Internship Training

at

U4RAD Technologies LLP

Designing Machine Learning Framework to detect COVID-19 Using Chest X-Ray Images

by

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PG/18/062

Under the guidance of

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Post Graduate Diploma in Hospital and Health Management

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International Institute of Health Management Research
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Completion of Dissertation from

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The certificate is awarded to

Isanaka Sai Josree

in recognition of having successfully completed his/her Internship in the department of

Digital Solutions

and has successfully completed his/her Project on

Designing Machine Learning Framework to detect COVID-19 Using Chest X-Ray Images

30.5.2020

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She comes across as a committed, sincere & diligent person who as a strong drive & zeal for learning.

We wish him/her all the best for future endeavors.

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The Candidate has successfully carried out the study designated to her during internship training and her approach to the study has been sincere, scientific and analytical.

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I wish her all success in all her future endeavors.

Dr. Pradeep K Panda
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The following dissertation titled **"DESIGNING MACHINE LEARNING FRAMEWORK TO DETECT COVID-19 USING CHEST X-RAY IMAGES"** at **"U4RAD TECHNOLOGIES"** is hereby approved as a certified study in management carried out and presented in a manner satisfactorily to warrant its acceptance as a prerequisite for the award of **Post Graduate Diploma in Health and Hospital Management** for which it has been submitted. It is understood that by this approval the undersigned do not necessarily endorse or approve any statement made, opinion expressed or conclusion drawn therein but approve the dissertation only for the purpose it is submitted.

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This is to certify that **Ms. Isanaka Sai Josree,** a graduate student of the **Post- Graduate Diploma in Health and Hospital Management** has worked under our guidance and supervision. She is submitting this dissertation titled "DESIGNING MACHINE LEARNING FRAMEWORK TO DETECT COVID-19 USING CHEST X-RAY IMAGES" at "U4RAD TECHNOLOGIES" in partial fulfillment of the requirements for the award of the **Post-Graduate Diploma in Health and Hospital Management.**

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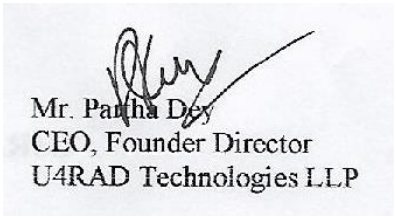

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FEEDBACK FORM

Name of the Student: I. Sai Josree

Dissertation Organization: U4RAD Technologies LLP

Area of Dissertation: Detection of Covid 19 from Chest X Ray

Attendance: Excellent (98%)

Objectives achieved: Process design of the Covid 19 detection from chest X Ray, an innovative way potential mass screening of Covid in this need of hour.

Deliverables: Design and Process flow documents, Development of front end of the tool

Strengths: Analytical ability to design complex process, Combination of both business, process and software development skills.

Suggestions for Improvement: To develop deep understanding of image analytics AI algorithm, Neural Networks.

Suggestions for Institute (course curriculum, industry interaction, placement, alumni):

More focus on emerging technologies like AI/ML/Cognitive, IoT, Cloud Computing, Blockchain, Mobility solutions, Big Data Analytics.

Signature of the Officer-in-Charge/ Organisation Mentor

PARTHA DEY - U4RAD

Date: 27th June 2020
Place: Gurgaon

Designing Machine Learning Model to detect COVID-19 Using Chest X-Ray Images

Author Name: Isanaka Sai Josree

Enrolment No: PG/18/062

Abstract

COVID-19 pandemic creating havoc in the world, a solution to fast interpret and diagnose the COVID-19 is much appreciated by health workers. In this crisis situation huge number of suspected patients are waiting for their confirmation tests. RT-PCR, considered to be the most reliable testing for COVID is unavailable at all the possible health centers and takes 24-48 hours to give the result. The alternative option of using CT is also not so reliable due to unavailability of required machines at all the health centers. Due to large number of suspected patients and with limited resource availability, Chest Radiography is considered to be the best option to triage for COVID-19. Huge demand of Radiologists has paved way to alternative solution of machine learning applications in medical imaging and has brought revolutions. Applying Convolutional Neural Networks on Chest Radiology helps in the immediate COVID-19 detection with a confidence level.

Objective of the Study is to design a Machine Learning model that would help in the COVID-19 detection by analysing the Chest Radiology images. An Exploratory Study using Secondary data was to understand the usage of Machine Learning with respect to medical imaging for diagnosis. Related news articles and published articles were studied. In-depth study on what parameters and steps are involved in training machine learning and their sequential association to improve the accuracy of the diagnosis was also done. Focus Group Discussion with radiologists involved the Qualitative research on the parameters was done.

Various parameters used to detect different infectious diseases in Chest Radiology are identified. Parameters list and their sequential association used to detect COVID-19 in CXR are identified and compared with the parameters list developed from discussions with the Radiologists. These studies are used to design a Machine Learning model that helps in the COVID-19 detection using Chest Radiography.

Keywords: Artificial Intelligence, Machine Learning, Convolutional Neural Networks, Chest Radiography

Acknowledgement

Above all and everyone, I thank the almighty and my parents for their love, support and everything.

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Abbreviations

nCoV	Novel Corona Virus
CAD	Computer Aided Diagnosis
ML	Machine Learning
DL	Deep Learning
AI	Artificial Intelligence
CNN	Convolutional Neural Networks
WHO	World Health Organization
COVID-19	Coronavirus Disease 2019
CT	Computed Tomography
CXR	Chest Radiology
SVM	Support Vector Machine
AUC	Area Under Curve

Chapter 1. Introduction

Initial outbreak of novel coronavirus (nCoV) considered as severe acute respiratory syndrome coronavirus-2 was reported in Wuhan, Hubei Province, China in December, 2019. Later, the disease spread across china and to other countries in the world. Further, novel coronavirus has emerged as a public health emergency of international concern as declared by World Health Organization (WHO). This disease caused by novel coronavirus is named as Coronavirus Disease 2019 (COVID-19) by WHO on February 12, 2020. COVID-19 is lethal disease with high morbidity rate, unlike other diseases caused by coronaviruses, such as Severe Acute Respiratory Syndrome (SARS) and Middle East Respiratory Syndrome (MERS). Countries are at different stages of national and subnational outbreaks. They are encouraged to strengthen their capacities for this health emergency and disaster risk management incorporating measures for prevention, mitigation, preparedness, response and recovery.

Clinical Spectrum and Infection Spread

The typical clinical features of COVID-19 include fever, cough, sore throat, headache, fatigue, muscle pain, and shortness of breath. Patients may initially present with diarrhea and nausea a few days prior to fever, suggesting fever is dominant but not the premier symptom of infection. A small number of patients can have headache and even relatively asymptomatic. Evidence of infection spread through human to human transmission by droplets, contact and fomite was provided after the infection was detected among the clusters of family members and medical workers. With COVID-19 inhibiting symptoms similar to common cold and common flu, it has become very difficult to detect the positive cases. This is resulting in vast and fast spread of the disease across the globe. Infection has shown a remarkable and fast increase in spread across the countries. To reduce this exponential spread of the infection, it is very important to detect cases in their early stages and control the infection from spreading.

