In [2]:
```
#importing all the libraries
import warnings;
#disable warnings
warnings.simplefilter('ignore')

import os
os.environ["KERAS_BACKEND"] = "tensorflow"

#set image data format to channels_last
from tensorflow.keras.backend import set_image_data_format
set_image_data_format('channels_last')

import numpy as np
from keras.datasets import mnist
from matplotlib import pyplot as plt
%matplotlib inline

from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import Dense, Dropout, Activation, Flatten
from tensorflow.keras.layers import Conv2D, MaxPooling2D
from tensorflow.keras.preprocessing.image import ImageDataGenerator


#from keras.utils import np_utils
#from tensorflow.keras.utils import np_utils

#np_utils no longer exists in this package
#replace with to_categorical, should be equivalent
from tensorflow.keras.utils import to_categorical
```

```
WARNING:tensorflow:From C:\Users\vbque\anaconda3\Lib\site-packages\keras\src\losses.p
y:2976: The name tf.losses.sparse_softmax_cross_entropy is deprecated. Please use tf.
compat.v1.losses.sparse_softmax_cross_entropy instead.
```

In [3]:
```
#read in the data
data = r'C:\Users\vbque\OneDrive\Desktop\Machine Learning\Assignment6\Assignment 6\dat

#data generators
batch_size = 32
img_height, img_width = 28, 28

train_datagen = ImageDataGenerator(rescale=1./255, validation_split=0.2)

#train
train_generator = train_datagen.flow_from_directory(
    data,
    target_size=(img_height, img_width),
    batch_size=batch_size,
    class_mode='categorical',
    subset='training'
)
```

```
Found 60 images belonging to 2 classes.
```

In [4]:
```
#validate
validation_generator = train_datagen.flow_from_directory(
    data,
    target_size=(img_height, img_width),
```

```
    batch_size=batch_size,
    class_mode='categorical',
    subset='validation'
)
```

```
Found 14 images belonging to 2 classes.
```

In [5]:
```
#make CNN model
model = Sequential()

model.add(Conv2D(32, (3, 3), activation='relu', input_shape=(28, 28, 3)))
model.add(Conv2D(64, (3, 3), activation='relu'))
model.add(MaxPooling2D((2, 2)))
model.add(Dropout(0.25))

model.add(Flatten())

#model.add(Dense(128, activation='relu'))
#model.add(Dropout(0.5))
#model.add(Dense(10, activation='softmax'))

model.add(Dense(64, activation='relu'))
model.add(Dense(2, activation='softmax'))  #2 classes: covid and normal

model.summary()
```

```
WARNING:tensorflow:From C:\Users\vbque\anaconda3\Lib\site-packages\keras\src\backend.
py:873: The name tf.get_default_graph is deprecated. Please use tf.compat.v1.get_defa
ult_graph instead.

WARNING:tensorflow:From C:\Users\vbque\anaconda3\Lib\site-packages\keras\src\layers\p
ooling\max_pooling2d.py:161: The name tf.nn.max_pool is deprecated. Please use tf.nn.
max_pool2d instead.

Model: "sequential"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 conv2d (Conv2D)             (None, 26, 26, 32)        896

 conv2d_1 (Conv2D)           (None, 24, 24, 64)        18496

 max_pooling2d (MaxPooling2  (None, 12, 12, 64)        0
 D)

 dropout (Dropout)           (None, 12, 12, 64)        0

 flatten (Flatten)           (None, 9216)              0

 dense (Dense)               (None, 64)                589888

 dense_1 (Dense)             (None, 2)                 130

=================================================================
Total params: 609410 (2.32 MB)
Trainable params: 609410 (2.32 MB)
Non-trainable params: 0 (0.00 Byte)
_________________________________________________________________
```

In [6]:
```
#compile
model.compile(optimizer='adam', loss='categorical_crossentropy', metrics=['accuracy'])
```

```
WARNING:tensorflow:From C:\Users\vbque\anaconda3\Lib\site-packages\keras\src\optimizers\__init__.py:309: The name tf.train.Optimizer is deprecated. Please use tf.compat.v1.train.Optimizer instead.
```

In [7]:
```python
#train the model
epochs = 10

history = model.fit(train_generator,
                    epochs=epochs,
                    validation_data=validation_generator,
                    steps_per_epoch=len(train_generator),
                    validation_steps=len(validation_generator))
```

```
Epoch 1/10
WARNING:tensorflow:From C:\Users\vbque\anaconda3\Lib\site-packages\keras\src\utils\tf_utils.py:492: The name tf.ragged.RaggedTensorValue is deprecated. Please use tf.compat.v1.ragged.RaggedTensorValue instead.

WARNING:tensorflow:From C:\Users\vbque\anaconda3\Lib\site-packages\keras\src\engine\base_layer_utils.py:384: The name tf.executing_eagerly_outside_functions is deprecated. Please use tf.compat.v1.executing_eagerly_outside_functions instead.

2/2 [==============================] - 2s 707ms/step - loss: 0.6550 - accuracy: 0.5167 - val_loss: 0.8210 - val_accuracy: 0.5000
Epoch 2/10
2/2 [==============================] - 1s 431ms/step - loss: 0.6739 - accuracy: 0.5333 - val_loss: 0.6068 - val_accuracy: 0.5714
Epoch 3/10
2/2 [==============================] - 1s 408ms/step - loss: 0.5011 - accuracy: 0.8167 - val_loss: 0.5707 - val_accuracy: 0.5714
Epoch 4/10
2/2 [==============================] - 1s 485ms/step - loss: 0.4277 - accuracy: 0.8833 - val_loss: 0.5167 - val_accuracy: 0.7857
Epoch 5/10
2/2 [==============================] - 1s 505ms/step - loss: 0.2941 - accuracy: 0.9667 - val_loss: 0.4703 - val_accuracy: 0.7857
Epoch 6/10
2/2 [==============================] - 1s 391ms/step - loss: 0.2173 - accuracy: 0.9833 - val_loss: 0.4446 - val_accuracy: 0.7857
Epoch 7/10
2/2 [==============================] - 1s 543ms/step - loss: 0.1409 - accuracy: 0.9667 - val_loss: 0.4155 - val_accuracy: 0.8571
Epoch 8/10
2/2 [==============================] - 1s 338ms/step - loss: 0.0959 - accuracy: 0.9833 - val_loss: 0.4747 - val_accuracy: 0.8571
Epoch 9/10
2/2 [==============================] - 1s 567ms/step - loss: 0.0526 - accuracy: 1.0000 - val_loss: 0.4268 - val_accuracy: 0.9286
Epoch 10/10
2/2 [==============================] - 1s 532ms/step - loss: 0.0593 - accuracy: 0.9833 - val_loss: 0.4794 - val_accuracy: 0.9286
```

In [8]:
```python
#model evaluation
score = model.evaluate(validation_generator, verbose=1)
print(f'Test loss: {score[0]}, Test accuracy: {score[1]}')

#test accuracy is 92.86%
```

```
1/1 [==============================] - 0s 161ms/step - loss: 0.4794 - accuracy: 0.928
6
Test loss: 0.4794378876686096, Test accuracy: 0.9285714030265808
```

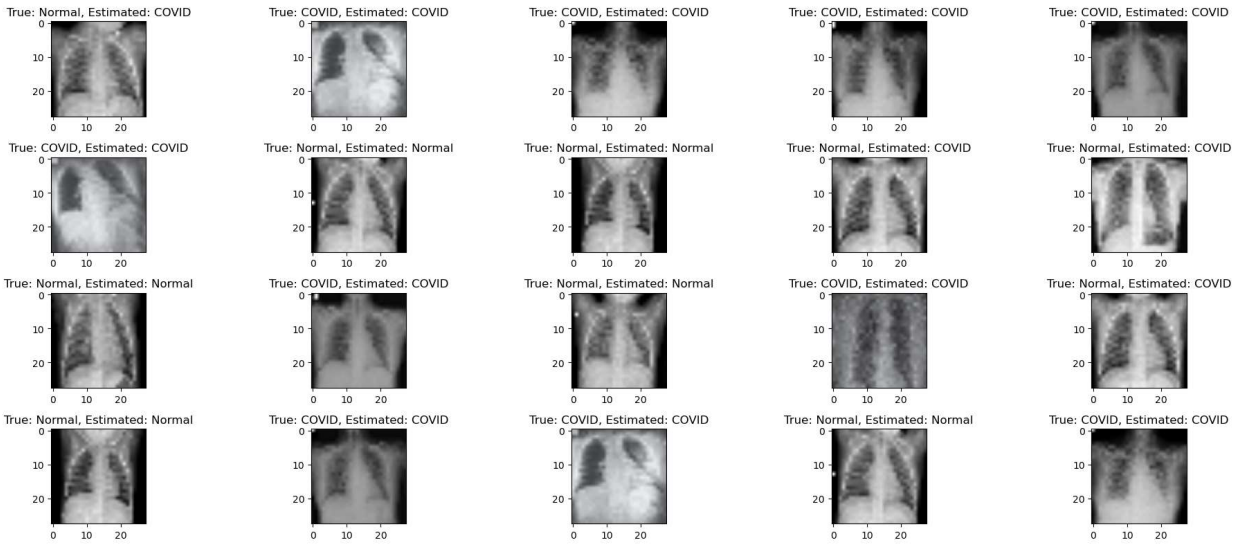
In [9]:
```python
#test set predictions
y_hat = model.predict(validation_generator)
```

```
1/1 [==============================] - 0s 199ms/step
```

In [ ]:
```python
#!pip install opencv-python
```

In [28]:
```python
import matplotlib.pyplot as plt
import numpy as np

plt.figure(figsize=(20, 8))  #increase the figure size for better visualization
j = 1
max_plots = 20  #20 images to be predicted
break_outer_loop = False
class_labels = {0: 'COVID', 1: 'Normal'}  #0 is COVID and 1 is Normal

for batch in validation_generator:
    images, labels = batch

    y_hat = model.predict(images)

    for i in range(len(y_hat)):
        threshold1 = y_hat[i] < 0.1
        y_hat[i][threshold1] = 0
        threshold2 = y_hat[i] > 0.9
        y_hat[i][threshold2] = 1
        y_hat[i] = y_hat[i].astype(int)

        estimated = np.argmax(y_hat[i])
        true = np.argmax(labels[i])

        plt.subplot(4, 5, j)  #4 rows, 5 images per row, 20 pics total
        title = f'True: {class_labels[true]}, Estimated: {class_labels[estimated]}'
        plt.imshow(images[i], interpolation='bilinear') #makes images clearer
        plt.title(title)

        if estimated == true:
            correct_predictions += 1

        j += 1
        if j > max_plots:
            break_outer_loop = True
            break

    if break_outer_loop:
        break

plt.tight_layout()
plt.show()
```

```
1/1 [==============================] - 0s 14ms/step
1/1 [==============================] - 0s 15ms/step
```



We can see in the 20 images in the output above (different each run), the classification under True: Normal or True: COVID shows the true classification of the images (which folder they come from). The Estimated: Normal or Estimated: COVID shows what the classification model predicted them to be.

The calculation of accuracy in one of the earlier chunks shows that the test accuracy is 92.86%.

False negatives occur as True: COVID, Estimated: Normal

False positives occur as True: Normal, Estimated: COVID

I ran the model a few times to get various outcomes in classification predictions. In some of the runs, there were a couple false negatives or positives (~86% accurate), but

some runs had 100% correct predictions (20/20).

Ultimately, the overall accuracy of 92.86% is good, and could potentially be increase by further normalizing the data, or having a larger dataset to train and test the model on.

In [ ]: