Assignment 6.2

July 9, 2021

1 Assignment 6.2

1.1 Assignment 6.2.a

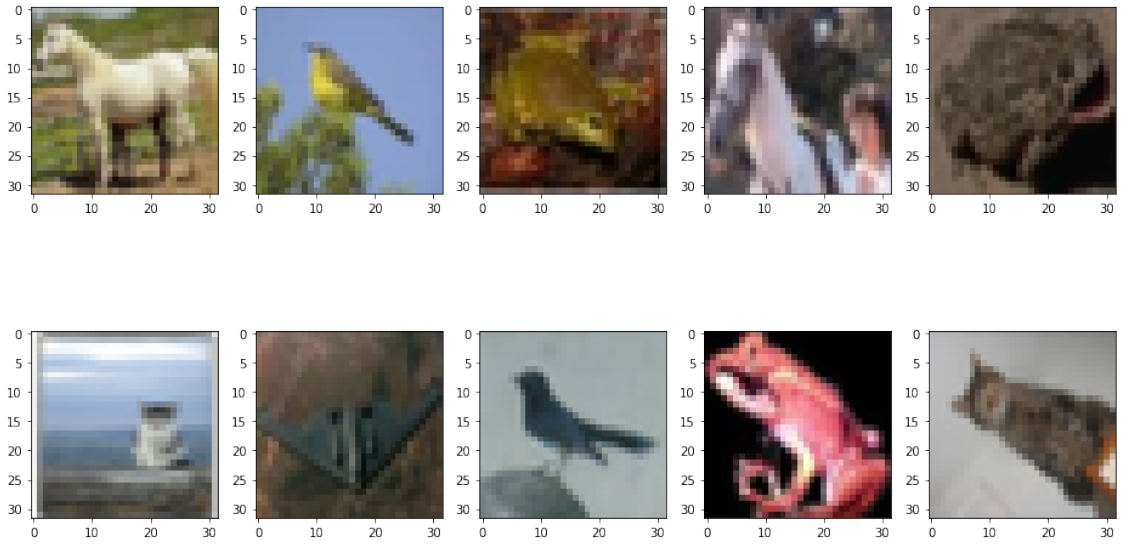
Using section 5.2 in Deep Learning with Python as a guide, create a ConvNet model that classifies images CIFAR10 small images classification dataset. Do not use dropout or data-augmentation in this part. Save the model, predictions, metrics, and validation plots in the dsc650/assignments/assignment06/results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

[1]:
```
import keras
import tensorflow as tf
import os
from keras.datasets import cifar10
import matplotlib.pyplot as plt
import numpy as np
import pandas as pd

from keras.preprocessing.image import ImageDataGenerator

import sklearn.metrics as metrics
from seaborn import heatmap
```

[2]:
```
(X_train, y_train), (X_test, y_test) = cifar10.load_data()
```

1.2 Data Exploration

[3]:
```
axs = [f'ax{i}' for i in range(0,10)]

fig, [axs[0:5],
      axs[5:10]] = plt.subplots(2,5, figsize=(16,9))

for ax in axs:
    ax.imshow(X_train[np.random.randint(0,10000)])

plt.show()
```



[4]:
```
print('X_train shape:', X_train.shape)
print('y_train shape:', y_train.shape)

print(X_train.shape[0], 'train samples')
print(X_test.shape[0], 'test samples')
```

```
X_train shape: (50000, 32, 32, 3)
y_train shape: (50000, 1)
50000 train samples
10000 test samples
```

1.3 Data Preprocessing

[5]:
```
X_train = X_train.astype('float32')
X_train /= 255

X_test = X_test.astype('float32')
X_test /= 255

X_val_train = X_train[:10000]
X_train = X_train[10000:]

# Convert target data to single array of shape (50000,) and (10000,)
y_train = y_train.reshape(y_train.shape[0])
y_test = y_test.reshape(y_test.shape[0])

y_val_train = y_train[:10000]
y_train = y_train[10000:]
```

1.4 ConvNet Model

[6]:
```
batch_size = 128
epochs = 200
```

[7]:
```
from keras.models import Sequential
from keras.layers import Conv2D, Activation, MaxPooling2D, Dropout, Dense,␣
↪Flatten
```

[8]:
```
model = Sequential()
model.add(Conv2D(32, (3, 3),
                 padding='same',
                 input_shape=X_train.shape[1:]))
model.add(MaxPooling2D((2, 2)))
model.add(Conv2D(64, (3, 3), activation='relu'))
model.add(MaxPooling2D((2, 2)))
model.add(Conv2D(128, (3, 3), activation='relu'))
model.add(MaxPooling2D((2, 2)))
model.add(Flatten())
model.add(Dense(512, activation='relu'))
model.add(Dense(10, activation='sigmoid'))

model.summary()
```

```
Model: "sequential"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv2d (Conv2D)              (None, 32, 32, 32)        896
_________________________________________________________________
max_pooling2d (MaxPooling2D) (None, 16, 16, 32)        0
_________________________________________________________________
conv2d_1 (Conv2D)            (None, 14, 14, 64)        18496
_________________________________________________________________
max_pooling2d_1 (MaxPooling2 (None, 7, 7, 64)          0
_________________________________________________________________
conv2d_2 (Conv2D)            (None, 5, 5, 128)         73856
_________________________________________________________________
max_pooling2d_2 (MaxPooling2 (None, 2, 2, 128)         0
_________________________________________________________________
flatten (Flatten)            (None, 512)               0
_________________________________________________________________
dense (Dense)                (None, 512)               262656
_________________________________________________________________
dense_1 (Dense)              (None, 10)                5130
=================================================================
Total params: 361,034
Trainable params: 361,034
```

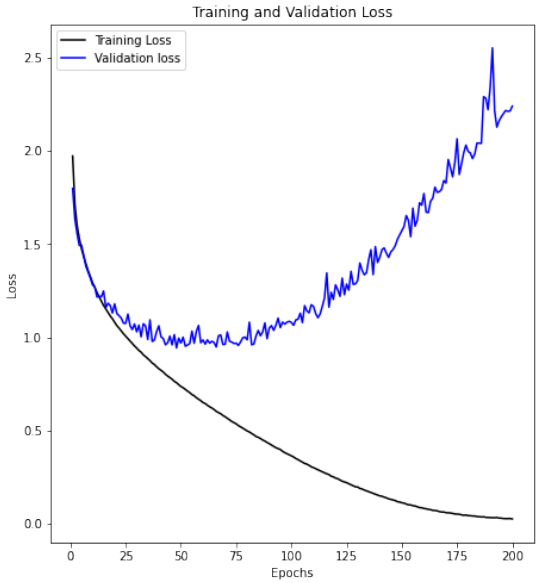
```
Non-trainable params: 0
_________________________________________________________________
```

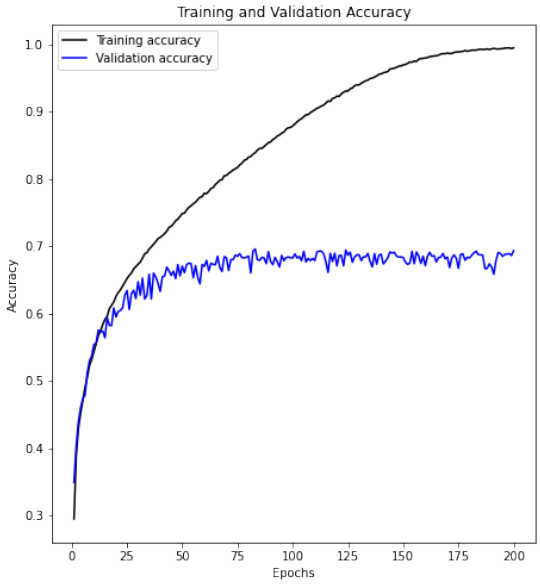
[9]:
```
model.compile(loss='sparse_categorical_crossentropy',
              optimizer=keras.optimizers.RMSprop(learning_rate=0.0001,␣
 ↪decay=1e-6),
              metrics=['acc'])
```

[10]:
```
history = model.fit(X_train,
                    y_train,
                    batch_size=batch_size,
                    epochs = epochs,
                    validation_data=(X_val_train, y_val_train),
                    verbose=False)
```

[11]:
```
results = model.evaluate(X_test, y_test)
print(results)

history_dict = history.history

acc = history_dict['acc']
val_acc = history_dict['val_acc']
loss_values = history_dict['loss']
val_loss_values = history_dict['val_loss']
epochs = range(1,len(acc) + 1)

# Plotting metrics
fig, [ax1, ax2] = plt.subplots(1,2, figsize=(16,8))

ax1.plot(epochs, loss_values,  'k', label = 'Training Loss')
ax1.plot(epochs, val_loss_values, 'b', label = 'Validation loss')
ax1.set_title('Training and Validation Loss')
ax1.set_xlabel("Epochs")
ax1.set_ylabel("Loss")
ax1.legend()

ax2.plot(epochs, acc,  'k', label = 'Training accuracy')
ax2.plot(epochs, val_acc, 'b', label = 'Validation accuracy')
ax2.set_title('Training and Validation Accuracy')
ax2.set_xlabel("Epochs")
ax2.set_ylabel("Accuracy")
ax2.legend()
plt.show()
```

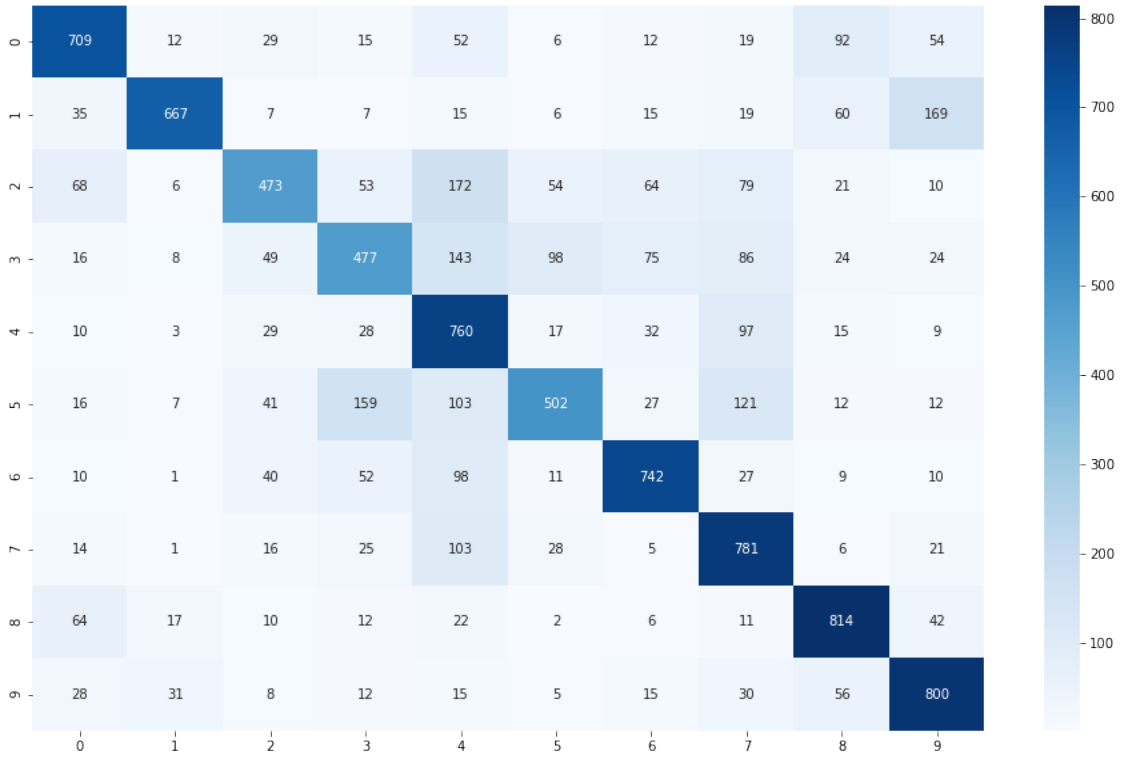
```
313/313 [==============================] - 2s 5ms/step - loss: 2.3716 - acc:
0.6730
[2.371561050415039, 0.6729999780654907]
```





[12]:
```
batch_size = 128
epochs = 60

model = Sequential()
model.add(Conv2D(32, (3, 3),
                 padding='same',
                 input_shape=X_train.shape[1:]))
model.add(MaxPooling2D((2, 2)))
model.add(Conv2D(64, (3, 3), activation='relu'))
model.add(MaxPooling2D((2, 2)))
model.add(Conv2D(128, (3, 3), activation='relu'))
model.add(MaxPooling2D((2, 2)))
model.add(Flatten())
model.add(Dense(512, activation='relu'))
model.add(Dense(10, activation='sigmoid'))

model.compile(loss='sparse_categorical_crossentropy',
              optimizer=keras.optimizers.RMSprop(learning_rate=0.0001,␣
 ↪decay=1e-6),
              metrics=['acc'])

history = model.fit(X_train,
                    y_train,
                    batch_size=batch_size,
                    epochs = epochs,
                    validation_data=(X_val_train, y_val_train),
                    verbose=False)
```

[13]:
```
predictions = model.predict(X_test)
confusion_matrix = metrics.confusion_matrix(y_true=y_test, y_pred=predictions.
 ↪argmax(axis=1))
fig, ax = plt.subplots(figsize=(16,10))
heatmap(confusion_matrix, annot = True, cmap='Blues', fmt='g', ax = ax);
```



[14]:
```
predictions.argmax(axis = 1).shape
```

[14]:
```
(10000,)
```

[15]:
```
labels = ['Airplane', 'Automobile', 'Bird', 'Cat', 'Deer', 'Dog', 'Frog',␣
 ↪'Horse', 'Ship', 'Truck']

df = pd.DataFrame()
df['prediction'] = predictions.argmax(axis=1)
df['actual'] = y_test
df['prediction'] = df['prediction'].apply(lambda x: labels[x])
df['actual'] = df['actual'].apply(lambda x: labels[x])
df.to_csv("results/model_6_a_predictions.csv")
df.sample(20)
```

[15]:

	prediction	actual
1384	Truck	Truck
1264	Ship	Ship
7653	Ship	Ship
2146	Bird	Bird
4286	Bird	Bird
3676	Truck	Truck
8386	Cat	Cat
7997	Truck	Automobile
2335	Deer	Dog
2559	Horse	Horse
3497	Airplane	Airplane
8016	Deer	Deer
1939	Horse	Frog
935	Bird	Bird
465	Deer	Deer
3646	Cat	Cat
3160	Frog	Frog
2767	Horse	Dog
9019	Truck	Truck
3047	Cat	Frog

[16]:
```
model.save('results/model_6_2_a.h5')
```

1.5 Assignment 6.2.b

Using section 5.2 in Deep Learning with Python as a guide, create a ConvNet model that classifies images CIFAR10 small images classification dataset. This time includes dropout and data-augmentation. 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.

[17]:
```
model = Sequential()
model.add(Conv2D(32, (3, 3), padding='same',
                 input_shape=X_train.shape[1:]))
model.add(Activation('relu'))
model.add(Conv2D(32, (3, 3)))
model.add(Activation('relu'))
model.add(MaxPooling2D(pool_size=(2, 2)))
model.add(Dropout(0.25))
model.add(Conv2D(64, (3, 3), padding='same'))
model.add(Activation('relu'))
model.add(Conv2D(64, (3, 3)))
model.add(Activation('relu'))
model.add(MaxPooling2D(pool_size=(2, 2)))
model.add(Dropout(0.25))
model.add(Flatten())
model.add(Dense(512))
```

```
model.add(Activation('relu'))
model.add(Dropout(0.5))
model.add(Dense(10))
model.add(Activation('softmax'))

model.summary()
```

```
Model: "sequential_2"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv2d_6 (Conv2D)            (None, 32, 32, 32)        896
_________________________________________________________________
activation (Activation)      (None, 32, 32, 32)        0
_________________________________________________________________
conv2d_7 (Conv2D)            (None, 30, 30, 32)        9248
_________________________________________________________________
activation_1 (Activation)    (None, 30, 30, 32)        0
_________________________________________________________________
max_pooling2d_6 (MaxPooling2 (None, 15, 15, 32)        0
_________________________________________________________________
dropout (Dropout)            (None, 15, 15, 32)        0
_________________________________________________________________
conv2d_8 (Conv2D)            (None, 15, 15, 64)        18496
_________________________________________________________________
activation_2 (Activation)    (None, 15, 15, 64)        0
_________________________________________________________________
conv2d_9 (Conv2D)            (None, 13, 13, 64)        36928
_________________________________________________________________
activation_3 (Activation)    (None, 13, 13, 64)        0
_________________________________________________________________
max_pooling2d_7 (MaxPooling2 (None, 6, 6, 64)          0
_________________________________________________________________
dropout_1 (Dropout)          (None, 6, 6, 64)          0
_________________________________________________________________
flatten_2 (Flatten)          (None, 2304)              0
_________________________________________________________________
dense_4 (Dense)              (None, 512)               1180160
_________________________________________________________________
activation_4 (Activation)    (None, 512)               0
_________________________________________________________________
dropout_2 (Dropout)          (None, 512)               0
_________________________________________________________________
dense_5 (Dense)              (None, 10)                5130
_________________________________________________________________
activation_5 (Activation)    (None, 10)                0
=================================================================
Total params: 1,250,858
```

```
Trainable params: 1,250,858
Non-trainable params: 0
_________________________________________________________________
```

[18]:
```
model.compile(loss='sparse_categorical_crossentropy',
              optimizer=keras.optimizers.RMSprop(learning_rate=0.0001,␣
 ↪decay=1e-6),
              metrics=['acc'])
```

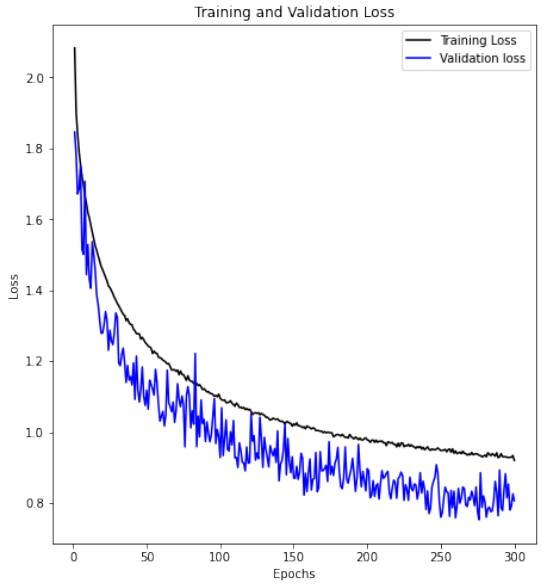
[19]:
```
batch_size = 128
epochs = 300
```

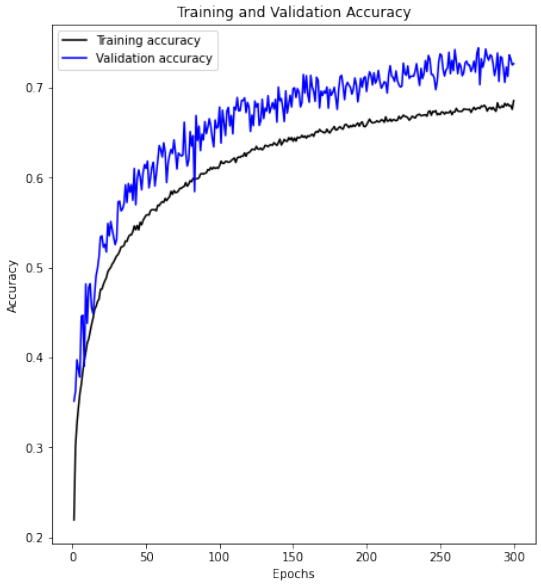
[20]:
```
datagen = ImageDataGenerator(
    rotation_range=40,
    width_shift_range=0.2,
    height_shift_range=0.2,
    shear_range=0.2,
    zoom_range=0.2,
    horizontal_flip=True)

datagen.fit(X_train)

history = model.fit(datagen.flow(X_train,
                                 y_train,
                                 batch_size=batch_size),
                    epochs=epochs,
                    validation_data=(X_val_train, y_val_train),
                    workers=4,
                    verbose=False)
```

[21]:
```
results = model.evaluate(X_test, y_test)
print(results)

history_dict = history.history

acc = history_dict['acc']
val_acc = history_dict['val_acc']
loss_values = history_dict['loss']
val_loss_values = history_dict['val_loss']
epochs = range(1,len(acc) + 1)

# Plotting metrics
fig, [ax1, ax2] = plt.subplots(1,2, figsize=(16,8))

ax1.plot(epochs, loss_values,  'k', label = 'Training Loss')
ax1.plot(epochs, val_loss_values, 'b', label = 'Validation loss')
ax1.set_title('Training and Validation Loss')
```

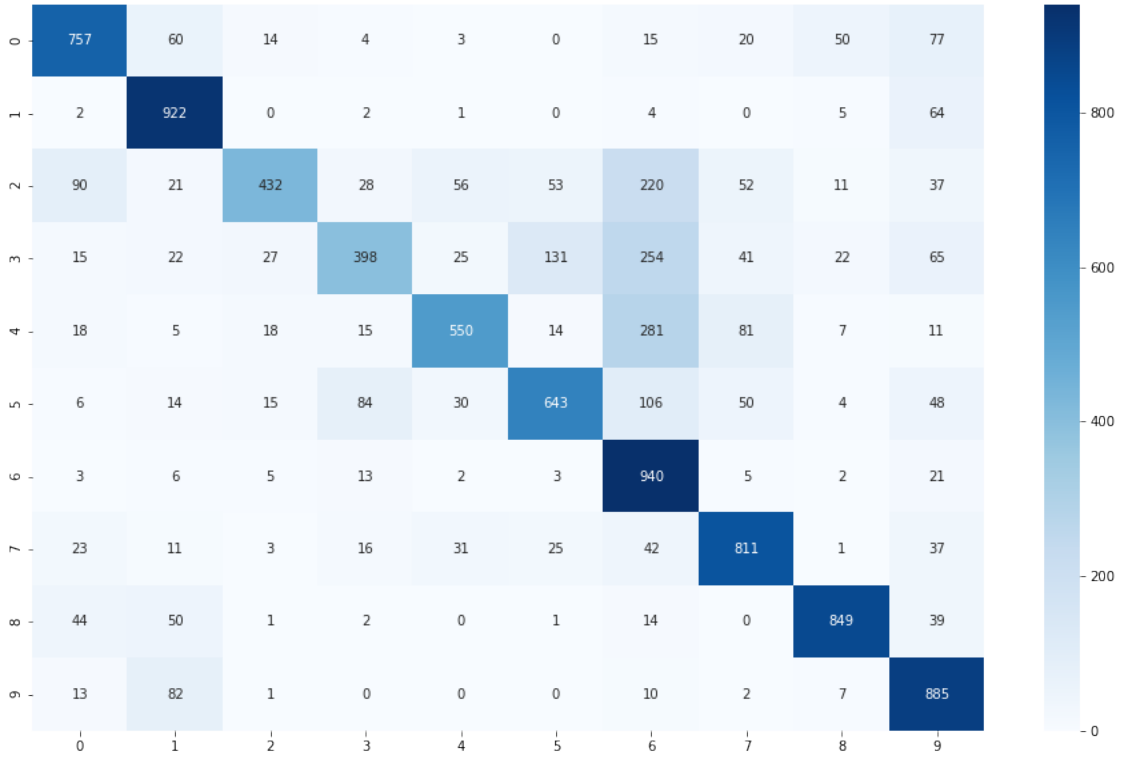
```
ax1.set_xlabel("Epochs")
ax1.set_ylabel("Loss")
ax1.legend()

ax2.plot(epochs, acc,  'k', label = 'Training accuracy')
ax2.plot(epochs, val_acc, 'b', label = 'Validation accuracy')
ax2.set_title('Training and Validation Accuracy')
ax2.set_xlabel("Epochs")
ax2.set_ylabel("Accuracy")
ax2.legend()
plt.show()
```

```
313/313 [==============================] - 2s 8ms/step - loss: 0.8179 - acc:
0.7187
[0.8179059028625488, 0.7186999917030334]
```





[22]:
```
predictions = model.predict(X_test)
confusion_matrix = metrics.confusion_matrix(y_true=y_test, y_pred=predictions.
 ↪argmax(axis=1))
fig, ax = plt.subplots(figsize=(16,10))
heatmap(confusion_matrix, annot = True, cmap='Blues', fmt='g', ax = ax);
```



[23]:
```
labels = ['Airplane', 'Automobile', 'Bird', 'Cat', 'Deer', 'Dog', 'Frog',␣
↪'Horse', 'Ship', 'Truck']

df = pd.DataFrame()
df['prediction'] = predictions.argmax(axis=1)
df['actual'] = y_test
df['prediction'] = df['prediction'].apply(lambda x: labels[x])
df['actual'] = df['actual'].apply(lambda x: labels[x])
df.to_csv("results/model_6_b_predictions.csv")
df.sample(20)
```

[23]:

	prediction	actual
9811	Automobile	Automobile
2368	Airplane	Airplane
9518	Truck	Truck
4599	Automobile	Ship
2648	Deer	Deer
1234	Automobile	Automobile
8059	Cat	Cat
780	Truck	Truck
6877	Ship	Airplane
131	Automobile	Automobile

```
9711        Deer        Deer
2102    Airplane    Airplane
2337       Horse       Horse
9285        Ship        Ship
4948  Automobile  Automobile
7863    Airplane    Airplane
5954        Ship        Ship
2398        Ship        Ship
9723       Horse       Horse
2805        Deer        Deer
```

[24]:
```
model.save('results/model_6_2_b.h5')
```