

C2W3_Assignment

March 9, 2021

1 Horse or Human? In-graph training loop Assignment

This assignment lets you practice how to train a Keras model on the [horses_or_humans](#) dataset with the entire training process performed in graph mode. These steps include: - loading batches - calculating gradients - updating parameters - calculating validation accuracy - repeating the loop until convergence

1.1 Setup

Import TensorFlow 2.0:

```
[1]: from __future__ import absolute_import, division, print_function,   
      ↪ unicode_literals  
      import numpy as np
```

```
[2]: import tensorflow as tf  
      import tensorflow_datasets as tfds  
      import tensorflow_hub as hub  
      import matplotlib.pyplot as plt
```

1.1.1 Prepare the dataset

Load the horses to human dataset, splitting 80% for the training set and 20% for the test set.

```
[3]: splits, info = tfds.load('horses_or_humans', as_supervised=True,   
      ↪ with_info=True, split=['train[:80%]', 'train[80%:]', 'test'], data_dir='./  
      ↪ data')  
  
(train_examples, validation_examples, test_examples) = splits  
  
num_examples = info.splits['train'].num_examples  
num_classes = info.features['label'].num_classes  
  
[4]: BATCH_SIZE = 32  
      IMAGE_SIZE = 224
```

1.2 Pre-process an image (please complete this section)

You'll define a mapping function that resizes the image to a height of 224 by 224, and normalizes the pixels to the range of 0 to 1. Note that pixels range from 0 to 255.

- You'll use the following function: `tf.image.resize` and pass in the (height,width) as a tuple (or list).
- To normalize, divide by a floating value so that the pixel range changes from [0,255] to [0,1].

```
[5]: # Create a autograph pre-processing function to resize and normalize an image
    ### START CODE HERE ###
    @tf.function
    def map_fn(img, label):
        image_height = 224
        image_width = 224
        ### START CODE HERE ###
        # resize the image
        img = tf.image.resize(img, (224, 224))
        # normalize the image
        img /= 255
        ### END CODE HERE
        return img, label
```

```
[6]: ## TEST CODE:

test_image, test_label = list(train_examples)[0]

test_result = map_fn(test_image, test_label)

print(test_result[0].shape)
print(test_result[1].shape)

del test_image, test_label, test_result
```

(224, 224, 3)

()

Expected Output:

(224, 224, 3)

()

1.3 Apply pre-processing to the datasets (please complete this section)

Apply the following steps to the `training_examples`: - Apply the `map_fn` to the `training_examples`
- Shuffle the training data using `.shuffle(buffer_size=)` and set the buffer size to the number of examples. - Group these into batches using `.batch()` and set the batch size given by the parameter.

Hint: You can look at how `validation_examples` and `test_examples` are pre-processed to get a sense of how to chain together multiple function calls.

```
[8]: # Prepare train dataset by using preprocessing with map_fn, shuffling and
      ↪batching
def prepare_dataset(train_examples, validation_examples, test_examples,
      ↪num_examples, map_fn, batch_size):
    ### START CODE HERE ###
    train_ds = train_examples.map(map_fn).shuffle(buffer_size = num_examples).
    ↪batch(batch_size)
    ### END CODE HERE ###
    valid_ds = validation_examples.map(map_fn).batch(batch_size)
    test_ds = test_examples.map(map_fn).batch(batch_size)

    return train_ds, valid_ds, test_ds
```

```
[9]: train_ds, valid_ds, test_ds = prepare_dataset(train_examples,
      ↪validation_examples, test_examples, num_examples, map_fn, BATCH_SIZE)
```

```
[10]: ## TEST CODE:

test_train_ds = list(train_ds)
print(len(test_train_ds))
print(test_train_ds[0][0].shape)

del test_train_ds
```

```
26
(32, 224, 224, 3)
```

