CNN-FCT-30E-13L-03

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
WARNING:tensorflow:Callbacks method `on_train_batch_end` is slow compared to the
batch time (batch time: 0.0134s vs `on_train_batch_end` time: 0.0218s). Check
your callbacks.
801/801 - 42s - loss: 0.2372 - accuracy: 0.8892 - val_loss: 0.0388 -
val_accuracy: 0.9910
Epoch 2/30
801/801 - 42s - loss: 0.0437 - accuracy: 0.9856 - val_loss: 0.0307 -
val_accuracy: 0.9870
Epoch 3/30
801/801 - 42s - loss: 0.0175 - accuracy: 0.9949 - val_loss: 0.0047 -
val_accuracy: 0.9980
Epoch 4/30
801/801 - 42s - loss: 0.0095 - accuracy: 0.9971 - val_loss: 0.0030 -
val_accuracy: 0.9990
Epoch 5/30
801/801 - 42s - loss: 0.0055 - accuracy: 0.9982 - val_loss: 0.0019 -
val_accuracy: 0.9990
Epoch 6/30
801/801 - 42s - loss: 0.0040 - accuracy: 0.9988 - val_loss: 0.0036 -
val_accuracy: 0.9990
Epoch 7/30
801/801 - 42s - loss: 0.0028 - accuracy: 0.9992 - val_loss: 0.0018 -
val_accuracy: 0.9990
Epoch 8/30
801/801 - 42s - loss: 0.0031 - accuracy: 0.9989 - val_loss: 9.8750e-04 -
val_accuracy: 1.0000
Epoch 9/30
801/801 - 42s - loss: 4.1295e-04 - accuracy: 0.9999 - val_loss: 3.4230e-04 -
val_accuracy: 1.0000
Epoch 10/30
801/801 - 42s - loss: 6.8102e-04 - accuracy: 0.9998 - val_loss: 0.0012 -
val_accuracy: 0.9990
```

```
Epoch 11/30
801/801 - 42s - loss: 0.0036 - accuracy: 0.9989 - val_loss: 2.0110e-04 -
val_accuracy: 1.0000
Epoch 12/30
801/801 - 42s - loss: 1.3069e-04 - accuracy: 1.0000 - val_loss: 1.1231e-04 -
val_accuracy: 1.0000
Epoch 13/30
801/801 - 42s - loss: 0.0017 - accuracy: 0.9994 - val_loss: 0.0020 -
val_accuracy: 0.9990
Epoch 14/30
801/801 - 42s - loss: 8.5570e-04 - accuracy: 0.9997 - val_loss: 5.1588e-05 -
val_accuracy: 1.0000
Epoch 15/30
801/801 - 42s - loss: 2.9603e-04 - accuracy: 0.9999 - val_loss: 6.8598e-04 -
val_accuracy: 1.0000
Epoch 16/30
801/801 - 42s - loss: 7.3349e-04 - accuracy: 0.9996 - val_loss: 0.0015 -
val_accuracy: 0.9990
Epoch 17/30
801/801 - 42s - loss: 2.4632e-05 - accuracy: 1.0000 - val_loss: 0.0016 -
val_accuracy: 0.9990
Epoch 18/30
801/801 - 42s - loss: 1.2387e-05 - accuracy: 1.0000 - val_loss: 6.9080e-04 -
val_accuracy: 1.0000
Epoch 19/30
801/801 - 42s - loss: 0.0014 - accuracy: 0.9996 - val_loss: 5.6314e-05 -
val_accuracy: 1.0000
Epoch 20/30
801/801 - 42s - loss: 3.6331e-05 - accuracy: 1.0000 - val_loss: 2.2584e-05 -
val_accuracy: 1.0000
Epoch 21/30
801/801 - 42s - loss: 6.9851e-06 - accuracy: 1.0000 - val_loss: 8.7772e-06 -
val_accuracy: 1.0000
Epoch 22/30
801/801 - 42s - loss: 6.2815e-06 - accuracy: 1.0000 - val_loss: 2.2372e-05 -
val_accuracy: 1.0000
Epoch 23/30
801/801 - 42s - loss: 0.0022 - accuracy: 0.9994 - val_loss: 4.1401e-05 -
val_accuracy: 1.0000
Epoch 24/30
801/801 - 42s - loss: 2.0929e-05 - accuracy: 1.0000 - val_loss: 5.3840e-05 -
val_accuracy: 1.0000
Epoch 25/30
801/801 - 42s - loss: 1.1425e-05 - accuracy: 1.0000 - val_loss: 3.2088e-05 -
val_accuracy: 1.0000
Epoch 26/30
801/801 - 42s - loss: 9.4546e-04 - accuracy: 0.9998 - val_loss: 5.0232e-05 -
val_accuracy: 1.0000
```

