



T81-558: Applications of Deep Neural Networks

Module 7: Generative Adversarial Networks

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- For more information visit the [class website](#).

Module 7 Material

- Part 7.1: Introduction to GANs for Image and Data Generation [\[Video\]](#) [\[Notebook\]](#)
- Part 7.2: Train StyleGAN3 with your Own Images [\[Video\]](#) [\[Notebook\]](#)
- Part 7.3: Exploring the StyleGAN Latent Vector [\[Video\]](#) [\[Notebook\]](#)
- **Part 7.4: GANs to Enhance Old Photographs Deoldify** [\[Video\]](#) [\[Notebook\]](#)
- Part 7.5: GANs for Tabular Synthetic Data Generation [\[Video\]](#) [\[Notebook\]](#)

Part 7.4: GANS to Enhance Old Photographs Deoldify

For the last two parts of this module, we will examine two applications of GANs. The first application is named [deoldify](#), which uses a PyTorch-based GAN to transform old photographs into more modern-looking images. The complete [source code](#) to Deoldify is provided, along with several examples [notebooks](#) upon which I based this part.

Install Needed Software

We begin by cloning the deoldify repository.

In [1]:

```
# HIDE OUTPUT
!git clone https://github.com/jantic/DeOldify.git DeOldify
%cd DeOldify
```

```
Cloning into 'DeOldify'...
remote: Enumerating objects: 2344, done.
remote: Counting objects: 100% (116/116), done.
remote: Compressing objects: 100% (107/107), done.
remote: Total 2344 (delta 57), reused 29 (delta 9), pack-reused 2228
Receiving objects: 100% (2344/2344), 69.46 MiB | 41.02 MiB/s, done.
Resolving deltas: 100% (1064/1064), done.
/content/DeOldify
```

Install any additional Python packages needed.

In [2]:

```
# HIDE OUTPUT
!pip install -r colab_requirements.txt
```

Collecting fastai==1.0.51

Downloading fastai-1.0.51-py3-none-any.whl (214 kB)

	10 kB	31.9 MB/s	eta 0:00:01
	20 kB	10.2 MB/s	eta 0:00:01
	30 kB	8.7 MB/s	eta 0:00:01
	40 kB	8.1 MB/s	eta 0:00:01
	51 kB	4.5 MB/s	eta 0:00:01
	61 kB	5.4 MB/s	eta 0:00:01
	71 kB	5.5 MB/s	eta 0:00:01
	81 kB	4.2 MB/s	eta 0:00:01
	92 kB	4.6 MB/s	eta 0:00:01
	102 kB	5.1 MB/s	eta 0:00:01
	112 kB	5.1 MB/s	eta 0:00:01
	122 kB	5.1 MB/s	eta 0:00:01
	133 kB	5.1 MB/s	eta 0:00:01
	143 kB	5.1 MB/s	eta 0:00:01
	153 kB	5.1 MB/s	eta 0:00:01
	163 kB	5.1 MB/s	eta 0:00:01
	174 kB	5.1 MB/s	eta 0:00:01
	184 kB	5.1 MB/s	eta 0:00:01
	194 kB	5.1 MB/s	eta 0:00:01
	204 kB	5.1 MB/s	eta 0:00:01
	214 kB	5.1 MB/s	

Collecting tensorboardX==1.6

Downloading tensorboardX-1.6-py2.py3-none-any.whl (129 kB)

	10 kB	36.3 MB/s	eta 0:00:01
	20 kB	44.7 MB/s	eta 0:00:01
	30 kB	50.4 MB/s	eta 0:00:01
	40 kB	52.1 MB/s	eta 0:00:01
	51 kB	52.4 MB/s	eta 0:00:01
	61 kB	54.5 MB/s	eta 0:00:01
	71 kB	54.4 MB/s	eta 0:00:01
	81 kB	52.5 MB/s	eta 0:00:01
	92 kB	53.9 MB/s	eta 0:00:01
	102 kB	54.7 MB/s	eta 0:00:01
	112 kB	54.7 MB/s	eta 0:00:01
	122 kB	54.7 MB/s	eta 0:00:01
	129 kB	54.7 MB/s	

