hw2

December 27, 2023

1 HOMEWORK 2 batch version

[ ]:
```
#%history -f output.txt
```

2 Libraries importation

[ ]:
```
import os
import cv2
import scipy
import numpy as np
import tensorflow as tf
from PIL import Image
from collections import defaultdict
from matplotlib import pyplot as plt
from sklearn.utils.class_weight import compute_class_weight
from tensorflow import keras
from keras.regularizers import l2
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import Conv2D, MaxPooling2D, Dense, Flatten,␣
↪Dropout, BatchNormalization
from tensorflow.keras.metrics import Precision, Recall, BinaryAccuracy
from tensorflow.keras.optimizers import Adam
from tensorflow.keras.preprocessing.image import ImageDataGenerator

print('libraries imported')
```

```
libraries imported
```

3 settings

[ ]:
```
# Avoid OOM errors by setting GPU memory consumption growth
gpus = tf.config.experimental.list_physical_devices('GPU')
for gpu in gpus:
    tf.config.experimental.set_memory_growth(gpu, True)
```

4 Data Collection

4.1 Data Augmentation

[ ]:
```
datagen = ImageDataGenerator(
    rotation_range=0,
    width_shift_range=0,
    height_shift_range=0,
    shear_range=0,
    zoom_range=0,
    horizontal_flip=True,
    rescale=1./255
)
```

4.2 Data Load

[ ]:
```
Train = datagen.flow_from_directory(
    'train',
    target_size=(256,256),
    batch_size=32,
    class_mode='categorical'
)

train_labels = []
train_labels = Train.classes
num_classes = Train.num_classes
train_labels_one_hot = tf.keras.utils.to_categorical(train_labels,␣
↪num_classes=num_classes)
```

```
Found 6369 images belonging to 5 classes.
```

4.3 Visualization of the dataset

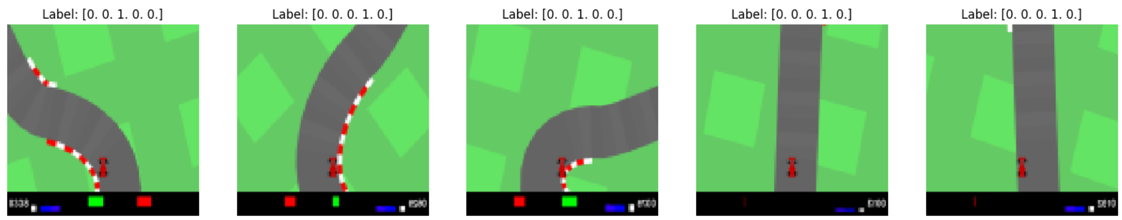
[ ]:
```
def visualize_dataset(dataset, num_samples=5):
    for images, labels in dataset:
        num_samples_batch = min(num_samples, len(images))
        fig, ax = plt.subplots(1, num_samples_batch, figsize=(20, 20))

        for i in range(num_samples_batch):
            ax[i].imshow((images[i] * 255).astype("uint8"))  # Remove the␣
↪rescaling here
            ax[i].set_title(f"Label: {labels[i]}")
            ax[i].axis("off")

        plt.show()
        break
```

```
# num_samples = 5
# for images, labels in Train.take(1):
#     num_samples_batch = min(num_samples, len(images))
#     fig, ax = plt.subplots(1, num_samples_batch, figsize=(20, 20))
#     for i in range(num_samples):
#         ax[i].imshow(images[i].numpy().astype("uint8"))
#         ax[i].set_title(f"Label: {labels[i]}")
#         ax[i].axis("off")
#     plt.show()
```

[ ]:
```
visualize_dataset(Train)
```



5 Data Preprocessing

- Resize images to a common size (e.g., 96x96, as mentioned in the description).
- Normalize pixel values to a range between 0 and 1.
- Consider data augmentation techniques (e.g., rotation, flipping) to increase the diversity of your training set.

6 Model Selection:

6.1 Model Design

- Define your own CNN architecture. Start with a simple architecture and gradually increase complexity if needed.
- Experiment with different layer configurations, activation functions, and filter sizes.
- Consider incorporating dropout for regularization.

6.2 Approach 1

- Define the first approach with a specific architecture, optimizer, and regularization techniques.
- Choose appropriate hyperparameters (learning rate, batch size, etc.).
- Train the model on the training set and evaluate on the test set.
- Collect and analyze metrics such as accuracy, precision, recall, and F1 score.

