In [1]:
```
import tensorflow as tf
from tensorflow import keras
import pandas as pd
import matplotlib.pyplot as plt
from sklearn.model_selection import train_test_split
import pydot, graphviz
import numpy as np
import pandas as pd
from tensorflow.keras.preprocessing.image import ImageDataGenerator
from tensorflow.keras import models,layers, optimizers
from tensorflow.keras.applications import VGG16
```

In [2]:
```
# save the relevant directories containing the pictures
# put an 'r' because the we want forward slash instead of backward slash
test_dir = r'C:\Users\tanch\OneDrive\Documents\Udemy\CNN for computer vision\Learning p
train_dir = r'C:\Users\tanch\OneDrive\Documents\Udemy\CNN for computer vision\Learning
validation_dir = r'C:\Users\tanch\OneDrive\Documents\Udemy\CNN for computer vision\Lear
```

Data preprocessing

In [3]:
```
# create ImageDataGenerator object
# specify to rescale pixel values to [0,1]
train_datagen = ImageDataGenerator(rescale = 1./255)
test_datagen = ImageDataGenerator(rescale = 1./255)

 # this generator generates data        # directory variable specified earlier
train_generator = train_datagen.flow_from_directory(train_dir,
                                                     # photos are resized to 150 x 150
                                                    target_size = (150,150),
                                                     # IMPT: images are generated in bat
                                                    batch_size = 20,
                                                    # specify binary classification
                                                    class_mode = 'binary')

                                                     # directory variable specified earl
validation_generator = test_datagen.flow_from_directory(validation_dir,
                                                     # photos are resized to 150 x 150
                                                    target_size = (150,150),
                                                     # photos will come in batches of 20
                                                    batch_size = 20,
                                                    # specify binary classification
                                                    class_mode = 'binary')
```

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

Building CNN

In [4]:

```
# specifying CNN model architecture
model = models.Sequential()
                          # using 32 filters of size 3x3  NOTE: default stride=1, default
model.add(layers.Conv2D( 32, (3,3), activation='relu',
                            # images were resized to 150x150 earlier
                          # 3 because images are colored
                            input_shape=(150,150,3)))
# each convolution layer has its own max pooling layer
model.add(layers.MaxPooling2D((2,2)))

                          # 64 filters of size 3x3
model.add(layers.Conv2D( 64, (3,3), activation='relu',input_shape=(150,150,3)))
model.add(layers.MaxPooling2D((2,2)))

                          # 128 filters of size 3x3
model.add(layers.Conv2D( 128, (3,3), activation='relu',input_shape=(150,150,3)))
model.add(layers.MaxPooling2D((2,2)))

                          # 128 filters of size 3x3
model.add(layers.Conv2D( 128, (3,3), activation='relu',input_shape=(150,150,3)))
model.add(layers.MaxPooling2D((2,2)))

# flatten to single array
model.add(layers.Flatten())

# 512 neuron hidden layer
model.add(layers.Dense(512, activation='relu'))

# 1 neuron output layer for binary classification
# sigmoid activation for binary classification
model.add(layers.Dense(1, activation='sigmoid'))
```

In [5]:
```
model.summary()
```

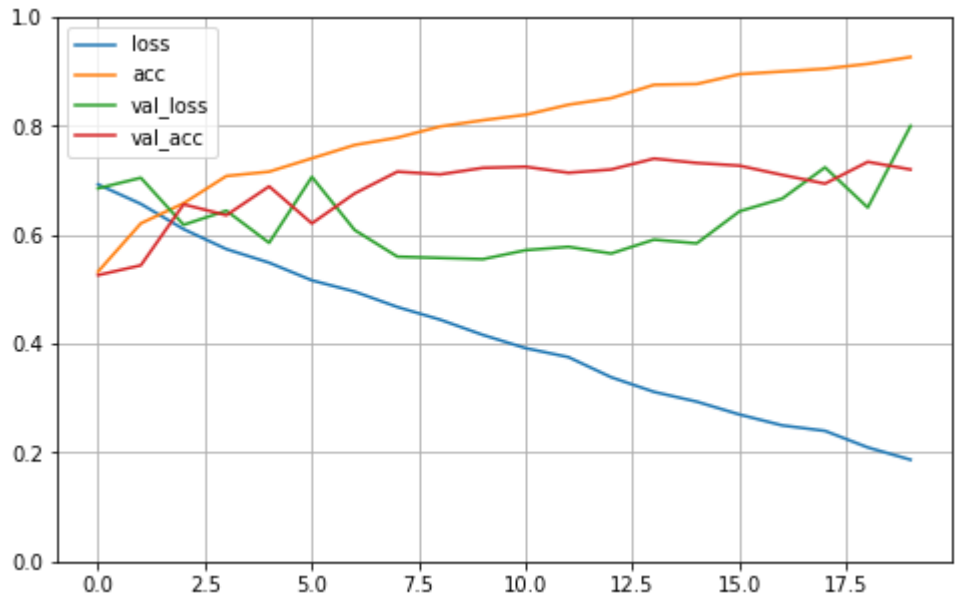
```
Model: "sequential"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv2d (Conv2D)              (None, 148, 148, 32)      896
_________________________________________________________________
max_pooling2d (MaxPooling2D) (None, 74, 74, 32)        0
_________________________________________________________________
conv2d_1 (Conv2D)            (None, 72, 72, 64)        18496
_________________________________________________________________
max_pooling2d_1 (MaxPooling2 (None, 36, 36, 64)        0
_________________________________________________________________
conv2d_2 (Conv2D)            (None, 34, 34, 128)       73856
_________________________________________________________________
max_pooling2d_2 (MaxPooling2 (None, 17, 17, 128)       0
_________________________________________________________________
conv2d_3 (Conv2D)            (None, 15, 15, 128)       147584
_________________________________________________________________
max_pooling2d_3 (MaxPooling2 (None, 7, 7, 128)         0
_________________________________________________________________
flatten (Flatten)            (None, 6272)              0
_________________________________________________________________
dense (Dense)                (None, 512)               3211776
_________________________________________________________________
dense_1 (Dense)              (None, 1)                 513
=================================================================
Total params: 3,453,121
Trainable params: 3,453,121
Non-trainable params: 0
_________________________________________________________________
```

In [6]:
```
model.compile(loss='binary_crossentropy',
              # RMSprop used over sgd    # learning rate set to 0.0001
             optimizer= optimizers.RMSprop(lr=1e-4),
             metrics=['acc'])
```

In [7]:
```
                    # training data comes from the train_generator
history = model.fit_generator(train_generator,
                    # IMPT: 20 x 100 = 2000 images in training set
                    steps_per_epoch=100,
                    epochs=20,
                    # validation data comes from the validation generator
                    validation_data=validation_generator,
                    # IMPT 20 x 50 = 1000 images in the validation set
                    validation_steps = 50)
```

```
WARNING:tensorflow:From <ipython-input-7-1dd1c2e963cd>:9: Model.fit_generator (from
tensorflow.python.keras.engine.training) is deprecated and will be removed in a fut
ure version.
Instructions for updating:
Please use Model.fit, which supports generators.
WARNING:tensorflow:sample_weight modes were coerced from
  ...
    to
  ['...']
WARNING:tensorflow:sample_weight modes were coerced from
  ...
    to
  ['...']
Train for 100 steps, validate for 50 steps
Epoch 1/20
100/100 [==============================] - 67s 667ms/step - loss: 0.6925 - acc: 0.5
325 - val_loss: 0.6854 - val_acc: 0.5260
Epoch 2/20
100/100 [==============================] - 65s 648ms/step - loss: 0.6568 - acc: 0.6
```

In [8]:
```
# visualise the training progression
pd.DataFrame(history.history).plot(figsize=(8,5))
plt.grid(True)
plt.gca().set_ylim(0,1)
plt.show()
```



- evident **overfitting as seen from the increasing difference between training and validation accruacy**

