy: 1.0000

Epoch 19/30
801/801 - 42s - loss: 3.0655e-04 - accuracy: 0.9999 - val_loss: 1.9987e-04 -
val_accuracy: 1.0000

Epoch 20/30
801/801 - 42s - loss: 0.0022 - accuracy: 0.9991 - val_loss: 5.4958e-05 -
val_accuracy: 1.0000

Epoch 21/30
801/801 - 42s - loss: 3.2814e-05 - accuracy: 1.0000 - val_loss: 1.7288e-05 -
val_accuracy: 1.0000

Epoch 22/30
801/801 - 42s - loss: 1.6411e-05 - accuracy: 1.0000 - val_loss: 2.1657e-05 -
val_accuracy: 1.0000

Epoch 23/30
801/801 - 42s - loss: 1.7197e-05 - accuracy: 1.0000 - val_loss: 3.2767e-06 -
val_accuracy: 1.0000

Epoch 24/30
801/801 - 42s - loss: 4.5718e-06 - accuracy: 1.0000 - val_loss: 3.0587e-06 -
val_accuracy: 1.0000

Epoch 25/30
801/801 - 42s - loss: 4.1339e-06 - accuracy: 1.0000 - val_loss: 4.3688e-06 -
val_accuracy: 1.0000

Epoch 26/30
801/801 - 42s - loss: 3.1712e-06 - accuracy: 1.0000 - val_loss: 6.2456e-06 -
val_accuracy: 1.0000

Epoch 27/30
801/801 - 42s - loss: 4.2730e-06 - accuracy: 1.0000 - val_loss: 1.1169e-06 -
val_accuracy: 1.0000

```
Epoch 28/30
801/801 - 41s - loss: 0.0022 - accuracy: 0.9995 - val_loss: 0.0021 -
val_accuracy: 0.9990
Epoch 29/30
801/801 - 42s - loss: 8.9882e-05 - accuracy: 1.0000 - val_loss: 1.2350e-04 -
val_accuracy: 1.0000
Epoch 30/30
801/801 - 42s - loss: 8.3602e-04 - accuracy: 0.9998 - val_loss: 1.7894e-04 -
val_accuracy: 1.0000
```

1.1.4 Saving the model

```
[12]: filename='models/CNN-FCT-30E-13L-01.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])

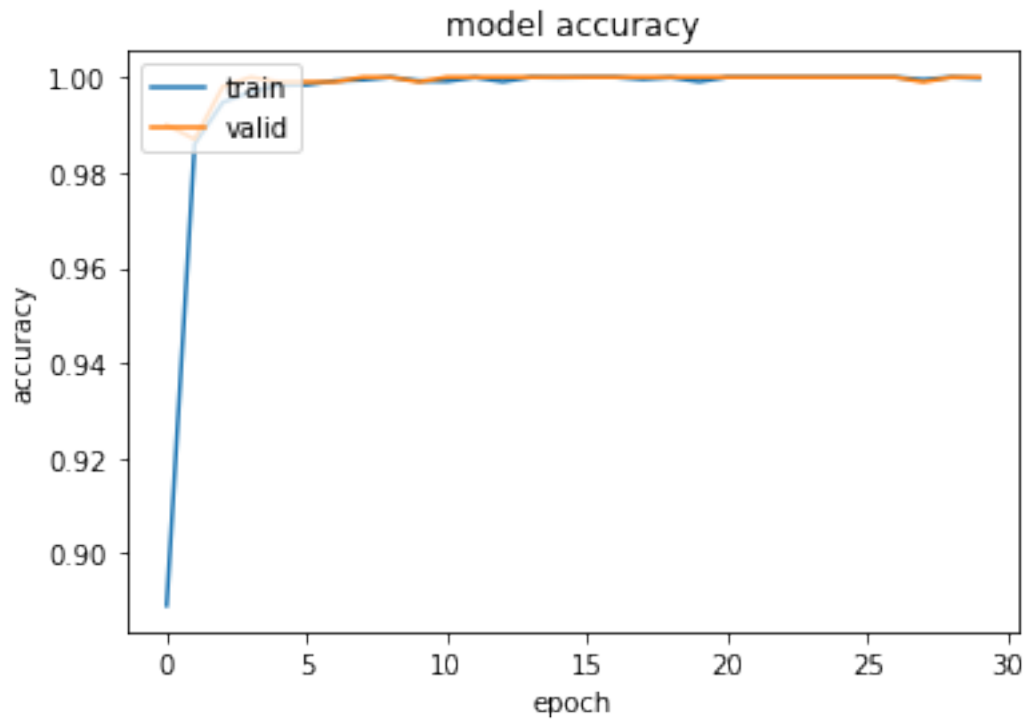
[15]: # Assertion that the model was saved and loaded successfully
      assert untrained_weights != saved_weights
      assert saved_weights == loaded_weights
```

1.1.6 Accuracy and loss of the trained model

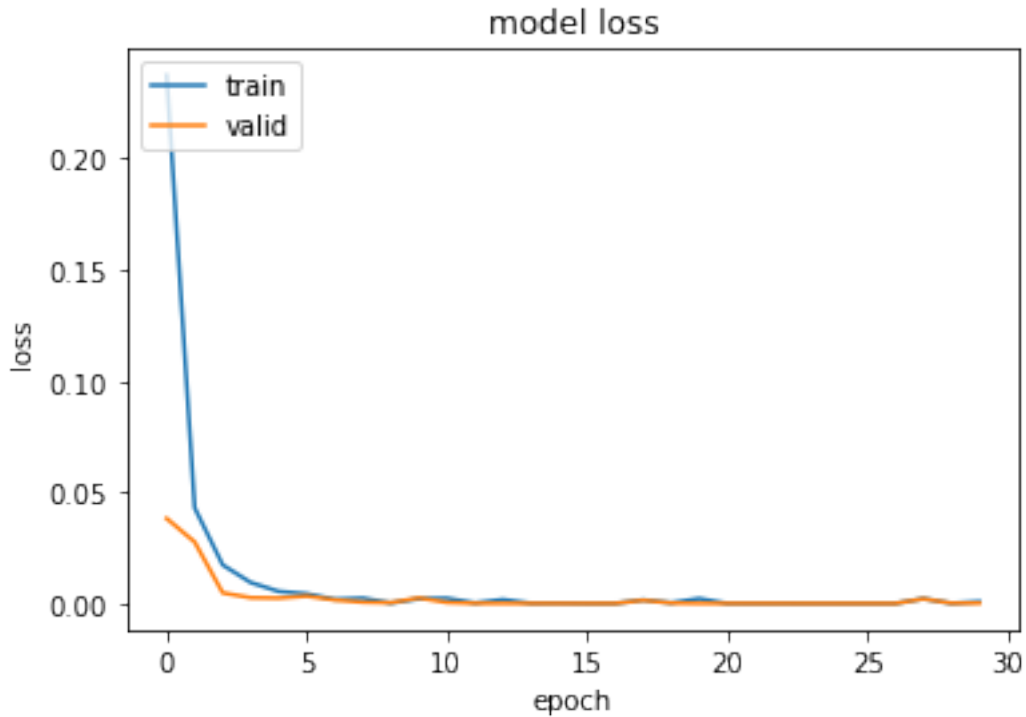
```
[16]: scores = loaded_model.evaluate(test_batches, verbose=2)
      print("Accuracy: %.2f%%" % (scores[1]*100))
      print("Loss: %.2f%%" % (scores[0]*100))
```

```
300/300 - 7s - loss: 7.3945e-04 - accuracy: 0.9997
Accuracy: 99.97%
Loss: 0.07%
```

```
[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' [1] :
 [8394]

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

```
[[1499   1]  
 [   0 1500]]
```

