In [ ]:
```
# CAP6619 Deep Learning Summer 2024 - CNNImageClassification.ipynb
# Benjamin Luo
# 6/9/2024
#
# CNN Image Classification
# Dog vs. Cat classification
# Downloaded data from https://www.kaggle.com/c/dogs-vs-cats/data
# For training set, used cat/dog 1-500, 3001-3500
# For test set, used cat/dog 1501-2000, 4000-4499
# For validation set, used cat/dog 1001-1500
```

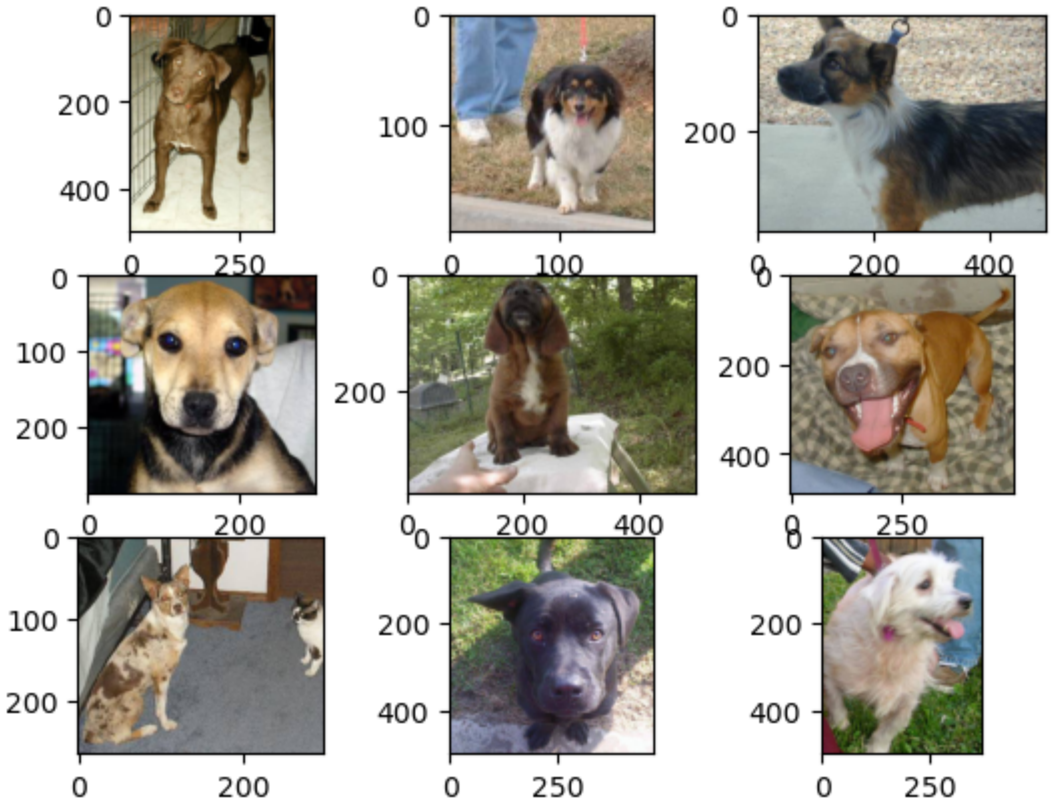
In [ ]:
```
from matplotlib import pyplot as plt
from matplotlib.image import imread
from keras.utils import to_categorical
from keras.models import Sequential
from keras.layers import Conv2D, MaxPooling2D, Dense, Dropout, Flatten, BatchNormal
from keras.optimizers import SGD
from keras.preprocessing.image import ImageDataGenerator

folder = "dogvscat/"
```

