1. Course Project

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The tentative title of team project:

- Mario Kart with Deep RL

2. Number of Parameters in Residule Net

- Table 1 in the CVPR'16 paper explains the 50 layer ResNet, which is roughly grouped into conv1, conv2, conv3, conv4, conv5, and final pooling plus 1000 fully connected layer.
- Please count how many parameters in conv1, conv2, conv3, conv4 and conv5, respectively. You can use Keras `model.count_parameters()' to verify your calculation.

```
from tensorflow import keras
import numpy as np
```

```
# assumed 3 channels of inputs
# conv1: layer [0,2)
# conv1 = conv + batch normolazation
conv1 =(3*7*7*64+64)+4*64 #9472+256

# conv2: layer [2,22)

# conv2a = (input_depth_64*output_depth_64 + bias)           #1d_kernel_para
#          +(bn_paras_4*output_depth_64)                     #batch_normalization
#          +(input_depth*kernel_size*output_depth + bias)    #2d_kernel_para
#          +(bn_paras_4*output_depth_64)                     #batch_normalization
#          +(input depth*kernel_size*output_depth + bias)    #2d_kernel_para
#          +(bn_paras_4*output_depth_256)                    #batch_normalization
#          +(pre_layer_input depth_64*output_depth_256 + bias) #paras that change di
#          +(bn_paras_4*output_depth_256)                    #batch_normalization

# conv2 = conv2a+conv2b+conv2c
conv2a = ((64*64+64)+4*64) + ((64*3*3*64+64)+4*64) + ((64*256+256)+4*256+(64*256+25
conv2b = ((256*64+64)+4*64)+((64*3*3*64+64)+4*64)+((64*256+256)+4*256)
conv2c = ((256*64+64)+4*64)+((64*3*3*64+64)+4*64)+((64*256+256)+4*256)


# conv3: layer [22,48)
conv3a = ((256*128+128)+4*128)+((128*3*3*128+128)+4*128)+((128*512+512)+4*512+(256*
conv3b = ((512*128+128)+4*128)+((128*3*3*128+128)+4*128)+((128*512+512)+4*512)
conv3c = ((512*128+128)+4*128)+((128*3*3*128+128)+4*128)+((128*512+512)+4*512)
conv3d = ((512*128+128)+4*128)+((128*3*3*128+128)+4*128)+((128*512+512)+4*512)

# conv4: layer [48,86)
conv4a = ((512*256+256)+4*256)+((256*3*3*256+256)+4*256)+((256*1024+1024)+4*1024+(5
conv4b = ((1024*256+256)+4*256)+((256*3*3*256+256)+4*256)+((256*1024+1024)+4*1024)
conv4c = ((1024*256+256)+4*256)+((256*3*3*256+256)+4*256)+((256*1024+1024)+4*1024)
conv4d = ((1024*256+256)+4*256)+((256*3*3*256+256)+4*256)+((256*1024+1024)+4*1024)
conv4e = ((1024*256+256)+4*256)+((256*3*3*256+256)+4*256)+((256*1024+1024)+4*1024)
conv4f = ((1024*256+256)+4*256)+((256*3*3*256+256)+4*256)+((256*1024+1024)+4*1024)

# conv5: layer [86, 106)
conv5a = ((1024*512+512)+4*512)+((512*3*3*512+512)+4*512)+((512*2048+2048)+4*2048+(
conv5b = ((2048*512+512)+4*512)+((512*3*3*512+512)+4*512)+((512*2048+2048)+4*2048)
conv5c = ((2048*512+512)+4*512)+((512*3*3*512+512)+4*512)+((512*2048+2048)+4*2048)

print('There are {} parameters in conv1, \n{} parameters in conv2, \n{} parameters
    conv1, conv2a+conv2b+conv2c, conv3a+conv3b+conv3c+conv3d,
    conv4a+conv4b+conv4c+conv4d+conv4e+conv4f, conv5a+conv5b+conv5c))
```

```
There are 9728 parameters in conv1,
220032 parameters in conv2,
1230336 parameters in conv3,
7129088 parameters in conv4
and 14998528 parameters in conv5
```

check the result

```
# import resnet50
from tensorflow. keras.applications.resnet50 import ResNet50
base_model = ResNet50(weights='imagenet', include_top=False, input_shape = (250,250
```

```
/usr/local/lib/python3.6/dist-packages/keras_applications/resnet50.py:265: Us
  warnings.warn('The output shape of `ResNet50(include_top=False)` '
Downloading data from https://github.com/fchollet/deep-learning-models/releas
94658560/94653016 [==============================] - 8s 0us/step
```

```
# base_model.count_params()
# base_model.layers
# base_model.summary()
```

```
# find the parameter of each conv layer
conv_layers={}
ind={}
k = 0
for i, layer in enumerate(base_model.layers):
  if isinstance(layer, keras.layers.Conv2D) or isinstance(layer, keras.layers.Batch
    ind[k]=layer.name
    conv_layers[k]=layer.count_params()
    k+=1

# len(conv_layers)
# check the result of conv5
# for i in range(86,106):
#   conv += conv_layers[i]
#   print(ind[i], conv_layers[i])



calculated_conv =[conv1, conv2a+conv2b+conv2c, conv3a+conv3b+conv3c+conv3d,
    conv4a+conv4b+conv4c+conv4d+conv4e+conv4f, conv5a+conv5b+conv5c]

base_model.count_params(), sum(np.array(calculated_conv)), base_model.count_params(
```

```
(23587712, 23587712, True)
```

3. Fine tuning deep CNNs

```
import os
import cv2
from six.moves.urllib import request

import numpy as np
import tensorflow as tf
from tensorflow import keras


%matplotlib inline
import matplotlib.pyplot as plt
```

```
batch_sz = 20
N_CLASSES = 2
IMG_SIZE=250
```

Data Loading

```
# retrieve data from url
def retrieve_data(src, dst, num, c=10):
  for i in range(num,num+c):
    url = src+str(i)+'-FaceId-0.jpg'
    filename = dst+str(i)+'.jpg'
    if not os.path.isfile(filename):
        request.urlretrieve(url=url, filename=filename)

# a example:
# src = 'http://columbia6894.github.io/hw/hw3data/justin/'
# dst = './train_dir/Justin/a'
# num = 10
# retrieve_data(src, dst, num)
```

```
# create directories and retrieve data into each directory

sub_dir = ['train_dir', 'validation_dir', 'test_dir' ]
classes = ['Justin', 'Jennifer' ]
to_classes = dict(enumerate(classes))
src_url = 'http://columbia6894.github.io/hw/hw3data/'
start_index = [1, 1, 11]
num_of_img = [10,20,10]

for i, dir_i in enumerate(sub_dir):
  os.mkdir(dir_i)
  num = start_index[i]
  c = num_of_img[i]
  for class_k in classes:
    os.mkdir(dir_i+'/'+class_k)
    src = src_url+class_k.lower()+'/'
    dst = './'+dir_i+'/'+class_k+'/'+class_k+'_'
    retrieve_data(src, dst, num, c)
```

```
#!rm -rf 'train_dir'
#!rm -rf 'test_dir'
# input_file = os.path.abspath('Justin')
# 'Jennifer'.lower()
# 'validation_dir'
```

```
os.listdir('train_dir')
```

```
['Justin', 'Jennifer']
```

Data Processing

```
train_dir = './train_dir'
validation_dir = './validation_dir'
test_dir = './test_dir'
```

```python
# data generator
from tensorflow.keras.preprocessing.image import ImageDataGenerator

# train
train_datagen = ImageDataGenerator(
      rescale=1./255,
      rotation_range=20,
      shear_range=0.2,
      width_shift_range=0.2,
      height_shift_range=0.2,
      zoom_range=0.2,
      horizontal_flip=True,
      fill_mode='nearest',
      validation_split=0.2)

train_generator = train_datagen.flow_from_directory(
        train_dir,
        target_size=(IMG_SIZE, IMG_SIZE),
        batch_size=batch_sz,
        class_mode='binary')



# validation
validation_datagen = ImageDataGenerator(rescale=1./255)

validation_generator = validation_datagen.flow_from_directory(
        validation_dir,
        target_size=(IMG_SIZE, IMG_SIZE),
        batch_size=int(batch_sz/2),
        class_mode='binary')


# test
test_datagen = ImageDataGenerator(rescale=1./255)

test_generator = test_datagen.flow_from_directory(
        test_dir,
        target_size=(IMG_SIZE, IMG_SIZE),
        batch_size=batch_sz,
        class_mode='binary',
        shuffle = False)
```

```
Found 20 images belonging to 2 classes.
Found 40 images belonging to 2 classes.
Found 20 images belonging to 2 classes.
```

Fine-Tuning

```
# look at base_model
print('This is the number of trainable weights '
      'before freezing the base_model:', len(base_model.trainable_weights))

# fixed params to reduce computation
for layer in base_model.layers[:-15]:
    layer.trainable = False
    if isinstance(layer, keras.layers.BatchNormalization):
        # we do aggressive exponential smoothing of batch norm
        # parameters to faster adjust to our new dataset
        layer.trainable = True
        layer.momentum = 0.9


# look at base_model
print('This is the number of trainable weights '
      'after freezing the base_model:', len(base_model.trainable_weights))
```

```
This is the number of trainable weights before freezing the base_model: 212
This is the number of trainable weights after freezing the base_model: 114
```

```
# base_model.layers[-15:]
# base_model.layers.pop()
# base_model.summary()
```

/# add top layers and make a new model x = keras.layers.Flatten()(base_model.output) x = keras.layers.Dense(256, activation="relu")(x) x = keras.layers.Dropout(0.5)(x) pred = keras.layers.Dense(N_CLASSES, activation="softmax")(x) model = keras.models.Model(inputs = base_model.input, outputs = pred)

```
# add top layers and make a new model
model = keras.models.Sequential()

model.add(base_model)
model.add(keras.layers.Flatten())
model.add(keras.layers.Dense(64,activation = 'relu'))
model.add(keras.layers.Dropout(0.25))
model.add(keras.layers.Dense(N_CLASSES, activation="softmax"))


# look at models
print('the base resnet50 model with', len(base_model.layers), 'layers')
print('the new fine-tuned model with', len(model.layers), 'layers')
```

```
the base resnet50 model with 175 layers
the new fine-tuned model with 5 layers
```

```
# compile
model.compile(  loss = "sparse_categorical_crossentropy",
                optimizer = keras.optimizers.RMSprop(lr=0.005),
                metrics = ["accuracy"] )
```

Train

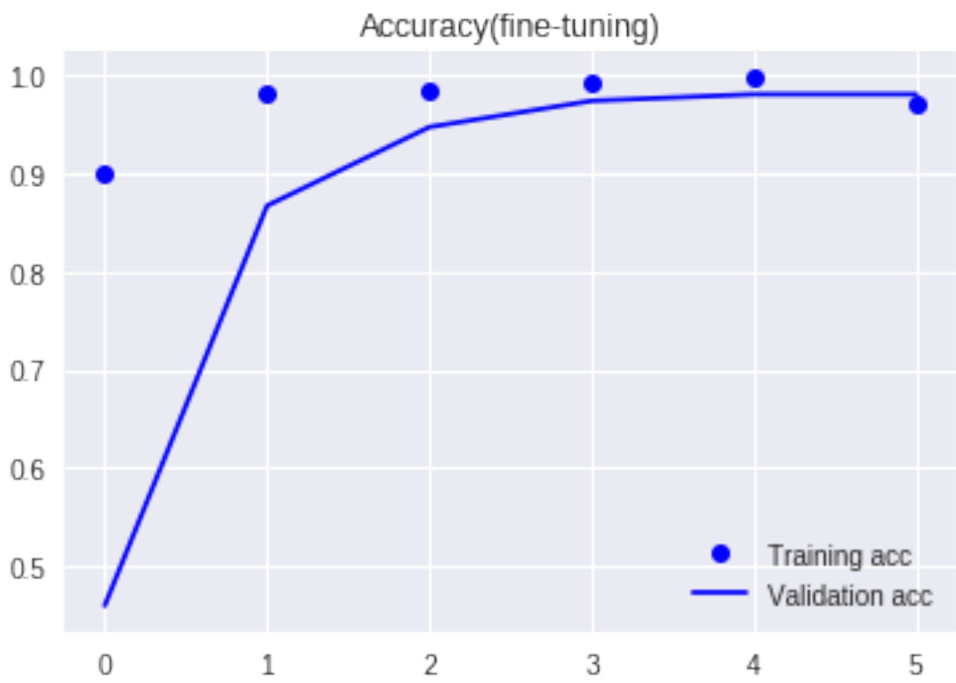
```
# prepare for train
early_stopping = keras.callbacks.EarlyStopping(monitor='val_loss',
                                               min_delta=0.001, patience=2,
                                               verbose=1, mode='auto')
```

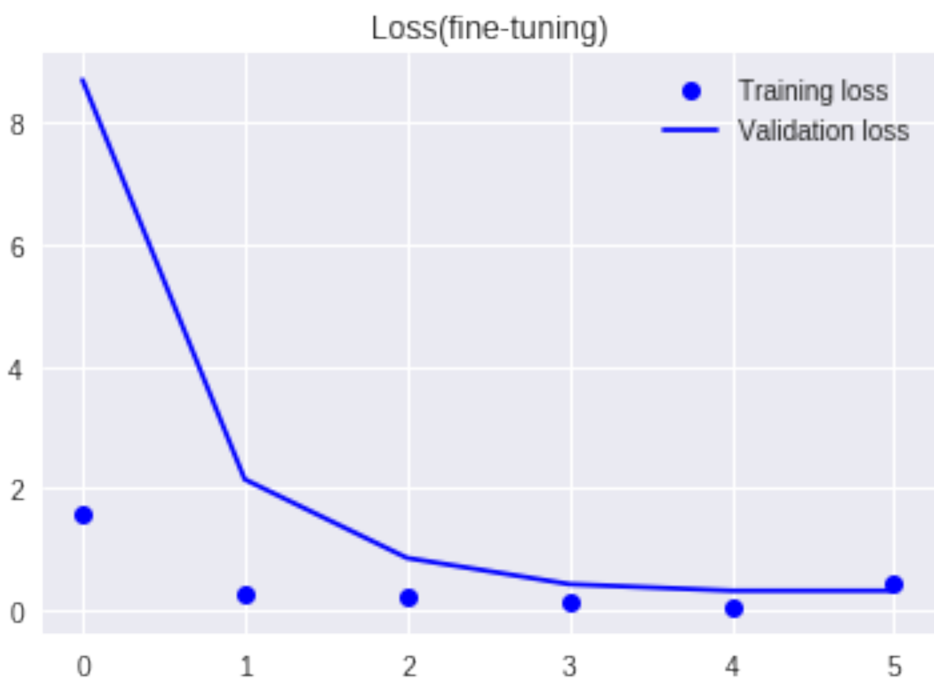
```
train = True
last_finished_epoch = 0
```

```
# train
if train:
    history = model.fit_generator(train_generator,
        steps_per_epoch = 30 , #len(train_dir)//10
        epochs=10,
        validation_data = validation_generator,
        validation_steps = 15,
        callbacks=[early_stopping],
        verbose=2,
        initial_epoch=last_finished_epoch)
    #model.save_weights('epochs_weights.h5')
```

```
Epoch 1/10
 - 19s - loss: 1.5987 - acc: 0.8983 - val_loss: 8.7038 - val_acc: 0.4600
Epoch 2/10
 - 18s - loss: 0.2725 - acc: 0.9817 - val_loss: 2.1491 - val_acc: 0.8667
Epoch 3/10
 - 19s - loss: 0.2447 - acc: 0.9833 - val_loss: 0.8596 - val_acc: 0.9467
Epoch 4/10
 - 18s - loss: 0.1343 - acc: 0.9917 - val_loss: 0.4298 - val_acc: 0.9733
Epoch 5/10
 - 18s - loss: 0.0538 - acc: 0.9967 - val_loss: 0.3224 - val_acc: 0.9800
Epoch 6/10
 - 18s - loss: 0.4635 - acc: 0.9700 - val_loss: 0.3224 - val_acc: 0.9800
Epoch 00006: early stopping
```

```
# plot the train process

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

epochs = range(len(acc))

plt.plot(epochs, acc, 'bo', label='Training acc')
plt.plot(epochs, val_acc, 'b', label='Validation acc')
plt.title('Accuracy(fine-tuning)')
plt.legend()

plt.figure()

plt.plot(epochs, loss, 'bo', label='Training loss')
plt.plot(epochs, val_loss, 'b', label='Validation loss')
plt.title('Loss(fine-tuning)')
plt.legend()

plt.show()
```