```
Epoch 27/30
801/801 - 42s - loss: 0.0015 - accuracy: 0.9997 - val_loss: 1.6911e-04 -
val_accuracy: 1.0000
Epoch 28/30
801/801 - 42s - loss: 4.3078e-05 - accuracy: 1.0000 - val_loss: 4.1456e-05 -
val_accuracy: 1.0000
Epoch 29/30
801/801 - 42s - loss: 9.5793e-06 - accuracy: 1.0000 - val_loss: 2.3026e-05 -
val_accuracy: 1.0000
Epoch 30/30
801/801 - 42s - loss: 5.7955e-06 - accuracy: 1.0000 - val_loss: 2.9630e-05 -
val_accuracy: 1.0000
```

1.1.4 Saving the model

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

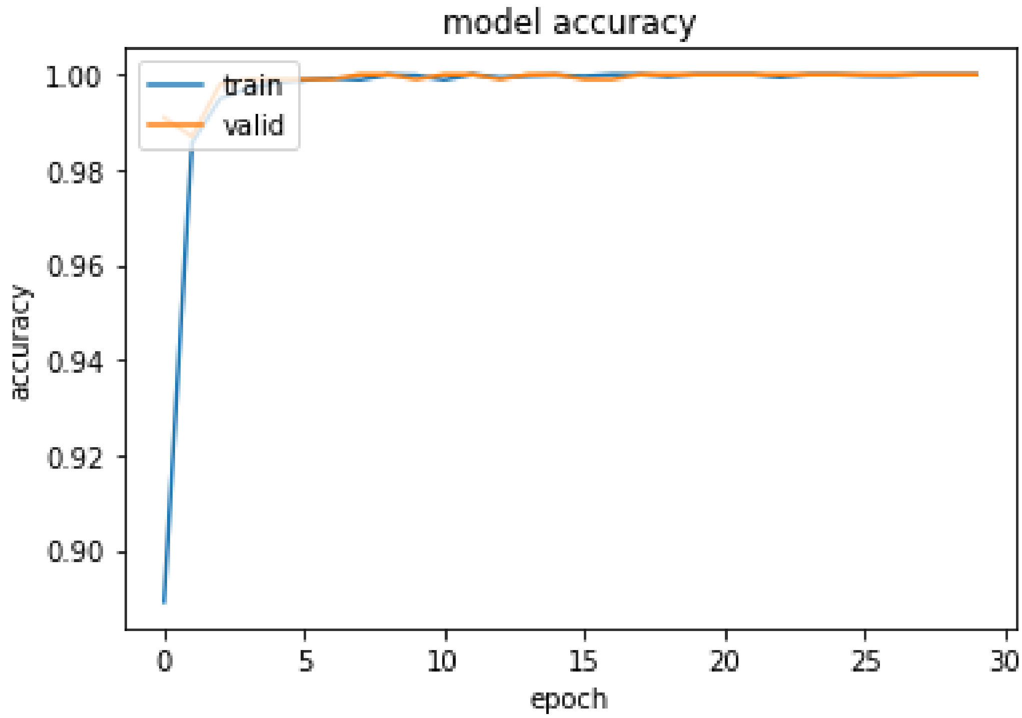
[15]:
```
# Assertion that the model was saved and loaded successfully
assert untrained_weights != saved_weights
assert saved_weights == loaded_weights
```

1.1.6 Accuracy and loss of the trained model

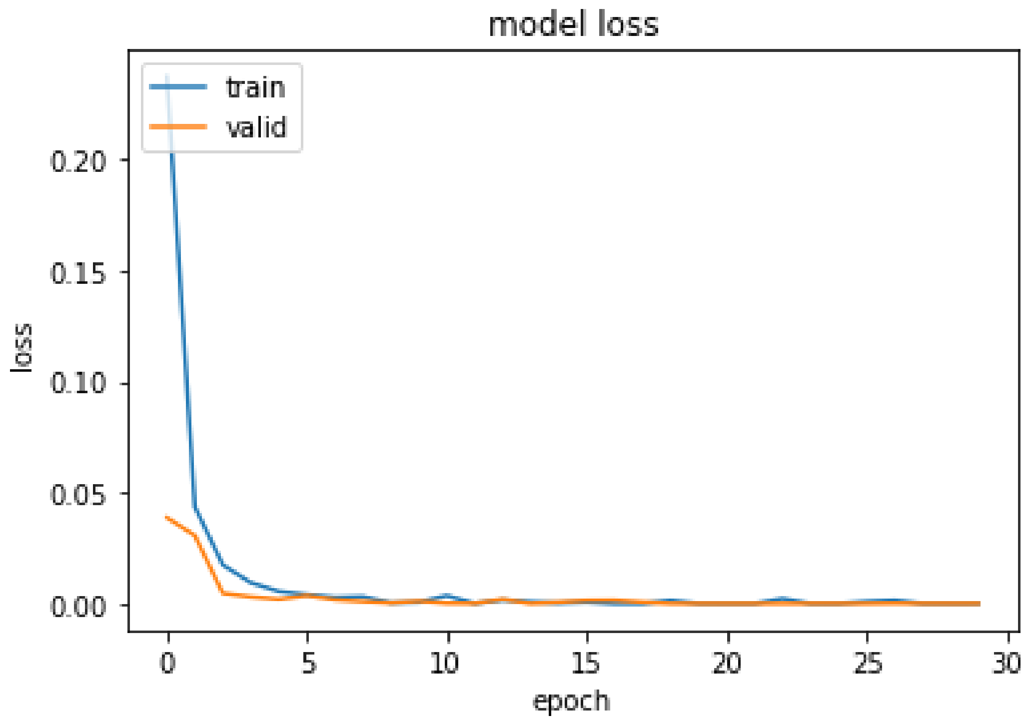
[16]:
```
scores = loaded_model.evaluate(test_batches, verbose=2)
print("Accuracy: %.2f%%" % (scores[1]*100))
print("Loss: %.2f%%" % (scores[0]*100))
```

```
300/300 - 7s - loss: 7.5353e-05 - 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]]
```