GANs with Python

Setup

Note: This workshop requires an understanding of basic Python. Experience from your own projects is fine.

1. Go to this link: **linktr.ee/dolica.ual**
2. Open the GANs with Python Notebook link.
3. Log in to your Google account.

What are GANs?

- GAN stands for Generative Adversarial Networks.
- They have exploded in popularity in quite a short time.
- It started in a pub...

So what does Generative Adversarial Network? Well let's start with the word *generative*...

Generative?

Generative: Capable of producing or creating something.

- **Discriminative:** Identifies and distinguishes between categories, such as recognising that a cat is a cat and a dog is a dog.
- **Generative:** Generates new instances of cats or dogs by applying learned patterns.

Later, we'll explore how GANs actually combine these things.

Adversarial?

Adversarial: involving people opposing or disagreeing with each other.

Network?

Neural networks are algorithms that endeavor to recognise the underlying relationships in a set of data.

Putting it all together...

We are *generating* fake data by using two neural *networks* that have an *adversarial* relationship.

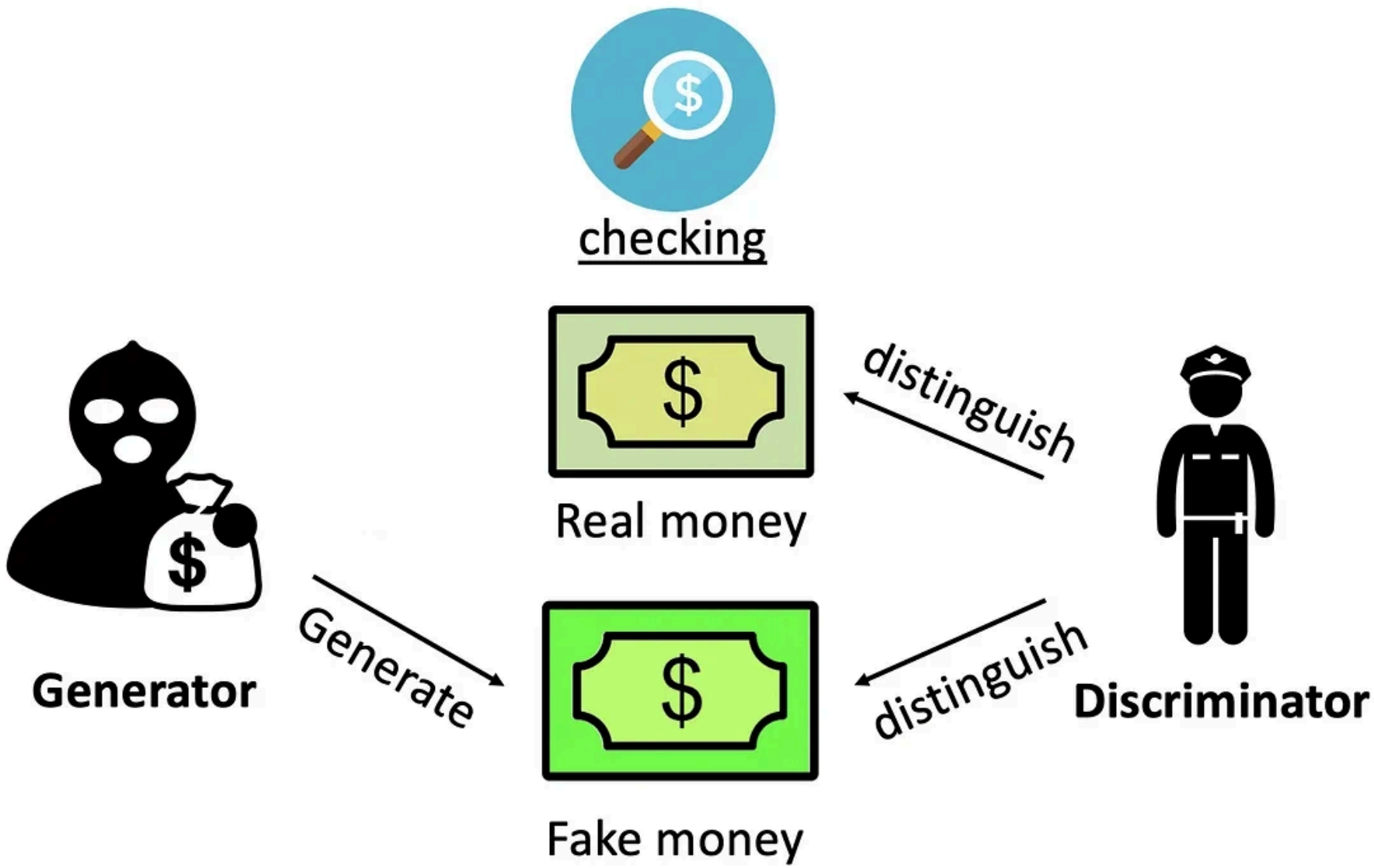
GAN Components

- A **Generator** ("the criminal") is trying to learn to create fake images
- A **Discriminator** ("the detective") is trying to tell real images from the fake images
- The two neural networks are *trained* simultaneously

We can think of a GAN as being like a turn-based game...

The GAN Game I

1. Our criminal creates a fake note
2. Our detective sees a real note and a fake note and is asked to tell which is which
3. The criminal "wins" a round of the game if it fools the detective
4. The detective "wins" a round of the game if it can spot the fake
5. The loser then goes away and changes their *strategy* in the next round of the game but the winner simply carries on what it was doing before


checking
Real money
distinguish
Generator
Generate
Fake money
distinguish
Discriminator

The GAN Game II

- The game takes place for several turns (or epochs) (or iterations...)
  - For us this can mean leaving the code running for several hours...
- We want our detective to get smarter, because that means the criminal has more of a challenge and is forced to *get better* at creating fake notes
- Ideally, what will happen is that the criminal's fake notes become so convicing that the detective can't tell the difference

Types of GANs

CycleGAN

The background is changed too.

StyleGAN - This Person Does Not Exist

Created using the StyleGAN developed by Nvidia.

StyleGAN - This Person Should Not Exist ??? 😱

BigGAN

So how does a program store an image?

