COVID-19 CT Scan Lesion Segmentation

by

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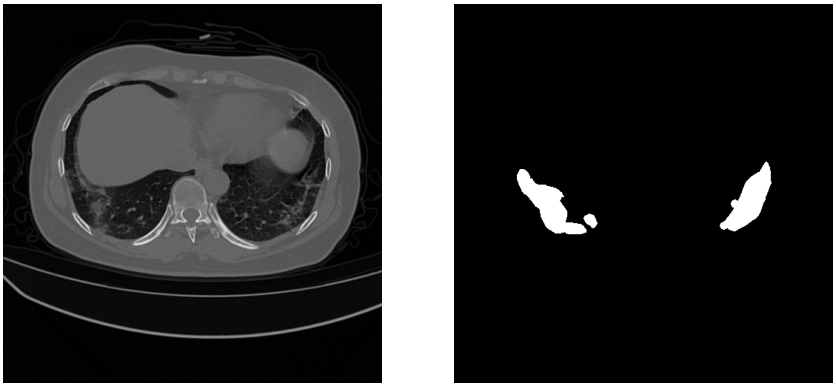

(a) CT scan (b) Ground Truth

Figure 1: Sample Data

Abstract

Image Processing has been always considered as top ranked research areas in Computer Sciences. Where Medical Image Processing/Analysis is among the key research topics as there are infinite problems relevant to medical domains that requires the fast computational power to help in order to save lives.
In this project the goal is to design a lesion segmentation system by using a dataset of Lungs CT scans having lesions in Covid-19.
Dataset consists of 2729 CT-scan image and ground truth mask pairs. All types of lesions are mapped to white color in the ground truth for consistency across dataset.
This project will be done in incremental phases, where firstly I'll be considering for such pre-processing techniques which result in highlighting lesions region the most .
In the second phase, I'll be looking forward for segmenting the lesion and comparing different techniques for segmenting in order to achieve better results.
If these phases are done well before time and I'll be comparing other researchers' methodology and improve further.

Dataset Source:
https://www.kaggle.com/maedemaftouni/covid19-ct-scan-lesion-segmentation-dataset

Keywords: Image Processing; Medical Image Analysis; Covid-19; CT Scan; Lesion; Segmentation; Ground Truth;

0.1 Introduction

A unexpected outbreak of the rare respiratory disease was reported in Wuhan, China, near the end of December 2019. The Chinese Center for Disease Control and Prevention examined the lower respiratory tracts of sick patients and discovered COVID-19, a novel coronavirus. COVID-19 is a systemic infection that primarily affects the endothelium layer of the lungs and spreads from person to person, whether symptomatic or asymptomatic.

Post-COVID-19 pulmonary fibrosis is characterised as the occurrence of fibrotic CT alterations on follow-up studies that are commonly clinically associated with decreased lung function. Even though histopathological patterns in post-COVID-19 pulmonary fibrosis have yet to be discovered, they are thought to be those of an organising and fibrotic phase of diffuse alveolar damage (DAD), fibrosing nonspecific interstitial pneumonitis, and organizing pneumonia. CT features being potentially identified in pulmonary fibrosis secondary to COVID-19 pneumonia have been suggested to include the presence of architectural distortion, reticular lesions, traction bronchiolectasis, ground-glass opacity, mosaic attenuation, and honeycombing in consideration of presumed histopathologic patterns. But according to the study by Pan et al (1), the CT features seen at one-year follow-up studies were those of fibrotic-like linear or multifocal reticular and/or cystic lesions.

There were no typical CT DAD findings, such as fibrosing nonspecific interstitial pneumonitis or organised pneumonia patterns. Follow-up CT characteristics of severe acute respiratory syndrome-associated coronavirus (SARS-CoV) infection produced comparable results. Patients with underlying interstitial lung disease, particularly those with poor lung function and obesity, are at a higher risk of death from COVID-19.

Finally, follow-up CT scans of COVID-19 pneumonia patients reveal persistent fibrotic-like linear or multifocal reticular/cystic lesions. So if we segment the lesion region, it'll be helpful for post COVID treatment by looking at the affected areas of lungs.

0.2 Literature Review

1. **Lung Lesion Segmentation Using Gaussian Filter and Discrete Wavelet Transform**

   By Kamil Dimililer, Ali Hesri and Yoney Kirsal Ever

   (10.1051/itmconf/20171101018)

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   2 Software Engineering Department, Near East University, North Cyprus, Mersin 10 Turkey

   Lesions inside the lungs are called a great early symptom for detection of Lung cancer. Lung cancer is a growing tumour that are cells covering the airways of the major respiratory system.
   Here they've used CT scans and applied image processing different applications and investigated the effectiveness of different types of discrete wavelets to obtain accurate results.
   Haar Wavelet, Db7 and Bi-orthogonal wavelet are being used along with Median and Gaussian Kernels.

2. **COVID-19 Lesion Segmentation Using Lung CT Scan Images: Comparative Study Based on Active Contour Models**

   By Younes Akbari, Hanadi Hassen, Somaya Al-Maadeed and Susu M.Zughaier

   (https://doi.org/10.3390/app11178039)

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   Pneumonia being a lung infection is highly threatening. COVID-19 causing pneumonia is being segmented here using CT scans to find how effective Active Contour Models (ACM) are. This research provides the basis on which further ACM related Lung Segmentation can be done in the COVID-19 domain.
   They've shown how initially contour results and improvements in result if (Gac, C-V, MAC, Lsacm, Frbacm) Models of Active Contour are used.

3. **Dual-branch combination network (DCN): Towards accurate diagnosis and lesion segmentation of COVID-19 using CT images**

   By Kai Gao, Jianpo Su, Zhongbiao Jiang et al.

   (https://doi.org/10.1016/j.media.2020.101836)

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As the COVID-19 outbroke from Wuhan China and as a result, many different diagnostic tools were developed, CT(computer tomography)-based diagnostic tool faced further complications due to lack of adequate manually-delineated samples. So dual-branch combination network (DCN) was developed to achieve classification and lesion segmentation which resulted in high accuracy. CT scan images are preprocessed first using U-net and then DCN is applied which uses FC Net to get lesion segmentation.

4. **Lung Lesion Detection in CT Scan Images Using the Fuzzy Local Information Cluster Means (FLICM) Automatic Segmentation Algorithm and Back Propagation Network Classification**

By M Lavanya and P Muthu Kannan

(https://dx.doi.org/10.22034%2FAPJCP.2017.18.12.3395)

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Lungs' cancer has always been a deadly and diagnostic method for lung tumours that weren't up to the mark then due to variation in lesions. These researchers proposed a segmentation technique using the FLI Cluster Mean algorithm for segmentation and further clustering is done to achieve accurate results after which Edge detection was done to extract features and Classification is achieved using Back Propagation Network.
It resulted in far better accuracy than existing methods of that time.

5. **Dense GAN and multi-layer attention based lesion segmentation method for COVID-19 CT images** By Ju Zhang, Lunduan Yu at el.

(https://doi.org/10.1016/j.bspc.2021.102901)

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Testing and screening during COVID-19 pandemic was a headache for governments. AS CT-scan images were clear diagnostic medium, medical imaging researchers proposed a technique in which novel Dense GAN was developed to get clear images and U-NET combined with multi-layer attention mechanism was used to get accurate lesion segmentation. Further related work resulted in Dense Generative Adversarial Network(DGAN)
Precision by this proposed method was as high up to 0.94.

6. **Label-Free Segmentation of COVID-19 Lesions in Lung CT**

By Qingsong Yao, Student Member, IEEE, Li Xiao, Member, IEEE, Peihang Liu and S. Kevin Zhou, Fellow, IEEE

(https://arxiv.org/pdf/2009.06456.pdf)

1 Institute of Computing Technology, Chinese Academy of Sciences

During the pandemic, there was a shortage of labelled images, which are required for a reliable solution for the diagnosis of CT based COVID lesion segmentation. Here they came up with a label-free solution by making the model learn strong patterns of lesions. They synthesized lesions from which a normalcy-recognizing network was learnt which separates normal tissue with lesions.
This work outperformed most unsupervised anomaly detection methods.

7. 3D GENERAL LESION SEGMENTATION IN CT

By Marie-Pierre Jolly and Leo Grady

(https://www.academia.edu/9551756)

1 Imaging and Visualization Department Princeton, NJ, USA

Due to diversity in the types, shapes and textures of lesions, it is really hard to come with a solution working for every type of lesion in a CT. They proposed an algorithm where one can segment any kind of lesion in a CT image.
The algorithm is dependant on a click or stroke inside the lesion and remembers its properties in 2D. Afterwards, the Walker algorithm has been used to produce multiple 2D segmentation outputs and a resulting final 3D segmentation.
The quantitative analysis stated it to be used for clinical purposes.

8. Comprehensive Comparison of Deep Learning Models for Lung and COVID-19 Lesion Segmentation in CT scans

By Paschalis Bizopoulos, Nicholas Vretos and Petros Daras

(https://arxiv.org/pdf/2009.06412.pdf)

1 Visual Computing Lab of the Information Technologies Institute, Centre for Research and Technology Hellas, Thessaloniki, Greece

Deep Learning has been always used for Medical Image Analysis. This paper refers to a comparison based study between different DL models (Unet, Linknet, FPN, PSPNet) and are combined with 25 randomly initialized and pre-trained encoders s (variations of VGG, DenseNet, ResNet, ResNext, DPN, MobileNet, Xception, Inception-v4, EfficientNet), to achieve better results for lesion segmentation in lungs CT scans after construction of 200 models and

setting three experimental setups.
They concluded by highlighting properties that affect the better working of DL for this job.

9. **Automatic COVID-19 lung infected region segmentation and measurement using CT-scans images**

By Adel Oulefki, Sos Agaian, Thaweesak Trongtirakul and Azzeddine Kassah Laouar
(https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7605758/)
1 Department of Computer Science, College of Staten Island, New York, Victory Blvd Staten Island, New York 10314, USA
2 Faculty of Industrial Education Rajamangala University of Technology Phra Nakhon, Vachira Phayaban Dusit Bangkok, Thailand

As the COVID-19 spread, health workers could not examine every patient properly and automation was the need of the hour. The main hurdle in The segmentation of lesions is similar grayscale values to the values of soft tissues, Intensity in-homogeneity and presence of the artifact. The researcher of this paper Proposed an enhancement method and compared it with state-of-the-art segmentation techniques on the same data. The enhanced method proposed by the researcher
showed promising results by mean of using masking metric and multilevel image thresholding for image segmentation by optimizing Kapur entropy.

10. **Weakly-Supervised Universal Lesion Segmentation with Regional Level Set Loss**

By Youbao Tang, Jinzheng Cai at el.
(https://arxiv.org/pdf/2105.01218.pdf)
1 PAII Inc., Bathesda, MD, USA
2 Ping An Technology, Shenzhen, PRC
3 Beijing United Family Hospital, Beijing, PRC
4 Chang Gung Memorial Hospital, Linkou, Taiwan, ROC

Not just lungs lesion detection and segmentation is a challenging task but segmenting any lesion is a hard task using CT scans. These researchers proposed a technique to segment lesions from anywhere in the whole body as universal lesion segmentation(ULS) for CT scans.
Manually annotating such huge data requirements was never easy. So weakly supervised model was used here by a combination of High-Resolution Network(HRNet) and Regional Level set(RLS) which resulted in best performance on the publicly large-scale DeepLesion dataset. And concluded this work by RLS as it enhanced performance significantly.

11. **Rapid Artificial Intelligence Solutions in a Pandemic - The COVID19-20 Lung CT Lesion Segmentation Challenge**

By Holger R, Ziyue Xu at el.

(https://arxiv.org/pdf/2105.01218.pdf)

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2 Sheikh Zayed Institute for Pediatric Surgical Innovation, Children's National Hospital, Washington, DC, USA

3 Division of Diagnostic Imaging and Radiology, Children's National Hospital, Washington, DC, USA

4 HIP Applied Computer Vision Lab, German Cancer Research Center (DKFZ), Heidelberg, Germany

Having efficient lungs lesion diagnostic tools was need of the hour then in 2020. So a international challenge was organized and task was to design AI methods for the automatic detection and quantification of COVID-19 lesions in chest CT. 1096 teams took part and here are the factual findings from top 10 winners, stated below:

- All teams utilized U-Net with some variations, Further more nnU-Net shown most success. Most of teams targeted segmentation directly while few targeted outputs.
- And for loss function Dice loss was found almost in every submission.

0.3 Methodology

0.3.1 Pre-processing

Due to the limitation of hardware resources, and time, No preprocessing was done and all images are fed as they were collected

0.3.2 Framework

Tensorflow Keras, Numpy, Matplotlib and other dependencies

0.3.3 Model Selection

Currently, I have used U-Net with the attention model having following details. Again due to hardware limitation 851 unique images were selected to train our DL model (U-Net) as it allows to have a versatile boundary.

11 hidden layers
Total params: 31,117,985
Trainable params: 31,105,953
Non-trainable params: 12,032

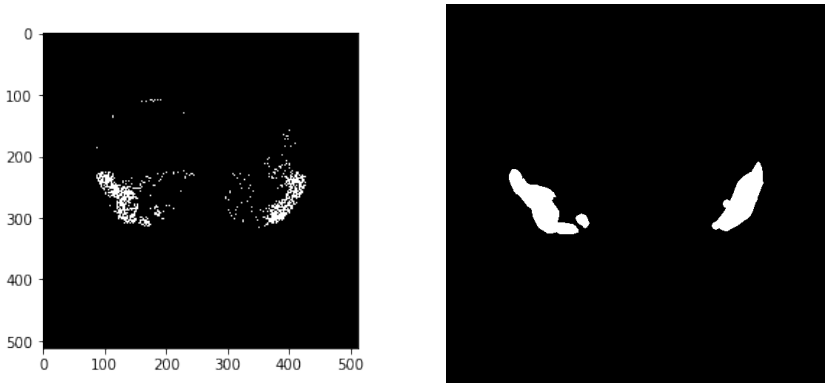
0.3.4 Evaluation

Intersection over union IoU has been used as the evaluation metric.

0.4 Results

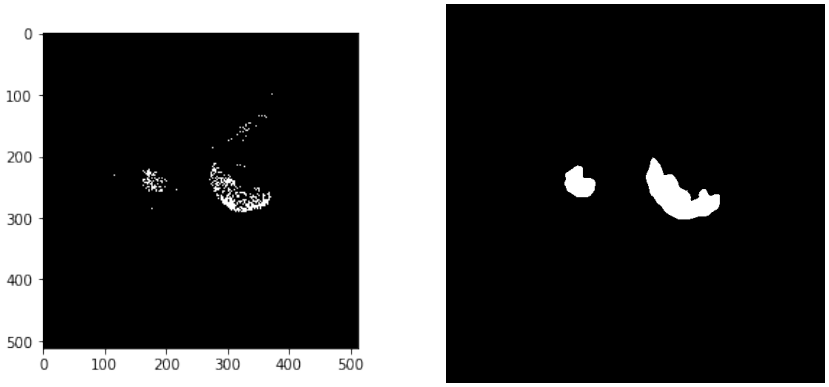
0.4.1 Testing Accuracy

Data was divided into 80 percent training and 20 percent testing and by UNet with attention model we achieved IoU of 0.60990273 on the pixel based resulting in form of mask. Predicted masks are attached below



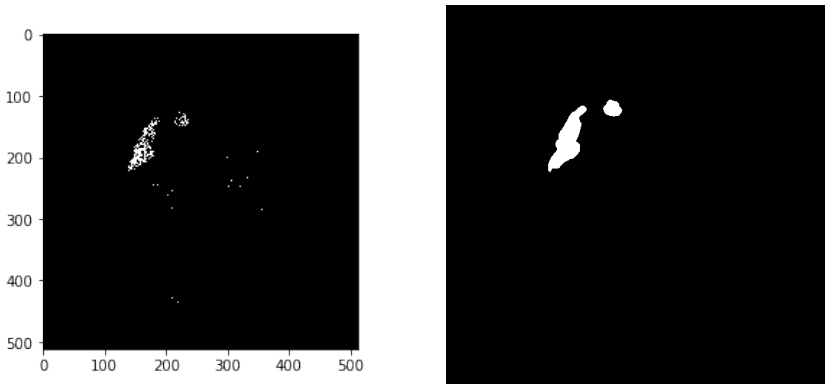
(a) Predicted (b) Ground Truth

Figure 2: Predicted Result



(a) Predicted (b) Ground Truth

Figure 3: Predicted Result



(a) Predicted (b) Ground Truth

Figure 4: Predicted Result