Creating realistic COVID-19 large 3D CT scans

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1 Introduction

There are a lot of important questions when considering this task, the primary are:

- What type of structure should we use?
- Is this task doable for dataset of around 300 samples?
- Can we create 3d scans of usable size?
- What would be the training time of a network that could converge to a decent solution?
- Can this be done with google colab resources and one month deadline?
- Alternative approach

2 What type of structure should we use?

There are many popular types of GANs used for various tasks eq. StypeGAN for style transfer or DiscoGAN used in learning cross-domain relations. We have to find or implement architecture dedicated to our type of problems to have any shot at solving this problem.

2.1 2D GANs inspection

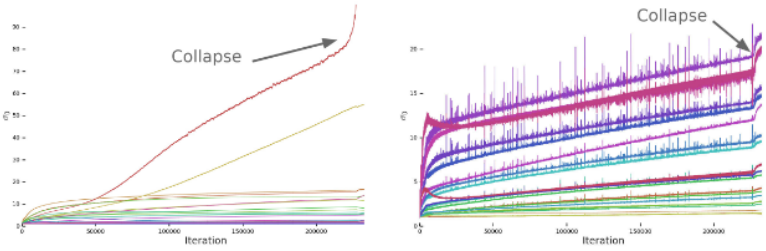
2.1.1 Progressively growing GANs

Using Progressively growing GANs could be the right choice, but NVIDIA in [1] described the training process to last 4 days, while they used 8 Tesla V100 GPUs and had smaller output shape (1024x1024 compared to 48x360x240). They were also using larger dataset consisting of 30000 pictures, but this actually brings us hope that our dataset of 300 scans could be enough to train working model. But due to mentioned aspects we won't use this approach because it seems to require way to much more computational power and time, than we have.

2.1.2 BigGan

This revolutionary paper from 2019 describes improvement to image generation process. They achieved state of the art image generation without need for progressive growth of GANs. But, they did it on JFT-300M dataset, which has 300 million images. They achieved those amazing scores by long and mostly

stabled stable learning process. But due to insufficient data and computational power their approach cannot be used in our case.



Training process of 250000 iterations and visualized collapse

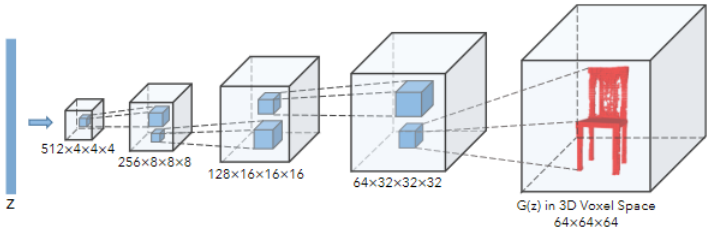
2.1.3 Deep learning-based synthetic CT generation from MR images

This article is about generating data which is very close to what we need, but not only do they take MRI scans as an input but also they use normal GAN which iterates on scans during training. What is interesting they had only 86 patients, which is way less than our 300, but they used 512x512x139 ct scans which gave them 139 inputs per patient resulting in overall in 12000 samples.

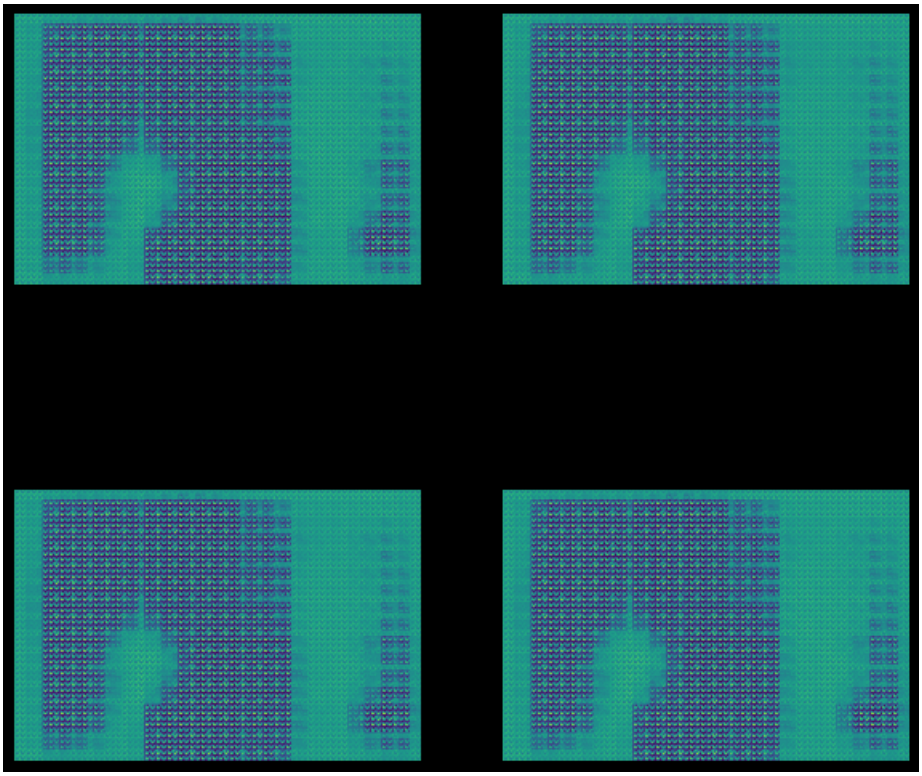
2.2 3D-GANs Inspection

2.2.1 3D Generative-Adversarial Modeling

In this work authors proposed a rather straightforward structure that could prove useful in our task. Sadly their work is from 2016 and is mostly based on the article introducing GAN, so this is a VanillaGAN, that can't really be scaled up.



They start from a probabilistic 200-dimensional vector, and after 5 steps they end up with 64x64x64 model. They focused on creating various different 3d models like chairs, cars, tables, guns. This is rather big achievement for their time and we tried to build model similar to theirs, but with little effect, as we do not have the same computational capabilities, and this was the result of 22 epochs after which our training was shutdown. We tried to improve our model, by applying changes to it's structure, but after next failures gave up. Looking at what model tried to tell us, probably for the best.



Those are 4 lung images at the depth of 24 out of 48.

3 Is this task doable for dataset of around 300 samples?

From what we seen in [1], [2], [5], [3], [4] and other places our 300 sample dataset is at least 100 times to small, keep in mind that google in [2] used 300M images for a task of generating images of size 512x512 which is smaller than our 512x512x48 and 240x360x48. But their GAN generated images of thousands of classes, we have only two. Nevertheless GANs are type of neural networks that often struggle with convergence and training collapsing and small dataset it major disadvantage while trying to achieve state of the art results in area of 3D-GANs.

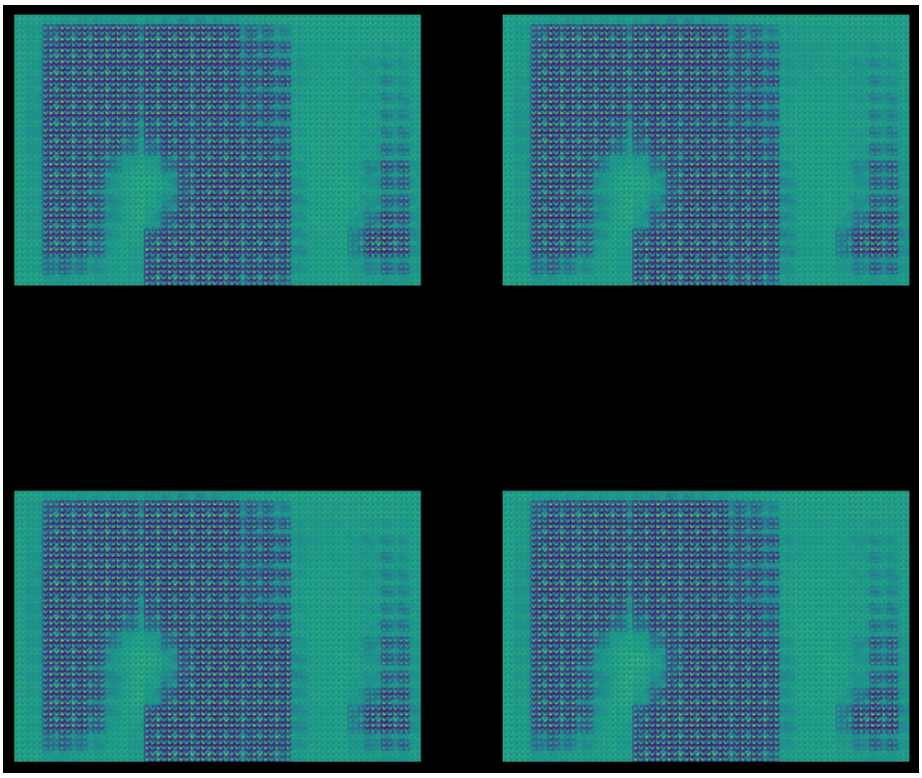
Can we create 3d scans of usable size? Typical CT scans have a size of 512x512 but they vary in depth. Typically only single images are used, but in our task and in some others 3D versions are necessary. Main problem is that CT scanners create scans of different depth. There is no know standard, and in our case they had from 30-60 layers of depth but as an example in [4] it was 139. This is why we will focus on delivering complete scans with fixed depth and hope that other methods can be used to transform them to necessary one. But for now due to problem with computational power and our training capabilities we will focus on creating zoomed 240x360x48 scans of lungs, which will be usable only in our case. In we find structure that works well in this smaller example we could perhaps scale it to 512x512x48 scans.

4 What would be the training time of a network that could converge to a decent solution?

It should be noted here that after studying similar works we believe that our model cannot be trained with dataset of our size. There is a possibility that some sophisticated techniques could be used to resolve this issue or future GAN architectures will not require so much data. In order to give this problem a shot we will assume that we have typical small dataset of 30000 samples, which is 100 times larger than current one.

We couldn't find model of desired structure in previous works but, the one presented in [5] is a simple one that could be build upon. This is what we tried and got negative results, but also some information about required training time.

Our training was performed using google Colab with their GPU and could be speed up with better GPUs. Sadly we don't have anything faster. Training on our small set took around 300s per epoch, which is not a bad result, but assuming we would have a dataset of sufficient size this would go up to 30000s which is 8,3 h per epoch. What's more I strongly believe that even at the end our architecture was to small due to the fact that we got so many square artifacts in our end result.



Our model currently has 25M trainable parameters, which is a lot, but not a lot for a 3D-GAN.

5 Can this be done with google colab resources and one month deadline?

We can create gray blobs, not lungs.

6 Alternative approach

Our last hope is to scale down original images to 128x128 resolution with the same depth. Create and train network for problem of this size, which possibly could be trained and then upscale the outputs to 512x512 resolution. This is a workaround that would still suffer from 3d medical data up scaling problems.

6.1 Up scaling ct scans

Medical ct scans are far from normal pictures, and many advanced techniques were created to upscale CT scans specifically, such as [0] or [0]. The best approach would be to not use normal vortex up-scaling but those especially crafted techniques, but although we were able to find some publications, we could not find any available codes or weights.

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