assignment06-2a_MeyerJake

April 23, 2023

0.1 Assignment 6-2a

0.1.1 DSC 650

0.1.2 Jake Meyer

0.1.3 04/22/2023

Using section 5.2 in Deep Learning with Python as a guide, create a ConvNet model that classifies images CIFAR10 small images classification dataset. Do not use dropout or data-augmentation in this part. Save the model, predictions, metrics, and validation plots in the dsc650/assignments/assignment06/results directory. If you are using JupyterHub, you can include those plots in your Jupyter notebook.

Using code from deep-learning-with-python-notebooks Using code from CIFAR-10 Photo Classification Dataset

[3]:

```
## Import the necessary modules for the assignment above.
import csv
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
import tensorflow as tf
import keras
import sklearn
from sklearn.model_selection import train_test_split
import itertools
from pathlib import Path
import time
import os, shutil

## Import the necessary keras components for the data and CNN
from keras import layers, models
from keras.datasets import cifar10
from keras.utils import to_categorical, np_utils
from keras.models import Sequential, load_model
from keras.layers.core import Dense, Dropout, Activation
from keras.layers import Conv2D, MaxPooling2D, Dense, Flatten
from keras.optimizers import SGD
import tensorflow.compat.v1 as tf
```

```
tf.disable_v2_behavior()
```

```
WARNING:tensorflow:From C:\Users\jkmey\anaconda3\envs\dsc650\lib\site-
packages\tensorflow\python\compat\v2_compat.py:107: disable_resource_variables
(from tensorflow.python.ops.variable_scope) is deprecated and will be removed in
a future version.
Instructions for updating:
non-resource variables are not supported in the long term
```

[4]:

```
## Print versions of essential packages
print("keras version: {}".format(keras.__version__))
print("tensorflow version: {}".format(tf.__version__))
print("pandas version: {}".format(pd.__version__))
print("numpy version: {}".format(np.__version__))
```

```
keras version: 2.11.0
tensorflow version: 2.11.0
pandas version: 1.5.3
numpy version: 1.24.2
```

[5]:

```
## Setup the directories for the assignment
current_dir = Path('C:/Users/jkmey/Documents/Github/DSC650_Course_Assignments/
  ↪dsc650/dsc650/assignments/assignment06')
results_dir = Path('C:/Users/jkmey/Documents/Github/DSC650_Course_Assignments/
  ↪dsc650/dsc650/assignments/assignment06/').joinpath('results')
results_dir.mkdir(parents = True, exist_ok = True)
```

0.1.4 Import the CIFAR10 Dataset

[6]:

```
## Load the dataset
(trainX, trainy), (testX, testy) = cifar10.load_data()
```

[7]:

```
## Understand the shape of the train and test datasets.
print('trainX: {}'.format(trainX.shape))
print('testX: {}'.format(testX.shape))
print('trainy: {}'.format(trainy.shape))
print('testy: {}'.format(testy.shape))
```

```
trainX: (50000, 32, 32, 3)
testX: (10000, 32, 32, 3)
trainy: (50000, 1)
testy: (10000, 1)
```

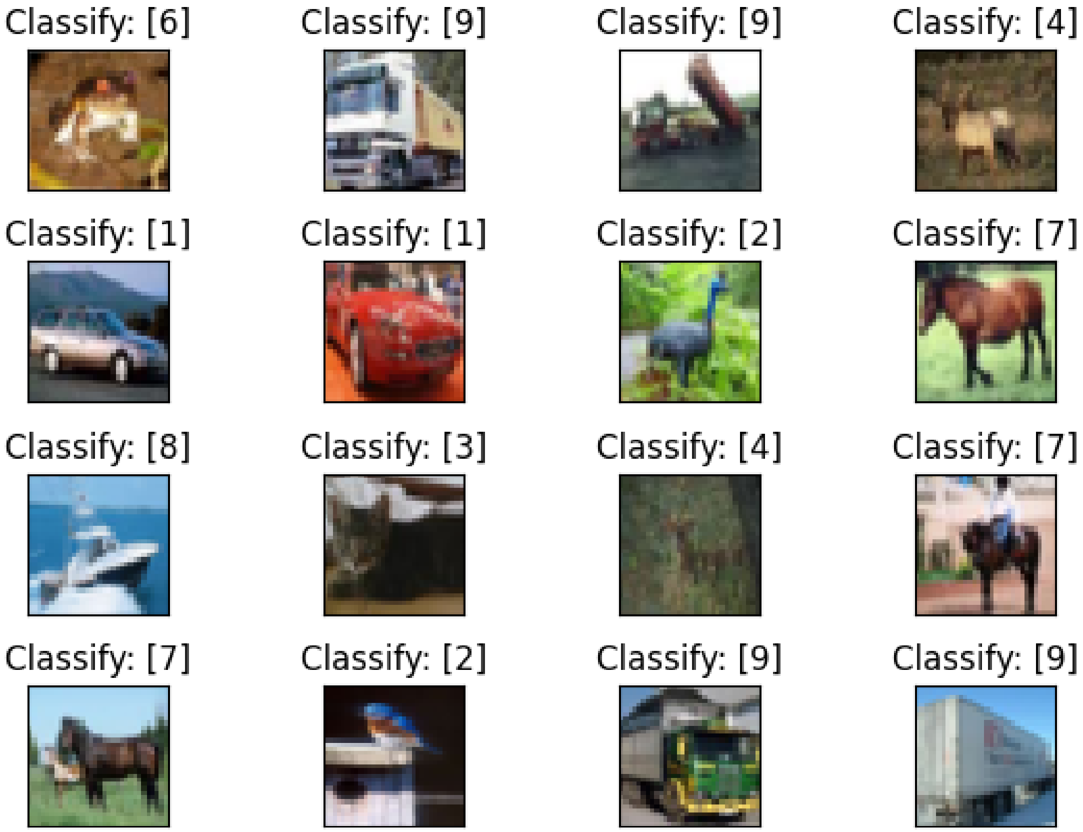
0.1.5 Show Training Images and Labels

[8]:

```
## Show the first 16 training images and labels for better understanding of the␣
  ↪data.
fig = plt.figure()
```

```
for i in range(16):
    plt.subplot(4,4,i+1)
    plt.tight_layout()
    plt.imshow(trainX[i], cmap = 'gray', interpolation='none')
    plt.title("Classify: {}".format(trainy[i]))
    plt.xticks([])
    plt.yticks([])
img_file = results_dir.joinpath('assignment06-2a_Sample_Images_QTY_16.png')
plt.savefig(img_file)
print("First 16 Training Images and Labels")
plt.show()
```

```
First 16 Training Images and Labels
```

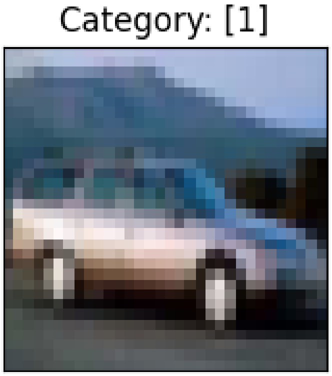


Referenced CIFAR10 for available classes.

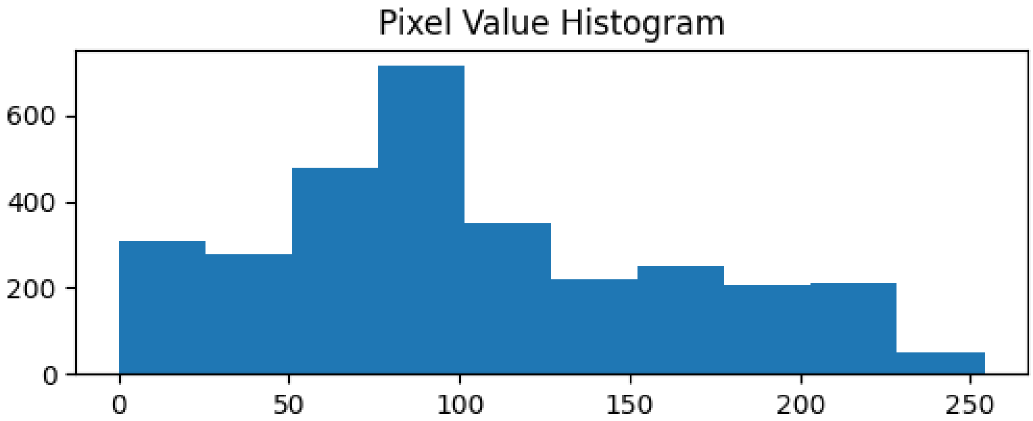
```
[9]: ## Define the classes for images within a list for the image dataset.
image_classes = ['airplane', 'automobile', 'bird', 'cat', 'cat', 'deer', 'dog',␣
 ↪'frog', 'horse', 'ship', 'truck']
```

0.1.6 Pixel Value Histogram

[10]:
```
## Code to check the digit in the train image with the label shown from 0-9.
fig = plt.figure()
plt.subplot(2,1,1)
plt.imshow(trainX[4], cmap = 'gray', interpolation = 'none')
plt.title('Category: {}'.format(trainy[4]))
plt.xticks([])
plt.yticks([])
img_file = results_dir.joinpath('assignment06-2a_Digit_Overview.png')
plt.savefig(img_file)
plt.show()
```



[11]:
```
## Pixel distribution shown in the plot below for the image chosen in the␣
 ↪previous cell.
plt.subplot(2,1,2)
plt.hist(trainX[4].reshape(3072)) # Value needs to be 3072 for reshape,␣
 ↪otherwise error
plt.title("Pixel Value Histogram")
img_file = results_dir.joinpath('assignment06-2a_Pixel_Value_Histogram.png')
plt.savefig(img_file)
plt.show()
```



0.1.7 Prepare the Data

[12]:
```
## Normalize the training and test images.
train_images = trainX.astype('float32') / 255
test_images = testX.astype('float32') / 255

## Convert the training and test labels to numbers.
train_labels = to_categorical(trainy)
test_labels = to_categorical(testy)
```

[13]:
```
## Split train_images and train_labels into train and validation subsets.
train_images_val = train_images[:10000]
train_images = train_images[10000:]
train_labels_val = train_labels[:10000]
train_labels = train_labels[10000:]
```

0.1.8 Create the ConvNet Model

[14]:
```
## Use the code from the textbook Github repository for section 5.2. Also,␣
 ↪remember the shape input shape (32,32,3)
model = Sequential()
model.add(Conv2D(32, (3, 3), activation='relu',␣
 ↪kernel_initializer='he_uniform', padding='same', input_shape=(32, 32, 3)))
model.add(Conv2D(32, (3, 3), activation='relu',␣
 ↪kernel_initializer='he_uniform', padding='same'))
model.add(MaxPooling2D((2, 2)))
model.add(Conv2D(64, (3, 3), activation='relu',␣
 ↪kernel_initializer='he_uniform', padding='same'))
model.add(Conv2D(64, (3, 3), activation='relu',␣
 ↪kernel_initializer='he_uniform', padding='same'))
model.add(MaxPooling2D((2, 2)))
model.add(Conv2D(128, (3, 3), activation='relu',␣
 ↪kernel_initializer='he_uniform', padding='same'))
model.add(Conv2D(128, (3, 3), activation='relu',␣
 ↪kernel_initializer='he_uniform', padding='same'))
model.add(MaxPooling2D((2, 2)))
model.add(Flatten())
model.add(Dense(128, activation='relu', kernel_initializer='he_uniform'))
model.add(Dense(10, activation='softmax'))

## Compile the Model. Choosing categorical crossentropy as loss and accuracy as␣
 ↪metric.
## Also, define an optimizer with a learning rate of 0.001 and momentum of 0.9.
opt = SGD(learning_rate=0.001, momentum=0.9)
model.compile(optimizer=opt, loss='categorical_crossentropy',␣
 ↪metrics=['accuracy'])
```

[15]:

```
## Show a summary of the model.
model.summary()
```

```
Model: "sequential"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 conv2d (Conv2D)             (None, 32, 32, 32)        896

 conv2d_1 (Conv2D)           (None, 32, 32, 32)        9248

 max_pooling2d (MaxPooling2D  (None, 16, 16, 32)       0
 )

 conv2d_2 (Conv2D)           (None, 16, 16, 64)        18496

 conv2d_3 (Conv2D)           (None, 16, 16, 64)        36928

 max_pooling2d_1 (MaxPooling  (None, 8, 8, 64)         0
 2D)

 conv2d_4 (Conv2D)           (None, 8, 8, 128)         73856

 conv2d_5 (Conv2D)           (None, 8, 8, 128)         147584

 max_pooling2d_2 (MaxPooling  (None, 4, 4, 128)        0
 2D)

 flatten (Flatten)           (None, 2048)              0

 dense (Dense)               (None, 128)               262272
 dense_1 (Dense)             (None, 10)                1290

=================================================================
Total params: 550,570
Trainable params: 550,570
Non-trainable params: 0
-----------------------------------------------------------------
```

0.1.9 Train the Model

[16]:
```
## Train the model and store the results in the variable history.
history = model.fit(train_images, train_labels, epochs=20, batch_size=32,␣
  ↪verbose = 1,
                         validation_data = (train_images_val, train_labels_val))
```

```
Train on 40000 samples, validate on 10000 samples
WARNING:tensorflow:OMP_NUM_THREADS is no longer used by the default Keras
config. To configure the number of threads, use tf.config.threading APIs.
Epoch 1/20
40000/40000 [==============================] - ETA: 0s - loss: 1.6764 - acc:
0.3981
```

```
C:\Users\jkmey\anaconda3\envs\dsc650\lib\site-
packages\keras\engine\training_v1.py:2333: UserWarning: `Model.state_updates`
will be removed in a future version. This property should not be used in
TensorFlow 2.0, as `updates` are applied automatically.
  updates = self.state_updates
```

```
40000/40000 [==============================] - 75s 2ms/sample - loss: 1.6764 -
acc: 0.3981 - val_loss: 1.4222 - val_acc: 0.4860
Epoch 2/20
40000/40000 [==============================] - 74s 2ms/sample - loss: 1.2945 -
acc: 0.5376 - val_loss: 1.1595 - val_acc: 0.5926
Epoch 3/20
40000/40000 [==============================] - 75s 2ms/sample - loss: 1.1051 -
acc: 0.6096 - val_loss: 1.0206 - val_acc: 0.6448
Epoch 4/20
40000/40000 [==============================] - 75s 2ms/sample - loss: 0.9723 -
acc: 0.6598 - val_loss: 0.9429 - val_acc: 0.6678
Epoch 5/20
40000/40000 [==============================] - 73s 2ms/sample - loss: 0.8608 -
acc: 0.6981 - val_loss: 0.9123 - val_acc: 0.6813
Epoch 6/20
40000/40000 [==============================] - 69s 2ms/sample - loss: 0.7757 -
acc: 0.7319 - val_loss: 0.8571 - val_acc: 0.6960
Epoch 7/20
40000/40000 [==============================] - 70s 2ms/sample - loss: 0.6954 -
acc: 0.7597 - val_loss: 0.8162 - val_acc: 0.7134
```

```
Epoch 8/20
40000/40000 [==============================] - 76s 2ms/sample - loss: 0.6233 -
acc: 0.7838 - val_loss: 0.8270 - val_acc: 0.7147
Epoch 9/20
40000/40000 [==============================] - 75s 2ms/sample - loss: 0.5516 -
acc: 0.8061 - val_loss: 0.8151 - val_acc: 0.7261
Epoch 10/20
40000/40000 [==============================] - 70s 2ms/sample - loss: 0.4909 -
acc: 0.8275 - val_loss: 0.8760 - val_acc: 0.7085
Epoch 11/20
40000/40000 [==============================] - 72s 2ms/sample - loss: 0.4224 -
acc: 0.8512 - val_loss: 0.8633 - val_acc: 0.7323
Epoch 12/20
40000/40000 [==============================] - 70s 2ms/sample - loss: 0.3670 -
acc: 0.8707 - val_loss: 0.8991 - val_acc: 0.7184
Epoch 13/20
40000/40000 [==============================] - 72s 2ms/sample - loss: 0.3093 -
acc: 0.8911 - val_loss: 1.0054 - val_acc: 0.7067
Epoch 14/20
40000/40000 [==============================] - 73s 2ms/sample - loss: 0.2593 -
acc: 0.9099 - val_loss: 0.9878 - val_acc: 0.7169
Epoch 15/20
40000/40000 [==============================] - 78s 2ms/sample - loss: 0.2159 -
acc: 0.9231 - val_loss: 1.1270 - val_acc: 0.7107
Epoch 16/20
40000/40000 [==============================] - 79s 2ms/sample - loss: 0.1790 -
acc: 0.9366 - val_loss: 1.1179 - val_acc: 0.7231
Epoch 17/20
40000/40000 [==============================] - 74s 2ms/sample - loss: 0.1497 -
acc: 0.9484 - val_loss: 1.2099 - val_acc: 0.7205
Epoch 18/20
40000/40000 [==============================] - 78s 2ms/sample - loss: 0.1279 -
acc: 0.9551 - val_loss: 1.3091 - val_acc: 0.7018
Epoch 19/20
40000/40000 [==============================] - 73s 2ms/sample - loss: 0.1105 -
acc: 0.9610 - val_loss: 1.2970 - val_acc: 0.7260
Epoch 20/20
40000/40000 [==============================] - 79s 2ms/sample - loss: 0.1050 -
acc: 0.9634 - val_loss: 1.4012 - val_acc: 0.7208
```

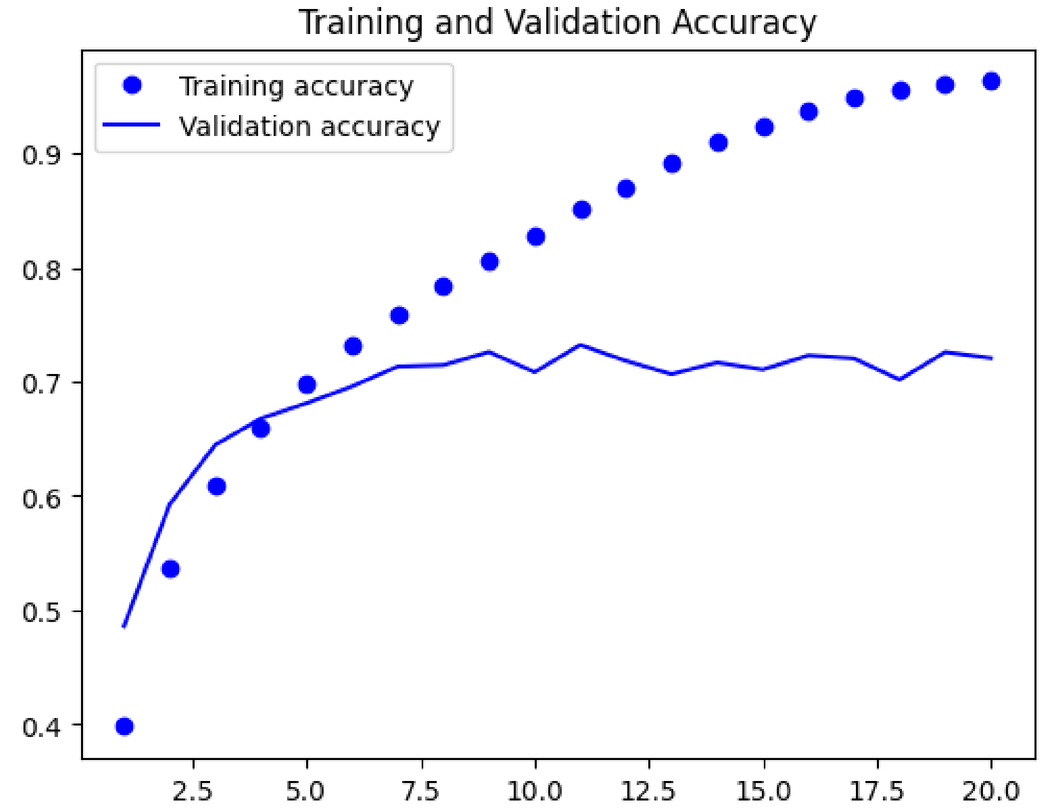
[17]:

```
## Save the result model file to the results directory.
result_model_file = results_dir.joinpath('assignment06-2a_Model.h5')
model.save(result_model_file)
print("Saved the Trained model at %s " % result_model_file)
```

```
Saved the Trained model at C:\Users\jkmey\Documents\Github\DSC650_Course_Assignm
ents\dsc650\dsc650\assignments\assignment06\results\assignment06-2a_Model.h5
```