[ ]:
```
model = Sequential()
```

[ ]:
```python
# Layers
# (3,3) is the pixel selection, 1 is the translation of pixels
model.add(Conv2D(32, (3,3), activation='relu', input_shape=(256,256,3)))
model.add(MaxPooling2D())
model.add(Dropout(0.25))

model.add(Conv2D(64, (3,3), activation='relu'))
model.add(MaxPooling2D())
model.add(Dropout(0.25))

model.add(Conv2D(128, (3,3), activation='relu'))
model.add(MaxPooling2D())
model.add(Dropout(0.25))

model.add(Flatten())

model.add(Dense(512, activation='relu'))
model.add(Dropout(0.5)) # Dropout layer to reduce overfitting

num_classes = 5
model.add(Dense(num_classes, activation='softmax'))
```

[ ]:
```python
optimizer = Adam(learning_rate=0.001)
```

[ ]:
```python
model.compile(optimizer, loss=tf._losses.CategoricalCrossentropy(),␣
↪metrics=['accuracy'])
```

[ ]:
```python
model.summary()
```

```
Model: "sequential"

_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 conv2d (Conv2D)             (None, 254, 254, 32)      896

 max_pooling2d (MaxPooling2  (None, 127, 127, 32)      0
 D)

 dropout (Dropout)           (None, 127, 127, 32)      0

 conv2d_1 (Conv2D)           (None, 125, 125, 64)      18496

 max_pooling2d_1 (MaxPoolin  (None, 62, 62, 64)        0
 g2D)

 dropout_1 (Dropout)         (None, 62, 62, 64)        0
```

```
 conv2d_2 (Conv2D)           (None, 60, 60, 128)       73856

 max_pooling2d_2 (MaxPoolin  (None, 30, 30, 128)       0
 g2D)

 dropout_2 (Dropout)         (None, 30, 30, 128)       0

 flatten (Flatten)           (None, 115200)            0

 dense (Dense)               (None, 512)               58982912
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 conv2d (Conv2D)             (None, 254, 254, 32)      896

 max_pooling2d (MaxPooling2  (None, 127, 127, 32)      0
 D)

 dropout (Dropout)           (None, 127, 127, 32)      0

 conv2d_1 (Conv2D)           (None, 125, 125, 64)      18496

 max_pooling2d_1 (MaxPoolin  (None, 62, 62, 64)        0
 g2D)

 dropout_1 (Dropout)         (None, 62, 62, 64)        0

 conv2d_2 (Conv2D)           (None, 60, 60, 128)       73856

 max_pooling2d_2 (MaxPoolin  (None, 30, 30, 128)       0
 g2D)

 dropout_2 (Dropout)         (None, 30, 30, 128)       0

 flatten (Flatten)           (None, 115200)            0

 dense (Dense)               (None, 512)               58982912

 dropout_3 (Dropout)         (None, 512)               0

 dense_1 (Dense)             (None, 5)                 2565

=================================================================
Total params: 59078725 (225.37 MB)
Trainable params: 59078725 (225.37 MB)
Non-trainable params: 0 (0.00 Byte)
_________________________________________________________________
```

6.3 Approach 2

- Define the second approach with a different architecture, optimizer, or regularization techniques.
- Adjust hyperparameters independently of the first approach.
- Train the model on the training set and evaluate on the test set.
- Collect and analyze metrics as done for the first approach.

[ ]:
```
model = keras.models.Sequential([
    keras.layers.Flatten(input_shape=(256, 256, 3)),
    keras.layers.Dense(64, activation='relu', kernel_regularizer=keras.
 ↪regularizers.l2(0.001)),
    keras.layers.Dense(32, activation='relu', kernel_regularizer=keras.
 ↪regularizers.l2(0.001)),
    keras.layers.Dense(num_classes, activation='softmax')
])
```

[ ]:
```
beta_1 = 0.9
beta_2 = 0.999
optimizer = Adam(learning_rate=0.01, beta_1=beta_1, beta_2=beta_2)
```

[ ]:
```
model.compile(optimizer, loss=tf._losses.CategoricalCrossentropy(),␣
 ↪metrics=['accuracy'])
```

[ ]:
```
model.summary
```

[ ]:
```
<bound method Model.summary of <keras.src.engine.sequential.Sequential object at
0x7fee0b64a6e0>>
```

6.4 Hyperparameter Analysis

- Choose at least one hyperparameter (e.g., learning rate) and perform a systematic analysis.
- Train models with different values of the chosen hyperparameter.
- Compare and visualize the impact on metrics.
- Consider to apply an early stopping of the training in order to avoid overfitting (see slide 11 pag 55)
- Consider if to apply Dropout or parameter sharing

7 Model Training

[ ]:
```
logdir = 'logs'
tensorboard_callback = tf.keras.callbacks.TensorBoard(log_dir=logdir)
```

without validation data:

[ ]:
```
class_labels = np.unique(train_labels)
class_weights = compute_class_weight(class_weight='balanced', classes=np.
 ↪unique(train_labels), y=train_labels)
```

```
class_weights_dict = dict(zip(class_labels, class_weights))
```

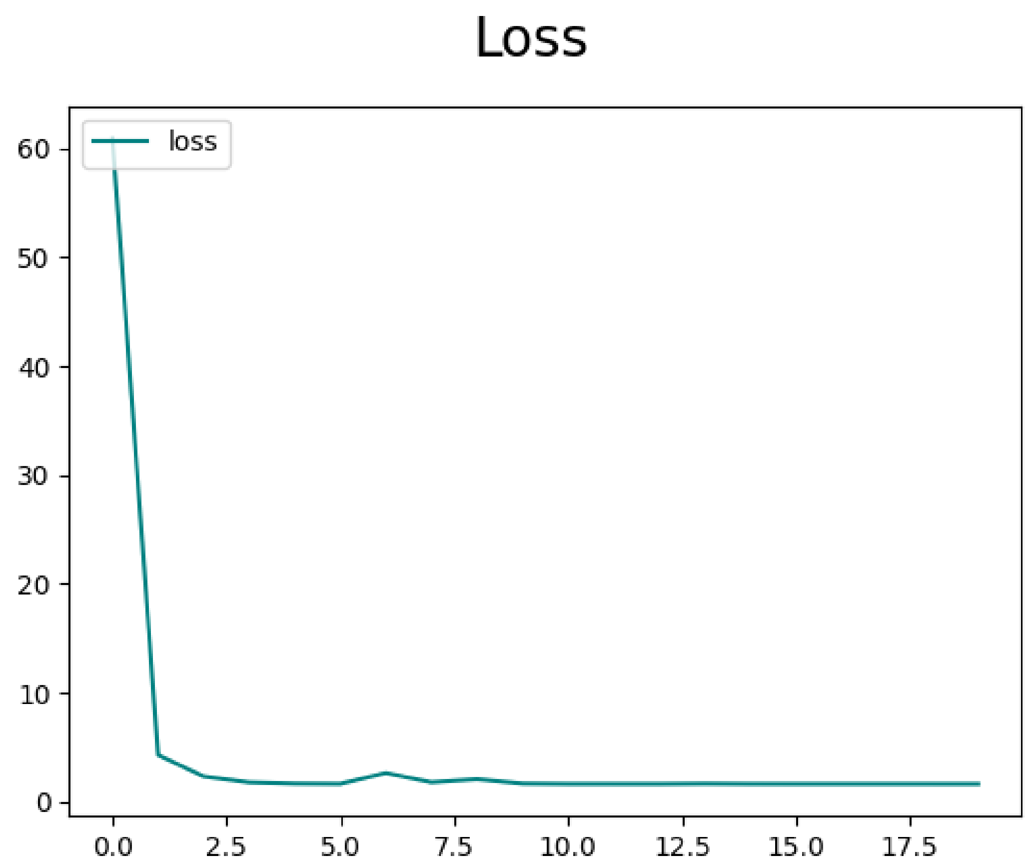
[ ]:
```
hist = model.fit(Train, epochs=20, callbacks=[tensorboard_callback],␣
 ↪class_weight=class_weights_dict)
```

```
Epoch 1/20
200/200 [==============================] - 24s 119ms/step - loss: 60.9023 -
accuracy: 0.1726
Epoch 2/20
200/200 [==============================] - 23s 115ms/step - loss: 4.2770 -
accuracy: 0.2068
Epoch 3/20
200/200 [==============================] - 23s 113ms/step - loss: 2.3106 -
accuracy: 0.1572
Epoch 4/20
200/200 [==============================] - 23s 114ms/step - loss: 1.7657 -
accuracy: 0.1696
Epoch 5/20
200/200 [==============================] - 23s 114ms/step - loss: 1.6542 -
accuracy: 0.1715
Epoch 6/20
200/200 [==============================] - 23s 114ms/step - loss: 1.6322 -
accuracy: 0.2407
Epoch 7/20
200/200 [==============================] - 23s 115ms/step - loss: 2.6176 -
accuracy: 0.2266
Epoch 8/20
200/200 [==============================] - 23s 114ms/step - loss: 1.7754 -
accuracy: 0.1449
Epoch 9/20
200/200 [==============================] - 23s 115ms/step - loss: 2.0546 -
accuracy: 0.1945
Epoch 10/20
200/200 [==============================] - 23s 114ms/step - loss: 1.6540 -
accuracy: 0.1735
Epoch 11/20
200/200 [==============================] - 23s 115ms/step - loss: 1.6239 -
accuracy: 0.2173
Epoch 12/20
200/200 [==============================] - 23s 114ms/step - loss: 1.6225 -
accuracy: 0.2402
Epoch 13/20
200/200 [==============================] - 23s 114ms/step - loss: 1.6221 -
accuracy: 0.1806
Epoch 14/20
200/200 [==============================] - 23s 115ms/step - loss: 1.6451 -
accuracy: 0.2140
```

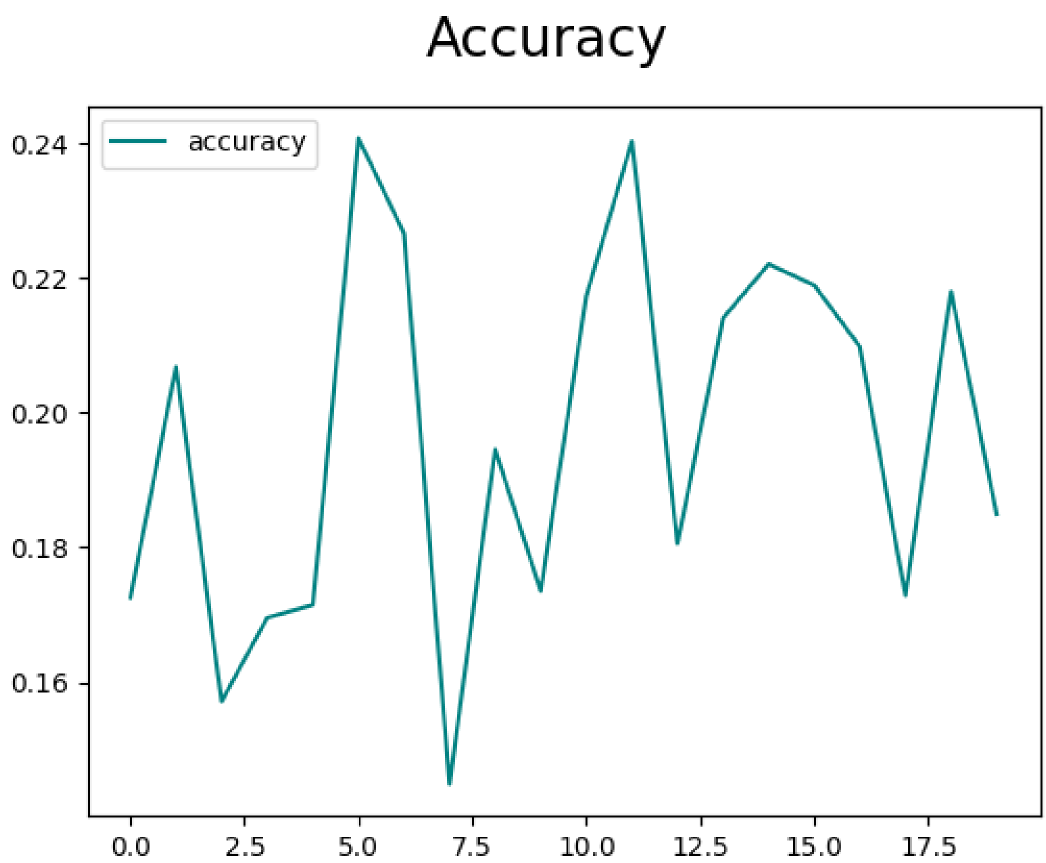
```
Epoch 15/20
200/200 [==============================] - 23s 116ms/step - loss: 1.6249 -
accuracy: 0.2220
Epoch 16/20
200/200 [==============================] - 23s 115ms/step - loss: 1.6219 -
accuracy: 0.2189
Epoch 17/20
200/200 [==============================] - 23s 115ms/step - loss: 1.6219 -
accuracy: 0.2098
Epoch 18/20
200/200 [==============================] - 23s 115ms/step - loss: 1.6222 -
accuracy: 0.1729
Epoch 19/20
200/200 [==============================] - 23s 115ms/step - loss: 1.6215 -
accuracy: 0.2179
Epoch 20/20
200/200 [==============================] - 23s 116ms/step - loss: 1.6215 -
accuracy: 0.1850
```

7.1 Plotting Model Performance

[ ]:
```
fig = plt.figure()
plt.plot(hist.history['loss'], color='teal', label='loss')
fig.suptitle('Loss', fontsize=20)
plt.legend(loc="upper left")
plt.show()
```



[ ]:
```
fig = plt.figure()
plt.plot(hist.history['accuracy'], color='teal', label='accuracy')
fig.suptitle('Accuracy', fontsize=20)
plt.legend(loc="upper left")
plt.show()
```



8 Evaluate Performance

[ ]:
```
pre = Precision()
re = Recall()
acc = BinaryAccuracy()
```

9 Test

[ ]:
```
Test = tf.keras.utils.image_dataset_from_directory('test')
test_iterator = Test.as_numpy_iterator()

all_X_test = []
all_y_test = []

for test_batch in test_iterator:
    X_test_batch, y_test_batch = test_batch
    X_test_normalized_batch = X_test_batch/255.0
    yhat_batch = model.predict(X_test_normalized_batch)
```

```
    all_X_test.append(X_test_normalized_batch)
    all_y_test.append(y_test_batch)

X_test_normalized = np.concatenate(all_X_test)
y_test = np.concatenate(all_y_test)

test_iterator = Test.as_numpy_iterator()
Test_batch = next(test_iterator)
X_test, y_test = Test_batch
X_test_normalized = X_test/255.0
```

```
Found 2749 files belonging to 5 classes.
1/1 [==============================] - 0s 35ms/step
1/1 [==============================] - 0s 21ms/step
1/1 [==============================] - 0s 21ms/step
1/1 [==============================] - 0s 31ms/step
1/1 [==============================] - 0s 17ms/step
1/1 [==============================] - 0s 18ms/step
1/1 [==============================] - 0s 21ms/step
1/1 [==============================] - 0s 20ms/step
1/1 [==============================] - 0s 20ms/step
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```

```
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1/1 [==============================] - 0s 19ms/step
```

```
1/1 [==============================] - 0s 18ms/step
1/1 [==============================] - 0s 18ms/step
1/1 [==============================] - 0s 40ms/step
```

[ ]:
```
yhat = model.predict(X_test_normalized)
```

```
1/1 [==============================] - 0s 28ms/step
1/1 [==============================] - 0s 28ms/step
```

[ ]:
```
pre = Precision()
re = Recall()
acc = BinaryAccuracy()
```

[ ]:
```
for batch in Test.as_numpy_iterator():
    X, y = batch
    yhat = model.predict(X)
    y_one_hot = tf.keras.utils.to_categorical(y, num_classes=num_classes)
    pre.update_state(y_one_hot, yhat)
    re.update_state(y_one_hot, yhat)
    acc.update_state(y_one_hot, yhat)
```

```
1/1 [==============================] - 0s 18ms/step
1/1 [==============================] - 0s 18ms/step
1/1 [==============================] - 0s 22ms/step
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```

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1/1 [==============================] - 0s 23ms/step
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1/1 [==============================] - 0s 20ms/step
1/1 [==============================] - 0s 20ms/step
1/1 [==============================] - 0s 19ms/step
1/1 [==============================] - 0s 18ms/step
```

[ ]:
```
print(f'Precision:{pre.result().numpy()}, Recall:{re.result().numpy()},␣
↪Accuracy:{acc.result().numpy()}')
```

```
Precision:0.0, Recall:0.0, Accuracy:0.800000011920929
```

10 Results Visualization and Comparison

- Create visualizations (tables, charts, graphs) to present your results.
- Provide detailed commentary on each visualization, explaining trends or differences observed.

10.1 Comparison on accuracy between methods

10.1.1 On train

[ ]:
```
fig=plt.figure(figsize=(16, 8))
# insert comparison on accuracies

plt.suptitle('Model accuracy comparison on train', fontsize=14)
plt.show()
```

10.1.2 On Test

[ ]:
```
fig=plt.figure(figsize=(16, 8))
# insert comparison on accuracies

plt.suptitle('Model accuracy comparison on test', fontsize=14)
plt.show()
```

10.2 Fine-Tuning

10.3 Deployment

[ ]:
```

```

##valutazioni da fare poi: - regularization per ridurre l'overfitting? - il numero di images cambia da classe a classe (train) vedere se serve prenderne un numero uguale per ciascuna classe -