## KJ MoChroi

## Image Classification

## DSC650: Big Data

## Spring 2023

In [1]:

```
# mounting drive to assignment06 folder
import os
from google.colab import drive
drive.mount('/content/drive', force_remount = True)
os.chdir('/content/drive/My Drive/Colab Notebooks/DSC650/assignments/assignment06')
!pwd
```

```
Mounted at /content/drive
/content/drive/My Drive/Colab Notebooks/DSC650/assignments/assignment06
```

# CNN - MNIST Dataset Classification

# Model

In [2]:

```
!pip install keras
```

```
Looking in indexes: https://pypi.org/simple, https://us-python.pkg.dev/colab-wheels/publ
ic/simple/
Requirement already satisfied: keras in /usr/local/lib/python3.10/dist-packages (2.12.0)
```

In [3]:

```
# Libraries
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
import keras
import tensorflow
from keras import layers
from keras import models
from keras.datasets import mnist
from keras.datasets import cifar10
from keras.utils import to_categorical
```

In [4]:

```
# import data
(train_images, train_labels), (test_images, test_labels) = mnist.load_data()
```

```
Downloading data from https://storage.googleapis.com/tensorflow/tf-keras-datasets/mnist.
npz
11490434/11490434 [==============================] - 0s 0us/step
```

In [5]:

```
# reshape and reformat data

train_images = train_images.reshape((train_images.shape[0], 28, 28, 1))
```

```python
train_images = train_images.astype('float32')/255

test_images = test_images.reshape((test_images.shape[0], 28, 28, 1))
test_images = test_images.astype('float32')/255

train_labels = to_categorical(train_labels)
test_labels = to_categorical(test_labels)
```

In [6]:

```python
# generate instance of sequential model
model = models.Sequential()
model.add(layers.Conv2D(32, (3,3), activation='relu', input_shape=(28,28,1)))
model.add(layers.MaxPooling2D((2,2)))
model.add(layers.Conv2D(64, (3,3), activation='relu'))
model.add(layers.MaxPooling2D((2,2)))
model.add(layers.Conv2D(64, (3,3), activation='relu'))
model.add(layers.Flatten())
model.add(layers.Dense(64, activation='relu'))
model.add(layers.Dense(10, activation='softmax'))
```

In [7]:

```python
# compile
model.compile(optimizer='rmsprop', loss='categorical_crossentropy', metrics=['accuracy'
```

In [8]:

```python
# holdout validation

validation_images = train_images[:10000]
partial_train_images = train_images[10000:]

validation_labels = train_labels[:10000]
partial_train_labels = train_labels[10000:]
```

In [9]:

```python
# csvlogger
from keras.callbacks import CSVLogger
csv_logger = CSVLogger('results/CNN_mnist_training.log')
```

In [10]:

```python
#  train model
history = model.fit(partial_train_images,
                    partial_train_labels,
                    epochs=10,
                    batch_size=64,
                    validation_data=(validation_images,validation_labels),
                    callbacks=[csv_logger])
```

```
Epoch 1/10
782/782 [==============================] - 21s 10ms/step - loss: 0.2002 - accuracy: 0.93
89 - val_loss: 0.1178 - val_accuracy: 0.9668
Epoch 2/10
782/782 [==============================] - 6s 8ms/step - loss: 0.0494 - accuracy: 0.9855
- val_loss: 0.0478 - val_accuracy: 0.9860
Epoch 3/10
782/782 [==============================] - 4s 5ms/step - loss: 0.0345 - accuracy: 0.9896
- val_loss: 0.0421 - val_accuracy: 0.9882
Epoch 4/10
782/782 [==============================] - 4s 5ms/step - loss: 0.0255 - accuracy: 0.9920
```

```
- val_loss: 0.0450 - val_accuracy: 0.9874
Epoch 5/10
782/782 [==============================] - 4s 5ms/step - loss: 0.0201 - accuracy: 0.9940
- val_loss: 0.0383 - val_accuracy: 0.9903
Epoch 6/10
782/782 [==============================] - 4s 4ms/step - loss: 0.0159 - accuracy: 0.9949
- val_loss: 0.0493 - val_accuracy: 0.9871
Epoch 7/10
782/782 [==============================] - 4s 5ms/step - loss: 0.0127 - accuracy: 0.9962
- val_loss: 0.0407 - val_accuracy: 0.9896
Epoch 8/10
782/782 [==============================] - 6s 7ms/step - loss: 0.0105 - accuracy: 0.9966
- val_loss: 0.0399 - val_accuracy: 0.9909
Epoch 9/10
782/782 [==============================] - 4s 5ms/step - loss: 0.0093 - accuracy: 0.9974
- val_loss: 0.0420 - val_accuracy: 0.9899
Epoch 10/10
782/782 [==============================] - 4s 5ms/step - loss: 0.0073 - accuracy: 0.9977
- val_loss: 0.0493 - val_accuracy: 0.9908
```

In [11]:

```
# save the model
model.save('results/CNN_mnist_model')
model.save('results/CNN_mnist_model.h5')
```

```
WARNING:absl:Found untraced functions such as _jit_compiled_convolution_op, _jit_compile
d_convolution_op, _jit_compiled_convolution_op while saving (showing 3 of 3). These func
tions will not be directly callable after loading.
```

## Predictions

In [12]:

```
predictions = model.predict(test_images)
predictions.tofile('results/CNN_mnist_predictions.csv', sep = ',')
```

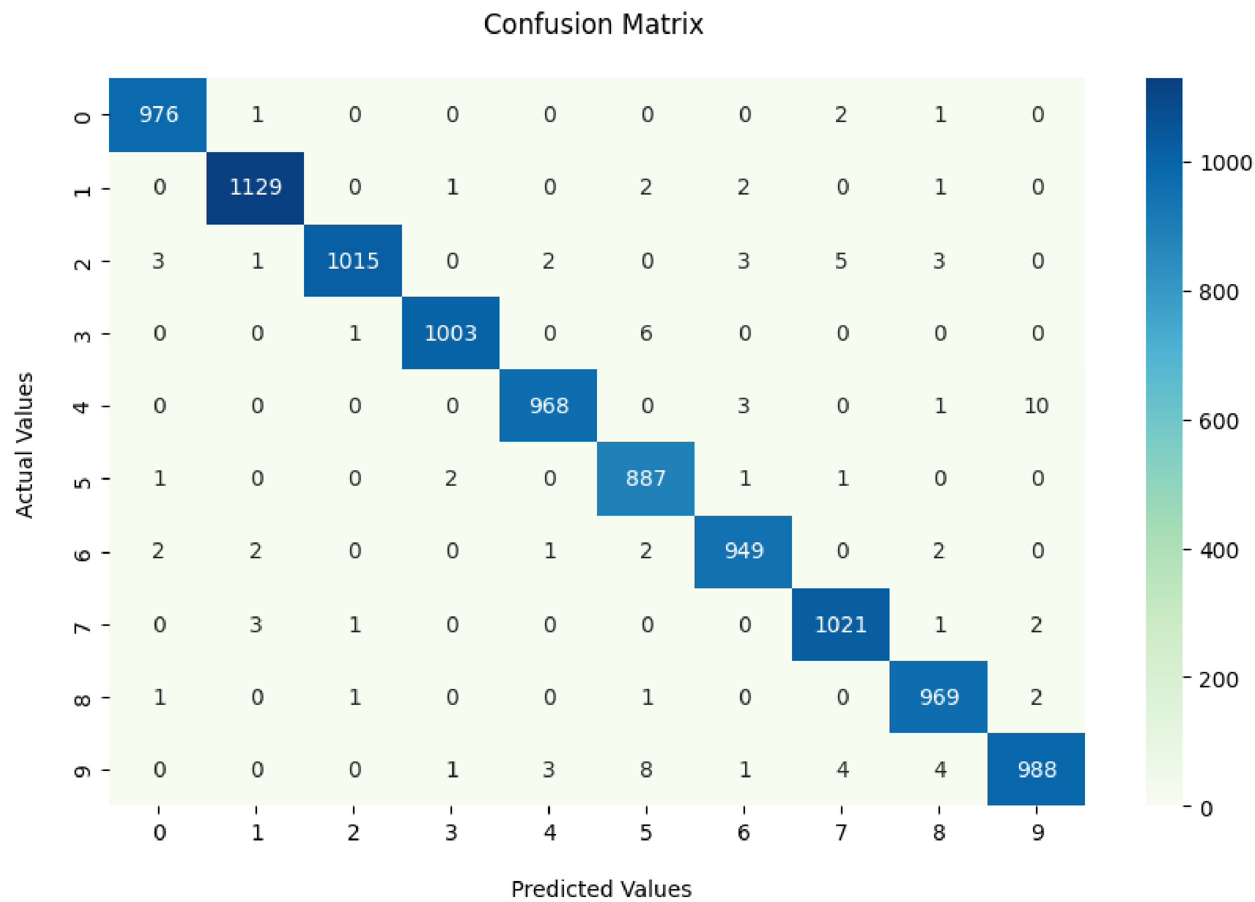
```
313/313 [==============================] - 1s 2ms/step
```

In [13]:

```
max_test_labels = np.argmax(test_labels, axis=1)

max_predictions = np.argmax(predictions, axis=1)
```

In [14]:

```
import seaborn as sns
from sklearn.metrics import confusion_matrix

confusion = confusion_matrix(max_test_labels, max_predictions)
plt.figure(figsize=(10,6))
fx=sns.heatmap(confusion, annot=True, fmt=".0f",cmap="GnBu")
fx.set_title('Confusion Matrix \n');
fx.set_xlabel('\n Predicted Values\n')
fx.set_ylabel('Actual Values\n');

plt.savefig("results/CNN_mnist_confusionmatrix.png")

plt.show()
```




# Metrics

In [15]:

```
results = model.evaluate(test_images, test_labels)
```

```
313/313 [==============================] - 1s 3ms/step - loss: 0.0474 - accuracy: 0.9905
```

In [16]:

```
from sklearn.metrics import classification_report
class_report = classification_report(max_test_labels, max_predictions)
print(class_report)
#open text file
text_file = open("results/CNN_mnist_metrics.txt", "w")

#write string to file
text_file.write(class_report)

#close file
text_file.close()
```

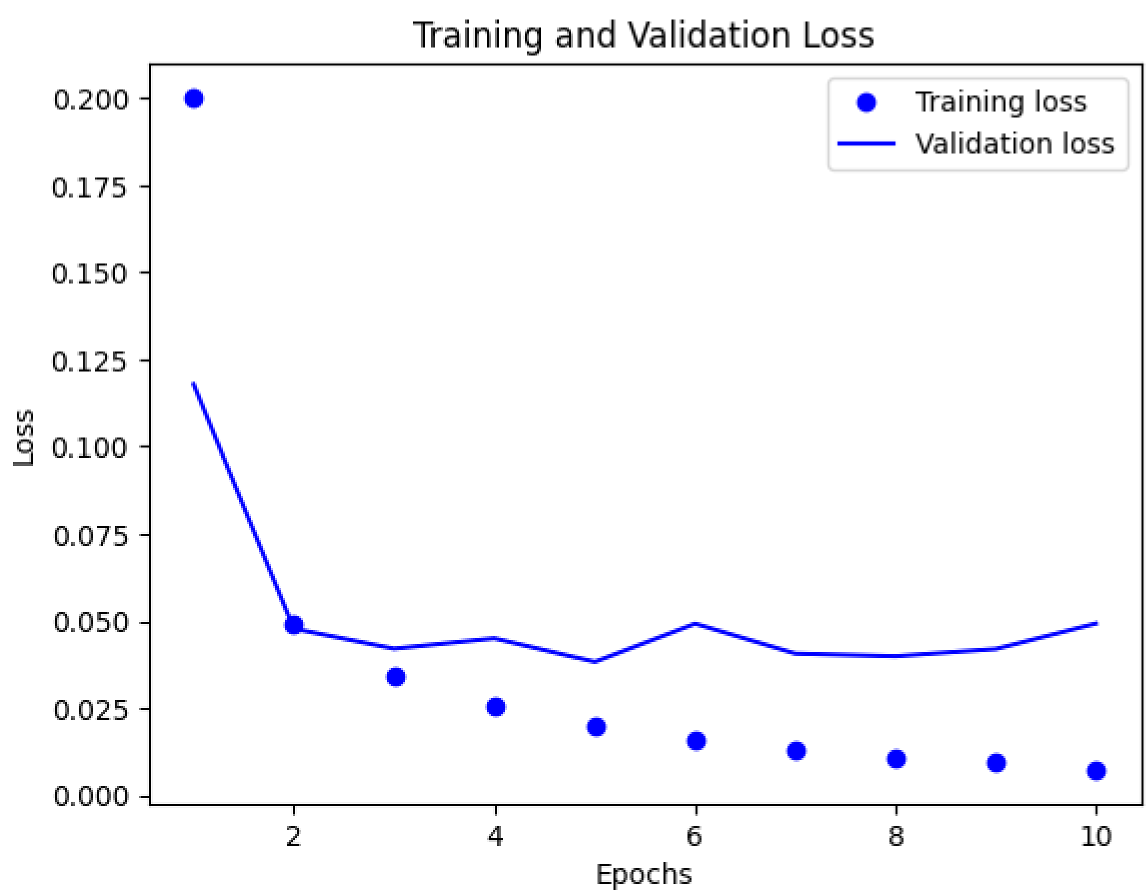
```
              precision    recall  f1-score   support

           0       0.99      1.00      0.99       980
           1       0.99      0.99      0.99      1135
           2       1.00      0.98      0.99      1032
           3       1.00      0.99      0.99      1010
           4       0.99      0.99      0.99       982
           5       0.98      0.99      0.99       892
           6       0.99      0.99      0.99       958
```

```
           7       0.99      0.99      0.99      1028
           8       0.99      0.99      0.99       974
           9       0.99      0.98      0.98      1009

    accuracy                           0.99     10000
   macro avg       0.99      0.99      0.99     10000
weighted avg       0.99      0.99      0.99     10000
```

## Validation Plots

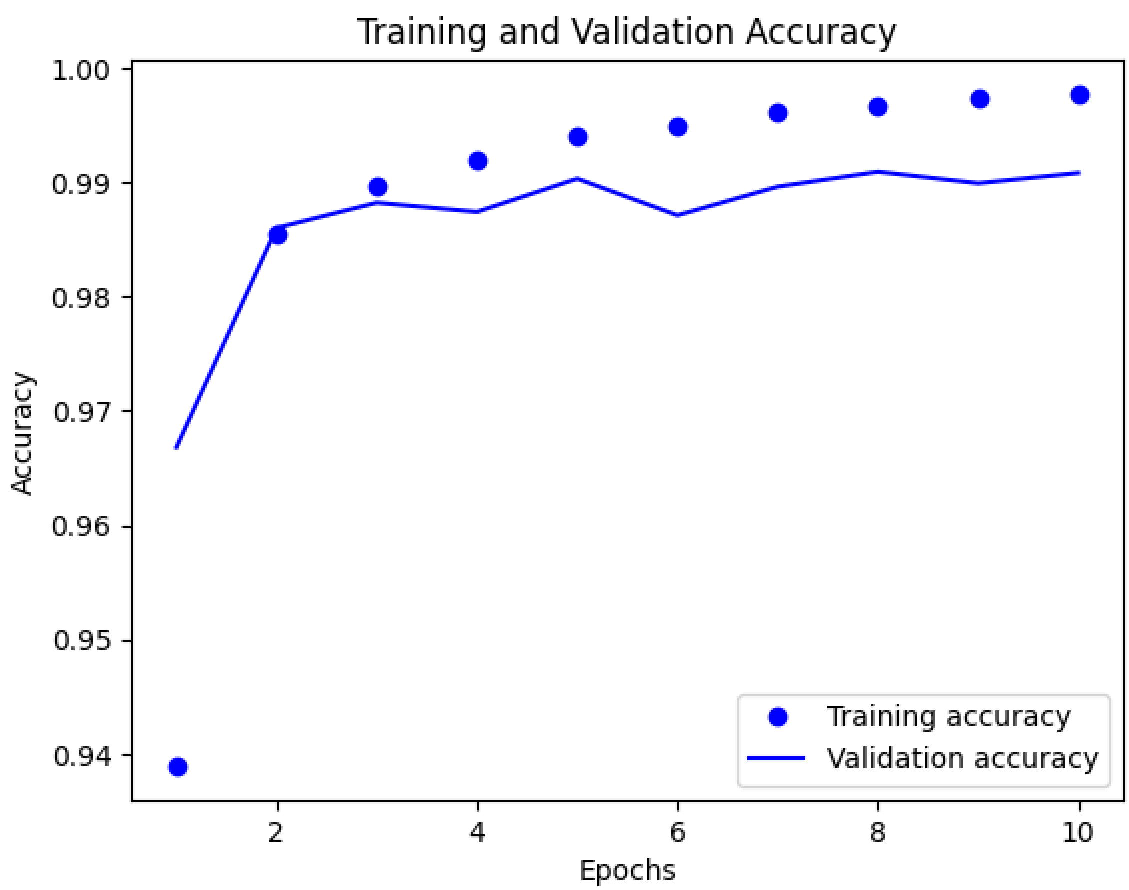
In [17]:

```python
# plot loss

loss = history.history['loss']
val_loss = history.history['val_loss']

epochs = range(1, len(loss)+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.xlabel('Epochs')
plt.ylabel('Loss')
plt.legend()

plt.savefig("results/CNN_mnist_loss.png")

plt.show()
```