Expected Output:

```
26
(32, 224, 224, 3)
```

1.3.1 Define the model

```
[11]: MODULE_HANDLE = 'data/resnet_50_feature_vector'
model = tf.keras.Sequential([
    hub.KerasLayer(MODULE_HANDLE, input_shape=(IMAGE_SIZE, IMAGE_SIZE, 3)),
    tf.keras.layers.Dense(num_classes, activation='softmax')
])
model.summary()
```

```
Model: "sequential"
```

```
-----
Layer (type)                 Output Shape          Param #
=====
```

keras_layer (KerasLayer)	(None, 2048)	23561152

dense (Dense)	(None, 2)	4098
=====		
Total params: 23,565,250		
Trainable params: 4,098		
Non-trainable params: 23,561,152		

1.4 Define optimizer: (please complete these sections)

Define the [Adam optimizer](#) that is in the `tf.keras.optimizers` module.

```
[12]: def set_adam_optimizer():
      ### START CODE HERE ###
      # Define the adam optimizer
      optimizer = tf.keras.optimizers.Adam()
      ### END CODE HERE ###
      return optimizer
```

```
[13]: ## TEST CODE:

      test_optimizer = set_adam_optimizer()

      print(type(test_optimizer))

      del test_optimizer
```

```
<class 'tensorflow.python.keras.optimizer_v2.adam.Adam'>
```

Expected Output:

```
<class 'tensorflow.python.keras.optimizer_v2.adam.Adam'>
```

1.5 Define the loss function (please complete this section)

Define the loss function as the [sparse categorical cross entropy](#) that's in the `tf.keras.losses` module. Use the same function for both training and validation.

```
[16]: def set_sparse_cat_crossentropy_loss():
      ### START CODE HERE ###
      # Define object oriented metric of Sparse categorical crossentropy for
      ↪ train and val loss
      train_loss = tf.keras.losses.SparseCategoricalCrossentropy()
      val_loss = tf.keras.losses.SparseCategoricalCrossentropy()
      ### END CODE HERE ###
      return train_loss, val_loss
```

```
[17]: ## TEST CODE:
```

```
test_train_loss, test_val_loss = set_sparse_cat_crossentropy_loss()

print(type(test_train_loss))
print(type(test_val_loss))

del test_train_loss, test_val_loss
```

```
<class 'tensorflow.python.keras.losses.SparseCategoricalCrossentropy'>
<class 'tensorflow.python.keras.losses.SparseCategoricalCrossentropy'>
```

Expected Output:

```
<class 'tensorflow.python.keras.losses.SparseCategoricalCrossentropy'>
<class 'tensorflow.python.keras.losses.SparseCategoricalCrossentropy'>
```

1.6 Define the accuracy function (please complete this section)

Define the accuracy function as the [sparse categorical accuracy](#) that's contained in the `tf.keras.metrics` module. Use the same function for both training and validation.

```
[18]: def set_sparse_cat_crossentropy_accuracy():
```

```
    ### START CODE HERE ###
```

```
    # Define object oriented metric of Sparse categorical accuracy for train_
    ↪and val accuracy
```

```
    train_accuracy = tf.keras.metrics.SparseCategoricalAccuracy()
```

```
    val_accuracy = tf.keras.metrics.SparseCategoricalAccuracy()
```

```
    ### END CODE HERE ###
```

```
    return train_accuracy, val_accuracy
```

```
[19]: ## TEST CODE:
```

```
test_train_accuracy, test_val_accuracy = set_sparse_cat_crossentropy_accuracy()

print(type(test_train_accuracy))
print(type(test_val_accuracy))

del test_train_accuracy, test_val_accuracy
```

```
<class 'tensorflow.python.keras.metrics.SparseCategoricalAccuracy'>
<class 'tensorflow.python.keras.metrics.SparseCategoricalAccuracy'>
```

Expected Output:

```
<class 'tensorflow.python.keras.metrics.SparseCategoricalAccuracy'>
<class 'tensorflow.python.keras.metrics.SparseCategoricalAccuracy'>
```

Call the three functions that you defined to set the optimizer, loss and accuracy

```
[20]: optimizer = set_adam_optimizer()
train_loss, val_loss = set_sparse_cat_crossentropy_loss()
train_accuracy, val_accuracy = set_sparse_cat_crossentropy_accuracy()
```

1.6.1 Define the training loop (please complete this section)

In the training loop: - Get the model predictions: use the model, passing in the input x - Get the training loss: Call `train_loss`, passing in the true y and the predicted y . - Calculate the gradient of the loss with respect to the model's variables: use `tape.gradient` and pass in the loss and the model's `trainable_variables`. - Optimize the model variables using the gradients: call `optimizer.apply_gradients` and pass in a `zip()` of the two lists: the gradients and the model's `trainable_variables`. - Calculate accuracy: Call `train_accuracy`, passing in the true y and the predicted y .

```
[21]: # this code uses the GPU if available, otherwise uses a CPU
device = '/gpu:0' if tf.config.list_physical_devices('GPU') else '/cpu:0'
EPOCHS = 2

# Custom training step
def train_one_step(model, optimizer, x, y, train_loss, train_accuracy):
    '''
    Trains on a batch of images for one step.

    Args:
        model (keras Model) -- image classifier
        optimizer (keras Optimizer) -- optimizer to use during training
        x (Tensor) -- training images
        y (Tensor) -- training labels
        train_loss (keras Loss) -- loss object for training
        train_accuracy (keras Metric) -- accuracy metric for training
    '''
    with tf.GradientTape() as tape:
        ### START CODE HERE ###
        # Run the model on input x to get predictions
        predictions = model(x)
        # Compute the training loss using `train_loss`, passing in the true y
        → and the predicted y
        loss = train_loss(y, predictions)

        # Using the tape and loss, compute the gradients on model variables using
        → tape.gradient
        grads = tape.gradient(loss, model.trainable_variables)

        # Zip the gradients and model variables, and then apply the result on the
        → optimizer
        optimizer.apply_gradients(zip(grads, model.trainable_variables))
```

```

# Call the train accuracy object on ground truth and predictions
train_accuracy(y, predictions)
### END CODE HERE
return loss

```

[22]: `## TEST CODE:`

```

def base_model():
    inputs = tf.keras.layers.Input(shape=(2))
    x = tf.keras.layers.Dense(64, activation='relu')(inputs)
    outputs = tf.keras.layers.Dense(1, activation='sigmoid')(x)
    model = tf.keras.Model(inputs=inputs, outputs=outputs)
    return model

test_model = base_model()

test_optimizer = set_adam_optimizer()
test_image = tf.ones((2,2))
test_label = tf.ones((1,))
test_train_loss, _ = set_sparse_cat_crossentropy_loss()
test_train_accuracy, _ = set_sparse_cat_crossentropy_accuracy()

test_result = train_one_step(test_model, test_optimizer, test_image,
    ↪test_label, test_train_loss, test_train_accuracy)
print(test_result)

del test_result, test_model, test_optimizer, test_image, test_label,
    ↪test_train_loss, test_train_accuracy

```

```
tf.Tensor(0.6931472, shape=(), dtype=float32)
```

Expected Output:

You will see a Tensor with the same shape and dtype. The value might be different.

```
tf.Tensor(0.6931472, shape=(), dtype=float32)
```

1.7 Define the ‘train’ function (please complete this section)

You’ll first loop through the training batches to train the model. (Please complete these sections)

- The `train` function will use a for loop to iteratively call the `train_one_step` function that you just defined.
- You’ll use `tf.print` to print the step number, loss, and `train_accuracy.result()` at each step. Remember to use `tf.print` when you plan to generate autograph code.

Next, you’ll loop through the batches of the validation set to calculation the validation loss and validation accuracy. (This code is provided for you). At each iteration of the loop:

- Use the model to predict on `x`, where `x` is the input from the validation set.
- Use `val_loss` to calculate the

validation loss between the true validation 'y' and predicted y. - Use val_accuracy to calculate the accuracy of the predicted y compared to the true y.

Finally, you'll print the validation loss and accuracy using tf.print. (Please complete this section) - print the final loss, which is the validation loss calculated by the last loop through the validation dataset. - Also print the val_accuracy.result().

