Pix2PixGAN_ExceedModel

December 3, 2021

1 Importing Libraries

[11]:
```
import numpy as np
import matplotlib.pyplot as plt
import tensorflow as tf
from keras import backend as K
from tensorflow import keras
from keras.layers import Input, Dense, Conv2D, Conv2DTranspose, Flatten,␣
↪Lambda, Reshape
from tensorflow.keras import layers
from keras.models import Model
from keras.losses import binary_crossentropy
import glob
from numpy import asarray
from keras.preprocessing.image import load_img, img_to_array
from os import listdir
from zipfile import ZipFile
from PIL import Image
from sklearn.model_selection import train_test_split
import tensorflow as tf
import numpy as np
from matplotlib import image
from matplotlib import pyplot as plt
import os
from keras.utils.vis_utils import plot_model
```

2 Extract Image zip file

[2]:
```
file_name = "Nature_Images.zip"

with ZipFile(file_name, 'r') as images:
  images.extractall()
```

[4]:
```
# Hyperparameters
batch_size = 64
img_size = 120
```

```
dataset_split = 1500

master_dir = 'Images/'
x = []
y = []
for image_file in os.listdir(master_dir)[0 : dataset_split]:
    rgb_image = Image.open(os.path.join(master_dir, image_file)).
 ↪resize((img_size, img_size))
    # Normalize the RGB image array
    rgb_img_array = (np.asarray(rgb_image)) / 255
    gray_image = rgb_image.convert('L')
    # Normalize the grayscale image array
    gray_img_array = (np.asarray(gray_image).reshape((img_size, img_size, 1))) /
 ↪ 255
    # Append both the image arrays
    x.append(gray_img_array)
    y.append(rgb_img_array)
```

3 Splitting Data

[5]:
```
# Train-test splitting
train_x, test_x, train_y, test_y = train_test_split(np.array(x), np.array(y),␣
 ↪test_size=0.1)

# Construct tf.data.Dataset object
dataset = tf.data.Dataset.from_tensor_slices((train_x, train_y))
dataset = dataset.batch(batch_size)
```

4 Generator

[6]:
```
def get_generator_model():

    inputs = tf.keras.layers.Input(shape=(img_size, img_size, 1))

    conv1 = tf.keras.layers.Conv2D(16, kernel_size=(5, 5), strides=1)(inputs)
    conv1 = tf.keras.layers.LeakyReLU()(conv1)
    conv1 = tf.keras.layers.Conv2D(32, kernel_size=(3, 3), strides=1)(conv1)
    conv1 = tf.keras.layers.LeakyReLU()(conv1)
    conv1 = tf.keras.layers.Conv2D(32, kernel_size=(3, 3), strides=1)(conv1)
    conv1 = tf.keras.layers.LeakyReLU()(conv1)

    conv2 = tf.keras.layers.Conv2D(32, kernel_size=(5, 5), strides=1)(conv1)
    conv2 = tf.keras.layers.LeakyReLU()(conv2)
    conv2 = tf.keras.layers.Conv2D(64, kernel_size=(3, 3), strides=1)(conv2)
    conv2 = tf.keras.layers.LeakyReLU()(conv2)
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    conv2 = tf.keras.layers.Conv2D(64, kernel_size=(3, 3), strides=1)(conv2)
    conv2 = tf.keras.layers.LeakyReLU()(conv2)

    conv3 = tf.keras.layers.Conv2D(64, kernel_size=(5, 5), strides=1)(conv2)
    conv3 = tf.keras.layers.LeakyReLU()(conv3)
    conv3 = tf.keras.layers.Conv2D(128, kernel_size=(3, 3), strides=1)(conv3)
    conv3 = tf.keras.layers.LeakyReLU()(conv3)
    conv3 = tf.keras.layers.Conv2D(128, kernel_size=(3, 3), strides=1)(conv3)
    conv3 = tf.keras.layers.LeakyReLU()(conv3)

    bottleneck = tf.keras.layers.Conv2D(128, kernel_size=(3, 3), strides=1,␣
↪activation='tanh', padding='same')(conv3)

    concat_1 = tf.keras.layers.Concatenate()([bottleneck, conv3])
    conv_up_3 = tf.keras.layers.Conv2DTranspose(128, kernel_size=(3, 3),␣
↪strides=1, activation='relu')(concat_1)
    conv_up_3 = tf.keras.layers.Conv2DTranspose(128, kernel_size=(3, 3),␣
↪strides=1, activation='relu')(conv_up_3)
    conv_up_3 = tf.keras.layers.Conv2DTranspose(64, kernel_size=(5, 5),␣
↪strides=1, activation='relu')(conv_up_3)

    concat_2 = tf.keras.layers.Concatenate()([conv_up_3, conv2])
    conv_up_2 = tf.keras.layers.Conv2DTranspose(64, kernel_size=(3, 3),␣
↪strides=1, activation='relu')(concat_2)
    conv_up_2 = tf.keras.layers.Conv2DTranspose(64, kernel_size=(3, 3),␣
↪strides=1, activation='relu')(conv_up_2)
    conv_up_2 = tf.keras.layers.Conv2DTranspose(32, kernel_size=(5, 5),␣
↪strides=1, activation='relu')(conv_up_2)

    concat_3 = tf.keras.layers.Concatenate()([conv_up_2, conv1])
    conv_up_1 = tf.keras.layers.Conv2DTranspose(32, kernel_size=(3, 3),␣
↪strides=1, activation='relu')(concat_3)
    conv_up_1 = tf.keras.layers.Conv2DTranspose(32, kernel_size=(3, 3),␣
↪strides=1, activation='relu')(conv_up_1)
    conv_up_1 = tf.keras.layers.Conv2DTranspose(3, kernel_size=(5, 5),␣
↪strides=1, activation='relu')(conv_up_1)

    model = tf.keras.models.Model(inputs, conv_up_1)
    return model
```

5 Discriminitor

[7]:
```
def get_discriminator_model():
    layers = [
        tf.keras.layers.Conv2D(32, kernel_size=(7, 7), strides=1,␣
↪activation='relu', input_shape=(120, 120, 3)),
```

```
        tf.keras.layers.Conv2D(32, kernel_size=(7, 7), strides=1,␣
↪activation='relu'),
        tf.keras.layers.MaxPooling2D(),
        tf.keras.layers.Conv2D(64, kernel_size=(5, 5), strides=1,␣
↪activation='relu'),
        tf.keras.layers.Conv2D(64, kernel_size=(5, 5), strides=1,␣
↪activation='relu'),
        tf.keras.layers.MaxPooling2D(),
        tf.keras.layers.Conv2D(128, kernel_size=(3, 3), strides=1,␣
↪activation='relu'),
        tf.keras.layers.Conv2D(128, kernel_size=(3, 3), strides=1,␣
↪activation='relu'),
        tf.keras.layers.MaxPooling2D(),
        tf.keras.layers.Conv2D(256, kernel_size=(3, 3), strides=1,␣
↪activation='relu'),
        tf.keras.layers.Conv2D(256, kernel_size=(3, 3), strides=1,␣
↪activation='relu'),
        tf.keras.layers.MaxPooling2D(),
        tf.keras.layers.Flatten(),
        tf.keras.layers.Dense(512, activation='relu'),
        tf.keras.layers.Dense(128, activation='relu'),
        tf.keras.layers.Dense(16, activation='relu'),
        tf.keras.layers.Dense(1, activation='sigmoid')]
    model = tf.keras.models.Sequential(layers)
    return model
```

6 Calculate Losses

[8]:
```
cross_entropy = tf.keras.losses.BinaryCrossentropy()
mse = tf.keras.losses.MeanSquaredError()

def discriminator_loss(real_output, fake_output):
    real_loss = cross_entropy(tf.ones_like(real_output) - tf.random.
↪uniform(shape=real_output.shape, maxval=0.1), real_output)
    fake_loss = cross_entropy(tf.zeros_like(fake_output) + tf.random.
↪uniform(shape=fake_output.shape, maxval=0.1), fake_output)
    total_loss = real_loss + fake_loss
    return total_loss

def generator_loss(fake_output , real_y):
    real_y = tf.cast(real_y, 'float32' )
    return mse(fake_output, real_y)

generator_optimizer = tf.keras.optimizers.Adam(0.0005)
discriminator_optimizer = tf.keras.optimizers.Adam(0.0005)
```

```
generator = get_generator_model()
discriminator = get_discriminator_model()
```

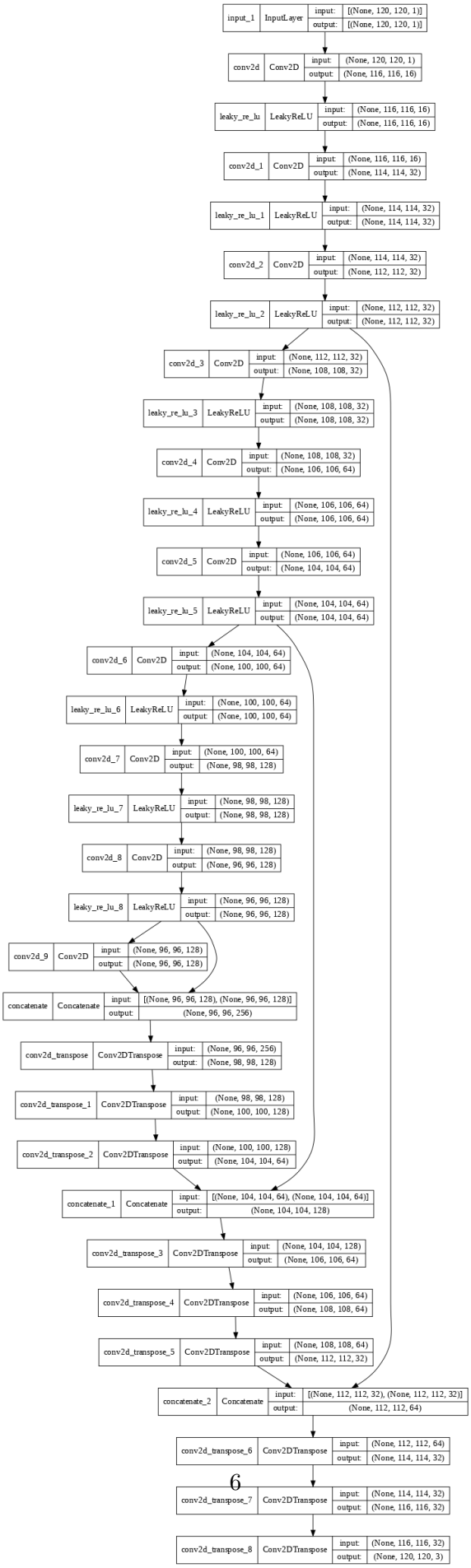
[ ]:
```
checkpoint_dir = './training_checkpoints'
checkpoint_prefix = os.path.join(checkpoint_dir, "ckpt")
checkpoint = tf.train.Checkpoint(generator_optimizer=generator_optimizer,
                                 ␣
 ↪discriminator_optimizer=discriminator_optimizer,
                                 generator=generator,
                                 discriminator=discriminator)
```

7 Training Model

[9]:
```
@tf.function
def train_step(input_x, real_y):

    with tf.GradientTape() as gen_tape, tf.GradientTape() as disc_tape:
        # Generate an image -> G(x)
        generated_images = generator(input_x, training=True)
        # Probability that the given image is real -> D(x)
        real_output = discriminator(real_y, training=True)
        # Probability that the given image is the one generated -> D(G(x))
        generated_output = discriminator(generated_images, training=True)

        # L2 Loss -> || y - G(x) ||^2
        gen_loss = generator_loss(generated_images, real_y)
        # Log loss for the discriminator
        disc_loss = discriminator_loss(real_output, generated_output)


    # Compute the gradients
    gradients_of_generator = gen_tape.gradient(gen_loss, generator.
 ↪trainable_variables)
    gradients_of_discriminator = disc_tape.gradient(disc_loss, discriminator.
 ↪trainable_variables)

    # Optimize with Adam
    generator_optimizer.apply_gradients(zip(gradients_of_generator, generator.
 ↪trainable_variables))
    discriminator_optimizer.apply_gradients(zip(gradients_of_discriminator,␣
 ↪discriminator.trainable_variables))
```

[12]:
```
plot_model(generator, to_file='generator.png', show_shapes=True,␣
 ↪show_layer_names=True, dpi=66)
```

[12]:


input_1 InputLayer input: [(None, 120, 120, 1)] output: [(None, 120, 120, 1)]
conv2d Conv2D input: (None, 120, 120, 1) output: (None, 116, 116, 16)
leaky_re_lu LeakyReLU input: (None, 116, 116, 16) output: (None, 116, 116, 16)
conv2d_1 Conv2D input: (None, 116, 116, 16) output: (None, 114, 114, 32)
leaky_re_lu_1 LeakyReLU input: (None, 114, 114, 32) output: (None, 114, 114, 32)
conv2d_2 Conv2D input: (None, 114, 114, 32) output: (None, 112, 112, 32)
leaky_re_lu_2 LeakyReLU input: (None, 112, 112, 32) output: (None, 112, 112, 32)
conv2d_3 Conv2D input: (None, 112, 112, 32) output: (None, 108, 108, 32)
leaky_re_lu_3 LeakyReLU input: (None, 108, 108, 32) output: (None, 108, 108, 32)
conv2d_4 Conv2D input: (None, 108, 108, 32) output: (None, 106, 106, 64)
leaky_re_lu_4 LeakyReLU input: (None, 106, 106, 64) output: (None, 106, 106, 64)
conv2d_5 Conv2D input: (None, 106, 106, 64) output: (None, 104, 104, 64)
leaky_re_lu_5 LeakyReLU input: (None, 104, 104, 64) output: (None, 104, 104, 64)
conv2d_6 Conv2D input: (None, 104, 104, 64) output: (None, 100, 100, 64)
leaky_re_lu_6 LeakyReLU input: (None, 100, 100, 64) output: (None, 100, 100, 64)
conv2d_7 Conv2D input: (None, 100, 100, 64) output: (None, 98, 98, 128)
leaky_re_lu_7 LeakyReLU input: (None, 98, 98, 128) output: (None, 98, 98, 128)
conv2d_8 Conv2D input: (None, 98, 98, 128) output: (None, 96, 96, 128)
leaky_re_lu_8 LeakyReLU input: (None, 96, 96, 128) output: (None, 96, 96, 128)
conv2d_9 Conv2D input: (None, 96, 96, 128) output: (None, 96, 96, 128)
concatenate Concatenate input: [(None, 96, 96, 128), (None, 96, 96, 128)] output: (None, 96, 96, 256)
conv2d_transpose Conv2DTranspose input: (None, 96, 96, 256) output: (None, 98, 98, 128)
conv2d_transpose_1 Conv2DTranspose input: (None, 98, 98, 128) output: (None, 100, 100, 128)
conv2d_transpose_2 Conv2DTranspose input: (None, 100, 100, 128) output: (None, 104, 104, 64)
concatenate_1 Concatenate input: [(None, 104, 104, 64), (None, 104, 104, 64)] output: (None, 104, 104, 128)
conv2d_transpose_3 Conv2DTranspose input: (None, 104, 104, 128) output: (None, 106, 106, 64)
conv2d_transpose_4 Conv2DTranspose input: (None, 106, 106, 64) output: (None, 108, 108, 64)
conv2d_transpose_5 Conv2DTranspose input: (None, 108, 108, 64) output: (None, 112, 112, 32)
concatenate_2 Concatenate input: [(None, 112, 112, 32), (None, 112, 112, 32)] output: (None, 112, 112, 64)
conv2d_transpose_6 Conv2DTranspose input: (None, 112, 112, 64) output: (None, 114, 114, 32)
conv2d_transpose_7 Conv2DTranspose input: (None, 114, 114, 32) output: (None, 116, 116, 32)
conv2d_transpose_8 Conv2DTranspose input: (None, 116, 116, 32) output: (None, 120, 120, 3)

[14]:
```
num_epochs = 100

for e in range(num_epochs):
    print(e)
    for (x, y) in dataset:
        # Here (x, y) represents a batch from our training dataset.
        print(x.shape)
        train_step(x, y)
```

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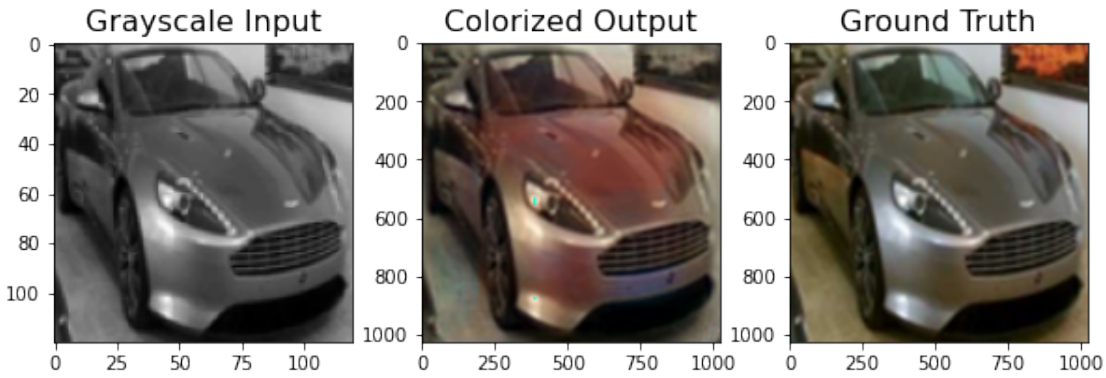
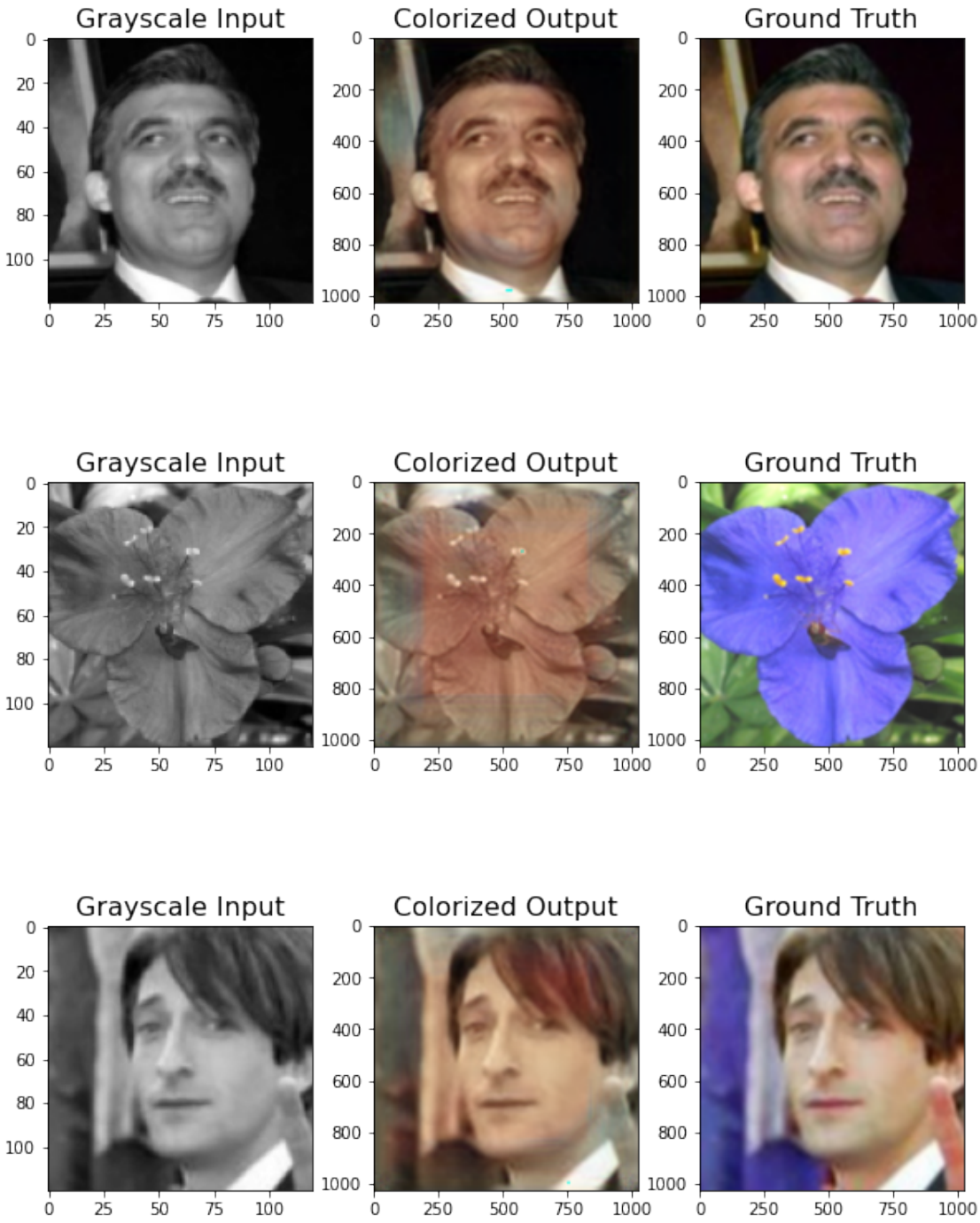
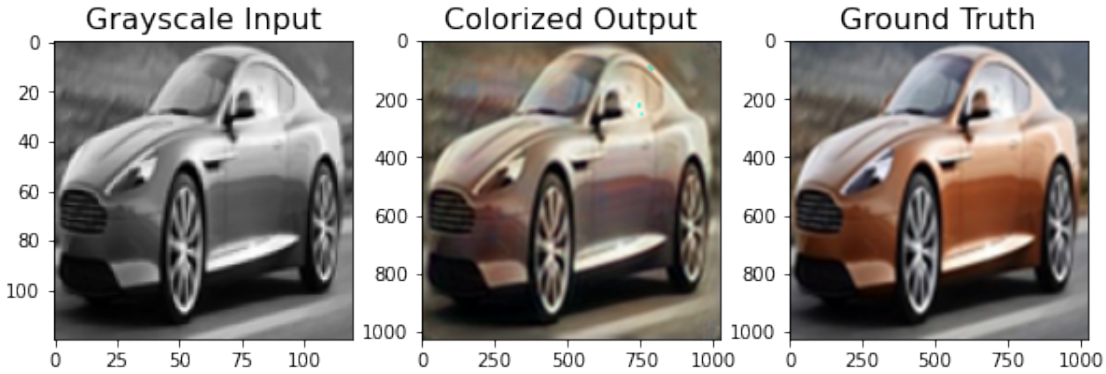
8 Inference

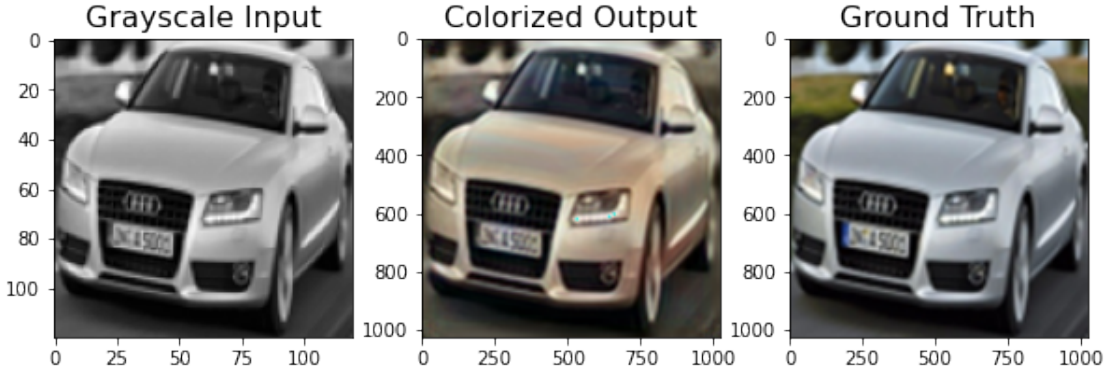
[16]:
```
y = generator(test_x[0:]).numpy()
```

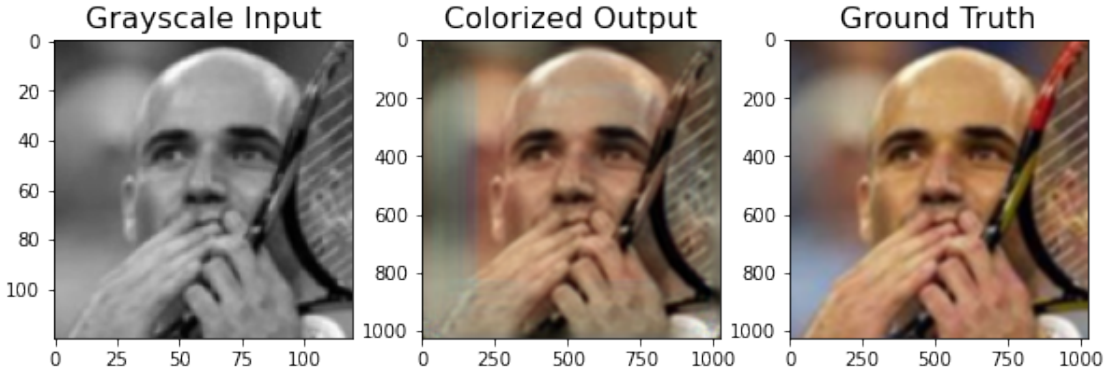
[17]:
```
for i in range(len(test_x)):
  plt.figure(figsize=(10,10))
  or_image = plt.subplot(3,3,1)
  or_image.set_title('Grayscale Input', fontsize=16)
  plt.imshow(test_x[i].reshape((120,120)), cmap='gray')

  in_image = plt.subplot(3,3,2)
  image = Image.fromarray((y[i] * 255).astype('uint8')).resize((1024, 1024))
  image = np.asarray(image)
  in_image.set_title('Colorized Output', fontsize=16)
  plt.imshow(image)

  ou_image = plt.subplot(3,3,3)
  image = Image.fromarray((test_y[i] * 255).astype('uint8')).resize((1024,␣
↪1024))
  ou_image.set_title('Ground Truth', fontsize=16)
  plt.imshow(image)

  plt.show()
```

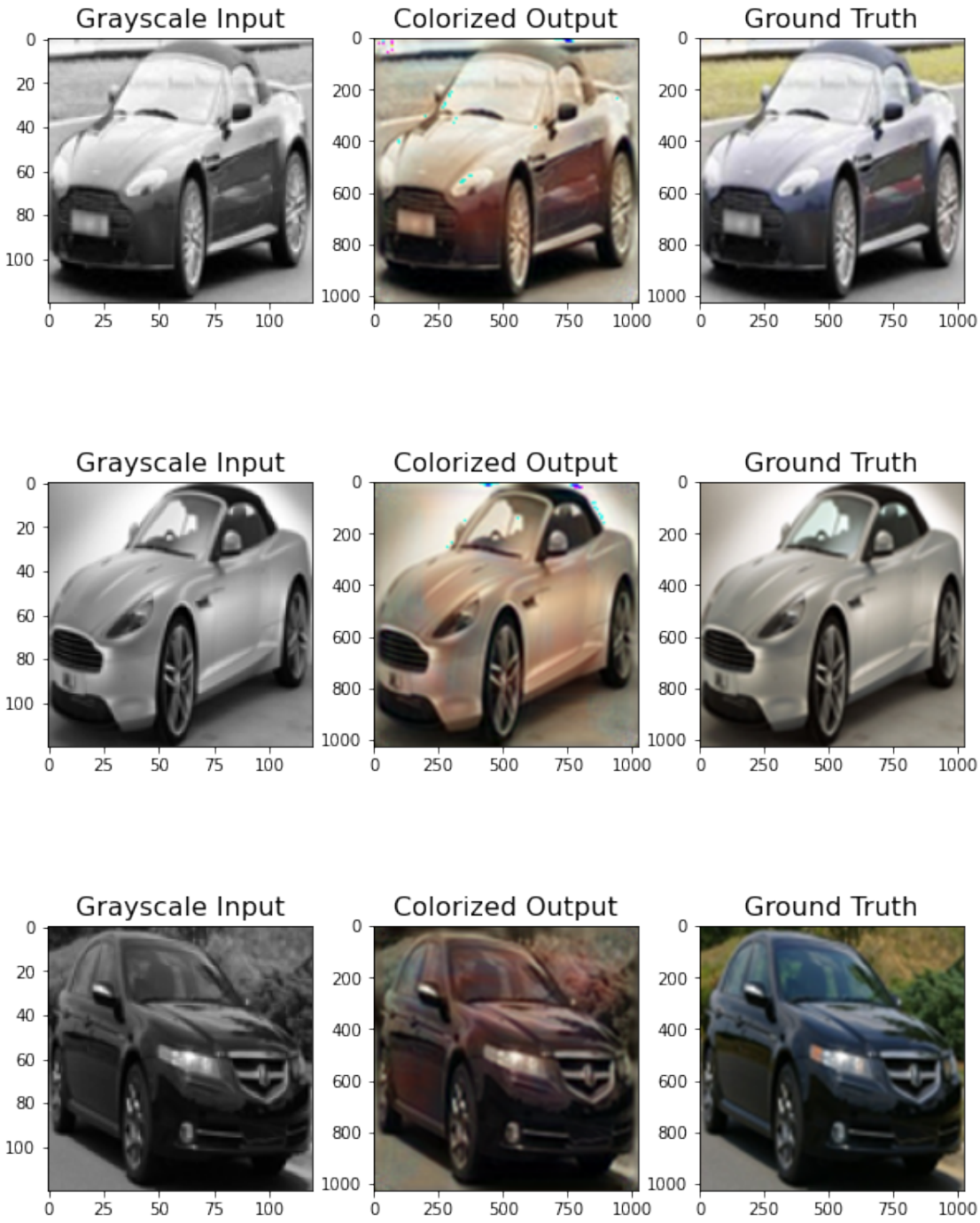



Grayscale Input
Colorized Output
Ground Truth
Grayscale Input
Colorized Output
Ground Truth
Grayscale Input
Colorized Output
Ground Truth


Grayscale Input
Colorized Output
Ground Truth


Grayscale Input
Colorized Output
Ground Truth


Grayscale Input
Colorized Output
Ground Truth


Grayscale Input
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Grayscale Input
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Ground Truth
Grayscale Input
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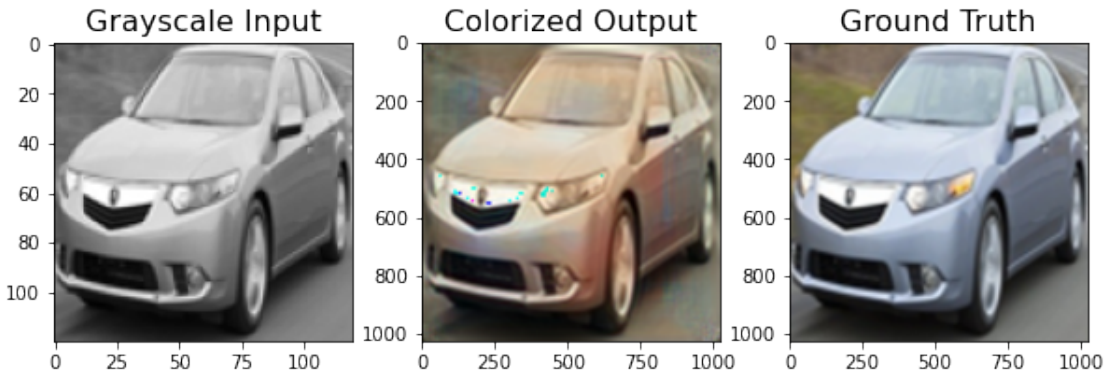
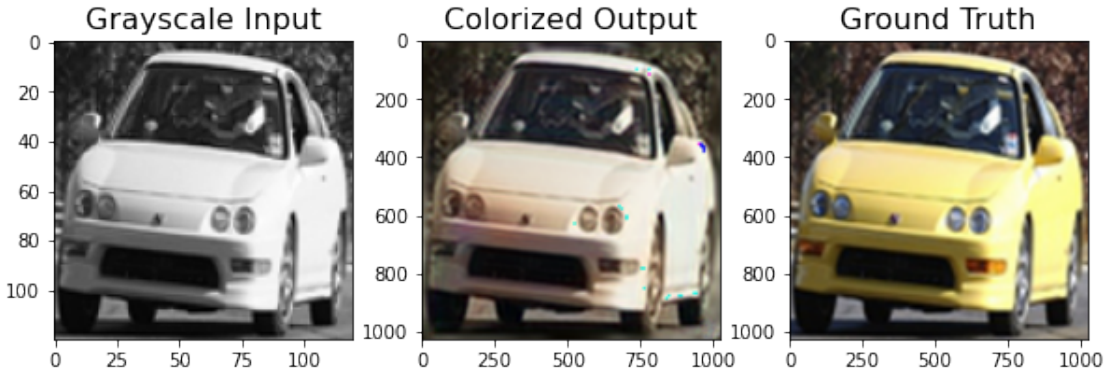
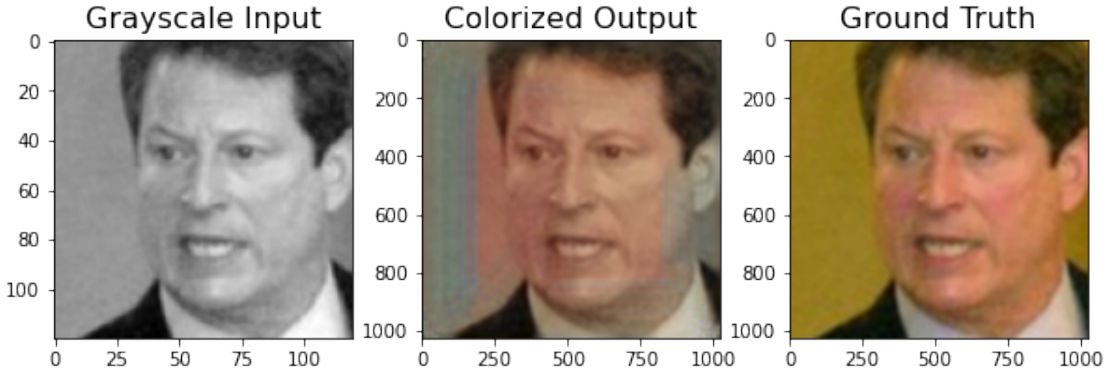
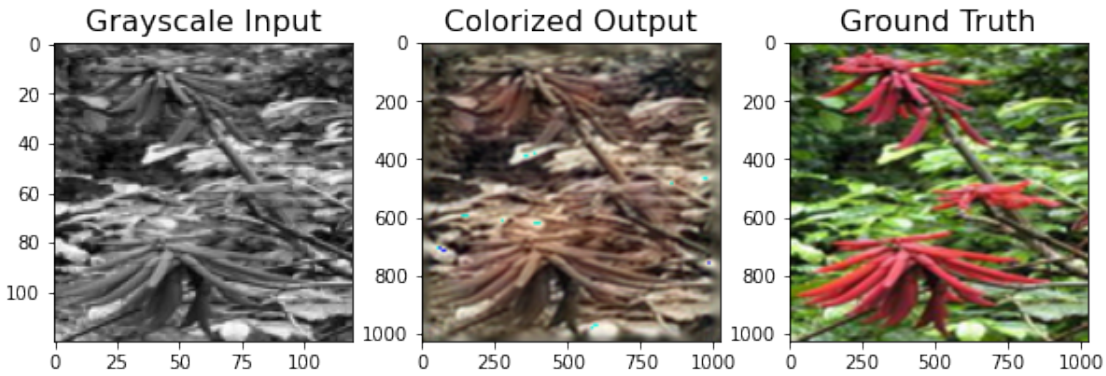
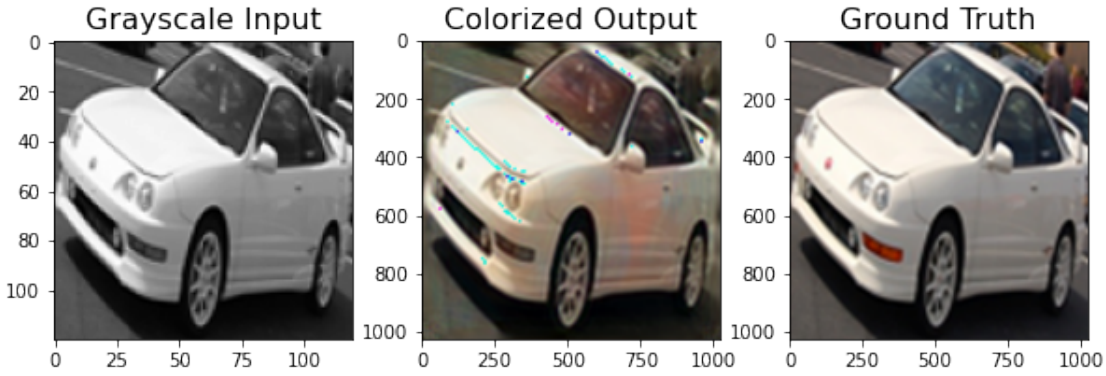
Ground Truth

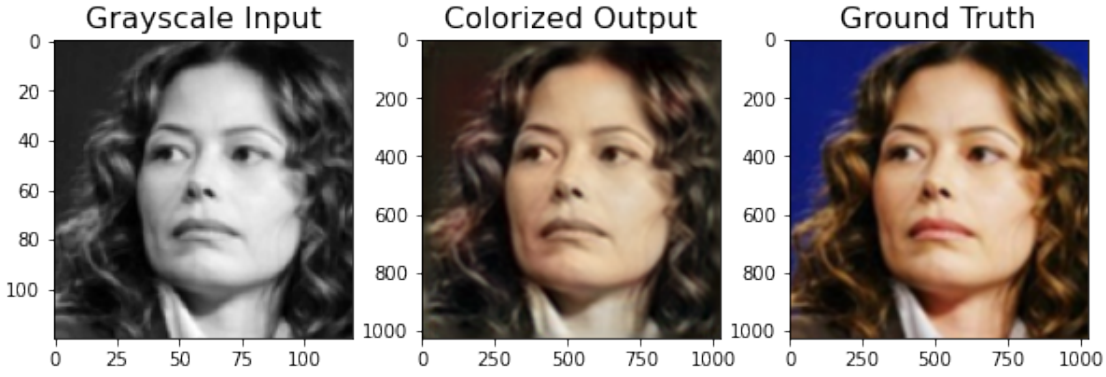

Grayscale Input
Colorized Output
Ground Truth

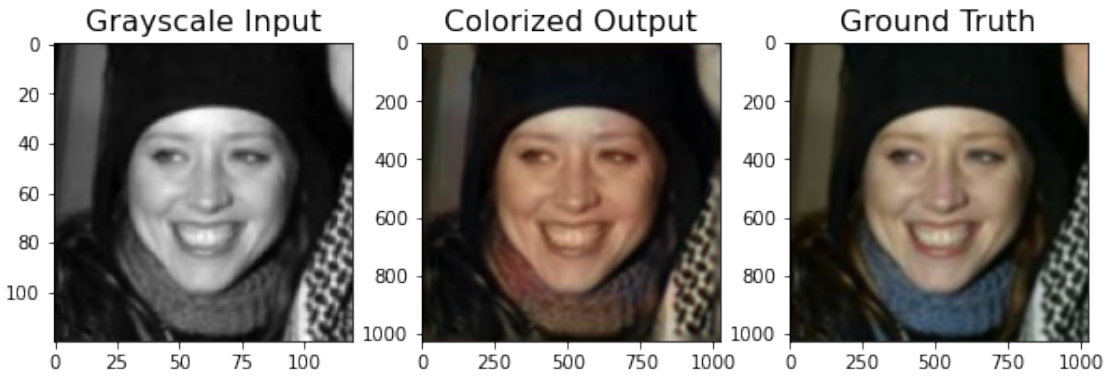

Grayscale Input
Colorized Output
Ground Truth

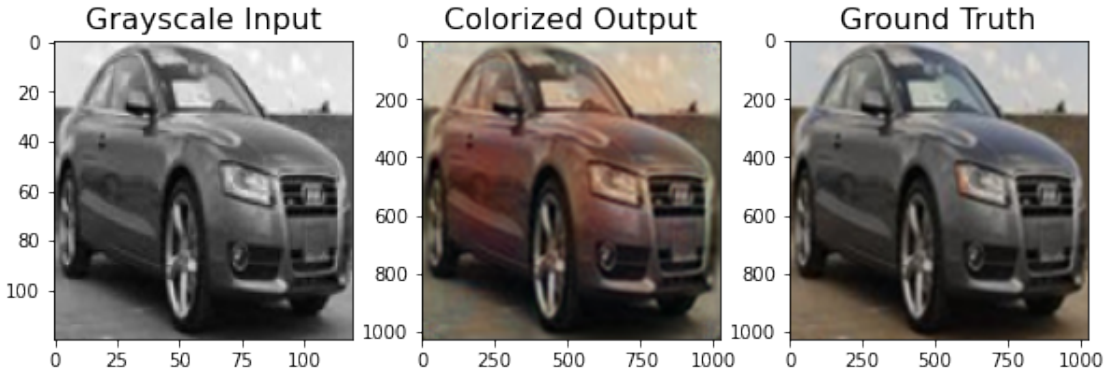

Grayscale Input
Colorized Output
Ground Truth

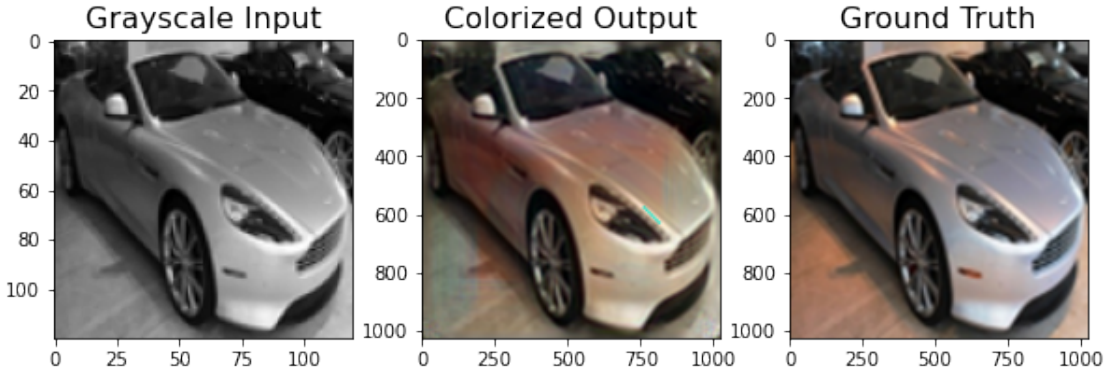

Grayscale Input
Colorized Output
Ground Truth

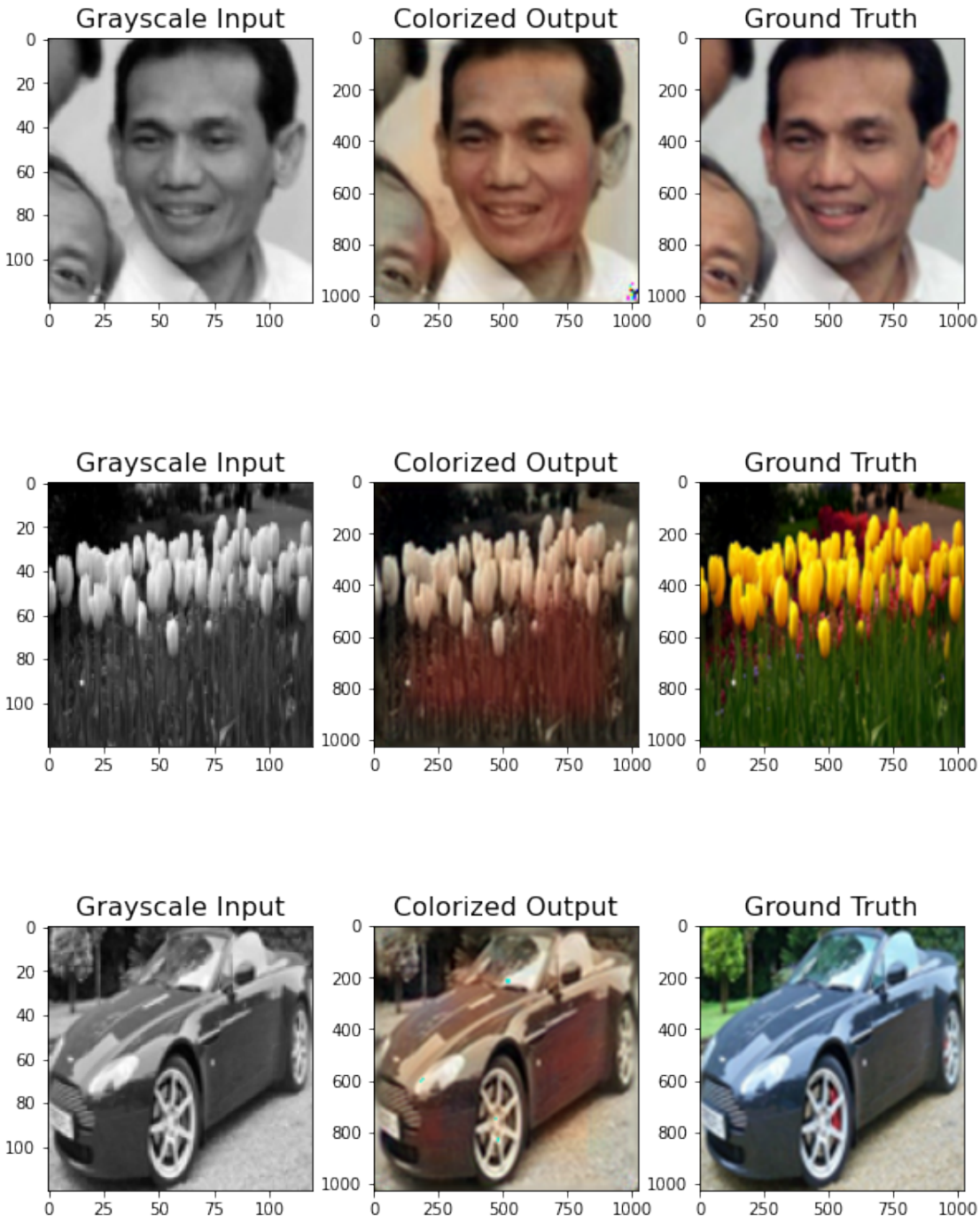

Grayscale Input
Colorized Output
Ground Truth

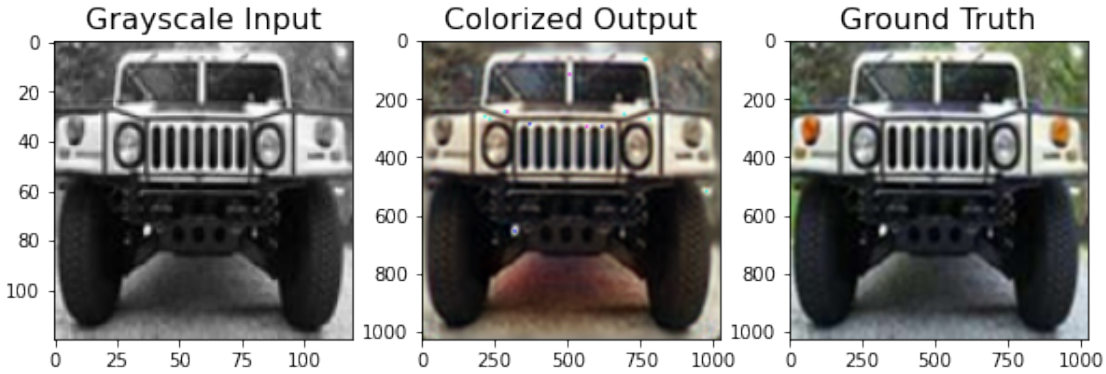

Grayscale Input
Colorized Output
Ground Truth

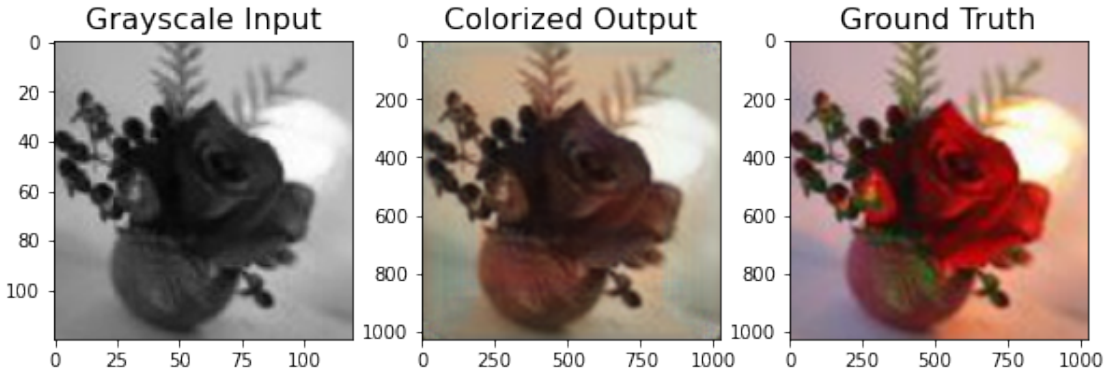

Grayscale Input
Colorized Output
Ground Truth

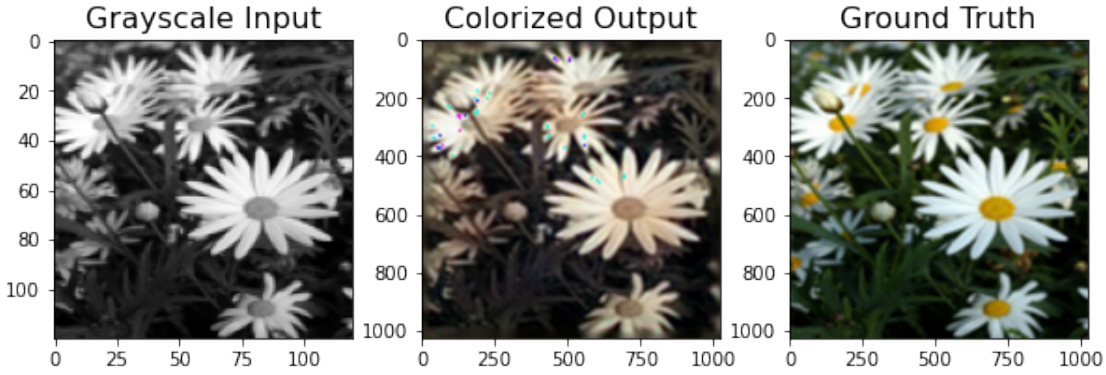

Grayscale Input
Colorized Output
Ground Truth

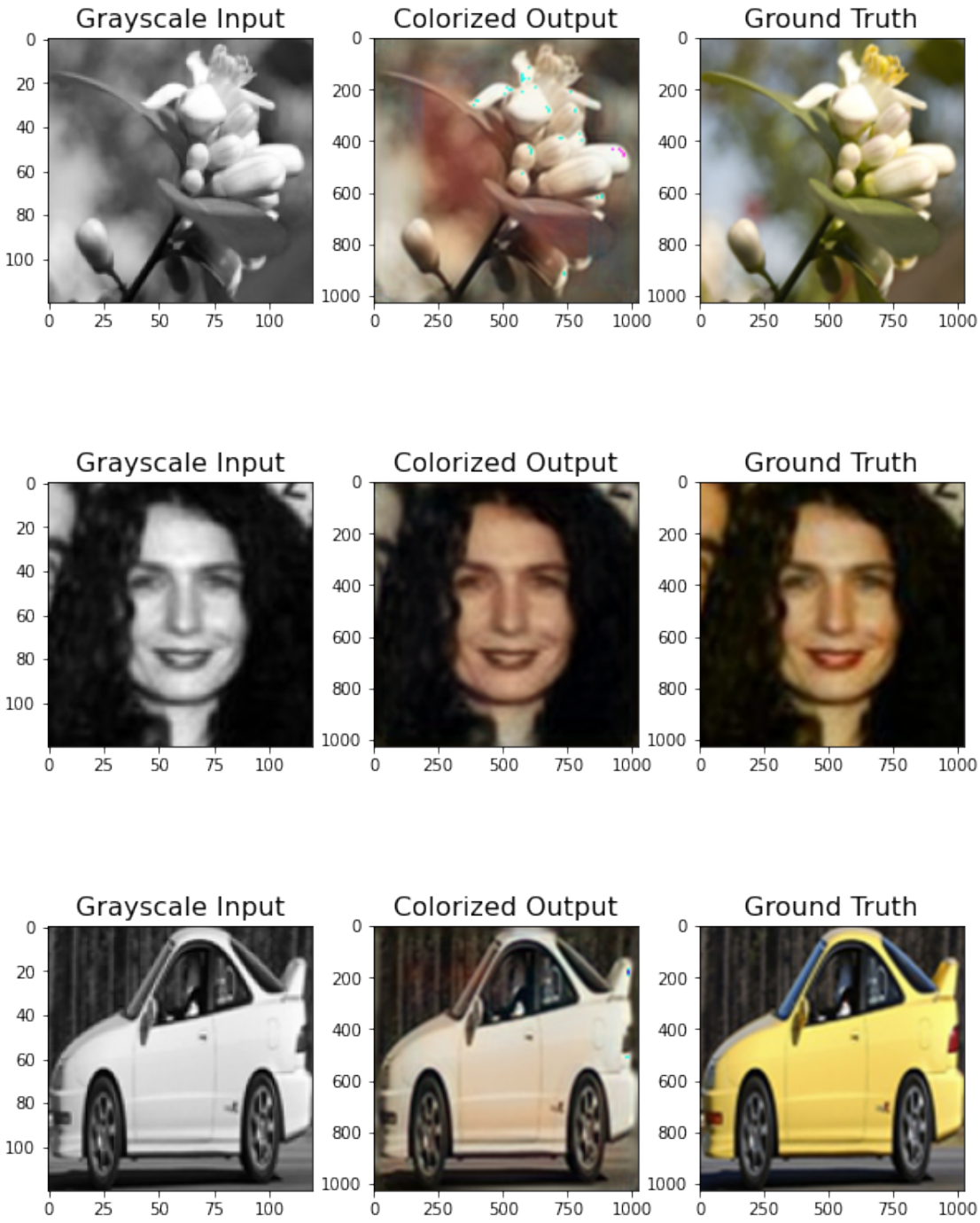

Grayscale Input
Colorized Output
Ground Truth


Grayscale Input
Colorized Output
Ground Truth
Grayscale Input
Colorized Output
Ground Truth
Grayscale Input
Colorized Output
Ground Truth


Grayscale Input
Colorized Output
Ground Truth


Grayscale Input
Colorized Output
Ground Truth


Grayscale Input
Colorized Output
Ground Truth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Colorized Output
Ground Truth
Grayscale Input
Colorized Output
Ground Truth
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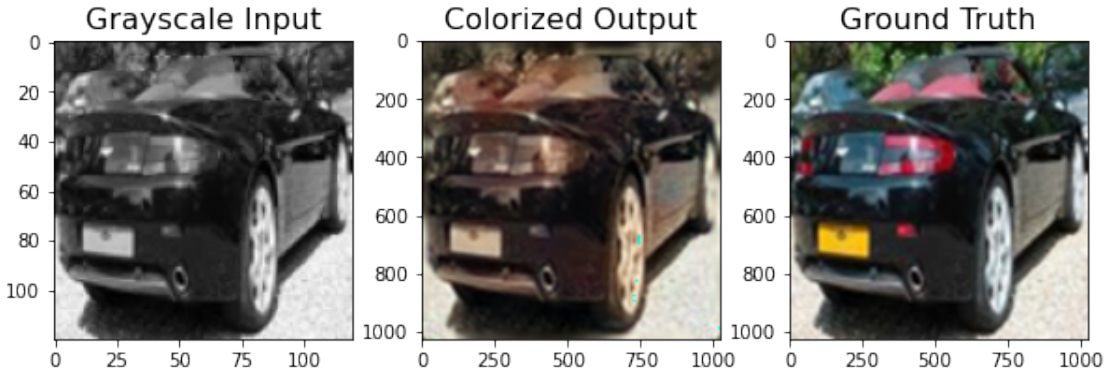
Colorized Output
Ground Truth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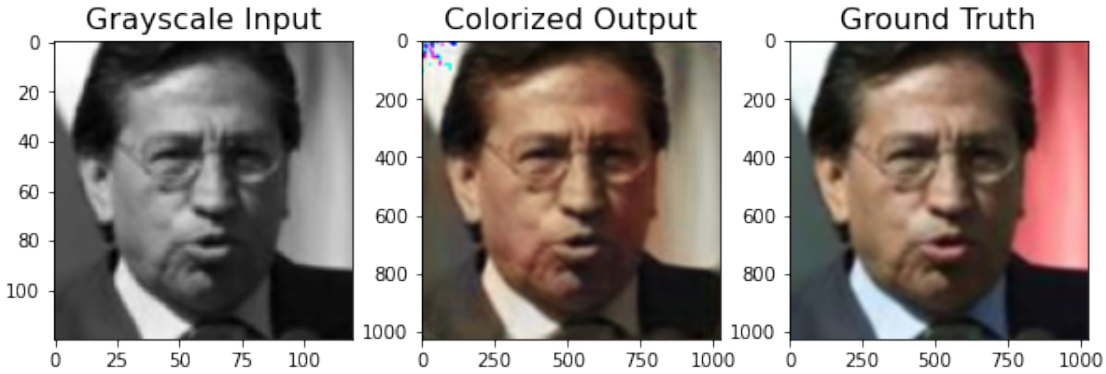
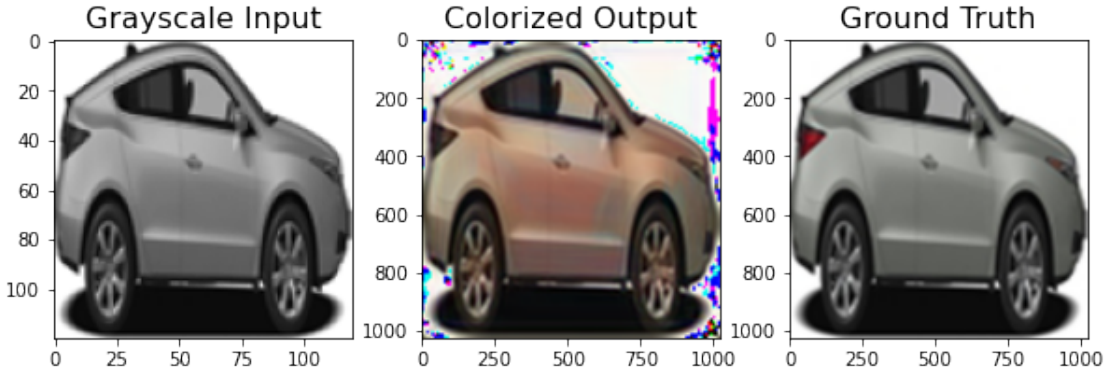
Colorized Output
Ground Truth


Grayscale Input
Colorized Output
Ground Truth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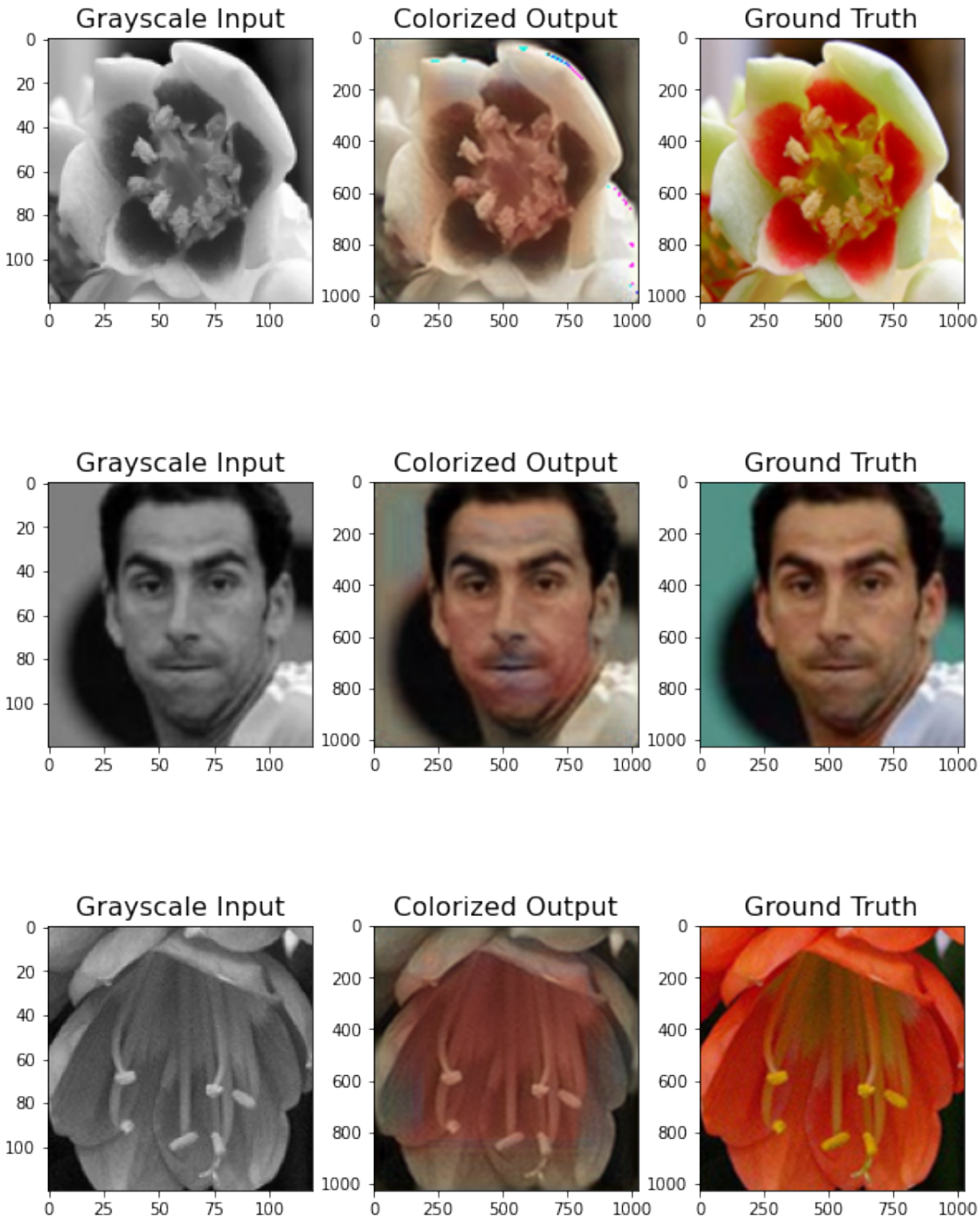
Colorized Output
Ground Truth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Ground Truth
Grayscale Input
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Ground Truth
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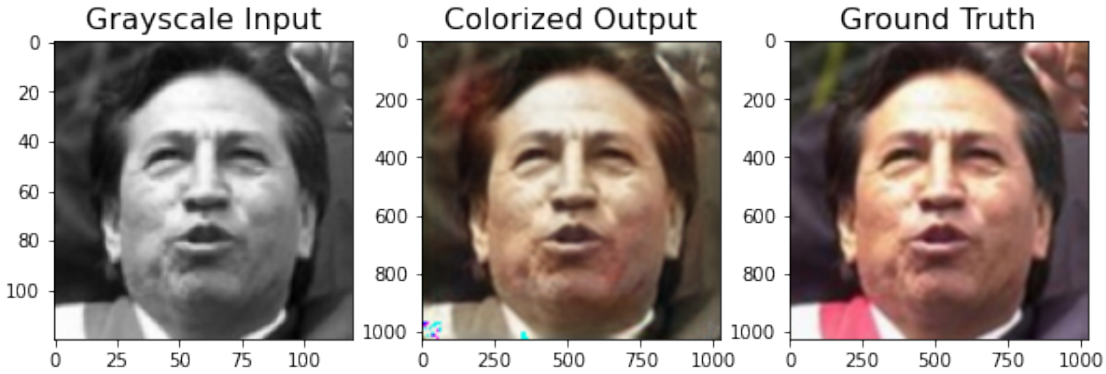
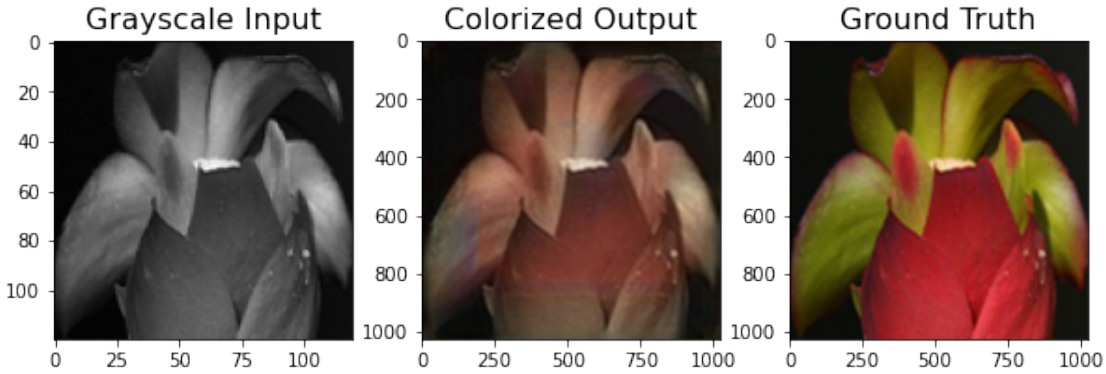
Colorized Output
Ground Truth


Grayscale Input
Colorized Output
Ground Truth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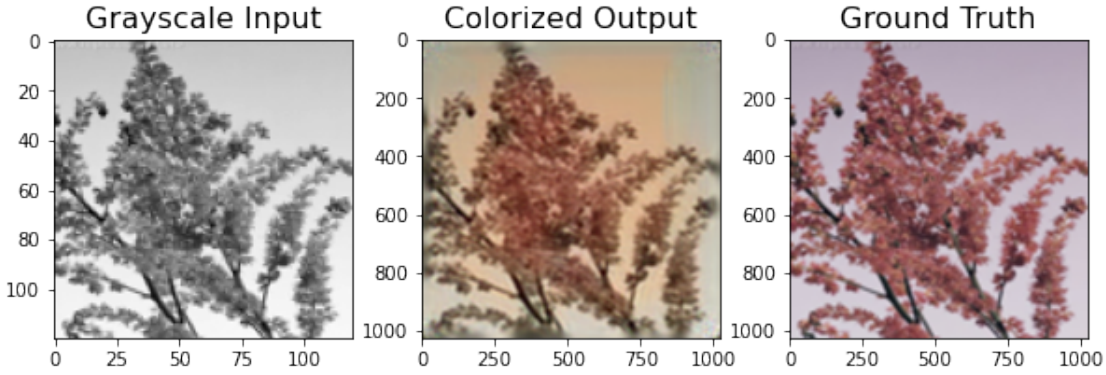
Colorized Output
Ground Truth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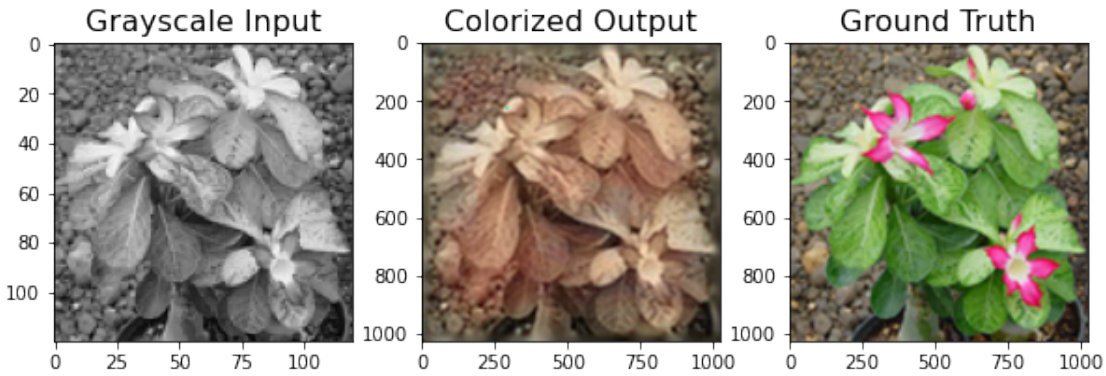
Colorized Output
Ground Truth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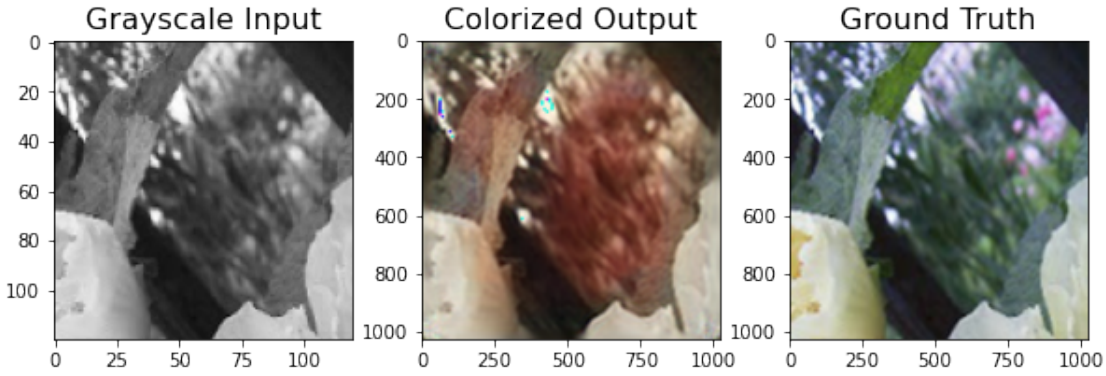
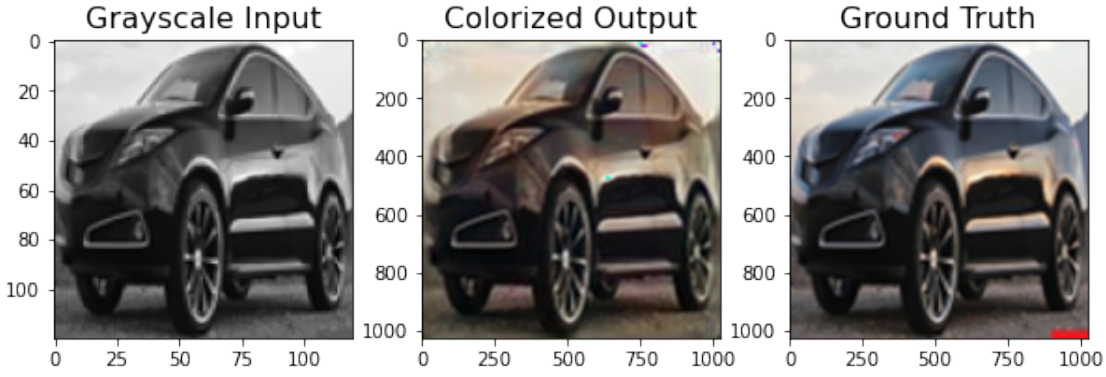
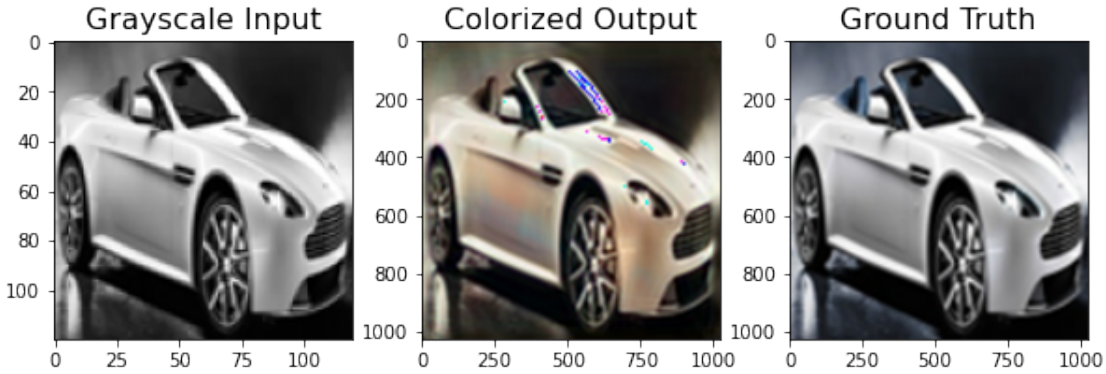
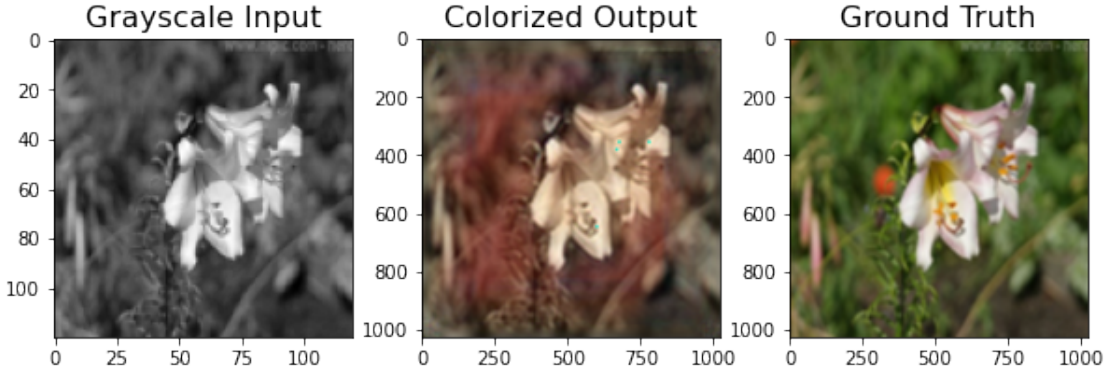
Colorized Output
Ground Truth


Grayscale Input
Colorized Output
Ground Truth


Grayscale Input
Colorized Output
Ground Truth


Grayscale Input
Colorized Output
Ground Truth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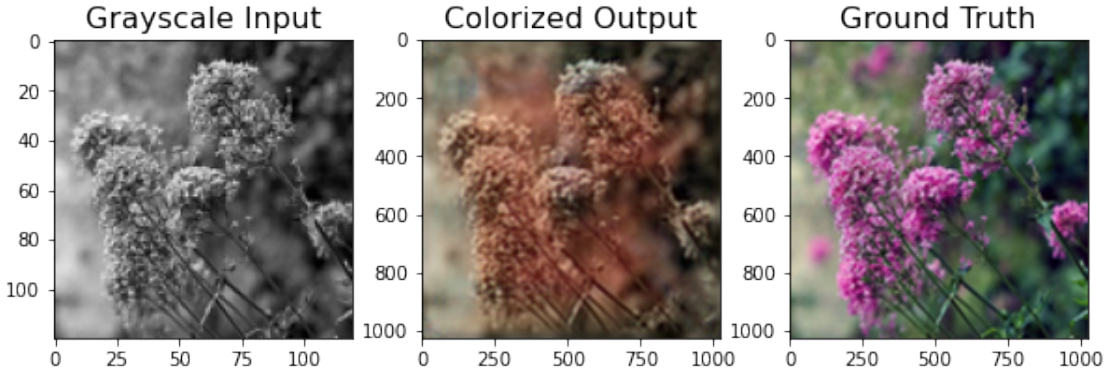
Colorized Output
Ground Truth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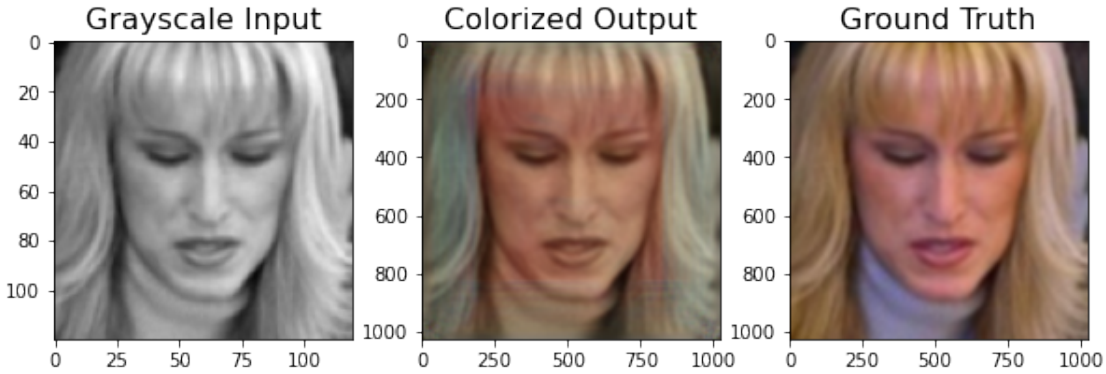
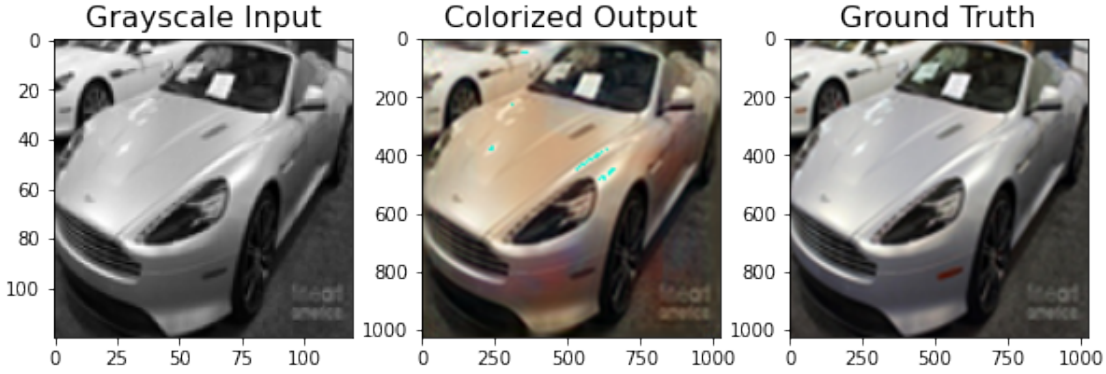
Colorized Output
Ground Truth


Grayscale Input
Colorized Output
Ground Truth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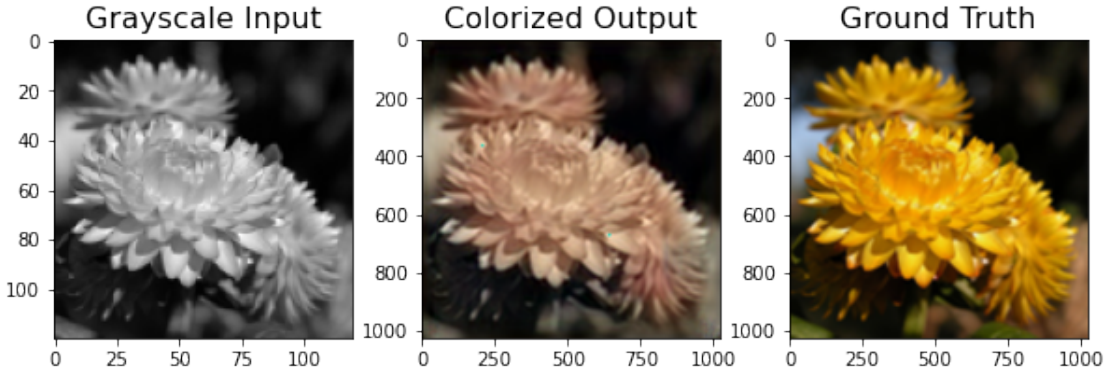
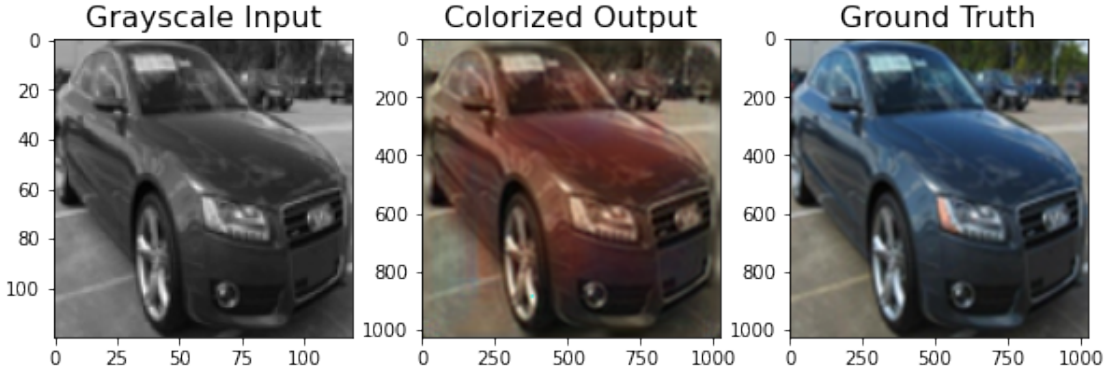
Colorized Output
Ground Truth


Grayscale Input
Colorized Output
Ground Truth


Grayscale Input
Colorized Output
Ground Truth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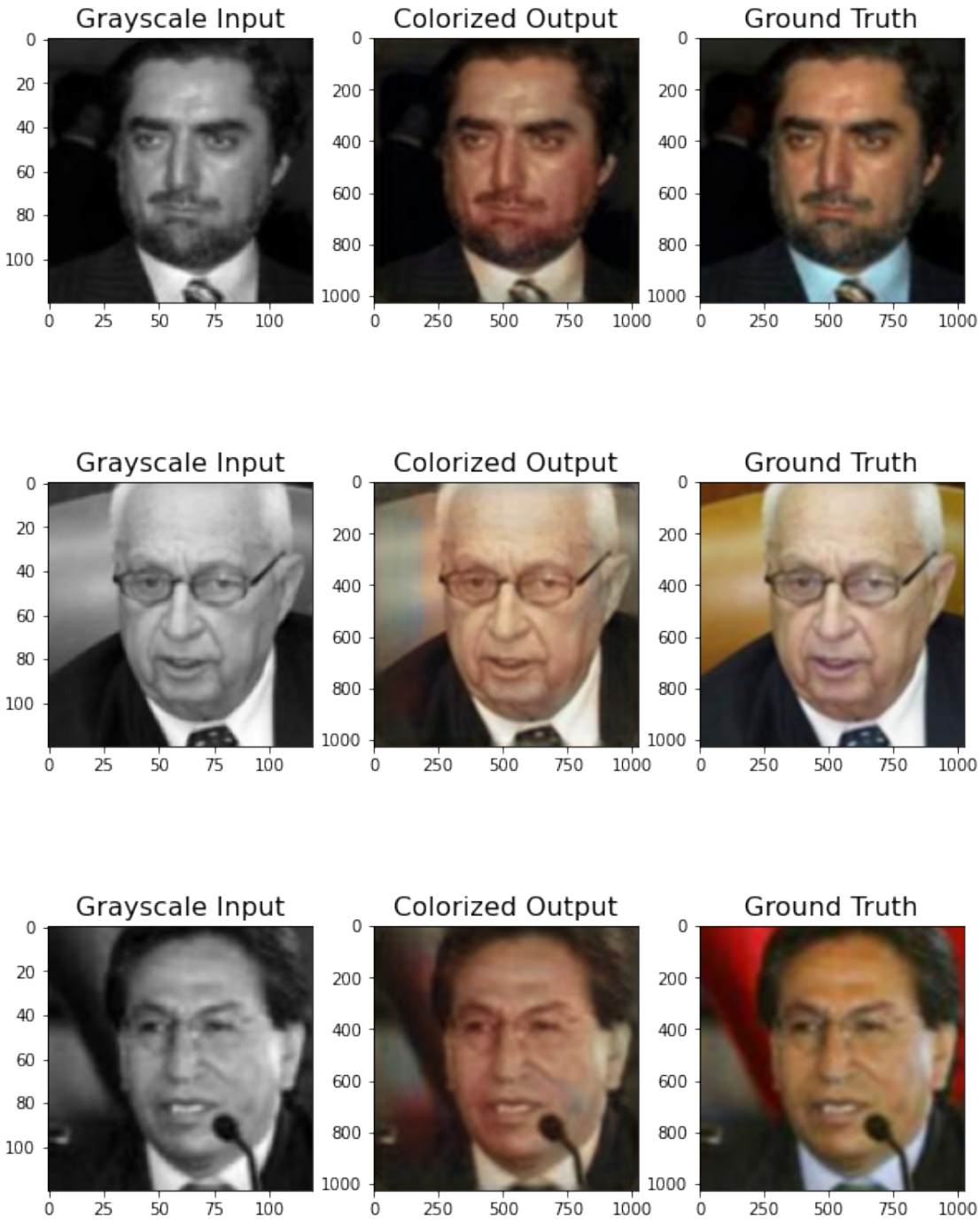
Ground Truth


Grayscale Input
Colorized Output
Ground Truth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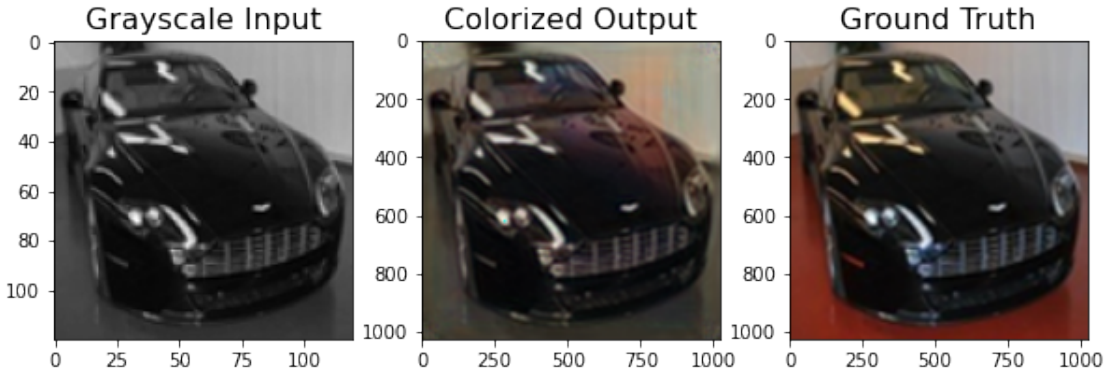
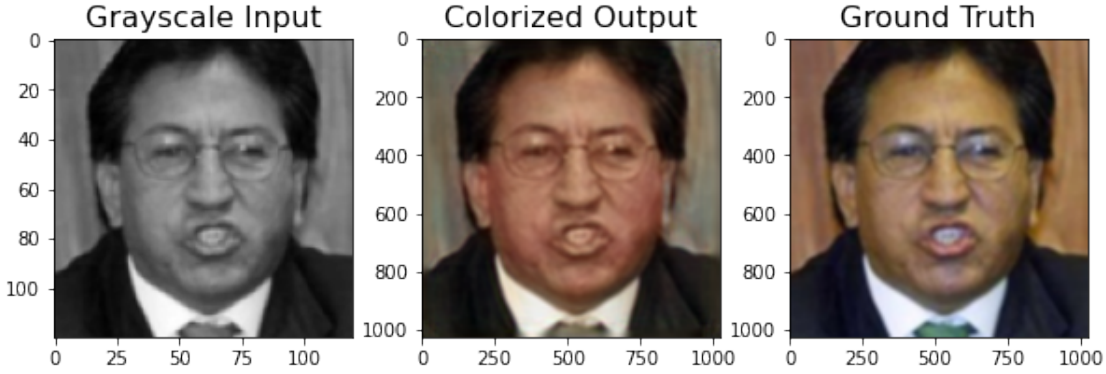

Grayscale Input
Colorized Output
Ground Truth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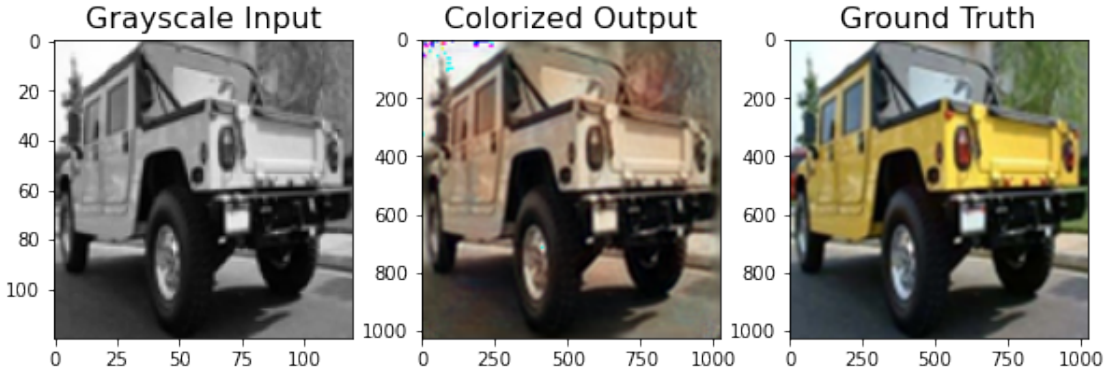
Colorized Output
Ground Truth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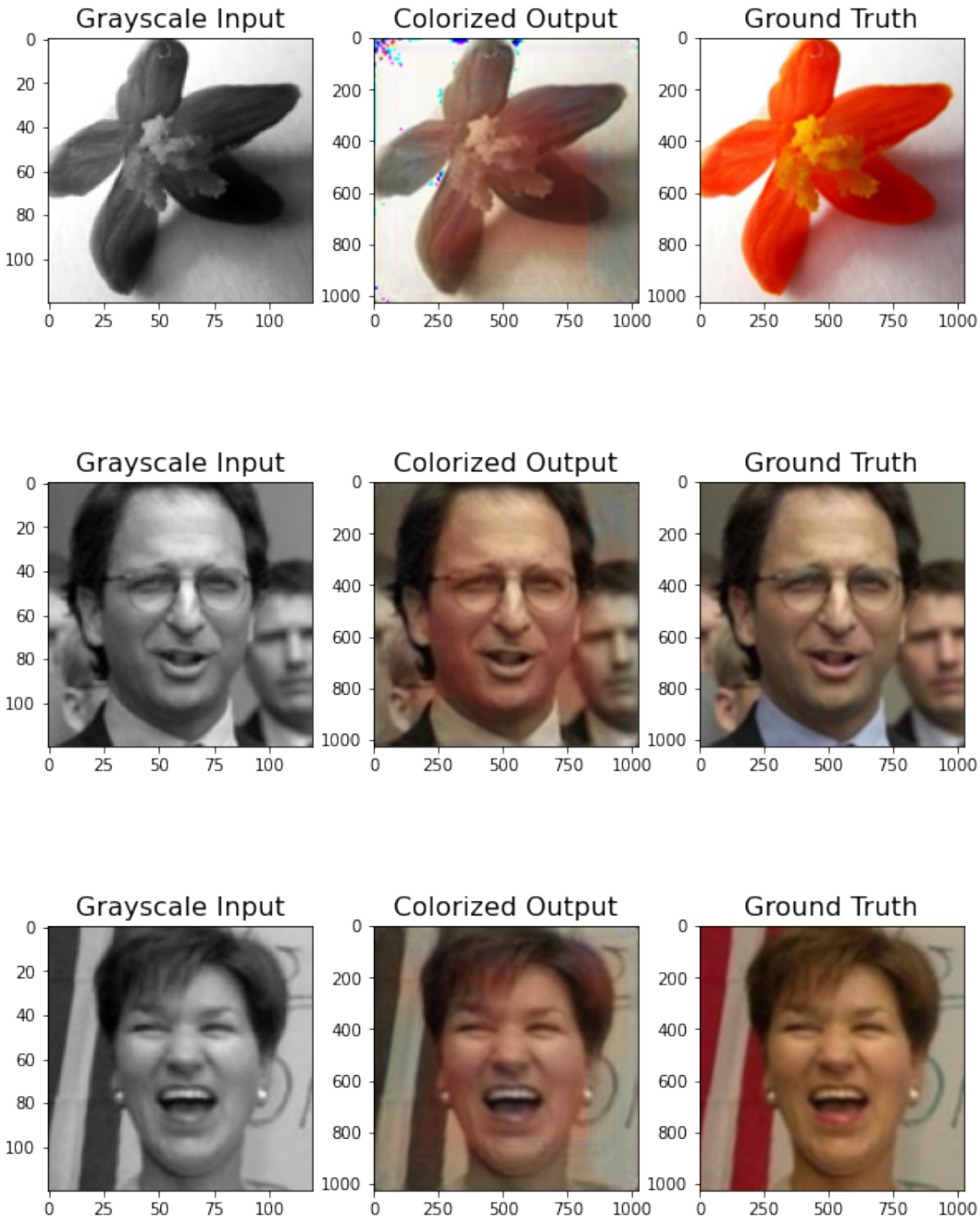
Ground Truth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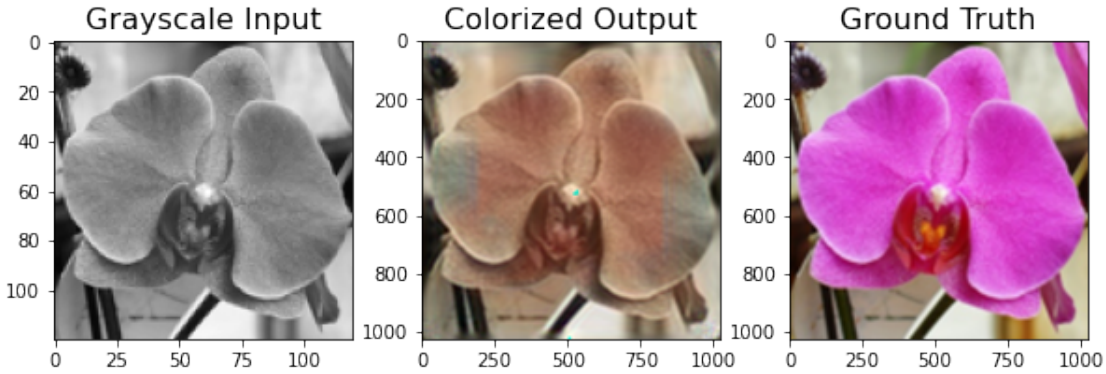
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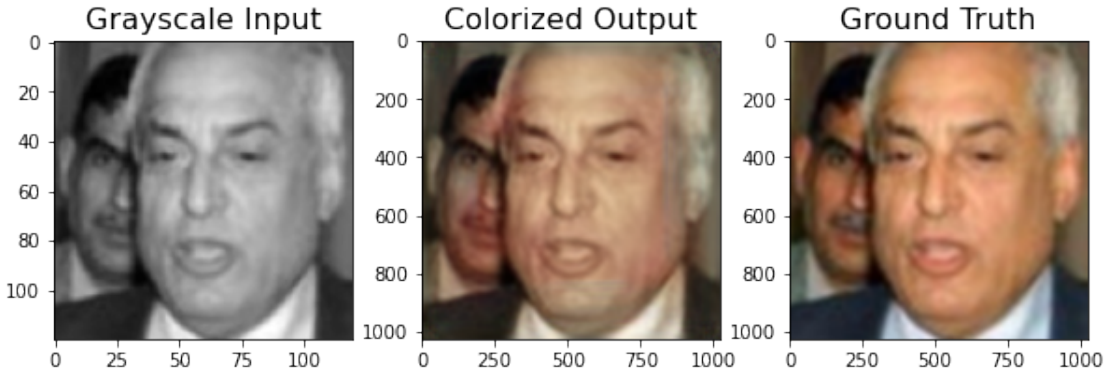
Colorized Output
Ground Truth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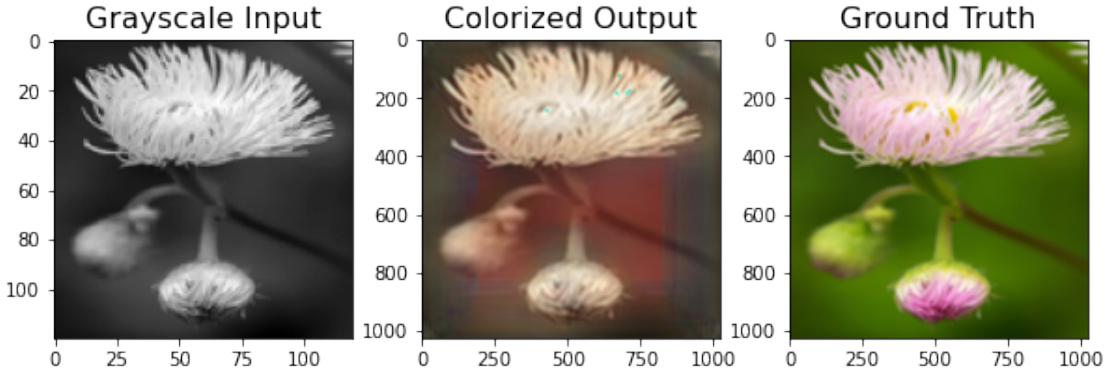
Colorized Output
Ground Truth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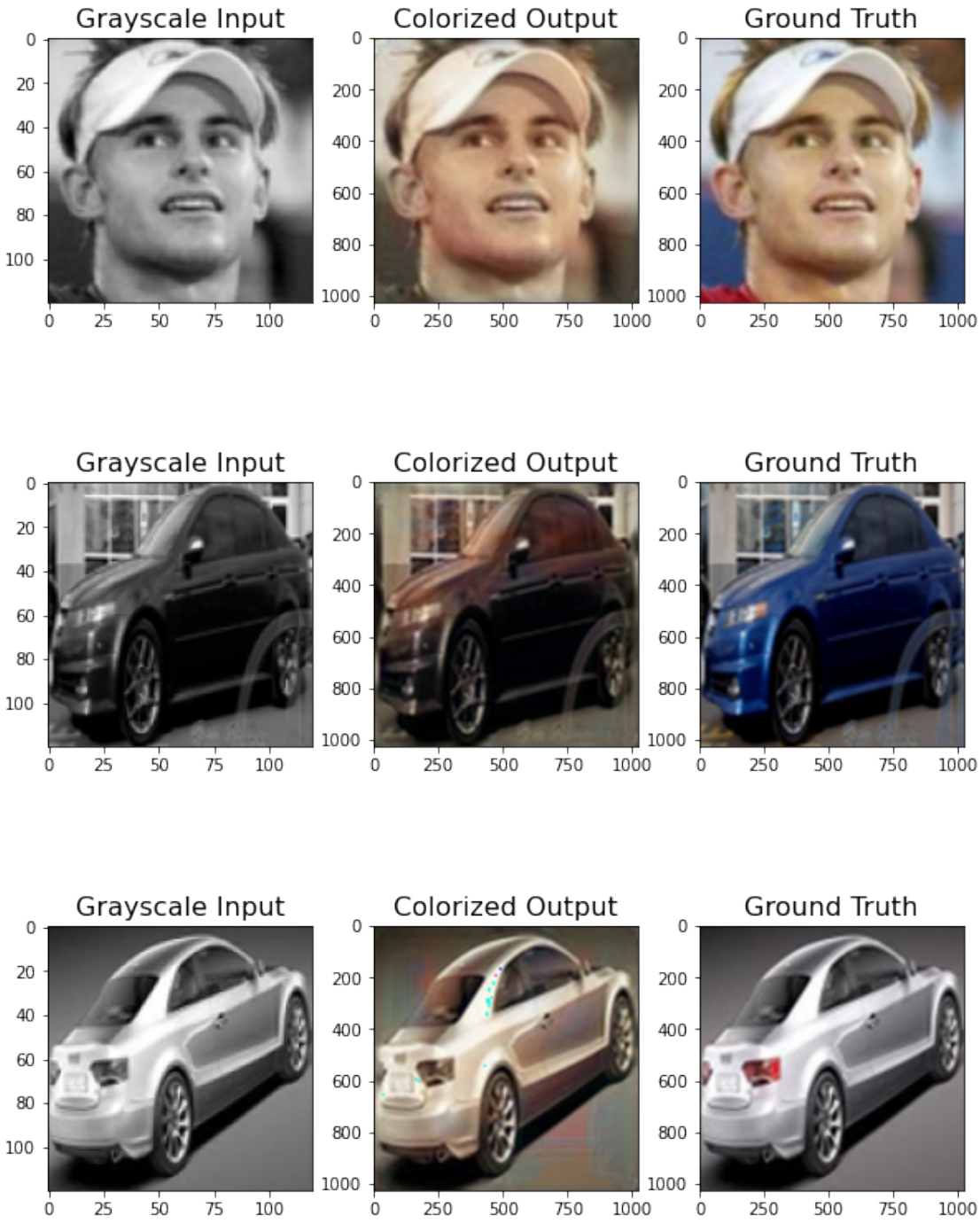
Colorized Output
Ground Truth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Ground Truth
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Colorized Output
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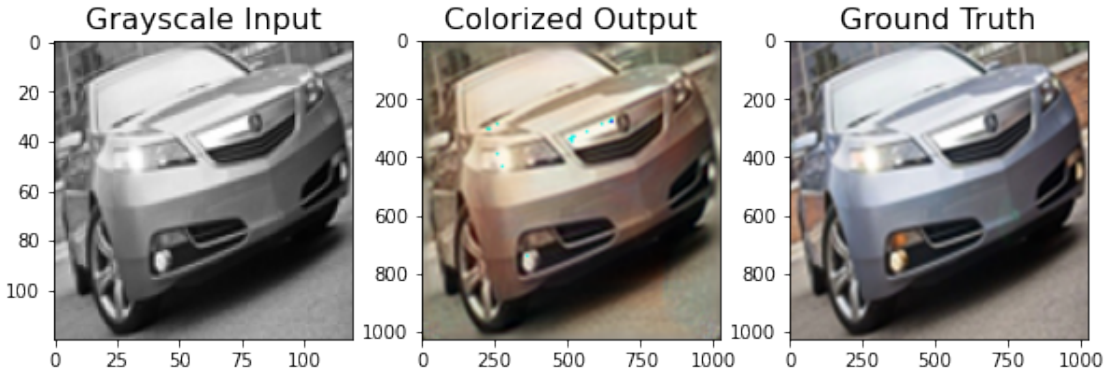
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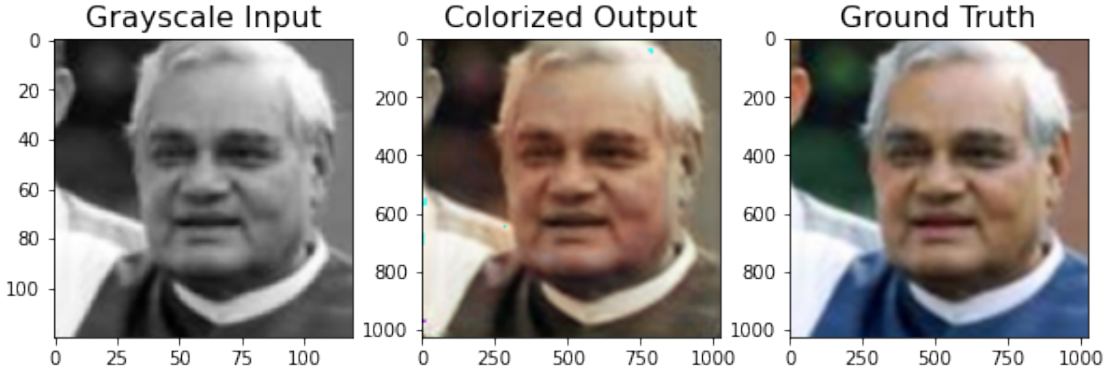
Colorized Output
Ground Truth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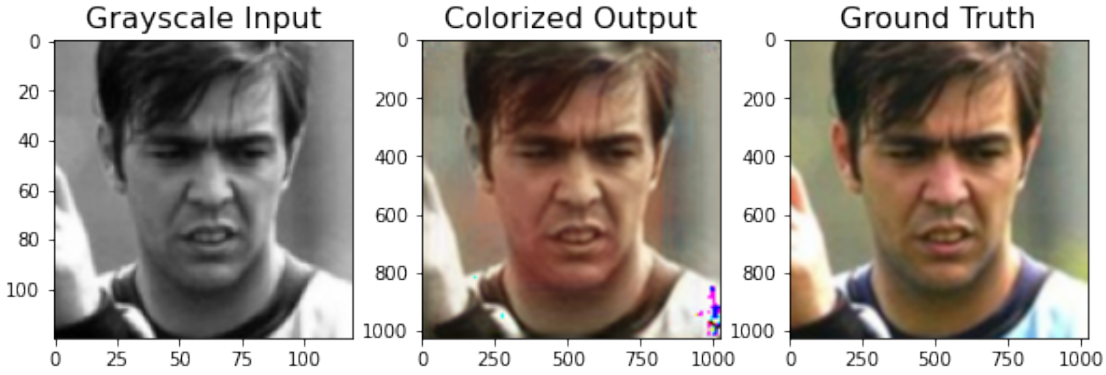
Colorized Output
Ground Truth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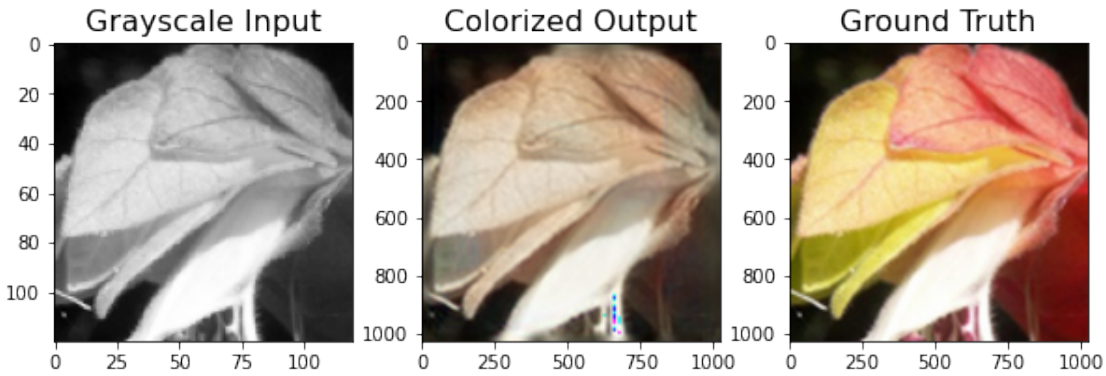
Colorized Output
Ground Truth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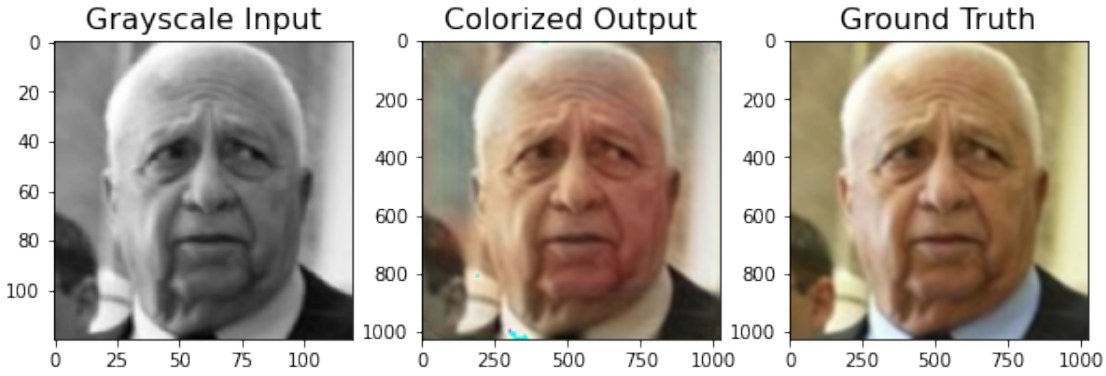
Colorized Output
Ground Truth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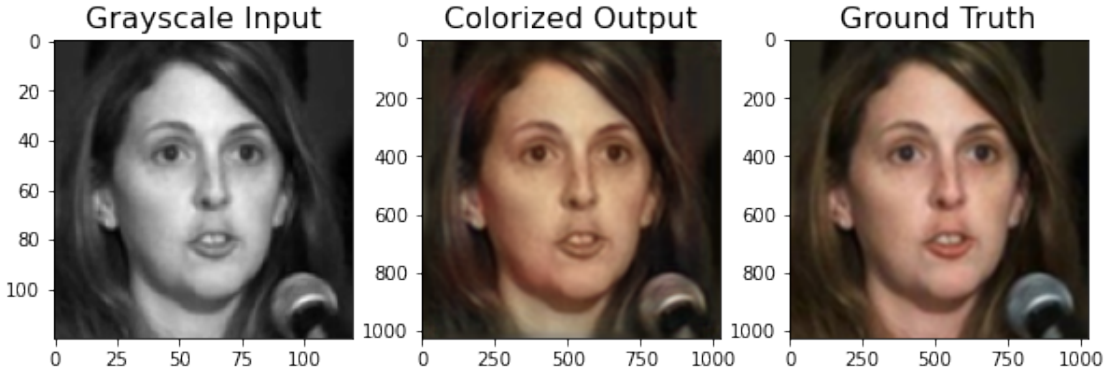
Colorized Output
Ground Truth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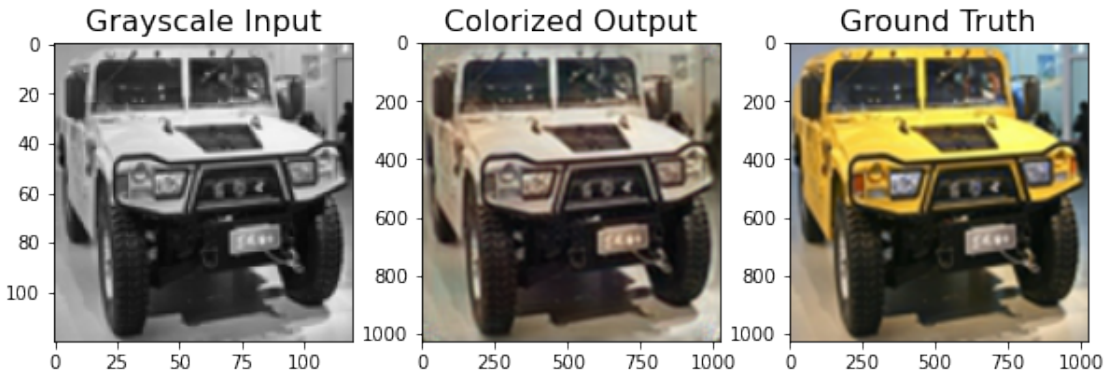
Colorized Output
Ground Truth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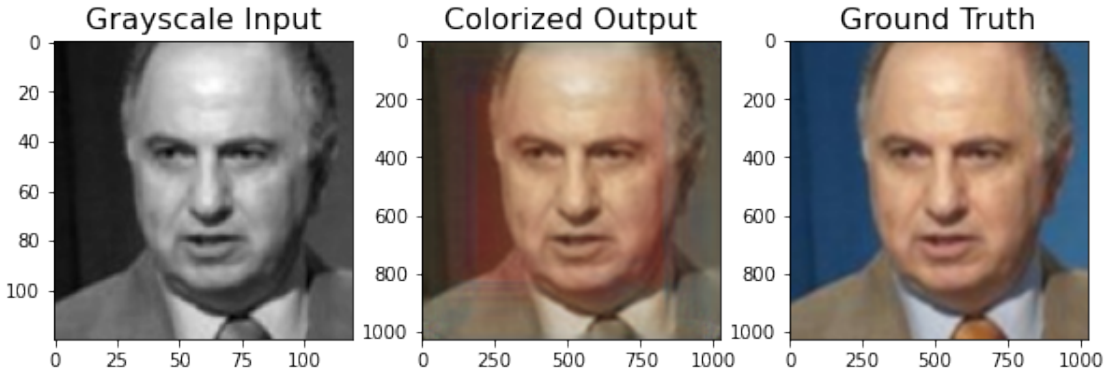
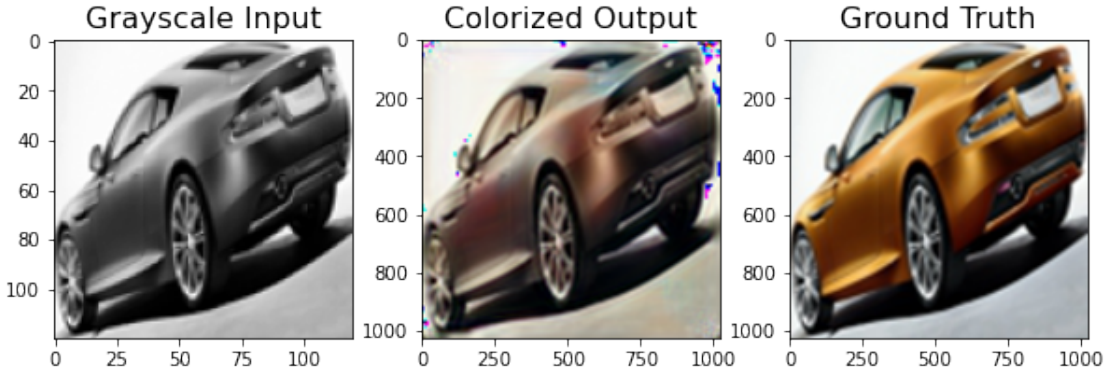
Colorized Output
Ground Truth