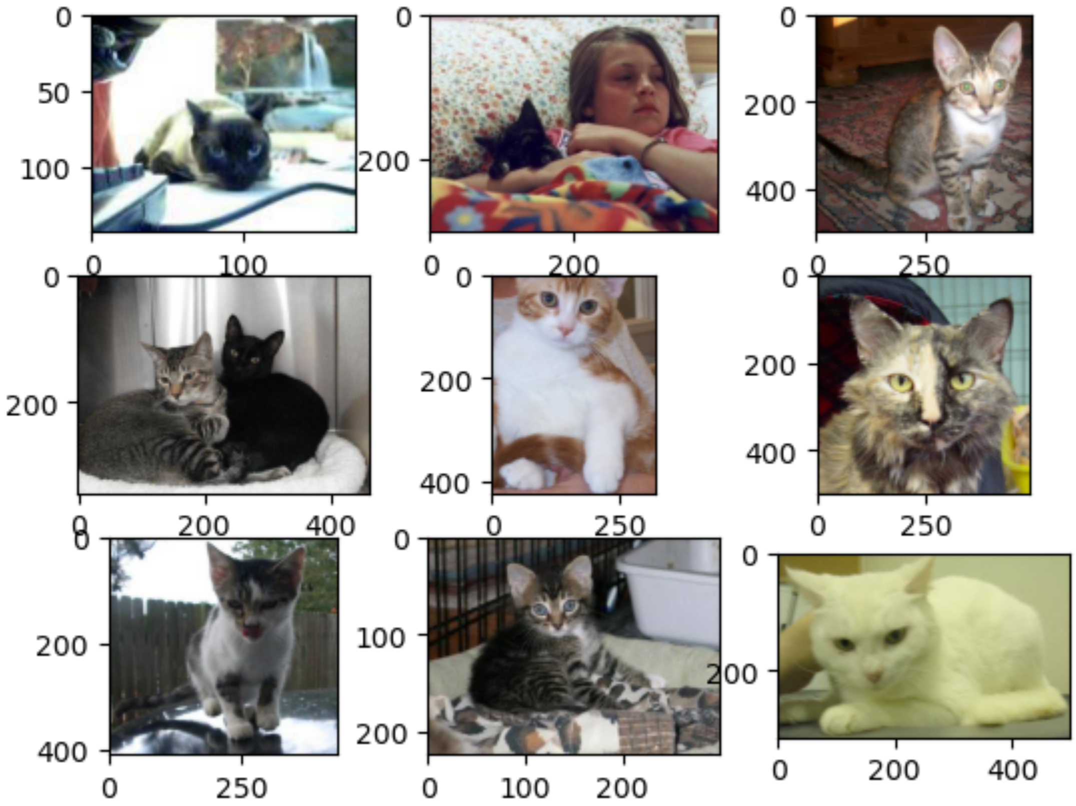
In [ ]:
```
def displayImages(foldername, dogorcat, startID):
    for i in range(9):
        plt.subplot(330+1+i)
        filename = foldername + dogorcat + "." + str(i+startID) + ".jpg"
        image = imread(filename)
        plt.imshow(image)

plt.show()
```

In [ ]:
```
displayImages(folder+"train/dog/", "dog", 1)
```



```
In [ ]: displayImages(folder+"train/cat/", "cat", 5)
```



```
In [ ]: training_data_generator = ImageDataGenerator(
            rotation_range=40,
            width_shift_range=0.2,
            height_shift_range=0.2,
            rescale=1./255,
            shear_range=0.2,
            zoom_range=0.2,
            horizontal_flip=True,
            fill_mode='nearest')
        validation_data_generator = ImageDataGenerator(rescale=1./255)
        test_data_generator = ImageDataGenerator(rescale=1./255)
```

In [ ]:

```
from tensorflow.keras.utils import array_to_img, img_to_array, load_img
img = load_img(folder+'train/dog/dog.1.jpg')
x = img_to_array(img)
x = x.reshape((1,) + x.shape)
i = 0
for batch in training_data_generator.flow(x, batch_size=1, save_to_dir='previews',
    i += 1
    if i > 10:
        break
```

In [ ]:

```
training_data_dir=folder+'train/'
validation_data_dir=folder+'validation/'
test_data_dir=folder+'test/'
IMAGE_WIDTH=150
IMAGE_HEIGHT=150
BATCH_SIZE=20

training_generator = training_data_generator.flow_from_directory(
    training_data_dir,
    target_size=(IMAGE_WIDTH, IMAGE_HEIGHT),
    batch_size=BATCH_SIZE,
    class_mode='binary'
)
validation_generator = validation_data_generator.flow_from_directory(
    validation_data_dir,
    target_size=(IMAGE_WIDTH,IMAGE_HEIGHT),
    batch_size=BATCH_SIZE,
    class_mode='binary'
)
test_generator = test_data_generator.flow_from_directory(
    test_data_dir,
    target_size=(IMAGE_WIDTH,IMAGE_HEIGHT),
    batch_size=1,
    class_mode='binary',
    shuffle=False
)
```

```
Found 2000 images belonging to 2 classes.
Found 1000 images belonging to 2 classes.
Found 2000 images belonging to 2 classes.
```