Lists Recap

In the previous workshop we covered Lists in Python. Lists are an ordered data structure that allow us to hold a collection of items.

```
my_list = [1, 2, 3, 4, 5]
my_other_list = ["a", "b", "c"]
my_empty_list = []
```

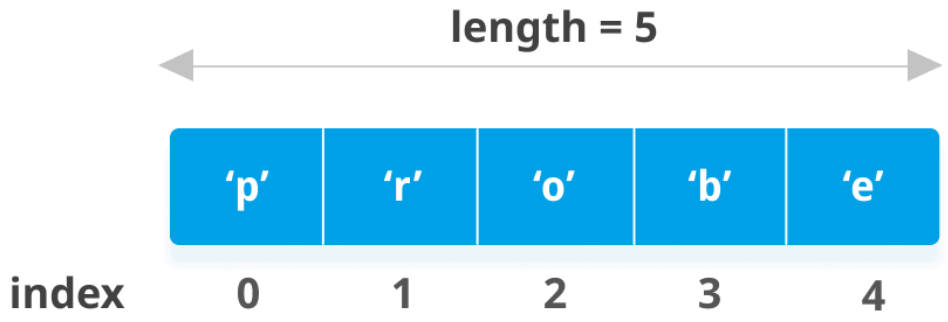
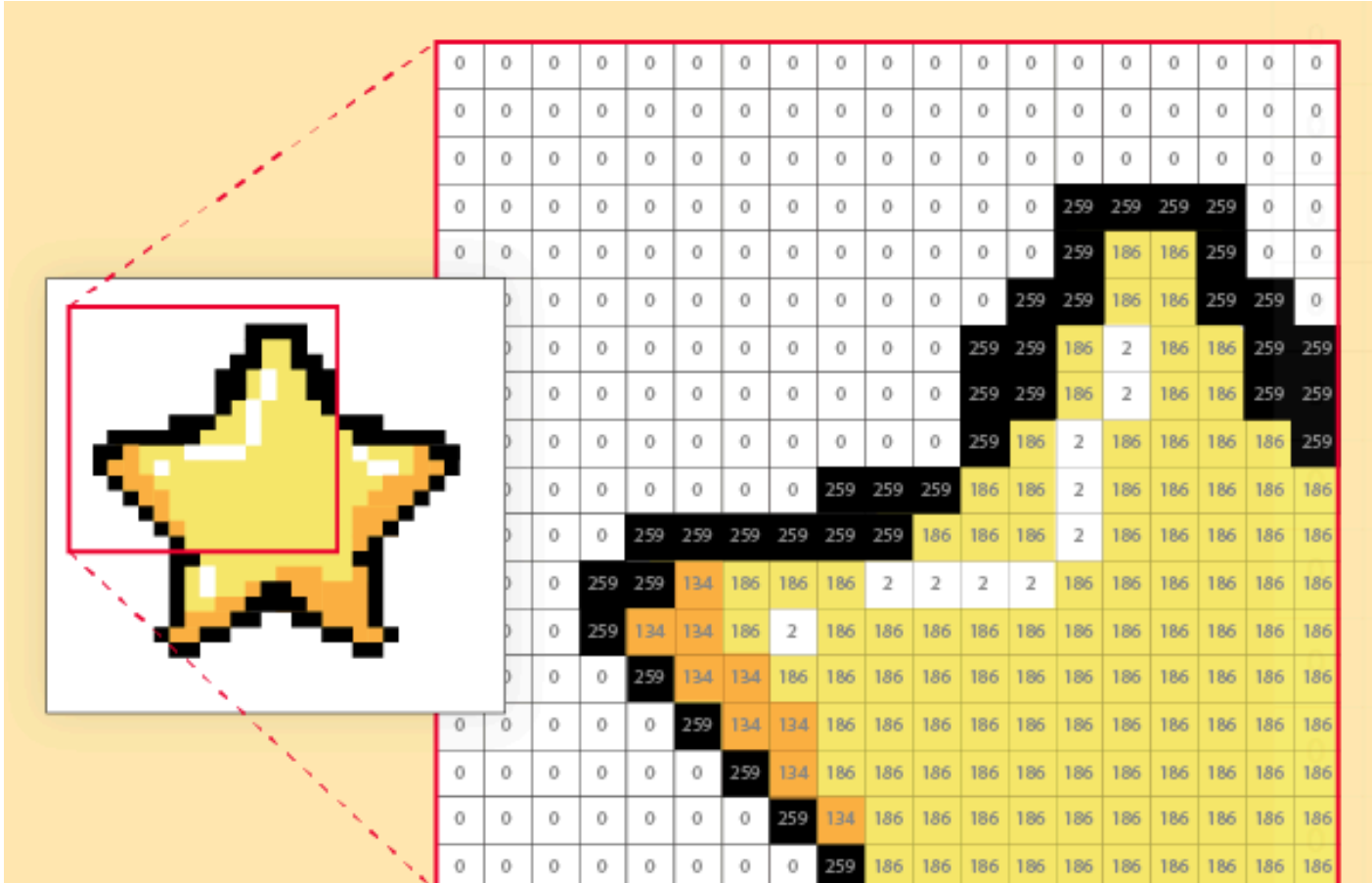


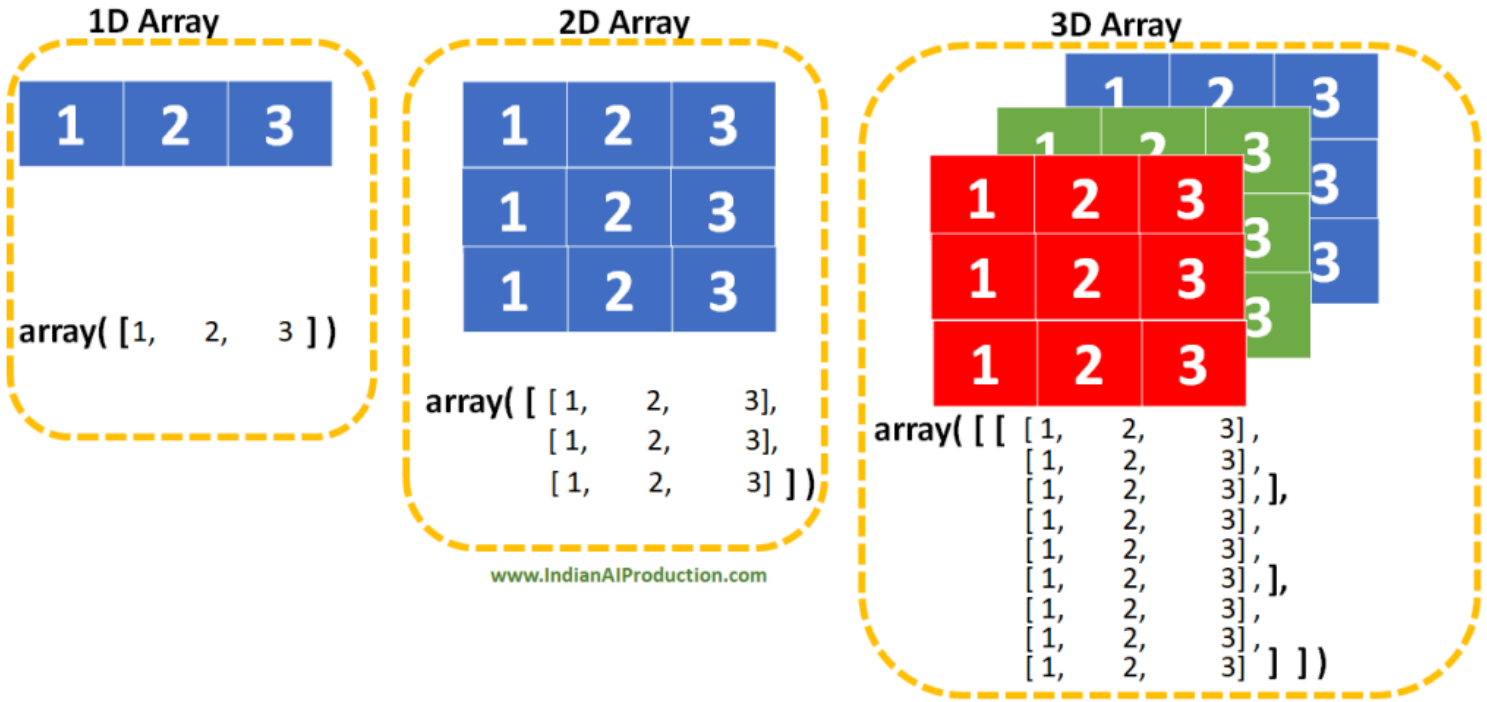
Image Data

So for images we ought to use something like a list for holding values for our pixels, but with something a bit more...



Arrays and Images

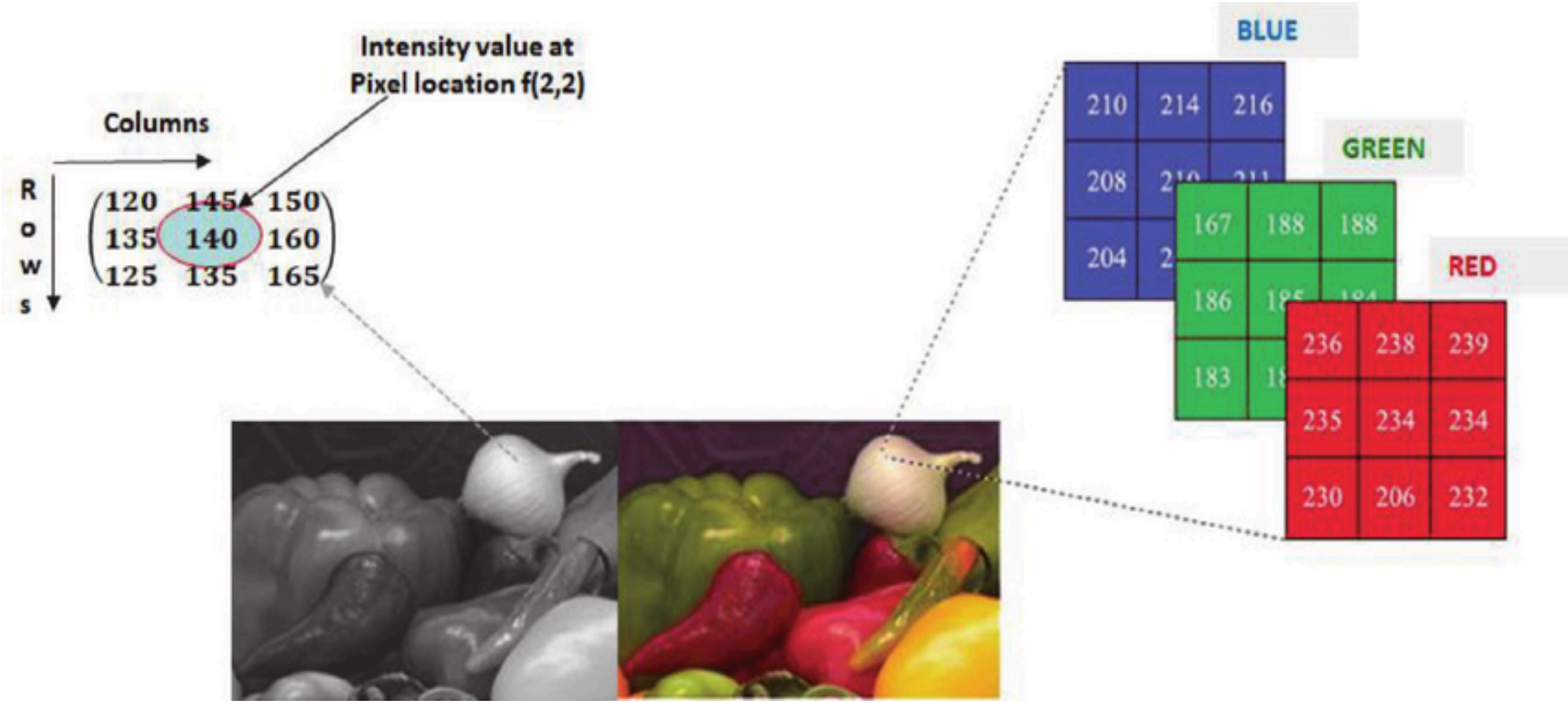
In the code we will store our images in the form of something called *arrays*. Like Lists, they are able to hold a collection of values and store them in a single variable. But because we are dealing with images we need a "grid" (or more accurately several grids) rather than a simple list.



Arrays and Images

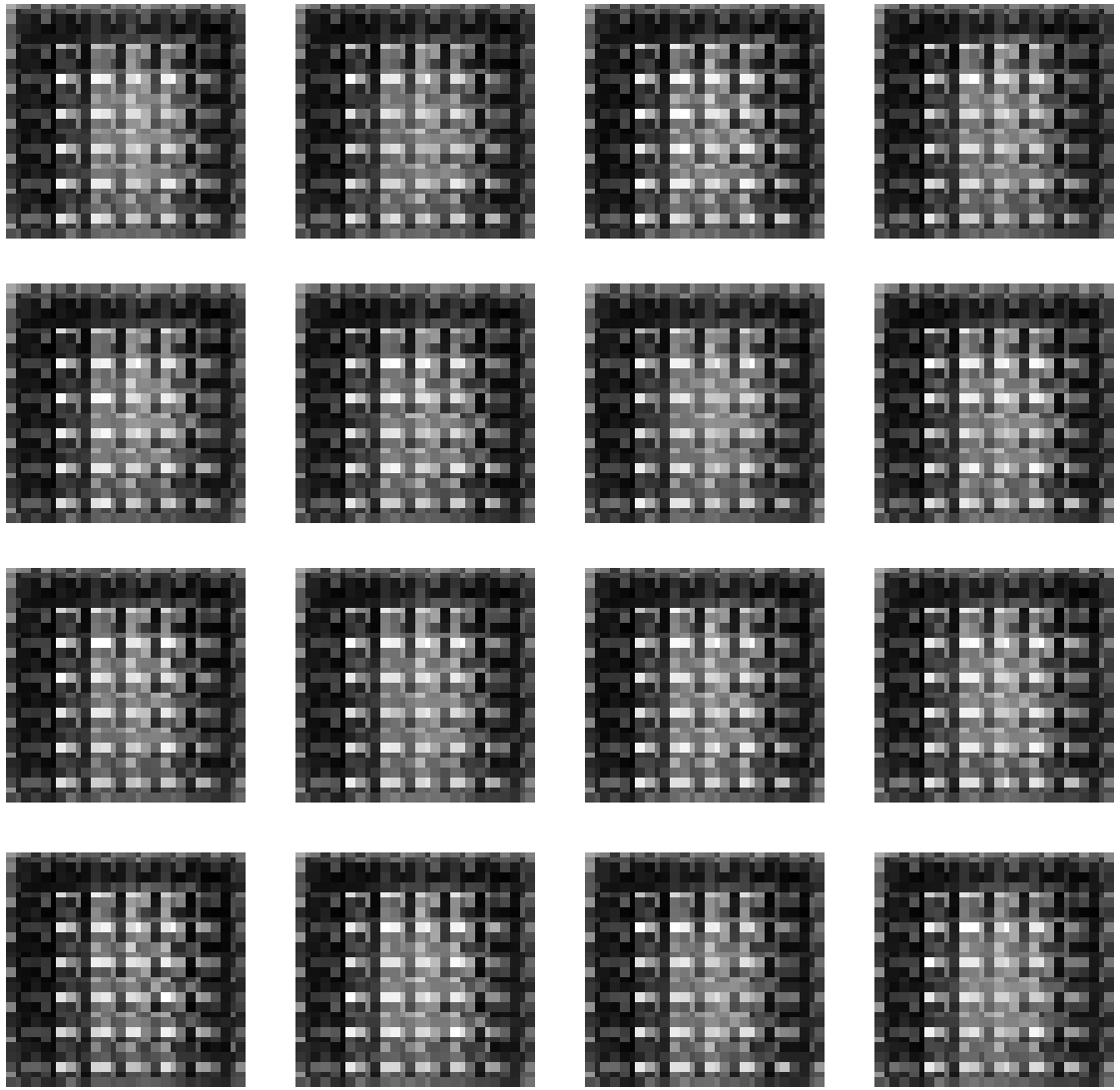
- Black and White images: 2D array for "brightness"
- Colour images: 3D array for RGB channels

The GAN has *less work to do* in the case of black and white images.


Intensity value at
Pixel location f(2,2)
Columns
Rows
120 145 150
135 140 160
125 135 165
BLUE
210 214 216
208
204
GREEN
167 188 188
186
183
RED
236 238 239
235 234 234
230 206 232

MNIST Dataset

- MNIST is a well-known dataset of handwritten numbers
- Very popular for testing image processing code

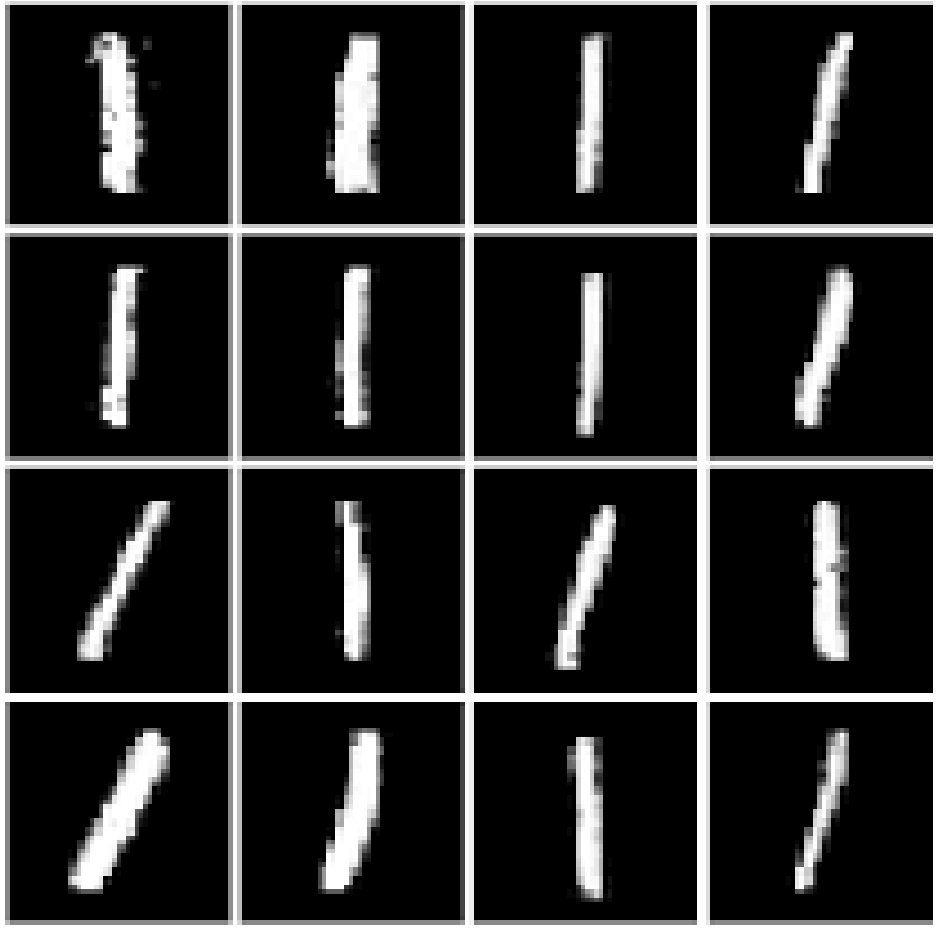


Basic Classification Example

https://www.3blue1brown.com/lessons/neural-networks

Issues with GANs

Mode Collapse



These are definitely ones...

Generated Images

Convergence Failure

Convergence failure is what happens when the generator and discriminator do not reach balance during training.

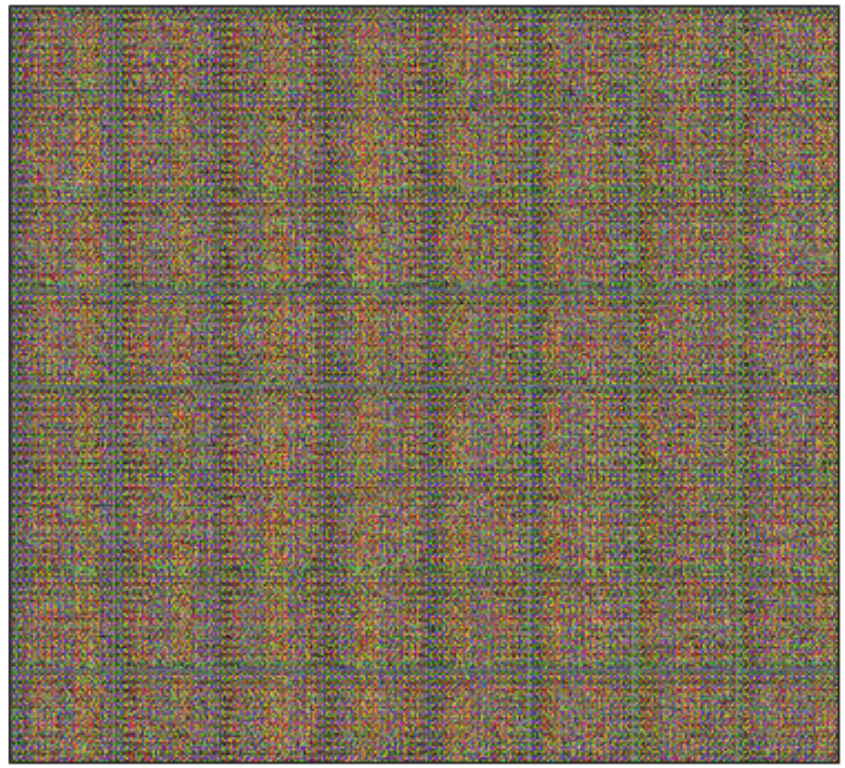
Discriminator Dominates

The detective becomes too smart too early in the game, so the criminal doesn't get a chance to properly learn what it should and shouldn't do to create convicing notes.

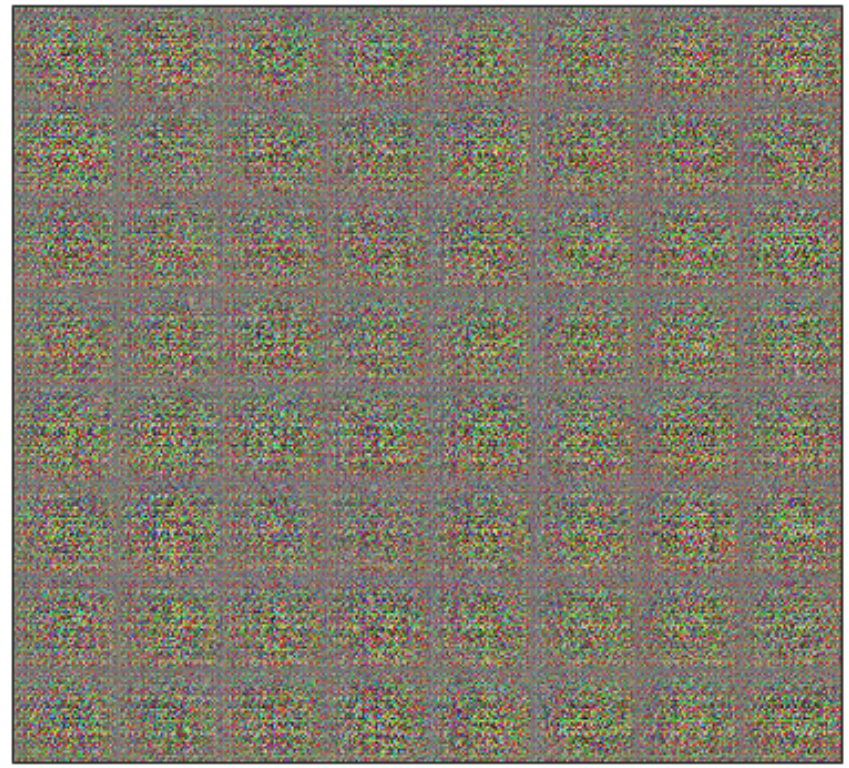
Generator Dominates

The criminal gets too smart too early in the game, so it's able to get away with making "meh" notes as these are still enough to fool the detective.

Generated Images



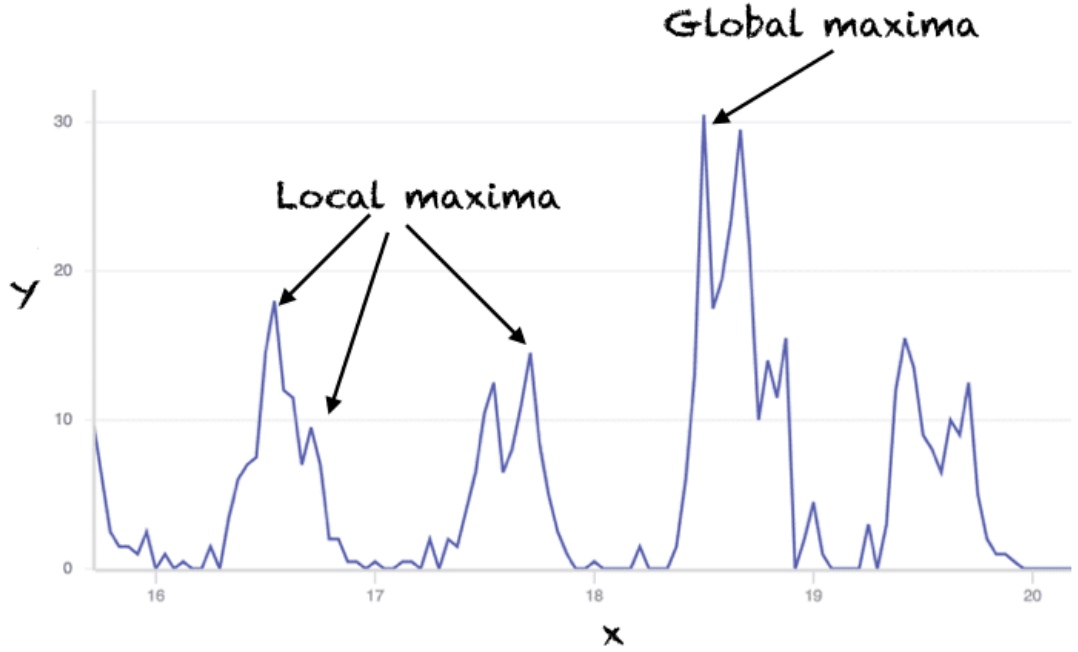
Generated Images



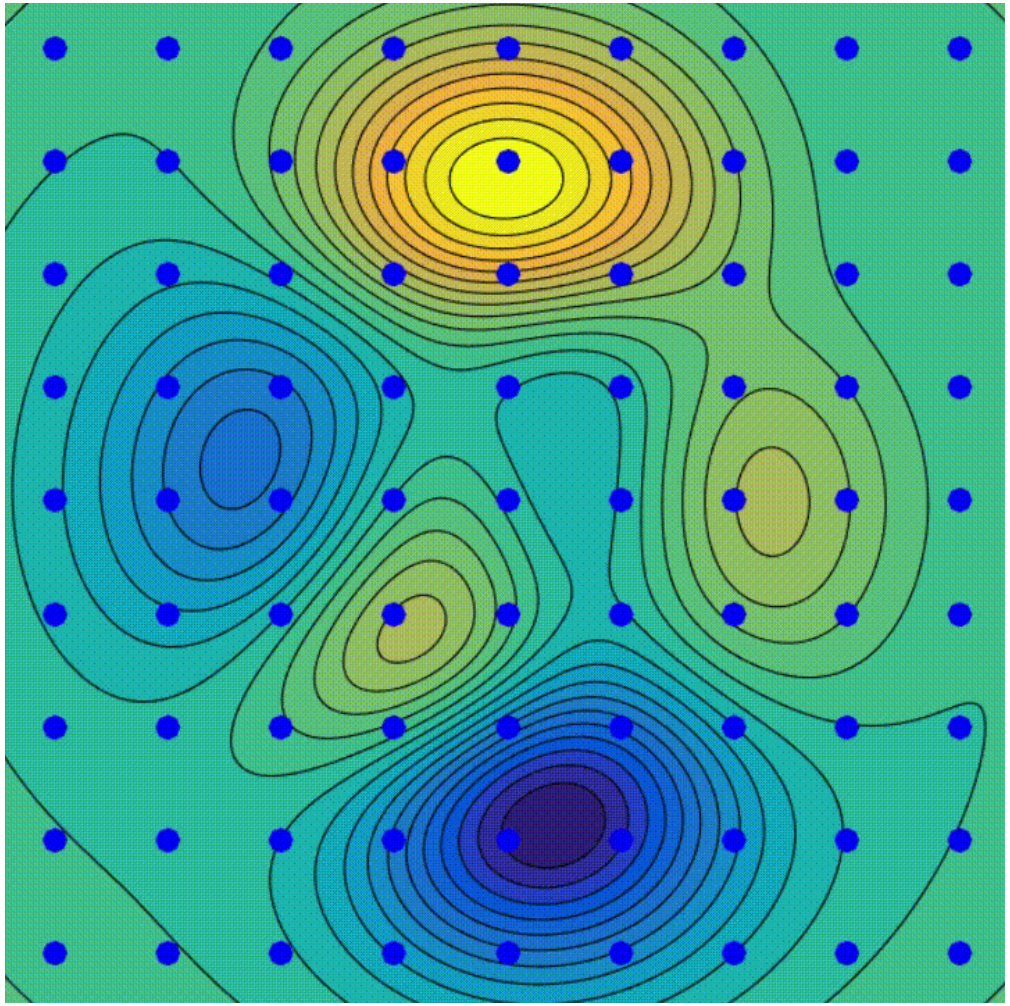
How do we know that our GAN is heading in a good direction?

Mathematical Optimisation (or Min-Max Problems)

GANs are based on the maths of optimisation. The objective of optimisation is to find the best solution to problem.



Gradient Descent



So what do we wish to "optimise" when running our GAN?

Loss Functions

Our loss functions give us an indication of how well the Generator and Discriminator are performing.

- x is a real image.
- $D(x)$ is the Discriminator's judgement on the real image.
- z is random noise.
- $G(z)$ is the Generator's attempt at creating a fake image.
- $D(G(z))$ is the Discriminator's judgement on the fake image.

The Discriminator wants $D(x)$ to be high as possible. For $D(G(z))$ the Discriminator wants this to be as low as possible while the Generator wants this to be as high as possible.

Loss Functions

Discriminator Loss

$$\frac{1}{m}\sum_{i=1}^{m}\log(D(x^i))+\log(1-D(G(z^i)))$$

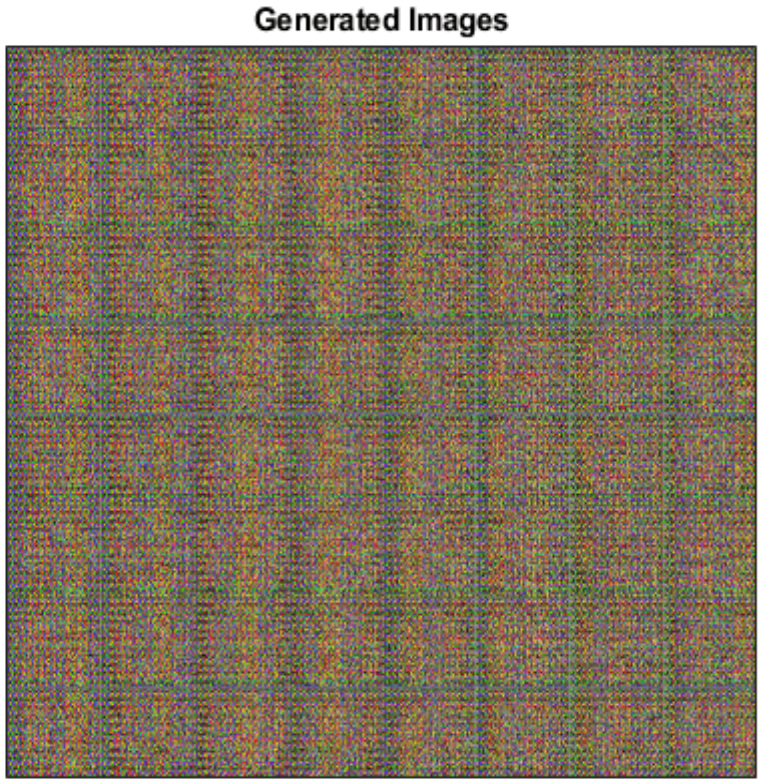
Generator Loss

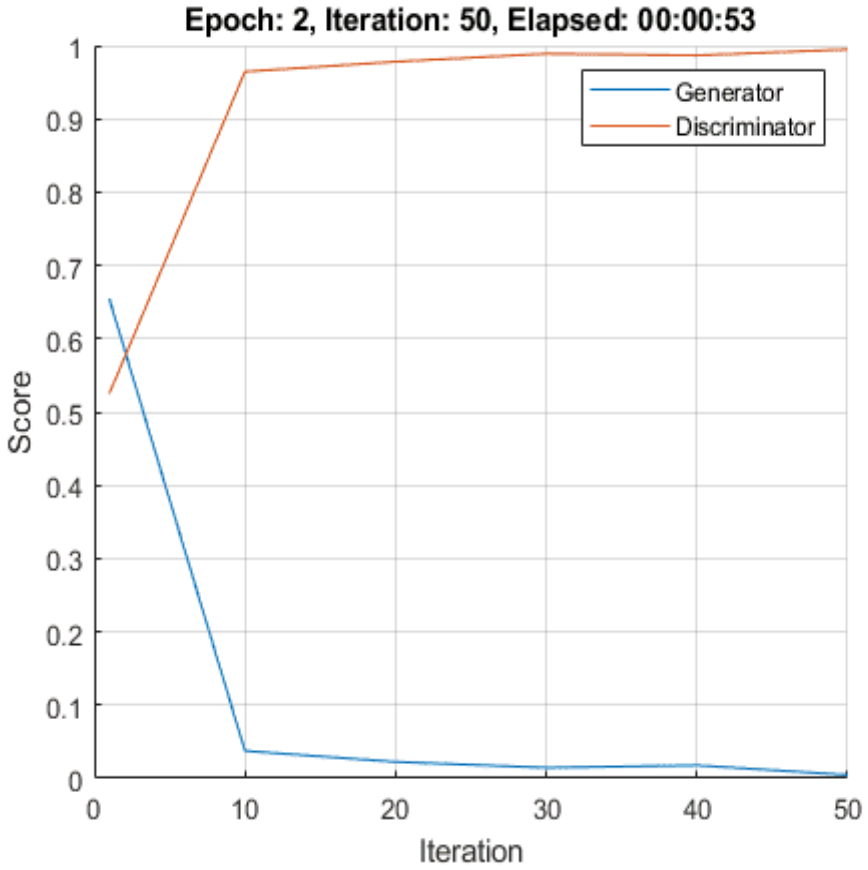
$$\frac{1}{m}\sum_{i=1}^{m}\log(1-D(G(z^i)))$$

The Discriminator wishes to **maximise** its loss function while the Generator wishes to **minimise** its loss function.

Convergence Failure

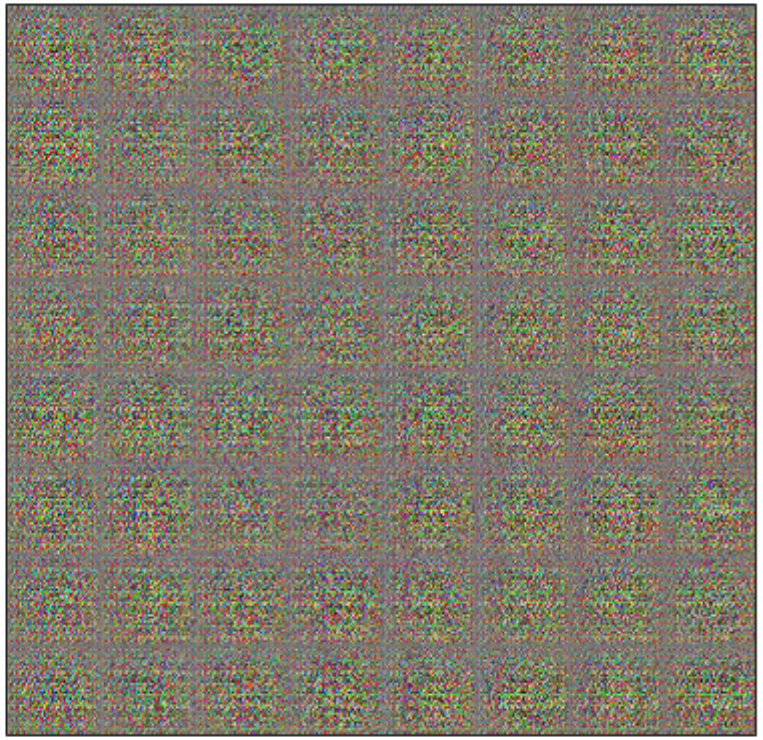
Discriminator Dominates

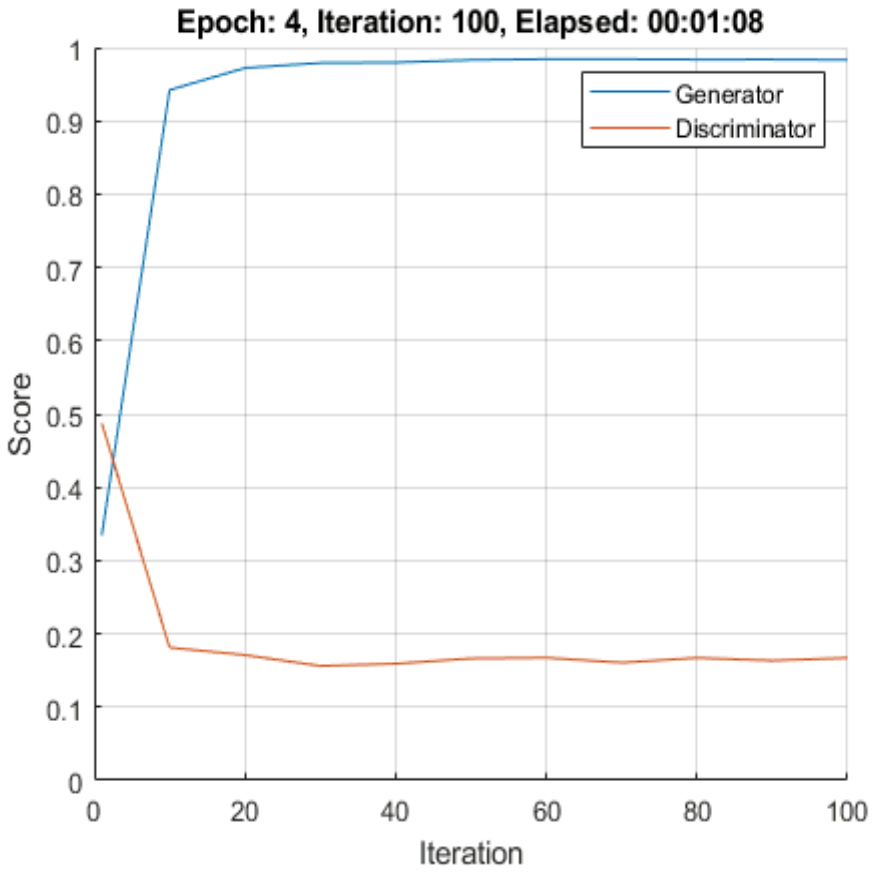




Convergence Failure

Generator Dominates





Now let's head over to the notebook...

Creative AI Stuff

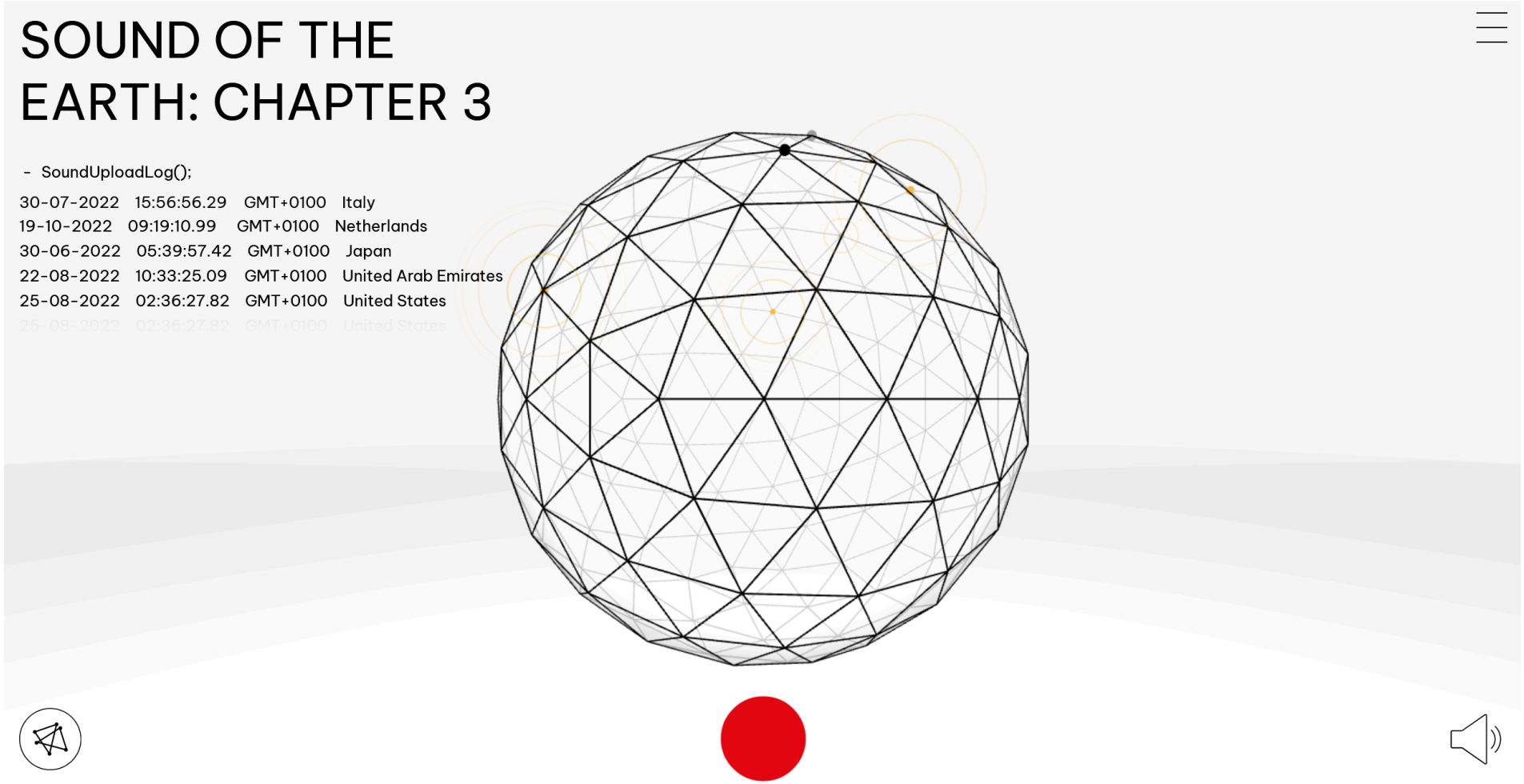
Artist + Machine Intelligence

https://ami.withgoogle.com/

K Allado-McDowell

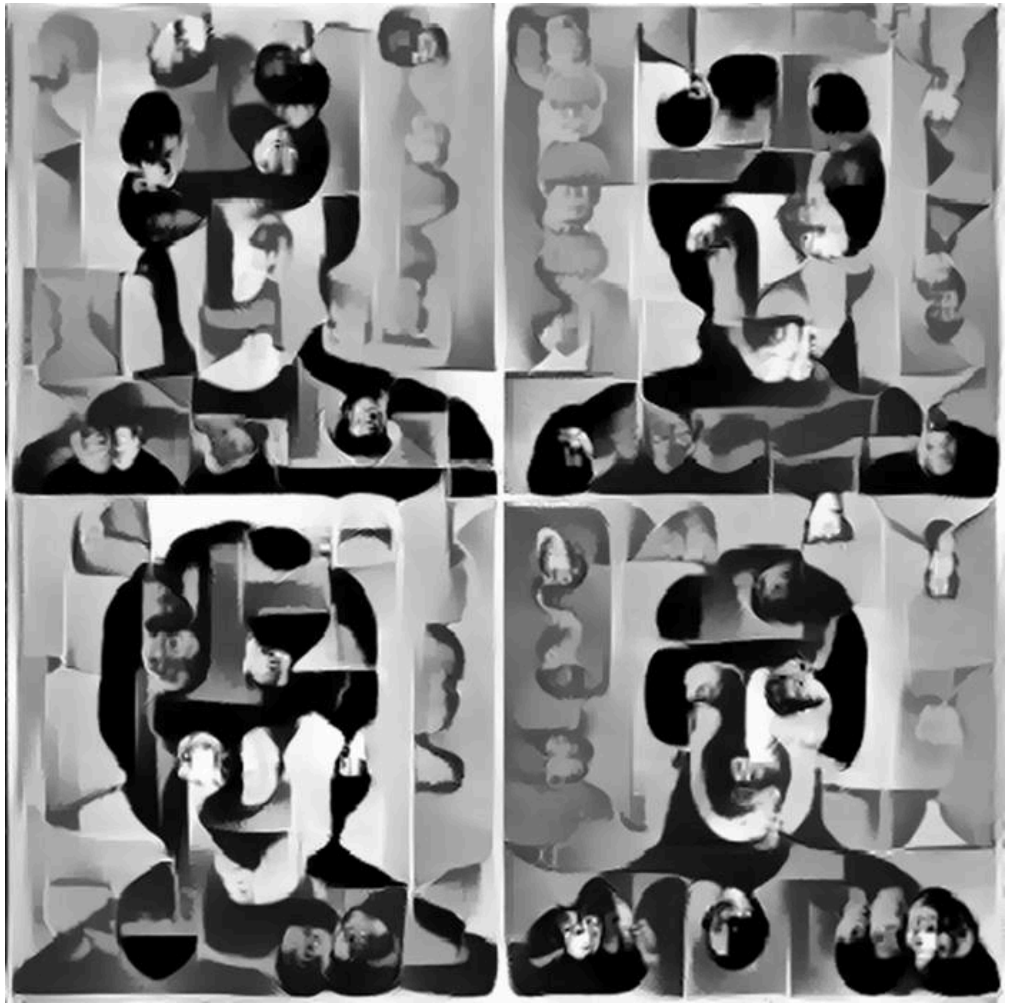
Google DeepDream

Sound of the Earth



https://soundoftheearth.org/

Dadabots



https://dadabots.bandcamp.com/album/deep-the-beatles

Ganrio

https://amyelizabethsmith01.medium.com/gans-sanrio-ganrio-21e263666929

Running the Code Locally

- Download Miniforge: https://github.com/conda-forge/miniforge
- Clone my repo: https://github.com/DolicaAkelloEgwel/gans-workshop
- Make sure you've installed the Python extension in VSCode
- Use `where` (Windows) in the Miniforge prompt
- Use this path in VSCode as your Conda path
- In Miniforge prompt, create an environment with the `environment.yml` file
- In VSCode, refresh available interpresters, then use the `gans-environment` as your Python Interpreter

MAKE YOUR FIRST GAN WITH PYTORCH

A gentle introduction to Generative Adversarial Networks, and a practical step-by-step tutorial on making your own with PyTorch.

Tariq Rashid

Deep learning with Generative Adversarial Networks

GANs IN ACTION

Jakub Langr
Vladimir Bok

MANNING

“You can think of generative models as giving artificial intelligence a form of **imagination**.” - Ian Goodfellow