Collecting ffmpeg-python

Downloading ffmpeg_python-0.2.0-py3-none-any.whl (25 kB)

Collecting youtube-dl>=2019.4.17

Downloading youtube_dl-2021.12.17-py2.py3-none-any.whl (1.9 MB)

	1.9 MB	79.2 MB/s	
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Requirement already satisfied: opencv-python>=3.3.0.10 in /usr/local/lib/python3.7/dist-packages (from -r colab_requirements.txt (line 5)) (4.1.2.30)

Requirement already satisfied: pillow in /usr/local/lib/python3.7/dist-packages (from -r colab_requirements.txt (line 6)) (7.1.2)

Requirement already satisfied: tornado~=5.1.0 in /usr/local/lib/python3.7/dist-packages (from -r colab_requirements.txt (line 7)) (5.1.1)

Requirement already satisfied: scipy in /usr/local/lib/python3.7/dist-packages (from fastai==1.0.51->-r colab_requirements.txt (line 1)) (1.4.1)

Requirement already satisfied: pandas in /usr/local/lib/python3.7/dist-packages (from fastai==1.0.51->-r colab_requirements.txt (line 1)) (1.3.5)

Requirement already satisfied: matplotlib in /usr/local/lib/python3.7/dist-packages (from fastai==1.0.51->-r colab_requirements.txt (line 1)) (3.2.2)

Requirement already satisfied: pyyaml in /usr/local/lib/python3.7/dist-packages (from fastai==1.0.51->-r colab_requirements.txt (line 1)) (3.13)

Requirement already satisfied: spacy>=2.0.18 in /usr/local/lib/python3.7/dist-packages (from fastai==1.0.51->-r colab_requirements.txt (line 1))

(2.2.4)

Requirement already satisfied: nvidia-ml-py3 in /usr/local/lib/python3.7/dist-packages (from fastai==1.0.51->-r colab_requirements.txt (line 1))

(7.352.0)

Requirement already satisfied: numexpr in /usr/local/lib/python3.7/dist-packages (from fastai==1.0.51->-r colab_requirements.txt (line 1)) (2.8.1)

Requirement already satisfied: beautifulsoup4 in /usr/local/lib/python3.7/dist-packages (from fastai==1.0.51->-r colab_requirements.txt (line 1))

(4.6.3)

Requirement already satisfied: requests in /usr/local/lib/python3.7/dist-packages (from fastai==1.0.51->-r colab_requirements.txt (line 1)) (2.23.0)

Requirement already satisfied: torchvision in /usr/local/lib/python3.7/dist-packages (from fastai==1.0.51->-r colab_requirements.txt (line 1)) (0.11.1+cu111)

Requirement already satisfied: torch>=1.0.0 in /usr/local/lib/python3.7/dist-packages (from fastai==1.0.51->-r colab_requirements.txt (line 1)) (1.10.0+cu111)

Collecting typing

Downloading typing-3.7.4.3.tar.gz (78 kB)

|██| 78 kB 6.8 MB/s

Requirement already satisfied: fastprogress>=0.1.19 in /usr/local/lib/python3.7/dist-packages (from fastai==1.0.51->-r colab_requirements.txt (line 1)) (1.0.2)

Requirement already satisfied: bottleneck in /usr/local/lib/python3.7/dist-packages (from fastai==1.0.51->-r colab_requirements.txt (line 1)) (1.3.4)

Requirement already satisfied: numpy>=1.15 in /usr/local/lib/python3.7/dist-packages (from fastai==1.0.51->-r colab_requirements.txt (line 1)) (1.21.5)

Requirement already satisfied: packaging in /usr/local/lib/python3.7/dist-packages (from fastai==1.0.51->-r colab_requirements.txt (line 1)) (21.3)

Requirement already satisfied: six in /usr/local/lib/python3.7/dist-packages (from tensorboardX==1.6->-r colab_requirements.txt (line 2)) (1.15.0)

Requirement already satisfied: protobuf>=3.2.0 in /usr/local/lib/python3.7/dist-packages (from tensorboardX==1.6->-r colab_requirements.txt (line 2)) (3.17.3)

Requirement already satisfied: plac<1.2.0,>=0.9.6 in /usr/local/lib/python3.7/dist-packages (from spacy>=2.0.18->fastai==1.0.51->-r colab_requirements.txt (line 1)) (1.1.3)

Requirement already satisfied: catalogue<1.1.0,>=0.0.7 in /usr/local/lib/python3.7/dist-packages (from spacy>=2.0.18->fastai==1.0.51->-r colab_requirements.txt (line 1)) (1.0.0)

Requirement already satisfied: preshed<3.1.0,>=3.0.2 in /usr/local/lib/python3.7/dist-packages (from spacy>=2.0.18->fastai==1.0.51->-r colab_requirements.txt (line 1)) (3.0.6)

Requirement already satisfied: cymem<2.1.0,>=2.0.2 in /usr/local/lib/python3.7/dist-packages (from spacy>=2.0.18->fastai==1.0.51->-r colab_requirements.txt (line 1)) (2.0.6)

Requirement already satisfied: thinc==7.4.0 in /usr/local/lib/python3.7/dist-packages (from spacy>=2.0.18->fastai==1.0.51->-r colab_requirements.txt (line 1)) (7.4.0)

Requirement already satisfied: wasabi<1.1.0,>=0.4.0 in /usr/local/lib/python3.7/dist-packages (from spacy>=2.0.18->fastai==1.0.51->-r colab_requirements.txt (line 1)) (0.9.0)

Requirement already satisfied: srsly<1.1.0,>=1.0.2 in /usr/local/lib/python3.7/dist-packages (from spacy>=2.0.18->fastai==1.0.51->-r colab_requirements.txt (line 1)) (1.0.5)

Requirement already satisfied: setuptools in /usr/local/lib/python3.7/dist-packages (from spacy>=2.0.18->fastai==1.0.51->-r colab_requirements.txt (line 1)) (57.4.0)

Requirement already satisfied: murmurhash<1.1.0,>=0.28.0 in /usr/local/lib/python3.7/dist-packages (from spacy>=2.0.18->fastai==1.0.51->-r colab_requirements.txt (line 1)) (1.0.6)

```

Requirement already satisfied: blis<0.5.0,>=0.4.0 in /usr/local/lib/python
3.7/dist-packages (from spacy>=2.0.18->fastai==1.0.51->-r colab_requiremen
ts.txt (line 1)) (0.4.1)
Requirement already satisfied: tqdm<5.0.0,>=4.38.0 in /usr/local/lib/pytho
n3.7/dist-packages (from spacy>=2.0.18->fastai==1.0.51->-r colab_requireme
nts.txt (line 1)) (4.63.0)
Requirement already satisfied: importlib-metadata>=0.20 in /usr/local/lib/
python3.7/dist-packages (from catalogue<1.1.0,>=0.0.7->spacy>=2.0.18->fast
ai==1.0.51->-r colab_requirements.txt (line 1)) (4.11.3)
Requirement already satisfied: zipp>=0.5 in /usr/local/lib/python3.7/dist-
packages (from importlib-metadata>=0.20->catalogue<1.1.0,>=0.0.7->spacy>=
2.0.18->fastai==1.0.51->-r colab_requirements.txt (line 1)) (3.7.0)
Requirement already satisfied: typing-extensions>=3.6.4 in /usr/local/lib/
python3.7/dist-packages (from importlib-metadata>=0.20->catalogue<1.1.0,>=
0.0.7->spacy>=2.0.18->fastai==1.0.51->-r colab_requirements.txt (line 1))
(3.10.0.2)
Requirement already satisfied: chardet<4,>=3.0.2 in /usr/local/lib/python
3.7/dist-packages (from requests->fastai==1.0.51->-r colab_requirements.tx
t (line 1)) (3.0.4)
Requirement already satisfied: certifi>=2017.4.17 in /usr/local/lib/python
3.7/dist-packages (from requests->fastai==1.0.51->-r colab_requirements.tx
t (line 1)) (2021.10.8)
Requirement already satisfied: urllib3!=1.25.0,!1.25.1,<1.26,>=1.21.1 in
/usr/local/lib/python3.7/dist-packages (from requests->fastai==1.0.51->-r
colab_requirements.txt (line 1)) (1.24.3)
Requirement already satisfied: idna<3,>=2.5 in /usr/local/lib/python3.7/di
st-packages (from requests->fastai==1.0.51->-r colab_requirements.txt (lin
e 1)) (2.10)
Requirement already satisfied: future in /usr/local/lib/python3.7/dist-pac
kages (from ffmpeg-python->-r colab_requirements.txt (line 3)) (0.16.0)
Requirement already satisfied: cycpler>=0.10 in /usr/local/lib/python3.7/di
st-packages (from matplotlib->fastai==1.0.51->-r colab_requirements.txt (l
ine 1)) (0.11.0)
Requirement already satisfied: python-dateutil>=2.1 in /usr/local/lib/pyth
on3.7/dist-packages (from matplotlib->fastai==1.0.51->-r colab_requirement
s.txt (line 1)) (2.8.2)
Requirement already satisfied: pyparsing!=2.0.4,!2.1.2,!2.1.6,>=2.0.1 in
/usr/local/lib/python3.7/dist-packages (from matplotlib->fastai==1.0.51->-
r colab_requirements.txt (line 1)) (3.0.7)
Requirement already satisfied: kiwisolver>=1.0.1 in /usr/local/lib/python
3.7/dist-packages (from matplotlib->fastai==1.0.51->-r colab_requirements.
txt (line 1)) (1.4.0)
Requirement already satisfied: pytz>=2017.3 in /usr/local/lib/python3.7/di
st-packages (from pandas->fastai==1.0.51->-r colab_requirements.txt (line
1)) (2018.9)
Building wheels for collected packages: typing
  Building wheel for typing (setup.py) ... done
  Created wheel for typing: filename=typing-3.7.4.3-py3-none-any.whl size=
26325 sha256=59cd22666e09f1de026cc1027fafc482d06516afe68f1f390a5815150309d
329
  Stored in directory: /root/.cache/pip/wheels/35/f3/15/01aa6571f0a72ee6ae
7b827c1491c37a1f72d686fd22b43b0e
Successfully built typing
Installing collected packages: typing, youtube-dl, tensorboardX, ffmpeg-py
thon, fastai
  Attempting uninstall: fastai
    Found existing installation: fastai 1.0.61
    Uninstalling fastai-1.0.61:
      Successfully uninstalled fastai-1.0.61
Successfully installed fastai-1.0.51 ffmpeg-python-0.2.0 tensorboardX-1.6
typing-3.7.4.3 youtube-dl-2021.12.17

```

Install the pretrained weights for deoldify.

In [3]:

```
# HIDE OUTPUT
```

```
!mkdir './models/'
```

```
CMD = "wget https://data.deepai.org/deoldify/ColorizeArtistic_gen.pth\"  
      \" -O ./models/ColorizeArtistic_gen.pth"
```

```
!{CMD}
```

```
--2022-04-03 18:32:26-- https://data.deepai.org/deoldify/ColorizeArtistic_gen.pth
```

```
Resolving data.deepai.org (data.deepai.org)... 138.201.36.183
```

```
Connecting to data.deepai.org (data.deepai.org)|138.201.36.183|:443... connected.
```

```
HTTP request sent, awaiting response... 200 OK
```

```
Length: 255144681 (243M) [application/octet-stream]
```

```
Saving to: './models/ColorizeArtistic_gen.pth'
```

```
./models/ColorizeAr 100%[=====>] 243.32M 29.3MB/s in 8.9  
s
```

```
2022-04-03 18:32:36 (27.4 MB/s) - './models/ColorizeArtistic_gen.pth' saved  
[255144681/255144681]
```

The authors of deoldify suggest that you might wish to include a watermark to let others know that AI-enhanced this picture. The following code downloads this standard watermark. The authors describe the watermark as follows:

"This places a watermark icon of a palette at the bottom left corner of the image. The authors intend this practice to be a standard way to convey to others viewing the image that AI colorizes it. We want to help promote this as a standard, especially as the technology continues to improve and the distinction between real and fake becomes harder to discern. This palette watermark practice was initiated and led by the MyHeritage in the MyHeritage In Color feature (which uses a newer version of DeOldify than what you're using here)."

