In [36]:
```
from keras import layers
from keras import models
from keras.datasets import mnist
from keras.utils import to_categorical
import matplotlib.pyplot as plt
import numpy as np
(train_images, train_labels), (test_images, test_labels) = mnist.load_data()
```

In [37]:
```
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 [38]:
```
model.summary()
```

```
Model: "sequential_5"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv2d_15 (Conv2D)           (None, 26, 26, 32)        320
_________________________________________________________________
max_pooling2d_10 (MaxPooling (None, 13, 13, 32)        0
_________________________________________________________________
conv2d_16 (Conv2D)           (None, 11, 11, 64)        18496
_________________________________________________________________
max_pooling2d_11 (MaxPooling (None, 5, 5, 64)          0
_________________________________________________________________
conv2d_17 (Conv2D)           (None, 3, 3, 64)          36928
_________________________________________________________________
flatten_4 (Flatten)          (None, 576)               0
_________________________________________________________________
dense_8 (Dense)              (None, 64)                36928
_________________________________________________________________
dense_9 (Dense)              (None, 10)                650
=================================================================
Total params: 93,322
Trainable params: 93,322
Non-trainable params: 0
_________________________________________________________________
```

In [39]:
```
train_images = train_images.reshape((60000, 28, 28, 1))
train_images = train_images.astype('float32') / 255

test_images = test_images.reshape((10000, 28, 28, 1))
test_images = test_images.astype('float32') / 255

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

x_val = train_images[:1000]
y_val = train_labels[:1000]

partial_x_train = train_images[1000:]
partial_y_train = train_labels[1000:]
#x_train = vectorize_sequences(train_images)
#x_test = vectorize_sequences(test_images)
#y_train = np.asarray(train_labels).astype('float32')
#y_test = np.asarray(test_labels).astype('float32')

model.compile(optimizer = 'rmsprop', loss = 'categorical_crossentropy', metric
s = ['accuracy'])
history = model.fit(partial_x_train,
                   partial_y_train,
                   epochs = 20,
                   batch_size = 64,
                   validation_data = (x_val, y_val))

#test_loss, test_acc = model.evaluate(test_images, test_labels)
```

```
Epoch 1/20
922/922 [==============================] - 12s 13ms/step - loss: 0.1700 - acc
uracy: 0.9466 - val_loss: 0.0975 - val_accuracy: 0.9790
Epoch 2/20
922/922 [==============================] - 12s 13ms/step - loss: 0.0468 - acc
uracy: 0.9850 - val_loss: 0.0861 - val_accuracy: 0.9860
Epoch 3/20
922/922 [==============================] - 12s 13ms/step - loss: 0.0320 - acc
uracy: 0.9901 - val_loss: 0.0668 - val_accuracy: 0.9880
Epoch 4/20
922/922 [==============================] - 12s 13ms/step - loss: 0.0235 - acc
uracy: 0.9926 - val_loss: 0.0516 - val_accuracy: 0.9900
Epoch 5/20
922/922 [==============================] - 12s 13ms/step - loss: 0.0189 - acc
uracy: 0.9941 - val_loss: 0.0661 - val_accuracy: 0.9880
Epoch 6/20
922/922 [==============================] - 12s 13ms/step - loss: 0.0155 - acc
uracy: 0.9949 - val_loss: 0.0554 - val_accuracy: 0.9870
Epoch 7/20
922/922 [==============================] - 12s 13ms/step - loss: 0.0120 - acc
uracy: 0.9959 - val_loss: 0.0474 - val_accuracy: 0.9900
Epoch 8/20
922/922 [==============================] - 12s 13ms/step - loss: 0.0103 - acc
uracy: 0.9968 - val_loss: 0.0620 - val_accuracy: 0.9870
Epoch 9/20
922/922 [==============================] - 12s 13ms/step - loss: 0.0091 - acc
uracy: 0.9973 - val_loss: 0.0615 - val_accuracy: 0.9890
Epoch 10/20
922/922 [==============================] - 12s 13ms/step - loss: 0.0075 - acc
uracy: 0.9976 - val_loss: 0.1149 - val_accuracy: 0.9890
Epoch 11/20
922/922 [==============================] - 12s 13ms/step - loss: 0.0064 - acc
uracy: 0.9980 - val_loss: 0.0965 - val_accuracy: 0.9880
Epoch 12/20
922/922 [==============================] - 12s 13ms/step - loss: 0.0061 - acc
uracy: 0.9982 - val_loss: 0.0850 - val_accuracy: 0.9880
Epoch 13/20
922/922 [==============================] - 12s 13ms/step - loss: 0.0054 - acc
uracy: 0.9984 - val_loss: 0.1128 - val_accuracy: 0.9890
Epoch 14/20
922/922 [==============================] - 12s 13ms/step - loss: 0.0049 - acc
uracy: 0.9985 - val_loss: 0.1155 - val_accuracy: 0.9910
Epoch 15/20
922/922 [==============================] - 12s 13ms/step - loss: 0.0047 - acc
uracy: 0.9987 - val_loss: 0.0951 - val_accuracy: 0.9910
Epoch 16/20
922/922 [==============================] - 12s 13ms/step - loss: 0.0039 - acc
uracy: 0.9986 - val_loss: 0.1215 - val_accuracy: 0.9880
Epoch 17/20
922/922 [==============================] - 12s 13ms/step - loss: 0.0035 - acc
uracy: 0.9991 - val_loss: 0.1201 - val_accuracy: 0.9920
Epoch 18/20
922/922 [==============================] - 12s 13ms/step - loss: 0.0043 - acc
uracy: 0.9989 - val_loss: 0.1147 - val_accuracy: 0.9870
Epoch 19/20
922/922 [==============================] - 12s 13ms/step - loss: 0.0036 - acc
uracy: 0.9989 - val_loss: 0.1253 - val_accuracy: 0.9920
```

```
Epoch 20/20
922/922 [==============================] - 12s 13ms/step - loss: 0.0027 - acc
uracy: 0.9992 - val_loss: 0.1522 - val_accuracy: 0.9920
```

In [35]:

```
```

Out[35]:
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```

In [43]:

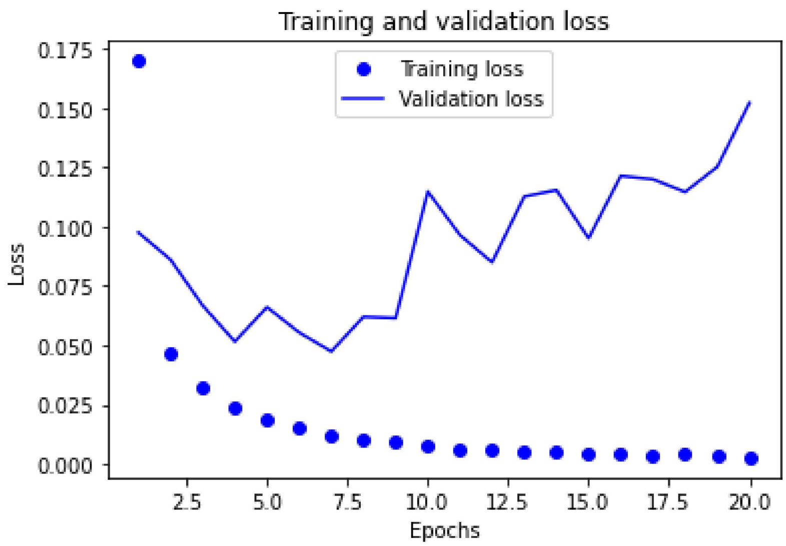
```
history_dict = history.history
loss_values = history_dict['loss']
accuracy_values = history_dict['accuracy']
val_accuracy_values = history_dict['val_accuracy']
val_loss_values = history_dict['val_loss']
#print(history_dict['binary_accuracy'])
print(history_dict.keys())
```

```
dict_keys(['loss', 'accuracy', 'val_loss', 'val_accuracy'])
```

In [44]:
```
epochs = range(1, len(accuracy_values) + 1)

plt.plot(epochs, loss_values, 'bo', label = 'Training loss')
plt.plot(epochs, val_loss_values, 'b', label = 'Validation loss')
plt.title('Training and validation loss')
plt.xlabel('Epochs')
plt.ylabel('Loss')
plt.legend()

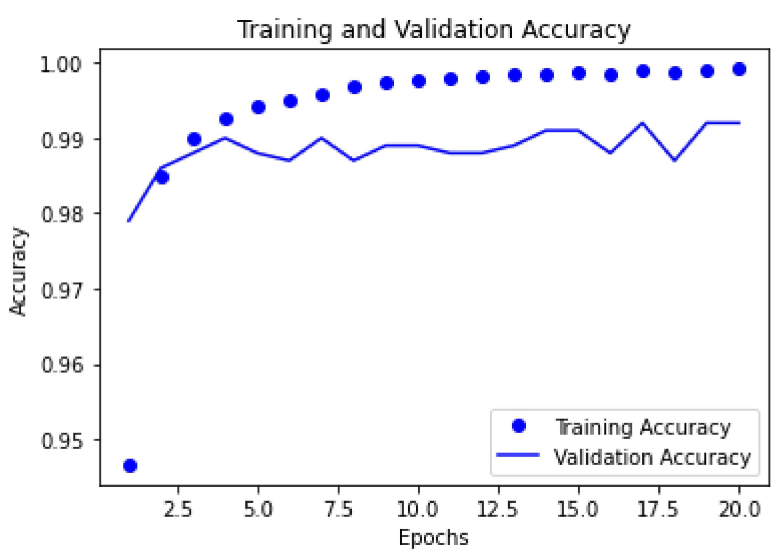
plt.show()
```



In [45]:
```
plt.clf()

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

plt.show()
```



In [46]:
```
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 [47]:
```
model.compile(optimizer = 'rmsprop', loss = 'categorical_crossentropy', metric
s = ['accuracy'])
history = model.fit(partial_x_train,
                    partial_y_train,
                    epochs = 7,
                    batch_size = 64,
                    validation_data = (x_val, y_val))
```

```
Epoch 1/7
922/922 [==============================] - 12s 13ms/step - loss: 0.1652 - acc
uracy: 0.9494 - val_loss: 0.1173 - val_accuracy: 0.9690
Epoch 2/7
922/922 [==============================] - 12s 13ms/step - loss: 0.0474 - acc
uracy: 0.9858 - val_loss: 0.0555 - val_accuracy: 0.9870
Epoch 3/7
922/922 [==============================] - 12s 13ms/step - loss: 0.0322 - acc
uracy: 0.9901 - val_loss: 0.0613 - val_accuracy: 0.9860
Epoch 4/7
922/922 [==============================] - 12s 13ms/step - loss: 0.0238 - acc
uracy: 0.9927 - val_loss: 0.0723 - val_accuracy: 0.9820
Epoch 5/7
922/922 [==============================] - 12s 13ms/step - loss: 0.0193 - acc
uracy: 0.9944 - val_loss: 0.0563 - val_accuracy: 0.9850
Epoch 6/7
922/922 [==============================] - 12s 13ms/step - loss: 0.0158 - acc
uracy: 0.9951 - val_loss: 0.0591 - val_accuracy: 0.9910
Epoch 7/7
922/922 [==============================] - 12s 13ms/step - loss: 0.0134 - acc
uracy: 0.9961 - val_loss: 0.0607 - val_accuracy: 0.9870
```

In [48]:
```
results = model.evaluate(test_images, test_labels)
```

```
313/313 [==============================] - 1s 4ms/step - loss: 0.0359 - accur
acy: 0.9908
```

In [49]:
```
results
```

Out[49]:
```
[0.035931408405303955, 0.9908000230789185]
```

In [ ]:
```
```