Project: Final Paper

CS8321: Neural Networks and Machine Learning

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Import Modules and Initialization

Before we begin, let's import essential packages for data analysis.

In [1]:
```
from __future__ import division

import multiprocessing.pool
import sys
import os
import tensorflow as tf
import keras.backend as K
import h5py
import numpy as np
import imageio
import matplotlib.pyplot as plt
import torch.nn as nn
import scipy.misc
import scipy.sparse
import scipy.sparse.linalg

from PIL import Image
from keras.models import Model, Sequential, load_model
from keras.layers import Conv2D, MaxPooling2D, GlobalMaxPooling2D, Input
, UpSampling2D
from keras.utils.data_utils import get_file
from keras.preprocessing.image import ImageDataGenerator
from keras.preprocessing import image
from keras.callbacks import Callback
from numpy.lib.stride_tricks import as_strided
from functools import partial

import warnings
warnings.simplefilter('ignore')

print(tf.__version__)
```

```
Using TensorFlow backend.

2.1.0
```

Building the VGG Encoder

In [2]:
```
def vgg_layers(inputs, target_layer):
    """
    Loads the layers of the VGG network
    """
    # Block 1
    x = Conv2D(64, (3, 3), activation='relu', padding='same', name='bloc
k1_conv1')(inputs)
    if target_layer == 1:
        return x
    x = Conv2D(64, (3, 3), activation='relu', padding='same', name='bloc
k1_conv2')(x)
    x = MaxPooling2D((2, 2), strides=(2, 2), name='block1_pool')(x)

    # Block 2
    x = Conv2D(128, (3, 3), activation='relu', padding='same', name='blo
ck2_conv1')(x)
    if target_layer == 2:
        return x
    x = Conv2D(128, (3, 3), activation='relu', padding='same', name='blo
ck2_conv2')(x)
    x = MaxPooling2D((2, 2), strides=(2, 2), name='block2_pool')(x)

    # Block 3
    x = Conv2D(256, (3, 3), activation='relu', padding='same', name='blo
ck3_conv1')(x)
    if target_layer == 3:
        return x
    x = Conv2D(256, (3, 3), activation='relu', padding='same', name='blo
ck3_conv2')(x)
    x = Conv2D(256, (3, 3), activation='relu', padding='same', name='blo
ck3_conv3')(x)
    x = Conv2D(256, (3, 3), activation='relu', padding='same', name='blo
ck3_conv4')(x)
    x = MaxPooling2D((2, 2), strides=(2, 2), name='block3_pool')(x)

    # Block 4
    x = Conv2D(512, (3, 3), activation='relu', padding='same', name='blo
ck4_conv1')(x)
    if target_layer == 4:
        return x
    x = Conv2D(512, (3, 3), activation='relu', padding='same', name='blo
ck4_conv2')(x)
    x = Conv2D(512, (3, 3), activation='relu', padding='same', name='blo
ck4_conv3')(x)
    x = Conv2D(512, (3, 3), activation='relu', padding='same', name='blo
ck4_conv4')(x)
    x = MaxPooling2D((2, 2), strides=(2, 2), name='block4_pool')(x)

    # Block 5
    x = Conv2D(512, (3, 3), activation='relu', padding='same', name='blo
ck5_conv1')(x)
    return x


def load_weights(model):
```

```
    """
    Loads the VGG weights from Chollet's github. Sets the following weig
hts to the convolutional layers.
    """

    link_p1 = 'https://github.com/fchollet/deep-learning-models/release
s/'
    link_p2 = 'download/v0.1/vgg19_weights_tf_dim_ordering_tf_kernels_no
top.h5'

    weights_path = get_file('vgg19_weights_tf_dim_ordering_tf_kernels_no
top.h5',
                            (link_p1+link_p2),
                            cache_subdir='models',
                            file_hash='253f8cb515780f3b799900260a226db6'
)
    f = h5py.File(weights_path)

    layer_names = [name for name in f.attrs['layer_names']]

    for layer in model.layers:
        b_name = layer.name.encode()
        if b_name in layer_names:
            g = f[b_name]
            weights = [g[name] for name in g.attrs['weight_names']]
            layer.set_weights(weights)
            layer.trainable = False

    f.close()


def VGG19(input_tensor=None, input_shape=None, target_layer=1):
    """
    VGG19, up to the target layer (1 for relu1_1, 2 for relu2_1, etc.);
        Prepares the VGG model
    """
    if input_tensor is None:
        inputs = Input(shape=input_shape)
    else:
        inputs = Input(tensor=input_tensor, shape=input_shape)
    model = Model(inputs, vgg_layers(inputs, target_layer), name='vgg19'
)
    load_weights(model)
    return model


def preprocess_input(x):
    """
    Preprocesses input for the model; Most notably this function transfe
rs the RGB of an image to BGR
    """
    # Convert 'RGB' -> 'BGR'
    if type(x) is np.ndarray:
        x = x[..., ::-1]
    else:
```

```
        x = tf.reverse(x, [-1])

    return x - np.array([103.939, 116.779, 123.68])
```

Building the Decoder

In [3]:
```
def decoder_layers(inputs, layer):
    """
    Gets a set of decoder layers for a decoder model; this structure wil
l for the most part mirror
        VGG's implementation
    """
    x = Conv2D(512, (3, 3), activation='relu', padding='same', name='dec
oder_block5_conv1')(inputs)
    if layer == 1:
        return x

    x = UpSampling2D((2, 2), name='decoder_block4_upsample')(x)
    x = Conv2D(512, (3, 3), activation='relu', padding='same', name='dec
oder_block4_conv4')(x)
    x = Conv2D(512, (3, 3), activation='relu', padding='same', name='dec
oder_block4_conv3')(x)
    x = Conv2D(512, (3, 3), activation='relu', padding='same', name='dec
oder_block4_conv2')(x)
    x = Conv2D(512, (3, 3), activation='relu', padding='same', name='dec
oder_block4_conv1')(x)
    if layer == 2:
        return x

    x = UpSampling2D((2, 2), name='decoder_block3_upsample')(x)
    x = Conv2D(256, (3, 3), activation='relu', padding='same', name='dec
oder_block3_conv4')(x)
    x = Conv2D(256, (3, 3), activation='relu', padding='same', name='dec
oder_block3_conv3')(x)
    x = Conv2D(256, (3, 3), activation='relu', padding='same', name='dec
oder_block3_conv2')(x)
    x = Conv2D(256, (3, 3), activation='relu', padding='same', name='dec
oder_block3_conv1')(x)
    if layer == 3:
        return x

    x = UpSampling2D((2, 2), name='decoder_block2_upsample')(x)
    x = Conv2D(128, (3, 3), activation='relu', padding='same', name='dec
oder_block2_conv2')(x)
    x = Conv2D(128, (3, 3), activation='relu', padding='same', name='dec
oder_block2_conv1')(x)
    if layer == 4:
        return x

    x = UpSampling2D((2, 2), name='decoder_block1_upsample')(x)
    x = Conv2D(64, (3, 3), activation='relu', padding='same', name='deco
der_block1_conv2')(x)
    x = Conv2D(64, (3, 3), activation='relu', padding='same', name='deco
der_block1_conv1')(x)
    if layer == 5:
        return x
```

Constructing the Model

In [4]:
```
def l2_loss(x):
    """
    Helper loss function using L2 normalization
    """
    return K.sum(K.square(x)) / 2

class EncoderDecoder:
    def __init__(self, input_shape=(256, 256, 3), target_layer=5,
                 decoder_path=None, loss_lambda=1):
        """
        Initialization function for the EncoderDecoder Object
        """
        self.input_shape = input_shape
        self.target_layer = target_layer
        self.loss_lambda = loss_lambda

        # Builds the model from the encoder and decoder functions seen a
bove
        self.encoder = VGG19(input_shape=input_shape, target_layer=targe
t_layer)
        if decoder_path:
            self.decoder = load_model(decoder_path, compile=False) # loa
d pre-trained weights for decoder
        else:
            self.decoder = self.create_decoder(target_layer) # ...or bui
ld weights froms scratch

        # models are sequentially constructed
        self.model = Sequential()
        self.model.add(self.encoder)
        self.model.add(self.decoder)

        self.loss = self.create_loss_fn(self.encoder)

        # using adam optimizer and our defined loss
        optimizer = tf.keras.optimizers.Adam(learning_rate=3e-5, beta_1=
0.4, beta_2=0.999)
        self.model.compile(optimizer=optimizer, loss=self.loss)

    def create_loss_fn(self, encoder):
        def get_encodings(inputs):
            """
            Gets the VGG encodings
            """
            encoder = VGG19(inputs, self.input_shape, self.target_layer)
            return encoder.output

        def loss(img_in, img_out):
            """
            Defined loss function for training
            """
            encoding_in = get_encodings(img_in)
            encoding_out = get_encodings(img_out)
            return l2_loss(img_out - img_in) + \
                   self.loss_lambda*l2_loss(encoding_out - encoding_in)
```

```
        return loss

    def create_decoder(self, target_layer):
        """
        Creates the decoder submodel from the decoder functions above
        """
        inputs = Input(shape=self.encoder.output_shape[1:])
        layers = decoder_layers(inputs, target_layer)
        output = Conv2D(3, (3, 3), activation='relu', padding='same',
                        name='decoder_out')(layers)
        return Model(inputs, output, name='decoder_%s' % target_layer)

    def export_decoder(self):
        """
        Exports the decoder weights/model
        """
        self.decoder.save('data/models/decoder_%s.h5' % self.target_laye
r)
```

Defining some Utility Functions

In [5]:
```
def count_number_of_images(path):
    """
    Counts the number of files within a directory; the structure of the
 directory must be
        dataset -> class directories -> class images
    """
    white_list_file_types = ['png', 'jpg', 'jpeg', 'bmp', 'ppm']
    num_samples = 0

    path, directories, files = next(os.walk(path))
    for directory in directories:
        path_of_dir = path + '/' + directory
        p, ds, fs = next(os.walk(path_of_dir))
        for f in fs:
            for file_type in white_list_file_types:
                if file_type in f:
                    num_samples += 1
    return num_samples

def format_image(img, is_clipping=False):
    """
    Formats an image by either clipping values below or above 0 and 255
 or alternatively
        normalizes the least and the greatest values relative to 0 and 2
55; float image is
        returned as a uint8
    """
    if is_clipping:
        img = np.clip(img / 255, 0, 1)

    else:
        if np.amin(img) < 0:
            adjust = - np.amin(img)
            img = img + adjust
        if np.amax(img) > 255:
            img = img.astype(np.float64) / np.amax(img)
        else:
            img = img.astype(np.float64) / 255

    img = 255 * img # Now scale by 255
    return img.astype(np.uint8)
```

Prepare Training

In [6]:
```
def create_gen(img_dir, target_size, batch_size):
    """
    Generates data from an image directory
    """
    datagen = ImageDataGenerator()
    gen = datagen.flow_from_directory(img_dir, target_size=target_size,
                                      batch_size=batch_size, class_mode=
None)
    def tuple_gen():
        for img in gen:
            if img.shape[0] != batch_size:
                continue

            # (X, y)
            yield (img, img)

    return tuple_gen()

class OutputPreview(Callback):

    def __init__(self, model, test_img_path, preview_dir_path, image_siz
e=(256, 256), increment=5000):
        test_img = image.load_img(test_img_path)
        """
        Initialization function for Output Preview Object; Declares clas
s variables
        """
        test_img = test_img.resize(image_size) # Assumes using 3 channel
s

        test_target = image.img_to_array(test_img)
        test_target = np.expand_dims(test_target, axis=0)
        self.test_img = test_target
        self.model = model

        self.preview_dir_path = preview_dir_path

        self.increment = increment
        self.iteration = 0

    def on_batch_end(self, batch, logs={}):
        """
        Defines what to do during training at the end of a batch; output
s current progress of image reconstruction
        """
        if (self.iteration % self.increment == 0):
            output_img = self.model.predict(self.test_img)[0]
            fname = '%d.jpg' % self.iteration
            out_path = os.path.join(self.preview_dir_path, fname)

            # normalize and convert image then save image to show previe
w of output
            output_img = format_image(output_img)
            imageio.imwrite(out_path, output_img)
```

```
        self.iteration += 1
```

Awesome. Everything is ready for creating our model and training. Now we're going to quickly create some variables to train.

In [7]:
```
# Parameters
train_path = 'data/datasets/faces'
image_size = (64, 64)
batch_size = 32
epochs = 6000

target_layer = 5 # ranges from values 1 through 5
loss_lambda = 1 # ranges from values 0 through 1

is_using_callbacks = True
callbacks_image_path = "data/input/nick1.png"
callbacks_preview_path = "data/output"
```

Execute Training

In [ ]:
```
# Generates data
gen = create_gen(train_path, image_size, batch_size)

# steps per epoch are determined by the number of samples and batch size
num_samples = count_number_of_images(train_path)
steps_per_epoch = num_samples // batch_size

# define our encoder_decoder model
encoder_decoder = EncoderDecoder(input_shape=(image_size[0], image_size[
1], 3),
                                 target_layer=target_layer,
                                 loss_lambda=loss_lambda)

# wether or not to use callbacks and preview decoded output during train
ing
if (is_using_callbacks):
    callbacks = [OutputPreview(encoder_decoder, callbacks_image_path,
                               callbacks_preview_path, image_size=image_
size)]
    encoder_decoder.model.fit_generator(gen, steps_per_epoch=steps_per_e
poch,
                                        epochs=epochs, callbacks=callbac
ks)
else:
    encoder_decoder.model.fit_generator(gen, steps_per_epoch=steps_per_e
poch, epochs=epochs)

# export trained output
encoder_decoder.export_decoder()
```

training output has been suppressed

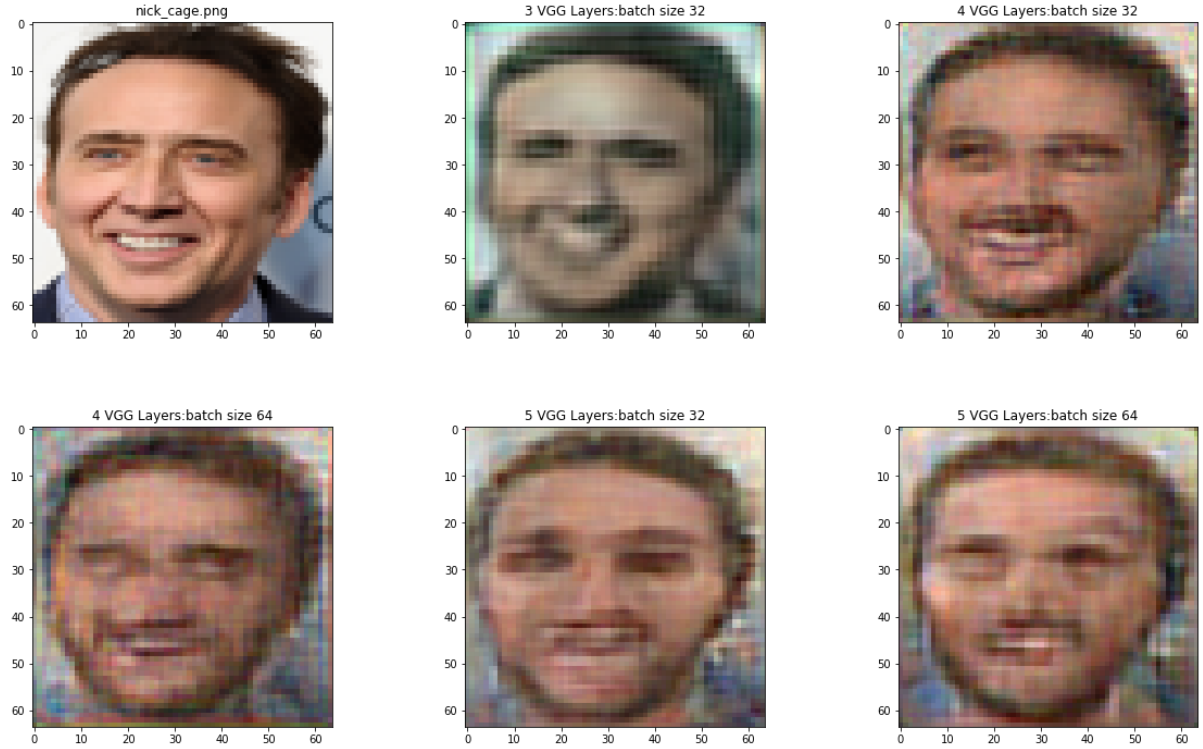
Encoder Prediction Function and Plotting Function

In [31]:
```
def get_prediction_from_autoencoder(decoder_path, input_image, input_ima
ge_size, target_layer):
    """
    Gets an output from a pretrained autoencoder using an input image
    """
    # Builds model through a specified weights path and target layer
    encoder_decoder = EncoderDecoder(input_shape=(64, 64, 3),
                                     decoder_path=decoder_path,
                                     target_layer=target_layer)

    # gets decoded output
    output_image = encoder_decoder.model.predict([input_image])[0]

    # Convert image to uint8
    output_image = format_image(output_image)

    # return image
    return output_image


def plot_image_gallery(image_dir_path, image_name, image_size=(64, 64)):
    """
    Plotting image gallery for decoded output from a encoder/decoder mod
el; Plots an original image next to five
    reconstructions from different model layers
    """
    plt.figure(figsize=(16, 10))
    plt.subplots_adjust(bottom=0, left=.01, right=.99, top=.90, hspace=.
35)

    # Plot Original
    plt.subplot(2, 3, 1)
    original_image = image.load_img(image_dir_path+'/'+image_name)
    original_image = original_image.resize(image_size)
    plt.imshow(original_image)
    plt.title(image_name, size=12)

    # preprocessing of original image
    original_image = image.img_to_array(original_image)
    original_image = np.expand_dims(original_image, axis=0)

    # Plot Decoder 1 Output
    plt.subplot(2, 3, 2)
    decoder_path = 'data/models/decoder_3_32.h5'
    img = get_prediction_from_autoencoder(decoder_path, original_image,
image_size, 3)
    plt.imshow(img)
    plt.title('3 VGG Layers:batch size 32')

    # Plot Decoder 2 Output
    plt.subplot(2, 3, 3)
    decoder_path = 'data/models/decoder_4_32.h5'
    img = get_prediction_from_autoencoder(decoder_path, original_image,
image_size, 4)
    plt.imshow(img)
```

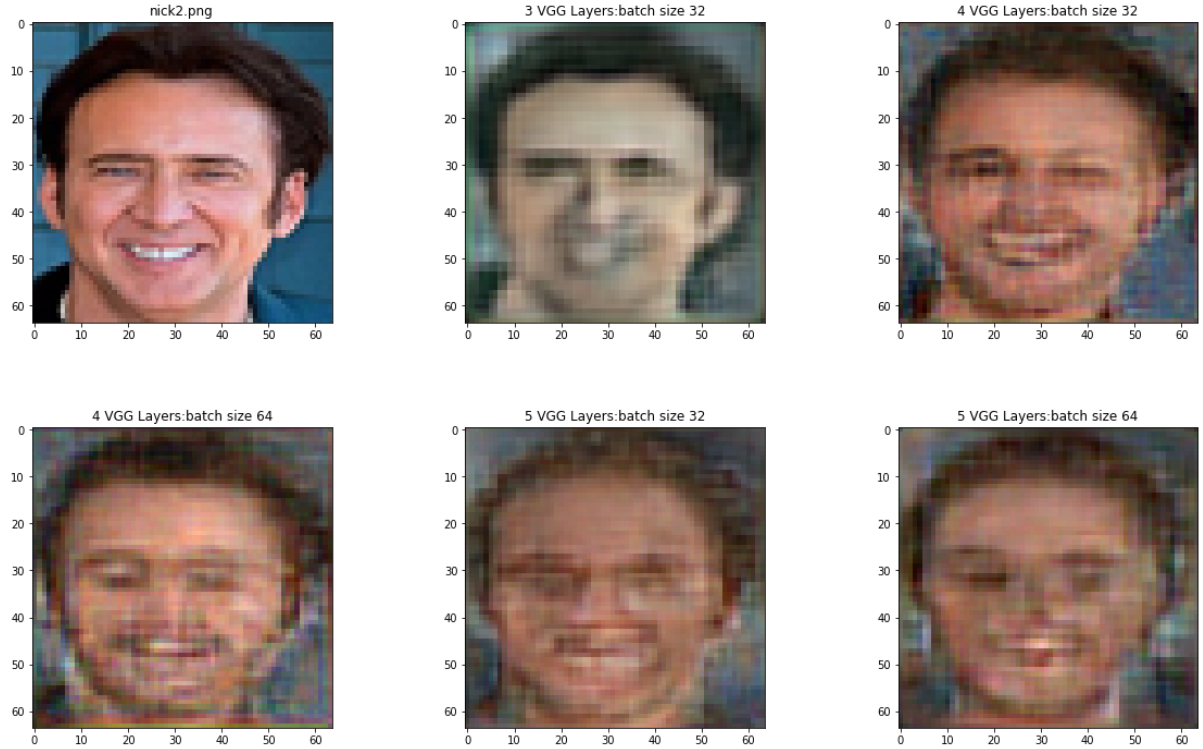
```
    plt.title('4 VGG Layers:batch size 32')

    # Plot Decoder 3 Output
    plt.subplot(2, 3, 4)
    decoder_path = 'data/models/decoder_4_64.h5'
    img = get_prediction_from_autoencoder(decoder_path, original_image,
image_size, 4)
    plt.imshow(img)
    plt.title('4 VGG Layers:batch size 64')

    # Plot Decoder 4 Output
    plt.subplot(2, 3, 5)
    decoder_path = 'data/models/decoder_5_32.h5'
    img = get_prediction_from_autoencoder(decoder_path, original_image,
image_size, 5)
    plt.imshow(img)
    plt.title('5 VGG Layers:batch size 32')

    # Plot Decoder 5 Output
    plt.subplot(2, 3, 6)
    decoder_path = 'data/models/decoder_5_64.h5'
    img = get_prediction_from_autoencoder(decoder_path, original_image,
image_size, 5)
    plt.imshow(img)
    plt.title('5 VGG Layers:batch size 64')
```

Training Evaluation

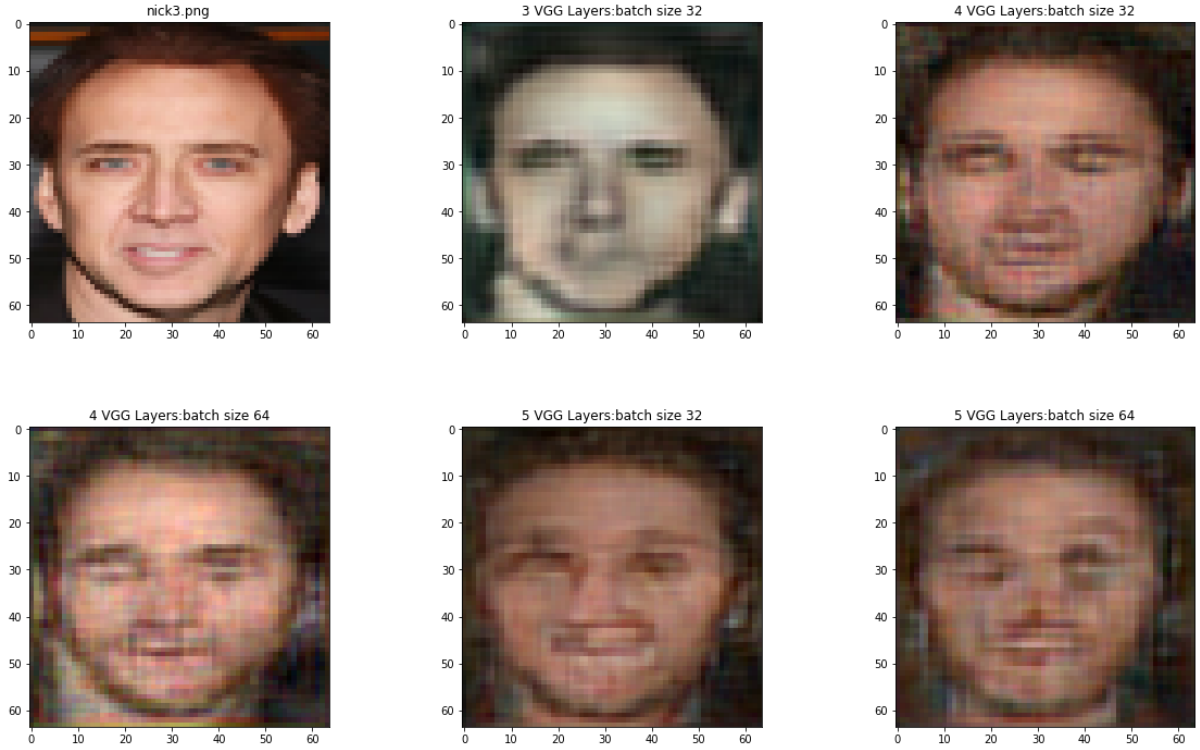
In [32]:
```
image_dir_path = 'data/input'

image_name = 'nick1.png'
plot_image_gallery(image_dir_path, image_name)
```



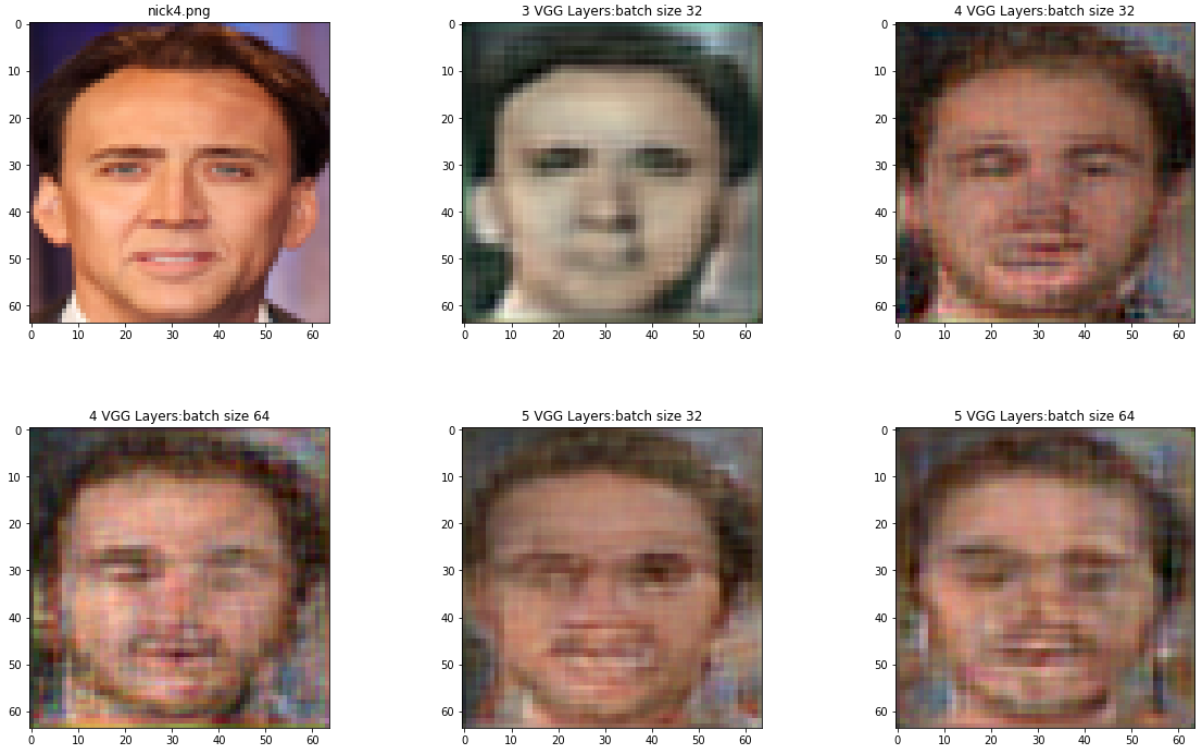
In [34]:
```
image_name = 'nick2.png'
plot_image_gallery(image_dir_path, image_name)
```



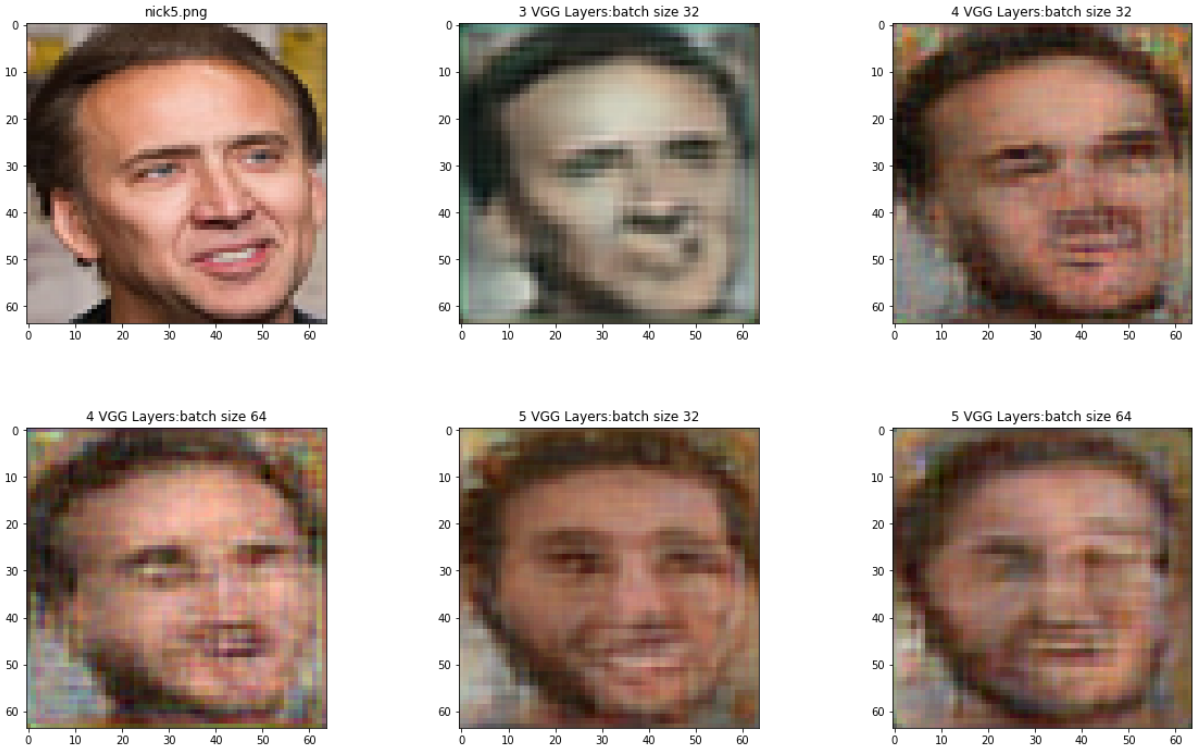
In [35]:
```
image_name = 'nick3.png'
plot_image_gallery(image_dir_path, image_name)
```



In [36]:
```
image_name = 'nick4.png'
plot_image_gallery(image_dir_path, image_name)
```

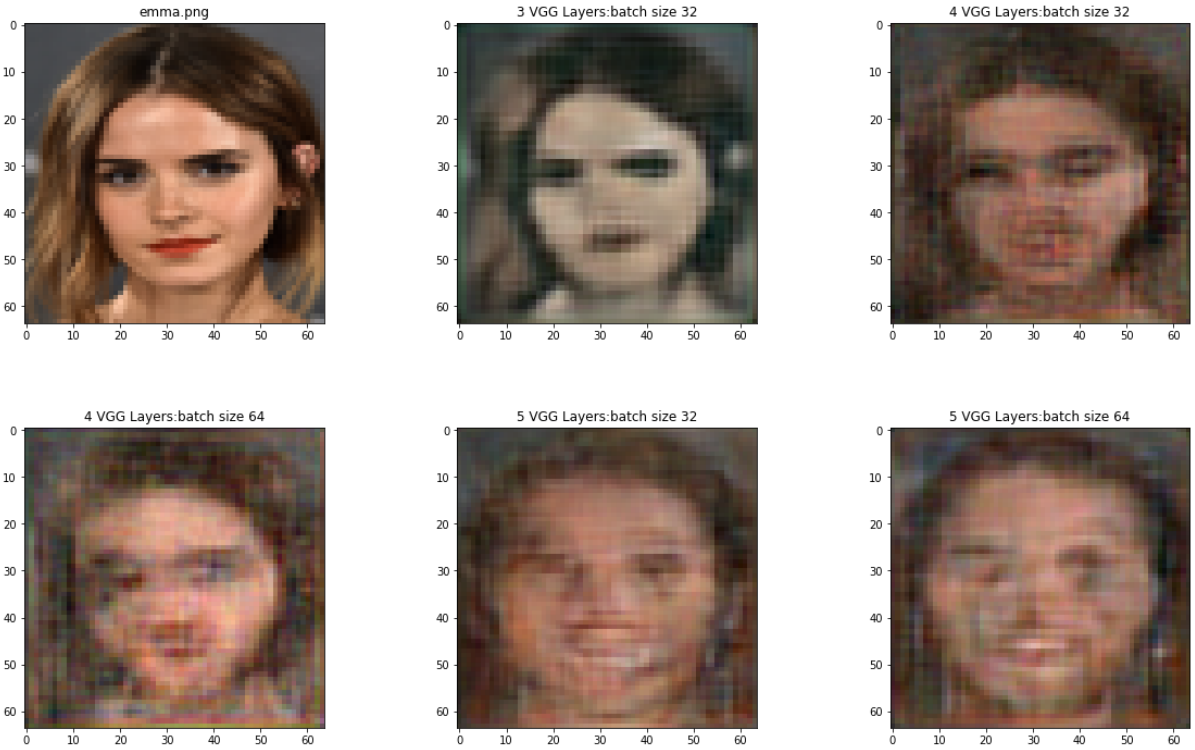


In [37]:
```
image_name = 'nick5.png'
plot_image_gallery(image_dir_path, image_name)
```

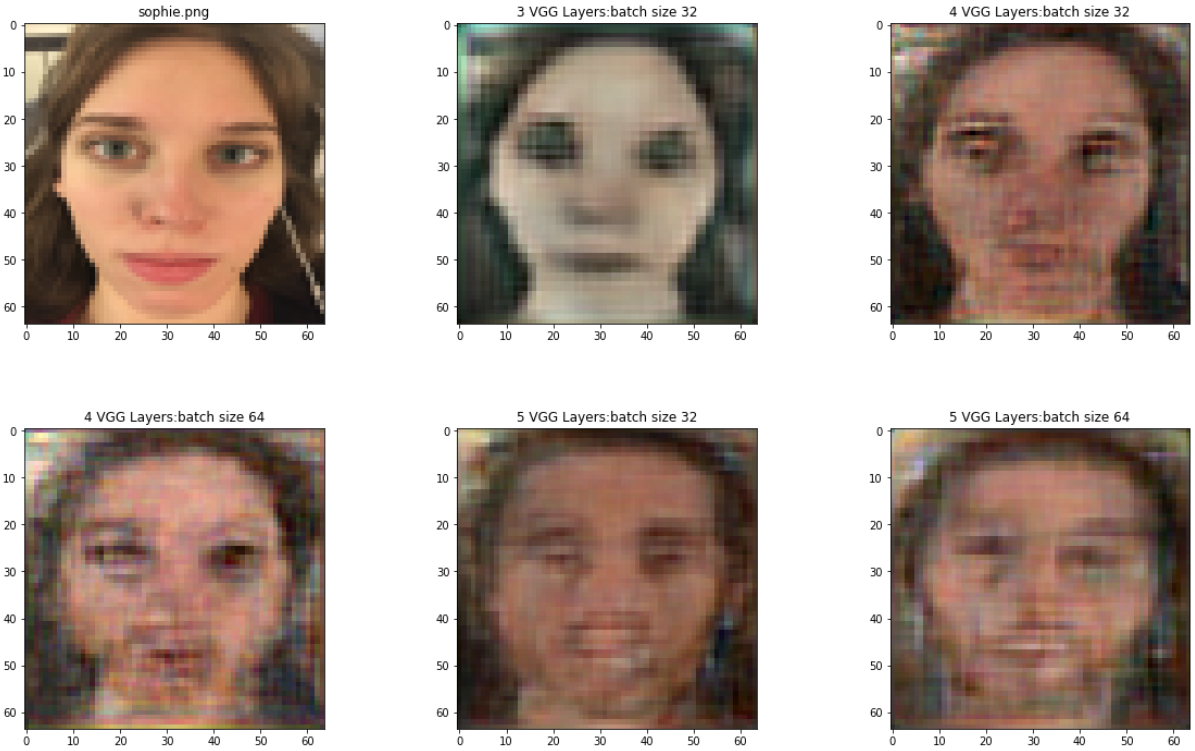


And let's do a few more just for fun

In [38]:
```
image_name = 'emma.png'
plot_image_gallery(image_dir_path, image_name)
```



In [39]:
```
image_name = 'sophie.png'
plot_image_gallery(image_dir_path, image_name)
```



In [40]:
```
image_name = 'jake.png'
plot_image_gallery(image_dir_path, image_name)
```

In [ ]:
```

```