Grayscale Input
Colorized Output
Ground Truth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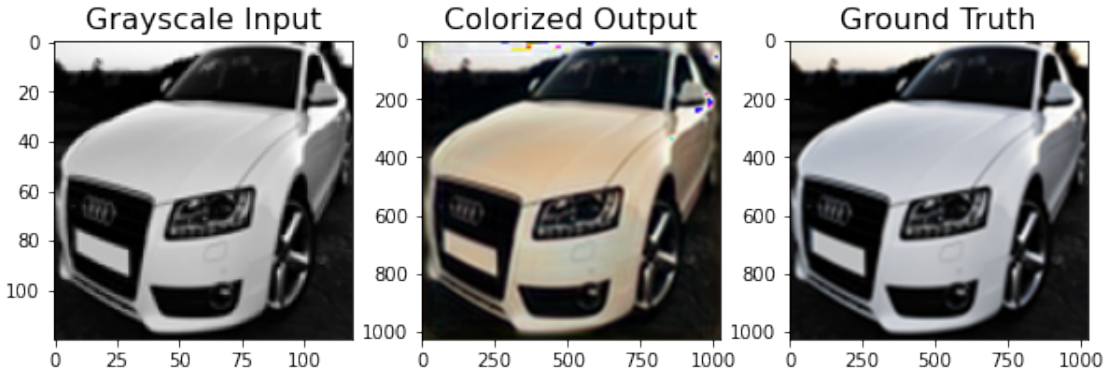
Colorized Output
Ground Truth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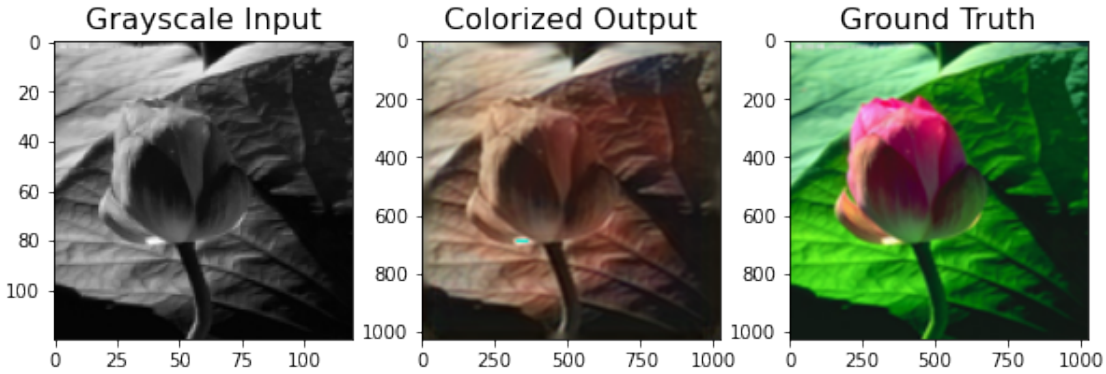
Colorized Output
Ground Truth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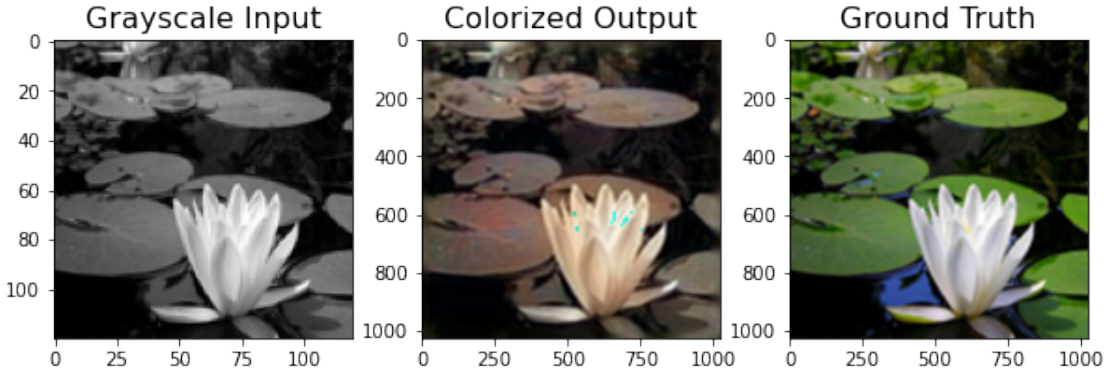
Colorized Output
Ground Truth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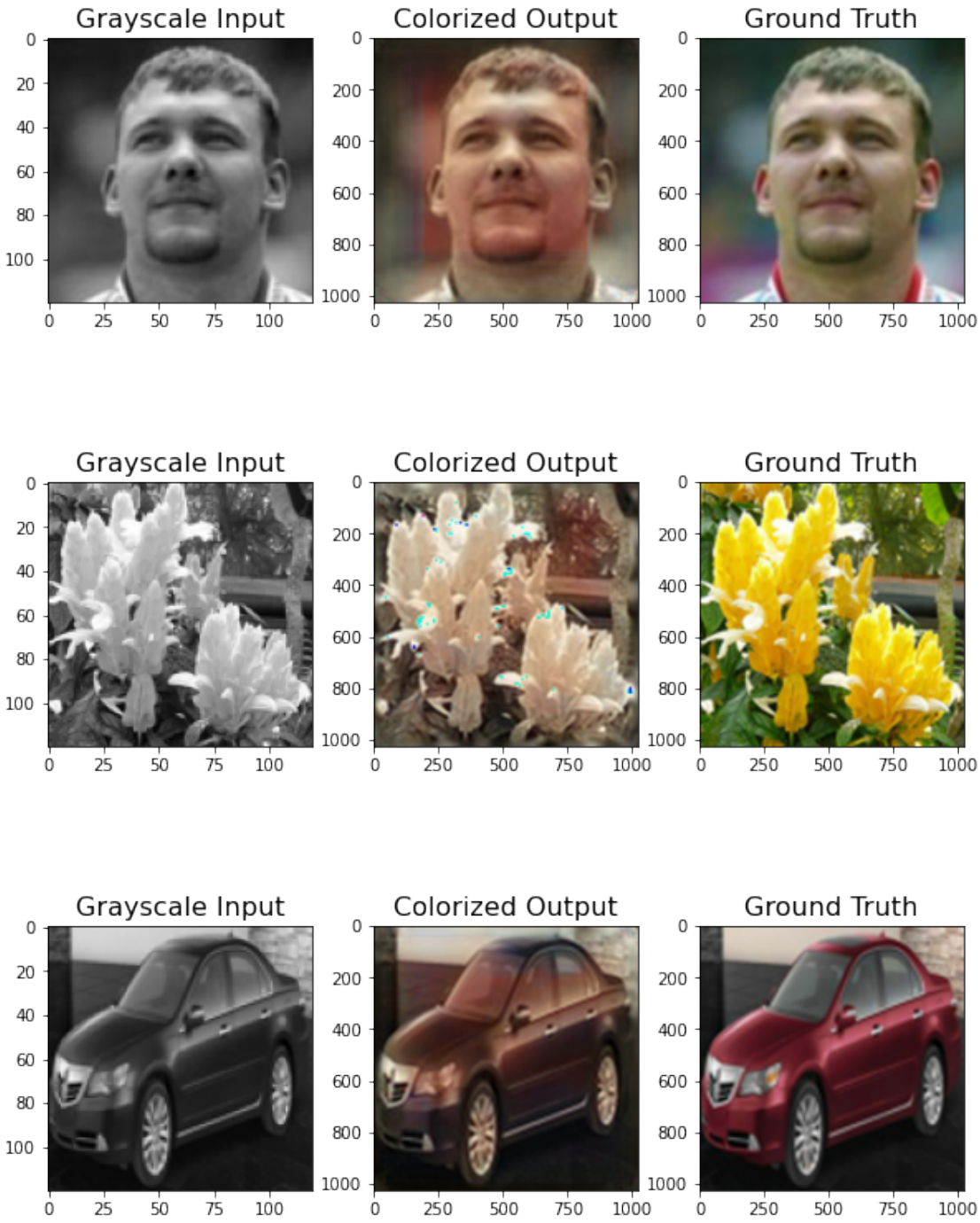
Colorized Output
Ground Truth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Colorized Output
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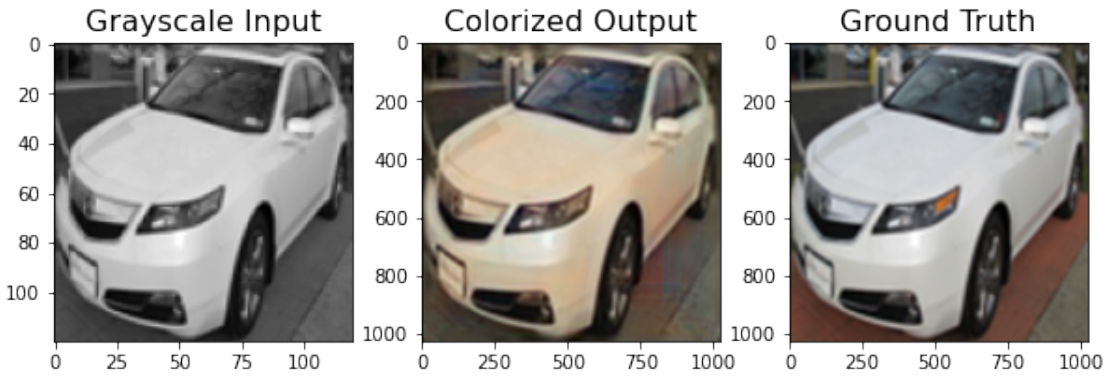
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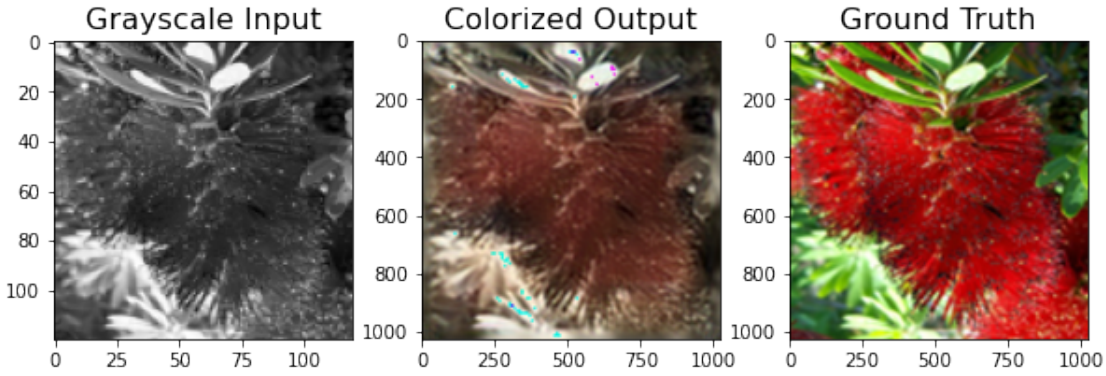
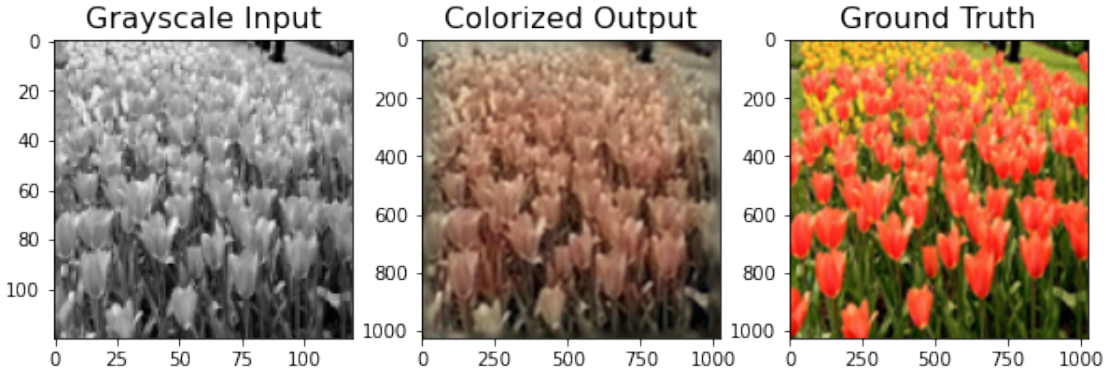
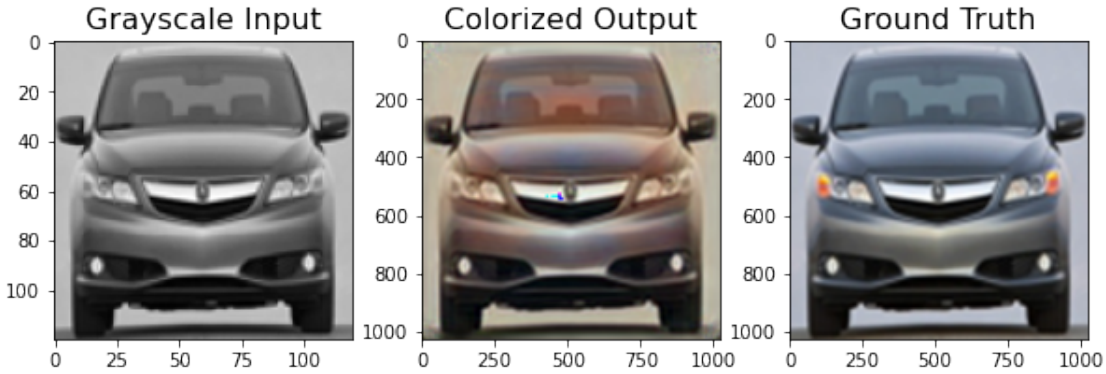
Colorized Output
Ground Truth


Grayscale Input
Colorized Output
Ground Truth


Grayscale Input
Colorized Output
Ground Truth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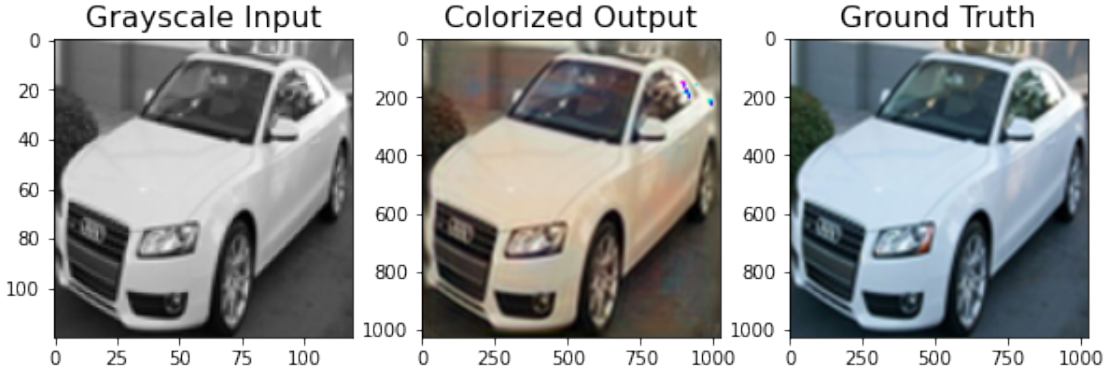
Colorized Output
Ground Truth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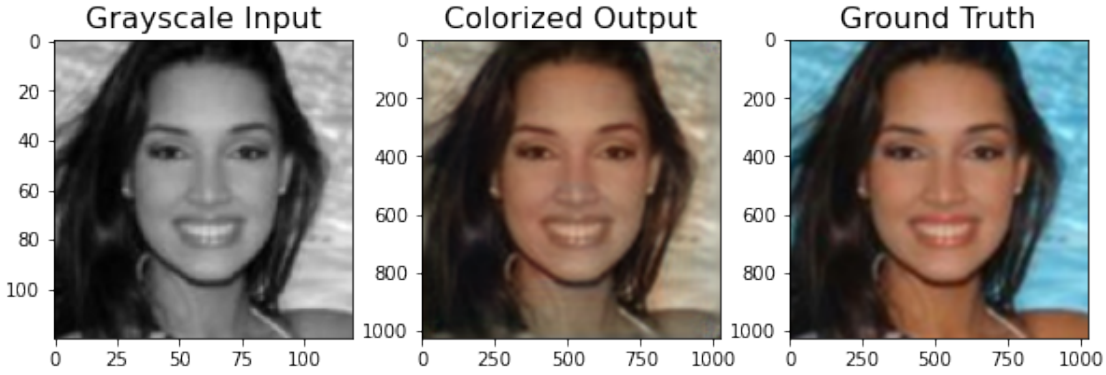
Colorized Output
Ground Truth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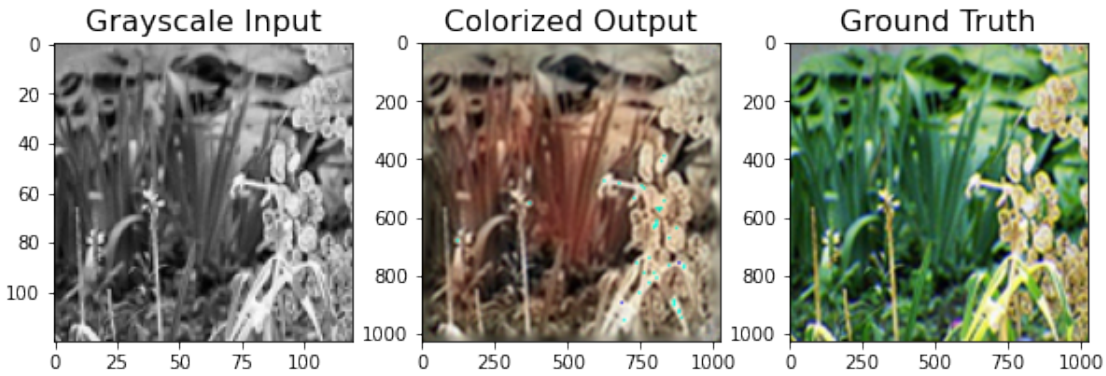
Colorized Output
Ground Truth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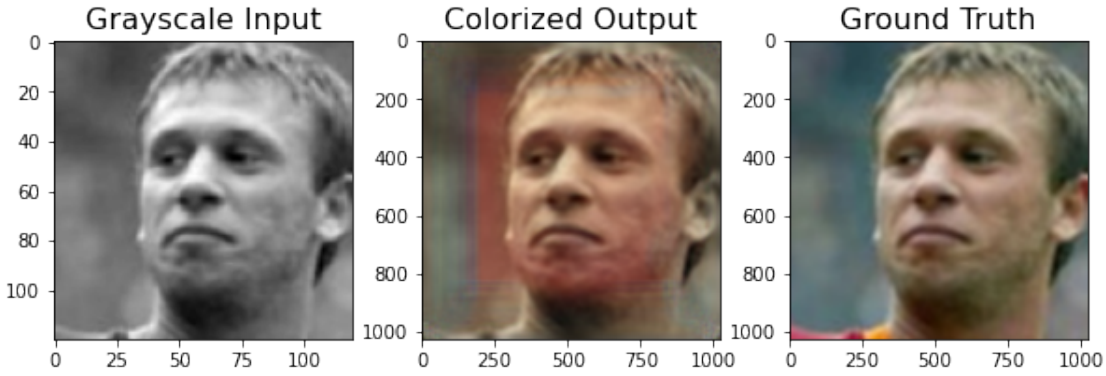
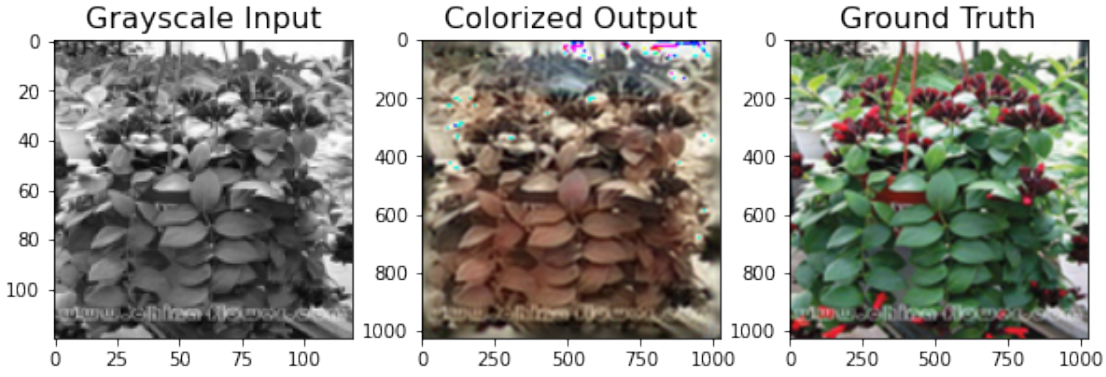
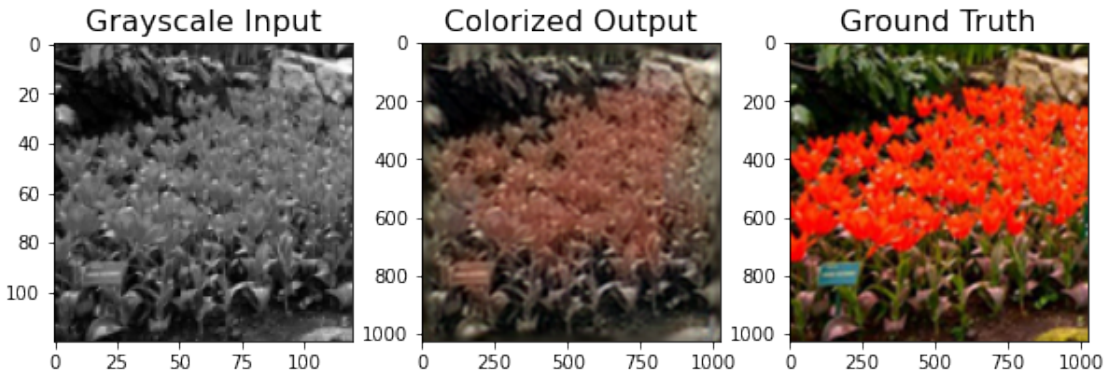
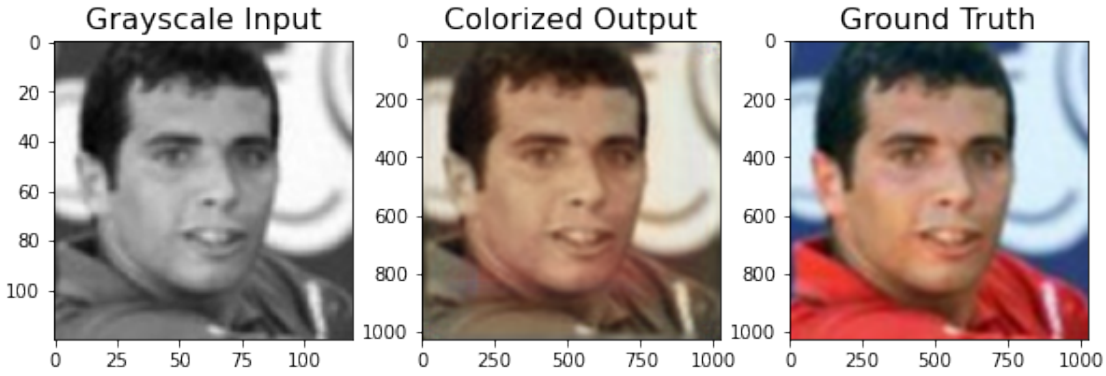
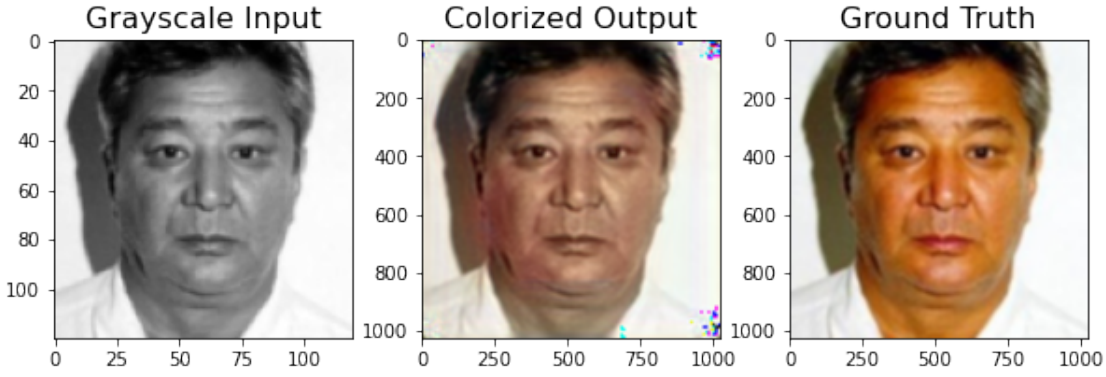
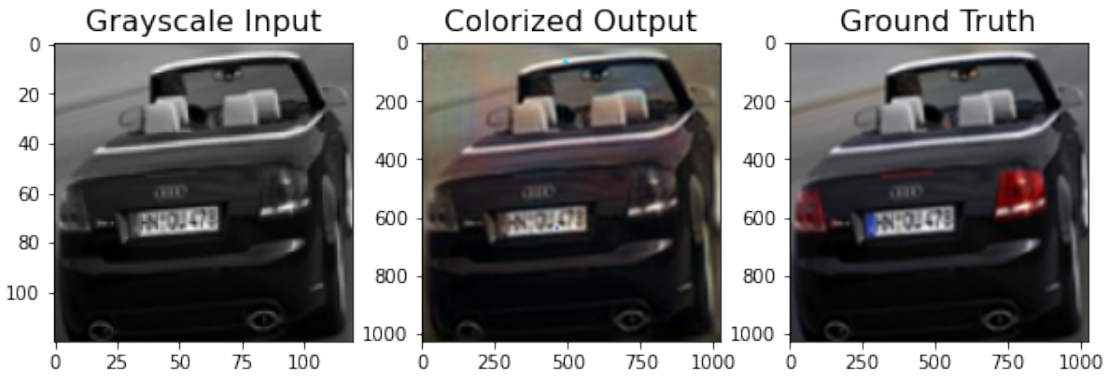

Grayscale Input
Colorized Output
Ground Truth

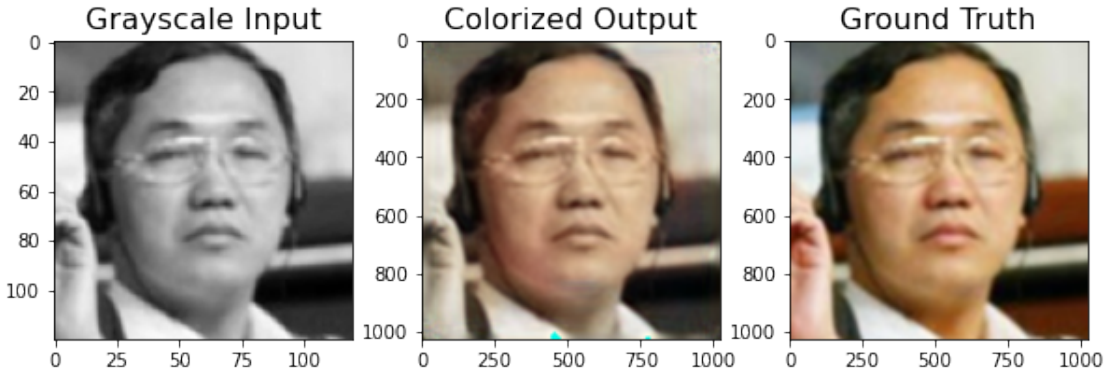

Grayscale Input
Colorized Output
Ground Truth


Grayscale Input
Colorized Output
Ground Truth


Grayscale Input
Colorized Output
Ground Truth


Grayscale Input
Colorized Output
Ground Truth


Grayscale Input
Colorized Output
Ground Truth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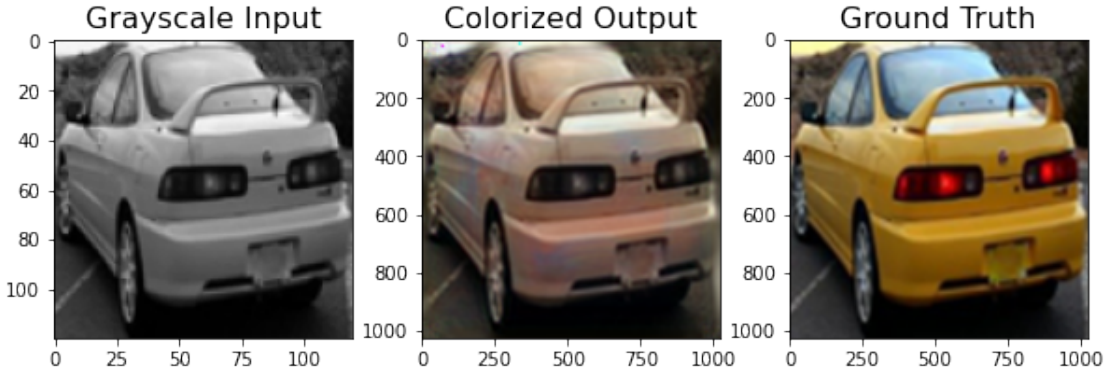
Colorized Output
Ground Truth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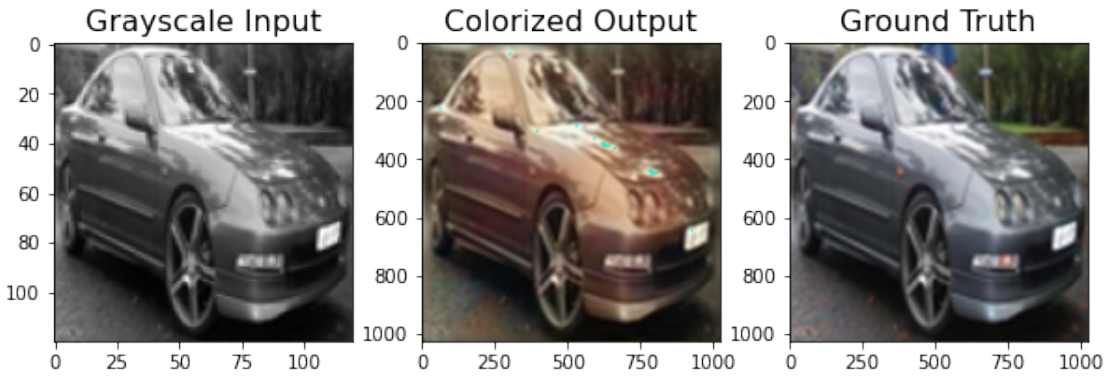
Colorized Output
Ground Truth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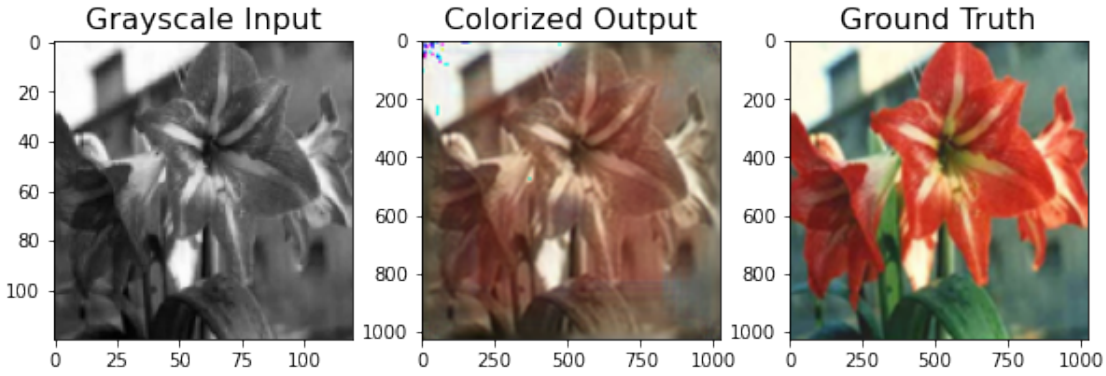
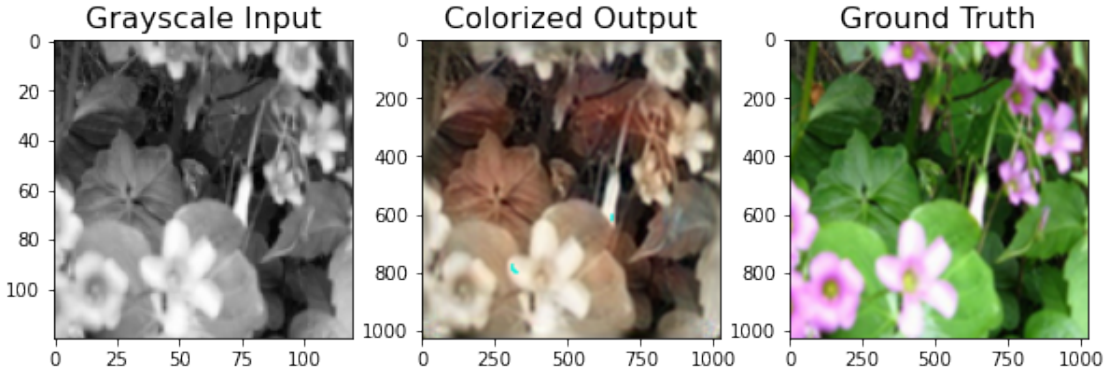
Colorized Output
Ground Truth


Grayscale Input
Colorized Output
Ground Truth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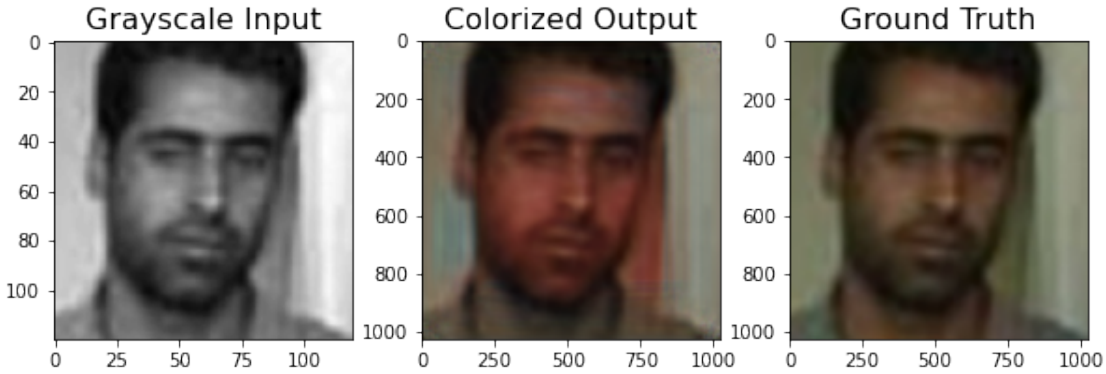
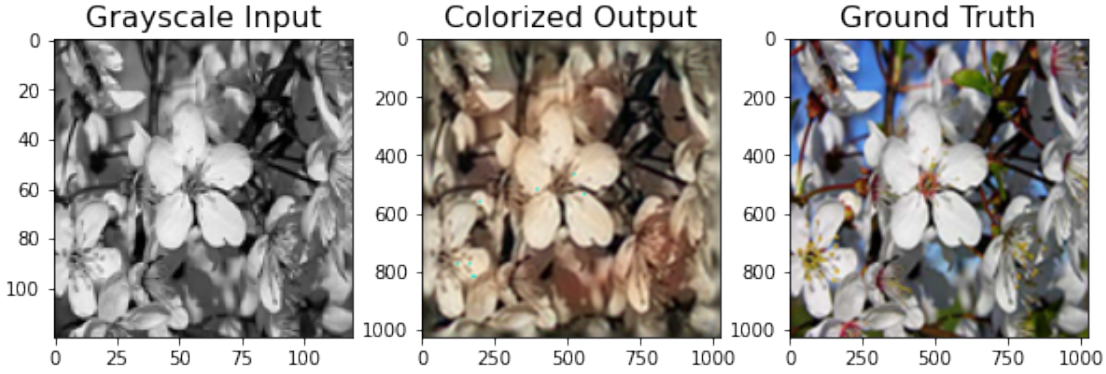
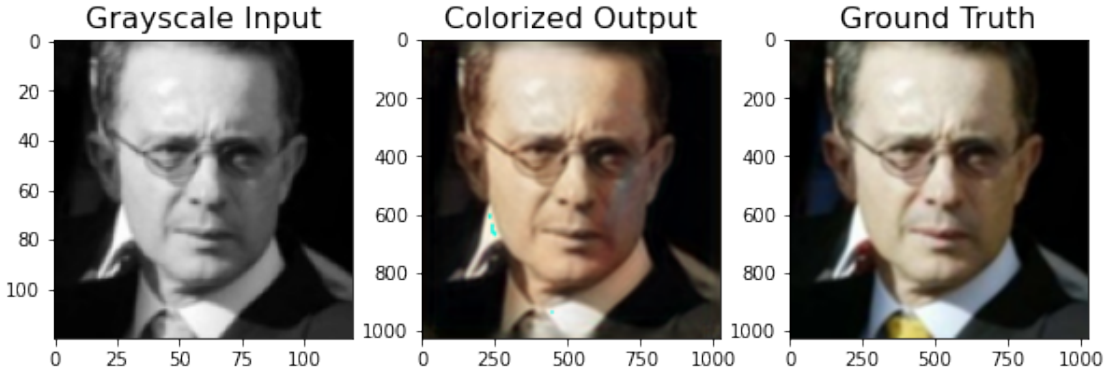
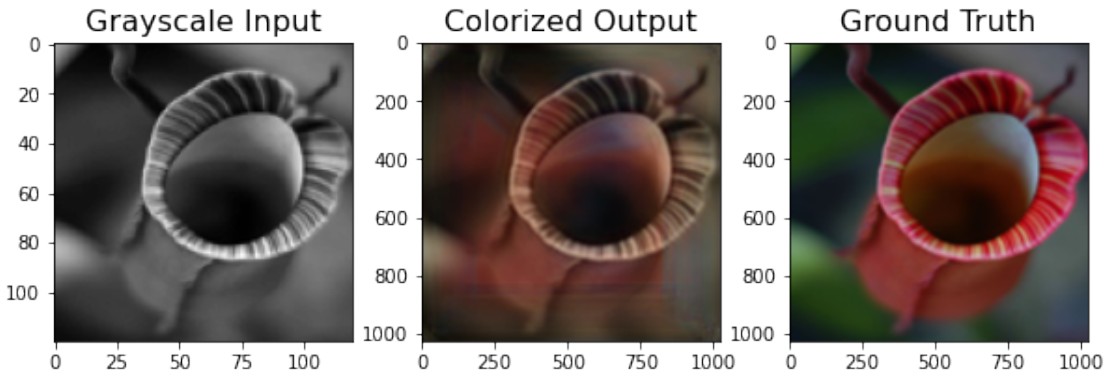
Colorized Output
Ground Truth


Grayscale Input
Colorized Output
Ground Truth


Grayscale Input
Colorized Output
Ground Truth


Grayscale Input
Colorized Output
Ground Truth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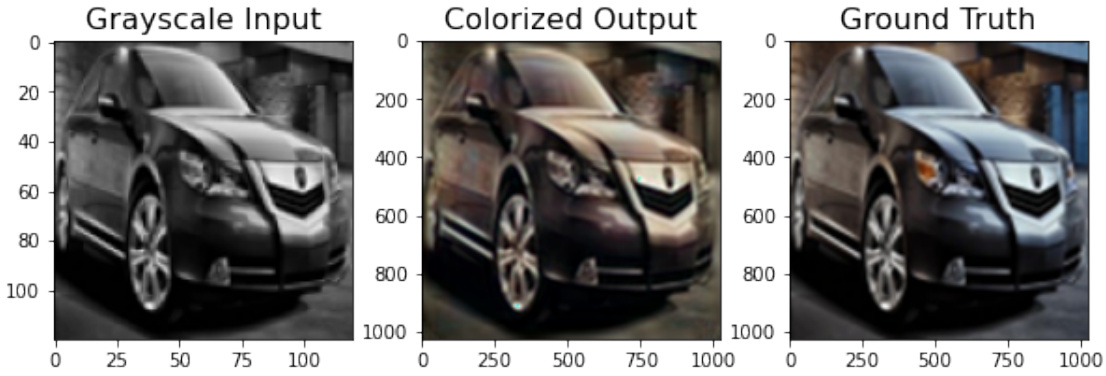
Colorized Output
Ground Truth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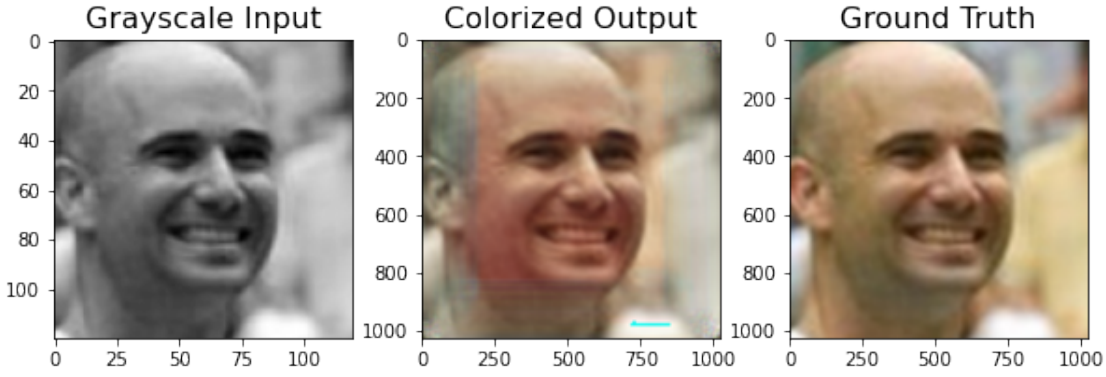
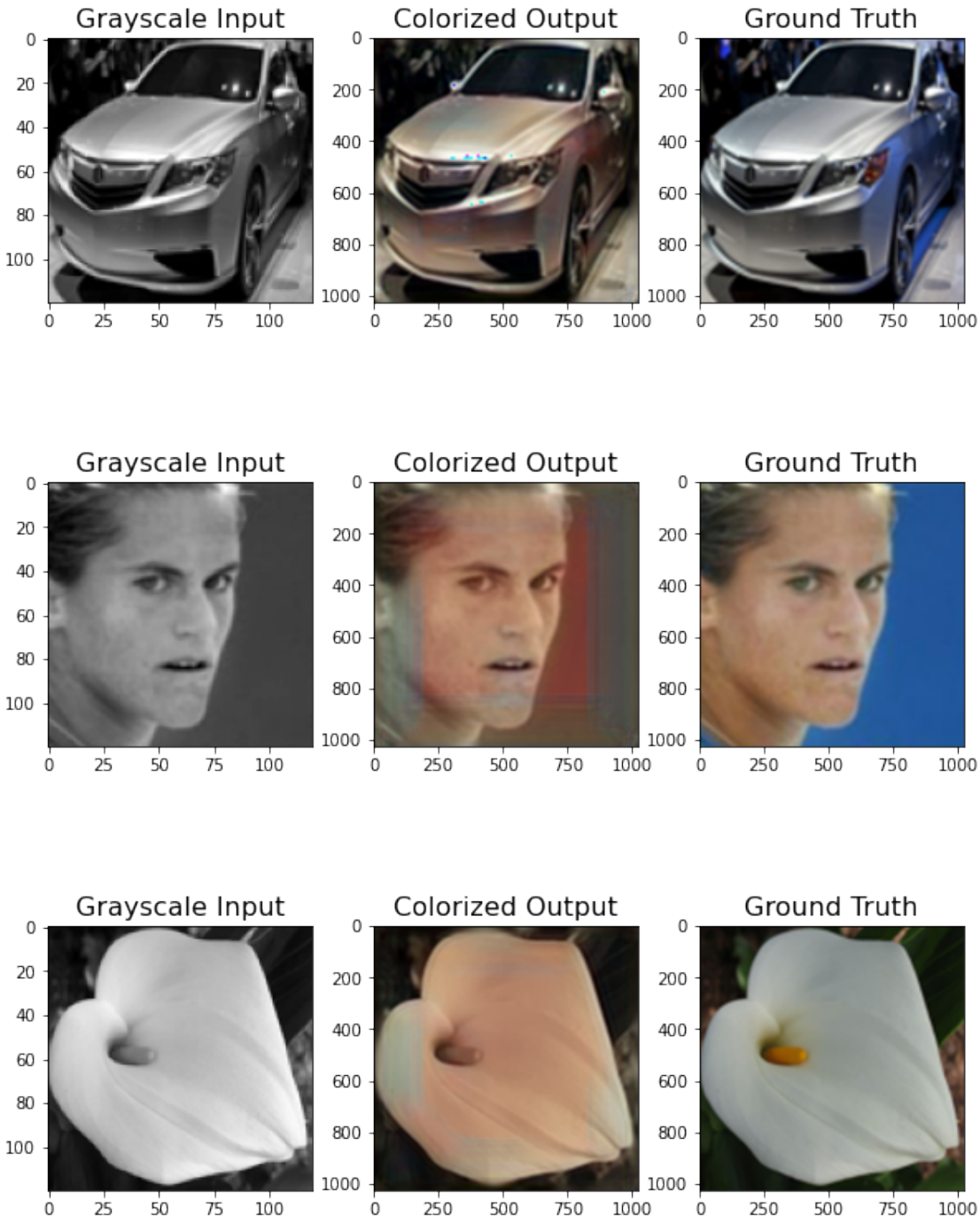
Colorized Output
Ground Truth


Grayscale Input
Colorized Output
Ground Truth


Grayscale Input
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Ground Truth
Grayscale Input
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Ground Truth
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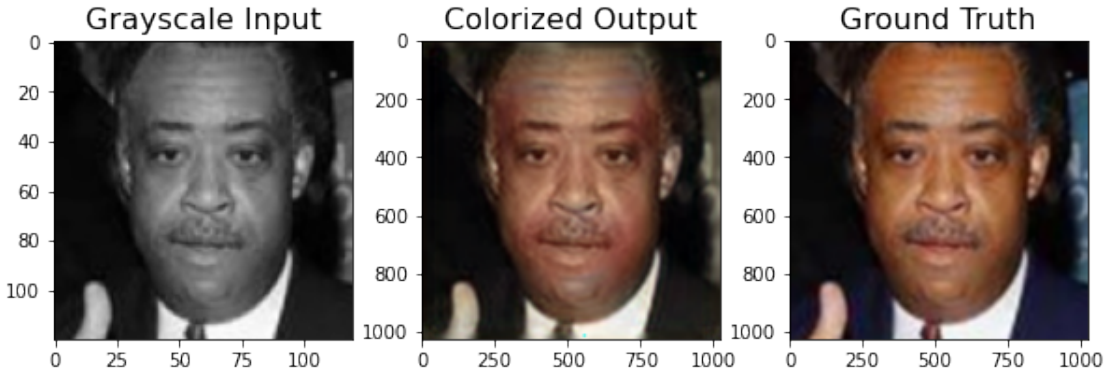
Colorized Output
Ground Truth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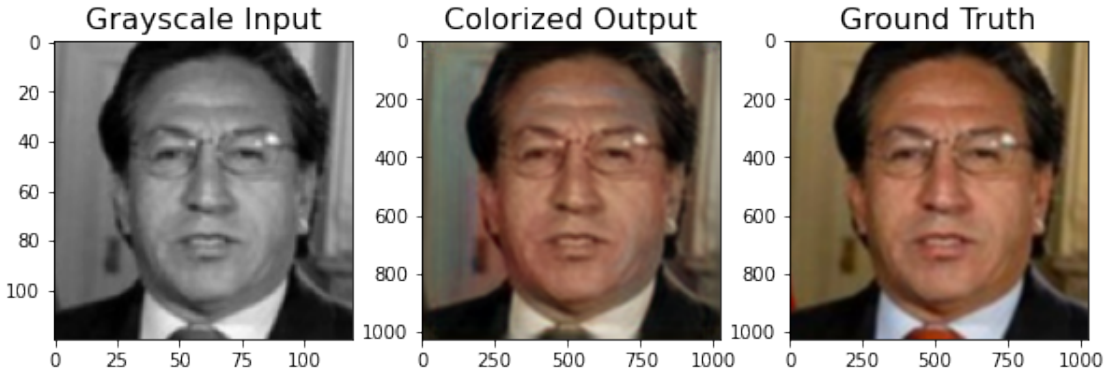
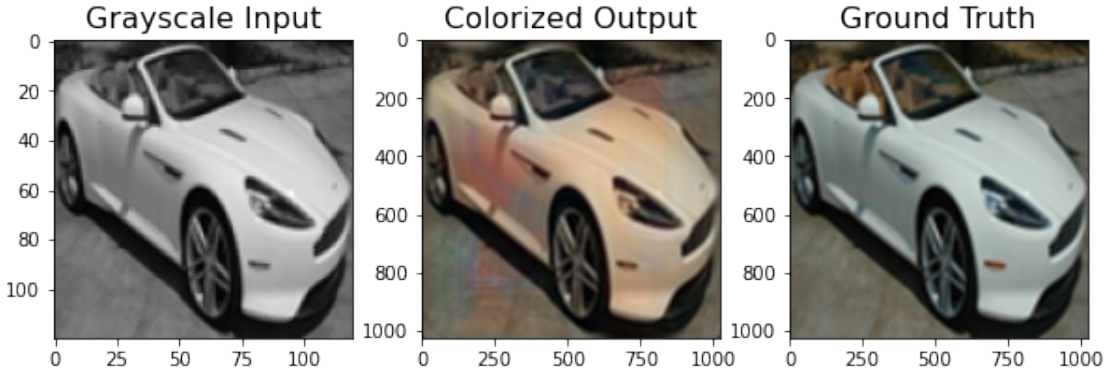
Colorized Output
Ground Truth


Grayscale Input
Colorized Output
Ground Truth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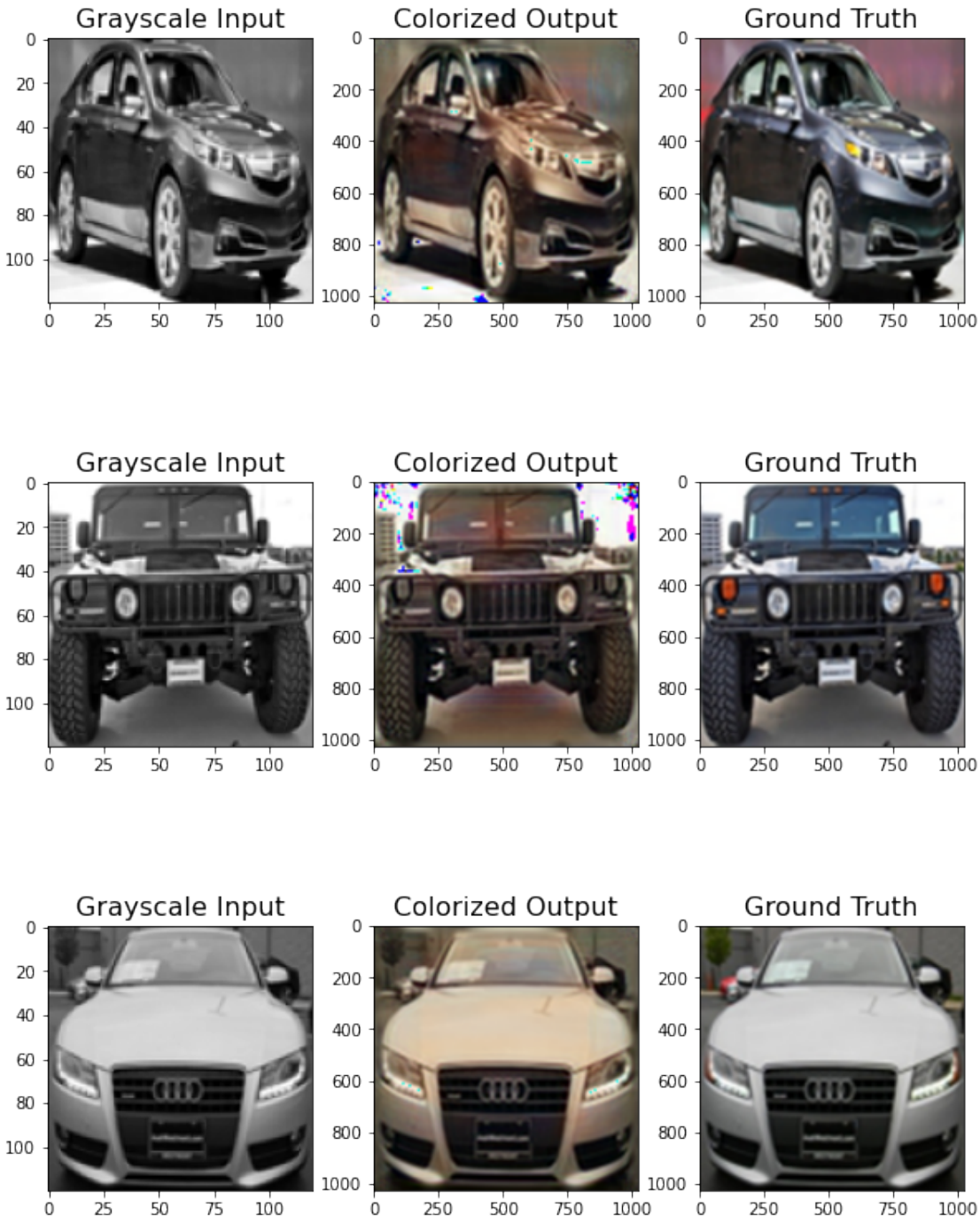
Colorized Output
Ground Truth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Ground Truth
Grayscale Input
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Ground Truth
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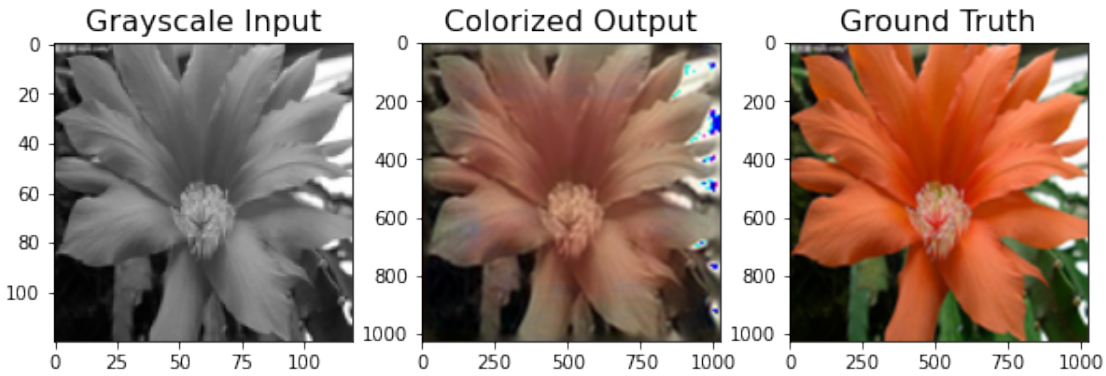
Colorized Output
Ground Truth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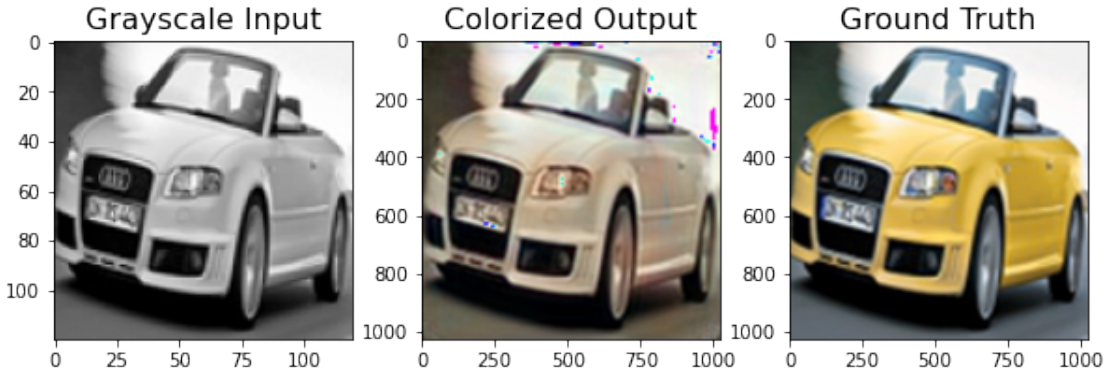
Colorized Output
Ground Truth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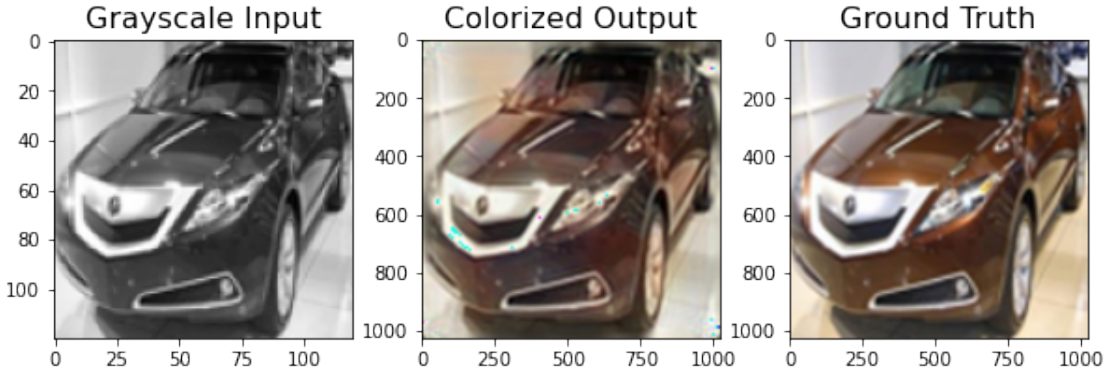
Colorized Output
Ground Truth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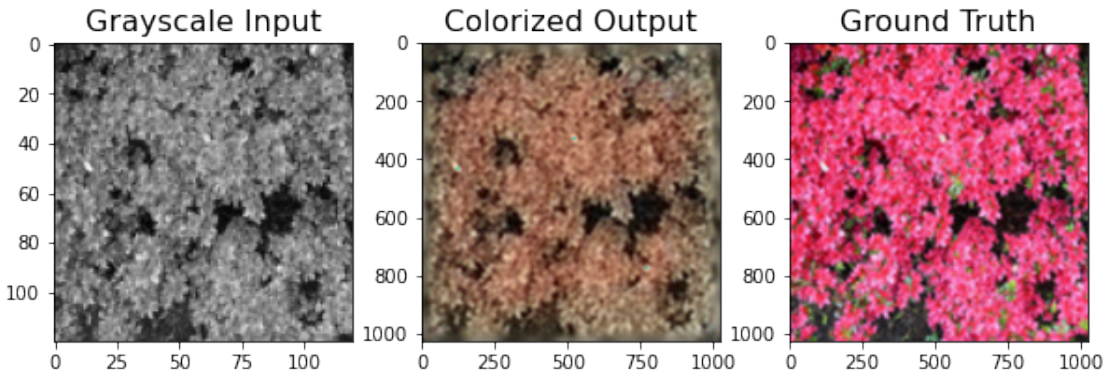
Colorized Output
Ground Truth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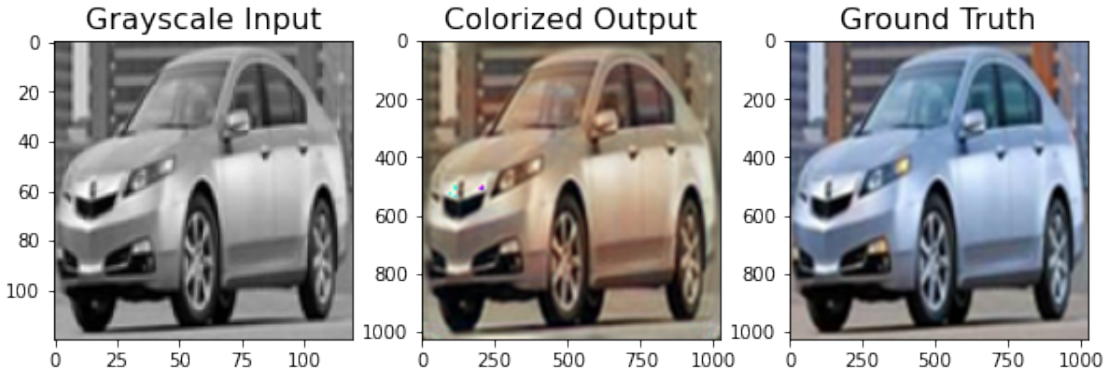
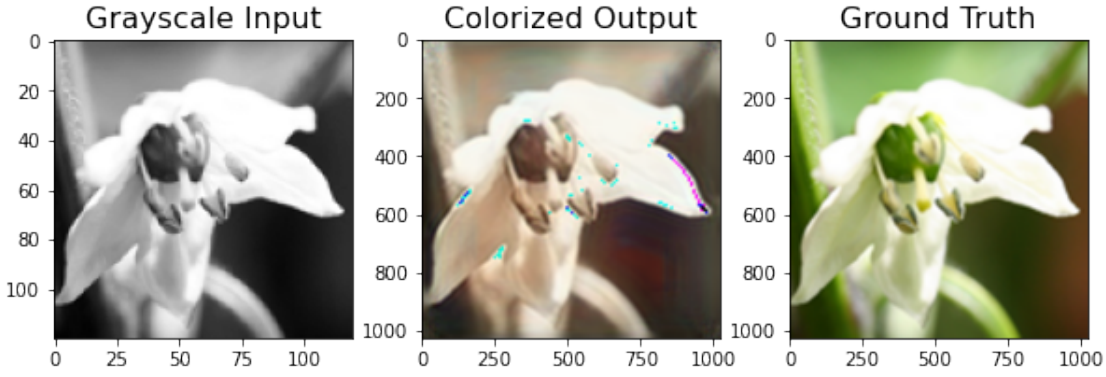
Colorized Output
Ground Truth


Grayscale Input
Colorized Output
Ground Truth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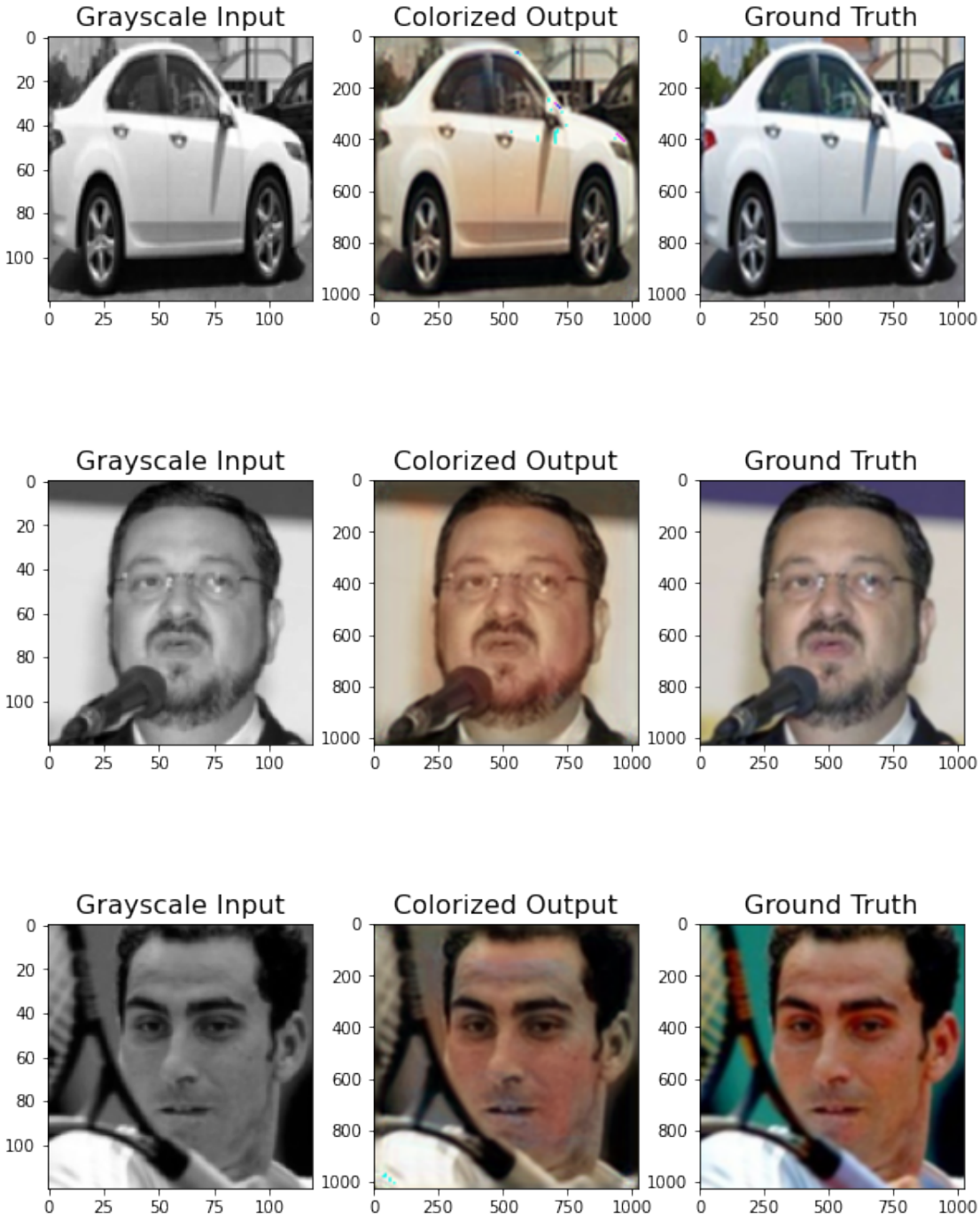
Colorized Output
Ground Truth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Ground Truth
Grayscale Input
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Ground Truth
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Colorized Output
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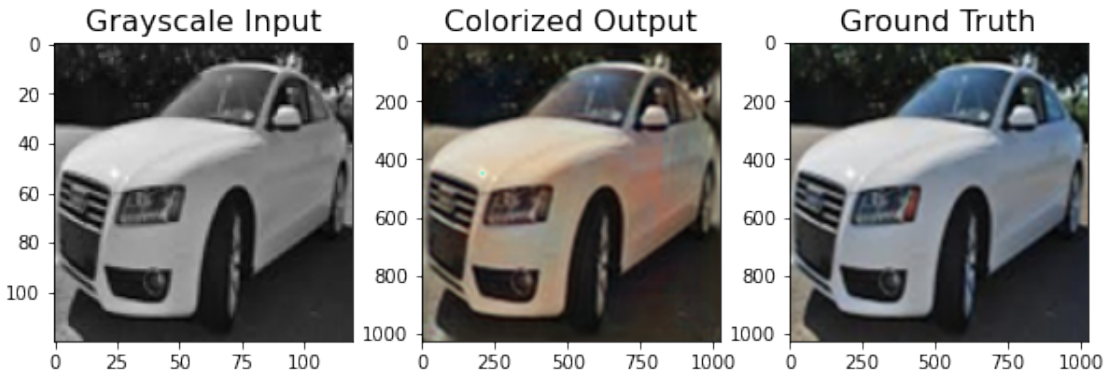
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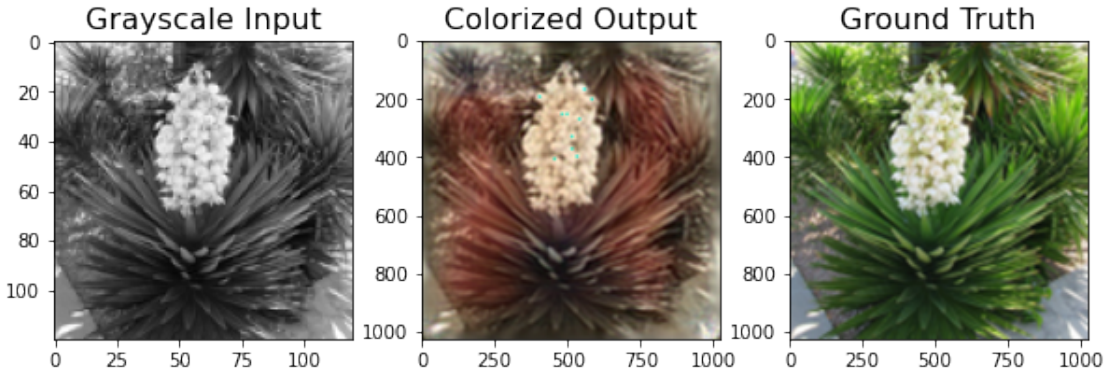
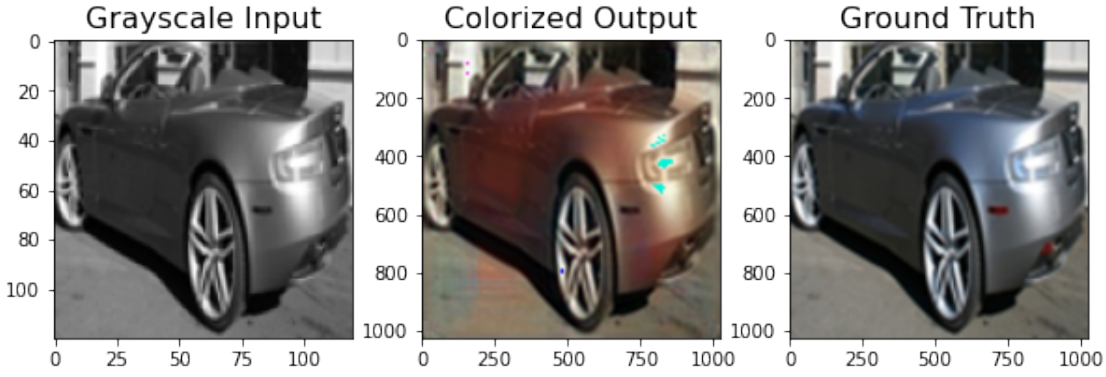
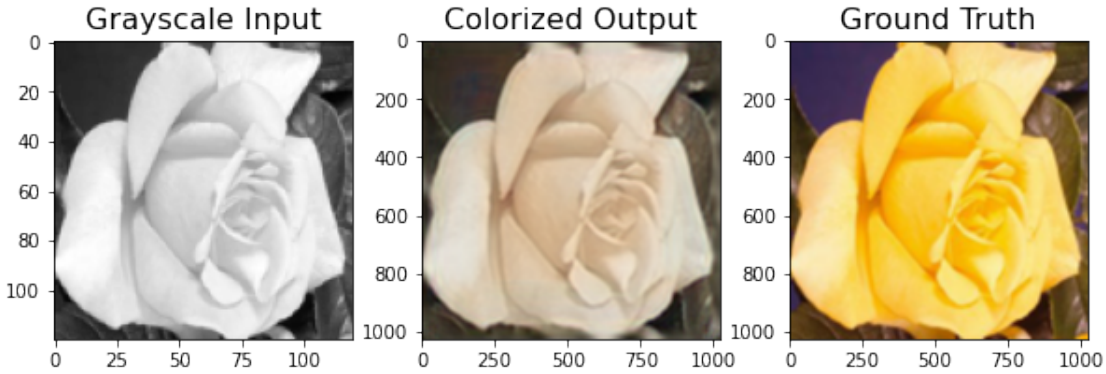
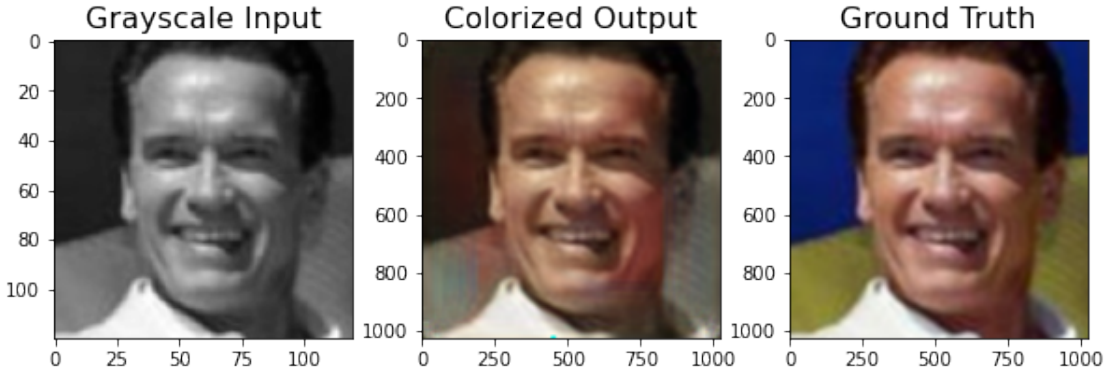
Colorized Output
Ground Truth


Grayscale Input
Colorized Output
Ground Truth


Grayscale Input
Colorized Output
Ground Truth


Grayscale Input
Colorized Output
Ground Truth


Grayscale Input
Colorized Output
Ground Truth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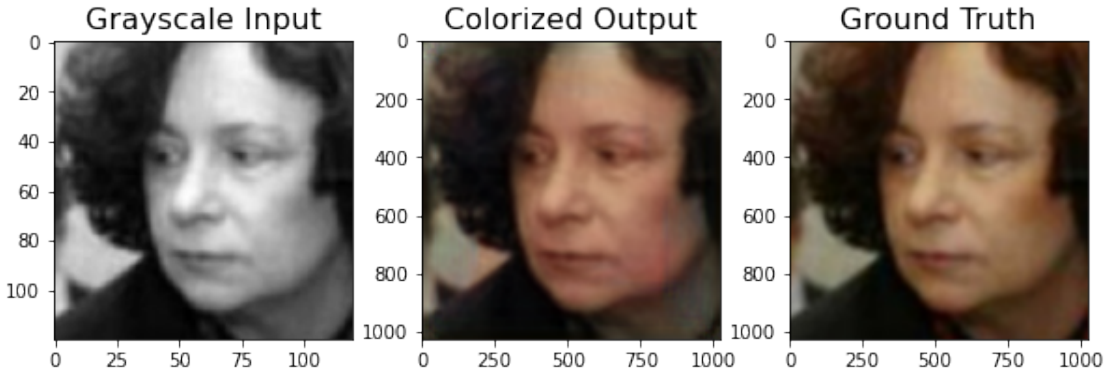
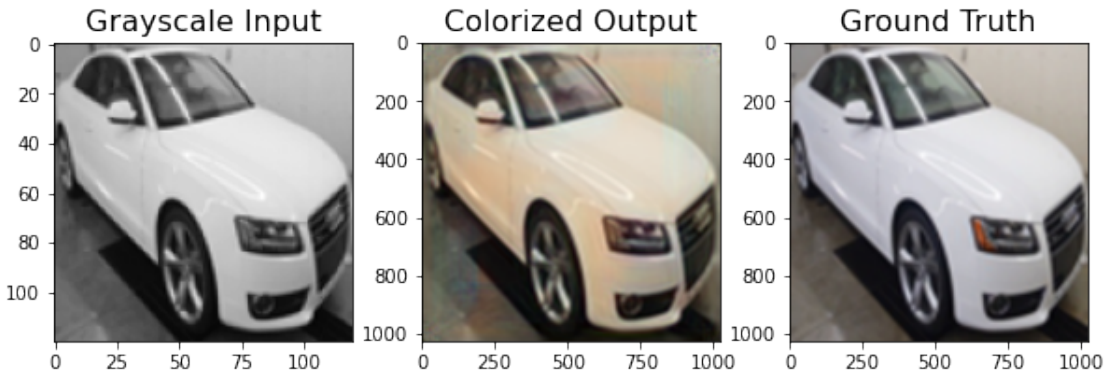
Colorized Output
Ground Truth