In [18]:

```
# plot accuracy

plt.clf()

acc = history.history['accuracy']
val_acc = history.history['val_accuracy']

plt.plot(epochs, acc, 'bo', label='Training accuracy')
plt.plot(epochs, val_acc, 'b', label='Validation accuracy')
plt.title('Training and Validation Accuracy')
plt.xlabel('Epochs')
plt.ylabel('Accuracy')
plt.legend()

plt.savefig("results/CNN_mnist_accuracy.png")

plt.show()
```




# CNN - CIFAR10 Small Image Classification Dataset

## Model

In [19]:

```
# Load data
```

```
(x_train, y_train), (x_test, y_test) = keras.datasets.cifar10.load_data()
assert x_train.shape == (50000, 32, 32, 3)
assert x_test.shape == (10000, 32, 32, 3)
assert y_train.shape == (50000, 1)
assert y_test.shape == (10000, 1)
```

```
Downloading data from https://www.cs.toronto.edu/~kriz/cifar-10-python.tar.gz
170498071/170498071 [==============================] - 2s 0us/step
```

In [20]:

```
y_train = to_categorical(y_train)
y_test = to_categorical(y_test)
```

In [21]:

```
# holdout validation

x_val = x_train[:10000]
partial_x_train = x_train[10000:]

y_val = y_train[:10000]
partial_y_train = y_train[10000:]
```

In [22]:

```
from keras.preprocessing.image import ImageDataGenerator
```

In [23]:

```
train_datagen = ImageDataGenerator(rescale=1./255)
test_datagen = ImageDataGenerator(rescale=1./255)

# train_datagen.fit(x_train)

batch_size = 32

train_generator = train_datagen.flow(x_train,
                                     y_train,
                                     batch_size=batch_size,
                                     shuffle=False)

validation_generator = test_datagen.flow(x_val,
                                         y_val,
                                         batch_size=batch_size,
                                         shuffle=False)


test_generator = test_datagen.flow(
    x_test,
    y_test,
    batch_size=batch_size,
    shuffle=False)
```

In [24]:

```
# model

model = models.Sequential()
model.add(layers.Conv2D(32, (3,3), activation='relu', input_shape=(32,32,3))) # output
model.add(layers.MaxPooling2D((2,2))) # output shape (15, 15, 32)
model.add(layers.Conv2D(64, (3,3), activation='relu')) # output shape (13, 13, 64)
model.add(layers.MaxPooling2D((2,2))) # output shape (6, 6, 64)
model.add(layers.Flatten())
```

```python
model.add(layers.Dense(512, activation='relu'))
model.add(layers.Dense(10, activation='softmax'))
```

In [25]:

```python
# compile
model.compile(optimizer='rmsprop',
              loss='categorical_crossentropy',
              metrics=['accuracy'])
```

In [26]:

```python
# csvlogger
from keras.callbacks import CSVLogger
csv_logger = CSVLogger('results/CNN_cifar10_training.log')
```

In [27]:

```python
#  train model
train_generator.reset()
validation_generator.reset()
history = model.fit(train_generator,
                              steps_per_epoch=len(x_train) // batch_size,
                              epochs=30,
                              validation_data=validation_generator,
                              validation_steps=50,
                              callbacks=[csv_logger])
```

```
Epoch 1/30
1562/1562 [==============================] - 11s 6ms/step - loss: 1.4046 - accuracy: 0.5
003 - val_loss: 0.9945 - val_accuracy: 0.6369
Epoch 2/30
1562/1562 [==============================] - 9s 5ms/step - loss: 0.9994 - accuracy: 0.65
28 - val_loss: 0.7725 - val_accuracy: 0.7344
Epoch 3/30
1562/1562 [==============================] - 8s 5ms/step - loss: 0.8096 - accuracy: 0.72
13 - val_loss: 0.6642 - val_accuracy: 0.7688
Epoch 4/30
1562/1562 [==============================] - 9s 6ms/step - loss: 0.6627 - accuracy: 0.77
26 - val_loss: 0.5261 - val_accuracy: 0.8263
Epoch 5/30
1562/1562 [==============================] - 9s 6ms/step - loss: 0.5367 - accuracy: 0.81
67 - val_loss: 0.3989 - val_accuracy: 0.8562
Epoch 6/30
1562/1562 [==============================] - 9s 6ms/step - loss: 0.4266 - accuracy: 0.85
43 - val_loss: 0.2688 - val_accuracy: 0.9187
Epoch 7/30
1562/1562 [==============================] - 8s 5ms/step - loss: 0.3345 - accuracy: 0.88
69 - val_loss: 0.2933 - val_accuracy: 0.8913
Epoch 8/30
1562/1562 [==============================] - 9s 6ms/step - loss: 0.2583 - accuracy: 0.91
29 - val_loss: 0.1402 - val_accuracy: 0.9556
Epoch 9/30
1562/1562 [==============================] - 9s 6ms/step - loss: 0.2022 - accuracy: 0.93
22 - val_loss: 0.0839 - val_accuracy: 0.9694
Epoch 10/30
1562/1562 [==============================] - 8s 5ms/step - loss: 0.1607 - accuracy: 0.94
63 - val_loss: 0.1001 - val_accuracy: 0.9694
Epoch 11/30
1562/1562 [==============================] - 9s 6ms/step - loss: 0.1317 - accuracy: 0.95
62 - val_loss: 0.0648 - val_accuracy: 0.9781
Epoch 12/30
```

```
1562/1562 [==============================] - 9s 6ms/step - loss: 0.1180 - accuracy: 0.96
26 - val_loss: 0.0417 - val_accuracy: 0.9862
Epoch 13/30
1562/1562 [==============================] - 8s 5ms/step - loss: 0.1027 - accuracy: 0.96
80 - val_loss: 0.0757 - val_accuracy: 0.9737
Epoch 14/30
1562/1562 [==============================] - 9s 6ms/step - loss: 0.0911 - accuracy: 0.97
14 - val_loss: 0.0328 - val_accuracy: 0.9894
Epoch 15/30
1562/1562 [==============================] - 9s 6ms/step - loss: 0.0835 - accuracy: 0.97
39 - val_loss: 0.0479 - val_accuracy: 0.9844
Epoch 16/30
1562/1562 [==============================] - 9s 6ms/step - loss: 0.0735 - accuracy: 0.97
74 - val_loss: 0.0211 - val_accuracy: 0.9937
Epoch 17/30
1562/1562 [==============================] - 8s 5ms/step - loss: 0.0712 - accuracy: 0.97
90 - val_loss: 0.0346 - val_accuracy: 0.9862
Epoch 18/30
1562/1562 [==============================] - 9s 6ms/step - loss: 0.0697 - accuracy: 0.98
01 - val_loss: 0.1002 - val_accuracy: 0.9750
Epoch 19/30
1562/1562 [==============================] - 9s 6ms/step - loss: 0.0662 - accuracy: 0.98
19 - val_loss: 0.0274 - val_accuracy: 0.9900
Epoch 20/30
1562/1562 [==============================] - 8s 5ms/step - loss: 0.0640 - accuracy: 0.98
18 - val_loss: 0.0527 - val_accuracy: 0.9844
Epoch 21/30
1562/1562 [==============================] - 8s 5ms/step - loss: 0.0598 - accuracy: 0.98
31 - val_loss: 0.0269 - val_accuracy: 0.9894
Epoch 22/30
1562/1562 [==============================] - 9s 6ms/step - loss: 0.0572 - accuracy: 0.98
52 - val_loss: 0.0741 - val_accuracy: 0.9775
Epoch 23/30
1562/1562 [==============================] - 10s 6ms/step - loss: 0.0550 - accuracy: 0.9
856 - val_loss: 0.0410 - val_accuracy: 0.9875
Epoch 24/30
1562/1562 [==============================] - 8s 5ms/step - loss: 0.0545 - accuracy: 0.98
60 - val_loss: 0.0366 - val_accuracy: 0.9906
Epoch 25/30
1562/1562 [==============================] - 9s 5ms/step - loss: 0.0497 - accuracy: 0.98
73 - val_loss: 0.0575 - val_accuracy: 0.9875
Epoch 26/30
1562/1562 [==============================] - 9s 6ms/step - loss: 0.0513 - accuracy: 0.98
78 - val_loss: 0.0217 - val_accuracy: 0.9931
Epoch 27/30
1562/1562 [==============================] - 10s 6ms/step - loss: 0.0460 - accuracy: 0.9
885 - val_loss: 0.0152 - val_accuracy: 0.9956
Epoch 28/30
1562/1562 [==============================] - 8s 5ms/step - loss: 0.0480 - accuracy: 0.98
85 - val_loss: 0.0320 - val_accuracy: 0.9919
Epoch 29/30
1562/1562 [==============================] - 11s 7ms/step - loss: 0.0490 - accuracy: 0.9
890 - val_loss: 0.0386 - val_accuracy: 0.9875
Epoch 30/30
1562/1562 [==============================] - 9s 6ms/step - loss: 0.0471 - accuracy: 0.98
90 - val_loss: 0.0556 - val_accuracy: 0.9881
```