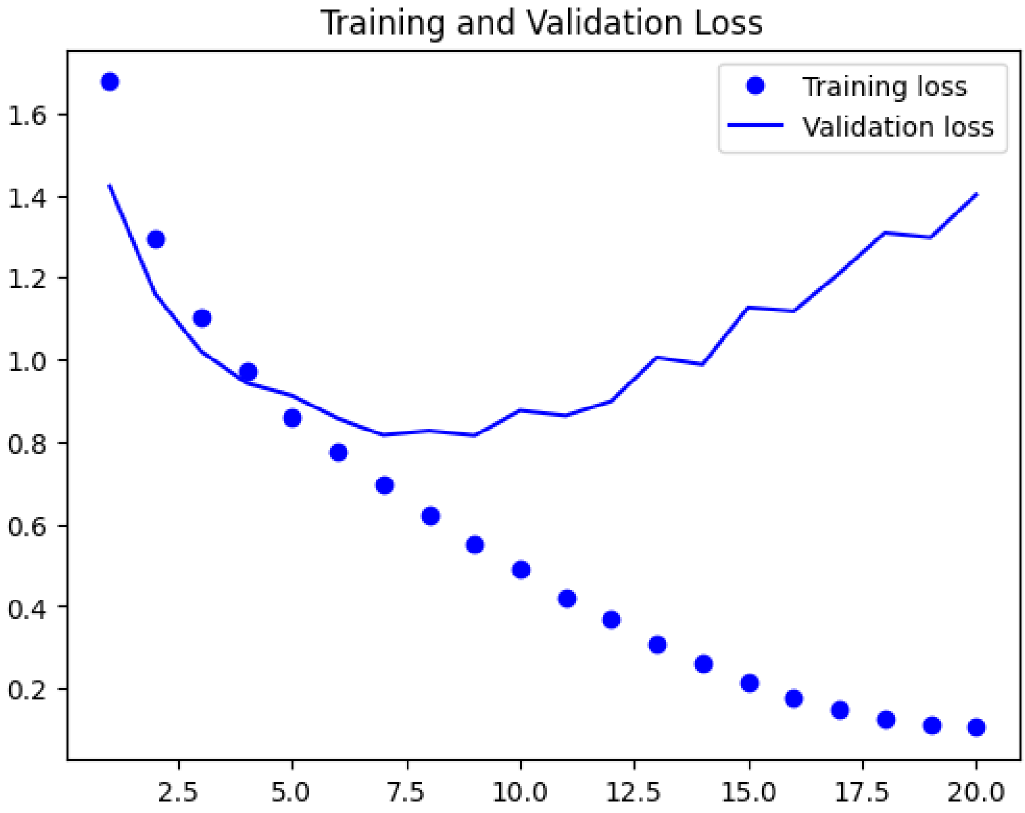
[18]:

```
## Generate and Save Plot of Training and Validation Accuracy from Model.
accuracy = history.history["acc"]
val_accuracy = history.history["val_acc"]
epochs = range(1, len(accuracy) + 1)
plt.plot(epochs, accuracy, "bo", label="Training accuracy")
plt.plot(epochs, val_accuracy, "b", label="Validation accuracy")
plt.title("Training and Validation Accuracy")
plt.legend()
img_file = results_dir.
 ↪joinpath('assignment06-2a_Training_and_Validation_Accuracy_Plot.png')
plt.savefig(img_file)
plt.show()
```



[19]:

```
## Generate and Save Plot of Training and Validation Loss from Model.
loss = history.history["loss"]
val_loss = history.history["val_loss"]
epochs = range(1, len(accuracy) + 1)
plt.plot(epochs, loss, "bo", label="Training loss")
plt.plot(epochs, val_loss, "b", label="Validation loss")
plt.title("Training and Validation Loss")
plt.legend()
img_file = results_dir.
  ↪joinpath('assignment06-2a_Training_and_Validation_Loss_Plot.png')
plt.savefig(img_file)
plt.show()
```



0.1.10 CNN Results on Test Data

[20]:
```
## Evaluate the model on the test subsets. Code from the textbook repository.
test_loss, test_acc = model.evaluate(test_images, test_labels)
```

[21]:
```
## Show the Test Accuracy and Loss from the cell above.
print("Test Accuracy: {}%".format((test_acc)*100))
print("Test Loss: {}".format(test_loss))
```

```
Test Accuracy: 71.10999822616577%
Test Loss: 1.493364258670807
```

[22]:
```
## Write the Test Accuracy and Loss to the results folder.
csv_test = results_dir.joinpath('assignment06-2a_Test_Accuracy_Loss_Results.
  ↪csv')
```

```
test_dict = {'Test Accuracy': test_acc,
             'Test Loss': test_loss}

with open(csv_test, 'w') as csv_file:
    writer = csv.writer(csv_file)
    for key, value in test_dict.items():
        writer.writerow([key,value])
```

0.1.11 Model Predictions

[23]:

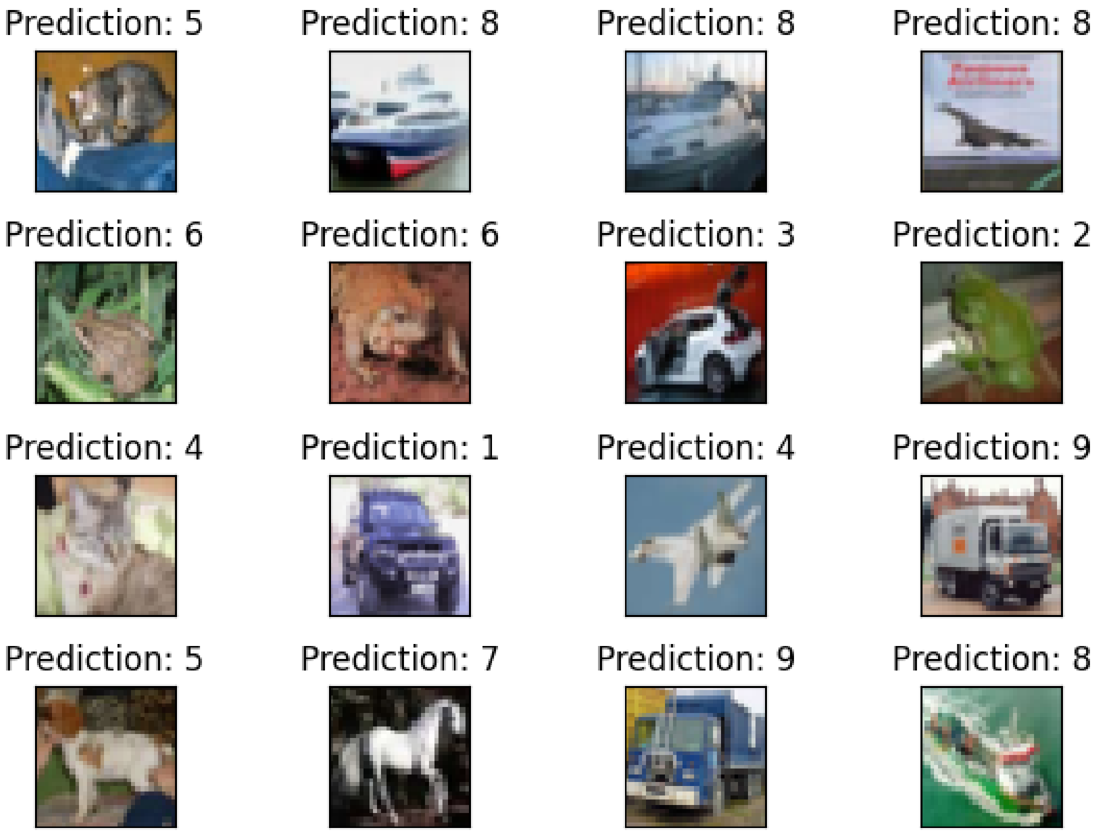
```
## Setup predictions from the model.
predict_test_labels = model.predict(test_images)
predict_classes = np.argmax(predict_test_labels, axis = 1)
predict_prob = np.max(predict_test_labels, axis = 1)
```

```
C:\Users\jkmey\anaconda3\envs\dsc650\lib\site-
packages\keras\engine\training_v1.py:2357: UserWarning: `Model.state_updates`
will be removed in a future version. This property should not be used in
TensorFlow 2.0, as `updates` are applied automatically.
  updates=self.state_updates,
```

[24]:

```
## Show an example predictions for the model.
fig = plt.figure()
for i in range(16):
    plt.subplot(4,4,i+1)
    plt.tight_layout()
    plt.imshow(test_images[i], cmap = 'gray', interpolation='none')
    plt.title("Prediction: {}".format(predict_classes[i]))
    plt.xticks([])
    plt.yticks([])
img_file = results_dir.joinpath('assignment06-2a_Prediction_Images_QTY_16.png')
plt.savefig(img_file)
print("16 Prediction Images and Labels")
plt.show()
```

```
16 Prediction Images and Labels
```


Prediction: 5
Prediction: 8
Prediction: 8
Prediction: 8
Prediction: 6
Prediction: 6
Prediction: 3
Prediction: 2
Prediction: 4
Prediction: 1
Prediction: 4
Prediction: 9
Prediction: 5
Prediction: 7
Prediction: 9
Prediction: 8