Grayscale Input
Colorized Output
Ground Truth


Grayscale Input
Colorized Output
Ground Truth


Grayscale Input
Colorized Output
Ground Truth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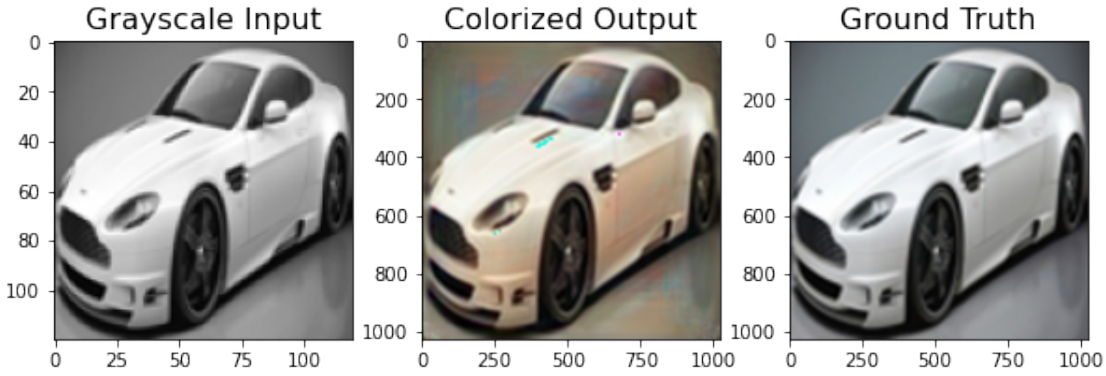
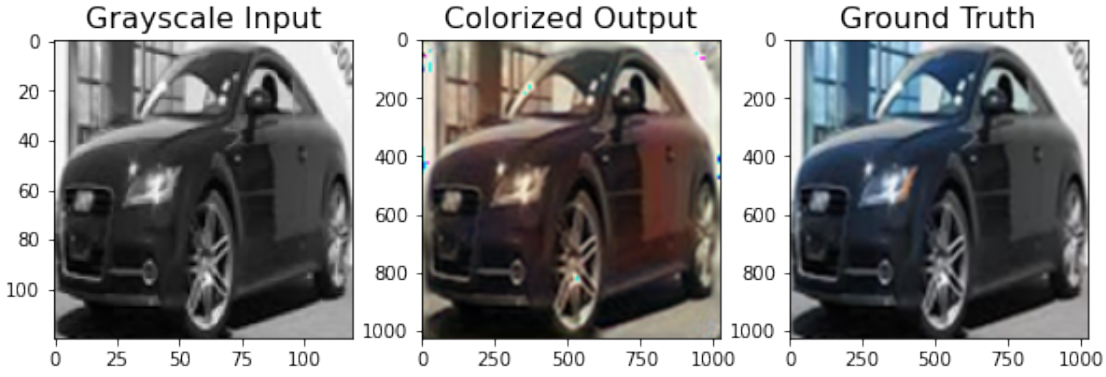
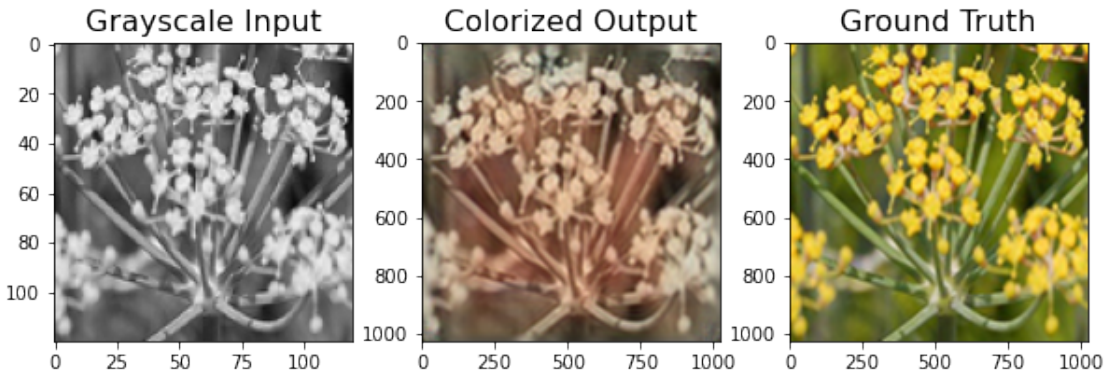
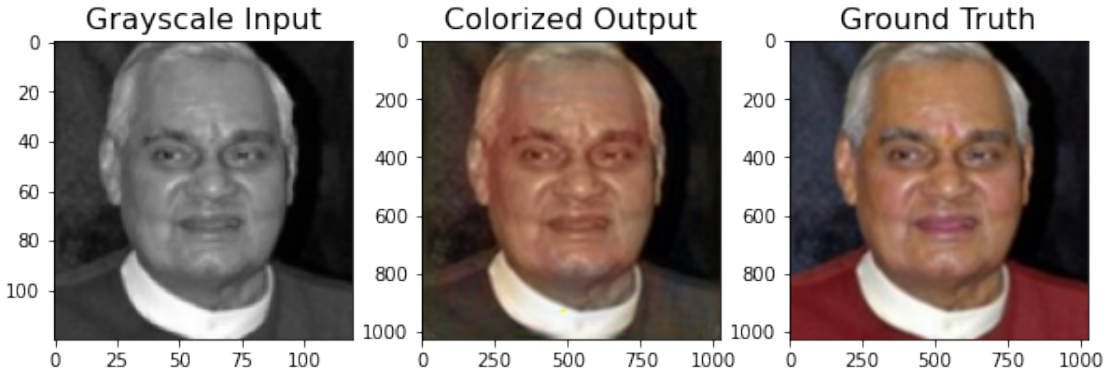
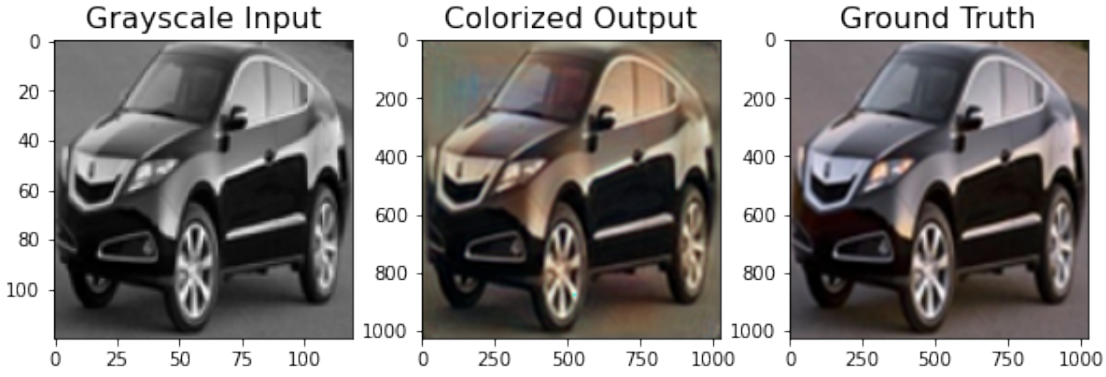
Colorized Output
Ground Truth

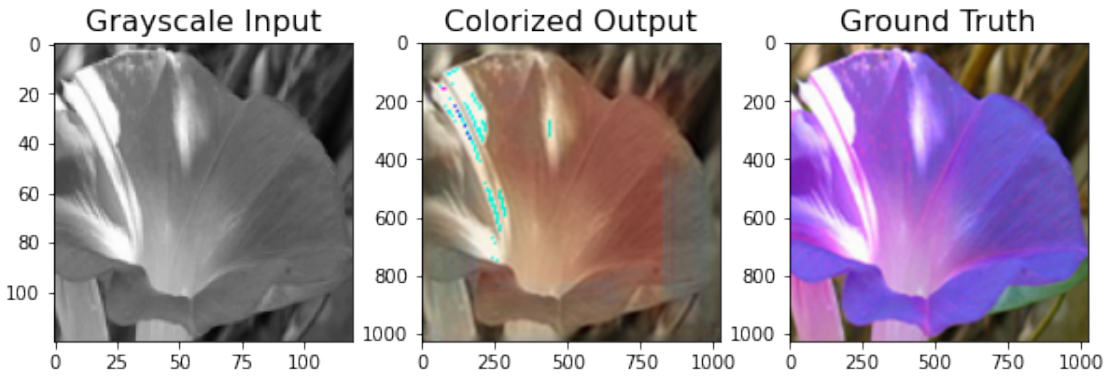

Grayscale Input
Colorized Output
Ground Truth


Grayscale Input
Colorized Output
Ground Truth


Grayscale Input
Colorized Output
Ground Truth


Grayscale Input
Colorized Output
Ground Truth


Grayscale Input
Colorized Output
Ground Truth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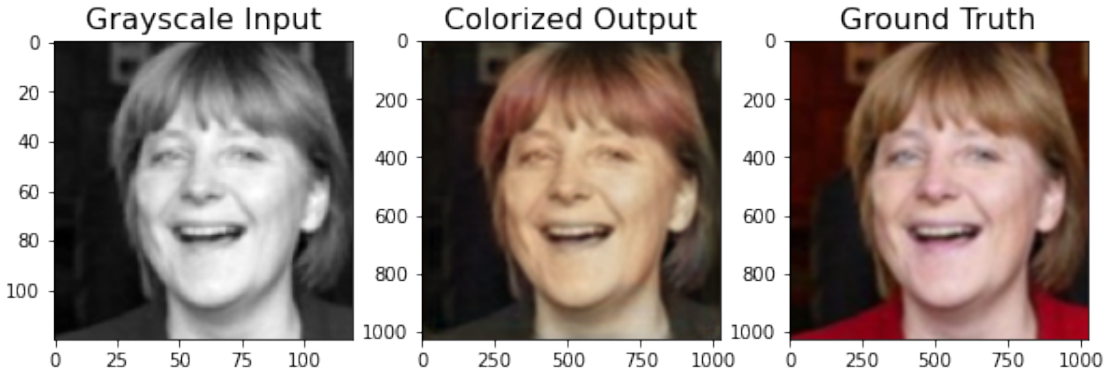
Colorized Output
Ground Truth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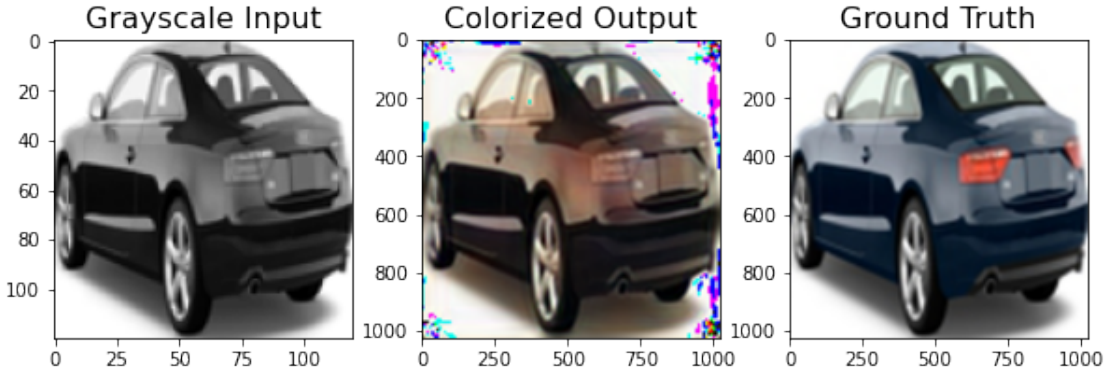
Colorized Output
Ground Truth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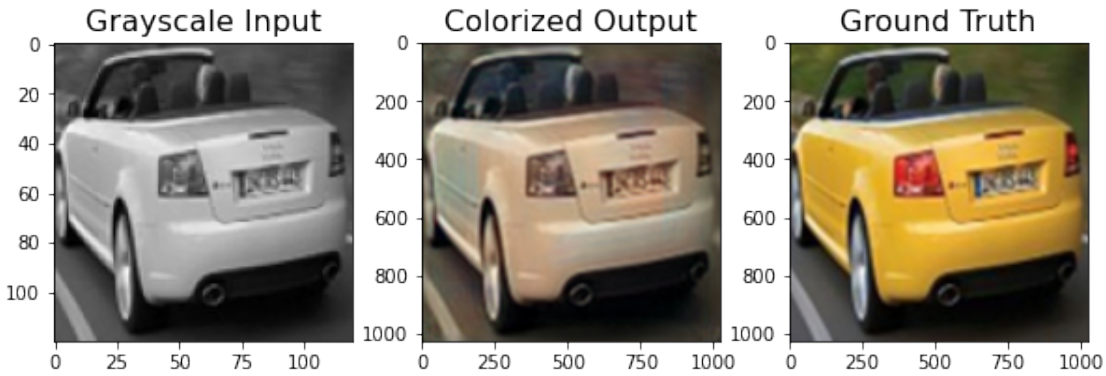
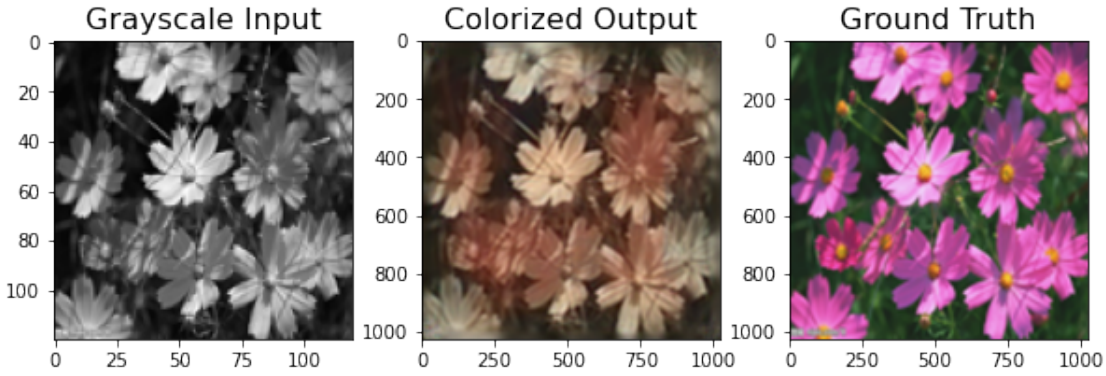
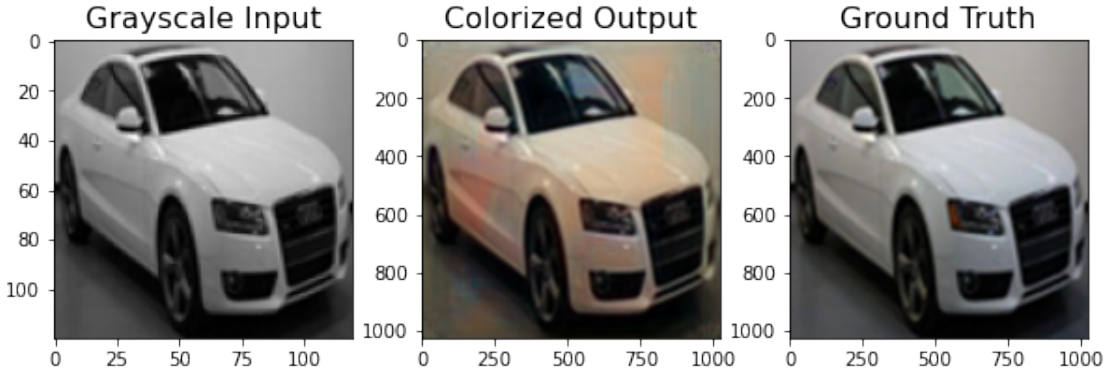
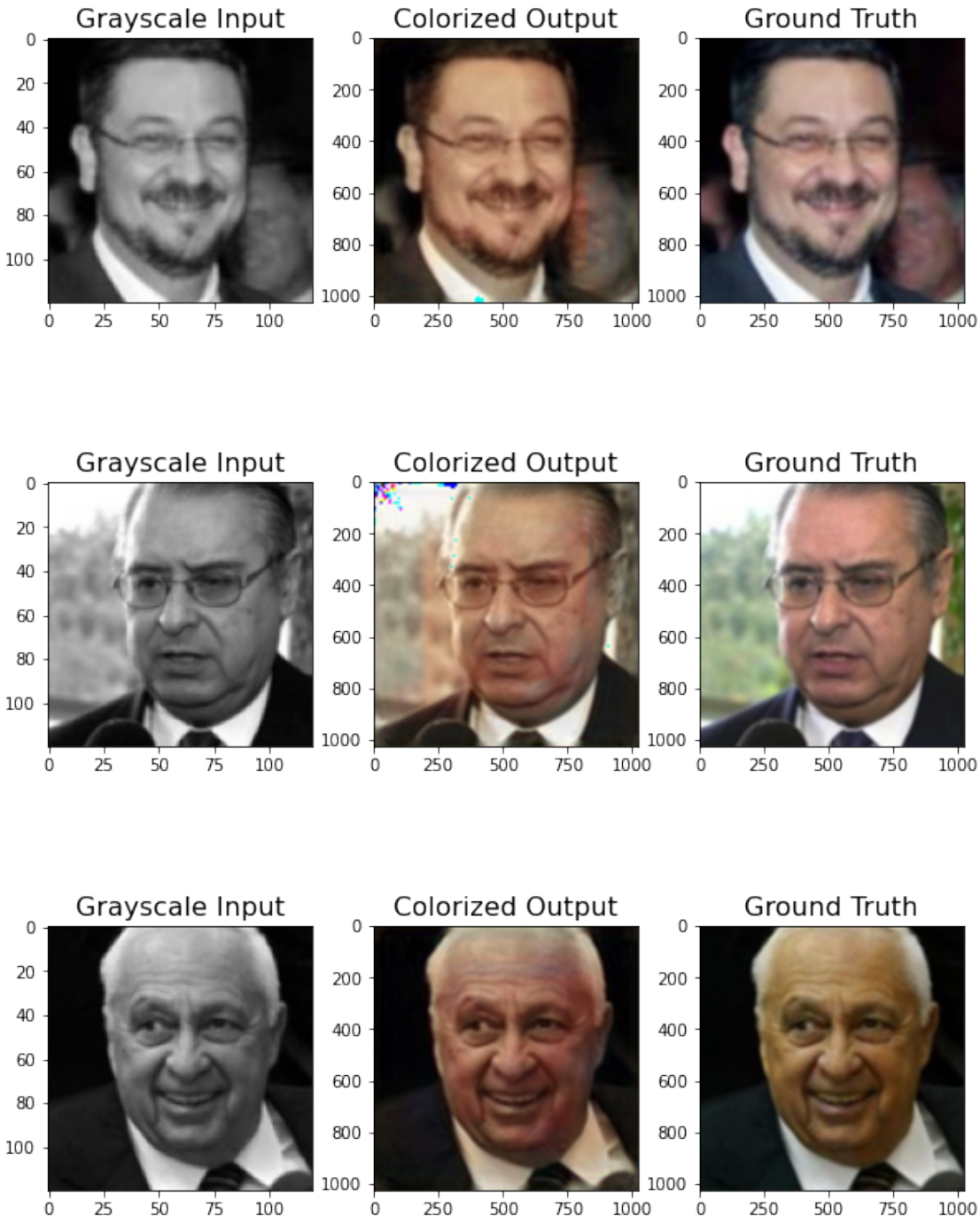
Colorized Output
Ground Truth


Grayscale Input
Colorized Output
Ground Truth


Grayscale Input
Colorized Output
Ground Truth


Grayscale Input
Colorized Output
Ground Truth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Ground Truth
Grayscale Input
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Colorized Output
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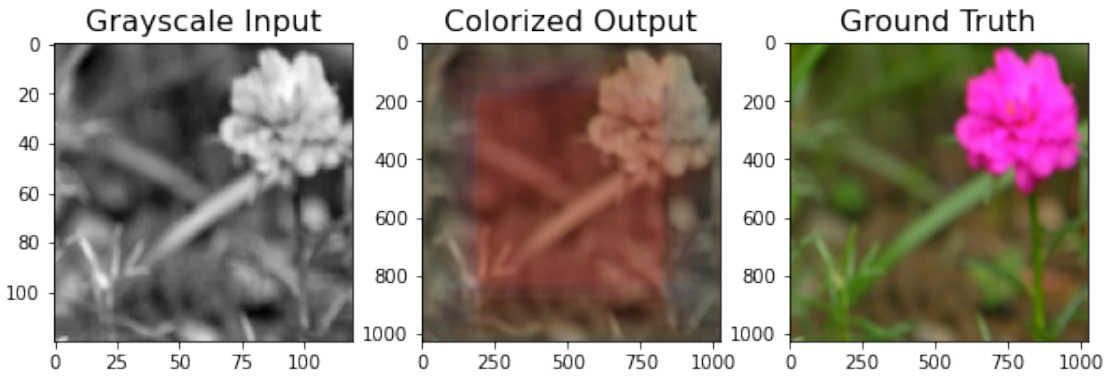
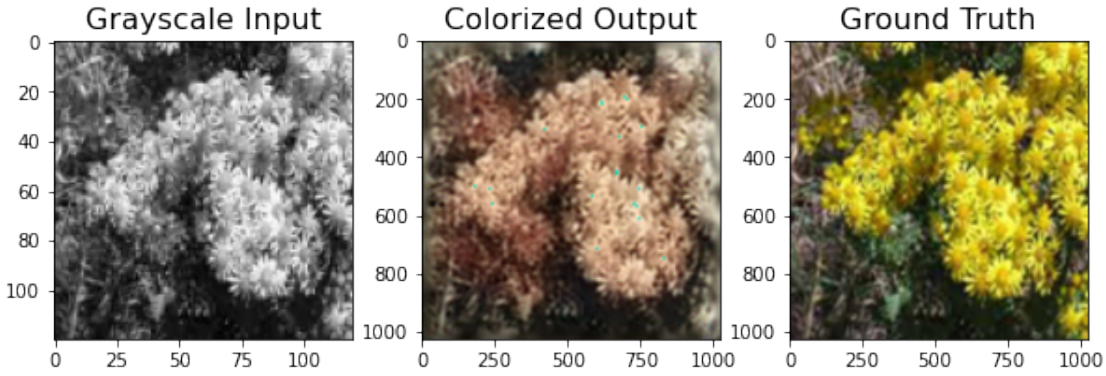
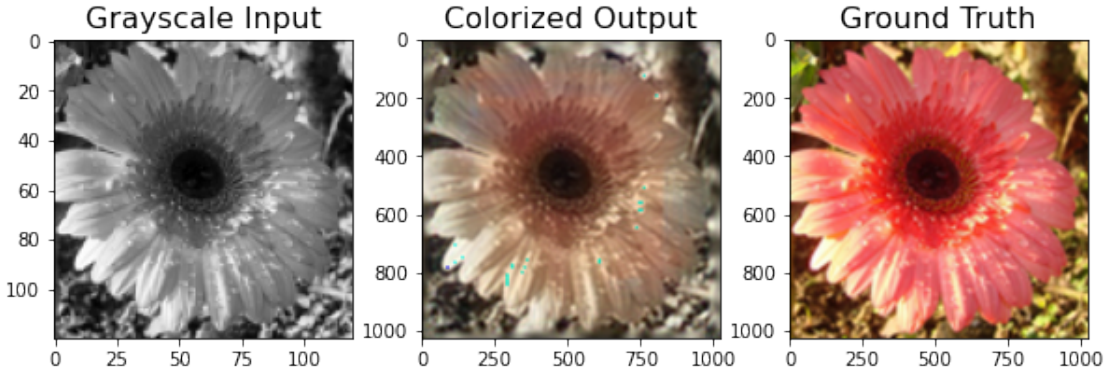
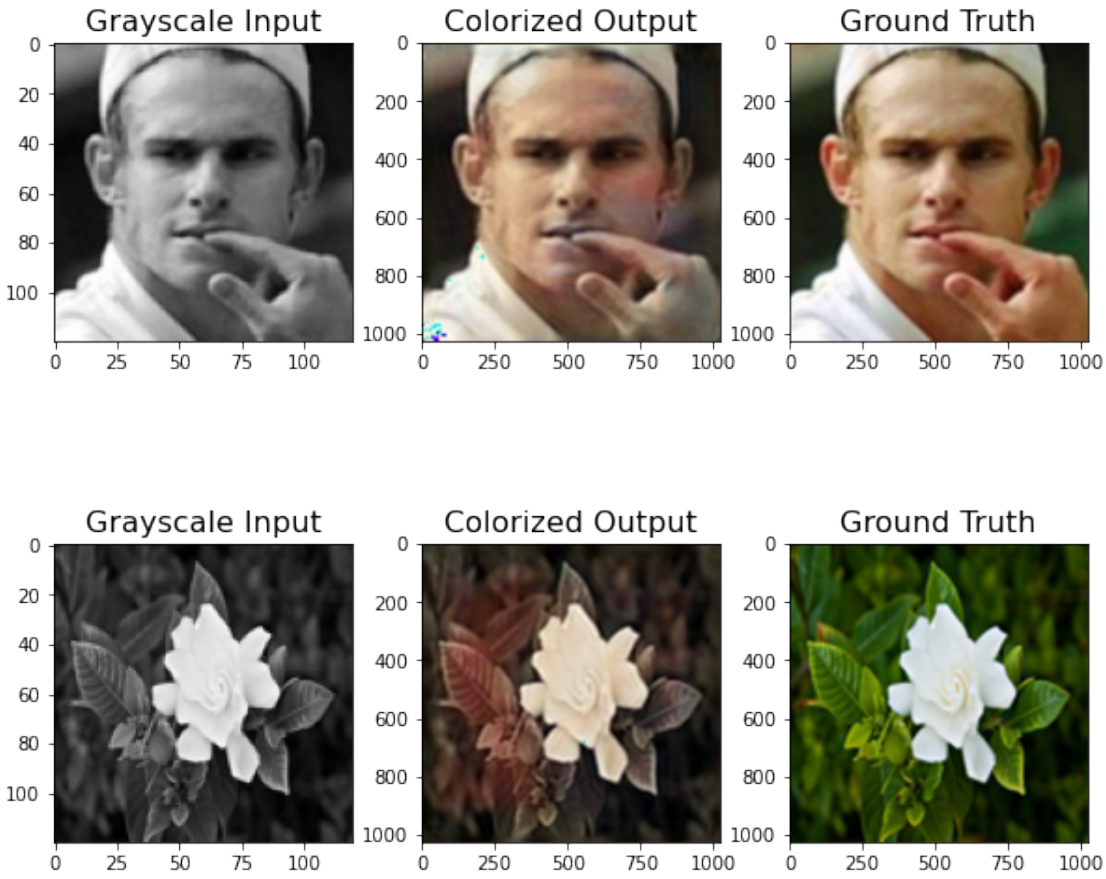

Grayscale Input
Colorized Output
Ground Truth


Grayscale Input
Colorized Output
Ground Truth


Grayscale Input
Colorized Output
Ground Truth


Grayscale Input
Colorized Output
Ground Truth
Grayscale Input
Colorized Output
Ground Truth