In [9]:
```
# save model
model.save('CNN_model.h5')
```

Improving the model with Data augmentation and Dropout

In [10]:
```
# create ImageDataGenerator that augments image
# specify to rescale pixel values to [0,1]
train_datagen_augmented = ImageDataGenerator(rescale = 1./255,
                                      # the generator can choose any value within these ra
                                     rotation_range=40,
                                     width_shift_range=0.2,
                                     height_shift_range=0.2,
                                     shear_range=0.2,
                                     zoom_range=0.2,
                                     horizontal_flip=True)

# data augmentation NOT required in validation set
test_datagen = ImageDataGenerator(rescale = 1./255)

 # this generator generates data        # directory variable specified earlier
train_generator_augmented = train_datagen_augmented.flow_from_directory(train_dir,
                                                         # photos are resized to 150 x 150
                                                        target_size = (150,150),
                                                         # IMPT: images are generated in bat
                                                        batch_size = 20,
                                                        # specify binary classification
                                                        class_mode = 'binary')

                                                         # directory variable specified earl
validation_generator = test_datagen.flow_from_directory(validation_dir,
                                                         # photos are resized to 150 x 150
                                                        target_size = (150,150),
                                                         # photos will come in batches of 20
                                                        batch_size = 20,
                                                        # specify binary classification
                                                        class_mode = 'binary')
```

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

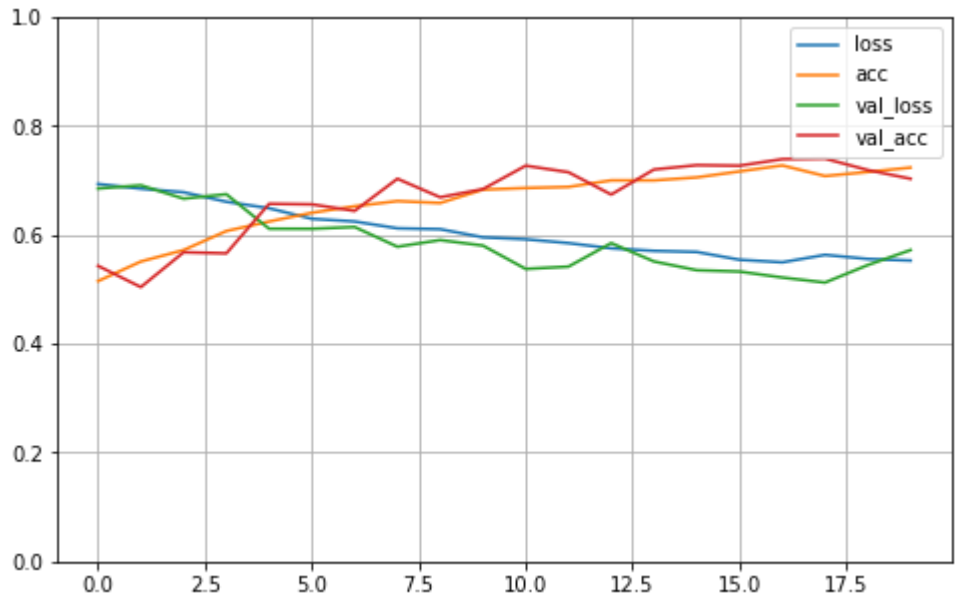
In [11]:
```
# model_2 with dropout 50%
model_2 = models.Sequential()
                        # using 32 filters of size 3x3  NOTE: default stride=1, default
model_2.add(layers.Conv2D( 32, (3,3), activation='relu',
                          # images were resized to 150x150 earlier
                        # 3 because images are colored
                          input_shape=(150,150,3)))
# each convolution layer has its own max pooling layer
model_2.add(layers.MaxPooling2D((2,2)))

                        # 64 filters of size 3x3
model_2.add(layers.Conv2D( 64, (3,3), activation='relu',input_shape=(150,150,3)))
model_2.add(layers.MaxPooling2D((2,2)))

                        # 128 filters of size 3x3
model_2.add(layers.Conv2D( 128, (3,3), activation='relu',input_shape=(150,150,3)))
model_2.add(layers.MaxPooling2D((2,2)))

                        # 128 filters of size 3x3
model_2.add(layers.Conv2D( 128, (3,3), activation='relu',input_shape=(150,150,3)))
model_2.add(layers.MaxPooling2D((2,2)))

# flatten to single array
model_2.add(layers.Flatten())

# in every epoch 50% of neurons are deactivated to reduce interneuron dependency and ov
model_2.add(layers.Dropout(0.5))

# 512 neuron hidden layer
model_2.add(layers.Dense(512, activation='relu'))

# 1 neuron output layer for binary classification
# sigmoid activation for binary classification
model_2.add(layers.Dense(1, activation='sigmoid'))
```

In [12]:
```
model_2.compile(loss='binary_crossentropy',
               # RMSprop used over sgd    # learning rate set to 0.0001
              optimizer= optimizers.RMSprop(lr=1e-4),
              metrics=['acc'])
```

In [13]:
```
                    # model is fit into augmented data
history = model_2.fit_generator(train_generator_augmented,
                    # IMPT: 32 x 100 = 3200 augmented images
                    steps_per_epoch=100,
                    epochs=20,
                    # validation data comes from the validation generator
                    validation_data=validation_generator,
                    # IMPT 32 x 50 = 1600 images in the validation set
                    validation_steps = 50)
```

```
WARNING:tensorflow:sample_weight modes were coerced from
  ...
    to
  ['...']
WARNING:tensorflow:sample_weight modes were coerced from
  ...
    to
  ['...']
Train for 100 steps, validate for 50 steps
Epoch 1/20
100/100 [==============================] - 76s 763ms/step - loss: 0.6933 - acc: 0.5
150 - val_loss: 0.6851 - val_acc: 0.5430
Epoch 2/20
100/100 [==============================] - 66s 663ms/step - loss: 0.6848 - acc: 0.5
510 - val_loss: 0.6910 - val_acc: 0.5040
Epoch 3/20
100/100 [==============================] - 80s 803ms/step - loss: 0.6782 - acc: 0.5
720 - val_loss: 0.6665 - val_acc: 0.5680
Epoch 4/20
```

In [14]:
```
# visualise the training progression
pd.DataFrame(history.history).plot(figsize=(8,5))
plt.grid(True)
plt.gca().set_ylim(0,1)
plt.show()
```



- clearly, **with the augmentation and dropot, overfitting is much lesser**

In [15]:
```
# save model
model_2.save('CNN_model_augmentation_plus_dropout.h5')
```

Improving mode with Transfer Learning

In [16]:
```
# create ImageDataGenerator that augments image
# specify to rescale pixel values to [0,1]
train_datagen_augmented = ImageDataGenerator(rescale = 1./255,
                                     # the generator can choose any value within these ra
                                    rotation_range=40,
                                    width_shift_range=0.2,
                                    height_shift_range=0.2,
                                    shear_range=0.2,
                                    zoom_range=0.2,
                                    horizontal_flip=True)

# data augmentation NOT required in validation set
test_datagen = ImageDataGenerator(rescale = 1./255)

 # this generator generates data        # directory variable specified earlier
train_generator_augmented = train_datagen_augmented.flow_from_directory(train_dir,
                                                         # photos are resized to 150 x 150
                                                        target_size = (150,150),
                                                         # IMPT: images are generated in bat
                                                        batch_size = 20,
                                                        # specify binary classification
                                                        class_mode = 'binary')

                                                         # directory variable specified earl
validation_generator = test_datagen.flow_from_directory(validation_dir,
                                                         # photos are resized to 150 x 150
                                                        target_size = (150,150),
                                                         # photos will come in batches of 20
                                                        batch_size = 20,
                                                        # specify binary classification
                                                        class_mode = 'binary')
```

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

In [17]:
```
# convotional base of VGG16 is used instead of creating our own
                     # these weights are the VGG16 final weights from imagenet competiti
conv_base = VGG16( weights = 'imagenet',
                   # specify that we only want the convolution base
                  include_top = False,
                   # colored input was resized to 150 x 150 earlier
                  input_shape = (150,150,3))
```

In [18]:
```
conv_base.summary()
```

```
Model: "vgg16"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_1 (InputLayer)         [(None, 150, 150, 3)]     0
_________________________________________________________________
block1_conv1 (Conv2D)        (None, 150, 150, 64)      1792
_________________________________________________________________
block1_conv2 (Conv2D)        (None, 150, 150, 64)      36928
_________________________________________________________________
block1_pool (MaxPooling2D)   (None, 75, 75, 64)        0
_________________________________________________________________
block2_conv1 (Conv2D)        (None, 75, 75, 128)       73856
_________________________________________________________________
block2_conv2 (Conv2D)        (None, 75, 75, 128)       147584
_________________________________________________________________
block2_pool (MaxPooling2D)   (None, 37, 37, 128)       0
_________________________________________________________________
block3_conv1 (Conv2D)        (None, 37, 37, 256)       295168
```

In [19]:
```
# before trainging, decide whether to let the convolutoon layer be trainable
conv_base.trainable = False
```

In [20]:
```
# initialise the model w VGG16 convolution base
model_3 = models.Sequential()
model_3.add(conv_base)

# flatten to single array
model_3.add(layers.Flatten())

# 256 neuron hidden layer
model_3.add(layers.Dense(256, activation='relu'))

# 1 neuron output layer for binary classification
# sigmoid activation for binary classification
model_3.add(layers.Dense(1, activation='sigmoid'))
```

In [21]:
```
# by freezing the convolution base, there are 14 mil less params to train
model_3.summary()
```

```
Model: "sequential_2"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
vgg16 (Model)                (None, 4, 4, 512)         14714688
_________________________________________________________________
flatten_2 (Flatten)          (None, 8192)              0
_________________________________________________________________
dense_4 (Dense)              (None, 256)               2097408
_________________________________________________________________
dense_5 (Dense)              (None, 1)                 257
=================================================================
Total params: 16,812,353
Trainable params: 2,097,665
Non-trainable params: 14,714,688
_________________________________________________________________
```

In [19]:
```
conv_base.summary()
```

```
Model: "vgg16"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_1 (InputLayer)         [(None, 150, 150, 3)]     0
_________________________________________________________________
block1_conv1 (Conv2D)        (None, 150, 150, 64)      1792
_________________________________________________________________
block1_conv2 (Conv2D)        (None, 150, 150, 64)      36928
_________________________________________________________________
block1_pool (MaxPooling2D)   (None, 75, 75, 64)        0
_________________________________________________________________
block2_conv1 (Conv2D)        (None, 75, 75, 128)       73856
_________________________________________________________________
block2_conv2 (Conv2D)        (None, 75, 75, 128)       147584
_________________________________________________________________
block2_pool (MaxPooling2D)   (None, 37, 37, 128)       0
_________________________________________________________________
block3_conv1 (Conv2D)        (None, 37, 37, 256)       295168
_________________________________________________________________
block3_conv2 (Conv2D)        (None, 37, 37, 256)       590080
_________________________________________________________________
block3_conv3 (Conv2D)        (None, 37, 37, 256)       590080
_________________________________________________________________
block3_pool (MaxPooling2D)   (None, 18, 18, 256)       0
_________________________________________________________________
block4_conv1 (Conv2D)        (None, 18, 18, 512)       1180160
_________________________________________________________________
block4_conv2 (Conv2D)        (None, 18, 18, 512)       2359808
_________________________________________________________________
block4_conv3 (Conv2D)        (None, 18, 18, 512)       2359808
_________________________________________________________________
block4_pool (MaxPooling2D)   (None, 9, 9, 512)         0
_________________________________________________________________
block5_conv1 (Conv2D)        (None, 9, 9, 512)         2359808
_________________________________________________________________
block5_conv2 (Conv2D)        (None, 9, 9, 512)         2359808
_________________________________________________________________
block5_conv3 (Conv2D)        (None, 9, 9, 512)         2359808
_________________________________________________________________
block5_pool (MaxPooling2D)   (None, 4, 4, 512)         0
=================================================================
Total params: 14,714,688
Trainable params: 0
Non-trainable params: 14,714,688
_________________________________________________________________
```