In [28]:

```
# save the model
model.save('results/CNN_cifar10_model')
```

```
model.save('results/CNN_cifar10_model.h5')
```

```
WARNING:absl:Found untraced functions such as _jit_compiled_convolution_op, _jit_compile
d_convolution_op while saving (showing 2 of 2). These functions will not be directly cal
lable after loading.
```

## Predictions

In [29]:

```
test_generator.reset()
predictions = model.predict(test_generator,steps = len(x_test) // batch_size)
predictions.tofile('results/CNN_cifar10_predictions.csv', sep = ',')
```

```
312/312 [==============================] - 1s 3ms/step
```

In [30]:

```
predictions.shape
```

Out[30]:

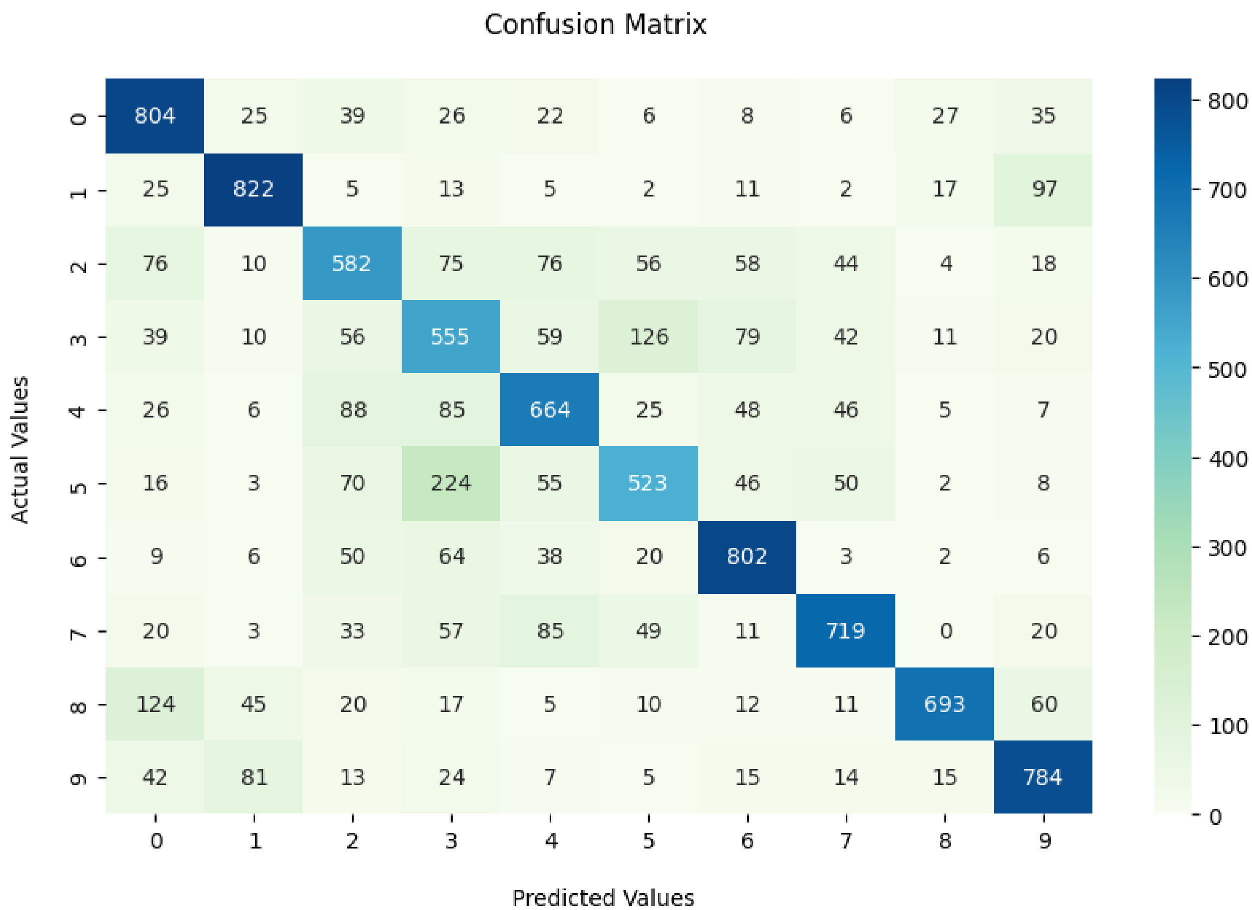
```
(9984, 10)
```

In [31]:

```
max_y_test = np.argmax(y_test[:9984], axis=1)

max_predictions = np.argmax(predictions, axis=1)
```

In [32]:

```
import seaborn as sns
from sklearn.metrics import confusion_matrix

confusion = confusion_matrix(max_y_test, max_predictions)
plt.figure(figsize=(10,6))
fx=sns.heatmap(confusion, annot=True, fmt=".0f",cmap="GnBu")
fx.set_title('Confusion Matrix \n');
fx.set_xlabel('\n Predicted Values\n')
fx.set_ylabel('Actual Values\n');

plt.savefig("results/CNN_cifar10_confusionmatrix.png")

plt.show()
```




# Metrics

In [33]:
```
test_generator.reset()
results = model.evaluate(test_generator)
```

```
313/313 [==============================] - 1s 4ms/step - loss: 4.7792 - accuracy: 0.6958
```

In [34]:
```
from sklearn.metrics import classification_report
class_report = classification_report(max_y_test, max_predictions)
print(class_report)

#open text file
text_file = open("results/CNN_cifar10_metrics.txt", "w")

#write string to file
text_file.write(class_report)

#close file
text_file.close()
```

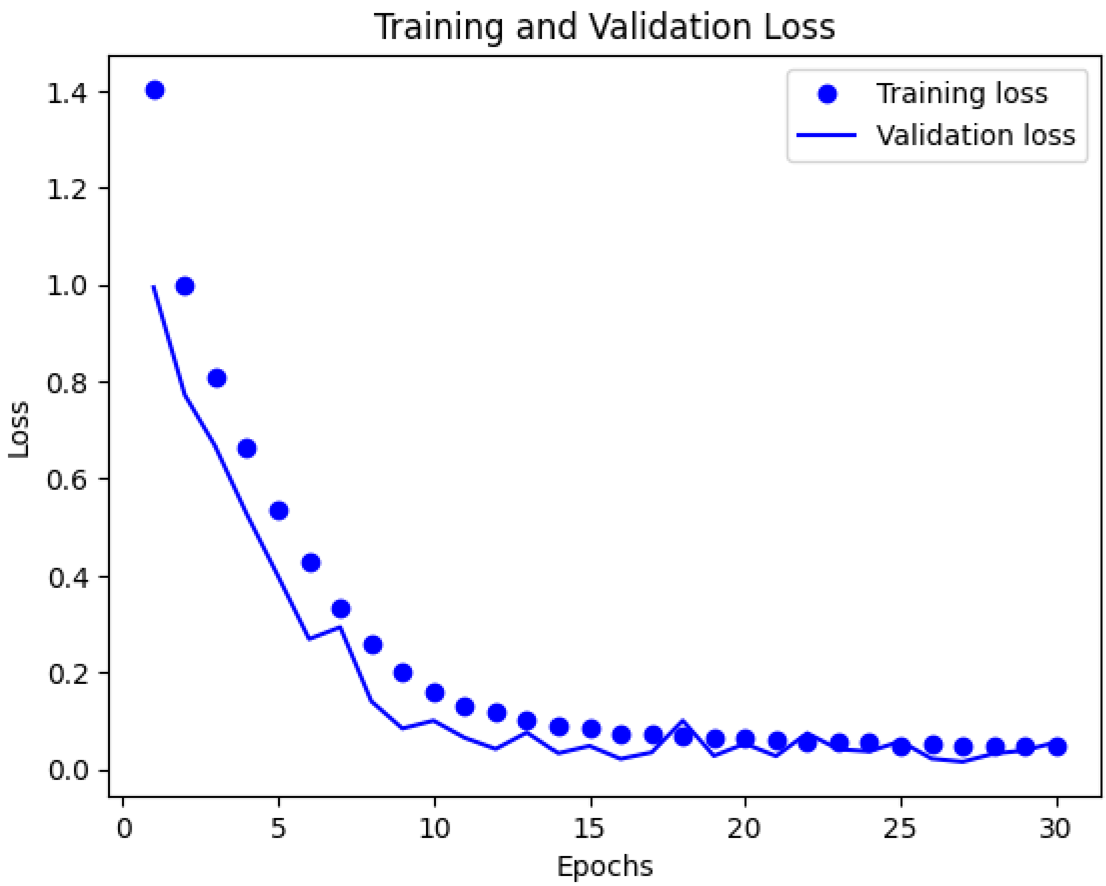
```
              precision    recall  f1-score   support

           0       0.68      0.81      0.74       998
           1       0.81      0.82      0.82       999
           2       0.61      0.58      0.60       999
           3       0.49      0.56      0.52       997
           4       0.65      0.66      0.66      1000
```

```
           5       0.64      0.52      0.58       997
           6       0.74      0.80      0.77      1000
           7       0.77      0.72      0.74       997
           8       0.89      0.70      0.78       997
           9       0.74      0.78      0.76      1000

    accuracy                           0.70      9984
   macro avg       0.70      0.70      0.70      9984
weighted avg       0.70      0.70      0.70      9984
```