In [ ]:

```
# Create a CNN classifier with at least 3 conv layers, 2 pooling layers, and two de

model = Sequential()
model.add(Conv2D(32, (3,3),activation='relu', input_shape=(IMAGE_HEIGHT,IMAGE_WIDTH
model.add(MaxPooling2D(pool_size=(3,3)))
```

```python
model.add(Conv2D(32, (3,3),activation='relu'))
model.add(MaxPooling2D(pool_size=(2,2)))

model.add(Flatten())
model.add(Dense(100,activation='relu'))
model.add(Dropout(0.5))
model.add(Dense(1,activation='sigmoid'))

model.compile(loss='binary_crossentropy',
              optimizer='rmsprop',
              metrics=['accuracy'])
model.summary()
```

```
Model: "sequential_2"

_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 conv2d_4 (Conv2D)           (None, 148, 148, 32)      896

 max_pooling2d_4 (MaxPooling  (None, 49, 49, 32)       0
 2D)

 conv2d_5 (Conv2D)           (None, 47, 47, 32)        9248

 max_pooling2d_5 (MaxPooling  (None, 23, 23, 32)       0
 2D)

 flatten_2 (Flatten)         (None, 16928)             0


_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 conv2d_4 (Conv2D)           (None, 148, 148, 32)      896

 max_pooling2d_4 (MaxPooling  (None, 49, 49, 32)       0
 2D)

 conv2d_5 (Conv2D)           (None, 47, 47, 32)        9248

 max_pooling2d_5 (MaxPooling  (None, 23, 23, 32)       0
 2D)

 flatten_2 (Flatten)         (None, 16928)             0

 dense_4 (Dense)             (None, 100)               1692900

 dropout_2 (Dropout)         (None, 100)               0

 dense_5 (Dense)             (None, 1)                 101

=================================================================
Total params: 1,703,145
Trainable params: 1,703,145
Non-trainable params: 0
_________________________________________________________________
```

In [ ]:

```
# Train the network on the training set, and report the performance of the classifi

EPOCHS=20
history = model.fit(
    training_generator,
    steps_per_epoch=len(training_generator.filenames) // BATCH_SIZE,
    epochs=EPOCHS,
    validation_data= validation_generator,
    validation_steps=len(validation_generator.filenames) // BATCH_SIZE)
```

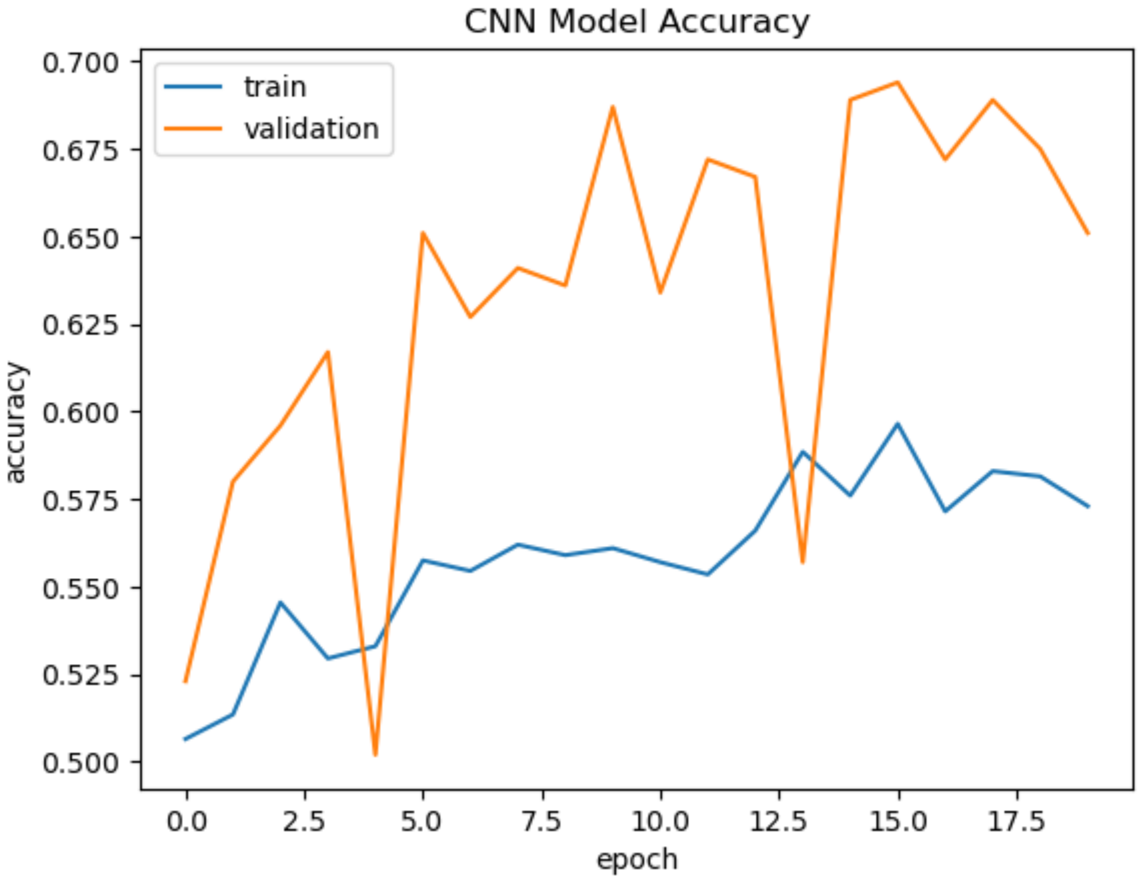
```
Epoch 1/20
100/100 [==============================] - 52s 506ms/step - loss: 0.7286 - accuracy:
0.5065 - val_loss: 0.6853 - val_accuracy: 0.5230
Epoch 2/20
100/100 [==============================] - 29s 286ms/step - loss: 0.7001 - accuracy:
0.5135 - val_loss: 0.6853 - val_accuracy: 0.5800
Epoch 3/20
100/100 [==============================] - 29s 288ms/step - loss: 0.7009 - accuracy:
0.5455 - val_loss: 0.6607 - val_accuracy: 0.5960
Epoch 4/20
100/100 [==============================] - 30s 300ms/step - loss: 0.6976 - accuracy:
0.5295 - val_loss: 0.6585 - val_accuracy: 0.6170
Epoch 5/20
100/100 [==============================] - 30s 295ms/step - loss: 0.6925 - accuracy:
0.5330 - val_loss: 0.8105 - val_accuracy: 0.5020
Epoch 6/20
100/100 [==============================] - 30s 296ms/step - loss: 0.6941 - accuracy:
0.5575 - val_loss: 0.6479 - val_accuracy: 0.6510
Epoch 7/20
100/100 [==============================] - 30s 297ms/step - loss: 0.6887 - accuracy:
0.5545 - val_loss: 0.6456 - val_accuracy: 0.6270
Epoch 8/20
100/100 [==============================] - 31s 309ms/step - loss: 0.6837 - accuracy:
0.5620 - val_loss: 0.6420 - val_accuracy: 0.6410
Epoch 9/20
100/100 [==============================] - 29s 290ms/step - loss: 0.6875 - accuracy:
0.5590 - val_loss: 0.6444 - val_accuracy: 0.6360
Epoch 10/20
100/100 [==============================] - 30s 299ms/step - loss: 0.6791 - accuracy:
0.5610 - val_loss: 0.6268 - val_accuracy: 0.6870
Epoch 11/20
100/100 [==============================] - 29s 292ms/step - loss: 0.6841 - accuracy:
0.5570 - val_loss: 0.6432 - val_accuracy: 0.6340
Epoch 12/20
100/100 [==============================] - 29s 288ms/step - loss: 0.6840 - accuracy:
0.5535 - val_loss: 0.6257 - val_accuracy: 0.6720
Epoch 13/20
100/100 [==============================] - 29s 290ms/step - loss: 0.6855 - accuracy:
0.5660 - val_loss: 0.6217 - val_accuracy: 0.6670
Epoch 14/20
100/100 [==============================] - 29s 293ms/step - loss: 0.6776 - accuracy:
0.5885 - val_loss: 0.7551 - val_accuracy: 0.5570
Epoch 15/20
100/100 [==============================] - 29s 292ms/step - loss: 0.6749 - accuracy:
0.5760 - val_loss: 0.6092 - val_accuracy: 0.6890
Epoch 16/20
100/100 [==============================] - 30s 298ms/step - loss: 0.6757 - accuracy:
0.5965 - val_loss: 0.6022 - val_accuracy: 0.6940
Epoch 17/20
100/100 [==============================] - 29s 290ms/step - loss: 0.6829 - accuracy:
0.5715 - val_loss: 0.6093 - val_accuracy: 0.6720
Epoch 18/20
100/100 [==============================] - 29s 287ms/step - loss: 0.6747 - accuracy:
0.5830 - val_loss: 0.5973 - val_accuracy: 0.6890
Epoch 19/20
100/100 [==============================] - 29s 292ms/step - loss: 0.6747 - accuracy:
```

```
0.5815 - val_loss: 0.6116 - val_accuracy: 0.6750
Epoch 20/20
100/100 [==============================] - 29s 292ms/step - loss: 0.6698 - accuracy:
0.5730 - val_loss: 0.6135 - val_accuracy: 0.6510
```

In [ ]:
```
_, acc = model.evaluate(test_generator, steps=len(test_generator), verbose=0)
print('Test Accuracy: %.3f%%' % (acc * 100.0))
```

```
Test Accuracy: 63.450%
```

In [ ]:
```
plt.plot(history.history['accuracy'])
plt.plot(history.history['val_accuracy'])
plt.title('CNN Model Accuracy')
plt.ylabel('accuracy')
plt.xlabel('epoch')
plt.legend(['train', 'validation'], loc='upper left')
plt.show()
```



In [ ]:
```
# Create a CNN classifier with at least 3 conv layers, 2 pooling layers, and two de

model = Sequential()
model.add(Conv2D(32, (3,3),activation='relu', input_shape=(IMAGE_HEIGHT,IMAGE_WIDTH
model.add(MaxPooling2D(pool_size=(3,3)))

model.add(Conv2D(32, (3,3),activation='relu'))
model.add(MaxPooling2D(pool_size=(2,2)))
model.add(Dropout(rate=0.5))
model.add(BatchNormalization())
model.add(Flatten())
model.add(Dense(100,activation='relu'))
model.add(Dropout(0.5))
model.add(Dense(1,activation='sigmoid'))

model.compile(loss='binary_crossentropy',
              optimizer='rmsprop',
              metrics=['accuracy'])
model.summary()
```

```
Model: "sequential_4"

_________________________________________________________________
 Layer (type)                Output Shape              Param #   
=================================================================
 conv2d_8 (Conv2D)           (None, 148, 148, 32)      896       
                                                                 
 max_pooling2d_8 (MaxPooling  (None, 49, 49, 32)       0         
 2D)                                                             
                                                                 
 conv2d_9 (Conv2D)           (None, 47, 47, 32)        9248      
                                                                 
 max_pooling2d_9 (MaxPooling  (None, 23, 23, 32)       0         
 2D)                                                             
                                                                 

_________________________________________________________________
 Layer (type)                Output Shape              Param #   
=================================================================
 conv2d_8 (Conv2D)           (None, 148, 148, 32)      896       
                                                                 
 max_pooling2d_8 (MaxPooling  (None, 49, 49, 32)       0         
 2D)                                                             
                                                                 
 conv2d_9 (Conv2D)           (None, 47, 47, 32)        9248      
                                                                 
 max_pooling2d_9 (MaxPooling  (None, 23, 23, 32)       0         
 2D)                                                             
                                                                 
 dropout_4 (Dropout)         (None, 23, 23, 32)        0         
                                                                 
 batch_normalization (BatchN  (None, 23, 23, 32)       128       
 ormalization)                                                   
                                                                 
 flatten_3 (Flatten)         (None, 16928)             0         
                                                                 
 dense_6 (Dense)             (None, 100)               1692900   
                                                                 
 dropout_5 (Dropout)         (None, 100)               0         
                                                                 
 dense_7 (Dense)             (None, 1)                 101       
                                                                 
=================================================================
Total params: 1,703,273
Trainable params: 1,703,209
Non-trainable params: 64
_________________________________________________________________
```

In [ ]:

```
# Train the network on the training set, and report the performance of the classifi

EPOCHS=20
history = model.fit(
    training_generator,
    steps_per_epoch=len(training_generator.filenames) // BATCH_SIZE,
    epochs=EPOCHS,
    validation_data= validation_generator,
    validation_steps=len(validation_generator.filenames) // BATCH_SIZE)
```

```
Epoch 1/20
100/100 [==============================] - 31s 302ms/step - loss: 0.8511 - accuracy:
0.5165 - val_loss: 0.7393 - val_accuracy: 0.5000
Epoch 2/20
100/100 [==============================] - 30s 301ms/step - loss: 0.7098 - accuracy:
0.5165 - val_loss: 0.6823 - val_accuracy: 0.5460
Epoch 3/20
100/100 [==============================] - 29s 287ms/step - loss: 0.7118 - accuracy:
0.4990 - val_loss: 0.6931 - val_accuracy: 0.5060
Epoch 4/20
100/100 [==============================] - 31s 306ms/step - loss: 0.7596 - accuracy:
0.5100 - val_loss: 12.2248 - val_accuracy: 0.5120
Epoch 5/20
100/100 [==============================] - 33s 329ms/step - loss: 0.6928 - accuracy:
0.4980 - val_loss: 2.5046 - val_accuracy: 0.5160
Epoch 6/20
100/100 [==============================] - 29s 290ms/step - loss: 0.7419 - accuracy:
0.5315 - val_loss: 1.4176 - val_accuracy: 0.5040
Epoch 7/20
100/100 [==============================] - 29s 294ms/step - loss: 0.6996 - accuracy:
0.4905 - val_loss: 2.0283 - val_accuracy: 0.5010
Epoch 8/20
100/100 [==============================] - 30s 299ms/step - loss: 0.7749 - accuracy:
0.5200 - val_loss: 0.6806 - val_accuracy: 0.5720
Epoch 9/20
100/100 [==============================] - 32s 318ms/step - loss: 0.6976 - accuracy:
0.5125 - val_loss: 0.9279 - val_accuracy: 0.5010
Epoch 10/20
100/100 [==============================] - 31s 308ms/step - loss: 0.7007 - accuracy:
0.5200 - val_loss: 4.1070 - val_accuracy: 0.5160
Epoch 11/20
100/100 [==============================] - 30s 302ms/step - loss: 0.6965 - accuracy:
0.4995 - val_loss: 0.6725 - val_accuracy: 0.5940
Epoch 12/20
100/100 [==============================] - 30s 296ms/step - loss: 0.6935 - accuracy:
0.5165 - val_loss: 0.6840 - val_accuracy: 0.5490
Epoch 13/20
100/100 [==============================] - 30s 297ms/step - loss: 0.7356 - accuracy:
0.5080 - val_loss: 0.6866 - val_accuracy: 0.5130
Epoch 14/20
100/100 [==============================] - 31s 313ms/step - loss: 0.6904 - accuracy:
0.5245 - val_loss: 0.6901 - val_accuracy: 0.5920
Epoch 15/20
100/100 [==============================] - 30s 303ms/step - loss: 0.6932 - accuracy:
0.5255 - val_loss: 30.3642 - val_accuracy: 0.5030
Epoch 16/20
100/100 [==============================] - 31s 310ms/step - loss: 0.6983 - accuracy:
0.5250 - val_loss: 1.8637 - val_accuracy: 0.5210
Epoch 17/20
100/100 [==============================] - 31s 314ms/step - loss: 0.6977 - accuracy:
0.5175 - val_loss: 0.7000 - val_accuracy: 0.5010
Epoch 18/20
100/100 [==============================] - 30s 297ms/step - loss: 0.6948 - accuracy:
0.5265 - val_loss: 61.5443 - val_accuracy: 0.5030
Epoch 19/20
100/100 [==============================] - 31s 305ms/step - loss: 0.7385 - accuracy:
```

```
0.5295 - val_loss: 18.8697 - val_accuracy: 0.5530
Epoch 20/20
100/100 [==============================] - 32s 319ms/step - loss: 0.6961 - accuracy:
0.5415 - val_loss: 4.4147 - val_accuracy: 0.5030
```

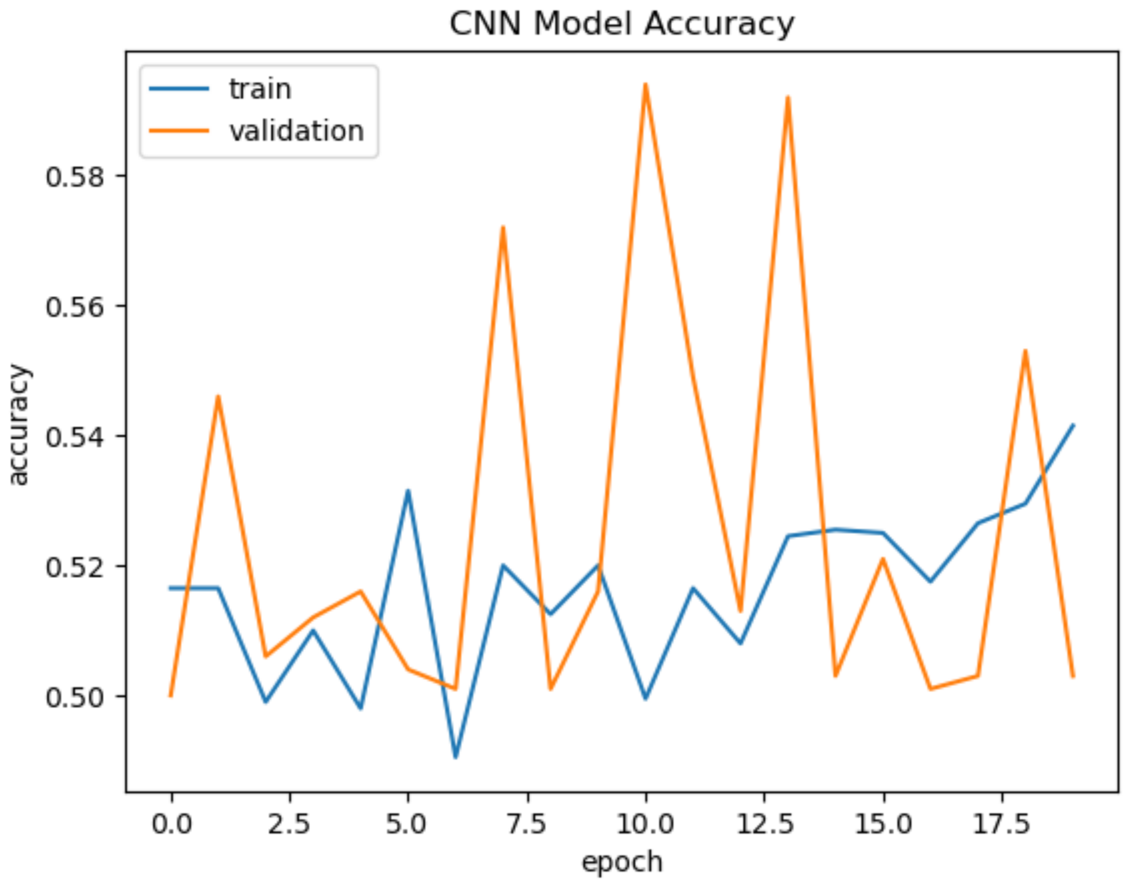
In [ ]:

```
_, acc = model.evaluate(test_generator, steps=len(test_generator), verbose=0)
print('Test Accuracy: %.3f%%' % (acc * 100.0))
```

```
Test Accuracy: 50.250%
```

In [ ]:

```
plt.plot(history.history['accuracy'])
plt.plot(history.history['val_accuracy'])
plt.title('CNN Model Accuracy')
plt.ylabel('accuracy')
plt.xlabel('epoch')
plt.legend(['train', 'validation'], loc='upper left')
plt.show()
```


CNN Model Accuracy
train
validation
accuracy
epoch