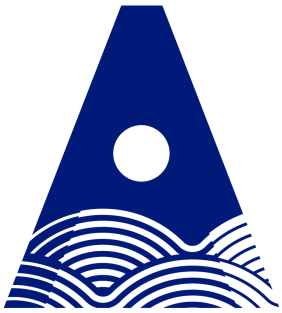

Ollscoil
Teicneolaíochta
an Atlantaigh

Atlantic
Technological
University

COVID - 19 Automated Detection using Convolutional Neural Networks and Generative Adversarial Networks

A thesis submitted
by

Ultan Kearns

in partial fulfillment of the requirements for the degree of
Master of Science in Computing in Big Data Analytics and Artificial Intelligence

Supervisor: Dr Paul Greaney

Submitted to Quality and Qualifications Ireland (QQI)

Dearbhú Cáilíochta agus Cáilíochtaí Éireann
October 2022

Contents

Declaration

I hereby certify that this material, which l now submit for assessment on the programme of study leading to the award of Master of Science in Computing in . . . , is entirely my own work and has not been taken from the work of others except and to the extent that such work has been cited and acknowledged within the text of my own work. No portion of the work contained in this thesis has been submitted in support of an application for another degree or qualification to this or any other institution. I understand that it is my responsibility to ensure that I have adhered to LYIT's rules and regulations.

I hereby certify that the material on which I have relied on for the purpose of my assessment is not deemed as personal data under the GDPR Regulations. Personal data is any data from living people that can be identified. Any personal data used for the purpose of my assessment has been psuedonymised and the data set and identifiers are not held by LYIT. Alternatively, personal data has been anonymised in line with the Data Protection Commissioners Guidelines on Anonymisation.

I give consent for my work to be held for the purposes of education assistance to future Computing students at LYIT and it will not be shared outside the Department of Computing at LYIT. I understand that my assessment may be shared with any other third party and will be held securely in LYIT in line with the Institute's Records Retention Policy.

Signed: Ultan Kearns

Date: Thursday 6th October, 2022

Acknowledgements

I would first of all like to thank my supervisor during this project Dr. Paul Greaney, he was a fantastic help throughout the course of writing this thesis and this work could not have been completed without his input and help.

I would also like to thank the lecturers who taught me so much during my postgraduate course, both Doctors Karla Munoz Esqueival and Shagufta Henna provided a fantastic introduction into many areas of Artificial Intelligence and the knowledge they imparted has helped me a lot throughout the course of conducting this research.

I would also like to thank Andrew Ng, his deep learning courses provided a great foundation into the realm of deep learning and Artificial Intelligence.

Acronyms

- AI - Artificial Intelligence
- ANN - Artificial Neural Network
- CNN - Convolutional Neural Network
- GAN - Generative Adversarial Network

List of Figures

Abstract

This paper aims to analyze the applications of generative adversarial networks in overcoming issues of data-shortages in relation to COVID-19. There are many COVID-19 data-sets compiled but some suffer from lack of data-quality and very few data-sets are reliable. In this paper I aim to create and train a convolutional neural network or CNNs to analyze X-Rays of patients lungs to automate the detection of COVID-19. The CNN will be trained with a number of images generated from different GAN architectures to determine which will prove most efficient in automating the detection of COVID-19. I also aim to use the GANs in conjunction with one and other to try out different combinations to see if feeding images generated by one GAN to other GANs will produce more accurate results when training the model.

Chapter 1

Introduction - An Overview of GANs, CNNs, & What I Aim To Accomplish in This Paper

1.1 What is A Generative Adversarial Network(GAN)

A generative adversarial network or GAN for short first appeared in a 2014 paper by Ian Goodfellow et al[1]. In this paper Goodfellow et al propose a new way to generate data via an adversarial process. The GAN essentially works as follows: two models are trained a generative model G which will generate the content from the data and another model D which will be the discriminator, judging if data created by the model came from the dataset rather than G. The goal of this training is to ensure data generated from G is realistic enough to fool our discriminator D into believing that our generated content came from the training set. It is in this way that we can create realistic "fake" data from our generative model.
There are a number of GAN architectures which are useful in different scenarios such as CycleGans[2] which are useful for translating images from a source domain $X -> Y$ in which Y is the target domain, StyleGan which was created by NVIDIA which allows more control over the generative process[3] & PixelRNN which can recreate images when given a fraction of the original and can generate new images based on probability[4].
In this paper I will use a number of different Generative Adversarial Network architectures and will use them in conjunction with each other by feeding content generated by one architecture into another to develop a more diverse training set for the final model.

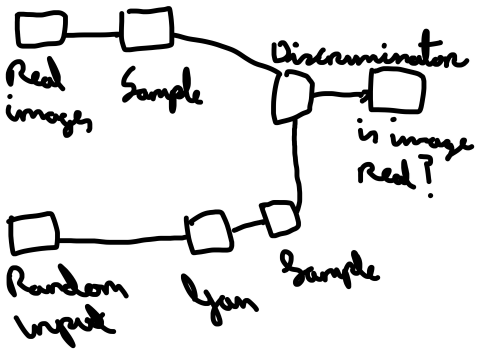

Figure 1.1: Basic Example of Generative Adversarial Network

As we can see from the image above we start the process by taking a sample of real images from our training data then passing it to the discriminator, we also take a sample from the GAN created images and pass that to the discriminator which will then determine if images are real are fake. After the discriminator determines if the image is real or fake backpropagation is then performed to train the model.