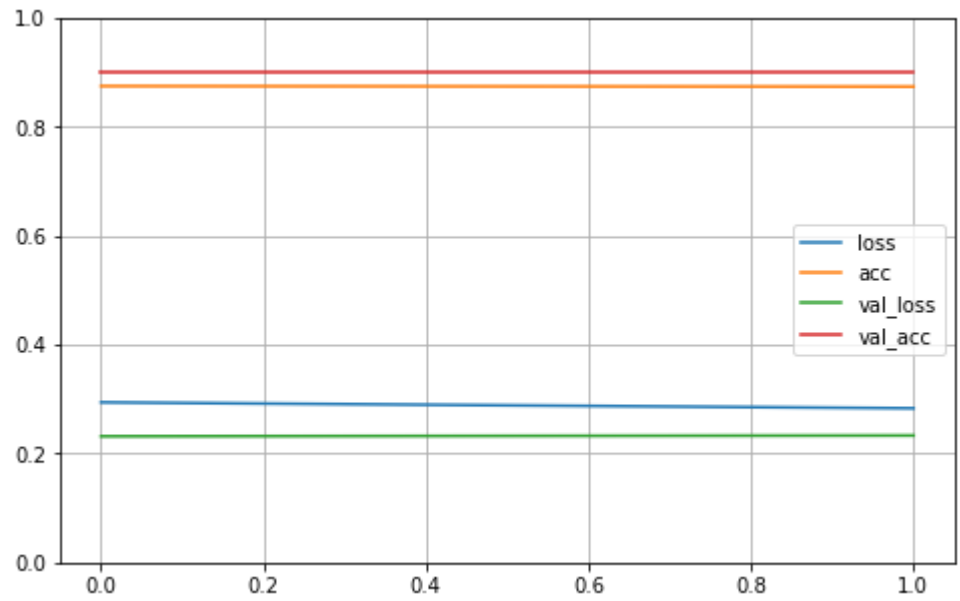
In [22]:
```
model_3.compile(loss='binary_crossentropy',
                # RMSprop used over sgd    # learning rate set much lower because we are
              optimizer= optimizers.RMSprop(lr=2e-5),
              metrics=['acc'])
```

In [23]:
```
# w early stopping we can set epochs to a high number and training will stop itself
checkpoint_cb = keras.callbacks.ModelCheckpoint('CNN_VGG16_early_stopping_model.h5',sav
                                                # if there are no improvements after 10
early_stopping_cb = keras.callbacks.EarlyStopping(patience = 10,
                                                  restore_best_weights = True)
```

In [37]:
```
                    # model is fit into augmented data
history = model_3.fit_generator(train_generator_augmented,
                    # IMPT: 32 x 100 = 3200 augmented images
                    steps_per_epoch=100,
                    epochs=2,
                    # validation data comes from the validation generator
                    validation_data=validation_generator,
                    # IMPT 32 x 50 = 1600 images in the validation set
                    validation_steps = 50,
                    # specify to save checkpoint via early stopping
                    callbacks= [checkpoint_cb, early_stopping_cb])
```

```
WARNING:tensorflow:sample_weight modes were coerced from
  ...
    to
  ['...']
WARNING:tensorflow:sample_weight modes were coerced from
  ...
    to
  ['...']
Train for 100 steps, validate for 50 steps
Epoch 1/2
100/100 [==============================] - 954s 10s/step - loss: 0.2941 - acc: 0.8750
- val_loss: 0.2318 - val_acc: 0.8990
Epoch 2/2
100/100 [==============================] - 908s 9s/step - loss: 0.2832 - acc: 0.8740 -
val_loss: 0.2333 - val_acc: 0.8990
```

In [38]:
```
# 31th to 32th epoch
pd.DataFrame(history.history).plot(figsize=(8,5))
plt.grid(True)
plt.gca().set_ylim(0,1)
plt.show()
```



In [34]:
```
# load saved model
model_3 = keras.models.load_model('CNN_VGG16_early_stopping_model.h5')
```

- validation has **plateau'ed at 0.90 with very little overfitting**
- **setting convolution base to trainable will improve accuracy significantly**, but will also take more time due to more params