# Validation Plots

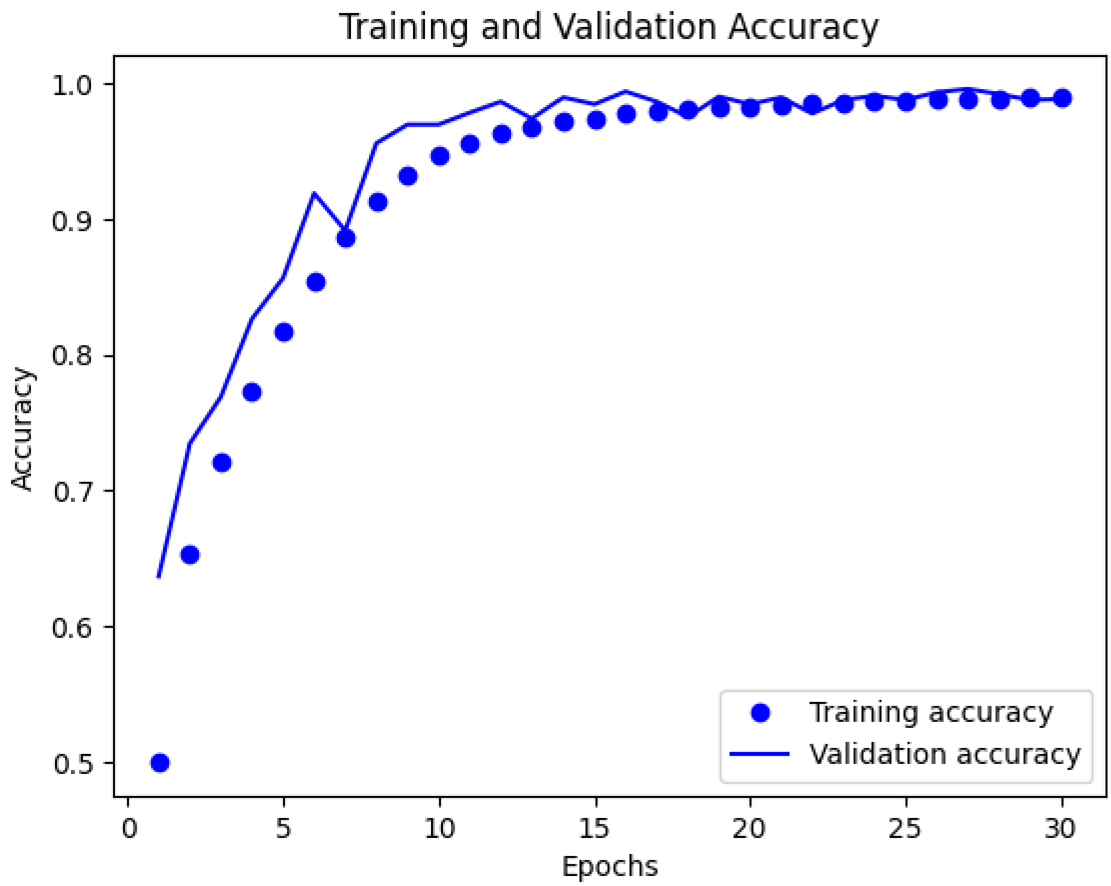
In [35]:

```
# plot loss

loss = history.history['loss']
val_loss = history.history['val_loss']

epochs = range(1, len(loss)+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.xlabel('Epochs')
plt.ylabel('Loss')
plt.legend()

plt.savefig("results/CNN_cifar10_loss.png")

plt.show()
```




In [36]:

```
# plot accuracy

plt.clf()

acc = history.history['accuracy']
val_acc = history.history['val_accuracy']

plt.plot(epochs, acc, 'bo', label='Training accuracy')
plt.plot(epochs, val_acc, 'b', label='Validation accuracy')
plt.title('Training and Validation Accuracy')
plt.xlabel('Epochs')
plt.ylabel('Accuracy')
plt.legend()

plt.savefig("results/CNN_cifar10_accuracy.png")

plt.show()
```




# CNN - CIFAR10 Small Image Classification Dataset with dropout and data augmentation

## Model

In [37]:
```
# Load data

(x_train, y_train), (x_test, y_test) = keras.datasets.cifar10.load_data()
assert x_train.shape == (50000, 32, 32, 3)
assert x_test.shape == (10000, 32, 32, 3)
assert y_train.shape == (50000, 1)
assert y_test.shape == (10000, 1)
```

In [38]:
```
y_train = to_categorical(y_train)
y_test = to_categorical(y_test)
```

In [39]:
```
# holdout validation

x_val = x_train[:10000]
partial_x_train = x_train[10000:]

y_val = y_train[:10000]
partial_y_train = y_train[10000:]
```

In [40]:

```python
from keras.preprocessing.image import ImageDataGenerator
```

In [41]:

```python
train_datagen = ImageDataGenerator(
    rescale=1./255,
    rotation_range=40,
    width_shift_range=0.2,
    height_shift_range=0.2,
    shear_range=0.2,
    zoom_range=0.2,
    horizontal_flip=True)

test_datagen = ImageDataGenerator(rescale=1./255)

# train_datagen.fit(x_train)

batch_size = 32

train_generator = train_datagen.flow(x_train,
                                     y_train,
                                     batch_size=batch_size,
                                     shuffle=False)

validation_generator = test_datagen.flow(x_val,
                                         y_val,
                                         batch_size=batch_size,
                                         shuffle=False)


test_generator = test_datagen.flow(
    x_test,
    y_test,
    batch_size=batch_size,
    shuffle=False)
```

In [42]:

```python
# model

model = models.Sequential()
model.add(layers.Conv2D(32, (3,3), activation='relu', input_shape=(32,32,3))) # output
model.add(layers.MaxPooling2D((2,2))) # output shape (15, 15, 32)
model.add(layers.Conv2D(64, (3,3), activation='relu')) # output shape (13, 13, 64)
model.add(layers.MaxPooling2D((2,2))) # output shape (6, 6, 64)
model.add(layers.Flatten())
model.add(layers.Dropout(0.5))
model.add(layers.Dense(512, activation='relu'))
model.add(layers.Dense(10, activation='softmax'))
```

In [43]:

```python
# compile
model.compile(optimizer='rmsprop',
              loss='categorical_crossentropy',
              metrics=['accuracy'])
```

In [44]:

```python
# csvlogger
from keras.callbacks import CSVLogger
csv_logger = CSVLogger('results/CNN_cifar10_augmented_training.log')
```

In [45]:

```python
#  train model
train_generator.reset()
validation_generator.reset()
history = model.fit(train_generator,
                              steps_per_epoch=len(x_train) // batch_size,
                              epochs=30,
                              validation_data=validation_generator,
                              validation_steps=50,
                              callbacks=[csv_logger])
```

```
Epoch 1/30
1562/1562 [==============================] - 38s 23ms/step - loss: 1.8116 - accuracy: 0.
3386 - val_loss: 1.5423 - val_accuracy: 0.4394
Epoch 2/30
1562/1562 [==============================] - 37s 24ms/step - loss: 1.6054 - accuracy: 0.
4214 - val_loss: 1.3397 - val_accuracy: 0.5219
Epoch 3/30
1562/1562 [==============================] - 38s 24ms/step - loss: 1.5310 - accuracy: 0.
4499 - val_loss: 1.2386 - val_accuracy: 0.5688
Epoch 4/30
1562/1562 [==============================] - 47s 30ms/step - loss: 1.4870 - accuracy: 0.
4679 - val_loss: 1.1367 - val_accuracy: 0.6200
Epoch 5/30
1562/1562 [==============================] - 39s 25ms/step - loss: 1.4581 - accuracy: 0.
4819 - val_loss: 1.0925 - val_accuracy: 0.6306
Epoch 6/30
1562/1562 [==============================] - 53s 34ms/step - loss: 1.4384 - accuracy: 0.
4918 - val_loss: 1.2544 - val_accuracy: 0.5531
Epoch 7/30
1562/1562 [==============================] - 57s 37ms/step - loss: 1.4211 - accuracy: 0.
4967 - val_loss: 1.1450 - val_accuracy: 0.5950
Epoch 8/30
1562/1562 [==============================] - 41s 26ms/step - loss: 1.4119 - accuracy: 0.
5021 - val_loss: 1.1287 - val_accuracy: 0.6062
Epoch 9/30
1562/1562 [==============================] - 42s 27ms/step - loss: 1.4085 - accuracy: 0.
5036 - val_loss: 1.2648 - val_accuracy: 0.5519
Epoch 10/30
1562/1562 [==============================] - 41s 26ms/step - loss: 1.3988 - accuracy: 0.
5081 - val_loss: 1.1723 - val_accuracy: 0.5863
Epoch 11/30
1562/1562 [==============================] - 41s 26ms/step - loss: 1.3946 - accuracy: 0.
5123 - val_loss: 1.0680 - val_accuracy: 0.6319
Epoch 12/30
1562/1562 [==============================] - 40s 25ms/step - loss: 1.3917 - accuracy: 0.
5132 - val_loss: 1.0410 - val_accuracy: 0.6331
Epoch 13/30
1562/1562 [==============================] - 42s 27ms/step - loss: 1.3813 - accuracy: 0.
5165 - val_loss: 1.1202 - val_accuracy: 0.6338
Epoch 14/30
1562/1562 [==============================] - 36s 23ms/step - loss: 1.3898 - accuracy: 0.
5144 - val_loss: 1.0727 - val_accuracy: 0.6144
Epoch 15/30
1562/1562 [==============================] - 37s 23ms/step - loss: 1.3792 - accuracy: 0.
5178 - val_loss: 1.0434 - val_accuracy: 0.6313
Epoch 16/30
1562/1562 [==============================] - 38s 24ms/step - loss: 1.3856 - accuracy: 0.
5193 - val_loss: 1.0193 - val_accuracy: 0.6562
```

```
Epoch 17/30
1562/1562 [==============================] - 37s 24ms/step - loss: 1.3898 - accuracy: 0.
5169 - val_loss: 1.0996 - val_accuracy: 0.6319
Epoch 18/30
1562/1562 [==============================] - 44s 28ms/step - loss: 1.3778 - accuracy: 0.
5209 - val_loss: 1.2364 - val_accuracy: 0.5806
Epoch 19/30
1562/1562 [==============================] - 37s 24ms/step - loss: 1.3877 - accuracy: 0.
5225 - val_loss: 1.0319 - val_accuracy: 0.6637
Epoch 20/30
1562/1562 [==============================] - 56s 36ms/step - loss: 1.3817 - accuracy: 0.
5199 - val_loss: 1.0921 - val_accuracy: 0.6250
Epoch 21/30
1562/1562 [==============================] - 37s 24ms/step - loss: 1.3863 - accuracy: 0.
5196 - val_loss: 1.0536 - val_accuracy: 0.6325
Epoch 22/30
1562/1562 [==============================] - 37s 24ms/step - loss: 1.3858 - accuracy: 0.
5201 - val_loss: 1.1315 - val_accuracy: 0.6338
Epoch 23/30
1562/1562 [==============================] - 38s 25ms/step - loss: 1.3874 - accuracy: 0.
5198 - val_loss: 1.0197 - val_accuracy: 0.6544
Epoch 24/30
1562/1562 [==============================] - 37s 24ms/step - loss: 1.3940 - accuracy: 0.
5174 - val_loss: 1.2417 - val_accuracy: 0.6388
Epoch 25/30
1562/1562 [==============================] - 41s 26ms/step - loss: 1.3892 - accuracy: 0.
5217 - val_loss: 1.0952 - val_accuracy: 0.6325
Epoch 26/30
1562/1562 [==============================] - 39s 25ms/step - loss: 1.3846 - accuracy: 0.
5214 - val_loss: 1.1270 - val_accuracy: 0.6306
Epoch 27/30
1562/1562 [==============================] - 38s 24ms/step - loss: 1.3926 - accuracy: 0.
5193 - val_loss: 1.0787 - val_accuracy: 0.6488
Epoch 28/30
1562/1562 [==============================] - 39s 25ms/step - loss: 1.4010 - accuracy: 0.
5158 - val_loss: 1.1407 - val_accuracy: 0.5994
Epoch 29/30
1562/1562 [==============================] - 39s 25ms/step - loss: 1.4010 - accuracy: 0.
5137 - val_loss: 1.0905 - val_accuracy: 0.6300
Epoch 30/30
1562/1562 [==============================] - 38s 24ms/step - loss: 1.3944 - accuracy: 0.
5188 - val_loss: 1.0220 - val_accuracy: 0.6475
```

In [46]:

```
# save the model
model.save('results/CNN_cifar10_augmented_model')
model.save('results/CNN_cifar10_augmented_model.h5')
```

```
WARNING:absl:Found untraced functions such as _jit_compiled_convolution_op, _jit_compile
d_convolution_op while saving (showing 2 of 2). These functions will not be directly cal
lable after loading.
```

# Predictions

In [47]:

```
test_generator.reset()
predictions = model.predict(test_generator,steps = len(x_test) // batch_size)
predictions.tofile('results/CNN_cifar10_augmented_predictions.csv', sep = ',')
```

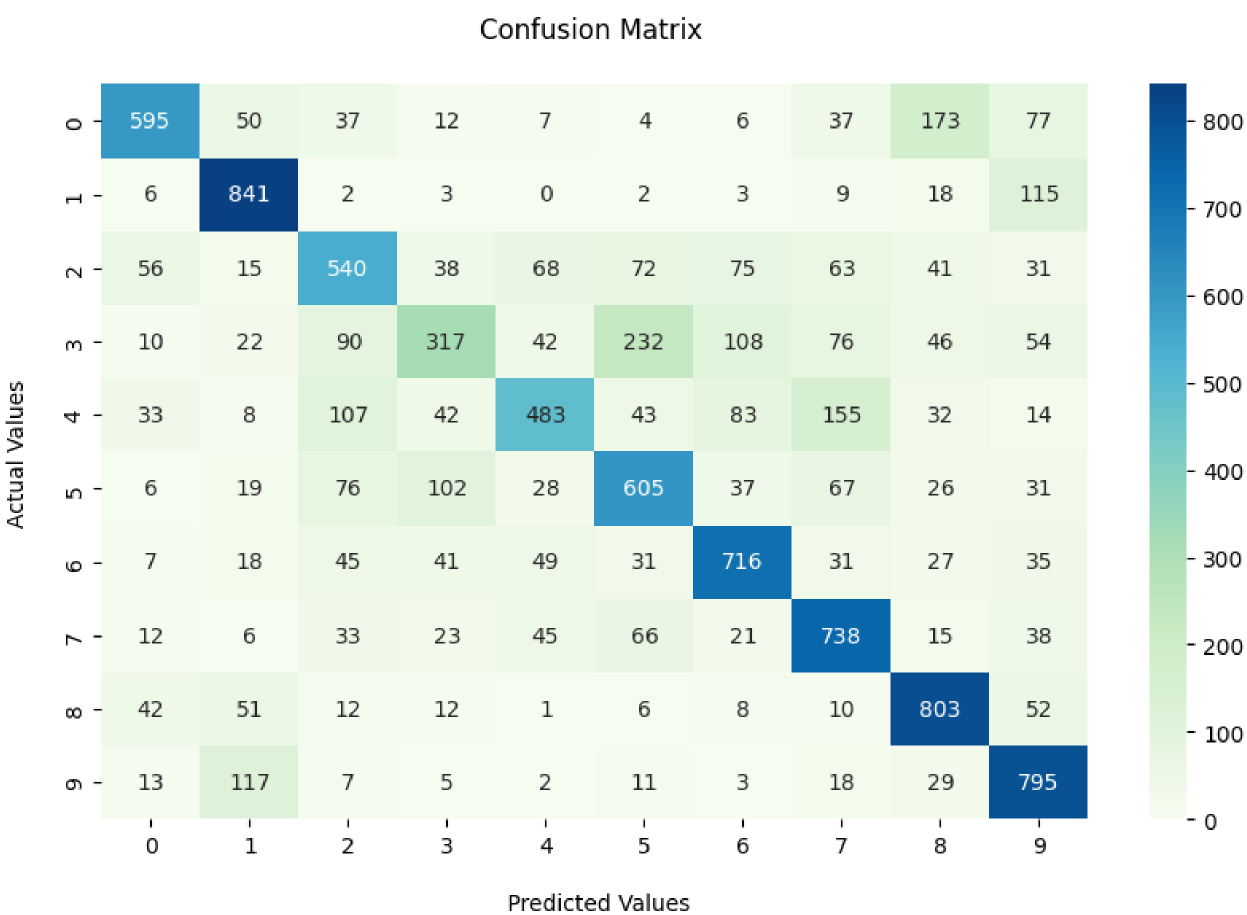
```
312/312 [==============================] - 1s 4ms/step
```

In [48]:
```python
predictions.shape
```

Out[48]:
```
(9984, 10)
```

In [49]:
```python
max_y_test = np.argmax(y_test[:9984], axis=1)

max_predictions = np.argmax(predictions, axis=1)
```

In [50]:
```python
import seaborn as sns
from sklearn.metrics import confusion_matrix

confusion = confusion_matrix(max_y_test, max_predictions)
plt.figure(figsize=(10,6))
fx=sns.heatmap(confusion, annot=True, fmt=".0f",cmap="GnBu")
fx.set_title('Confusion Matrix \n');
fx.set_xlabel('\n Predicted Values\n')
fx.set_ylabel('Actual Values\n');

plt.savefig("results/CNN_cifar10_augmented_confusionmatrix.png")

plt.show()
```




# Metrics

In [51]:

```
test_generator.reset()
results = model.evaluate(test_generator)
```

```
313/313 [==============================] - 1s 5ms/step - loss: 1.0655 - accuracy: 0.6443
```

In [52]:

```
from sklearn.metrics import classification_report
class_report = classification_report(max_y_test, max_predictions)
print(class_report)

#open text file
text_file = open("results/CNN_cifar10_augmented_metrics.txt", "w")

#write string to file
text_file.write(class_report)

#close file
text_file.close()
```

```
              precision    recall  f1-score   support

           0       0.76      0.60      0.67       998
           1       0.73      0.84      0.78       999
           2       0.57      0.54      0.55       999
           3       0.53      0.32      0.40       997
           4       0.67      0.48      0.56      1000
           5       0.56      0.61      0.58       997
           6       0.68      0.72      0.70      1000
           7       0.61      0.74      0.67       997
           8       0.66      0.81      0.73       997
           9       0.64      0.80      0.71      1000

    accuracy                           0.64      9984
   macro avg       0.64      0.64      0.64      9984
weighted avg       0.64      0.64      0.64      9984
```

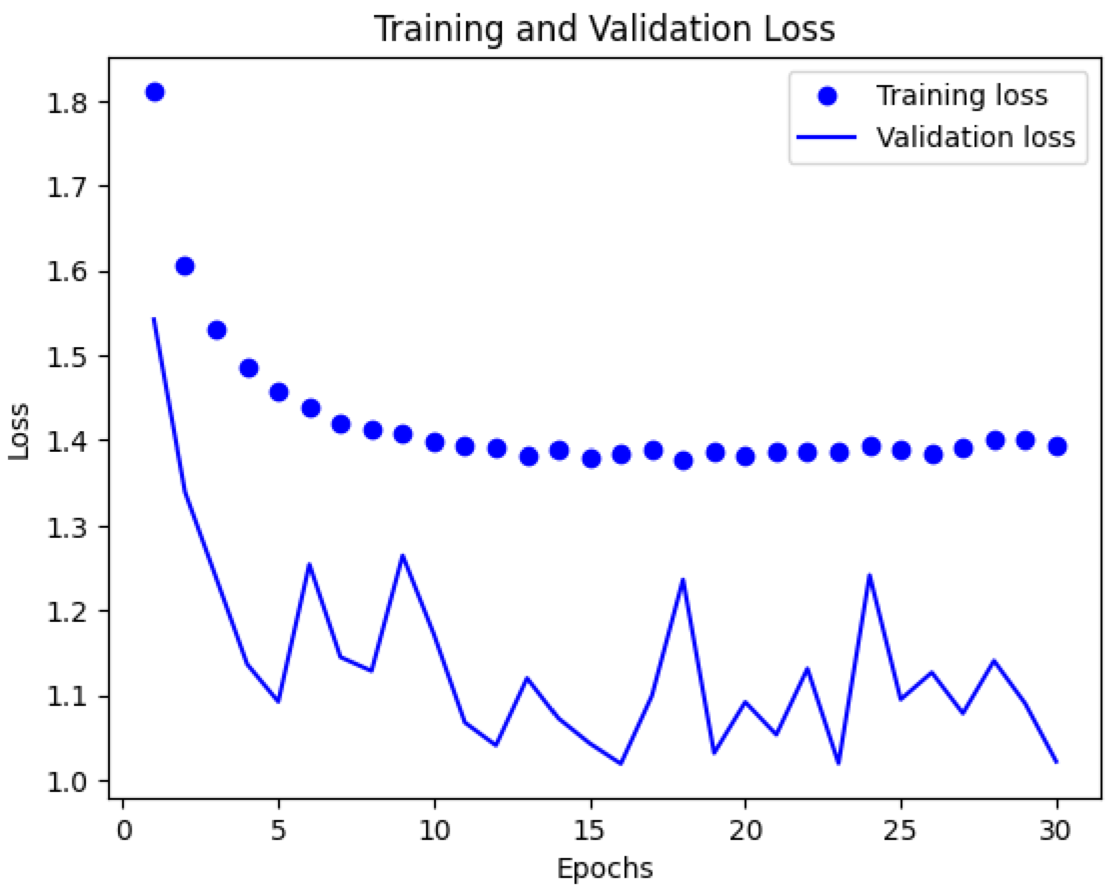
# Validation Plots

In [52]:

In [53]:

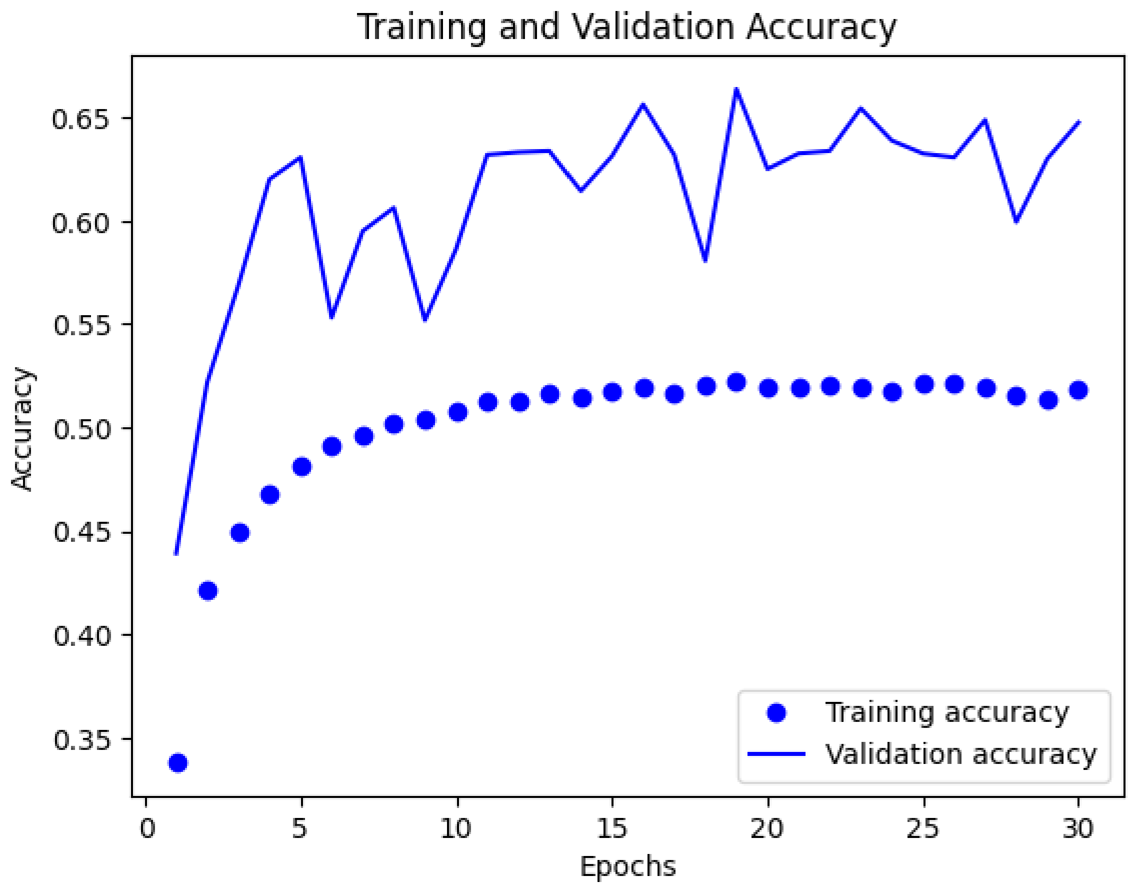
```
# plot loss

loss = history.history['loss']
val_loss = history.history['val_loss']

epochs = range(1, len(loss)+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.xlabel('Epochs')
plt.ylabel('Loss')
plt.legend()

plt.savefig("results/CNN_cifar10_augmented_loss.png")
```

```
plt.show()
```




In [54]:

```
# plot accuracy

plt.clf()

acc = history.history['accuracy']
val_acc = history.history['val_accuracy']

plt.plot(epochs, acc, 'bo', label='Training accuracy')
plt.plot(epochs, val_acc, 'b', label='Validation accuracy')
plt.title('Training and Validation Accuracy')
plt.xlabel('Epochs')
plt.ylabel('Accuracy')
plt.legend()

plt.savefig("results/CNN_cifar10_augmented_accuracy.png")

plt.show()
```




In [54]:

```
# I expected the model with augmentation and dropout to perform better than the model w
```

## Resnet50 Pretrained Model Predictions

In [56]:

```
import tensorflow
import keras
from keras import applications
from keras import preprocessing
from tensorflow.keras.applications.resnet50 import ResNet50
from tensorflow.keras.preprocessing import image
from tensorflow.keras.applications.resnet50 import preprocess_input, decode_predictions
import numpy as np

model = ResNet50(weights='imagenet')
```

```
Downloading data from https://storage.googleapis.com/tensorflow/keras-applications/resne
t/resnet50_weights_tf_dim_ordering_tf_kernels.h5
102967424/102967424 [==============================] - 1s 0us/step
```

In [57]:

```
img_path = 'images/river.jpg'
img = image.load_img(img_path, target_size=(224, 224))
x = image.img_to_array(img)
x = np.expand_dims(x, axis=0)
x = preprocess_input(x)

preds = model.predict(x)
print('Predicted:', decode_predictions(preds, top=3)[0])
```

```
1/1 [==============================] - 3s 3s/step
Downloading data from https://storage.googleapis.com/download.tensorflow.org/data/imagen
et_class_index.json
35363/35363 [==============================] - 0s 0us/step
Predicted: [('n09468604', 'valley', 0.38834167), ('n09246464', 'cliff', 0.09706052), ('n
09332890', 'lakeside', 0.094666556)]
```

In [58]:

```
img_path = 'images/tree.jpg'
img = image.load_img(img_path, target_size=(224, 224))
x = image.img_to_array(img)
x = np.expand_dims(x, axis=0)
x = preprocess_input(x)

preds = model.predict(x)
print('Predicted:', decode_predictions(preds, top=3)[0])
```

```
1/1 [==============================] - 0s 27ms/step
Predicted: [('n02793495', 'barn', 0.11131605), ('n04604644', 'worm_fence', 0.10649704),
('n11879895', 'rapeseed', 0.10641846)]
```

In [59]:

```
img_path = 'images/chicken.jpg'
img = image.load_img(img_path, target_size=(224, 224))
x = image.img_to_array(img)
x = np.expand_dims(x, axis=0)
x = preprocess_input(x)

preds = model.predict(x)
print('Predicted:', decode_predictions(preds, top=3)[0])
```

```
1/1 [==============================] - 0s 36ms/step
Predicted: [('n01514859', 'hen', 0.8507484), ('n01514668', 'cock', 0.14899172), ('n01855
672', 'goose', 0.00017138451)]
```

In [60]:

```
img_path = 'images/donkey.jpg'
img = image.load_img(img_path, target_size=(224, 224))
x = image.img_to_array(img)
x = np.expand_dims(x, axis=0)
x = preprocess_input(x)

preds = model.predict(x)
print('Predicted:', decode_predictions(preds, top=3)[0])
```

```
1/1 [==============================] - 0s 43ms/step
Predicted: [('n02423022', 'gazelle', 0.24799536), ('n02437616', 'llama', 0.23290879),
('n02410509', 'bison', 0.13938038)]
```

In [64]:

```
img_path = 'images/boat.jpg'
img = image.load_img(img_path, target_size=(224, 224))
x = image.img_to_array(img)
x = np.expand_dims(x, axis=0)
x = preprocess_input(x)

preds = model.predict(x)
print('Predicted:', decode_predictions(preds, top=3)[0])
```

```
1/1 [==============================] - 0s 24ms/step
Predicted: [('n04273569', 'speedboat', 0.50600773), ('n03344393', 'fireboat', 0.1657924
```

5), ('n09332890', 'lakeside', 0.10772088)]

In [65]:

```
img_path = 'images/crosswalk.jpg'
img = image.load_img(img_path, target_size=(224, 224))
x = image.img_to_array(img)
x = np.expand_dims(x, axis=0)
x = preprocess_input(x)

preds = model.predict(x)
print('Predicted:', decode_predictions(preds, top=3)[0])
```

```
1/1 [==============================] - 0s 77ms/step
Predicted: [('n03733281', 'maze', 0.7480029), ('n03717622', 'manhole_cover', 0.0728127
7), ('n04355338', 'sundial', 0.030221142)]
```

In [66]:

```
img_path = 'images/traffic_light.jpg'
img = image.load_img(img_path, target_size=(224, 224))
x = image.img_to_array(img)
x = np.expand_dims(x, axis=0)
x = preprocess_input(x)

preds = model.predict(x)
print('Predicted:', decode_predictions(preds, top=3)[0])
```

```
1/1 [==============================] - 0s 81ms/step
Predicted: [('n06874185', 'traffic_light', 0.9994947), ('n03126707', 'crane', 0.00018885
13), ('n04371774', 'swing', 0.00016358876)]
```

In [67]:

```
img_path = 'images/dog.jpg'
img = image.load_img(img_path, target_size=(224, 224))
x = image.img_to_array(img)
x = np.expand_dims(x, axis=0)
x = preprocess_input(x)

preds = model.predict(x)
print('Predicted:', decode_predictions(preds, top=3)[0])
```

```
1/1 [==============================] - 0s 46ms/step
Predicted: [('n02099712', 'Labrador_retriever', 0.7671822), ('n02099601', 'golden_retrie
ver', 0.21572998), ('n02113799', 'standard_poodle', 0.005650355)]
```

In [68]:

```
img_path = 'images/cat.jpg'
img = image.load_img(img_path, target_size=(224, 224))
x = image.img_to_array(img)
x = np.expand_dims(x, axis=0)
x = preprocess_input(x)

preds = model.predict(x)
print('Predicted:', decode_predictions(preds, top=3)[0])
```

```
1/1 [==============================] - 0s 46ms/step
Predicted: [('n02123394', 'Persian_cat', 0.9989759), ('n02123045', 'tabby', 0.000451667
8), ('n02127052', 'lynx', 0.00016683698)]
```

In [69]:

```
img_path = 'images/bird.jpg'
img = image.load_img(img_path, target_size=(224, 224))
x = image.img_to_array(img)
```

```python
x = np.expand_dims(x, axis=0)
x = preprocess_input(x)

preds = model.predict(x)
print('Predicted:', decode_predictions(preds, top=3)[0])
```

```
1/1 [==============================] - 0s 48ms/step
Predicted: [('n01531178', 'goldfinch', 0.9966943), ('n01530575', 'brambling', 0.00200899
6), ('n01537544', 'indigo_bunting', 0.0003059842)]
```