1.2 What is An Artificial Neural Network? (ANN)

An Artificial Neural Network or ANN for short is a network of neurons / nodes which will be used for training a model to perform a certain task, they are made up of an input layer, N hidden layers, and finally an output layer. Each layer will have it's own activation function and will adjust it's weights and biases to determine the final output of the model.[5] These networks were heavily inspired by biological processes which occur in the brain.
Artificial Neural Networks are a general purpose model used to solve a number of common problems.

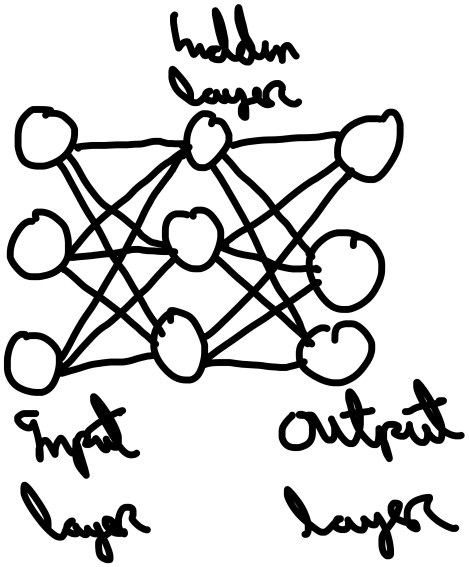

Figure 1.2: Basic Example of Artificial Neural Network

This is a basic example of an Artificial Neural Network1.2, as we can see from the image above the network has an input layer, a hidden layer and an output layer. Generally when creating these networks we determine the inputs and the outputs based on the different classifications we are trying to predict. The above network could be used to predict if an image is of a cat, a dog or a fish for example. There can multiple hidden layers in an ANN and all of the layers neurons can be adjusted. In reality Artificial Neural Networks will typically be far bigger than the example given above in terms of neurons and hidden layers but for illustrative purposes the above diagram will suffice.

1.3 What is a Convolutional Neural Network? (CNN)

A Convolutional Neural Network or CNN for short, is a type of neural network which is primarily used for tasks involving image and pattern recognition[5] The structure is similar to an ANN in which we have an input layer, N hidden layers, and finally an output layer. As with the Artificial Neural Network each of these layers will have an activation function and it's own weights and biases to determine the final output for a given input. The model will be fed an image which is made up of vectors(RGB) and from that image the model will

determine certain patterns and classify the given image which in this context will be either COVID-19 Positive or COVID-19 Negative.
There are a few ways in which CNNs differ from ANNs in that they are comprised of three layers which are the convolutional layer, the pooling layer and fully connected layers[5]. The convolutional layer is responsible for determining the output of a given input, the pooling layer will reduce the parameters of a given input by means of downsampling and finally the fully connected layers will then determine and classify the output for a given input. The convolutional layers parameters utilize learnable kernels, this layer also produces a $2D$ activation map which will be used to determine if a neuron fires or not for a given input. We can adjust hyper-parameters in the convolutional layer to greatly reduce the complexity of the model through optimization which can be achieved by adjusting the following hyper-parameters: depth, stride and zero padding.
Depth is related to the output volume produced by the convolutional layers in the model which can be manually set by adjusting the number of neurons in each layer. Reducing the depth of the model will greatly increase the training time but at the expense of performance. Stride is related to the spatial dimensionality of the input which will determine our receptive field(every neuron is connected only to a small region of the input this region is referred to as the receptive field[5]), if the stride is set to a low integer we will produce extremely large activations and if it is set too high we won't produce enough activations.
Finally we have zero-padding this will pad the border of the images input to our model reducing their dimensionality, padding is useful for increasing the accuracy of the model as it can possibly eliminate areas of the image which are not useful for the model and can also improve training time times(in some use cases).[6]
Through the adjustment of the hyper-parameters mentioned above and through the utilization of different activation functions the Convolutional Neural Network's accuracy can be improved through a process of trial and error.

1.4 Supervised Learning

Supervised Learning is a type of learning involving labelled data to train the model[7]. The data is labelled manually by a data-scientist which can be a long and laborious process depending on a number of factors(size of the data, number of classes etc.) but offers many benefits when it comes to training models. Supervised learning performs extremely well at tasks involving classification(classifying data into a given category) and regression(understanding the relationships between independent & dependent variables).

1.5 Unsupervised Learning

Unsupervised Learning is a type of machine learning involving unlabelled data to train the model[7]. This type of machine learning requires no human intervention since the data is unlabelled and will detect relationships between data based on the raw data fed in to the model. This type of machine learning is used for the following tasks: Clustering(grouping data together based on shared characteristics or features), Association(Finding relationships between features), and Dimensionality reduction(Reducing the number of features in a given data-set without compromising the integrity of said data). The key differences between supervised and unsupervised learning are: labelled vs unlabelled datasets, and finding relationships in data(unsupervised) or trying to predict and classify data(supervised).