In [4]:

```
# HIDE OUTPUT
CMD = "wget https://media.githubusercontent.com/media/jantic/"\
      "DeOldify/master/resource_images/watermark.png "\
      "-O /content/DeOldify/resource_images/watermark.png"
!{CMD}
```

```
--2022-04-03 18:32:36-- https://media.githubusercontent.com/media/jantic/
DeOldify/master/resource_images/watermark.png
Resolving media.githubusercontent.com (media.githubusercontent.com)... 185
.199.108.133, 185.199.109.133, 185.199.110.133, ...
Connecting to media.githubusercontent.com (media.githubusercontent.com)|18
5.199.108.133|:443... connected.
HTTP request sent, awaiting response... 200 OK
Length: 9210 (9.0K) [image/png]
Saving to: '/content/DeOldify/resource_images/watermark.png'
```

```
/content/DeOldify/r 100%[=====>] 8.99K --KB/s in 0s
```

```
2022-04-03 18:32:36 (84.3 MB/s) - '/content/DeOldify/resource_images/water
mark.png' saved [9210/9210]
```

Initialize Torch Device

First, we must initialize a Torch device. If we have a GPU available, we will detect it here. I assume that you will run this code from Google CoLab, with a GPU. It is possible to run this code from a local GPU; however, some modification will be necessary.

In [5]:

```
import sys

#NOTE: This must be the first call in order to work properly!
from deoldify import device
from deoldify.device_id import DeviceId
#choices: CPU, GPU0...GPU7
device.set(device=DeviceId.GPU0)

import torch

if not torch.cuda.is_available():
    print('GPU not available.')
else:
    print('Using GPU.')
```

Using GPU.

We can now call the model. I will enhance an image from my childhood, probably taken in the late 1970s. The picture shows three miniature schnauzers. My childhood dog (Scooby) is on the left, followed by his mom and sister. Overall, a stunning improvement. However, the red in the fire engine riding toy is lost, and the red color of the picnic table where the three dogs were sitting.

In [6]:

```
# HIDE OUTPUT
import fastai
from deoldify.visualize import *
```

```

import warnings
from urllib.parse import urlparse
import os

warnings.filterwarnings("ignore", category=UserWarning,
                        message=".*?Your .*? set is empty.*?")

URL = 'https://raw.githubusercontent.com/jeffheaton/'\
      't81_558_deep_learning/master/photos/scooby_family.jpg'

!wget {URL}

a = urlparse(URL)
before_file = os.path.basename(a.path)

RENDER_FACTOR = 35
WATERMARK = False

colorizer = get_image_colorizer(artistic=True)

after_image = colorizer.get_transformed_image(
    before_file, render_factor=RENDER_FACTOR,
    watermarked=WATERMARK)
#print("Starting image:")

```

```

--2022-04-03 18:32:43-- https://raw.githubusercontent.com/jeffheaton/t81_
558_deep_learning/master/photos/scooby_family.jpg
Resolving raw.githubusercontent.com (raw.githubusercontent.com)... 185.199
.109.133, 185.199.111.133, 185.199.108.133, ...
Connecting to raw.githubusercontent.com (raw.githubusercontent.com)|185.19
9.109.133|:443... connected.
HTTP request sent, awaiting response... 200 OK
Length: 43719 (43K) [image/jpeg]
Saving to: 'scooby_family.jpg'

```

```

scooby_family.jpg      0%[                               ]      0  ---KB/s
scooby_family.jpg    100%[=====>]  42.69K  ---KB/s    in 0.0
ls

```

```
2022-04-03 18:32:43 (4.19 MB/s) - 'scooby_family.jpg' saved [43719/43719]
```

```

Downloading: "https://download.pytorch.org/models/resnet34-b627a593.pth" t
o /root/.cache/torch/hub/checkpoints/resnet34-b627a593.pth
  0%|          | 0.00/83.3M [00:00<?, ?B/s]

```

You can see the starting image here.

In [7]:

```

from IPython import display
display.Image(URL)

```


Out[7]:



You can see the deoldify version here. Please note that these two images will look similar in a black and white book. To see it in color, visit this [link](#).

In [8]:

`after_image`

Out[8]:

