DATA40230 Digital Humanities: Practice and Theory Summative Project – April 2021
Computer Vision Project - This Van Gogh Does not Exist.

1. Introduction

1.1 Overview

This project presents an exploration of Generative Adversarial Neural Networks (GANs) as a tool for art synthesis. It firstly provides an overview of the technological background to GANs and a short introduction to their mechanics and uses, and an introduction to the artist Vincent Van Gogh and his place in computer vision projects. In section 3 the report covers the creation of a dataset of Van Gogh's work via web scraping the pre-processing required for introduction to the model. Section 4 then covers the implementation of a GAN itself, while section 5 provides examples of output from the finished model. Section 6 provides space for discussion and conclusion about the results. An annex of additional results are provided in section 7, while bibliography of relevant literature and reference code is included in section 8.

1.2 Project Objectives

1. Gain a preliminary understanding of the key concepts, architecture and uses of GANs.
2. Find or create an appropriate dataset.
3. Successfully execute a simplistic GAN model.
4. Generate an example of a fake piece of artwork in the style of Vincent Van Gogh.

2. Background

2.4. GANs

Generative Adversarial Neural Networks (GAN) were first devised by Ian Goodfellow at Montreal University in 2014. GANS have their roots in game theory, as at a simplistic level a GAN is a system of two neural networks pitting against each other in a cat and mouse style game. The generator model produces fake images, and the Discriminator model judges whether the images it is presented with are fake. This decision is based on the previous images it has been given during training. Eventually the generator model will make such an accurate image that it will fool the discriminator model. At this point the model is trained and can be used to generate highly realistic looking output images.

In 2019 Uber engineer Phillip Wang published "*Thispersondoesnotexist.com*", a website that uses a GAN to generate high resolution images of the human face. With each refresh the webpage offers up another image of a face generated entirely through an AI model. The advent of this website has spawned a variety of successors across a range of different themes, from horses to night skies and even a tongue in cheek website that generates a fake British MP at the touch of a button[1]. These is the inspiration behind the current project.

[1] This example is hosted here: *https://vole.wtf/this-mp-does-not-exist/*.

While much has been done with the concept of face generation, there have been fewer projects dealing with art generation. Those projects that do generate art with GANs usually focus on abstract modern art[2]. Although due to similar aesthetics it can be argued, GANs produce their own form of modern art in the early training stages and could very easily become a its own genre. It would be interesting to see more GAN generated art in traditional art spaces.

The training process on these models can be difficult to implement correctly. Additionally, even with the aid of a high-end GPU, training a model from scratch on high resolution images can take an exorbitantly long time. To combat this a lot of GAN models, use transfer learning. Transfer learning is where a pretrained model with its own trained weights are used to train models for similar problems, the idea being the new model will take less time to train. Thispersondoesnotexist.com uses StyleGAN; a type of GAN created by Nvidia Researchers in 2018 that is specifically trained to produce high resolution faces.

2.2 Vincent Van Gogh and Art History

Vincent Van Gogh is an artist celebrated worldwide for his transformative impressionist paintings. During a career that spanned only around 10 years, he produced around 2000 works of art, 800 of which were oil paintings, with the vast majority being sketches and studies sometimes on the letters he sent to his brother. Van Gogh's style is distinctive and ubiquitous as the artist himself with his later work developing into a style known for vibrant colours and powerful expressive brush marks. Van Gogh's tumultuous life, famous struggle with mental health issues and posthumous fame informs the trope of the "tortured genius artist" that informs the behaviour and perceptions of artists to this day. The idea of an artist suffering for their art, if not originated, then was strengthened by Vincent's story. His famous work and unique style are an ideal example to feed into a GAN, as they are so distinctive and well known.

2.3 Van Gogh and Computer Vision

As one of the most popular artists in western canon, his work has naturally been utilized before in computer vision products, most of these projects are neural style transfer projects such as in *A Neural Algorithm of Artistic Style* by Bethge, Ecker and Gatys (2016), where Van Gogh's style is transferred onto different input images. There have not been any publicly available examples of training a generative GAN on Van Gogh's work.

What will make a GAN trained on Van Gogh's work very interesting will be the marked contrast between his early work, where his style is more muted and earthy, compared to his later work, with his vibrant colour choices and dramatic brush strokes. This evolution is displayed in *Fig 1* with an example from a landscape at the start of his career, *Cottages* (1883), and one of the last paintings he ever produced *Wheatfield with Crows* (1890). Interpreting this dramatic shift in style presents an interesting challenge for a trained GAN. It will be interesting to see whether it ends up producing a variety of generated images in each style, or whether it will produce images that area hybrid of both styles.

[2] Hosted at: https://thisartworkdoesnotexist.com/ . For more examples of GAN based internet projects https://thisxdoesnotexist.com/ hosts a collection of links to several different examples.

Fig 1. Above: Cottages (1883) Below: *Wheatfield with Crows (1890)*

3.0. Dataset Creation and Pre-Processing

3.1. Initial Dataset

As Van Gogh is a popular artist and all his work is firmly in the public domain, it was highly likely that another data scientist had already curated and published a complete dataset. After searching dataset sharing websites however this did not appear to be the case, so a custom dataset would need to be created. In the interim, there was a 5000 strong image dataset called “Impressionist Classifier Data” (Banerjee, 2020) featuring works from Van Gogh but also included examples from 9 other notable impressionist artists. The dataset was kept as a backup in case the curation of the Van Gogh dataset took too long to implement. Luckily, this was not necessary.

3.2. Custom Van Gogh Dataset

The Van Gogh dataset was scraped from the internet. There were a few options from where the images could be scraped, notably the Van Gogh Museum website. However, that website does not allow web scraping. Instead Wikiart, the visual art specialized version of Wikipedia was selected for its simple HTML structure, which in turn ensured that the resulting code created to scrape it would also only need to be simple in scope. The dataset was scraped from the wikiart website using the python packages Beautiful

soup and urllib. Detailed comments on how the code for this task operates is included in the corresponding attached .ipynb file.

As previously mentioned, Van Gogh produced sketches and doodles in his letters. These were included in the dataset as It will be interesting to see how the model dealt with such vastly differing examples in artwork, from oil paintings to a small sketch on the side of a letter. Similarly, if this GAN aims to attempt to recreated and generate a completely new Van Gogh, the more examples of Van Gogh's work in the training dataset will only benefit the generative power of the finished model. A doodle is no less a piece of Van Gogh's work than Starry Night. After completion, the dataset consisted of 1919 images.

3.3. Dataset Pre-Processing

Datasets that are fed into GANs need to satisfy two criteria: they must have a square resolution and each image must have the same number of channels. The dataset cannot have a mix of RGB colour files, black and white files or png file with a transparent layer. For this project all the images will have 3 image channels as all will be full colour jpegs.

The square criteria was trickier to execute as the majority of Van Gogh's work, and indeed most images of art, are not square. This means that images Instead used a custom method devised by Gonsalves (2021) which resized and adjusted the aspect ratio of the image based on the median aspect ratio of the entire dataset. This preserves more information from the original painting or sketch than any other method. For example, using a black box around the original image, or resizing an image to only use the middle square of a painting. The former wastes a lot of the algorithm training on a black box while the latter cuts up and discards a lot of crucial features from a painting. As the aspect ratios have been adjusted before training, the generated output will also have to have its aspect ratio adjusted after generation to get rid of the distortion given to it from the training dataset. All 1919 images were resized into 1024x1024 resolution. The code for scraping and ratio readjusting both before and after the GAN were sourced and then modified from Gonsalves (2021) and are available in the attached documents.

4.0 The Model

4.1. Transfer Learning and Google Collab.

As this project has a relatively short timeframe, transfer learning was used to speed up model training. The model that was eventually used was StyleGAN 2 ADA, an updated and streamlined version of StyleGAN which is designed to be good at compensating for small size datasets, which in theory will reduce training time. Originally this project did aim explore different types of transfer learning for GANS, such as comparing the outcome of the original StyleGAN to its updated counterpart as there are many models and downloadable weights available to download and use. There was also the possibility to investigate other GAN types altogether like CycleGAN or DCGAN. However, this idea was scrapped for time.

All code, including dataset creation and pre-processing, was executed using Google Collaboratory Pro. Google Collab was chosen as it gave priority access to a high-end GPU (Usually a Nvidia Tesla P100) and 24GB of RAM while also promising mostly uninterrupted runtimes for up to 24 hours (notwithstanding periods of high user demand). All these aspects are extremely necessary for executing GANs on high resolution images.

4.1. Initial Attempts and Setbacks

The biggest setback in this project was dataset curation, as finding, modifying and executing code to resize and adjust all the images in the correct way for a GAN took some considerable time, and ended up delaying progress on creating the GAN itself. However, creating and resizing a dataset was eventually successful, however there was no time to create a custom code to convert the images back after generation, so all images in the results section still suffer from the wrong aspect ratio.

Before sourcing the code for the successful GAN, there were a variety of attempts that were not successful. The first code to try was an older model that used the original StyleGAN (Srinivasan, 2020). While this code did run, it did not run long enough to train a full model. Troubleshooting this code became too time consuming, especially for a model that did not use the most up to date version of StyleGan, so work on this code was dismissed. Shrestha (2019) provided a similarly workable code using Keras which had an interesting solution to the image resizing problem. It converted images to binary files and saved it as a NumPy array. Despite solving the dataset problem and being an easy code to read and modify, it seemed to be incompatible with running in Google Collab, which is where it needed to be executed to access a GPU. This code too was abandoned.

4.2. The successfully executed GAN.

The final model was created using the custom dataset GAN training tutorial from Schultz (2020) which uses StyleGan 2 ADA from the official Nvidia research division via GitHub and was built using the TensorFlow python package.

In practice Google Collab ran the final GAN uninterrupted for on average for of around 7 hours at a time, before disconnecting due to busy servers or sometimes Wi-Fi connection issues. This however was not a catastrophic problem as the model was set to generate both a pickle file and a jpeg of an example of the generated fake paintings twice an hour. This helped to give a visual indicator of what the current model generating capabilities were and to save a copy of the model periodically. This variable could be set to as high as 8 or 16 snapshots an hour, but in the interest of storage space, it was set to 2. The code was set up to make it possible to introduce the latest pickle file to restart training at any given point, so disconnection was for the most part not a large set back.

There was very little custom editing done to the code downloaded from Schultz (2021) apart from an editing of two lines to reduce snapshot production.

5.0. The Results

The GAN was trained for total of 56 hours but this was not long enough for the model to be trained completely so visually the outputs are recognisable to a human viewer as not being authentic Van Gogh's. In this section there are included a selection of successful examples of content generated by the GAN. In the annex there are links to videos displaying different explorations through space including linear interpolation through w and z space and noise loop interpolation.

Fig.1 shows a selection of fakes generated after 1 hour of training. Notice that you can still see the remains of human faces from the weights from StyleGAN 2.

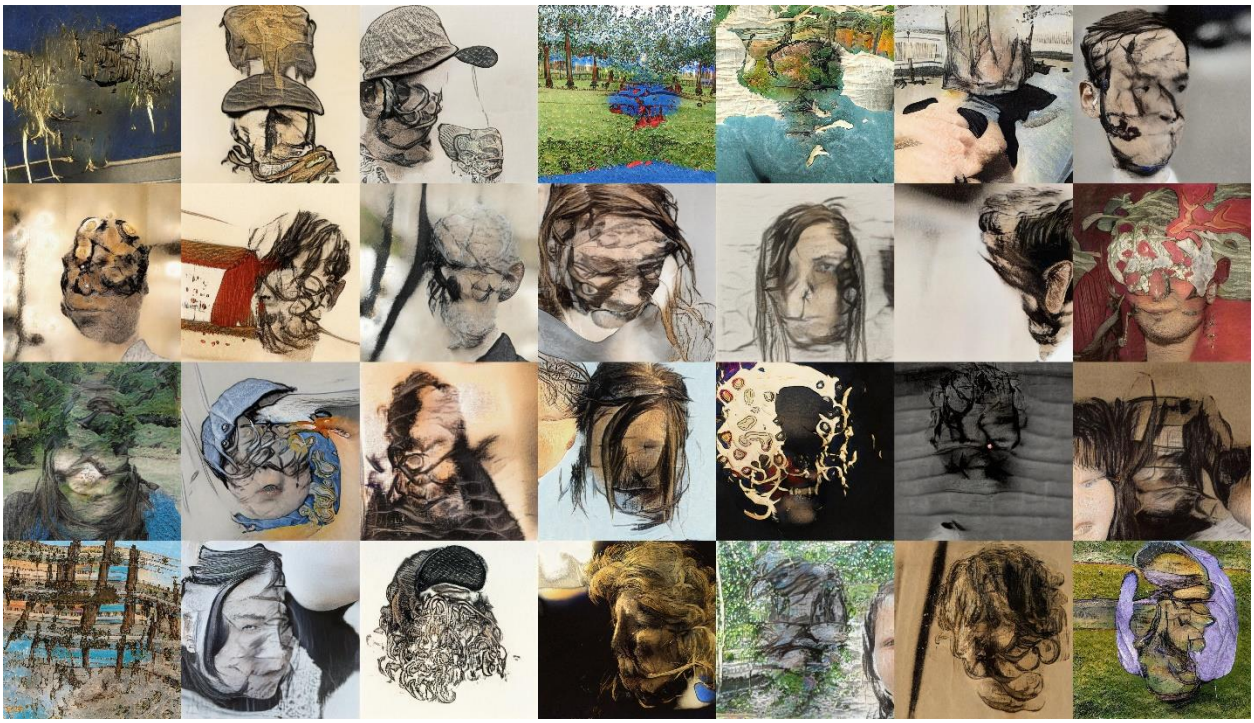

Fig 2. Fakes after 1 hour of training.

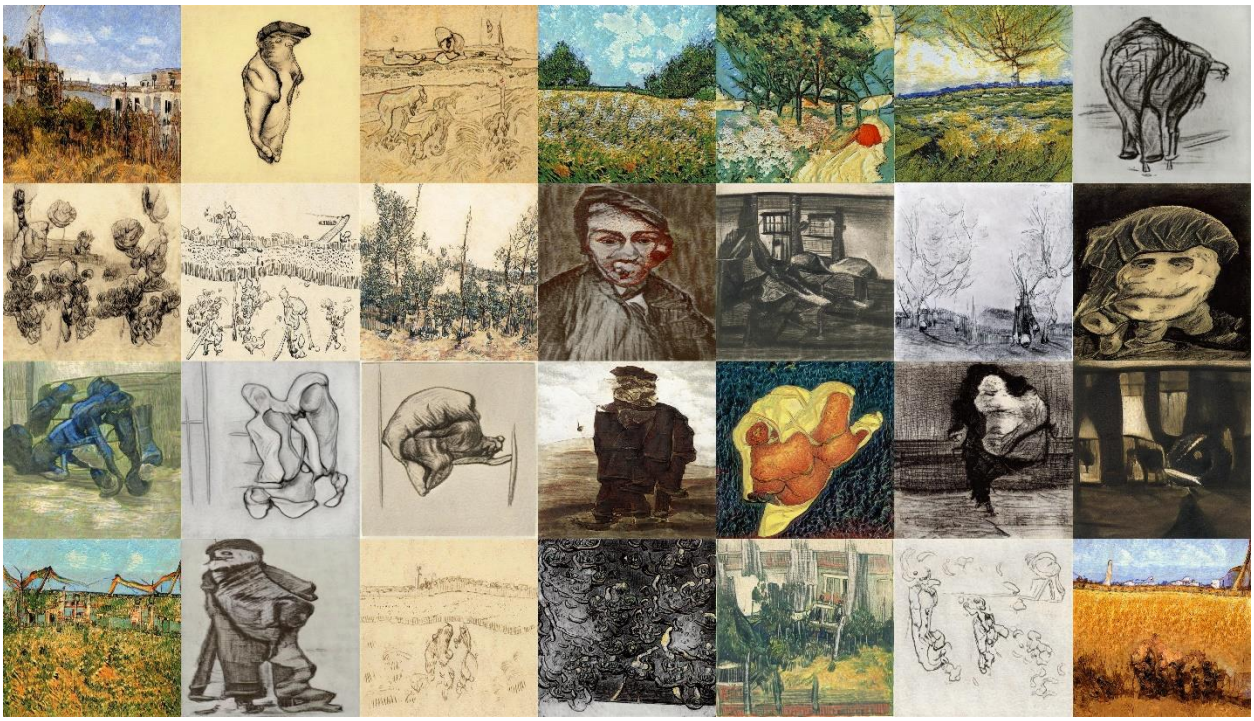

Fig 3. Fakes after 56 hours of training.

Fig3. Shows the results 54 hours later. There are no facial features where they should not be, and there is an interesting mix of landscapes, sketches and other modern art style blobs, with some colour and subject choices that are emblematic of Van Gogh's work.

Fig .4 An image of flowers generated from the GAN after 56 hours.

Fig 5. An intriguing landscape

Fig.6 An image that invokes an olive grove.

Fig.7 A generated image that emulates a sketch from a letter. Notice the line at the top that looks like handwriting.

Fig.8. An attempt at a portrait.

6.0. Discussion and Conclusion

6.1. Discussion

When generating random output, results skewed toward images resembling sketches and monochrome work. This is unsurprising as sketches made up most of the original dataset. Intriguingly, the most common colour other than browns to appear in generated images was a distinct vibrant yellow; a colour Van Gogh used prolifically to the point where modern researchers still debate whether he had a condition that caused his vision to be tinged yellow. It is interesting that this a long with a pale sky blue are the most used colours in output images.

The model also seems to have gone the hypothesised route of creating a fusion between the early Van Gogh's muddy style and his later colourful style. This is notable in fig.4, where the subject matter (flowers) often a mark of his later career, is "painted" with the muddy colour palette of his early career. As the model was not fully trained it only produced partially executed examples of portraits, but it would be interesting to see what type of people the GAN eventually produces when fed all Van Gogh's portraits.

6.2. Potential Avenues for Extending the Project

There are a variety of ways this project could be approved or extended, most prominently ideally the model would be set to train for a longer amount of time and be fully trained to produce more convincing examples of paintings. The entire vanilla GAN could be run again but with a smaller resolution size of 512x512 or even 526x526, to cut down on training time and storage space. Another aspect to introduce could be using text generation in tandem with the GAN to generate an appropriate name for the newly generated image.

Beyond this, the project is simplistic in scope and has not covered model parameters or metrics in depth as the goal was simply to execute a standard GAN. Tweaking any of the parameters could change the entire outcome of a GAN. Implementing metrics on each epoch would also give a better idea of the accuracy of the model and help training. As mentioned before there are more different types of GANs that this dataset could be applied to, DCGAN, CycleGAN etc, and will probably give different results. An interesting avenue to explore would be the prospect of text to image generation, wherein a GAN generates an image based on user text input. A user would be able to type in a phrase like "orchard in springtime" and the model could then produce a bespoke piece of art a long these lines. Gonsalves (2021) lays down framework for making this possible with an open-source natural language supervision model system called CLIP, which provides a link between visual concepts and language.

6.3 Conclusions and Final Thoughts

The highlighting of trends in Van Gogh's paintings has very interesting connotations for training GANs on other artist corpuses. They could be used as a tool to identify the most prolific aspects of an artist's work, which could create a system of topic modelling or document clustering for visual media. Taking the key themes of one artist in relation to another.

7.0 Annex

Below are links to some supplementary video-based output from the finished GAN model:

- A video of interpolation through w space: **https://drive.google.com/file/d/1UKYGPU0_q74S05bfiWF3oF9meIkLy13a/view?usp=sharing**
- A video of interpolation through z space: **https://drive.google.com/file/d/1UKYGPU0_q74S05bfiWF3oF9meIkLy13a/view?usp=sharing**
- A video of noise loop interpolation **https://drive.google.com/file/d/1ijJShCCQgLgBwyC0G0RZWZ6I7MfHISS6/view?usp=sharing**

8.0. Bibliography

References for Dataset Creation and Featured Images:

- Banerjee, P., 2020. *Impressionist_Classifier_Data*. [online] Kaggle.com. Available at: <https://www.kaggle.com/delayedkarma/impressionist-classifier-data> [Accessed 3 April 2021].
- Gonsalves, R., 2021. *GANscapes: Using AI to Create New Impressionist Paintings*. [online] Medium. Available at: <https://towardsdatascience.com/ganscapes-using-ai-to-create-new-impressionist-paintings-d6af1cf94c56> [Accessed 19 April 2021].
- Van Gogh Museum. 2021. *Collection*. [online] Available at: <https://www.vangoghmuseum.nl/en/collection> [Accessed 1 May 2021].
- www.wikiart.org. 2021. *Vincent van Gogh - 1931 artworks - painting*. [online] Available at: <https://www.wikiart.org/en/vincent-van-gogh/> [Accessed 23 April 2021].

References for GAN code:

- Fernández Jauregui, A., 2020. *How to code a GAN in Python with Google Colab - Ander Fernández*. [online] anderfernandez.com. Available at: <https://anderfernandez.com/en/blog/how-to-code-gan-in-python/> [Accessed 14 April 2021].
- GitHub. 2019. *NVlabs/stylegan*. [online] Available at: <https://github.com/NVlabs/stylegan> [Accessed 8 April 2021].
- GitHub. 2021. *NVlabs/stylegan2-ada*. [online] Available at: <https://github.com/NVlabs/stylegan2-ada> [Accessed 27 April 2021].
- Patil, R., 2018. *Training GANs using Google Colaboratory !*. [online] Medium. Available at: <https://towardsdatascience.com/training-gans-using-google-colaboratory-f91d4e6f61fe> [Accessed 11 April 2021].
- Schultz, D., 2020. *Custom Training StyleGan2-ADA*. [online] GitHub. Available at: <https://github.com/dvschultz/ml-art-colabs/blob/master/Stylegan2_ada_Custom_Training.ipynb> [Accessed 11 April 2021].
- Shrestha, A., 2019. *Generating Modern Art using Generative Adversarial Network(GAN) on Spell*. [online] Medium. Available at: <https://towardsdatascience.com/generating-modern-arts-using-generative-adversarial-network-gan-on-spell-39f67f83c7b4> [Accessed 9 April 2021].
- Srinivasan, P., 2020. *Training StyleGAN using Transfer learning in Google Colab!*. [online] Analytics Vidhya. Available at: <https://www.analyticsvidhya.com/blog/2020/12/training-stylegan-using-transfer-learning-on-a-custom-dataset-in-google-colaboratory/> [Accessed 6 April 2021].

References for background literature:

- Flaherty, D., 2021. *Artistic Approaches to Machine Learning*. Postgraduate. Queensland University of Technology
- Gatys, L., Ecker, A. and Bethge, M., 2016. A Neural Algorithm of Artistic Style. *Journal of Vision*, 16(12), p.326.
- Goodfellow, I., Pouget-Abadie, J., Mirza, M., Xu, B., Warde-Farley, D., Ozair, S., Courville, A. and Bengio, Y., 2014. *Generative Adversarial Nets*. Departement d'informatique et de recherche operationnelle Universit e de Montreal.

- Hora, K., 2021. *This X Does Not Exist*. [online] Thisxdoesnotexist.com. Available at: <https://thisxdoesnotexist.com/> [Accessed 1 May 2021].