1.6 Tensorflow

Tensorflow is an open-source library used for machine-learning and Artificial Intelligence research worldwide[8]. Tensorflow provides numerous modules and classes which will be the foundation of building both the Generative Adversarial Network and the Convolutional Neural Network. There have been numerous case-studies proving the efficacy of Tensorflow in solving many AI / ML problems and the library is used by the likes of Google, airB&B, ARM, Coca Cola, Intel, and many more[9].
Given the renown and reputation of Tensorflow and after exploring the documentation online I thought that this would be a welcome library to include when implementing the complex models which will be needed to automate the detection of COVID-19 and to implement the Generative Adversarial Networks to increase the robustness of the Convolutional Neural Network.

1.7 Keras

Keras is a deep-learning framework for python which will provide a number of helpful functions / methods when creating and training the CNN[10]. Keras is built on top of Tensorflow and will help greatly with data-loading, pre-processing and the overall building of the model. Keras is commonly used by data-scientists and researchers due to the powerful methods it offers and the time it saves. The additional classes and modules Keras provides will greatly help with and reduce the time of building both the Convolutional Neural Network and the Generative Adversarial Network.
Like Tensorflow Keras has been used by a number of companies and is well recognised in the Artificial Intelligence community. It's uses include Computer Vision, Natural Language Processing, Generative Deep-Learning and Reinforcement Learning just to name a few[11].

1.8 Purpose of this paper and aims of this research

The main objective of this research is to develop a robust model which can accurately analyze X-Rays of patients and determine from said X-Rays if the patient is afflicted with COVID-19. I plan to do this by utilizing a number of different GAN architectures which will create realistic "fake" data which will then be used to train a number of models, from this training I plan to compare and contrast the results when generating data with different architectures to determine the best configuration for data generation to train the CNN model.
I plan on utilizing existing data sets which I will list in the next section when training the Generative Adversarial Models, through trial and error I plan on determining the best architecture of GANs to use for training the model for this use-case.

1.9 Data-sets Used in This Paper

- COVID-19 Radiography Database[12]
- COVID-19 Chest Xray[13]
- COVID-19 Pneumonia Normal Chest Xray PA Dataset[14]

Chapter 2

Literature Review - Examining Current Paradigms & Research into GANs, CNNs and Their Applications in The Automated Detection of Diseases

Chapter 3

Implementation

3.1 Libraries Used

3.2 GAN Architectures

3.3 CNN Design

Chapter 4

Results of Research

Chapter 5

Future Work and Research

Bibliography

[1] A. Goodfellow *et al.*, "Generative adversarial nets," 2014. [Online]. Available: https://arxiv.org/pdf/1406.2661.pdf.

[2] P. Zhu *et al.*, "Unpaired image-to-image translation using cycle-consistent adversarial networks," 2020. [Online]. Available: https://arxiv.org/pdf/1703.10593.pdf.

[3] A. Karras Laine, "A style-based generator architecture for generative adversarial networks," 2019. [Online]. Available: https://arxiv.org/pdf/1812.04948.pdf.

[4] K. Oord Kalchbrenner, "Pixel recurrent neural networks," 2016. [Online]. Available: https://arxiv.org/pdf/1601.06759.pdf.

[5] K. O'Shea and R. Nash, "An introduction to convolutional neural networks," [Online]. Available: https://arxiv.org/pdf/1511.08458.pdf.

[6] M. Hashemi, "Enlarging smaller images before inputting into convolutional neural network: Zero-padding vs. interpolation," [Online]. Available: https://journalofbigdata.springeropen.com/articles/10.1186/s40537-019-0263-7.

[7] J. Delua, "Supervised vs. unsupervised learning: What's the difference?," [Online]. Available: https://www.ibm.com/cloud/blog/supervised-vs-unsupervised-learning.

[8] Multiple, "Tensorflow," [Online]. Available: https://www.tensorflow.org/.

[9] Multiple, "Tensorflow case studies," [Online]. Available: https://www.tensorflow.org/about/case-studies/.

[10] Multiple, "Keras," [Online]. Available: https://keras.io/.

[11] Multiple, "Keras examples," [Online]. Available: https://keras.io/examples/.

[12] C. Rahman *et al.*, "Covid-19 radiography database," [Online]. Available: https://www.kaggle.com/datasets/tawsifurrahman/covid19-radiography-database.

[13] J. P. Cohen, P. Morrison, and L. Dao, "Covid-19 image data collection," *arXiv*, 2020. [Online]. Available: https://github.com/ieee8023/covid-chestxray-dataset.

[14] Asraf, "Covid19 with pneumonia and normal chest xray(pa) dataset," [Online]. Available: `https://www.kaggle.com/datasets/amanullahasraf/covid19-pneumonia-normal-chest-xray-pa-dataset`.