Test the 11-20 picture for each class and my own face

```
probs = model.predict_generator(test_generator)
#probs = model.predict(test_data, 2, verbose=1)
```

```
true_y = np.array([0]*10+[1]*10)
preds_y = np.argmax(probs, axis=1)
compr = preds_y - true_y

# the image in the above problem which i recognized correctly
corr_img = np.where(compr == 0)[0]
corr_confidence = probs.max(axis=1)
list(zip(corr_img,corr_confidence[corr_img]))
```

```
[(0, 1.0),
 (1, 1.0),
 (2, 1.0),
 (3, 1.0),
 (4, 1.0),
 (5, 1.0),
 (6, 1.0),
 (7, 1.0),
 (8, 1.0),
 (9, 1.0),
 (10, 1.0),
 (11, 1.0),
 (12, 1.0),
 (13, 1.0),
 (14, 1.0),
 (15, 1.0),
 (16, 1.0),
 (17, 1.0),
 (18, 1.0),
 (19, 1.0)]
```

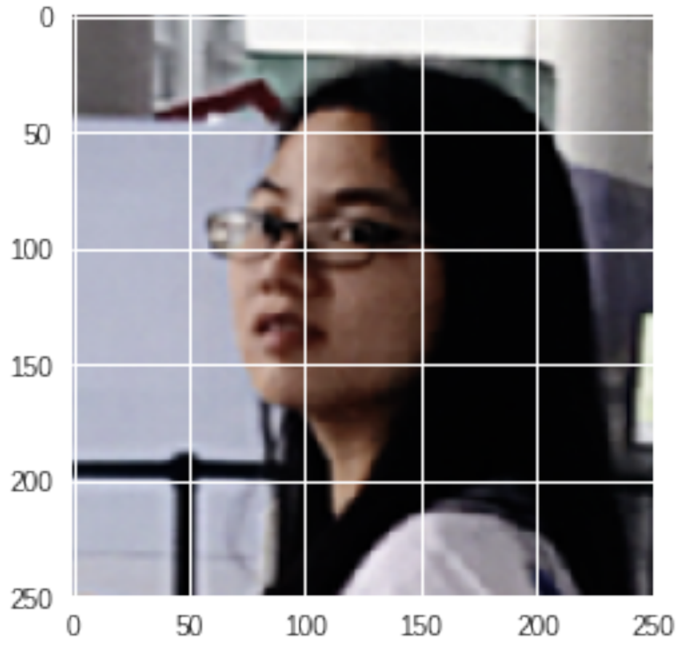
```
from google.colab import files
uploaded = files.upload()
```

Choose Files no files selected Upload widget is only available when the cell has been executed in the current browser session. Please rerun this cell to enable.

```
Saving my_img.png to my_img.png
```

```
img = cv2.imread('my_img.png')
img = cv2.resize(img, (IMG_SIZE, IMG_SIZE))
plt.imshow(cv2.cvtColor(img, cv2.COLOR_BGR2RGB))
```

```
<matplotlib.image.AxesImage at 0x7f81a0922898>
```




```
img = np.expand_dims(img,0)
prob = model.predict(img,verbose=1) # the second prediction

# result
to_classes[np.argmax(prob)], prob.max(axis=1)[0]
```

```
1/1 [==============================] - 1s 636ms/step
('Jennifer', 1.0)
```

4. Adversarial Attack

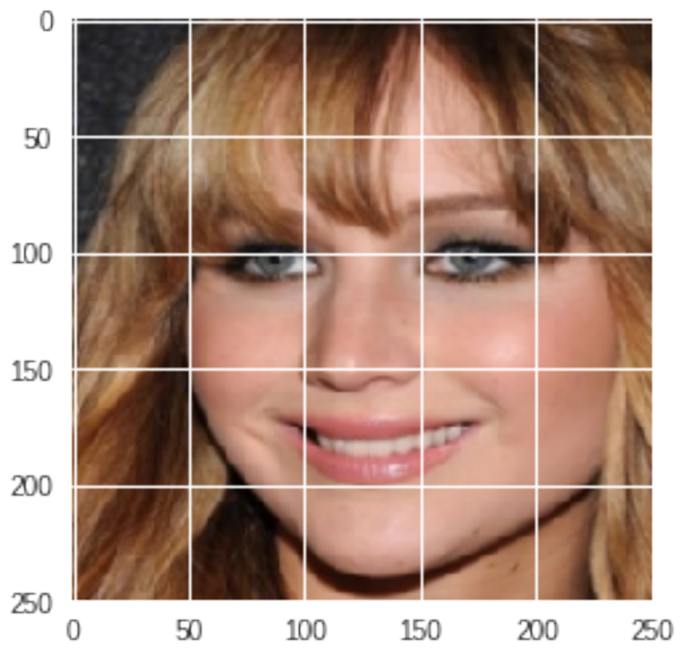
Take one of Justin or Jennifer's test image in the above problem which you recognized correctly, and show that you can fool the classifer by adding some unnoticeable noise.

pick a correctly predicted test image

```
# test data to np.array

testdir = []
for class_k in os.listdir('test_dir'):
  for imgdir in os.listdir('test_dir/'+class_k):
    testdir.append('test_dir/'+class_k+'/'+imgdir)


test_data = []
for imgdir in testdir:
  img = cv2.imread(imgdir)
  img = cv2.resize(img, (IMG_SIZE, IMG_SIZE))
  test_data.append(img)

test_data = np.stack(test_data, axis=0)
```

```
# pick an image in correcly-recognized image with index i=10
target_img_ind = corr_img[10]
target_img = test_data[target_img_ind]
plt.imshow(cv2.cvtColor(target_img, cv2.COLOR_BGR2RGB))
```

```
<matplotlib.image.AxesImage at 0x7f3a6ec57a90>
```



noise

```
#! git clone https://github.com/Hyperparticle/one-pixel-attack-keras
#! cd ./one-pixel-attack-keras
#noise = np.random.normal(250, 0.1, (250,250,3))
#max(noise.flatten())
```

```
# adding an unnoticeable noise
noise = np.random.normal(0.1, 0.01, (250,250,3))
```

attack

```
# attack
adversarial = cv2.resize(target_img, (IMG_SIZE, IMG_SIZE))
adversarial = (adversarial + noise)/255.
adversarial = np.expand_dims(adversarial,0)
snd_prob = model.predict(adversarial,verbose=1) # the second prediction

# result
fst_pred = to_classes[preds_y[target_img_ind]], corr_confidence[target_img_ind]
snd_pred = to_classes[np.argmax(snd_prob)], snd_prob.max(axis=1)[0]
print(fst_pred[0], snd_pred[0])
```

```
1/1 [==============================] - 0s 33ms/step
Jennifer Justin
```

```
plt.figure(figsize=[10,15])

plt.subplot(1, 3, 1)
plt.title('Original output: '+ fst_pred[0])
plt.imshow(cv2.cvtColor(target_img, cv2.COLOR_BGR2RGB))
plt.axis('off')


plt.subplot(1, 3, 2)
plt.title('Adversarial output: '+ snd_pred[0] )
plt.imshow(adversarial[0])
# plt.imshow(adversarial[:, :, ::-1] / 255)  # ::-1 to convert BGR to RGB
plt.axis('off')

plt.subplot(1, 3, 3)
plt.title('Difference')
plt.imshow(noise/255.)
plt.axis('off')

plt.show()
```