HINT If you submit your assignment and see this error for your stderr output:

Cannot convert 1e-07 to EagerTensor of dtype int64

Please check your calls to train_accuracy and val_accuracy to make sure that you pass in the true and predicted values in the correct order (check the documentation to verify the order of parameters).

```
[23]: # Decorate this function with tf.function to enable autograph on the training
      ↪ loop
      @tf.function
      def train(model, optimizer, epochs, device, train_ds, train_loss,
      ↪ train_accuracy, valid_ds, val_loss, val_accuracy):
          """
          Performs the entire training loop. Prints the loss and accuracy per step
          ↪ and epoch.

          Args:
              model (keras Model) -- image classifier
              optimizer (keras Optimizer) -- optimizer to use during training
              epochs (int) -- number of epochs
              train_ds (tf Dataset) -- the train set containing image-label pairs
              train_loss (keras Loss) -- loss function for training
              train_accuracy (keras Metric) -- accuracy metric for training
              valid_ds (Tensor) -- the val set containing image-label pairs
              val_loss (keras Loss) -- loss object for validation
              val_accuracy (keras Metric) -- accuracy metric for validation
          """
          step = 0
          loss = 0.0
          for epoch in range(epochs):
              for x, y in train_ds:
                  # training step number increments at each iteration
                  step += 1
                  with tf.device(device_name=device):
                      ### START CODE HERE ###
                      # Run one training step by passing appropriate model parameters
                      # required by the function and finally get the loss to report
                      ↪ the results
                      loss = train_one_step(model, optimizer, x, y, train_loss,
                      ↪ train_accuracy)
                      ### END CODE HERE ###
```



```

# Use tf.print to report your results.
# Print the training step number, loss and accuracy
tf.print('Step', step,
        ': train loss', loss,
        '; train accuracy', train_accuracy.result())

with tf.device(device_name=device):
    for x, y in valid_ds:
        # Call the model on the batches of inputs x and get the
        ↪ predictions
        y_pred = model(x)
        loss = val_loss(y, y_pred)
        val_accuracy(y, y_pred)

# Print the validation loss and accuracy
### START CODE HERE ###
tf.print('val loss', loss, '; val accuracy', val_accuracy.result())
### END CODE HERE ###

```

Run the `train` function to train your model! You should see the loss generally decreasing and the accuracy increasing.

Note: Please let the training finish before submitting and do not modify the next cell. It is required for grading. This will take around 5 minutes to run.

```

[24]: train(model, optimizer, EPOCHS, device, train_ds, train_loss, train_accuracy,
        ↪ valid_ds, val_loss, val_accuracy)

```

```

Step 1 : train loss 0.877281189 ; train accuracy 0.46875
Step 2 : train loss 0.525540948 ; train accuracy 0.578125
Step 3 : train loss 0.478051573 ; train accuracy 0.645833313
Step 4 : train loss 0.388120949 ; train accuracy 0.6953125
Step 5 : train loss 0.248240054 ; train accuracy 0.74375
Step 6 : train loss 0.215071827 ; train accuracy 0.776041687
Step 7 : train loss 0.119466819 ; train accuracy 0.808035731
Step 8 : train loss 0.101878732 ; train accuracy 0.83203125
Step 9 : train loss 0.11198137 ; train accuracy 0.850694418
Step 10 : train loss 0.0726101771 ; train accuracy 0.865625
Step 11 : train loss 0.0893262774 ; train accuracy 0.875
Step 12 : train loss 0.0407192819 ; train accuracy 0.885416687
Step 13 : train loss 0.0203935951 ; train accuracy 0.894230783
Step 14 : train loss 0.02463088 ; train accuracy 0.901785731
Step 15 : train loss 0.0104218824 ; train accuracy 0.908333361
Step 16 : train loss 0.0134954546 ; train accuracy 0.9140625
Step 17 : train loss 0.0158557128 ; train accuracy 0.91911763
Step 18 : train loss 0.00974750426 ; train accuracy 0.923611104
Step 19 : train loss 0.0114166234 ; train accuracy 0.927631557
Step 20 : train loss 0.00516576413 ; train accuracy 0.93125

```

```
Step 21 : train loss 0.00722021237 ; train accuracy 0.934523821
Step 22 : train loss 0.00244604237 ; train accuracy 0.9375
Step 23 : train loss 0.00554676354 ; train accuracy 0.940217376
Step 24 : train loss 0.00526826456 ; train accuracy 0.942708313
Step 25 : train loss 0.0279345326 ; train accuracy 0.94375
Step 26 : train loss 0.00354680698 ; train accuracy 0.945255458
val loss 0.00399609841 ; val accuracy 1
Step 27 : train loss 0.0109420158 ; train accuracy 0.947306812
Step 28 : train loss 0.00518083572 ; train accuracy 0.949209929
Step 29 : train loss 0.0132165495 ; train accuracy 0.950980365
Step 30 : train loss 0.00215262733 ; train accuracy 0.952631593
Step 31 : train loss 0.00418820139 ; train accuracy 0.954175174
Step 32 : train loss 0.00397633808 ; train accuracy 0.955621302
Step 33 : train loss 0.00241329707 ; train accuracy 0.956979
Step 34 : train loss 0.00226100348 ; train accuracy 0.958256
Step 35 : train loss 0.00739988592 ; train accuracy 0.959459484
Step 36 : train loss 0.00132492068 ; train accuracy 0.960595429
Step 37 : train loss 0.00644258503 ; train accuracy 0.961669505
Step 38 : train loss 0.00219181809 ; train accuracy 0.962686539
Step 39 : train loss 0.00174351968 ; train accuracy 0.963651061
Step 40 : train loss 0.00324025843 ; train accuracy 0.964566946
Step 41 : train loss 0.00151252351 ; train accuracy 0.96543777
Step 42 : train loss 0.00263457908 ; train accuracy 0.96626687
Step 43 : train loss 0.00294312299 ; train accuracy 0.967057109
Step 44 : train loss 0.00220903987 ; train accuracy 0.967811167
Step 45 : train loss 0.00210370752 ; train accuracy 0.968531489
Step 46 : train loss 0.0127428137 ; train accuracy 0.969220221
Step 47 : train loss 0.00245096651 ; train accuracy 0.969879508
Step 48 : train loss 0.00182671507 ; train accuracy 0.970511138
Step 49 : train loss 0.00240753195 ; train accuracy 0.971116841
Step 50 : train loss 0.00271257339 ; train accuracy 0.971698105
Step 51 : train loss 0.00198602537 ; train accuracy 0.972256482
Step 52 : train loss 0.00158018258 ; train accuracy 0.972627759
val loss 0.0015464921 ; val accuracy 1
```

2 Evaluation

You can now see how your model performs on test images. First, let's load the test dataset and generate predictions:

```
[25]: test_imgs = []
      test_labels = []

      predictions = []
      with tf.device(device_name=device):
          for images, labels in test_ds:
```

```

preds = model(images)
preds = preds.numpy()
predictions.extend(preds)

test_imgs.extend(images.numpy())
test_labels.extend(labels.numpy())

```

Let's define a utility function for plotting an image and its prediction.

```

[26]: # Utilities for plotting

class_names = ['horse', 'human']

def plot_image(i, predictions_array, true_label, img):
    predictions_array, true_label, img = predictions_array[i], true_label[i],
    ↪img[i]
    plt.grid(False)
    plt.xticks([])
    plt.yticks([])

    img = np.squeeze(img)

    plt.imshow(img, cmap=plt.cm.binary)

    predicted_label = np.argmax(predictions_array)

    # green-colored annotations will mark correct predictions. red otherwise.
    if predicted_label == true_label:
        color = 'green'
    else:
        color = 'red'

    # print the true label first
    print(true_label)

    # show the image and overlay the prediction
    plt.xlabel("{} {:.2f}% ({})" .format(class_names[predicted_label],
                                         100*np.max(predictions_array),
                                         class_names[true_label]),
              color=color)

```

2.0.1 Plot the result of a single image

Choose an index and display the model's prediction for that image.

```
[27]: # Visualize the outputs

# you can modify the index value here from 0 to 255 to test different images
index = 8
plt.figure(figsize=(6,3))
plt.subplot(1,2,1)
plot_image(index, predictions, test_labels, test_imgs)
plt.show()
```

0



horse 100% (horse)

[]: