Deploy and monitor a machine learning workflow for Image Classification

Setting up this notebook

Notes about the instance size and kernel setup: this notebook has been tested on

```
    The Python 3 (Data Science) kernel
    The ml.t3.medium Sagemaker notebook instance
```

Data Staging

We'll use a sample dataset called CIFAR to simulate the challenges Scones Unlimited are facing in Image Classification. In order to start working with CIFAR we'll need to:

- 1. Extract the data from a hosting service
- 2. Transform it into a usable shape and format
- 3. Load it into a production system

In other words, we're going to do some simple ETL!

1. Extract the data from the hosting service

In the cell below, define a function extract_cifar_data that extracts python version of the CIFAR-100 dataset. The CIFAR dataset is open source and generously hosted by the University of Toronto at: https://www.cs.toronto.edu/~kriz/cifar-100-python.tar.gz

Let's test it out! Run the following cell and check whether a new file cifar.tar.gz is created in the file explorer.

```
In [2]: extract_cifar_data("https://www.cs.toronto.edu/~kriz/cifar-100-python.tar.gz")
```

2. Transform the data into a usable shape and format

Clearly, distributing the data as a gzipped archive makes sense for the hosting service! It saves on bandwidth, storage, and it's a widely-used archive format. In fact, it's so widely used that the Python community ships a utility for working with them, tarfile, as part of its Standard Library. Execute the following cell to decompress your extracted dataset:

A new folder cifar-100-python should be created, containing meta, test, and train files. These files are pickles and the CIFAR homepage provides a simple script that can be used to load them. We've adapted the script below for you to run:

```
import pickle
with open("./cifar-100-python/meta", "rb") as f:
    dataset_meta = pickle.load(f, encoding='bytes')
with open("./cifar-100-python/test", "rb") as f:
    dataset_test = pickle.load(f, encoding='bytes')
with open("./cifar-100-python/train", "rb") as f:
    dataset_train = pickle.load(f, encoding='bytes')
```

```
In [3]: dataset_test.keys()
```

Out[3]: dict_keys([b'filenames', b'batch_label', b'fine_labels', b'coarse_labels', b'dat
 a'])

```
In [4]: # Feel free to explore the datasets
dataset_train.keys() # dataset_train is a data dictionary
```

```
Out[4]: dict_keys([b'filenames', b'batch_label', b'fine_labels', b'coarse_labels', b'dat
    a'])
```

As documented on the homepage, b'data' contains rows of 3073 unsigned integers, representing three channels (red, green, and blue) for one 32x32 pixel image per row.

```
In [5]: 32*32*3
Out[5]: 3072
```

For a simple gut-check, let's transform one of our images. Each 1024 items in a row is a channel (red, green, then blue). Each 32 items in the channel are a row in the 32x32 image. Using python, we can stack these channels into a 32x32x3 array, and save it as a PNG file:

```
In [6]: dataset_train[b'data'][0]
Out[6]: array([255, 255, 255, ..., 10, 59, 79], dtype=uint8)

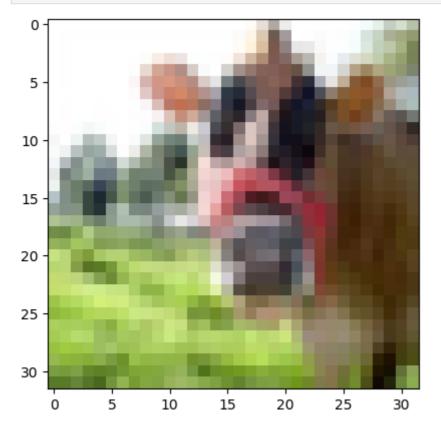
In [7]: import numpy as np

# Each 1024 in a row is a channel (red, green, then blue)
row = dataset_train[b'data'][0]
red, green, blue = row[0:1024], row[1024:2048], row[2048:]

# Each 32 items in the channel are a row in the 32x32 image
red = red.reshape(32,32)
green = green.reshape(32,32)
blue = blue.reshape(32,32)
# Combine the channels into a 32x32x3 image!
combined = np.dstack((red,green,blue))
```

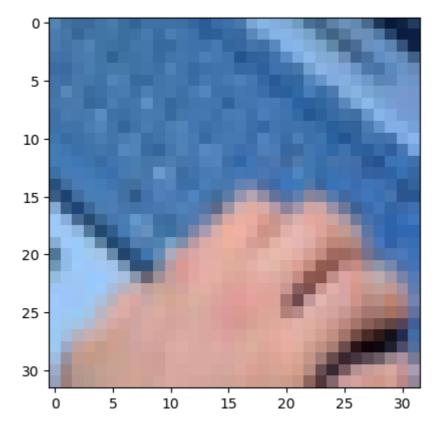
For a more concise version, consider the following:

```
import matplotlib.pyplot as plt
plt.imshow(test_image);
plt.show()
```



Looks like a cow! Let's check the label. dataset_meta contains label names in order, and dataset_train has a list of labels for each row.

```
print(dataset_meta[b'fine_label_names'][19])
In [10]:
         b'cattle'
         dataset_train.keys()
In [11]:
         dict_keys([b'filenames', b'batch_label', b'fine_labels', b'coarse_labels', b'dat
Out[11]:
In [12]:
          print(dataset_train[b'filenames'][10])
          print(dataset_train[b'batch_label'][10])
          print(dataset_train[b'fine_labels'][10]) #to be used in next step
          print(dataset_train[b'coarse_labels'][10])
         b'computer_keyboard_s_000757.png'
         97
         39
         5
         dataset_meta.keys()
In [13]:
         dict_keys([b'fine_label_names', b'coarse_label_names'])
Out[13]:
          dataset_meta[b'fine_label_names'][39]
In [14]:
         b'keyboard'
Out[14]:
          row = dataset_train[b'data'][10]
In [15]:
          # All in one:
          test_image_2 = np.dstack((
              row[0:1024].reshape(32,32),
              row[1024:2048].reshape(32,32),
              row[2048:].reshape(32,32)
          ))
          import matplotlib.pyplot as plt
          plt.imshow(test_image_2);
          plt.show()
```



Our image has a label of 19, so let's see what the 19th item is in the list of label names.

Ok! 'cattle' sounds about right. By the way, using the previous two lines we can do:

Now we know how to check labels, is there a way that we can also check file names? dataset_train also contains a b'filenames' key. Let's see what we have here:

```
In [17]: print(dataset_train[b'filenames'][0])
```

b'bos_taurus_s_000507.png'

"Taurus" is the name of a subspecies of cattle, so this looks like a pretty reasonable filename. To save an image we can also do:

```
In [18]: plt.imsave("file.png", test_image)
```

Your new PNG file should now appear in the file explorer -- go ahead and pop it open to see!

Now that you know how to reshape the images, save them as files, and capture their filenames and labels, let's just capture all the bicycles and motorcycles and save them. Scones Unlimited can use a model that tells these apart to route delivery drivers automatically.

In the following cell, identify the label numbers for Bicycles and Motorcycles:

```
In [19]: import pandas as pd
```

```
# Todo: Filter the dataset_train and dataset_meta objects to find the label numbers
         dictionary = {}
         for n in list(range(200)):
             key1 = dataset_train[b'fine_labels'][n]
             value 1 = dataset meta[b'fine label names'][key1]
             dictionary[key1] =value_1
         # print(dictionary)
         myKeys = list(dictionary.keys())
         myKeys.sort()
         sorted_dict = {i: dictionary[i] for i in myKeys}
         # print(sorted dict)
         for label_value, label_name in sorted_dict.items():
             if label_name == b'bicycle':
                  print(f'label: {label_name} has lable number: {label_value}')
             elif label_name == b'motorcycle':
                  print(f'label: {label_name} has lable number: {label_value}')
         label: b'bicycle' has lable number: 8
         label: b'motorcycle' has lable number: 48
In [20]:
             # In the above code we identified that bicycle is 8, and motorcycle = 48
```

Good job! We only need objects with label 8 and 48 -- this drastically simplifies our handling of the data! Below we construct a dataframe for you, and you can safely drop the rows that don't contain observations about bicycles and motorcycles. Fill in the missing lines below to drop all other rows:

```
#Construct the dataframe
In [21]:
         df_train = pd.DataFrame({
             "filenames": dataset_train[b'filenames'],
             "labels": dataset_train[b'fine_labels'],
             "row": range(len(dataset_train[b'filenames']))
         })
         # Drop all rows from df train where label is not 8 or 48 # Query can also be used
         df_train = df_train[(df_train['labels'] == 8) | (df_train['labels'] == 48)]
         # Decode df_train.filenames so they are regular strings
         df train["filenames"] = df train["filenames"].apply(
             lambda x: x.decode("utf-8")
         df test = pd.DataFrame({
             "filenames": dataset test[b'filenames'],
              "labels": dataset_test[b'fine_labels'],
              "row": range(len(dataset_test[b'filenames']))
         })
         # Drop all rows from df_test where label is not 8 or 48
         df_test = df_test[(df_test['labels'] == 8) | (df_test['labels'] == 48)]
         # Decode df test.filenames so they are regular strings
         df_test["filenames"] = df_test["filenames"].apply(
```

[8 48] [8 48]

```
lambda x: x.decode("utf-8")
)

In [22]: print(df_train['labels'].unique())
print(df_test['labels'].unique())
```

Now that the data is filtered for just our classes, we can save all our images.

```
In [72]: !mkdir ./train
!mkdir ./test
```

In the previous sections we introduced you to several key snippets of code:

1. Grabbing the image data:

```
dataset_train[b'data'][0]
```

1. A simple idiom for stacking the image data into the right shape

```
import numpy as np
np.dstack((
    row[0:1024].reshape(32,32),
    row[1024:2048].reshape(32,32),
    row[2048:].reshape(32,32)
))
```

1. A simple matplotlib utility for saving images

```
plt.imsave(path+row['filenames'], target)
```

Compose these together into a function that saves all the images into the ./test and ./train directories. Use the comments in the body of the save_images function below to guide your construction of the function:

```
import os
In [23]:
         def save_images(image_row_num , image_filename, path_target_location, dataset):
             save_images is a function for saving images from the dataset
             to the provided target path folders
             Arguments:
             image_row_num
                                   -- Row number of image to be saved in the train/test loca
             image_filename -- Imagename with which image will be saved
             path_target_locatio -- Target folder location where image will be saved
                                   -- Original images containing all the images
             dataset
             .....
             # Grab the image data in row-major form
             img_data = dataset[b'data'][image_row_num]
             # Consolidated stacking/reshaping from earlier
             target = np.dstack((
                 img_data[0:1024].reshape(32,32),
                 img_data[1024:2048].reshape(32,32),
                 img_data[2048:].reshape(32,32)
             ))
```

```
# Saving the image
try:
    image_file_path = os.path.join( path_target_location, image_filename)
    plt.imsave(image_file_path, target)
except e:
    return f"Error Saving {image_filename} to folder {path_target_location} \n
# Return any signal data you want for debugging
return f"Successfully saved {image_filename} to folder {path_target_location}.
```

```
In [24]: #Saving all the Train dataset images
for dtrain in df_train.itertuples():
    print(save_images(dtrain.row, dtrain.filenames,"./train", dataset_train))

#Saving all the Test dataset images
for dtest in df_test.itertuples():
    print(save_images(dtest.row, dtest.filenames,"./test", dataset_test))
```

Successfully saved bike_s_000682.png to folder ./train. Successfully saved bike_s_000127.png to folder ./train. Successfully saved cycle s 002598.png to folder ./train. Successfully saved minibike_s_000824.png to folder ./train. Successfully saved motorcycle s 001856.png to folder ./train. Successfully saved bicycle_s_000537.png to folder ./train. Successfully saved moped_s_000169.png to folder ./train. Successfully saved motorcycle s 001453.png to folder ./train. Successfully saved safety_bike_s_000482.png to folder ./train. Successfully saved dirt_bike_s_000124.png to folder ./train. Successfully saved minibike_s_001863.png to folder ./train. Successfully saved minibike_s_001177.png to folder ./train. Successfully saved motorcycle_s_001792.png to folder ./train. Successfully saved minibike s 001969.png to folder ./train. Successfully saved velocipede_s_001585.png to folder ./train. Successfully saved moped_s_000035.png to folder ./train. Successfully saved bike_s_000256.png to folder ./train. Successfully saved minibike_s_000571.png to folder ./train. Successfully saved motorcycle_s_001119.png to folder ./train. Successfully saved moped s 000009.png to folder ./train. Successfully saved ordinary_bicycle_s_000023.png to folder ./train. Successfully saved motorcycle_s_001693.png to folder ./train. Successfully saved safety bicycle s 001570.png to folder ./train. Successfully saved safety_bike_s_000989.png to folder ./train. Successfully saved bicycle_s_001673.png to folder ./train. Successfully saved ordinary_bicycle_s_000100.png to folder ./train. Successfully saved bike_s_000544.png to folder ./train. Successfully saved motorcycle_s_001368.png to folder ./train. Successfully saved bicycle_s_000392.png to folder ./train. Successfully saved motorbike_s_000221.png to folder ./train. Successfully saved safety bike s 000311.png to folder ./train. Successfully saved cycle s 001745.png to folder ./train. Successfully saved motorcycle_s_002030.png to folder ./train. Successfully saved motorcycle_s_000074.png to folder ./train. Successfully saved cycle_s_002978.png to folder ./train. Successfully saved bike_s_001679.png to folder ./train. Successfully saved bicycle_s_000536.png to folder ./train. Successfully saved bike_s_000926.png to folder ./train. Successfully saved motorcycle s 000070.png to folder ./train. Successfully saved safety bicycle s 000655.png to folder ./train. Successfully saved safety_bicycle_s_000427.png to folder ./train. Successfully saved minibike_s_000324.png to folder ./train. Successfully saved minibike s 001631.png to folder ./train. Successfully saved motorcycle_s_000629.png to folder ./train. Successfully saved motorcycle_s_000605.png to folder ./train. Successfully saved motorcycle_s_001973.png to folder ./train. Successfully saved bike_s_000555.png to folder ./train. Successfully saved bicycle s 002762.png to folder ./train. Successfully saved bicycle s 000778.png to folder ./train. Successfully saved bike_s_001613.png to folder ./train. Successfully saved motorcycle s 001180.png to folder ./train. Successfully saved minibike_s_001279.png to folder ./train. Successfully saved minibike_s_000451.png to folder ./train. Successfully saved motorbike_s_000346.png to folder ./train. Successfully saved minibike s 000117.png to folder ./train. Successfully saved bicycle s 001448.png to folder ./train. Successfully saved motorcycle s 000790.png to folder ./train. Successfully saved bicycle_s_002373.png to folder ./train. Successfully saved safety bicycle s 001202.png to folder ./train. Successfully saved motorcycle s 000001.png to folder ./train. Successfully saved bike_s_001882.png to folder ./train. Successfully saved bike_s_001113.png to folder ./train. Successfully saved minibike s 000362.png to folder ./train. Successfully saved cycle_s_000718.png to folder ./train.

Successfully saved velocipede_s_001338.png to folder ./train. Successfully saved minibike_s_001972.png to folder ./train. Successfully saved ordinary bicycle s 000107.png to folder ./train. Successfully saved motorcycle_s_000776.png to folder ./train. Successfully saved safety bike s 000934.png to folder ./train. Successfully saved bicycle_s_002218.png to folder ./train. Successfully saved safety_bicycle_s_001240.png to folder ./train. Successfully saved ordinary bicycle s 000355.png to folder ./train. Successfully saved motorcycle_s_000454.png to folder ./train. Successfully saved motorcycle_s_000245.png to folder ./train. Successfully saved minibike s 000743.png to folder ./train. Successfully saved safety_bike_s_000830.png to folder ./train. Successfully saved minibike s 001573.png to folder ./train. Successfully saved motorbike s 000141.png to folder ./train. Successfully saved minibike_s_000652.png to folder ./train. Successfully saved motorbike_s_000058.png to folder ./train. Successfully saved bicycle_s_000279.png to folder ./train. Successfully saved safety_bike_s_001608.png to folder ./train. Successfully saved bicycle_s_000522.png to folder ./train. Successfully saved bicycle_s_002569.png to folder ./train. Successfully saved bicycle_s_000829.png to folder ./train. Successfully saved velocipede_s_000586.png to folder ./train. Successfully saved dirt bike s 000017.png to folder ./train. Successfully saved cycle_s_001640.png to folder ./train. Successfully saved bicycle_s_000282.png to folder ./train. Successfully saved motorcycle_s_000713.png to folder ./train. Successfully saved bike_s_000035.png to folder ./train. Successfully saved bike_s_000299.png to folder ./train. Successfully saved minibike_s_002198.png to folder ./train. Successfully saved safety_bicycle_s_001253.png to folder ./train. Successfully saved minibike s 000110.png to folder ./train. Successfully saved motorcycle s 001370.png to folder ./train. Successfully saved motorcycle_s_001363.png to folder ./train. Successfully saved ordinary_bicycle_s_000060.png to folder ./train. Successfully saved minibike s 001653.png to folder ./train. Successfully saved bicycle_s_001338.png to folder ./train. Successfully saved cycle_s_002053.png to folder ./train. Successfully saved velocipede_s_001056.png to folder ./train. Successfully saved minibike s 000402.png to folder ./train. Successfully saved motorbike s 000124.png to folder ./train. Successfully saved cycle_s_002638.png to folder ./train. Successfully saved velocipede s 000949.png to folder ./train. Successfully saved safety bike s 000921.png to folder ./train. Successfully saved ordinary_bicycle_s_000297.png to folder ./train. Successfully saved motorcycle_s_001580.png to folder ./train. Successfully saved velocipede_s_000139.png to folder ./train. Successfully saved bicycle_s_000561.png to folder ./train. Successfully saved ordinary bicycle s 000161.png to folder ./train. Successfully saved minibike s 000518.png to folder ./train. Successfully saved motorcycle_s_000167.png to folder ./train. Successfully saved cycle s 000318.png to folder ./train. Successfully saved velocipede s 001958.png to folder ./train. Successfully saved ordinary_bicycle_s_000201.png to folder ./train. Successfully saved bike_s_001462.png to folder ./train. Successfully saved bicycle s 000437.png to folder ./train. Successfully saved velocipede s 000825.png to folder ./train. Successfully saved safety bike s 000100.png to folder ./train. Successfully saved minibike s 000654.png to folder ./train. Successfully saved bicycle_s_000021.png to folder ./train. Successfully saved moped s 000030.png to folder ./train. Successfully saved velocipede s 001142.png to folder ./train. Successfully saved motorbike_s_000117.png to folder ./train. Successfully saved ordinary bicycle s 000036.png to folder ./train. Successfully saved motorcycle_s_000787.png to folder ./train.

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Successfully saved bicycle s 001218.png to folder ./test.
```

In []:

3. Load the data

Now we can load the data into S3.

Using the sagemaker SDK grab the current region, execution role, and bucket.

```
import sagemaker
session = sagemaker.session.Session()
bucket= session.default_bucket()
```

```
print("Default Bucket: {}".format(bucket))

region = session.boto_region_name
print("AWS Region: {}".format(region))

role = sagemaker.get_execution_role()
print("RoleArn: {}".format(role))
```

Default Bucket: sagemaker-us-east-1-935549625822

AWS Region: us-east-1

RoleArn: arn:aws:iam::935549625822:role/service-role/AmazonSageMaker-ExecutionRole

-20221228T183318

With this data we can easily sync your data up into S3!

```
import os

os.environ["DEFAULT_S3_BUCKET"] = bucket
!aws s3 sync ./train s3://${DEFAULT_S3_BUCKET}/train/
!aws s3 sync ./test s3://${DEFAULT_S3_BUCKET}/test/
```

```
upload: train/bicycle_s_000017.png to s3://sagemaker-us-east-1-935549625822/train/
bicycle_s_000017.png
upload: train/bicycle_s_000039.png to s3://sagemaker-us-east-1-935549625822/train/
bicycle_s_000039.png
upload: train/bicycle s 000035.png to s3://sagemaker-us-east-1-935549625822/train/
bicycle_s_000035.png
upload: train/bicycle_s_000038.png to s3://sagemaker-us-east-1-935549625822/train/
bicycle s 000038.png
upload: train/bicycle_s_000099.png to s3://sagemaker-us-east-1-935549625822/train/
bicycle_s_000099.png
upload: train/bicycle_s_000137.png to s3://sagemaker-us-east-1-935549625822/train/
bicycle_s_000137.png
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bicycle_s_000051.png
upload: train/bicycle_s_000021.png to s3://sagemaker-us-east-1-935549625822/train/
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bicycle s 000043.png
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upload: test/motorcycle s 002112.png to s3://sagemaker-us-east-1-935549625822/tes
t/motorcycle s 002112.png
upload: test/motorcycle_s_001960.png to s3://sagemaker-us-east-1-935549625822/tes
t/motorcycle_s_001960.png
upload: test/motorcycle_s_001906.png to s3://sagemaker-us-east-1-935549625822/tes
t/motorcycle s 001906.png
upload: test/motorcycle s 002026.png to s3://sagemaker-us-east-1-935549625822/tes
t/motorcycle s 002026.png
upload: test/motorcycle_s_001971.png to s3://sagemaker-us-east-1-935549625822/tes
t/motorcycle s 001971.png
upload: test/ordinary_bicycle_s_000105.png to s3://sagemaker-us-east-1-93554962582
2/test/ordinary_bicycle_s_000105.png
upload: test/ordinary_bicycle_s_000158.png to s3://sagemaker-us-east-1-93554962582
2/test/ordinary_bicycle_s_000158.png
```

```
upload: test/ordinary_bicycle_s_000113.png to s3://sagemaker-us-east-1-93554962582
2/test/ordinary_bicycle_s_000113.png
upload: test/motorcycle_s_002177.png to s3://sagemaker-us-east-1-935549625822/tes
t/motorcycle_s_002177.png
upload: test/ordinary bicycle s 000350.png to s3://sagemaker-us-east-1-93554962582
2/test/ordinary_bicycle_s_000350.png
upload: test/ordinary_bicycle_s_000284.png to s3://sagemaker-us-east-1-93554962582
2/test/ordinary bicycle s 000284.png
upload: test/motorcycle_s_002126.png to s3://sagemaker-us-east-1-935549625822/tes
t/motorcycle_s_002126.png
upload: test/ordinary_bicycle_s_000169.png to s3://sagemaker-us-east-1-93554962582
2/test/ordinary_bicycle_s_000169.png
upload: test/ordinary_bicycle_s_000431.png to s3://sagemaker-us-east-1-93554962582
2/test/ordinary bicycle s 000431.png
upload: test/safety_bicycle_s_000235.png to s3://sagemaker-us-east-1-935549625822/
test/safety bicycle s 000235.png
upload: test/ordinary_bicycle_s_000437.png to s3://sagemaker-us-east-1-93554962582
2/test/ordinary_bicycle_s_000437.png
upload: test/safety_bicycle_s_001575.png to s3://sagemaker-us-east-1-935549625822/
test/safety_bicycle_s_001575.png
upload: test/safety_bicycle_s_001322.png to s3://sagemaker-us-east-1-935549625822/
test/safety_bicycle_s_001322.png
upload: test/safety_bicycle_s_000315.png to s3://sagemaker-us-east-1-935549625822/
test/safety_bicycle_s_000315.png
upload: test/safety_bicycle_s_001286.png to s3://sagemaker-us-east-1-935549625822/
test/safety_bicycle_s_001286.png
upload: test/safety_bike_s_000192.png to s3://sagemaker-us-east-1-935549625822/tes
t/safety_bike_s_000192.png
upload: test/safety_bike_s_000390.png to s3://sagemaker-us-east-1-935549625822/tes
t/safety_bike_s_000390.png
upload: test/safety bicycle s 000280.png to s3://sagemaker-us-east-1-935549625822/
test/safety bicycle s 000280.png
upload: test/safety_bike_s_000438.png to s3://sagemaker-us-east-1-935549625822/tes
t/safety_bike_s_000438.png
upload: test/safety_bicycle_s_001153.png to s3://sagemaker-us-east-1-935549625822/
test/safety_bicycle_s_001153.png
upload: test/safety_bike_s_000541.png to s3://sagemaker-us-east-1-935549625822/tes
t/safety_bike_s_000541.png
upload: test/safety_bike_s_000791.png to s3://sagemaker-us-east-1-935549625822/tes
t/safety bike s 000791.png
upload: test/safety_bike_s_000488.png to s3://sagemaker-us-east-1-935549625822/tes
t/safety bike s 000488.png
upload: test/safety_bike_s_001065.png to s3://sagemaker-us-east-1-935549625822/tes
t/safety_bike_s_001065.png
upload: test/safety_bike_s_001087.png to s3://sagemaker-us-east-1-935549625822/tes
t/safety_bike_s_001087.png
upload: test/safety_bike_s_000699.png to s3://sagemaker-us-east-1-935549625822/tes
t/safety bike s 000699.png
upload: test/safety bike s 001132.png to s3://sagemaker-us-east-1-935549625822/tes
t/safety_bike_s_001132.png
upload: test/safety bike s 001088.png to s3://sagemaker-us-east-1-935549625822/tes
t/safety bike s 001088.png
upload: test/trail_bike_s_000073.png to s3://sagemaker-us-east-1-935549625822/tes
t/trail_bike_s_000073.png
upload: test/safety_bike_s_000540.png to s3://sagemaker-us-east-1-935549625822/tes
t/safety bike s 000540.png
upload: test/velocipede s 000041.png to s3://sagemaker-us-east-1-935549625822/tes
t/velocipede s 000041.png
upload: test/velocipede_s_000001.png to s3://sagemaker-us-east-1-935549625822/tes
t/velocipede s 000001.png
upload: test/safety_bike_s_001690.png to s3://sagemaker-us-east-1-935549625822/tes
t/safety_bike_s_001690.png
upload: test/velocipede_s_000292.png to s3://sagemaker-us-east-1-935549625822/tes
t/velocipede_s_000292.png
```

```
upload: test/velocipede_s_000863.png to s3://sagemaker-us-east-1-935549625822/tes
t/velocipede_s_000863.png
upload: test/safety_bike_s_001481.png to s3://sagemaker-us-east-1-935549625822/tes
t/safety_bike_s_001481.png
upload: test/velocipede s 000106.png to s3://sagemaker-us-east-1-935549625822/tes
t/velocipede_s_000106.png
upload: test/safety_bike_s_001253.png to s3://sagemaker-us-east-1-935549625822/tes
t/safety bike s 001253.png
upload: test/velocipede_s_001232.png to s3://sagemaker-us-east-1-935549625822/tes
t/velocipede_s_001232.png
upload: test/velocipede_s_001277.png to s3://sagemaker-us-east-1-935549625822/tes
t/velocipede_s_001277.png
upload: test/velocipede_s_000369.png to s3://sagemaker-us-east-1-935549625822/tes
t/velocipede s 000369.png
upload: test/velocipede_s_001335.png to s3://sagemaker-us-east-1-935549625822/tes
t/velocipede_s_001335.png
upload: test/velocipede_s_001355.png to s3://sagemaker-us-east-1-935549625822/tes
t/velocipede_s_001355.png
upload: test/velocipede_s_001699.png to s3://sagemaker-us-east-1-935549625822/tes
t/velocipede_s_001699.png
upload: test/velocipede_s_001744.png to s3://sagemaker-us-east-1-935549625822/tes
t/velocipede_s_001744.png
upload: test/velocipede_s_001466.png to s3://sagemaker-us-east-1-935549625822/tes
t/velocipede_s_001466.png
upload: test/velocipede_s_001201.png to s3://sagemaker-us-east-1-935549625822/tes
t/velocipede_s_001201.png
upload: test/velocipede_s_001790.png to s3://sagemaker-us-east-1-935549625822/tes
t/velocipede_s_001790.png
upload: test/velocipede_s_001633.png to s3://sagemaker-us-east-1-935549625822/tes
t/velocipede_s_001633.png
upload: test/velocipede_s_001379.png to s3://sagemaker-us-east-1-935549625822/tes
t/velocipede_s_001379.png
```

And that's it! You can check the bucket and verify that the items were uploaded.

Model Training

For Image Classification, Sagemaker also expects metadata e.g. in the form of TSV files with labels and filepaths. We can generate these using our Pandas DataFrames from earlier:

```
In [26]:

def to_metadata_file(df, prefix):
    df["s3_path"] = df["filenames"]
    df["labels"] = df["labels"].apply(lambda x: 0 if x==8 else 1)
    return df[["row", "labels", "s3_path"]].to_csv(
        f"{prefix}.lst", sep="\t", index=False, header=False
    )

to_metadata_file(df_train.copy(), "train")
to_metadata_file(df_test.copy(), "test")
```

We can also upload our manifest files:

Using the bucket and region info we can get the latest prebuilt container to run our training job, and define an output location on our s3 bucket for the model. Use the image_uris function from the SageMaker SDK to retrieve the latest image-classification image below:

Defaulting to the only supported framework/algorithm version: 1. Ignoring framework/algorithm version: latest.

We're ready to create an estimator! Create an estimator img_classifier_model that uses one instance of ml.p3.2xlarge . Ensure that y ou use the output location we defined above - we'll be referring to that later!

We can also set a few key hyperparameters and define the inputs for our model:

```
In [30]: df_train.describe()
```

Out[30]: labels row **count** 1000.000000 1000.000000 mean 28.000000 24082.050000 20.010008 14346.778606 std min 8.000000 16.000000 25% 8.000000 11157.000000 50% 28.000000 23898.000000 **75%** 48.000000 36013.750000 max 48.000000 49985.000000

```
In [31]: # to get number of training samples
    df_train.shape
```

Out[31]: (1000, 3)

```
In [32]: # setting hyperparamaters
img_classifier_model.set_hyperparameters(
    image_shape= '3,32,32',
    num_classes= 2,
    num_training_samples= df_train.shape[0]
)
```

The image-classification image uses four input channels with very specific input parameters. For convenience, we've provided them below:

```
from sagemaker.debugger import Rule, rule configs
In [33]:
         from sagemaker.session import TrainingInput
         model_inputs = {
                  "train": sagemaker.inputs.TrainingInput(
                      s3_data=f"s3://{bucket}/train/",
                      content_type="application/x-image"
                  ),
                  "validation": sagemaker.inputs.TrainingInput(
                      s3_data=f"s3://{bucket}/test/",
                      content_type="application/x-image"
                 ),
                  "train_lst": sagemaker.inputs.TrainingInput(
                      s3_data=f"s3://{bucket}/train.lst",
                      content_type="application/x-image"
                  "validation_lst": sagemaker.inputs.TrainingInput(
                      s3_data=f"s3://{bucket}/test.lst",
                      content_type="application/x-image"
                  )
         }
```

Great, now we can train the model using the model_inputs. In the cell below, call the fit method on our model,:

```
In [34]: # Training the model
img_classifier_model.fit(model_inputs)
```

```
2023-02-04 17:00:12 Starting - Starting the training job...ProfilerReport-16755300
12: InProgress
2023-02-04 17:01:02 Starting - Preparing the instances for training.....
2023-02-04 17:02:03 Downloading - Downloading input data...
2023-02-04 17:02:43 Training - Downloading the training image.....
2023-02-04 17:05:03 Training - Training image download completed. Training in prog
ress...Docker entrypoint called with argument(s): train
Running default environment configuration script
Nvidia gpu devices, drivers and cuda toolkit versions (only available on hosts wit
h GPU):
Sat Feb 4 17:05:18 2023
NVIDIA-SMI 515.65.07 Driver Version: 515.65.07 CUDA Version: 11.7
 GPU Name Persistence-M Bus-Id Disp.A | Volatile Uncorr. ECC |
 Fan Temp Perf Pwr:Usage/Cap | Memory-Usage | GPU-Util Compute M.
 ______
  0 Tesla V100-SXM2... On | 00000000:00:1E.0 Off | 0
 N/A 34C P0 23W / 300W | 0MiB / 16384MiB | 0%
                                                                Default
                                                                 N/A
                            Processes:
GPU GI CI PID Type Process name
                                                              GPU Memory
                                                          Usage
       ID ID
No running processes found
+-----
Checking for nvidia driver and cuda compatibility.
CUDA Compatibility driver provided.
Proceeding with compatibility check between driver, cuda-toolkit and cuda-compat.
Detected cuda-toolkit version: 11.1.
Detected cuda-compat version: 455.32.00.
Detected Nvidia driver version: 515.65.07.
Nvidia driver compatible with cuda-toolkit. Disabling cuda-compat.
[02/04/2023 17:05:22 INFO 140161468585792] Reading default configuration from /op
t/amazon/lib/python3.7/site-packages/image_classification/default-input.json: {'us
e_pretrained_model': 0, 'num_layers': 152, 'epochs': 30, 'learning_rate': 0.1, 'lr
_scheduler_factor': 0.1, 'optimizer': 'sgd', 'momentum': 0, 'weight_decay': 0.000
1, 'beta 1': 0.9, 'beta 2': 0.999, 'eps': 1e-08, 'gamma': 0.9, 'mini batch size':
32, 'image_shape': '3,224,224', 'precision_dtype': 'float32'}
[02/04/2023 17:05:22 INFO 140161468585792] Merging with provided configuration fro
m /opt/ml/input/config/hyperparameters.json: {'image_shape': '3,32,32', 'num_class
es': '2', 'num_training_samples': '1000'}
[02/04/2023 17:05:22 INFO 140161468585792] Final configuration: { 'use pretrained m
odel': 0, 'num_layers': 152, 'epochs': 30, 'learning_rate': 0.1, 'lr_scheduler_fac
tor': 0.1, 'optimizer': 'sgd', 'momentum': 0, 'weight_decay': 0.0001, 'beta_1': 0.
9, 'beta_2': 0.999, 'eps': 1e-08, 'gamma': 0.9, 'mini_batch_size': 32, 'image_shap e': '3,32,32', 'precision_dtype': 'float32', 'num_classes': '2', 'num_training_sam
ples': '1000'}
[02/04/2023 17:05:22 INFO 140161468585792] Searching for .lst files in /opt/ml/inp
ut/data/train lst.
[02/04/2023 17:05:22 INFO 140161468585792] Creating record files for train.lst
[02/04/2023 17:05:22 INFO 140161468585792] Done creating record files...
[02/04/2023 17:05:22 INFO 140161468585792] Searching for .lst files in /opt/ml/inp
ut/data/validation lst.
[02/04/2023 17:05:22 INFO 140161468585792] Creating record files for test.lst
[02/04/2023 17:05:22 INFO 140161468585792] Done creating record files...
[02/04/2023 17:05:22 INFO 140161468585792] use_pretrained_model: 0
[02/04/2023 17:05:22 INFO 140161468585792] multi label: 0
[02/04/2023 17:05:22 INFO 140161468585792] Performing random weight initialization
```

```
[02/04/2023 17:05:22 INFO 140161468585792] ---- Parameters ----
[02/04/2023 17:05:22 INFO 140161468585792] num_layers: 152
[02/04/2023 17:05:22 INFO 140161468585792] data type: <class 'numpy.float32'>
[02/04/2023 17:05:22 INFO 140161468585792] epochs: 30
[02/04/2023 17:05:22 INFO 140161468585792] optimizer: sgd
[02/04/2023 17:05:22 INFO 140161468585792] momentum: 0.9
[02/04/2023 17:05:22 INFO 140161468585792] weight_decay: 0.0001
[02/04/2023 17:05:22 INFO 140161468585792] learning rate: 0.1
[02/04/2023 17:05:22 INFO 140161468585792] num_training_samples: 1000
[02/04/2023 17:05:22 INFO 140161468585792] mini_batch_size: 32
[02/04/2023 17:05:22 INFO 140161468585792] image_shape: 3,32,32
[02/04/2023 17:05:22 INFO 140161468585792] num_classes: 2
[02/04/2023 17:05:22 INFO 140161468585792] augmentation_type: None
[02/04/2023 17:05:22 INFO 140161468585792] kv store: device
[02/04/2023 17:05:22 INFO 140161468585792] checkpoint_frequency not set, will stor
e the best model
[02/04/2023 17:05:22 INFO 140161468585792] ------
[02/04/2023 17:05:22 INFO 140161468585792] Setting number of threads: 7
[17:05:26] /opt/brazil-pkg-cache/packages/AIAlgorithmsMXNet/AIAlgorithmsMXNet-1.4.
x_ecl_Cuda_11.1.x.38.0/AL2_x86_64/generic-flavor/src/src/operator/nn/./cudnn/./cud
nn_algoreg-inl.h:97: Running performance tests to find the best convolution algori
thm, this can take a while... (setting env variable MXNET_CUDNN_AUTOTUNE DEFAULT t
o 0 to disable)
[02/04/2023 17:05:31 INFO 140161468585792] Epoch[0] Batch [20]#011Speed: 122.324 s
amples/sec#011accuracy=0.532738
[02/04/2023 17:05:33 INFO 140161468585792] Epoch[0] Train-accuracy=0.571573
[02/04/2023 17:05:33 INFO 140161468585792] Epoch[0] Time cost=6.901
[02/04/2023 17:05:33 INFO 140161468585792] Epoch[0] Validation-accuracy=0.552083
[02/04/2023 17:05:33 INFO 140161468585792] Storing the best model with validation
accuracy: 0.552083
[02/04/2023 17:05:34 INFO 140161468585792] Saved checkpoint to "/opt/ml/model/imag
e-classification-0001.params"
[02/04/2023 17:05:37 INFO 140161468585792] Epoch[1] Batch [20]#011Speed: 188.535 s
amples/sec#011accuracy=0.702381
[02/04/2023 17:05:39 INFO 140161468585792] Epoch[1] Train-accuracy=0.704637
[02/04/2023 17:05:39 INFO 140161468585792] Epoch[1] Time cost=5.025
[02/04/2023 17:05:39 INFO 140161468585792] Epoch[1] Validation-accuracy=0.791667
[02/04/2023 17:05:39 INFO 140161468585792] Storing the best model with validation
accuracy: 0.791667
[02/04/2023 17:05:40 INFO 140161468585792] Saved checkpoint to "/opt/ml/model/imag
e-classification-0002.params"
[02/04/2023 17:05:43 INFO 140161468585792] Epoch[2] Batch [20]#011Speed: 191.959 s
amples/sec#011accuracy=0.691964
[02/04/2023 17:05:45 INFO 140161468585792] Epoch[2] Train-accuracy=0.687500
[02/04/2023 17:05:45 INFO 140161468585792] Epoch[2] Time cost=4.993
[02/04/2023 17:05:45 INFO 140161468585792] Epoch[2] Validation-accuracy=0.729167
[02/04/2023 17:05:49 INFO 140161468585792] Epoch[3] Batch [20]#011Speed: 191.350 s
amples/sec#011accuracy=0.711310
[02/04/2023 17:05:51 INFO 140161468585792] Epoch[3] Train-accuracy=0.732863
[02/04/2023 17:05:51 INFO 140161468585792] Epoch[3] Time cost=4.993
[02/04/2023 17:05:51 INFO 140161468585792] Epoch[3] Validation-accuracy=0.781250
[02/04/2023 17:05:55 INFO 140161468585792] Epoch[4] Batch [20]#011Speed: 188.927 s
amples/sec#011accuracy=0.790179
[02/04/2023 17:05:57 INFO 140161468585792] Epoch[4] Train-accuracy=0.782258
[02/04/2023 17:05:57 INFO 140161468585792] Epoch[4] Time cost=5.067
[02/04/2023 17:05:57 INFO 140161468585792] Epoch[4] Validation-accuracy=0.822917
[02/04/2023 17:05:58 INFO 140161468585792] Storing the best model with validation
accuracy: 0.822917
[02/04/2023 17:05:58 INFO 140161468585792] Saved checkpoint to "/opt/ml/model/imag
e-classification-0005.params"
[02/04/2023 17:06:02 INFO 140161468585792] Epoch[5] Batch [20]#011Speed: 181.438 s
amples/sec#011accuracy=0.813988
[02/04/2023 17:06:03 INFO 140161468585792] Epoch[5] Train-accuracy=0.798387
[02/04/2023 17:06:03 INFO 140161468585792] Epoch[5] Time cost=5.320
```

```
[02/04/2023 17:06:04 INFO 140161468585792] Epoch[5] Validation-accuracy=0.812500
[02/04/2023 17:06:08 INFO 140161468585792] Epoch[6] Batch [20]#011Speed: 191.216 s
amples/sec#011accuracy=0.833333
[02/04/2023 17:06:09 INFO 140161468585792] Epoch[6] Train-accuracy=0.821573
[02/04/2023 17:06:09 INFO 140161468585792] Epoch[6] Time cost=4.980
[02/04/2023 17:06:10 INFO 140161468585792] Epoch[6] Validation-accuracy=0.817708
[02/04/2023 17:06:14 INFO 140161468585792] Epoch[7] Batch [20]#011Speed: 192.886 s
amples/sec#011accuracy=0.828869
[02/04/2023 17:06:15 INFO 140161468585792] Epoch[7] Train-accuracy=0.818548
[02/04/2023 17:06:15 INFO 140161468585792] Epoch[7] Time cost=4.953
[02/04/2023 17:06:16 INFO 140161468585792] Epoch[7] Validation-accuracy=0.803571
[02/04/2023 17:06:20 INFO 140161468585792] Epoch[8] Batch [20]#011Speed: 190.247 s
amples/sec#011accuracy=0.830357
[02/04/2023 17:06:21 INFO 140161468585792] Epoch[8] Train-accuracy=0.822581
[02/04/2023 17:06:21 INFO 140161468585792] Epoch[8] Time cost=5.005
[02/04/2023 17:06:22 INFO 140161468585792] Epoch[8] Validation-accuracy=0.786458
[02/04/2023 17:06:26 INFO 140161468585792] Epoch[9] Batch [20]#011Speed: 191.299 s
amples/sec#011accuracy=0.839286
[02/04/2023 17:06:27 INFO 140161468585792] Epoch[9] Train-accuracy=0.836694
[02/04/2023 17:06:27 INFO 140161468585792] Epoch[9] Time cost=4.975
[02/04/2023 17:06:28 INFO 140161468585792] Epoch[9] Validation-accuracy=0.843750
[02/04/2023 17:06:28 INFO 140161468585792] Storing the best model with validation
accuracy: 0.843750
[02/04/2023 17:06:28 INFO 140161468585792] Saved checkpoint to "/opt/ml/model/imag
e-classification-0010.params"
[02/04/2023 17:06:32 INFO 140161468585792] Epoch[10] Batch [20]#011Speed: 190.409
samples/sec#011accuracy=0.849702
[02/04/2023 17:06:33 INFO 140161468585792] Epoch[10] Train-accuracy=0.852823
[02/04/2023 17:06:33 INFO 140161468585792] Epoch[10] Time cost=4.994
[02/04/2023 17:06:34 INFO 140161468585792] Epoch[10] Validation-accuracy=0.802083
[02/04/2023 17:06:38 INFO 140161468585792] Epoch[11] Batch [20]#011Speed: 193.506
samples/sec#011accuracv=0.854167
[02/04/2023 17:06:39 INFO 140161468585792] Epoch[11] Train-accuracy=0.862903
[02/04/2023 17:06:39 INFO 140161468585792] Epoch[11] Time cost=4.943
[02/04/2023 17:06:40 INFO 140161468585792] Epoch[11] Validation-accuracy=0.834821
[02/04/2023 17:06:44 INFO 140161468585792] Epoch[12] Batch [20]#011Speed: 189.836
samples/sec#011accuracy=0.886905
[02/04/2023 17:06:45 INFO 140161468585792] Epoch[12] Train-accuracy=0.880040
[02/04/2023 17:06:45 INFO 140161468585792] Epoch[12] Time cost=5.001
[02/04/2023 17:06:46 INFO 140161468585792] Epoch[12] Validation-accuracy=0.802083
[02/04/2023 17:06:50 INFO 140161468585792] Epoch[13] Batch [20]#011Speed: 193.098
samples/sec#011accuracy=0.849702
[02/04/2023 17:06:51 INFO 140161468585792] Epoch[13] Train-accuracy=0.864919
[02/04/2023 17:06:51 INFO 140161468585792] Epoch[13] Time cost=4.948
[02/04/2023 17:06:52 INFO 140161468585792] Epoch[13] Validation-accuracy=0.843750
[02/04/2023 17:06:55 INFO 140161468585792] Epoch[14] Batch [20]#011Speed: 190.852
samples/sec#011accuracy=0.921131
[02/04/2023 17:06:57 INFO 140161468585792] Epoch[14] Train-accuracy=0.903226
[02/04/2023 17:06:57 INFO 140161468585792] Epoch[14] Time cost=4.989
[02/04/2023 17:06:58 INFO 140161468585792] Epoch[14] Validation-accuracy=0.843750
[02/04/2023 17:07:01 INFO 140161468585792] Epoch[15] Batch [20]#011Speed: 190.043
samples/sec#011accuracy=0.900298
[02/04/2023 17:07:03 INFO 140161468585792] Epoch[15] Train-accuracy=0.902218
[02/04/2023 17:07:03 INFO 140161468585792] Epoch[15] Time cost=5.070
[02/04/2023 17:07:04 INFO 140161468585792] Epoch[15] Validation-accuracy=0.861607
[02/04/2023 17:07:04 INFO 140161468585792] Storing the best model with validation
accuracy: 0.861607
[02/04/2023 17:07:04 INFO 140161468585792] Saved checkpoint to "/opt/ml/model/imag
e-classification-0016.params"
[02/04/2023 17:07:08 INFO 140161468585792] Epoch[16] Batch [20]#011Speed: 192.666
samples/sec#011accuracy=0.921131
[02/04/2023 17:07:09 INFO 140161468585792] Epoch[16] Train-accuracy=0.904234
[02/04/2023 17:07:09 INFO 140161468585792] Epoch[16] Time cost=4.950
[02/04/2023 17:07:10 INFO 140161468585792] Epoch[16] Validation-accuracy=0.843750
```

```
[02/04/2023 17:07:14 INFO 140161468585792] Epoch[17] Batch [20]#011Speed: 192.050
samples/sec#011accuracy=0.924107
[02/04/2023 17:07:15 INFO 140161468585792] Epoch[17] Train-accuracy=0.933468
[02/04/2023 17:07:15 INFO 140161468585792] Epoch[17] Time cost=4.972
[02/04/2023 17:07:16 INFO 140161468585792] Epoch[17] Validation-accuracy=0.854167
[02/04/2023 17:07:20 INFO 140161468585792] Epoch[18] Batch [20]#011Speed: 191.641
samples/sec#011accuracy=0.921131
[02/04/2023 17:07:21 INFO 140161468585792] Epoch[18] Train-accuracy=0.921371
[02/04/2023 17:07:21 INFO 140161468585792] Epoch[18] Time cost=4.992
[02/04/2023 17:07:22 INFO 140161468585792] Epoch[18] Validation-accuracy=0.848958
[02/04/2023 17:07:26 INFO 140161468585792] Epoch[19] Batch [20]#011Speed: 191.061
samples/sec#011accuracy=0.928571
[02/04/2023 17:07:27 INFO 140161468585792] Epoch[19] Train-accuracy=0.933468
[02/04/2023 17:07:27 INFO 140161468585792] Epoch[19] Time cost=4.986
[02/04/2023 17:07:28 INFO 140161468585792] Epoch[19] Validation-accuracy=0.852679
[02/04/2023 17:07:32 INFO 140161468585792] Epoch[20] Batch [20]#011Speed: 187.348
samples/sec#011accuracy=0.934524
[02/04/2023 17:07:33 INFO 140161468585792] Epoch[20] Train-accuracy=0.934476
[02/04/2023 17:07:33 INFO 140161468585792] Epoch[20] Time cost=5.066
[02/04/2023 17:07:34 INFO 140161468585792] Epoch[20] Validation-accuracy=0.859375
[02/04/2023 17:07:38 INFO 140161468585792] Epoch[21] Batch [20]#011Speed: 190.505
samples/sec#011accuracy=0.953869
[02/04/2023 17:07:39 INFO 140161468585792] Epoch[21] Train-accuracy=0.947581
[02/04/2023 17:07:39 INFO 140161468585792] Epoch[21] Time cost=5.026
[02/04/2023 17:07:40 INFO 140161468585792] Epoch[21] Validation-accuracy=0.854167
[02/04/2023 17:07:44 INFO 140161468585792] Epoch[22] Batch [20]#011Speed: 191.100
samples/sec#011accuracy=0.965774
[02/04/2023 17:07:45 INFO 140161468585792] Epoch[22] Train-accuracy=0.961694
[02/04/2023 17:07:45 INFO 140161468585792] Epoch[22] Time cost=4.994
[02/04/2023 17:07:46 INFO 140161468585792] Epoch[22] Validation-accuracy=0.843750
[02/04/2023 17:07:50 INFO 140161468585792] Epoch[23] Batch [20]#011Speed: 191.878
samples/sec#011accuracv=0.968750
[02/04/2023 17:07:51 INFO 140161468585792] Epoch[23] Train-accuracy=0.965726
[02/04/2023 17:07:51 INFO 140161468585792] Epoch[23] Time cost=4.974
[02/04/2023 17:07:52 INFO 140161468585792] Epoch[23] Validation-accuracy=0.861607
[02/04/2023 17:07:56 INFO 140161468585792] Epoch[24] Batch [20]#011Speed: 189.272
samples/sec#011accuracy=0.982143
[02/04/2023 17:07:57 INFO 140161468585792] Epoch[24] Train-accuracy=0.977823
[02/04/2023 17:07:57 INFO 140161468585792] Epoch[24] Time cost=5.015
[02/04/2023 17:07:58 INFO 140161468585792] Epoch[24] Validation-accuracy=0.869792
[02/04/2023 17:07:58 INFO 140161468585792] Storing the best model with validation
accuracy: 0.869792
[02/04/2023 17:07:58 INFO 140161468585792] Saved checkpoint to "/opt/ml/model/imag
e-classification-0025.params"
[02/04/2023 17:08:02 INFO 140161468585792] Epoch[25] Batch [20]#011Speed: 189.255
samples/sec#011accuracy=0.961310
[02/04/2023 17:08:03 INFO 140161468585792] Epoch[25] Train-accuracy=0.963710
[02/04/2023 17:08:03 INFO 140161468585792] Epoch[25] Time cost=5.087
[02/04/2023 17:08:04 INFO 140161468585792] Epoch[25] Validation-accuracy=0.833333
[02/04/2023 17:08:08 INFO 140161468585792] Epoch[26] Batch [20]#011Speed: 191.597
samples/sec#011accuracy=0.964286
[02/04/2023 17:08:09 INFO 140161468585792] Epoch[26] Train-accuracy=0.967742
[02/04/2023 17:08:09 INFO 140161468585792] Epoch[26] Time cost=4.996
[02/04/2023 17:08:10 INFO 140161468585792] Epoch[26] Validation-accuracy=0.833333
[02/04/2023 17:08:14 INFO 140161468585792] Epoch[27] Batch [20]#011Speed: 191.099
samples/sec#011accuracy=0.967262
[02/04/2023 17:08:15 INFO 140161468585792] Epoch[27] Train-accuracy=0.963710
[02/04/2023 17:08:15 INFO 140161468585792] Epoch[27] Time cost=4.990
[02/04/2023 17:08:16 INFO 140161468585792] Epoch[27] Validation-accuracy=0.790179
[02/04/2023 17:08:20 INFO 140161468585792] Epoch[28] Batch [20]#011Speed: 190.290
samples/sec#011accuracy=0.967262
[02/04/2023 17:08:21 INFO 140161468585792] Epoch[28] Train-accuracy=0.965726
[02/04/2023 17:08:21 INFO 140161468585792] Epoch[28] Time cost=5.026
[02/04/2023 17:08:22 INFO 140161468585792] Epoch[28] Validation-accuracy=0.859375
```

```
[02/04/2023 17:08:26 INFO 140161468585792] Epoch[29] Batch [20]#011Speed: 191.286 samples/sec#011accuracy=0.974702 [02/04/2023 17:08:27 INFO 140161468585792] Epoch[29] Train-accuracy=0.974798 [02/04/2023 17:08:27 INFO 140161468585792] Epoch[29] Time cost=4.984 [02/04/2023 17:08:28 INFO 140161468585792] Epoch[29] Validation-accuracy=0.791667 2023-02-04 17:08:44 Uploading - Uploading generated training model 2023-02-04 17:09:25 Completed - Training job completed ProfilerReport-1675530012: NoIssuesFound Training seconds: 434 Billable seconds: 434
```

If all goes well, you'll end up with a model topping out above .8 validation accuracy. With only 1000 training samples in the CIFAR dataset, that's pretty good. We could definitely pursue data augmentation & gathering more samples to help us improve further, but for now let's proceed to deploy our model.

Getting ready to deploy

To begin with, let's configure Model Monitor to track our deployment. We'll define a DataCaptureConfig below:

Note the destination_s3_uri parameter: At the end of the project, we can explore the data_capture directory in S3 to find crucial data about the inputs and outputs Model Monitor has observed on our model endpoint over time.

With that done, deploy your model on a single ml.m5.xlarge instance with the data capture config attached:

-----!image-classification-2023-02-04-17-09-54-144

Note the endpoint name for later as well.

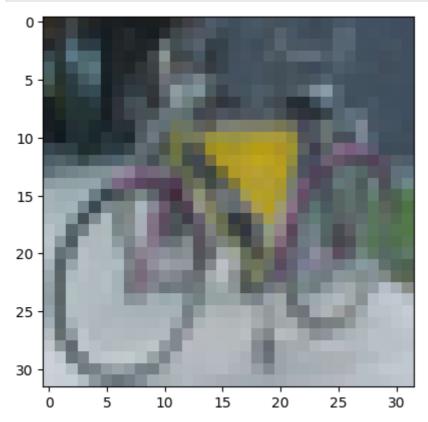
Next, instantiate a Predictor:

```
In [37]: predictor = deployment
```

In the code snippet below we are going to prepare one of your saved images for prediction. Use the predictor to process the payload.

```
from sagemaker.serializers import IdentitySerializer
In [39]:
          import base64
          predictor.serializer = IdentitySerializer("image/png")
          with open("./test/bicycle_s_001789.png", "rb") as f:
              payload = f.read()
          inference = predictor.predict(payload, initial_args={'ContentType': 'application/x
          Your inference object is an array of two values, the predicted probability value for each
          of your classes (bicycle and motorcycle respectively.) So, for example, a value of b'[0.91,
          0.09]' indicates the probability of being a bike is 91% and being a motorcycle is 9%.
In [40]:
          print(inference)
          # probability of being a bike is 99.3%
          b'[0.999622106552124, 0.000377906602807343]'
In [41]:
          # creating a pandas dataframe to test the inference in below steps
          import pandas as pd
          abc = dataset_test[b'filenames']
          a= pd.DataFrame(abc, columns= ['name'])
          a.head()
Out[41]:
                              name
          0
                b'volcano_s_000012.png'
                b'woods_s_000412.png'
          2
                   b'seal_s_001803.png'
          3 b'mushroom_s_001755.png'
          4 b'adriatic_sea_s_000653.png'
In [42]:
          a[a.name == b'bicycle s 001789.png']
          # 6848
Out[42]:
                              name
          6848 b'bicycle_s_001789.png'
          # Testing if the bicycle_s_001789.png is actual bicyle or not to test the
In [43]:
          # accuracy of endpoint inference
In [44]:
          import numpy as np
          row = dataset_test[b'data'][6848]
           # All in one:
          test image 3 = np.dstack((
              row[0:1024].reshape(32,32),
              row[1024:2048].reshape(32,32),
              row[2048:].reshape(32,32)
          ))
```

```
import matplotlib.pyplot as plt
plt.imshow(test_image_3);
plt.show()
```



```
In [107... #monitors = predictor.list_monitors()
    #for monitor in monitors:
    # monitor.delete_monitoring_schedule()

#predictor.delete_endpoint()
```

No monitors found for endpoint. endpoint: image-classification-2023-01-18-18-00-38-248

Draft Lambdas and Step Function Workflow

Your operations team uses Step Functions to orchestrate serverless workflows. One of the nice things about Step Functions is that workflows can call other workflows, so the team can easily plug your workflow into the broader production architecture for Scones Unlimited.

In this next stage you're going to write and deploy three Lambda functions, and then use the Step Functions visual editor to chain them together! Our functions are going to work with a simple data object:

```
{
    "inferences": [], # Output of predictor.predict
    "s3_key": "", # Source data S3 key
    "s3_bucket": "", # Source data S3 bucket
    "image_data": "" # base64 encoded string containing the image data
}
```

A good test object that you can use for Lambda tests and Step Function executions, throughout the next section, might look like this:

```
{
   "image_data": "",
   "s3_bucket": MY_BUCKET_NAME, # Fill in with your bucket
   "s3_key": "test/bicycle_s_000513.png"
}
```

Using these fields, your functions can read and write the necessary data to execute your workflow. Let's start with the first function. Your first Lambda function will copy an object from S3, base64 encode it, and then return it to the step function as image_data in an event.

Go to the Lambda dashboard and create a new Lambda function with a descriptive name like "serializelmageData" and select thr 'Python 3.8' runtime. Add the same permissions as the SageMaker role you created earlier. (Reminder: you do this in the Configuration tab under "Permissions"). Once you're ready, use the starter code below to craft your Lambda handler:

```
import json
import boto3
import base64
s3 = boto3.client('s3')
def lambda_handler(event, context):
    """A function to serialize target data from S3"""
    # Get the s3 address from the Step Function event input
    key = ## TODO: fill in
    bucket = ## TODO: fill in
    # Download the data from s3 to /tmp/image.png
    ## TODO: fill in
    # We read the data from a file
    with open("/tmp/image.png", "rb") as f:
        image_data = base64.b64encode(f.read())
    # Pass the data back to the Step Function
    print("Event:", event.keys())
    return {
        'statusCode': 200,
        'body': {
            "image_data": image_data,
            "s3_bucket": bucket,
            "s3_key": key,
            "inferences": []
        }
    }
```

The next function is responsible for the classification part - we're going to take the image output from the previous function, decode it, and then pass inferences back to the the Step Function.

Because this Lambda will have runtime dependencies (i.e. the SageMaker SDK) you'll need to package them in your function. *Key reading*:

https://docs.aws.amazon.com/lambda/latest/dg/python-package-create.html#python-package-create-with-dependency

Create a new Lambda function with the same rights and a descriptive name, then fill in the starter code below for your classifier Lambda.

```
import json
import sagemaker
import base64
from sagemaker.serializers import IdentitySerializer
# Fill this in with the name of your deployed model
ENDPOINT = ## TODO: fill in
def lambda_handler(event, context):
    # Decode the image data
    image = base64.b64decode(## TODO: fill in)
    # Instantiate a Predictor
    predictor = ## TODO: fill in
    # For this model the IdentitySerializer needs to be "image/png"
    predictor.serializer = IdentitySerializer("image/png")
    # Make a prediction:
    inferences = ## TODO: fill in
    # We return the data back to the Step Function
    event["inferences"] = inferences.decode('utf-8')
    return {
        'statusCode': 200,
        'body': json.dumps(event)
    }
```

Finally, we need to filter low-confidence inferences. Define a threshold between 1.00 and 0.000 for your model: what is reasonble for you? If the model predicts at .70 for it's highest confidence label, do we want to pass that inference along to downstream systems? Make one last Lambda function and tee up the same permissions:

```
import json

THRESHOLD = .93

def lambda_handler(event, context):
    # Grab the inferences from the event
    inferences = ## TODO: fill in

# Check if any values in our inferences are above THRESHOLD
    meets_threshold = ## TODO: fill in

# If our threshold is met, pass our data back out of the
    # Step Function, else, end the Step Function with an error
```

```
if meets_threshold:
    pass
else:
    raise("THRESHOLD_CONFIDENCE_NOT_MET")

return {
    'statusCode': 200,
    'body': json.dumps(event)
}
```

Once you have tested the lambda functions, save the code for each lambda function in a python script called 'lambda.py'.

With your lambdas in place, you can use the Step Functions visual editor to construct a workflow that chains them together. In the Step Functions console you'll have the option to author a Standard step function *Visually*.

When the visual editor opens, you'll have many options to add transitions in your workflow. We're going to keep it simple and have just one: to invoke Lambda functions. Add three of them chained together. For each one, you'll be able to select the Lambda functions you just created in the proper order, filter inputs and outputs, and give them descriptive names.

Make sure that you:

- 1. Are properly filtering the inputs and outputs of your invokations (e.g. \$.body)
- 2. Take care to remove the error handling from the last function it's supposed to "fail loudly" for your operations colleagues!

Take a screenshot of your working step function in action and export the step function as JSON for your submission package.

Great! Now you can use the files in ./test as test files for our workflow. Depending on our threshold, our workflow should reliably pass predictions about images from ./test on to downstream systems, while erroring out for inferences below our confidence threshold!

Testing and Evaluation

Do several step function invokations using data from the ./test folder. This process should give you confidence that the workflow both *succeeds* AND *fails* as expected. In addition, SageMaker Model Monitor will generate recordings of your data and inferences which we can visualize.

Here's a function that can help you generate test inputs for your invokations:

```
import random
import boto3
import json

def generate_test_case():
    # Setup s3 in boto3
    s3 = boto3.resource('s3')
```

```
# Randomly pick from sfn or test folders in our bucket
objects = s3.Bucket(bucket).objects.filter(Prefix='test')

# Grab any random object key from that folder!
obj = random.choice([x.key for x in objects])

return json.dumps({
    "image_data": "",
    "s3_bucket": bucket,
    "s3_key": obj
})
generate_test_case()
```

Out[94]: '{"image_data": "", "s3_bucket": "sagemaker-us-east-1-935549625822", "s3_key": "te st/motorcycle_s_001892.png"}'

In the Step Function dashboard for your new function, you can create new executions and copy in the generated test cases. Do several executions so that you can generate data you can evaluate and visualize.

Once you've done several executions, let's visualize the record of our inferences. Pull in the JSONLines data from your inferences like so:

```
In [95]: from sagemaker.s3 import S3Downloader

# In S3 your data will be saved to a datetime-aware path
# Find a path related to a datetime you're interested in
data_path = 's3://sagemaker-us-east-1-935549625822/data_capture/image-classification
S3Downloader.download(data_path, "captured_data")

# Feel free to repeat this multiple times and pull in more data
```

In [96]: data_path = 's3://sagemaker-us-east-1-935549625822/data_capture/image-classification
S3Downloader.download(data_path, "captured_data")

The data are in JSONLines format, where multiple valid JSON objects are stacked on top of eachother in a single <code>jsonl</code> file. We'll import an open-source library, <code>jsonlines</code> that was purpose built for parsing this format.

```
In [97]: !pip install jsonlines
  import jsonlines
```

Keyring is skipped due to an exception: 'keyring.backends'
Requirement already satisfied: jsonlines in /opt/conda/lib/python3.7/site-packages
(3.1.0)

Requirement already satisfied: typing-extensions in /opt/conda/lib/python3.7/site-packages (from jsonlines) (4.4.0)

Requirement already satisfied: attrs>=19.2.0 in /opt/conda/lib/python3.7/site-pack ages (from jsonlines) (22.1.0)

WARNING: Running pip as the 'root' user can result in broken permissions and conflicting behaviour with the system package manager. It is recommended to use a virtual environment instead: https://pip.pypa.io/warnings/venv

```
[notice] A new release of pip available: 22.3.1 -> 23.0
[notice] To update, run: pip install --upgrade pip
```

Now we can extract the data from each of the source files:

```
In [98]: import os
```

```
# List the file names we downloaded
file_handles = os.listdir("./captured_data")

# Dump all the data into an array
json_data = []
for jsonl in file_handles:
    with jsonlines.open(f"./captured_data/{jsonl}") as f:
        json_data.append(f.read())
```

The data should now be a list of dictionaries, with significant nesting. We'll give you an example of some code that grabs data out of the objects and visualizes it:

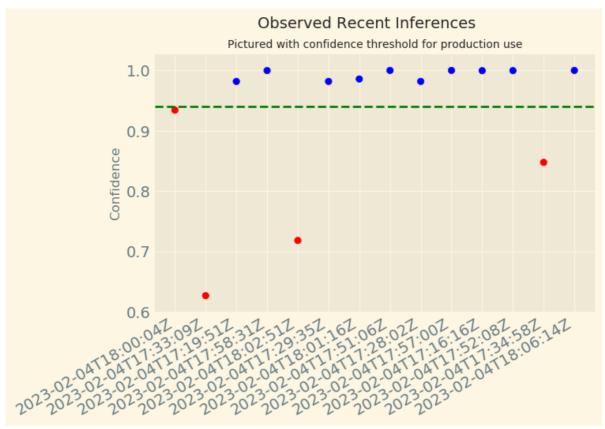
```
In [99]: # Define how we'll get our data
def simple_getter(obj):
    inferences = obj["captureData"]["endpointOutput"]["data"]
    timestamp = obj["eventMetadata"]["inferenceTime"]
    return json.loads(inferences), timestamp

simple_getter(json_data[0])

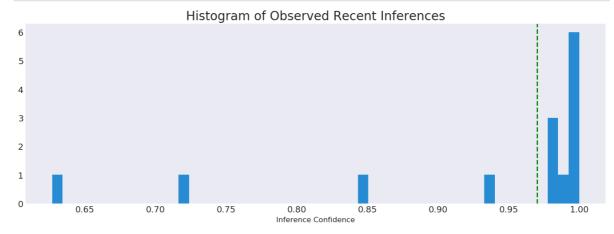
Out[99]: ([0.06582030653953552, 0.9341797232627869], '2023-02-04T18:00:04Z')
```

Finally, here's an example of a visualization you can build with this data. In this last part, you will take some time and build your own - the captured data has the input images, the resulting inferences, and the timestamps.

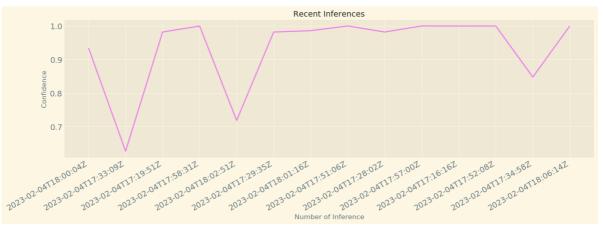
```
# Populate the data for the x and y axis
In [100...
          import matplotlib.pyplot as plt
          x = []
          y = []
          for obj in json_data:
              inference, timestamp = simple_getter(obj)
              y.append(max(inference))
              x.append(timestamp)
          # Todo: here is an visualization example, take some time to build another visual the
          # Plot the data
          plt.scatter(x, y, c=['r' if k <.97 else 'b' for k in y ])</pre>
          plt.axhline(y=0.94, color='g', linestyle='--')
          plt.ylim(bottom=.60)
          # Add Labels
          plt.ylabel("Confidence")
          plt.suptitle("Observed Recent Inferences", size=14)
          plt.title("Pictured with confidence threshold for production use", size=10)
          # Give it some pizzaz!
          plt.style.use("Solarize_Light2")
          plt.gcf().autofmt_xdate()
          plt.show()
```



```
In [101... fig, ax = plt.subplots(figsize=(15,5))
    ax.hist(y, bins=50)
    ax.axvline(x=0.97, color='green', linestyle='--')
    ax.set_xlabel("Inference Confidence")
    ax.set_title("Histogram of Observed Recent Inferences", size=20)
    #plt.style.use("fivethirtyeight")
    plt.show()
```



```
fig, ax = plt.subplots(figsize=(15,5))
ax.plot(x, y, linewidth = 2, color = 'violet', alpha = 1)
ax.set_title("Recent Inferences", fontsize=14)
ax.set_xlabel("Number of Inference")
ax.set_ylabel("Confidence")
plt.style.use( 'seaborn-dark')
fig.autofmt_xdate()
plt.show()
```



Todo: build your own visualization

Congratulations!

You've reached the end of the project. In this project you created an event-drivent ML workflow that can be incorporated into the Scones Unlimited production architecture. You used the SageMaker Estimator API to deploy your SageMaker Model and Endpoint, and you used AWS Lambda and Step Functions to orchestrate your ML workflow. Using SageMaker Model Monitor, you instrumented and observed your Endpoint, and at the end of the project you built a visualization to help stakeholders understand the performance of the Endpoint over time. If you're up for it, you can even go further with these stretch goals:

- Extend your workflow to incorporate more classes: the CIFAR dataset includes other vehicles that Scones Unlimited can identify with this model.
- Modify your event driven workflow: can you rewrite your Lambda functions so that the
 workflow can process multiple image inputs in parallel? Can the Step Function "fan out"
 to accommodate this new workflow?
- Consider the test data generator we provided for you. Can we use it to create a "dummy data" generator, to simulate a continuous stream of input data? Or a big paralell load of data?
- What if we want to get notified every time our step function errors out? Can we use the Step Functions visual editor in conjunction with a service like SNS to accomplish this?
 Try it out!