Diagnosis/Screening of COVID-19

According to the guidelines provided by Ministry of Health & Family Welfare (MoHFW), a patient is a suspect of COVID-19, if the person exhibits respiratory symptoms like fever, cough, and shortness of breath. Patient with two clinical conditions and exposure history is a suspected case. If no exposure history is available, three clinical conditions are considered for suspected cases. RT-PCR tests are required for the confirmed COVID positive cases and is considered a reference standard for coronavirus cases diagnosis. Computed Tomography of Chest images can also be considered as an option for diagnosis of coronavirus. Yet, lab test turnaround times for results are very long and have scarcity and shortage CT availability at the health centres. Under these circumstances, X-Ray images as a first line tool to diagnose and treat suspected cases of COVID-19 as quickly as possible, with the help of Radiologists.

CXR Screening

Portable Chest Radiography (CXR) has the advantage of eliminating the need for patient transfer and might reduce the use of laboratory tests with long turnaround times. Though, X-ray is insensitive for early detection of disease, it can be useful to establish a baseline for disease progression. According to researchers, Guan, et al, and Wong, et al CXR is found to have a sensitivity of 59% for initial detection of COVID-19-related abnormalities. Based on the X-Ray results, suspected individuals can be segregated and sent for further confirmation tests.

Computer Aided Diagnosis Solution

With X-Rays being the first line tool for COVID-19 diagnosis, Radiology specialists are in huge demand. With exponential growth of infection, examining images and addressing reports has to be faster. Waiting for specialists could sometimes take more than few hours. Therefore, computer aided diagnosis is proposed to enhance the level of performance. Though computer aided diagnosis has shown improvements in the detection, it is yet to be approved for routine

clinical usage. It is also important for automated system to reach the human level of diagnostic accuracy.

Machine learning models have huge application in image analytics and computer vision. A machine learning model can show high accuracy if large number of parameters are used to train the model. ML models has already shown a high performance in object detection by reaching human level in daily life. These models can also be assessed in medical imaging interpretation particularly radiology examinations to produce high accurate results. Such models that yields high productivity are most desired during COVID-19 crisis. Commonly used techniques of machine learning for radiology field include classification, detection and segmentation.

- **Classification**: A task to categorize or label an image into a specific class. This is considered to be the fundamental task to carry any further ML tasks. This is performed by Radiologists who excel in their domain to classify abnormal images form normal radiology images.

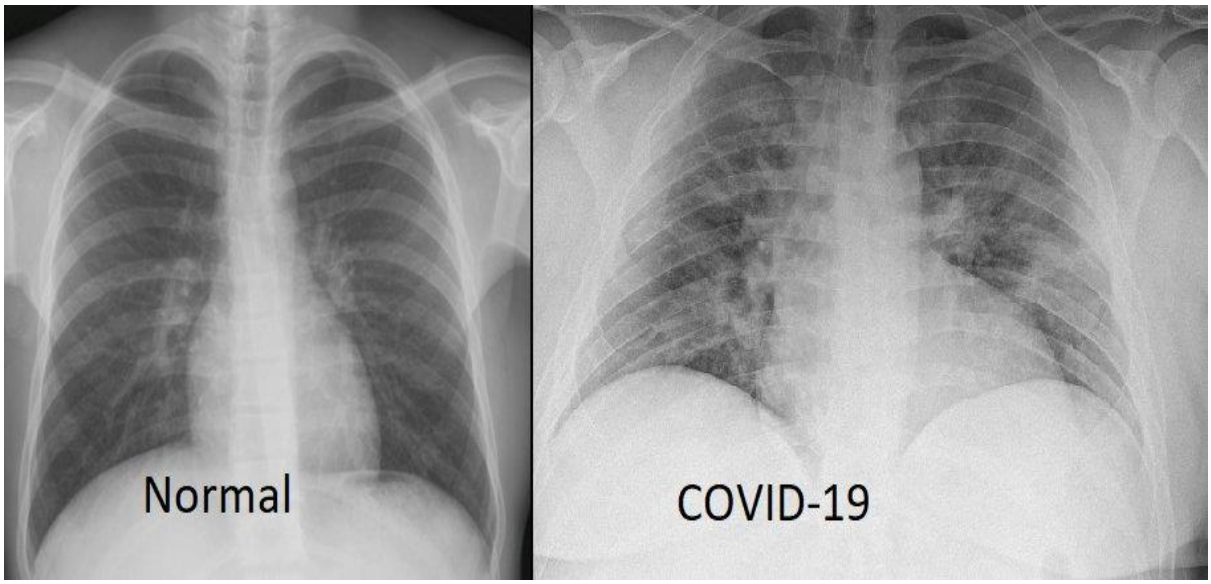

Figure 1. 1: Classification of COVID-19 from Normal Chest x-ray

- **Detection**: A technique to plot the location of any object that is of interest for the task performance. In particular, infection related anomalies are distinguished by plotting the exact area of the anomalies by the domain expert radiologists in the abnormal images.

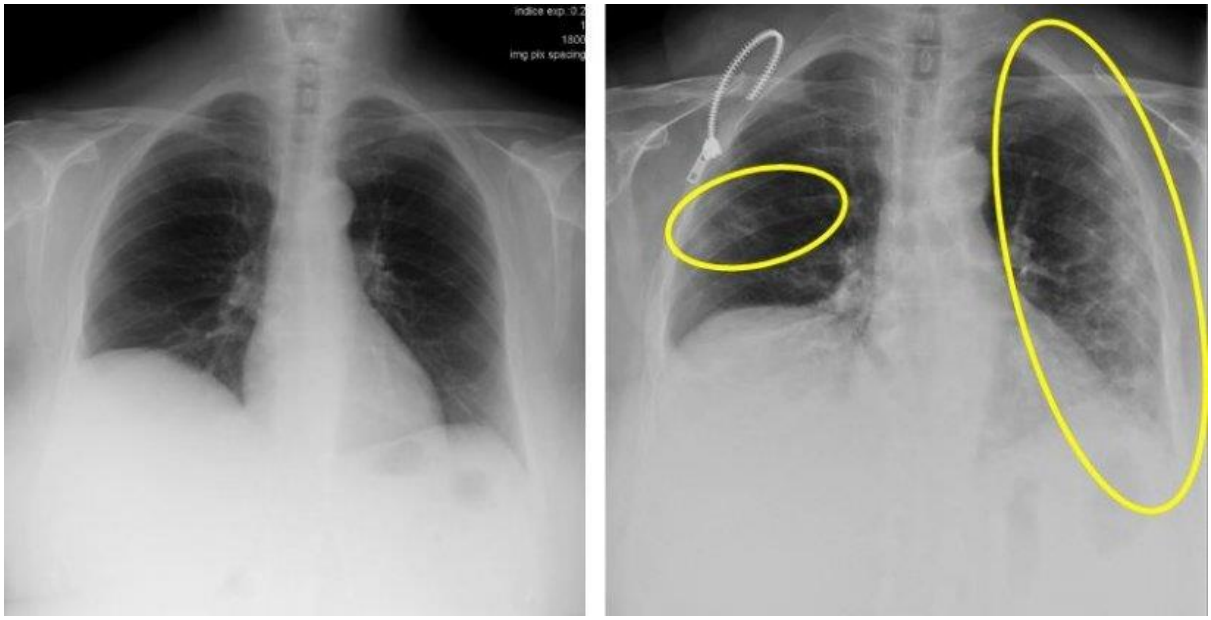

Figure 1. 2: Detection of COVID-19 Anomalies in CXR

- **Segmentation**: This technique is used to identify the pixel-wise boundaries of any feature of the image. This requires the radiologists to annotate the abnormal images manually thus training the system to understand anomalies.

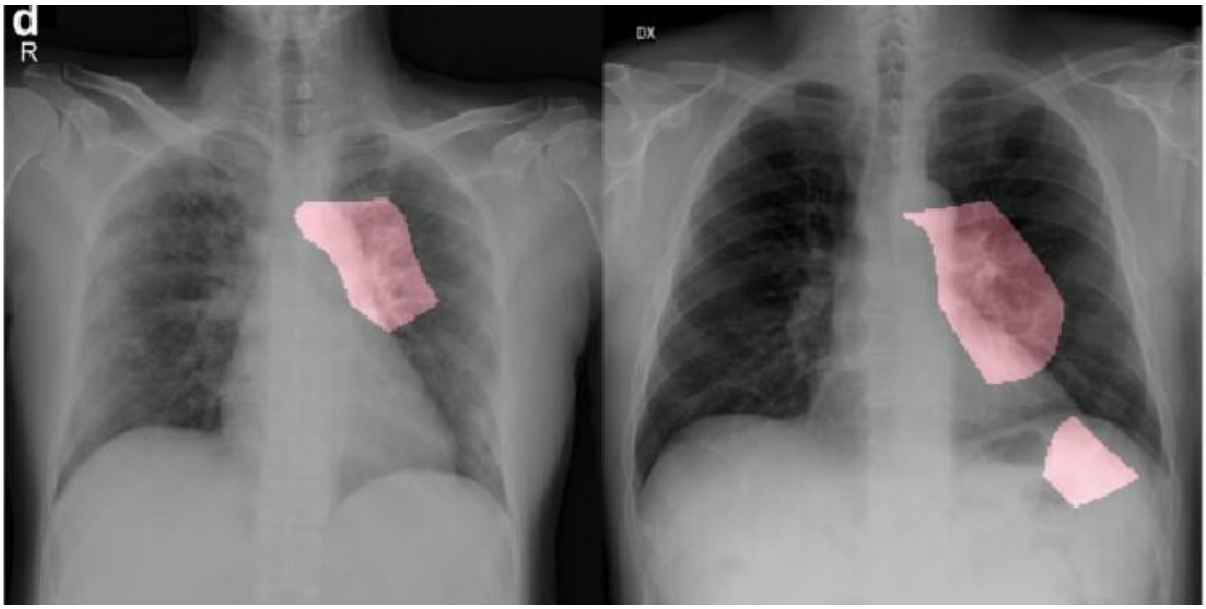

Figure 1. 3: Segmentation of COVID-19 anomalies in CXR

Aim

The aim of the study is to design a Machine Learning model that would help in the COVID-19 detection by analyzing the Chest Radiography images.

Specific Objectives

1. To study and understand the various features of chest radiography images involved in to identify various infectious lung diseases
2. To study and explore the application of Convolutional neural networks of machine learning in detecting COVID-19 by analyzing chest radiography images
3. To discuss with the specialists and understand the parameters and their association for the accurate detection of COVID-19 presence in Chest Radiography.
4. Compare the data from secondary research articles with the practical discussion data to design a Machine Learning model to detect COVID-19 diseases in the Chest Radiography

Chapter 2. Rationale and Research Question

Rationale

Despite the various surveillance programs and screening methods being implemented by health Department, COVID-19 tests and cases have been increasing in numbers. Thermal screening is used as the first step of the quick screening of suspected COVID-19 cases at various health camps with huge number of population to be tested. Thermal screening is not an efficient screening method for COVID-19, as temperature fluctuations can be caused due to various reasons. Person with even the slightest change in body temperature is to be further tested for confirmation of COVID-19 through Chest Radiography, the next possible fast screening method. Leveraging CXR images has greater advantage for COVID screening in resource constrained and highly affected areas:

- **Rapid triaging**: CXR imaging rapid triaging helps when huge number of symptomatic patients arrive at clinics of suspected COVID-19. It is effective in places with minimal RT-CPR kits available.
- **Availability and Accessibility**: As CXR imaging is considered standard equipment in many centres due to its low maintenance costs as compared to CT images. So, it is accessible in most health centres.
- **Portability**: With portable digital CXR systems, imaging can be performed at home or at an isolated place, thus avoiding the transmission of COVID-19 patients.
- **Low cost Installation**: Installation cost of Chest radiology equipment is very cheap and is affordable even at basic health centres with a very minimal cost. This also includes the low maintenance costs of the equipment due to its affordability factor.

Currently, portable chest radiography is considered to be the fastest method to screen the suspected COVID-19 cases mainly due to its availability, accessibility and portability. Chest radiography can be with minimal risk of spreading the infection by implementing a no touch portable machine deployment and scanning, resulting in fast and immediate scanning of x-ray images without any personal contact with the patient.

The anomalies in the CXR are used to differentiate COVID-19 infection with other infections and take the immediate steps to treat the COVID-19 positive cases. Use of Chest X-ray screening method also involves many challenges like delayed reporting, radiologist unavailability, longer waiting time for diagnosis report. To address these challenges, U4RAD identified an opportunity to use technology based solution for rapid screening of COVID-19 cases with the latest advancements in medical imaging diagnostics.

Diagnostic advancements in computer vision has paved way for many innovative AI solutions to detect abnormal images in medical diagnosis. These innovative AI solutions have shown advancements in the chest radiology diagnostics. With these advancements in place, many teleradiology companies working on various imaging techniques have taken a step towards COVID detection by implementing the same image diagnosis approach used to detect various other infections in the chest radiology.

An AI based solution using Deep learning algorithm can be used on the chest X-rays to detect the COVID-19 cases. **U4RAD** innovative AI based solution using Deep learning algorithm to detect the COVID-19 is called **U4COVID.** The U4COVID solution is the technological breakthrough specifically designed and created for rapid mass screening of possible COVID-19 cases with higher accuracy than thermal screening that is currently being implemented.

Research Questions

- What are the different features that help to detect various viral diseases including COVID-19 in Chest X-ray images?
- What are the features and their weightage that define COVID-19 and its level of suspicion in chest x-rays images?
- What is the feasibility to develop a ML model to detect COVID-19 through chest x-rays?

Chapter 3. Review of Literature

Chest Radiography is currently one of the most important methods to detect COVID-19. This is considered to be the fast and inexpensive method available for COVID diagnosis in scare resource regions. Pandemic crisis and shortage of radiologists to interpret the images is momentarily a critical challenge.

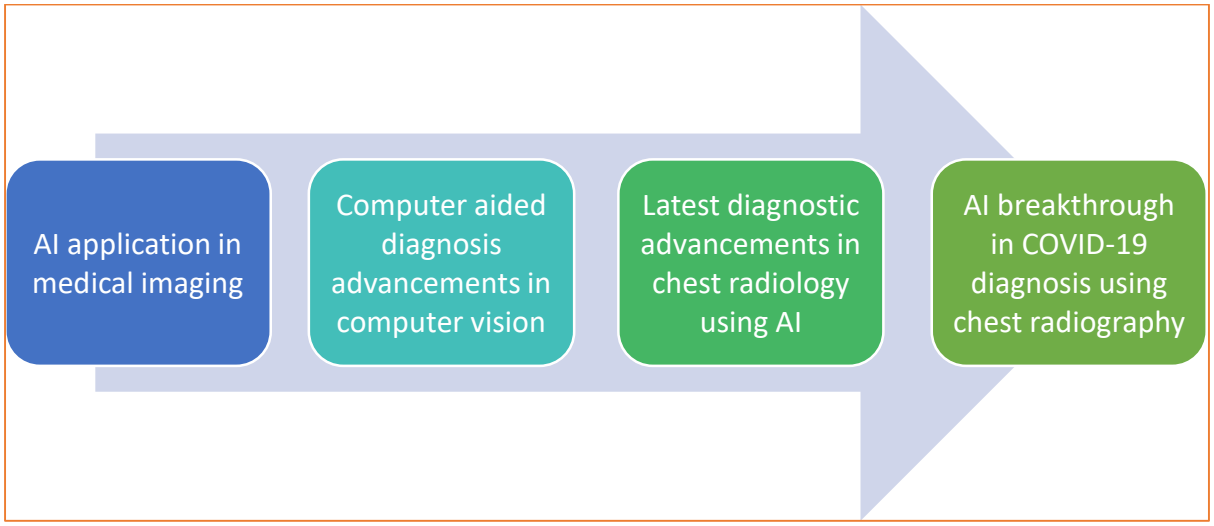

Figure 3. 1: Literature Review area of progress

Many researchers have done studies and proposed AI interpretation models to detect COVID-19 to address the challenge. *Linda Wang, Zhong Qiu Lin and Alexander Wong (2020)* together developed a deep convolutional neural network design called COVID-Net to detect COVID-19 cases from Chest X-Ray images. This solution is tested and validated on its detections based on relevant information rather than erroneous information. COVID-Net has exhibited sensitivity of 91% in COVID-19 detection and of 95% in detecting Normal images. This AI system is available in open source format to researchers and citizens alike to encourage development of high accurate solutions.

Behold.ai has developed a Red dot algorithm to detect COVID-19 cases. The algorithm is also used to detect Pneumonia cases instantly. This algorithm was trained with more than 30000

images, reviewed and reported by consultant radiologists. Red dot algorithm has exhibited sensitivity of 85% for COVID-19 cases. [*behold.ai, 2020*]

Lunit, a medical AI software company, pioneer in AI powered solutions to analyse chest X-ray images, have developed a Lunit INSIGHT CXR system to detect coronavirus-related pneumonia by finding the consolidations in the x-ray images. AI system for chest X-ray analysis, developed by Lunit, can detect 10 different findings including lung nodule, consolidations and others with 97-99 % accuracy.

Lunit, has released special version of AI solution to detect coronavirus related consolidation in Chest X-ray images and made publicly available for free usage. Lunit Software is currently installed and been in use at coronavirus care centers in South Korea. [*Ki Hwan Kim, 2020*]

CAD4COVID is a deep learning solution, to detect COVID-19 characteristics on chest radiography developed by Thirona and Delft imaging. CAD4COVID was built on the core of CAD4TB, an AI solution used to screen TB cases. The system has exhibited a sensitivity of 85% and specificity of 61%. This AI system was compared with six independent radiologists and evaluated using AUC. [*Thirona, Delft imaging, 2020*]

A COVID-19 detection model using deep learning algorithm was developed to provide fast and reliable screening. The model is mainly developed to detect COVID-19 and non COVID-19 cases through classification and anomaly detection methods. This AI system has shown a sensitivity of 96% for COVID cases and 70.65% for non COVID-19 cases. [*Jianpeng Zhang, Yutong Xie, Yi Li3, Chunhua Shen, and Yong Xia, 2020*]

A deep convolutional neural network architecture called Decompose, Transfer and Compose (DeTraC) was used to develop a model to classify and detect COVID-19 cases. DeTraC architecture was used to train the model of feature detection and to deal any irregularities identified in the Chest radiography images and correctly detect the abnormalities. DeTraC has

achieved a high accuracy of 95% in the detection of COVID-19 cases. [*Asmaa Abbas, Mohammed M. Abdelsamea, Mohamed Medhat Gaber, 2020*]

COVIDX-Net, a new deep learning framework was developed by combining seven existing deep learning algorithms to automatically diagnose the COVID-19 cases. AI system used the available best image classifier algorithms to train the new model producing a tuned deep learning classifier. The proposed framework is mainly used to classify positive and negative COVID-19 cases based on seven classifiers. COVIDX-Net tested the accuracy of all the seven classifiers and identified VGG19 and DenseNet as best classifiers exhibiting similar performance of automated COVIDX-Net model. [*Ezz El-Din Hemdan, Marwa A. Shouman, Mohamed Esmail Karar, 2020*]

Based on the various articles reviewed, the automated systems are mostly restricted to the usage of Classification and Detection techniques for medical imaging. A very limited models have proposed the usage of Segmentation techniques as part of medical imaging analysis. Segmentation involves complex algorithms to develop a model. Segmentation algorithm can help in the detecting abnormalities in the Chest X-ray image by identifying the exact location of the abnormality. This identification of abnormality can help in better diagnosis and to classify the diagnosis.

Chapter 4. Methodology

Data Collection

Secondary research was done to understand the usage of Machine Learning with respect to medical imaging for diagnosis. Related news articles and published articles were studied to understand how machine learning is used in detecting various infectious diseases using Chest Radiography. Further, more articles were referred to understand the how the computer aided diagnosis was utilized in COVID-19 detection. In-depth study on what parameters and steps are involved in training machine learning and their sequential association to improve the accuracy of the diagnosis was also done.

Various search terms of the study like Chest Radiology, Machine Learning, Deep Learning, Artificial Intelligence, Convolutional Neural Networks and COVID-19 detection were included as part of the secondary research. These terms were mainly searched through different databases like PubMed, Google Scholar, Pro Quest and IEE Xplore and number of articles were studies and analyzed.

All the published papers, research articles, news articles and reports which includes the usage of AI techniques for anomaly detection in the Chest X-ray images were included in the selection criteria. Articles and papers that studied CT images for anomaly detection were excluded from the selection criteria. Any paper that does not include AI techniques utilization for abnormality detection were also excluded.

With basic understanding of working of Machine Learning training for Auto diagnosis using Chest radiography, direct interaction with a group of Radiologists was done to have better understanding of the diagnosis procedure of the COVID-19 using Chest radiography.

In-depth interviews were conducted with Radiologists and Data scientists for better clarification on features involved for COVID-19 detection. These features are then classified into five categories to detect the level of suspicion of COVID-19. This also includes the sequential order of the various parameters that are used for training and the extent of which each parameter is given importance during the training was discussed.

Data Analysis and representation

Data collected through literature research included various infection types that are diagnosed through chest x-rays. Each infection related is separately studied and analyzed. Features and the process of identifying the features and their usage in infection detection was listed and represented in tabular format. Each diagnosis has different features list and process of detecting the disease and these are listed in the format.

Further, various papers on COVID-19 infection detection were studied and the features and the process used for COVID detection in the chest radiology images were also listed. Feature extraction includes all the classifications involved and the various abnormalities identified in the process of COVID detection.

Data collected from in-depth interviews was analyzed to form a chart with various classifications and features intact. This chart also represents the weightage of each feature of the classification possesses in the suspicion of COVID-19. These feature weightage and classifications helps in the accurate detection and identification of level of suspicion of COVID-19.

Based on all the tables, charts and information gathered and their analysis, a pictorial representation of the machine learning framework was designed. This pictorial representation shows the sequential steps involved in the COVID-19 detection using the chest x-ray images from the data collection to the diagnosis results display.

Chapter 5. Results

a. Various Applications of ML for CRX:

Chest Radiography is considered a first line tool to diagnose various thoracic diseases. CR is considered to be most frequently and widely used examination today. With COVID-19 crisis, the usage of CR has increased due to its availability and accessibility compared to other tests. Therefore, researchers are focusing on the computer-sided diagnosis for CRs. Various CAD systems have achieved successful results for various diseases like pulmonary modules, pulmonary tuberculosis, pneumonia and pneumothorax. Various machine learning models using various parameters are used based on the output needed.

Few such models and different parameters used for various disease detection is listed below:

- **Pneumonia**:

  Detection of Pneumonia and its classification in to viral and bacterial pneumonia involved two step process. The first parameter is identification of left and right lung region as two segments. Later each segment is identified for the abnormality. For bacterial pneumonia, white inflammatory fluid is identified in the alveoli as compared to normal chest radiography image. While for viral pneumonia, a white spot on the left most part of the chest or a diffuse interstitial pattern is used for detection in the lungs. For this study, area under curve (AUC) parameter is used to classify the pneumonia type on the basis of amount of white fluid infected the chest.

- **Pneumothorax:**

  Pneumothorax characteristics can include curved contour and regions against chest wall and ribs and might overlap as well. As a result, it is important to identify the global boundary region of the image and then proceed with identification of abnormal regions locally, following a two-step process for the region and abnormality identification and

then a Support Vector Machine (SVM) algorithm is applied to determine the classification of pneumothorax as normal or abnormal lung.

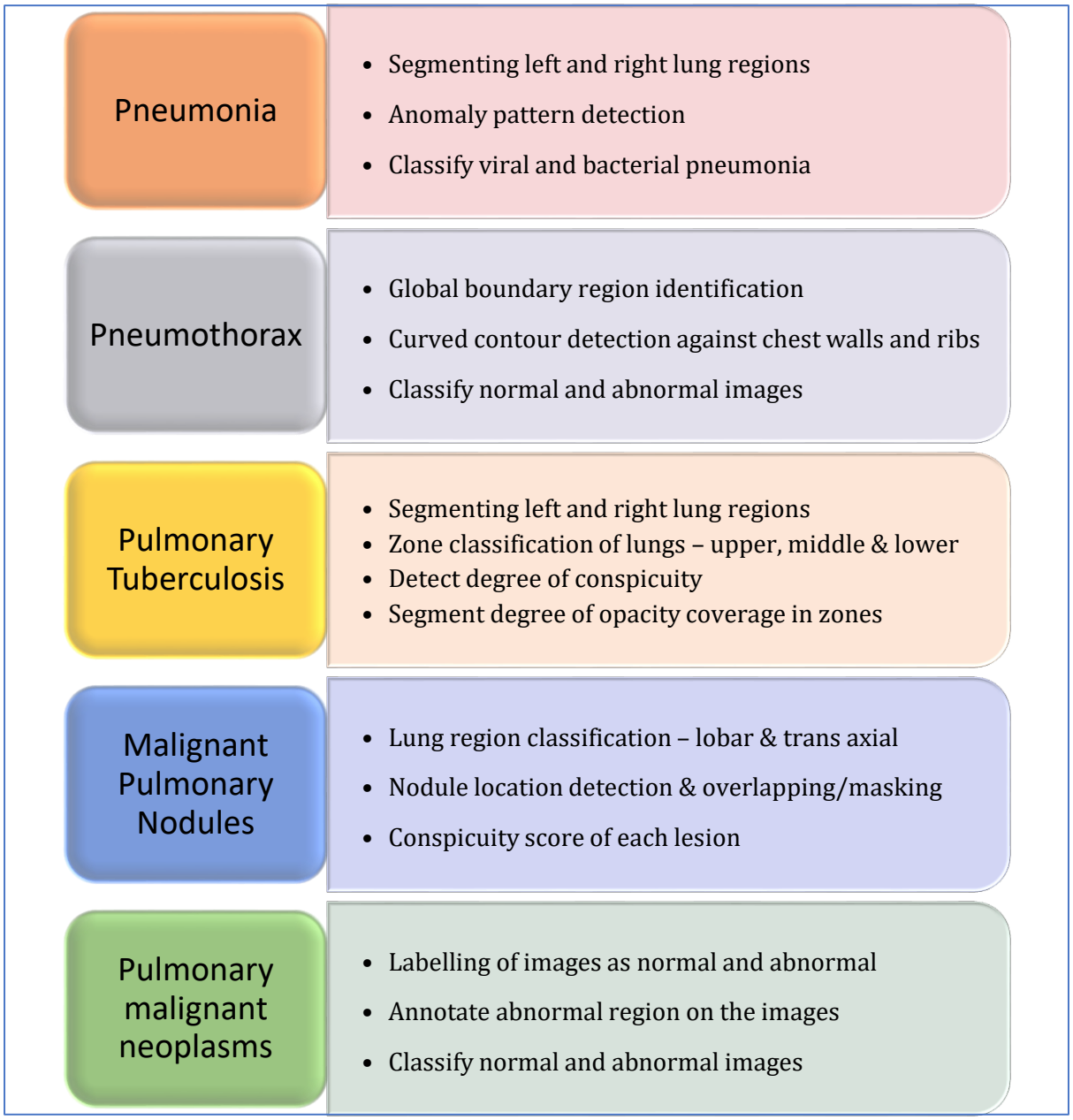

Figure 5. 1: Differentiating features for AI detection

- **Pulmonary Tuberculosis:**

  Machine Learning techniques is used to detect the degree of conspicuity of tuberculosis i.e., the degree of pulmonary parenchymal involvement by TB. To determine this, the image is segmented into right and left lungs and then they are divided into three zones

namely upper, middle and lower. After region division, the degree of opacity coverage in these zones is identified, based on which the degree of conspicuity is defined as subtle, intermediate and readily apparent.

- **Malignant Pulmonary Nodules**:

  Detection of pulmonary nodule in the Chest Radiography involved various parameters. Radiologists annotated the location of the nodules in the images. Parameters considered to identify nodules are:

  - lobar distribution – Right upper, Right middle, Right lower, Left upper, Left lower
  - Trans axial Location – Medial half of lung, Lateral half of lung
  - Craniocaudal location
  - Overlapping or masking

  Conspicuity of each lesion on the CXR is given a score from 1to 5 based on the visibility of the lesion. Pixel-level annotation was used for the detection of the lesion in the image.

- **Pulmonary malignant neoplasms:**

  Study to diagnose malignant neoplasms involve data curation process which is a two-step process. First step is the image labelling. This is performed to categorize normal and abnormal CRs correctly. Second step involves the image annotation by the radiologists. In this process, every abnormal labelled image are marked for the exact location of each abnormal finding on the CR. Validation of this study was done based on AUC parameter to classify normal and abnormal findings.

b. COVID-19 Detection using CRX:

Development, test and validation of any CNN model requires a dataset with large number of COVID-19 positive case datasets. These huge datasets required for the study are not easily accessible and are unavailable for open access. But with the need for faster interpretation of radiography images in COVID crisis, COVID datasets with annotations were made open source. This helped many researchers to conduct various studies on COVID-19 datasets and explore convolutional neural networks for computer vision tasks.

With the huge need of automated system diagnosis and open source data sets, Machine Learning models have been proposed to detect COVID-19 and other abnormalities over COVID-19 using Chest Radiography images. Many models are validated and have exhibited good accuracy results. Few algorithms even declared to be more effective than in-person radiologists in detecting or diagnosing the abnormalities. With the huge demand of CAD systems and with huge opportunities available many studies on COVID-19 using Chest Radiography images are being brought to the market at different stages.

The most commonly used algorithm for COVID-19 detection is the classification of CRX images as either COVID positive or COVID negative. It uses a basic technique of Machine Learning model called, classification. It involves the usage of the dataset with both COVID-19 positive confirmed CR images and normal CR images. These images are labelled by the radiologists as normal and abnormal. This helps to study the pattern difference in the normal and abnormal images. These images with the labels are fed to the system for training. Based on this training, system learns to classify the image as either normal or abnormal and gives the result as positive or negative with a confidence level. The results of the tasks are presented with a specific statistical method (metrics). Once presented, results can be evaluated by using area under receiver operating characteristic curve (AUC).

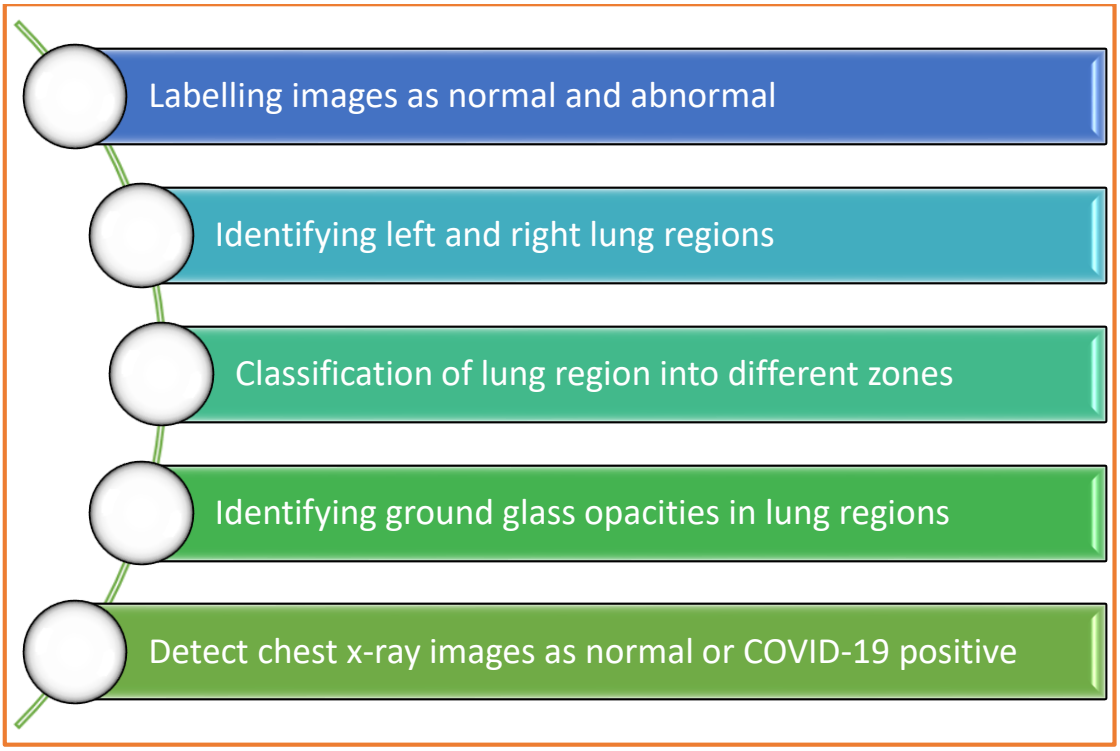

Figure 5. 2: COVID-19 differentiating features in CXR

c. Differentiating Features of COVID-19 and their Classification

Various differentiating features of COVID-19 in Chest x-ray images were identified through the Radiologists and Data scientists' interviews. These features helps in the identifying and differentiating COVID-19 from other infections in chest x-ray images. These features are then classified into five types based on side of the body part, Distribution of anomalies in the lung regions, presence of GGO's, number of GGO's identified and level of COVID-19 suspicion as per above features. The classification of features help to identify the level of suspicion of COVID-19 presence in the chest x-ray image. The below image describes the classification of the features and their contribution to detect the level of suspicion. The Level of suspicion o fCOVID-19 is high at the left extreme features compared to right extreme as described in the figure below.

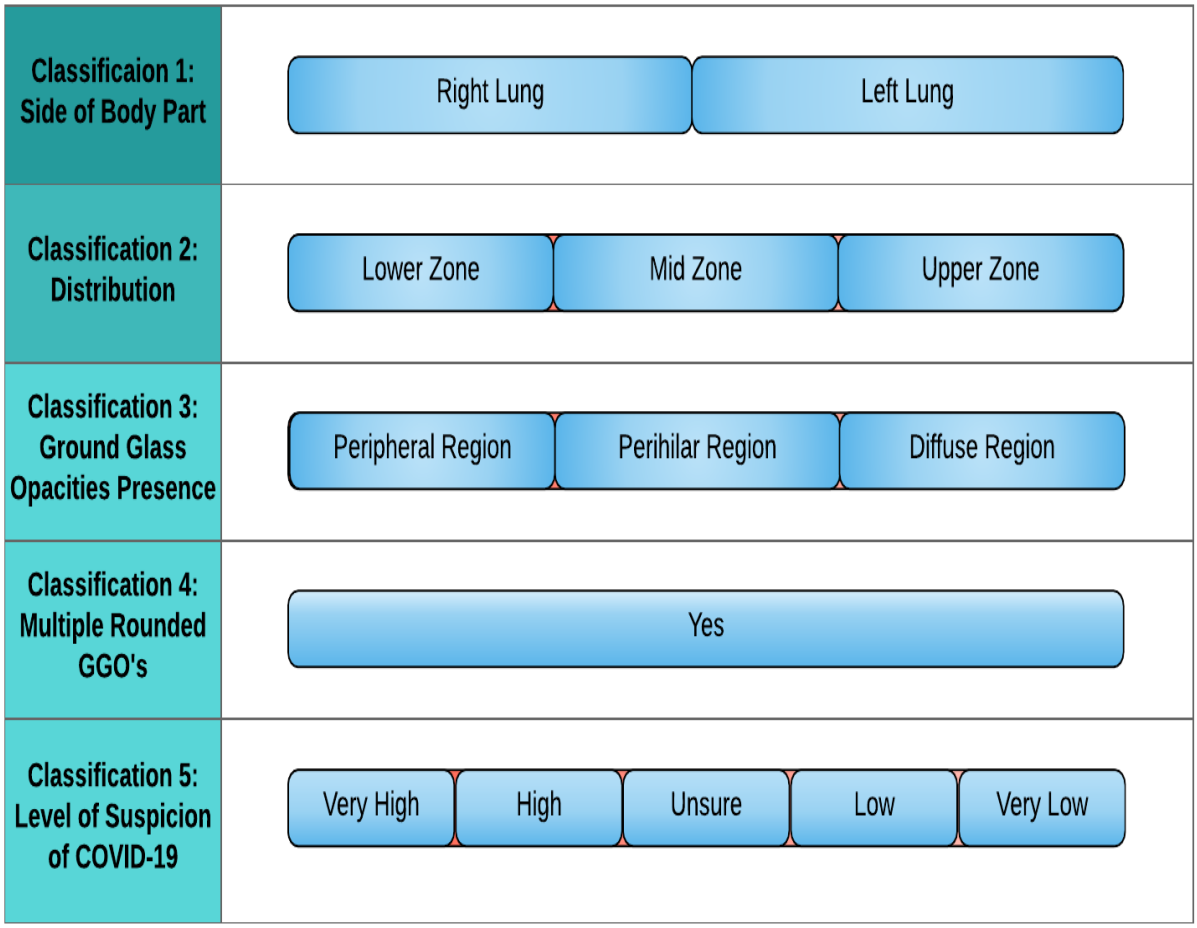

Figure 5. 3: COVID-19 features and their classification

First classification of Body part is used to have more detailed information on the further classifications of the features. Ground Glass Opacities are considered to be the anomaly that are identified in the COVID suspects. The presence of GGO's in Lower zone lung distribution and in peripheral region increases the level of suspicion of COVID. Whereas, GGO's presence in diffuse region is considered less suspicious of COVID. Multiple GGO's presence in any region or zone of the lungs leads of high level of COVID suspicion in the suspects. Based on these classification distribution, level of COVID suspicion is detected in the chest radiology images. Based on the level of suspicion, the suspect can be considered for further screening or any further treatment without any delay, thus reducing the risk of spread of the infection and increase the containment.

d. ML Framework for COVID-19 Detection

Based on the research on various parameters and features identification for anomaly detection in chest x-ray, and their utilization in designing the machine learning framework to detect COVID-19 resulted in a model framework. The framework involves a series of steps from initial x-ray image feeding to the result output. The model involves the input of large dataset for accurate results. Once data set, a collection of both normal and abnormal x-ray images are collected, framework involves a series of steps to be followed to detect COVID-19 and give the result.

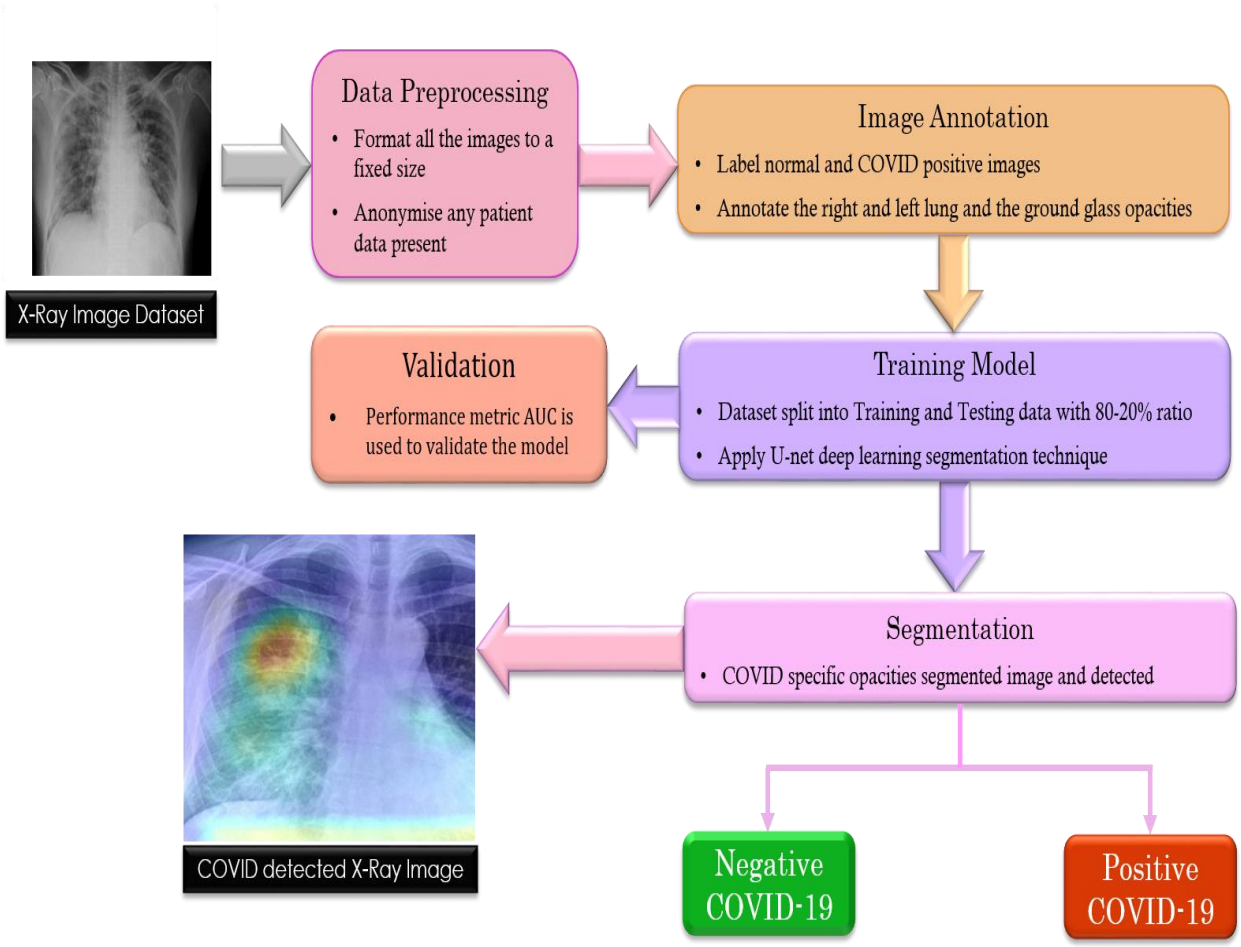

Figure 5. 4: ML Framework to detect COVID-19

i. **Data Preprocessing:**

This step involves, processing of all the collected images into a simple and similar format like same size, resolution and maintain it across all the images of the dataset. It also includes to anonymize the patient data and any other sensitive or confidential information from the dataset images.

ii. **Image Annotation:**

All the images are annotated by the radiologists who have very good knowledge and expertise in radiography. Annotation of images is done based on all the features that are identified during the research. Each features requires the annotation in the images to accurately detect the anomalies in the images. Every image is labelled as normal or abnormal for differentiation.

iii. **Model Training:**

Once, images are labelled and annotated by the radiologists, they are classified as training and test data sets, and training set is fed to the AI model for training. After the training, model is tested with the test data to verify the results and accuracy. The model is again trained with the dataset and tested for accurate detection of diagnosis. This process is repeated till the required accuracy of the model is obtained.

iv. **Validation:**

Once the model is developed, it involves the validation on the dataset training and testing based on the results. The results are plotted graphically and validated for true positives and true negatives using the AUC curve. Based on the representation of the performance metric, the model is validated and further action points are noted.

v. Segmentation:

Based on the training provided to the model, COVID-19 anomalies are detected with the help of segmentation technique. This involves the highlighting the regions and the anomalies of the infection on the images. Every segmentation can be colour coded to differentiate anomalies with the regions and zones and lungs in the x-ray images.

vi. Output:

Based on the dataset training of the model and segmentation algorithm, whenever a new image is fed to the model, it analyses and gives the result as either Positive COVID-19 or Negative COVID-19. It also presents a marked chest x-ray that is fed for detection with the anomalies highlighted in the image thus displaying the position of ground glass opacities presence and their presence in the radiology images.

Conclusion:

Coronavirus is one of the major pathogens that affects the human respiratory system primarily. The world has experienced outbreaks due to coronavirus in the past including Middle-East respiratory syndrome and severe acute respiratory syndrome caused by MERS-CoV and SARS-CoV strains of coronavirus. The recent COVID-19 infections first presented in patients with pneumonia like symptoms and acute respiratory distress syndrome. The WHO declared COVID-19 as a pandemic at a global level on February 11, 2020. It has caused major havoc in the healthcare systems globally. It the major concern for healthcare and global governments to tackle at this given point in time.

The primary concern of global healthcare organizations and national healthcare institutions is increasing the testing capacity in an accurate and a rapid manner in order to detect the infection at the earliest. An increase in the volume of testing will help faster diagnoses, which in turn will help to reduce or limit the spread. Due to scarce resources distribution and time taking process of sample testing and test result reception, an alternative feasible method of using chest x-ray is adopted in every remote healthcare center.

Detection through chest x-rays for possible COVID-19 has become a major method for diagnosis. Due to its high availability and low cost screening, this method was adopted at a very fast pace. Machine learning for this purpose has been a point of breakthrough for the healthcare workers to diagnose COVID-19 accurately and effectively. The diagnosis through chest x-rays have been used as first-line diagnostic technique due to minimal installation requirements.

Many Teleradiology companies are taking steps towards rapid COVID detection using AI in countries like US, UK, China and Korea. An opportunity identified by U4RAD is an innovative AI based solution using Deep learning algorithm to detect the COVID-19 called U4COVID.

U4COVID detects the COVID-19 infection and its level of suspicion of the infection using the Chest x-ray images, nad classifies the image as either positive COVID-19 or Negative COVID-19. Detection of level of suspicion of COVID-19 based on the feature and classification training to the system is the unique and differentiating feature of U4COVID.

U4COVID solution is a technological breakthrough specifically designed and created for the rapid mass screening of possible COVID -19 cases with a higher degree of sensitivity & accuracy than thermal scanning that is currently being widely implemented.

The solution revolves around an Augmented Intelligence (AI) cloud based application that reads low dose, digital X-rays. Stringent quality control measures in conjunction with a radiologist's supervised reporting. It ensures not just a higher accuracy of detection, but also eliminates machine learning errors.

U4COVID can be trained with other datasets to differentiate and diagnose various lung infections from chest x-rays. The feature detection of various infectious lung diseases in chest x-ray along with COVID-19 detection would help in faster, better and accurate diagnosis.

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