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COVID-19 Detection using Deep Learning Based Approaches

A thesis submitted in partial fulfillment of the requirements for the degree

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by

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Dedications

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Abbreviations list

AI	Artificial Intelligence
ML	Machine Learning
DL	Deep Learning
MRI	Magnetic Resonance Imaging
CT	Computed Tomography
CAT	Computed Axial Tomography
PET	Positron Emission Tomography
CNN	Convolutional Neural Network
RNN	Recurrent Neural Network
DNN	Deep Neural Network
DBN	Deep Belief Networks
KNN	K-Nearest Neighbor
SVM	Support Vector Machines
SAE	Stacked AutoEncoder
PNG	Portable Network Graphics
DICOM	Digital Imaging and Communications in Medicine
TIFF	Tagged Image File Format
GPU	Graphics Processing Unit
CPU	Central processing unit
TPU	Tensor Processing Unit
API	Application Programming Interface

General introduction

The ongoing pandemic of Covid-19 is causing a serious global crisis now. With over 12 million COVID19 positive cases around the world and an important number of deaths too . This virus poses a huge threat towards humanity nowadays. At present, tests for detecting the presence of COVID19 are performed based on reverse transcription-polymerase chain reaction (RT-PCR), which usually takes from four to six hours to give results. In addition, the availability of testing kits poses another problem in terms of efficient detection of this virus.

Covid-19 can also be detected from chest CT scans across multifocal bilateral patchy ground-glass opacities (GGOs) or consolidation with interlobular septal and vascular thickening, mostly in the peripheral fields of the lungs.

The solutions up above are realizable but still not efficient because all of them need manual detection by doctors, in addition this process is a tedious task, tiring, likely to involve human error and the most important thing is that it takes so much time to know the great inflation in the number of infected people, time became the main factor in limiting the spread of Covid-19.

Our work aims to solve this time problem by building a Deep Learning model that automatically detects Covid-19 in a CT scan in fractions of a second.

The domain of medical imaging has seen major changes in last years, due to the big advancements in the field of Deep Learning and Computer Vision. During the current COVID19 pandemic, successful application of Deep Learning based approaches can be efficient, especially with respect to fast testing and detection of the disease and this is exactly what our project is aiming.

Our dissertation is organized as follows:

- **Chapter 1:** COVID-19 and Medical Imaging.

  In this chapter, we will be covering some medical basics, after that we define Coronavirus, when and how it all started, and we will also cover medical imaging and its types.

- **Chapter 2:** Deep Learning.

  In this chapter, we will talk about some basics like Artificial Intelligence passing after that to Machine Learning, and some of its types, Finale we will have a close look on Deep Learning.

- **Chapter 3:** Diseases detection using Deep Learning based on medical images.

  In this chapter, we will be talking of some common algorithms used for image processing and diseases detection. After that, we will strong our knowledge, by mentioning some related works as well.

- **Chapter 4:** Materials and Methods.

  This chapter will be divided into two sections, In the first section we will talk about dataset we will use, mentioning all its details. After that we pass to the methods section, where we will talk about our proposed models.

- **Chapter 5:** Implementation and Tests.

  In this chapter, we will implement our proposed models and discuss the results obtained.

Finally, we close this work with a general conclusion.

Chapter 1

Covid-19 and medical imaging

1.1 Introduction

In order to detect whether a patient is infected with Covid-19 or not, using his medical images, we first need to take a basic idea of two important points Covid-19 and Medical imaging.

In this chapter, we will be covering some medical basics, after that we define Corona Virus, when and how it all started, having also some details of infection, transmission and symptoms of this last. Finally, we will be covering medical imaging and its types, adding to it some of its modalities and benign uses.

1.2 Basic Knowledge

In this section, we will be covering the basics of what is called Virus, after that we will be seeing some of its characteristics.

1.2.1 Virus

As a start, a Virus is a microscopic parasite with a diameter of less than 200 nanometers (nm), that is generally much smaller than a bacterium, it cannot grow or reproduce apart from a living cell. This last invades living cells and uses their chemical machinery to keep itself alive and to replicate itself [1].

Viruses cause many common human infections and are also responsible for a number of rare diseases [1].

Note: Viruses can infect animals, plans, and even other microorganisms not only human beings.

1.2.2 Characteristics of a virus

Origin

Viruses may have come to light from mobile genetic elements that gained the ability to move between cells. They may be descendants of previously free-living organisms that adapted a parasitic replication strategy [2].

Structure

Viruses display a wide diversity of shapes and sizes, but eventually each virus is a nuclear acid (RNA or DNA) surrounded by a coating, referred to as an envelope or capsid [2].

Replication

Viruses cannot replicate on their own, but rather depend on their host cell's protein synthesis pathways to reproduce. This typically occurs by the virus inserting its genetic material in host cells, co-opting the proteins to create viral replicates, until the cell bursts from the high volume of new viral particles [3].

Basically the replication cycle goes through five basic stages. These include **attachment, penetration, uncoating, replication, assembly, and virion release** [3].

Transmission

Viral transmission is the process by which viruses spread between hosts. It includes spread to members of the same host species or spread to different species in the case of viruses that can cross species barriers [4].

Viruses may transmit from person to person, and from mother to child during pregnancy or delivery. They can spread through:

- Touch.
- Exchanges of saliva, coughing, or sneezing.

- Sexual contact.
- Contaminated food or water.
- Insects that carry them from one person to another.

Epidemiology is the study of how diseases are transmitted through a population. Epidemiologists perform descriptive or analytic studies to characterize the chain of viral infection throughout a population and design control measures to interrupt it [4].

1.3 Viral diseases

We cannot talk about the reproduction and transmission of viruses without mentioning some of what these viruses can cause, after a period known as the incubation period, symptoms may begin to appear as a result of diseases that afflicted the human body due to the huge spread of the virus [5].

Some of human diseases caused by viruses. These include:

- The common cold and different types of flu.
- Hepatitis (A, B, C).
- Ebola and Hanta fever.
- HIV, the virus that causes AIDS.
- COVID-19 (Recently reappeared – December 2019).

1.4 COVID-19

1.4.1 Definition

SARS-CoV-2, commonly known as covid-19 are frequent RNA viruses of the Coronaviridae family, which are responsible for digestive and respiratory infections in humans and animals. The virus owes its name to the appearance of its viral particles, bearing growths that resemble a crown [6].

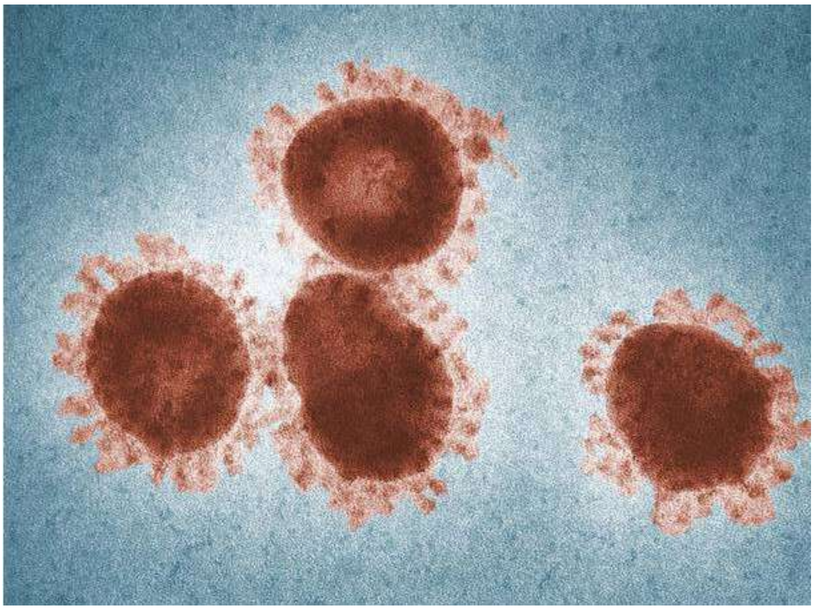

Figure 1.1: COVID-19 close-up.

1.4.2 How did it start?

The disease appears to have started from Wuhan seafood market where some wild animals are traded illegally like bats and snakes, Wuhan is a city in Eastern China with a population of over 11 million [6].

Coronaviruses are known to jump from animals to humans, so it's thought that the first people infected with the disease (a group made up of stallholders from the seafood market) took it from contact with animals [6].

The animal source of Covid-19 is still unknown, although there are some strong contenders. A team of virologists at the Wuhan Institute for Virology released a detailed paper showing that covid-19 genetic makeup is 96% identical to that of a coronavirus found in bats [6].

The Wuhan seafood market was shut down for inspection and cleaning on January 1, but by then Covid-19 was already starting to spread beyond the market. On January 21, the World Health Organization Western Pacific office said that the disease was also being transmitted between humans after the infection of a medical by the same virus [6].

1.4.3 Infection and transmission

According to the world health organization[1] people can catch COVID-19 from others who have the virus. The disease spreads primarily from person to person through small droplets from the nose or mouth, which are expelled when a person with COVID-19 or have symptoms such as fever or tiredness, coughs, sneezes, or speaks.

These droplets are relatively heavy, do not travel far and quickly sink to the ground. People can catch COVID-19 if they breathe in these droplets from a person infected with the virus. This is why it is important to stay at least 1 meter away from others. These droplets can land on objects and surfaces around the person such as tables, doorknobs and handrails. People can become infected by touching these objects or surfaces, then touching their eyes, nose or mouth. This is why it is important to wash hands regularly with soap and water or clean with alcohol-based hand rub.

Many people with COVID-19 experience only mild symptoms. This is particularly true in the early stages of the disease. It is possible to catch COVID-19 from someone who has just a mild cough and does not feel ill.

Some reports have indicated that people with no symptoms can transmit the virus. It is not yet known how often it happens.

1.4.4 Symptoms

The world health organization says that the most known symptoms of the virus are:

- Fever.
- Dry cough.
- Tiredness.

There are other less common symptoms, these symptoms are usually mild and begin gradually. Such as:

- Aches and pains, headache.

[1] https://www.who.int/emergencies/diseases/novel-coronavirus-2019

- Sore throat.
- Diarrhea.
- Conjunctivitis, nasal congestion.
- Loss of taste or smell .
- Rash on skin or discoloration of fingers or toes.

Most people recover from the virus without needing hospital treatment, around one out of every five people who gets COVID-19 becomes seriously ill and develops difficulty breathing.

Older people, and those with medical problems like high blood pressure, heart and lung problems, diabetes, or cancer, are at higher risk of developing serious illness. However, anyone can catch COVID-19 and become seriously ill.

1.4.5 Statistics

Coronavirus is affecting 213 countries and territories around the world, these countries have reported in September 2019 a total of **32,246,238 confirmed cases** that originated from Wuhan, China, and a death toll of **984,177 deaths**.

In the same month **Algeria** has reported **50,400 coronavirus confirmed cases, 1,698 died and 35,428 have recovered**.

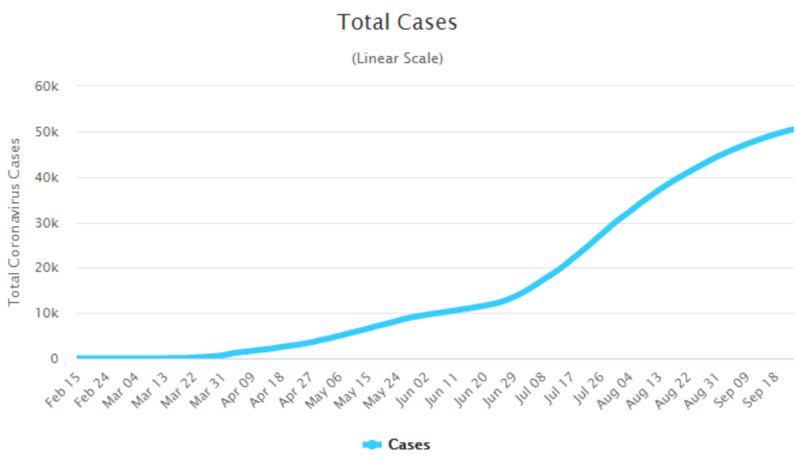

Figure 1.2: COVID-19 total cases in Algeria.

1.5 Medical Imaging

After we saw some basic information about Covid-19 ,now in this section we pass to Medical Imaging, some history, types and the important role it plays detection of many disease.

1.5.1 Definition

Medical imaging : is the technique and process of creating visual representations of internal structures of the body using several technologies such as electromagnetic radiation to produce medical images, these images are used for clinical analysis and medical intervention, as well as visual representation of the function of some organs or tissues [7].

A medical image can be defined as the materialization in the form of images the interior of human body or samples obtained by biopsy... etc. they are all produced by medical imaging technologies and techniques [7].

1.5.2 History

The term of medical imaging has seen the light **in 1895** with the invention of the x-ray by a German professor of physics, Wilhelm Rontgen accidentally discovers the ability to look through the skin and see the bones of the body while performing experiments on another project. While working with a cathode ray generator, he noticed an image that was left when the cathode rays came into contact with the vacuum tube. He performed the first X-ray on his wife's hand and even gave the technology the name we use today, calling this discovery "X" rays because they were unsure what exactly they were. This invention was eventually standardized by William Coolidge and his X-ray known as the "Coolidge tube" is what all modern X-ray machines are based from. The first X-rays required at least 11 minutes of exposure to produce a quality image. Now X-rays take only a few seconds and they use about 2% of the radiation amount seen in the early 20th century machines [8].

In the 1950's nuclear medicine started to utilized as a way to diagnose pathology in the body. This is based on having the patient infused with radionucleotides that are combined with pharmaceutical compounds that will find their way to organs or groups of cells that are more active than others are. These images are recorded by a gamma camera and can detect medical problems earlier than other tests [8].

During the 1960's sonar was beginning to be used after having been used for many years as a war time tool to detect enemy ships during World War Two, after that scientists discovered that sending sound waves into the body would bounce off the internal structures and then returned to the ultrasound machine to be reformatted into images for doctors to see. This allowed doctors to non-invasively search for tumors and other growths [8].

In 1970, the technology of Magnetic Resonance Imaging (MRI) was developed by Dr. Raymond Damadian, he discovers that different animal tissues emit different signals, as well as that cancerous tissues, take much longer to return the signal sent through them. This is the basics for magnetic resonance imaging. In 1977, Dr. Damadian created the first full-body MRI machine which he named the "Indomitable" [8].

1972 showed the first instance of Computed Tomography (CT scan). When Godfrey Hounsfield invented the CT machine. His theory is that you could see into an object if you took X-rays from different angles of the object through a machine that would appear as "slices" which could then be put together to form an image. With this idea, he formed the first "axial tomography" machine that we now know as the CT machine. In 1979, he received the Nobel Prize in Medicine and was later knighted by the British Royal Family [8].

Medical imaging has been well improved since the first x-rays over 125 years ago.

All of these machines have entered into the digital age and now updated with the latest technology available which mean much more accuracy and less need to exploratory surgery, this hopefully will lead to early diagnosis and better treatment options for many patients [8].

1.5.3 Types

There are many different types of medical imaging techniques, which use different technologies to produce images for different purposes. We will introduce the most common imaging techniques alongside with the techniques we already presented in history of medical imaging.

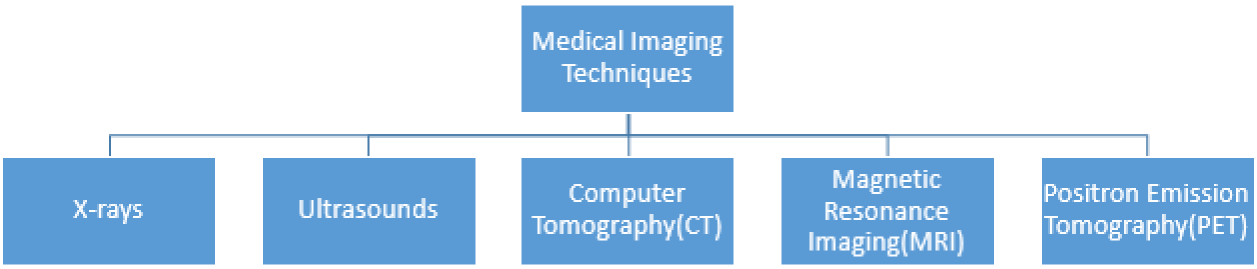

Figure 1.3: Medical imaging techniques.

1. X-Ray

   X-rays are one of the most common types of scans. According to the National Institute of Biomedical Imaging and Bio-engineering, An x-ray is a very common procedure used to get images of inside of the body. They are used to produce images of bones, usually to see if and where there are breaks (Figure 1.4); bone tumors can also be seen on x-rays. They can be used to guide surgeons as they are operating. The way it works is already explained in history of medical imaging, and these are some of its advantages and disadvantages [9].

Advantages

- The machine does not surround the whole body, so will not cause anxiety in people with claustrophobia which is a form of anxiety disorder, in which an irrational fear of having no escape or being closed-in can lead to a panic attack.
- The procedure only takes a few minutes.

Disadvantages

- Some contrast agents may cause unwanted side effects.
- X-rays expose the patient to unwanted radiation, which could potentially cause cancer, however the amount of radiation given off is minimal.

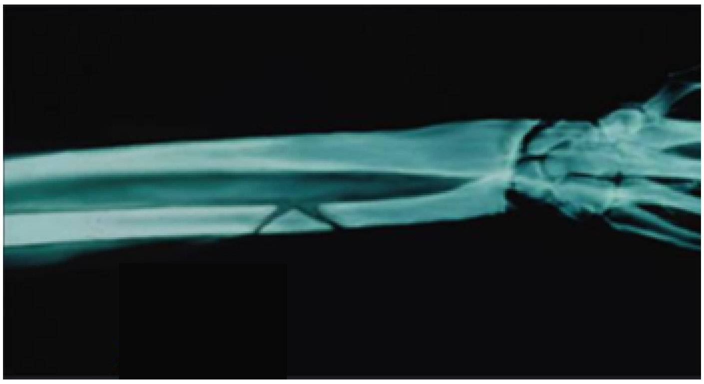

Figure 1.4: X-ray of a broken arm.

2. Ultrasounds

   Ultrasounds[2] uses high frequency waves to show what is inside the human body. It called sonogram too, it can produce images of unborn children in real time (Figure 1.5). it is used in diagnosis and during certain procedures for guiding surgeons too.the way it work is explained in history imaging part, as all technologies it has strength and week points, some of them are illustrated down below.

[2]https://www.radiologyinfo.org/en/info.cfm?pg=genus

Advantages

- Usually there are no after-effects of ultrasound scans. This means normal activity can be resumed straight after.
- The results are seen in real time, so there is no need to wait.

Disadvantages

- Some probe covers have latex, which can be a problem if the patient is allergic to latex.
- Endoscopic ultrasounds can cause a sore throat or bloating, or in extreme cases, internal bleeding.

Figure 1.5: Ultrasound image of an unborn baby.

3. Computer Tomography (CT)

   Or **computed axial tomography (CAT)**,CT scanners uses X-rays to produce cross-sectional images of the body.CT scans provide better clarity than conventional X-rays with more detailed images of the internal organs, bones, soft tissue and blood vessels within the body.it can visualize Upper body, such as the brain, neck, spine, chest too,it's way of working is well explained in history of medical imaging, They are used in diagnosis, for like finding tumors, or visualizing broken bones, finding more detail after another scan such as an x-ray, keeping up with any developing conditions, e.g. cancer. It is so important that when scanning children, the dose of radiation must be lowered than that used for adults to prevent an unreasonable dose of radiation for the necessary imaging to be obtained. As a consequence pediatric CT scanner were created [10][11].

As the previous techniques it have some advantages and disadvantages some are written down below [10][11].

Advantages

- CT scans don't take too much time,about 10 - 20 minutes.
- Results are so fast comparing to some other types of scans.
- CT scans are painless because they are non-invasive.

Disadvantages

- Exposure to radiation. The more patient's body is being scanned, the more it's been exposed to radiation.

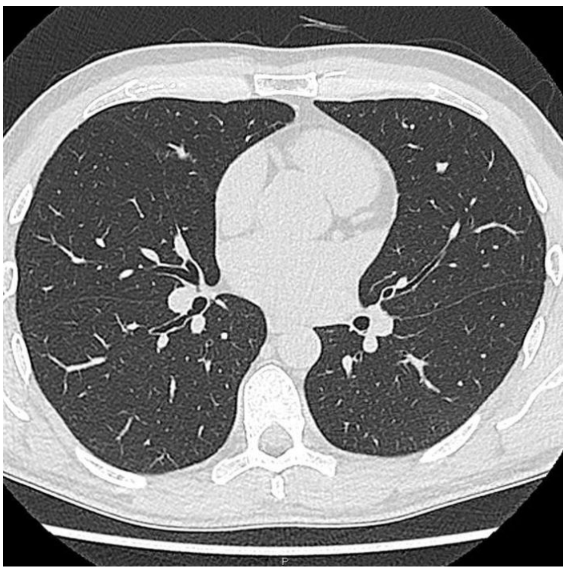

Figure 1.6: Example of a chest CT scan.

4. Magnetic Resonance Imaging (MRI)

   A magnetic resonance imaging scan[3], known as MRI scan, is an accurate(detailed) cross-sectional image of human body parts.uses a strong magnetic field and radio waves to generate images of the body that can't be seen well using X-rays or CT scans, i.e. it enables the view inside a joint or ligament to be seen, rather than just the outside.

   It is similar to a CT scan, but has a higher quality (Figure 1.7), so it is easier to see differences in tissues, as shown in the picture below.

   It can be used to get images of the brain and spinal cord, bones, the heart, blood vessels and different internal organs, it's used are similar to those of a CT scanner: diagnosis, getting more detail for treatment planning, and monitoring of ongoing treatment. It has also some advantages and disadvantages.

   Advantages

   - MRI scans are painless and safe also the magnetic fields and radio waves have no negative effects on the human body.
   - They don't use x-ray radiation exposure, so pregnant women and babies can use it if necessary non-invasive.

   Disadvantages

   - MRI scans enclose too much of the body, as consequence people with claustrophobia will feel uncomfortable.
   - Metal cannot go inside of an MRI scanner, so people with implants that contain metal such as pacemakers cannot use them.
   - MRI is too loud than a CT scanner. They can take too much time, from 15 to 90 minutes.

[3]https://orthoinfo.aaos.org/en/treatment/xrays-ct-scans-and-mris

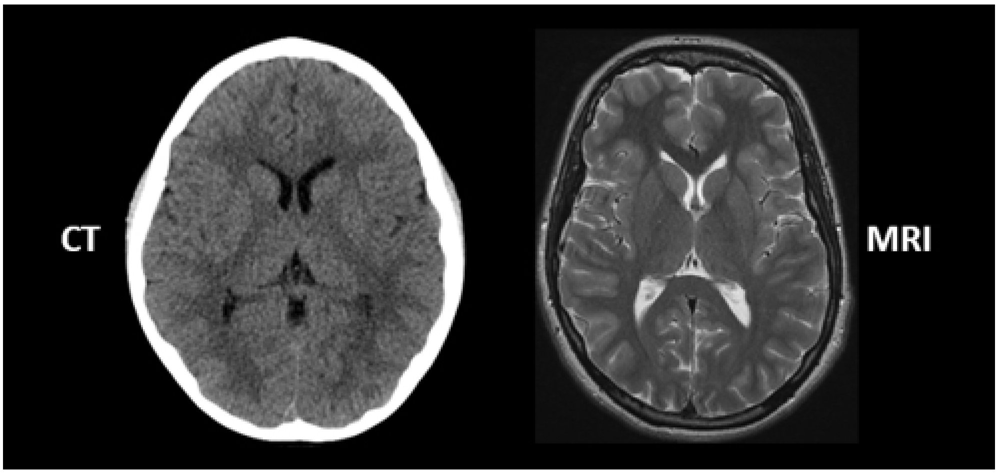

Figure 1.7: CT scan vs. MRI scan.

5. Positron Emission Tomography (PET)

   A **PET**[4] scan use small amounts of radioactive materials (radiopharmaceuticals), to look at specific organs if they're operating well. After the radiopharmaceutical is given, it goes to the specific organ to be examined. After that a device called a gamma camera detects the location of the radiopharmaceutical, and provides information about the examined organ function (Figure 1.8).it can be used to create a 3D image of the interior body. It can also be combined with CT and MRI scans to create a clearer image to show what is going on. It is used to detect the progress of cancer, and can be used to get high resolution images of the brain. They are mostly used in people who have already cancer because they can clearly show how far the cancer has spread or responded to treatments. They are also used in the planning of surgery. Dementia can also be diagnosed with a PET scan, as it can show if the brain's normal function is changed. The PET scan takes about 30 minutes.

   As the technologies illustrated up above this also have some strength and weakness points and these are some of this last.

[4]https://www.cancer.net/navigating-cancer-care/diagnosing-cancer/tests-and-procedures/positron-emission-tomography-and-computed-tomography-pet-ct-scans

Advantages

- The radiotracer fluorodeoxyglucose is similar to normal glucose, so the body treats them the same.
- The PET scan can reveal cell level metabolic changes which a CT or MRI cannot.

Disadvantages

- The exposure to radiation, which may provoke cancer, but the load is quite small and the radioactive tracer has a short half-life.
- Patients should avoid pregnant women and everyone who should not be exposed to radiation for a few hours after the scan.

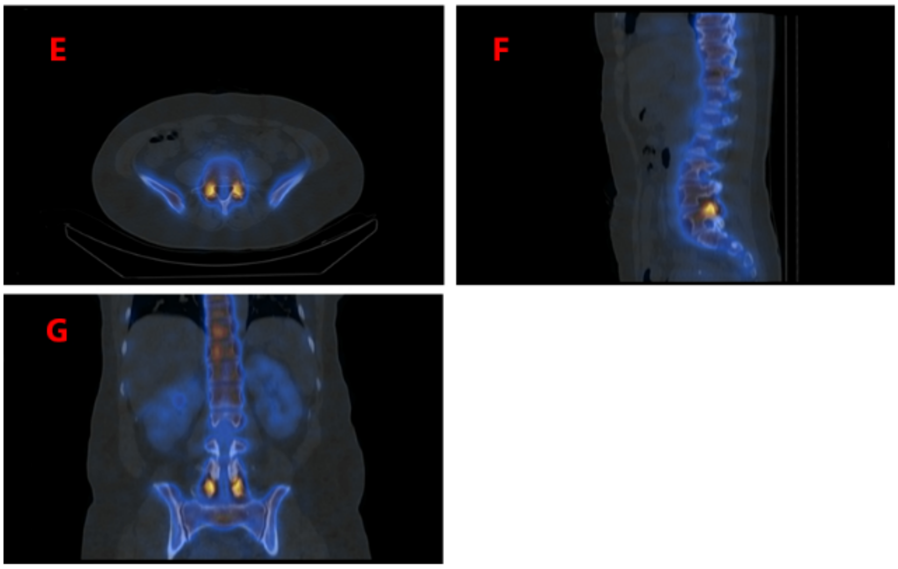

Figure 1.8: PET scan.

1.5.4 The importance of medical imaging

Medical imaging is a very important section in medical domain, it changed the face of the health care industry and granted for scientists more information about the human body [12].

For diagnosing a disease, doctors often order scans such as X-ray, CT scan, or MRI. Medical imaging is so important for confirming doctors' diagnosis. Medical imaging can also assist in decisions of treatment and future care of the illness. With the evolution of technology, medical imaging can let the doctor know of internal problems which normal external diagnostic couldn't detect. Medical imaging is necessary in following the progress of a sickness, it allow the doctor to see the efficacy of treatment then adjust it if required [12].

Ultrasound imaging is so important for expectant mothers. It gives obstetricians an improved picture of baby's health, ultrasound is used on other parts of the body like soft tissues of the neck and breasts... etc. It is also used as a guide for biopsies of soft tissues [12].

Surgeons use medical imaging as an aid in surgeries, for an example CT scans are used during surgeries to guide doctors across sensitive human internal parts [12].

Medical imaging is specifically helpful in detecting cancer, this disease requires very early detection (which is granted by medical imaging) to improve the chances of survival [12].

Medical imaging is the first step in put a stop to the spread of cancer by early detection .the early detection makes the healing or eliminating of cancer possible. All the technologies such as CT, MRI, PET, Ultrasound imaging and X-ray imaging are very important in the fight against cancer. After the diagnosis of this harmful illness, medical imaging is frequently used to track the progress of cancer treatment and showing the growth or disappearance of cancer signs [12].

Medical imaging has changed so many people's lives for the better, it's an important part of the health care world and an essential tool for doctors for the diagnostics, treatment, and prevention of disease such as cancer [12].

1.6 How to detect COVID-19 in chest CT scans

To date, According to the literature, the typical findings of chest CT images of individuals with COVID-19 are multifocal bilateral patchy ground-glass opacities (GGOs) or consolidation with interlobular septal and vascular thickening, mostly in the periph-eral fields of the lungs. The most common morphology of these opacities are patchy and round ones, followed by triangular and linear ones. CT findings can change as the disease progresses [13].

In the early stage, chest CT shows small lobular and sub-segmental patchy GGOs, interstitial changes, and thickening vascular lumens throughout as shown in Figure 1.9 – A [13].

In the progressive (after 3 days), the lesions gradually progress to multiple GGOs in the lungs, and some patients may have dense consolidation in the lobes as shown in Figure 1.9 – B [13].

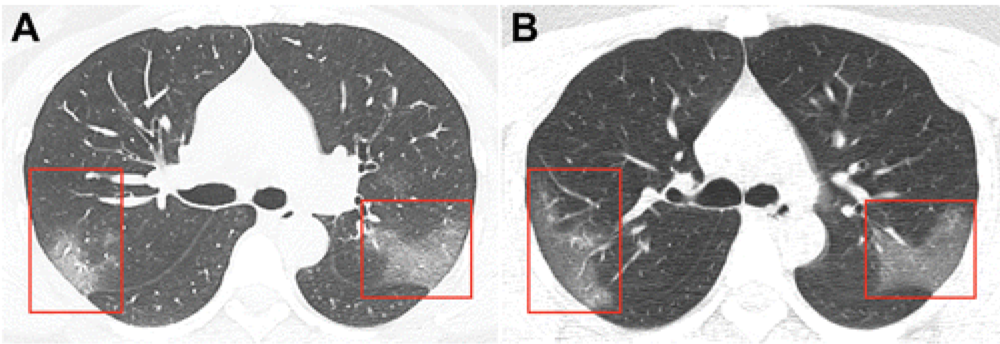

Figure 1.9: CT images showing the development of Coronavirus within 3 days.

1.7 Conclusion

We have devoted this chapter to the presentation of basic concepts like viruses, next we had a close look at the novel Coronavirus, after that we went through an important part of medicine which is medical imaging, we explained what is medical imaging, when and where it began, then some of its types and it's important role in health-care world exactly in preventing, diagnosing and treatment of dreadful diseases like cancer.

In order to detect Coronavirus from medical images, and automate this last, new methods must be introduced. Deep learning, which is an important point that literally has the lion's share.

In the next chapter we are going to present Machine Learning more in specific, Deep Learning (DL) and its different learning methods.

Chapter 2

Deep learning

2.1 Introduction

In order to develop an algorithm capable of automatizing the detection of COVID-19 using medical imaging, we need to introduce an important point, which is Deep Learning.

In this chapter, we will first talk about some basic things like Artificial Intelligence (AI), passing after that to Machine Learning, and some of its types, Finale we will see Deep Learning, giving some definitions, and we will also detail its different types below.

2.2 Machine Learning

2.2.1 Definition

Artificial intelligence[1] is often defined as the science of creating and programming computers capable of performing tasks that require intelligence when it needs to be done by a human being.

Machine learning (ML) is an application of artificial intelligence (AI) that provides systems the ability to automatically learn and improve from experience without being explicitly programmed. ML focuses on the development of computer programs that can access data and use it learn for themselves.

ML enables analysis of massive quantities of data. While it generally delivers faster,

[1] https://expertsystem.com/machinelearning- definition/

more accurate results in order to identify profitable opportunities or dangerous risks, it may also require additional time and resources to train it properly.

ML is one of the fields of study of artificial intelligence. **Deep learning** is a subset of machine learning, which uses the neural networks to analyze different factors with a structure that is similar to the human neural system.

2.2.2 Machine Learning types

As explained, machine learning algorithms have the ability to improve themselves through training. Today, ML algorithms are trained using three prominent methods. These are three types of machine learning: supervised learning, unsupervised learning, and reinforcement learning, as outlined in Figure 2.1.

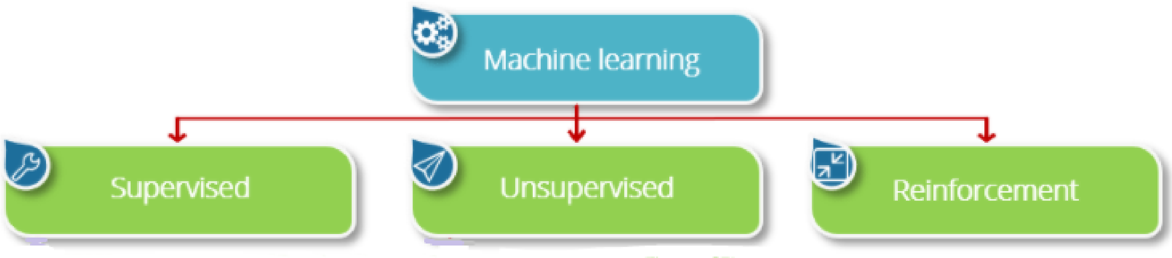

Figure 2.1: Types of ML.

1. **Supervised Learning:**

   It is the one, where you can consider the learning is guided by a teacher **(Train Me!)**. We have a dataset which acts as a teacher and its role is to train the model or the machine. Once the model gets trained it can start making a prediction or decision when new data is given to it (Figure 2.2) [14].

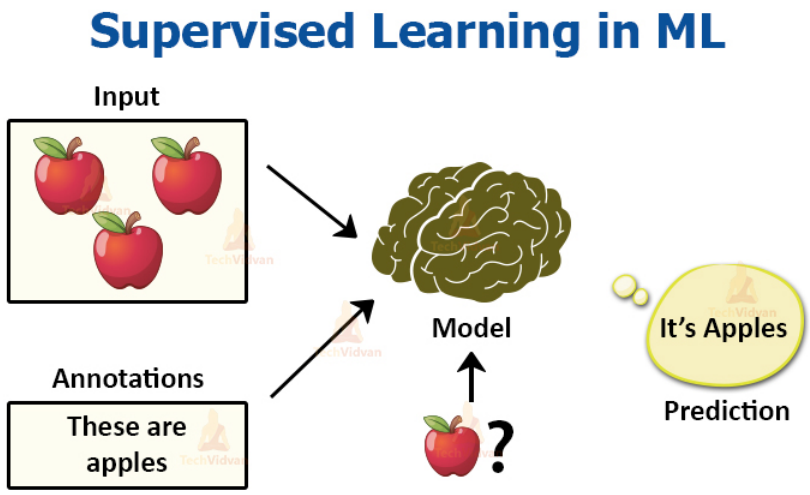

Figure 2.2: Example of Supervised Learning in ML.

2. **Unsupervised Learning:**

The model learns through observation and finds structures in the data. Once the model is given a dataset, it automatically finds patterns and relationships in the dataset by creating clusters in it **(I am self-sufficient in learning!)**. What it cannot do is add labels to the cluster, like it cannot say this a group of cats or dogs, but it will separate all the cats from dogs [14].

Suppose we presented images of cats, dogs to the model, so what it does, based on some patterns and relationships it creates clusters and divides the dataset into those clusters. Now if a new data is fed to the model, it adds it to one of the created clusters (Figure 2.3) [14].

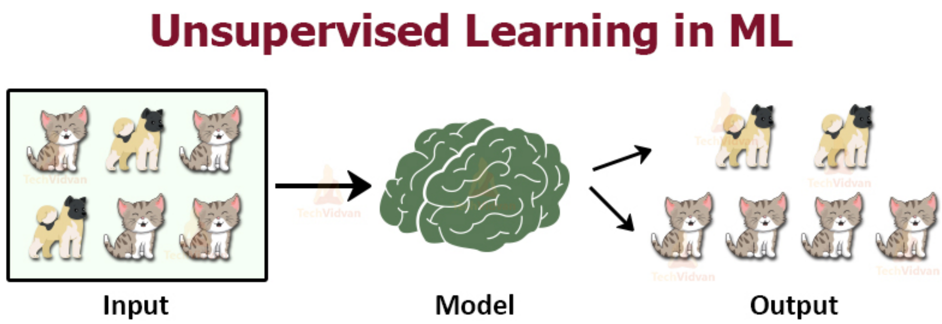

Figure 2.3: Example of Unsupervised Learning in ML.

3. **Reinforcement Learning:**

   It is the ability of an agent to interact with the environment and find out what is the best outcome. It follows the concept of hit and trial method **(My life My Rules!)** [14].

   The agent is rewarded or penalized with a point for a correct or a wrong answer, and on the basis of the positive reward points gained the model trains itself. And again once trained it gets ready to predict the new data presented to it (Figure 2.4) [14].

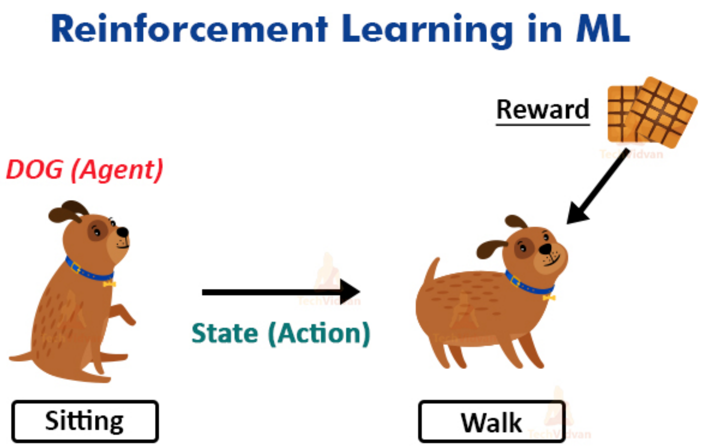

Figure 2.4: Example of Reinforcement Learning in ML.

2.3 Machine Learning algorithms

ML have many algorithms, each one is specialized in a specific field of applications , we are going to introduce some of them and concentrate on our main objective which is detecting covid-19 in images this means the field of computer vision(image recognition) using CNNs.

2.3.1 K-Nearest Neighbor (KNN)

K-Nearest neighbor (KNN) is a simple, lazy and nonparametric classifier. It is preferred when all the features are continuous. KNN is also called as case-based reasoning and has been used in many applications like pattern recognition, statistical estimation, and medical diagnosis [15].

Classification is obtained by identifying the nearest neighbor to determine the class of an unknown sample. KNN is preferred over other classification algorithms due to its high convergence speed and simplicity. KNN classification has two stages: [15]

1. Find the k number of instances in the dataset that is closest to instance S.
2. These k number of instances then vote to determine the class of instance S.

K-NN classification:

The test sample (inside circle) should be classified either to the first class of blue squares or to the second class of red triangles. If k = 3 (outside circle) it is as-signed to the second class because there are 2 triangles and only 1 square inside the inner circle. If, for example k = 5 it is assigned to the first class (3 squares vs. 2 triangles outside the outer circle). As shown in Figure 2.5[2].

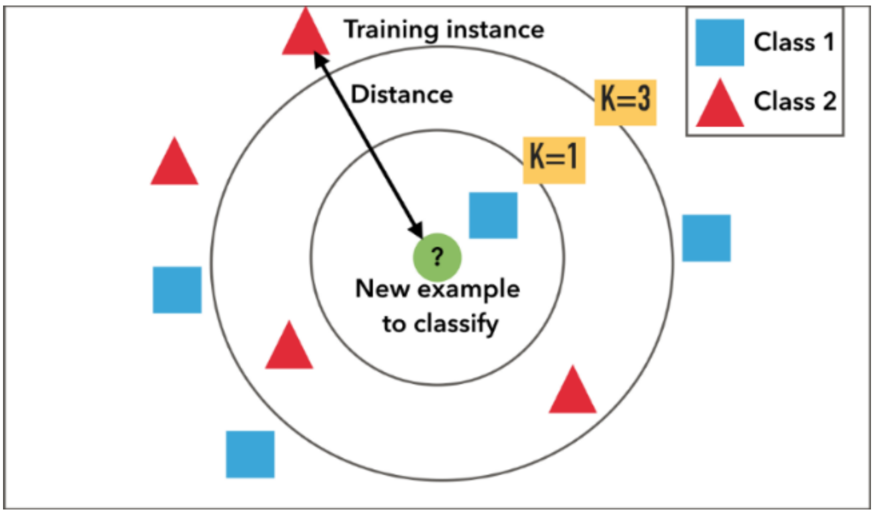

Figure 2.5: K-NN classification.

KNN accuracy:

The Accuracy of KNN depends on distance metric and K value. Various ways of measuring the distance between two instances are cosine, Euclidian distance. To evaluate the new

[2]https://blog.usejournal.com/a-quick-introductionto-k-nearest-neighbors-algorithm-62214cea29c7

unknown sample, KNN computes its K nearest neighbors and assign a class by majority voting [15].

2.3.2 Support vector machines (SVM)

SVM is a powerful method for building a classifier. It aims to create a decision boundary between two classes that enables the prediction of labels from one or more feature vectors. This decision boundary, known as the hyperplane, is orientated in such a way that it is as far as possible from the closest data points from each of the classes. These closest points are called support vectors. (Figure 2.6) [16]

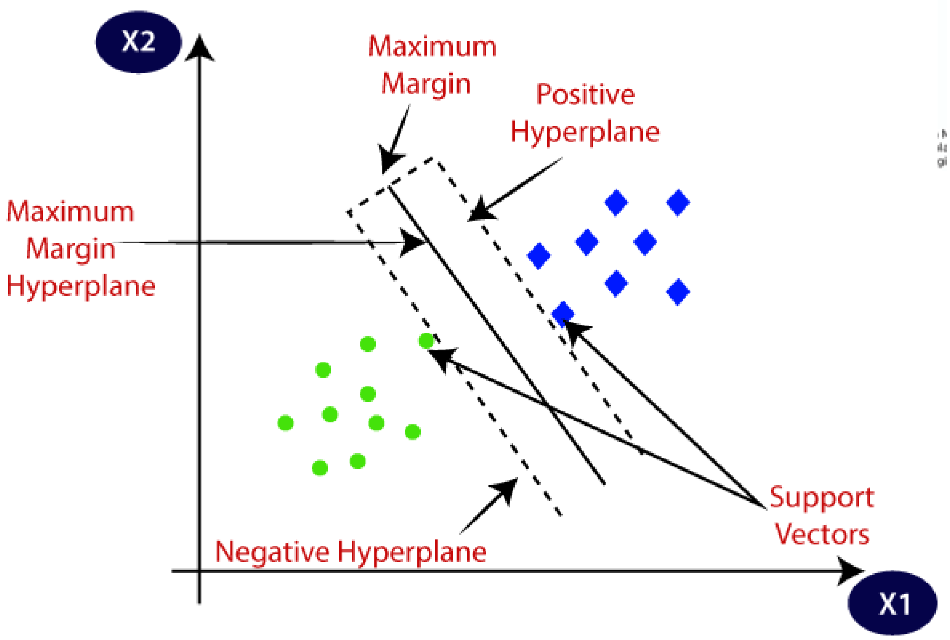

Figure 2.6: SVM method explained.

SVM learning is one of many ML methods. Compared to the other ML methods SVM is very powerful at recognizing subtle patterns in complex datasets. SVM can be used to recognize handwriting, recognize fraudulent credit cards, identify a speaker, as well as detect face [16].

Support vector machines types:

SVM can be of two types [17]:

1. **Linear SVM:** it is used for linearly separable data, which means if a dataset can be classified into two classes by using a single straight line, then such data is termed as linearly separable data, and classifier is used called as Linear SVM classifier.

2. **Non-linear SVM:** it is used for non-linearly separated data, which means if a dataset cannot be classified by using a straight line, then such data is termed as non-linear data and classifier used is called as Non-linear SVM classifier.

2.4 Deep Learning

2.4.1 Definition

Deep Learning is a subset of Machine Learning, which on the other hand is a subset of Artificial Intelligence.

It is a new field of machine learning research based on a particular type of learning mechanism, characterized by the effort to create a multi-layer learning model, in which the deeper layers take into account the results of the previous layers, each time tweaking them a little to improve the outcome, This overview of learning layers is inspired by how the human brain processes information and reacts to external stimuli, it has the ability to handle large amounts of data by adding more layers to the model [18].

2.4.2 Deep Learning VS Machine Learning

First thing we must know that deep learning is a subset of machine learning as shown in the figure down below.

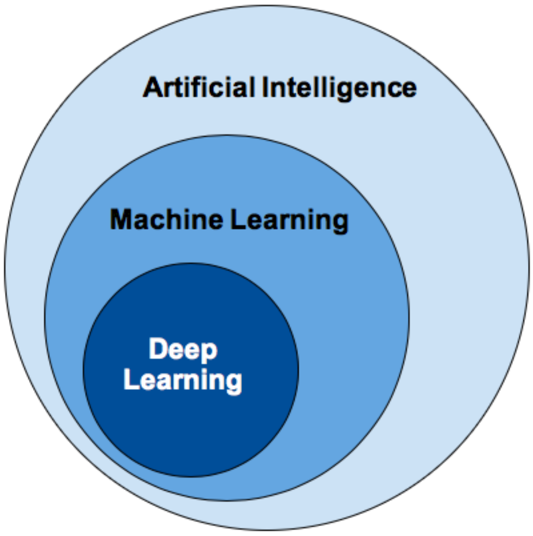

Figure 2.7: AI vs ML vs DL.

The other big difference between Deep Learning and traditional Machine Learning algorithms is the well adaption of DL algorithms, this means the larger amount of data supplied, the better the performance of a Deep Learning algorithm. Unlike several Machine Learning algorithms which have a limitation of data that they can receive, Deep Learning models theoretically have no such limitations and they have even gone so far as to pass human performance in domains like image processing [19].

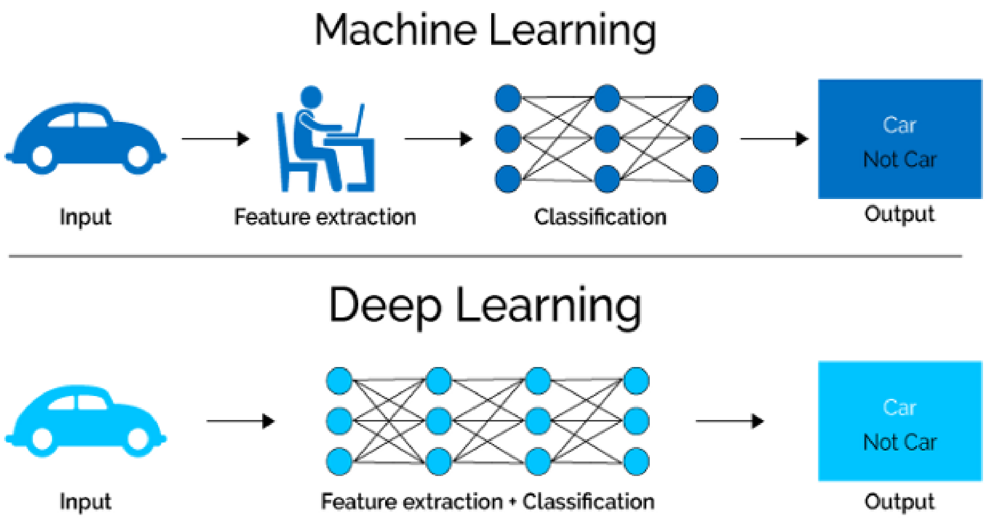

Figure 2.8: Machine learning process compared to Deep learning.

The figure 2.8 shows that deep learning algorithms require much less human intervention then machine learning, it's capable of automatic feature extraction through its neural network unlike machine learning algorithms which need a software engineer to identify features, it is a difficult and time consuming step and requires specialist [19].

Deep learning demands more data than machine learning algorithm to function properly due to the complex multi-layer structure. It is an important point to focus on in order to eliminate fluctuations and make high-quality interpretations [19].

2.4.3 Deep Learning applications

Since its appearance, deep learning made a revolution in artificial intelligence world and applications, due to its significant improvements in performance, DL imposed itself in many fields as shown in the figure down below.

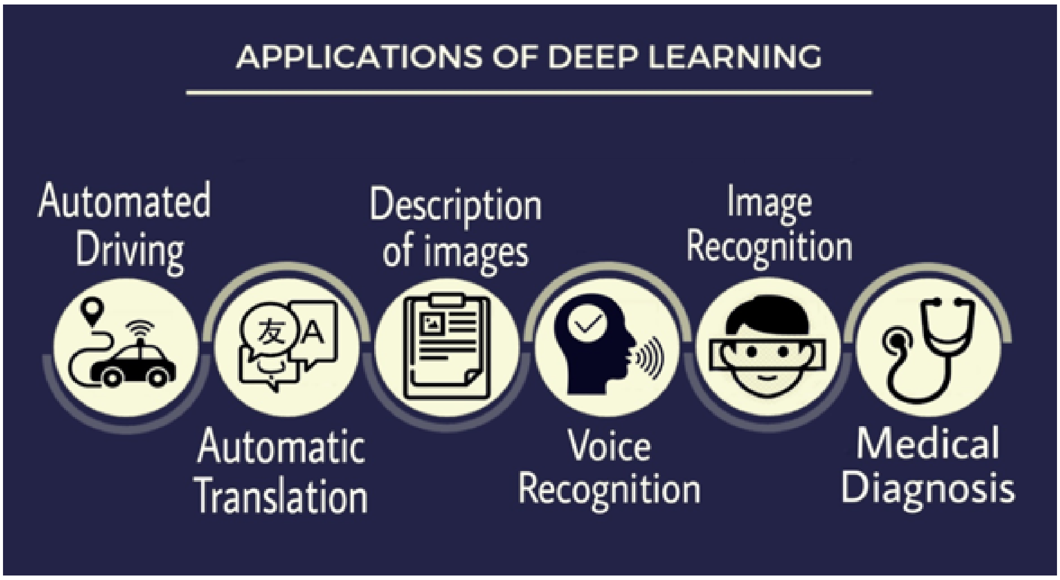

Figure 2.9: Deep learning applications.

- **Automatic translation**

  Deep learning is the reason why we have access to different translation services. One of the most popular ones, Google Translate, deep learning has helped this application improve tremendously. From just typing a word, to pronouncing a word, it sure is a big improvement from what is started out to be.

- **Images description**

  By combining CNNs and RNNs, researchers were able to build a model that can generate descriptions for unlabeled images. This model is able of aligning generated words with features found in images.

- **Automated driving**

  Car companies are building many types of driver-assistance services based on deep learning algorithms, modern cars with such services are able to automatically detect objects such as stop signs and traffic lights also detect pedestrians, Companies like Tesla took this domain even further by building full self-driving cars.

- **Voice recognition**

  Voice recognition is a technique allows analyzing the human voice to transcribe it in the form of a text usable by a machine.

- **Computer vision (image recognition)**

  For decades, computer vision relied heavily on traditional image processing methods, which means a lot of manual tuning and specialization. Deep learning, on the other hand, ignores nearly all of that, with deep learning, a lot of new applications of computer vision techniques have been introduced and are now becoming parts of our everyday lives, and these include face recognition and indexing, photo stylization…etc. it has resulted dramatic improvements to almost every computer vision task.

- **Medical diagnosis**

  Deep learning has been playing an important role in medical diagnosis and research. It helps with diagnosis of life-threatening diseases and understanding genetics to predict future risks of diseases.

  With deep learning cancer researchers can automatically find cancer cells and doctors can automatically detect and contour pneumonia in patient's CT scans, it specially contribute in medical diagnosis by image r recognition which can detect many diseases only from medical images which is the main objective of our study and the goal of this dissertation, all of this became applicable because of CNNs.

2.5 Deep learning algorithms

DL have many algorithms , each one specialized in a specific field of applications , we are going to introduce some of them and concentrate on our main objective which is detecting covid-19 in images this means the field of computer vision(image recognition) using CNNs.

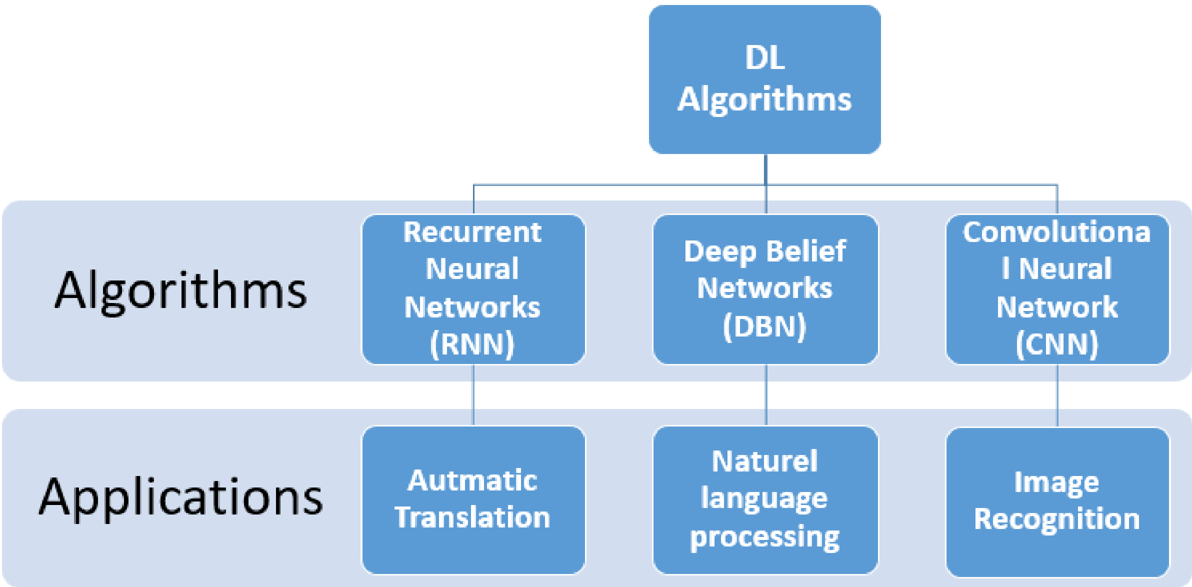

Figure 2.10: Some DL algorithms and its applications.

2.5.1 Recurrent Neural Networks (RNN)

A recurrent neural network (RNN) is a type of artificial neural network where information can travel in both ways, mainly used in speech recognition and automatic natural language processing [20].

RNNs are designed to recognize the sequential characteristics and data usage patterns required to predict the next most likely scenario [20].

RNNs tend to intervene in linguistic models for identifying the next letter of a word or the next word of a sentence based on the data preceding them [20].

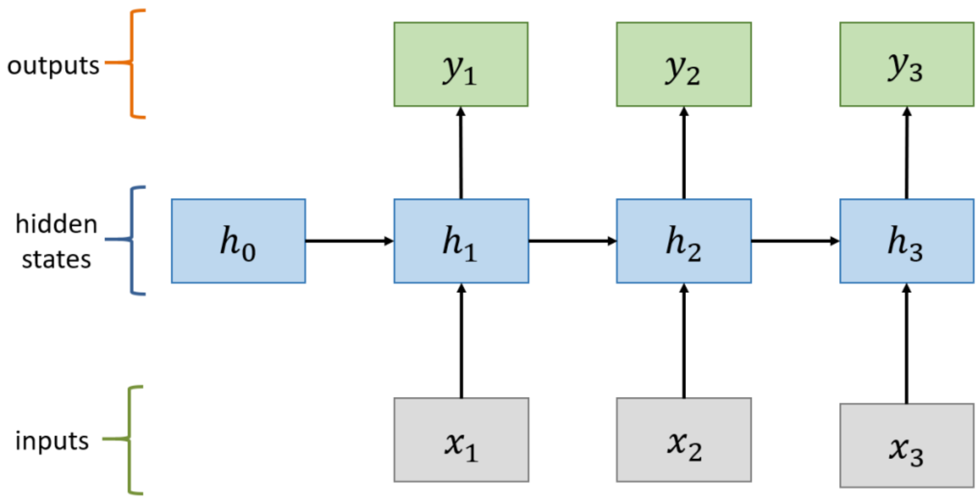

Figure 2.11: Standard RNN architecture.

2.5.2 Deep Belief Networks (DBN)

Deep Belief Network (DBN) is a class of deep neural network, composed of several layers of latent variables (hidden units) with connections between the layers, some experts describe the deep belief network as a set of restricted Boltzmann machines (RBMs) stacked on top of one another [21].

When trained to a set of unsupervised examples, a DBN can learn to probabilistically reconstruct its entries. The layers then act as feature detectors. After this learning step, a DBN can be further trained with supervision to perform the classification, they are mostly used in naturel language processing [21].

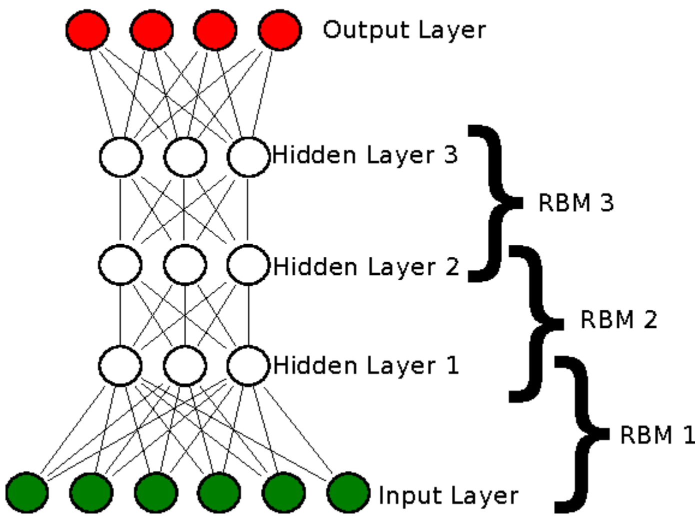

Figure 2.12: Standard DBN architecture.

2.5.3 Convolutional Neural Network (ConvNet/CNN)

CNN is a Deep Learning algorithm widely used in image processing, it can take an input image, assign importance to various aspects (objects) in the image and be able to differentiate one from the other. The pre-processing required in a ConvNet is much lower as compared to other classification algorithms. While in traditional methods filters are hand-engineered, with enough training, ConvNets have the ability to learn these filters/characteristics [22].

Since our main objective of this study is to detect diseases in medical images this means the computer vision domain which is the specialty field of CNN algorithms so we need further understanding of them.

Understanding Convolutional Neural Networks (CNN):

CNN image classifications takes an input image, process it and classify it under certain categories (Eg. Dog, Cat, Tiger, Lion). Computers sees an input image as array of pixels and it depends on the image resolution. Based on the image resolution, it will see h * w * d (h = Height, w = Width, d = Dimension). Eg. An image of 6 x 6 x 3 array of matrix of RGB (3 refers to RGB values) and an image of 4 x 4 x 1 array of matrix of grayscale image [23].

Every CNN model consist of two distinct parts the first part is the convolutional part itself. It works as a feature extractor from images. An image is passed through a succession of filters, or convolution kernel, creating new images called convolution maps. Some intermediate filters reduce the resolution of the image by a local maximum operation. In the end, the convolution maps are flattened and concatenated into a vector of characteristics [23].

We can't talk on convolutional layers without talking on the pooling layers, Pooling is an important process in a convolutional network, it extracts the important values of the pixels and allows to reduce the size of an image (the number of data processed decreases and therefore the computation time will also be reduced) while preserving the relevant characteristics [23].

There are two types of **pooling maximum pooling and average pooling**

Max Pooling returns the maximum value of the part of the image covered by the filter, on the other hand.

Average Pooling returns the average of all values in the part of the image covered by the filter.

This vector at the output of the convolutional part is connected to the input of the second part which is made up of fully connected layers (Dense layers). The role of this part is to combine the characteristics of the output of the first part to classify the image. The output of the second part is a last layer comprising one neuron to each category [23].

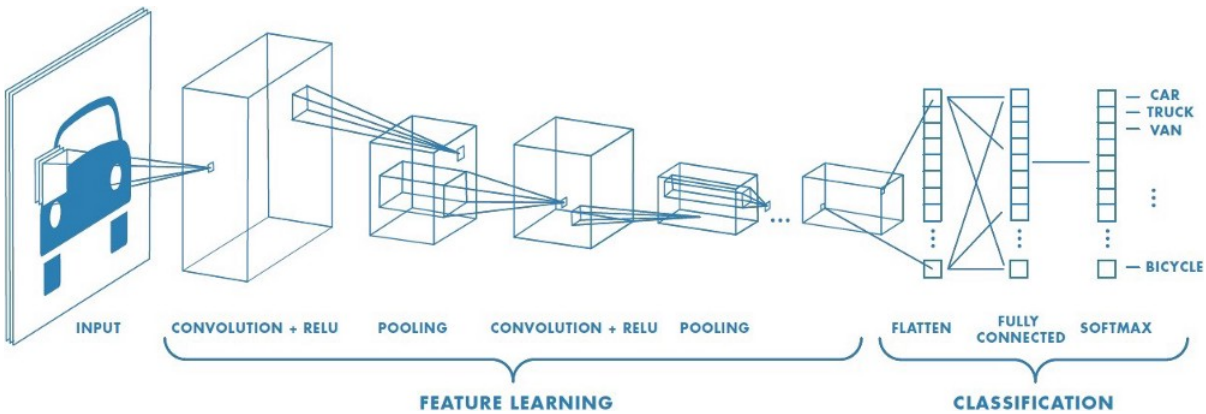

Figure 2.13: Standard CNN architecture.

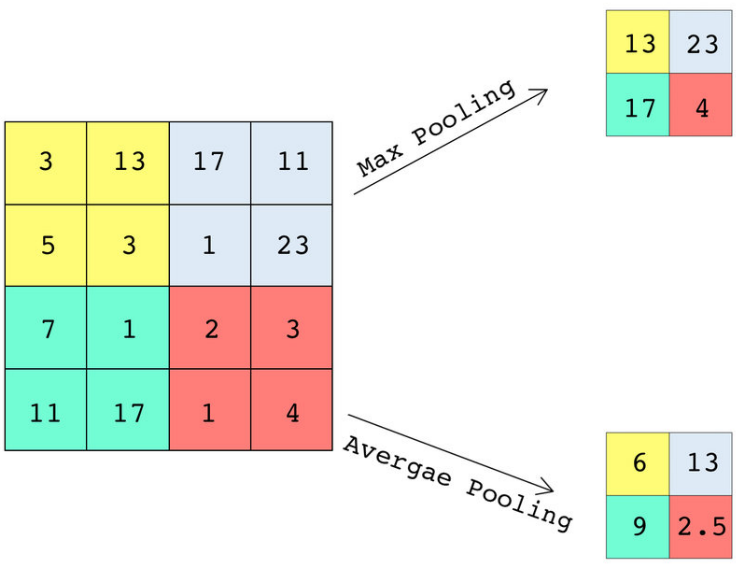

Figure 2.14: Pooling with 2*2 filter.

2.6 Conclusion

In this chapter, we have presented machine learning with its different types. We notably talked about Deep Learning, and the difference between DL and ML. Also we gave some DL application domains. At the end, we presented some types of neural networks, and more particularly, CNNs, on which our solution is based.

After we introduced Deep learning, now we can clearly see that, we are able to automatize the detection of COVID-19 using medical imaging.

In the next chapter, we will talk about some used algorithms in the imagery processing field, with a view to use the perfect methods for our project, we will also mention some related works as an example of how DL is used alongside medical imaging for diseases detection.

Chapter 3

Diseases detection using deep learning based on medical images

3.1 Introduction

After we learnt about machine learning and deep learning, CNNs in the previous chapter. Now we go to the next step, which is how medical imaging is used alongside machine learning or deep learning in order to automate the process of detecting COVID-19, in other words, what algorithms or methods are in use to accomplish this last?

In this chapter, we will be talking of some common algorithms used for image processing. After that we will strong our knowledge, by naming some related works, well detailed. Finally we will have a close view of Resources and tools used.

3.2 Medical image processing algorithms

Many algorithms are used for medical image processing, among them we mention:

- K-NN.
- SVM.
- CNN.

All these algorithms are detailed in the previous chapter.

3.3 Related works

Latest improvements in deep learning models and the availability of huge datasets have assisted algorithms to outperform medical personnel in numerous medical imaging tasks. And from the existing projects in this field we mention:

3.3.1 An Efficient Deep Learning Approach to Pneumonia Classification in Healthcare

In 2019, **Okeke Stephen, Mangal Sain, Uchenna Joseph Maduh and Do-Un Jeong** proposed a convolutional neural network model trained from scratch to classify and detect the presence of pneumonia from a collection of chest X-ray image samples [24].

The experiment was based on a chest X-ray image dataset proposed in **"Labeled Optical Coherence Tomography (OCT) and Chest X-Ray Images for Classification"**. They deployed Keras open-source deep learning framework with tensorflow backend to build and train a convolutional neural network model [25].

The original dataset contain three main folders which are training, testing, and validation each one consist of two subfolders pneumonia (P) and normal (N) chest X-ray images [26].

Several data augmentation methods has been applied to images in order to increase the size and quality of the dataset, including solving overfitting problems too.

The proposed CNN model consists of two major parts:

1. Feature extractors.
2. Classifier.

The feature extractors contains four convolutional layers with different sizes, each one of them followed by a max-pooling layer.

The classifier part is placed at the far end of the model, it begins with a flattened layer (flattening the output of feature extractor part), and two dense layers to perform the classification tasks.

The final results obtained are training **loss=0.1288, training accuracy=0.9531, validation loss: 0.1835**, and validation accuracy of 0.9373 for image size 200*200.

Other experiments were done on the same model but with variant image sizes and the results are as follows in Table 3.1.

Data size	Training accuracy	Validation accuracy
100	0.9375	0.9226
150	0.9422	0.9343
200	**0.9531**	**0.9373**
250	0.9513	0.9297
300	0.9566	0.9267
Average	0.94814	0.93012

Table 3.1: Performance of the classification model on different image sizes.

3.3.2 Using Deep Learning for Classification of Lung Nodules on Computed Tomography Images

in 2017, **QingZeng Song, Lei Zhao, XingKe Luo and XueChen Dou** submitted a study about the classification of lung nodules (Malignant or Benign) on CT scans using DL [27].

They proposed to employ respectively, the convolution neural network (CNN), deep neural network (DNN), and stacked autoencoder (SAE).

The dataset[1] used in this study is LIDC-IDRI, which contains 244,527 images of 1010 lung nodules cases.

The first two categories are identified as benign. The latter two categories were identified as malignant. As a total, 9106 nodular images are obtained.

The sizes of the lung nodule are different. In order to obtain the textural and size characteristics of the lung nodules, the size of the images is set at 28 $\times$ 28 uniformly.

[1]https://wiki.cancerimagingarchive.net/display/Public/LIDC-IDRI

The architecture of the CNN model used in this study are illustrated in (Figure 3.1) down below.

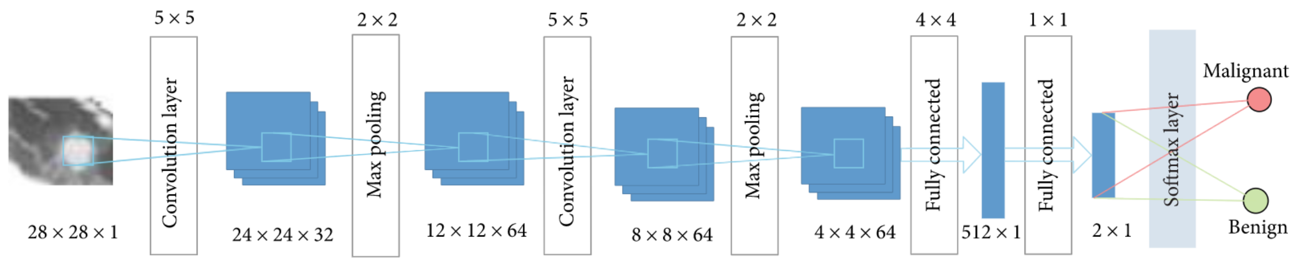

Figure 3.1: Architecture of the CNN model.

A Deep neural network (DNN) is also used in this study, a DNN is an increase in the number of hidden nodes in a simple neural network. The deep neural network does not contain any convolutional layers and can be used to carry on more complex input calculation [27].

The architecture of the DNN model used in this study are shown down below.

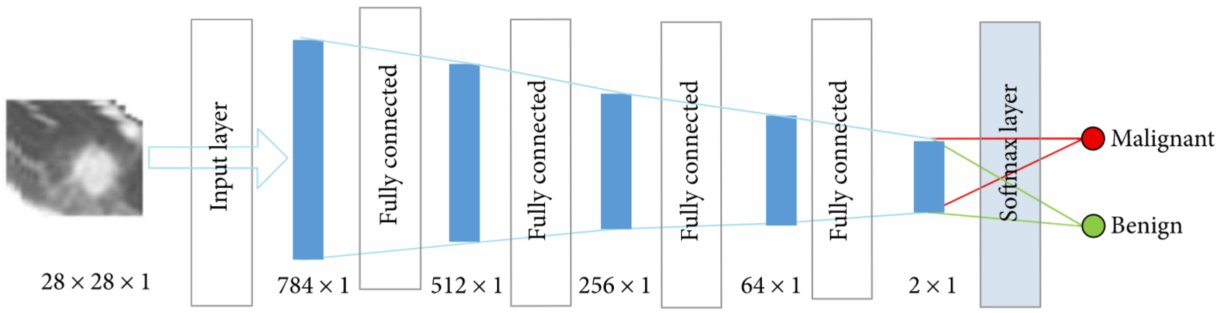

Figure 3.2: Architecture of the DNN model.

A Stacked Autoencoder (SAE) neural network is a multilayer sparse autoencoder of a neural network. The sparse autoencoder is divided into three layers, namely, the input layer, hidden layer, and output layer. The number of neurons in the input and output layers is the same, and the number of hidden neurons is less than that of the input layer [27].

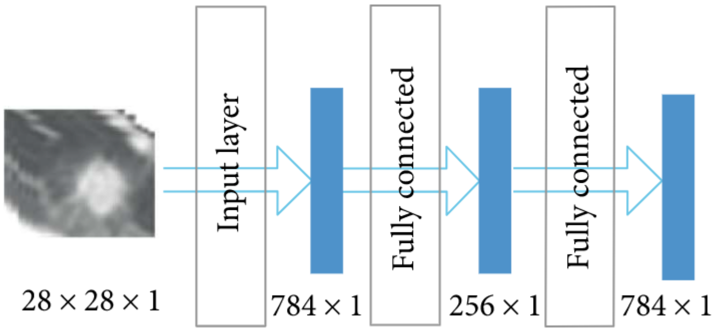

Figure 3.3: Sparse autoencoder architecture.

In this paper, multiple sparse auto encoders are combined to construct a SAE network with multiple hidden layers and a final classifier.

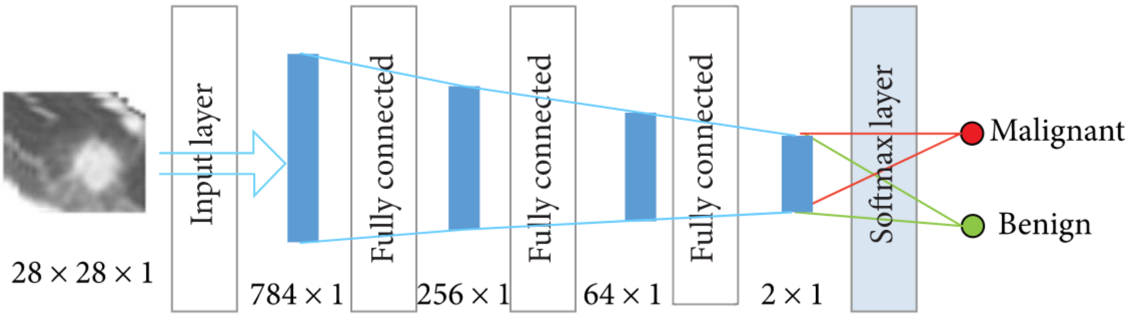

Figure 3.4: Architecture of the SAE model.

4581 images of lung nodules images were used in the training process. Among them, 2265 cases benign lung nodules and 2311 malignant lung nodules. 10% of the training dataset is used for validation. The same dataset is applied to the three different kinds of network architecture [27].

All the results of the whole study are summarized in the table down below.

Models	Accuracy
CNN	0.9375
DNN	0.9422
SAE	0.9513

Table 3.2: Results for all architectures.

3.3.3 Identifying COVID19 from Chest CT Images: A Deep Convolutional Neural Networks Based Approach

In 13 July 2020, **Arnab Kumar Mishra, Sujit Kumar Das, Pinki Roy and Sivaji Bandyopadhyay** submitted an article about identifying covid-19 from chest CT images, they used various deep CNN based approaches, and proposed a decision fusion based approach, it combines predictions from multiple individual models to produce a final prediction [28].

The dataset used in this study contains 360 positive COVID19 cases and 397 negative Chest Computed Tomography images.

These CT images are in different sizes corresponding to height ((maximum=1853, average=491, and minimum=153) and width (maximum=1485, average=383, and minimum=124), all the images have been converted into Portable Network Graphics (.png) format for both positive and negative class images and resized to 224 x 224 x3 [29].

In this work individual baseline models are extensively evaluated. These baseline models include VGG16, InceptionV3, ResNet50, DenseNet121, and DenseNet201. These entire baseline models convolution parts are kept exactly the same as the standard models. However, the fully connected parts of the models are fixed as three fully connected layers (4096, 4096, and 1000), each with ReLU activation and finally a single-node prediction layer with Sigmoid activation function. Apart from these baseline models, a decision fusion based approach is also considered in this work.

The main idea of this decision fusion approach is that the mistakes of individual models may be dealt with by combining the individual predictions via majority voting approach, which can potentially improve the overall efficiency of the baseline models.

The architecture of the proposed model and the decision fusion approach representation are illustrated in the figures down below respectively.

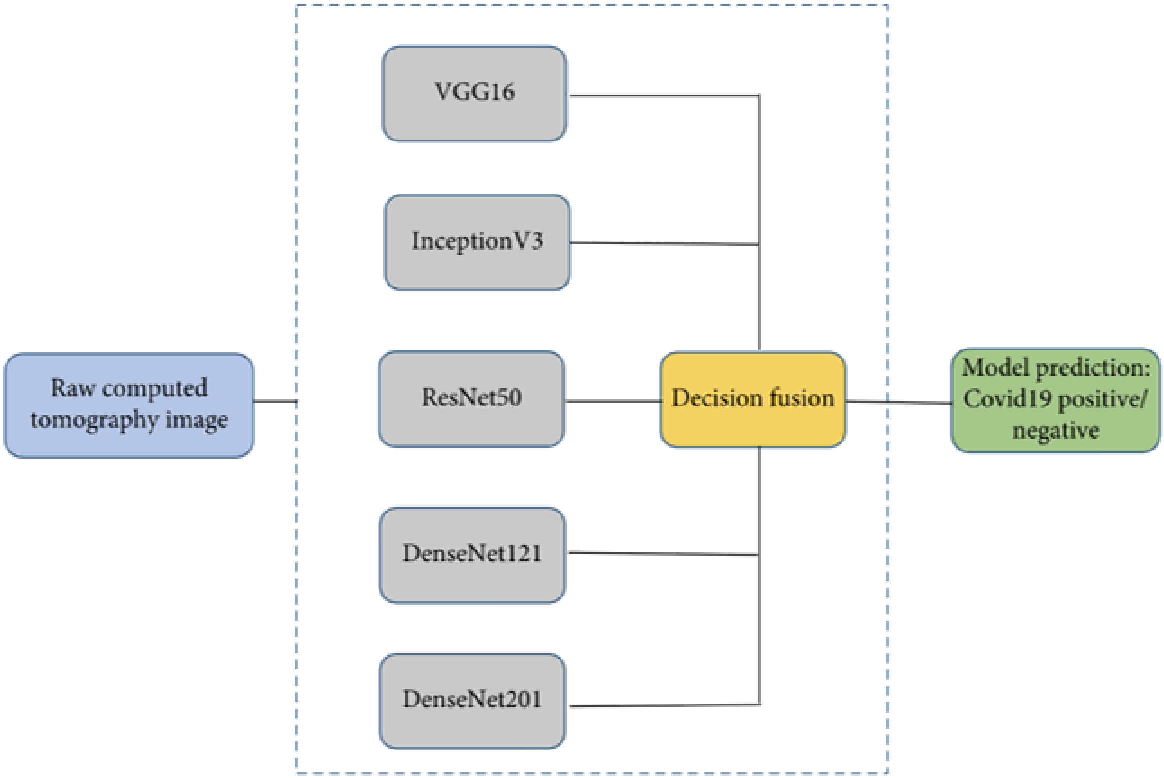

Figure 3.5: Architecture of the proposed model.

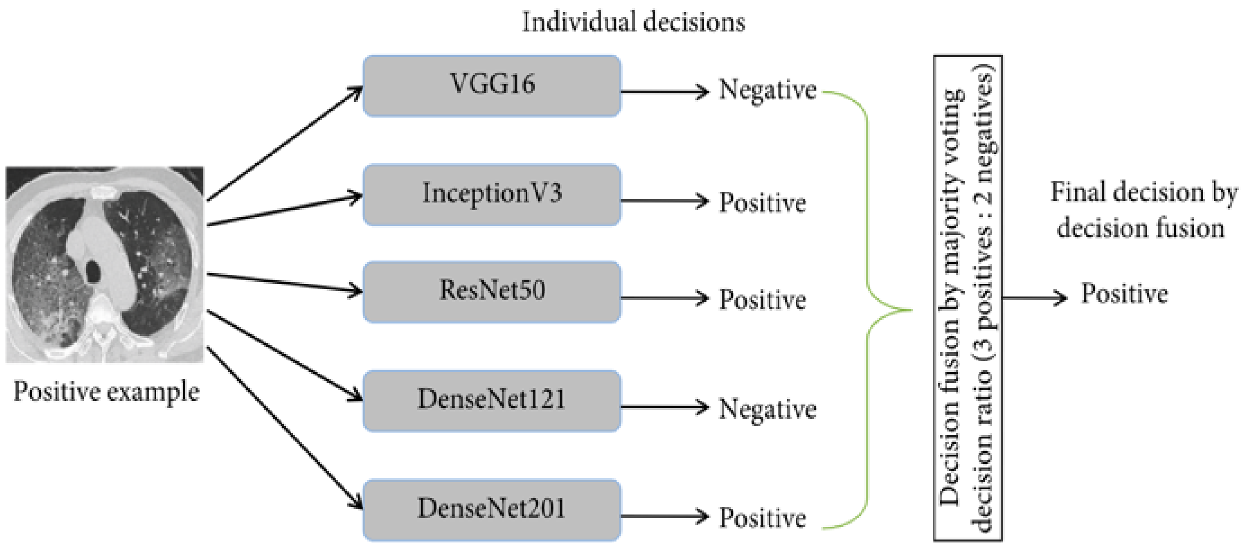

Figure 3.6: Decision fusion approach representation.

Various performance metrics are used in this work like Accuracy, F1-Score, Sensitivity, Specificity, Precision, and Recall to perform experimental evaluation of the models. These evaluation metrics are particularly useful while evaluating a medical screening system.

All the results obtained are illustrated in the figure down below.

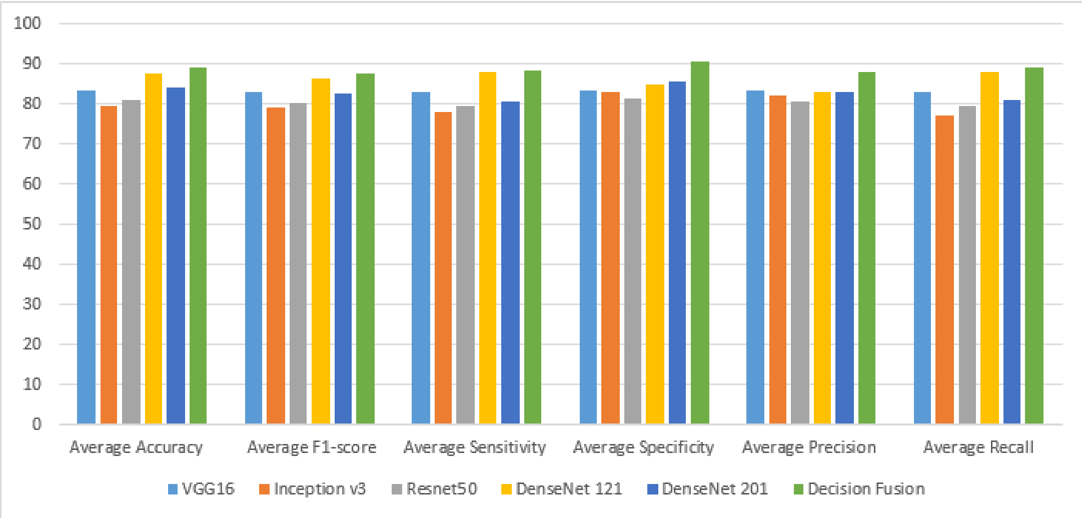

Figure 3.7: Results of the proposed models.

3.4 Resources

The main resource in any artificial intelligence study is the dataset to use. Now days the only thing that costs much more than money are information, unfortunately much datasets especially medical imaging datasets are not free or not public accessible due to privacy issues.

However, even that public medical imaging datasets are highly difficult to obtain we could find some good ones that even can help us in our study and from them we mention:

3.4.1 National institutes of health Database of 100,000 Chest X-Rays

This database[2] was uploaded by Summers Ronald on September 1, 2017 and recently modified (Jul 20, 2020), its size is 45.7 GB and it contains 112,120 frontal-view chest X-

[2]https://nihcc.app.box.com/v/ChestXray-NIHCC

ray PNG labeled images in 1024*1024 resolution with metadata for every image(written by professional radiologists) , the dataset also contains two data split files (**train_val_list.txt** and **test_list.txt**).

It contains **14 common chest disease categories** (1, Atelectasis; 2, Cardiomegaly; 3, Effusion; 4, Infiltration; 5, Mass; 6, Nodule; 7, Pneumonia; 8, Pneumothorax; 9, Consolidation; 10, Edema; 11, Emphysema; 12, Fibrosis; 13, Pleural_Thickening; 14 Hernia).

In the figure down below we show some we show a sample of the data set images (Figure 3.8).

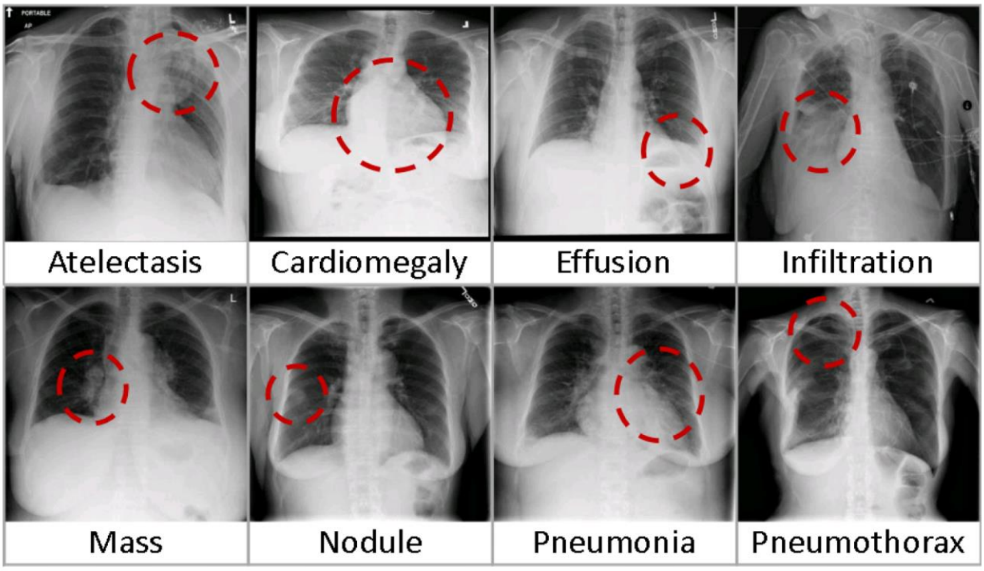

Figure 3.8: Eight visual examples of common chest diseases.

The dataset comes also with a schema of distributions of 14 disease categories with co-occurrence statistics (Figure 3.9).

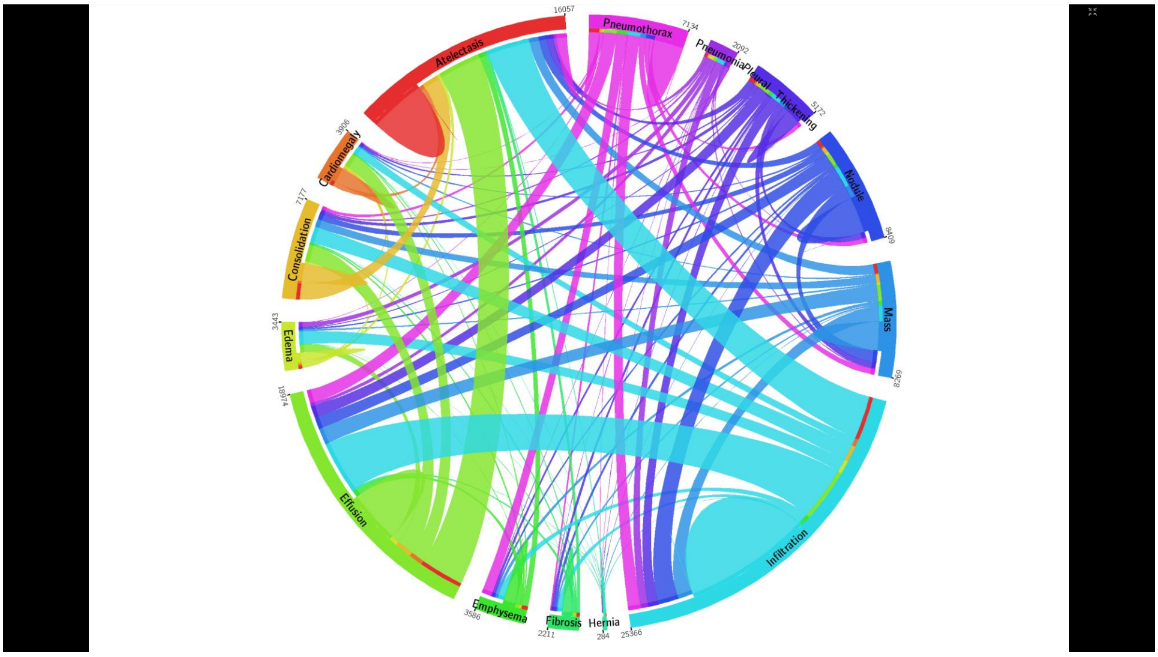

Figure 3.9: Distributions of 14 disease categories with co-occurrence statistics.

3.4.2 A Large-Scale CT and PET/CT Dataset for Lung Cancer Diagnosis

This dataset consists of CT and PET-CT DICOM images of lung cancer subjects with XML Annotation files that indicate tumor location with bounding boxes, The location of each tumor was annotated by five academic thoracic radiologists with expertise . The images were acquired from patients with suspicion of lung cancer [30].

It contains 260,826 images with a whole size of 132 GB, the CT resolution is 512 $\times$ 512 pixels and the PET resolution is 200 $\times$ 200 pixels.

In the figure down below are some sample images from the dataset (Figure 3.10).

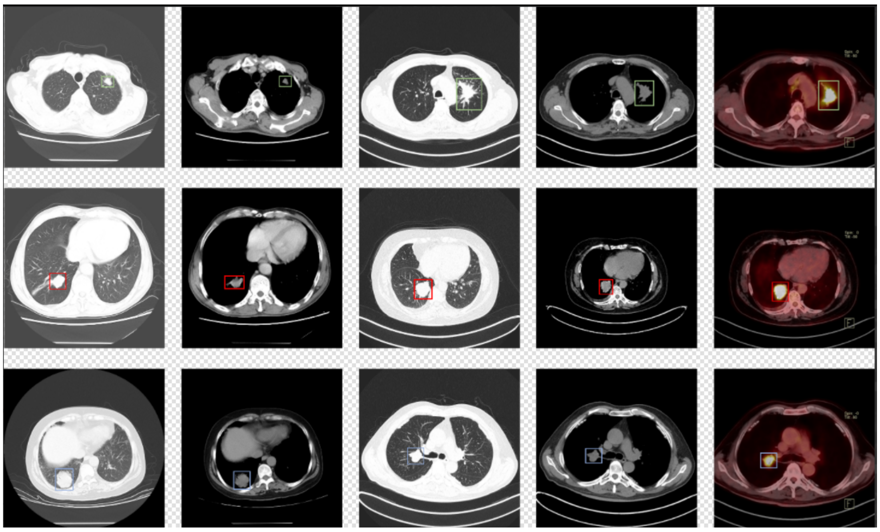

Figure 3.10: Some images from the dataset.

Moreover, because the Covid-19 is recent his datasets are too few and without many metadata about the datasets itself, from the publically available datasets we can mention:

3.4.3 Extensive COVID-19 X-Ray and CT Chest Images Dataset

This dataset consists of Non-COVID and COVID cases of both X-ray and CT images. The dataset contains two main folders, one for the X-ray images, which includes two separate sub-folders of 5500 Non-COVID images and 4044 COVID images. The other folder contains the CT images. It includes two separate sub-folders of 2628 Non-COVID images and 5427 COVID images [31].

3.4.4 COVID-19 dataset by AI HUB

This dataset published in Google drive[3] by the website AI HUB without any information or meta-data.

The dataset contains three main folders (train, validation and test), each of them consist of two subfolders corona and normal. Each subfolder have a collection of images which are obvious chest CT scans in the form of jpeg that reduces the quality of images especially medical images where the quality and resolution of images are an important factor[32].

[3]https://drive.google.com/drive/folders/1zQEETpbfSDqY-ZNeSNmJPaykkPuEY-QM

3.4.5 COVID-19 CT scans dataset

This dataset is published on Kaggle[4] with a size of **7.37GB**, it contains 20 CT scans of patients diagnosed with COVID-19 as well as segmentations of lungs and infections made by experts. Images are in **Nifti (*.nii)** format published in **Avril, 2020.**

Data source by **Paiva, O.**, 2020. CORONACASES.ORG - Helping Radiologists To Help People In More Than 100 Countries! — Coronavirus Cases. [online] Coronacases.org, and **Glick, Y.**, 2020. Viewing Playlist: COVID-19 Pneumonia — Radiopaedia.Org. [online] Radiopaedia.org.

Expert annotations by **Ma Jun, Ge Cheng, Wang Yixin, An Xingle, Gao Jiantao, Yu Ziqi, . . . He Jian**. (2020). COVID-19 CT Lung and Infection Segmentation Dataset (Version Verson 1.0) [Data set]. **Zenodo.**

This dataset contains 4 sub-folders:

1. CT_scans.
2. Infection_mask.
3. lung_mask.
4. lung_and_infection_mask.

A sample from the dataset is shown in figure below.

[4]https://www.kaggle.com/andrewmvd/covid19-ct-scans

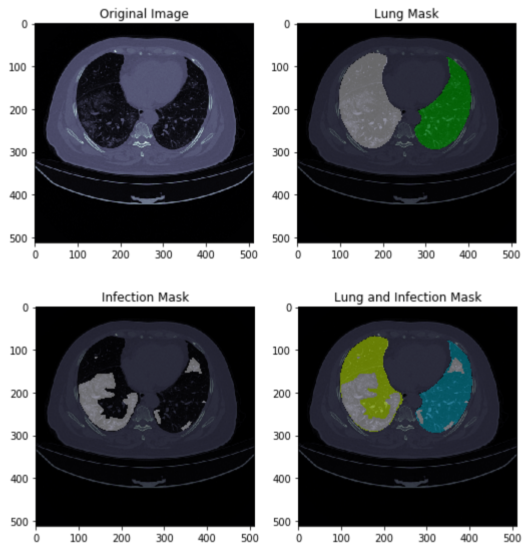

Figure 3.11: Sample of dataset.

3.4.6 COVID-CT

This dataset is published on Github[5] in May 11, 2020, by **UCSD-AI4H.** Images are collected from COVID19-related papers from **medRxiv, bioRxiv, NEJM, JAMA, Lancet,** etc. CTs containing COVID-19 abnormalities are selected by reading the figure captions in the papers. All copyrights of the data belong to the authors and publishers of these papers.

Data Description:

- The COVID-CT-Dataset has 349 CT images containing clinical findings of COVID-19 from 216 patients. They are in **./Images-processed/CT_COVID.zip**.
- Non-COVID CT scans are in **./Images-processed/CT_NonCOVID.zip**.
- The meta information (e.g., patient ID, patient information, DOI, image caption) is in **COVID-CT-MetaInfo.xlsx**.

[5]https://github.com/UCSD-AI4H/COVID-CT

3.5 Conclusion

After we cited some used algorithms for medical images processing, and we had a close look at some related works. Now we pass to the next chapter where we will dive deeper into our conception.

In the next chapter, we will present the dataset we are going to use. Then, we will choose and study the classification method that fits with our problem, and propose some models in order to get to choose the best model based on its results.

Chapter 4

Materials and Methods

4.1 Introduction

The field of medical imaging has seen revolutionary changes in recent past, due to the advancements in the field of Deep learning, for many diseases, like Cancer, Pneumonia, SARS, and so forth. During the current COVID19 pandemic, successful application of such DL based approaches can potentially be of very high utility, especially with respect to fast testing and detection of the disease [28].

After we saw DL algorithms used in medical image processing in the past chapter, related works section. Now in this chapter we pass to our main problematic, which is the classification of a group of medical CT scans images using DL algorithms into two classes: Coronavirus infected patient or not.

Recent advancements in the field of DL, especially in the medical imaging domain, indicate the potential usage of various Deep CNN architectures. In our proposed solution we will be using CNN architectures alongside a dataset of **63,849** TIFF format (Tagged Image File Format) images from 378 patients between male and female. All the dataset will pass through a first phase where we flip, rotate, zoom, and shift our input images in order to augment this last, after that we will pass to the second phase, where CNN takes the lion's part, it will be used to classify our dataset into two classes X and Y, simply said to define whether a patient is infected with Coronavirus or not.

This chapter will be divided in two sections, materials and methods. In the first section we will talk about dataset we will use, mentioning all its details from patients age, gender... etc. After that we pass to the methods section, where we will talk about our proposed models, and some basics of each one (activation functions, loss functions, optimizers).

4.2 Materials

4.2.1 Dataset

In the previous chapter, we cited some existing used datasets for COVID-19 classification. These last have many negative points we mention:

- The quality of images are degraded, which may render the diagnosis decisions less accurate.
- The number of bits per pixel is reduced.
- The resolution of images is reduced.
- Number of COVID-19 positive cases is small.

The Dataset[1] we chose, images are 16-bit grayscale TIFF format with 512*512 pixels resolution. It contains 96 positive COVID-19 cases and 282 negative cases (table 4.1), the distribution gender and range of age are shown in the figure 4.1. Some sample COVID-19 positive and negative CT images are shown in figure 4.2.

COVID-19 Patients	Normal People	COVID-19 Images	Normal Images
96	282	15589	48260

Table 4.1: Number of images and patients.

[1] https://bit.ly/3kzwAXG

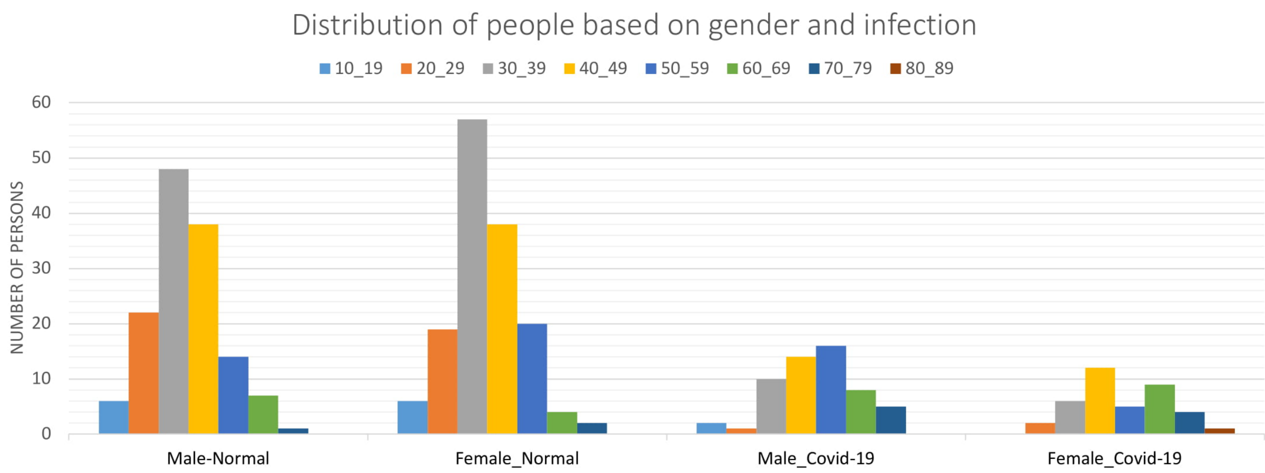

Figure 4.1: The distribution of our dataset.

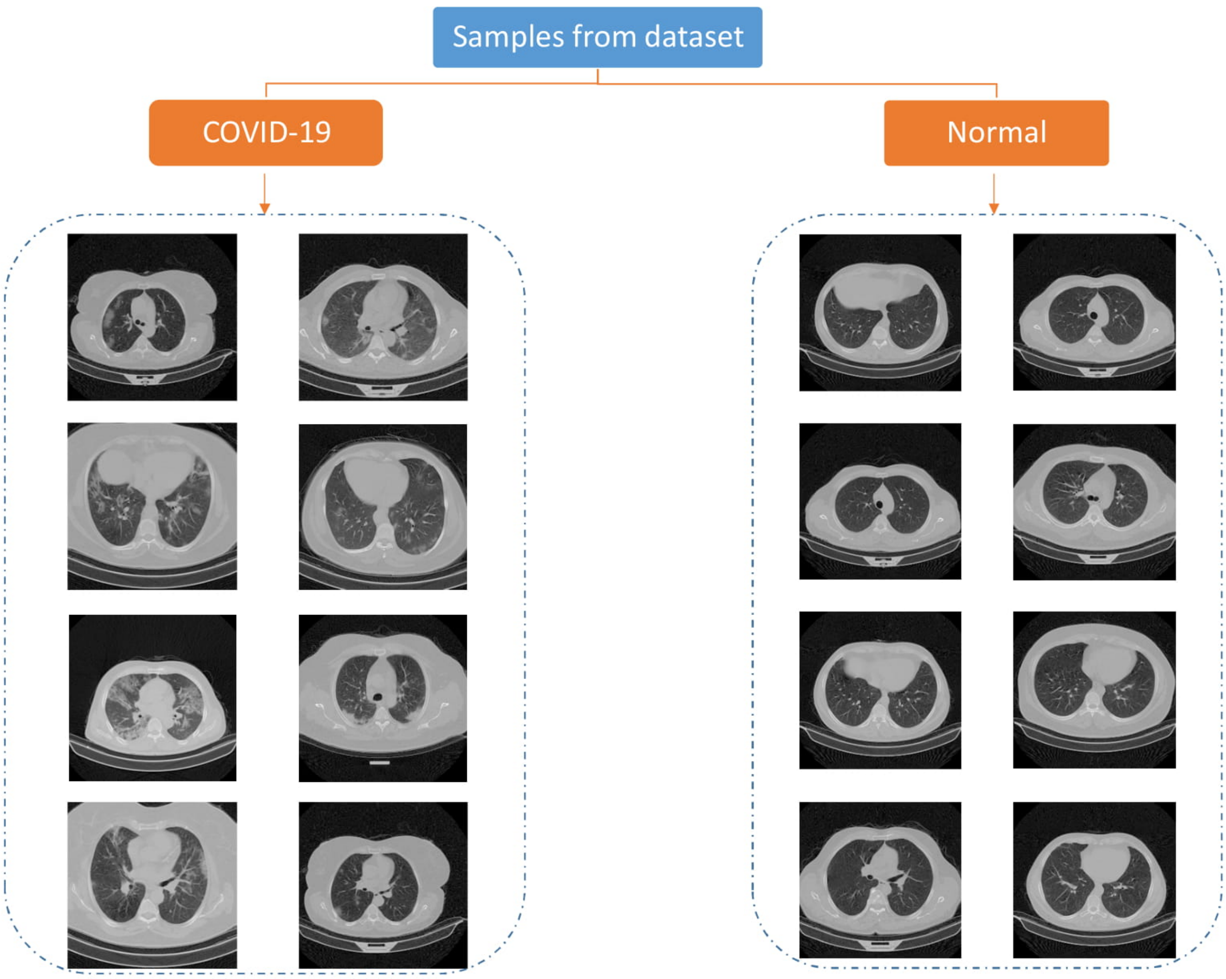

Figure 4.2: Examples of positive/negative COVID19 CT scan images.

Images will be divided into three important sub-sets as it follows:

1. **Training set:** 80% are used in the training phase.

2. **Testing set:** 10% are used in the test phase.

3. **Validation set:** 10% are used in the validation phase.

Dataset	Images number
Training set	51079
Testing set	6385
Validation set	6385
Total	63849

Table 4.2: Dataset representation.

4.2.2 Dataset preparation

In order to get an exact and reliable results analysis, a selection algorithm will be used, we will try to keep only scans where the infection points may appear.

The infection points are clear on the open-lung images better than the closed-lung images.

The main difference between an open lung and closed lung is that the open lung image has lower pixel values (near to black) in the middle of the lung (Figure 4.3).

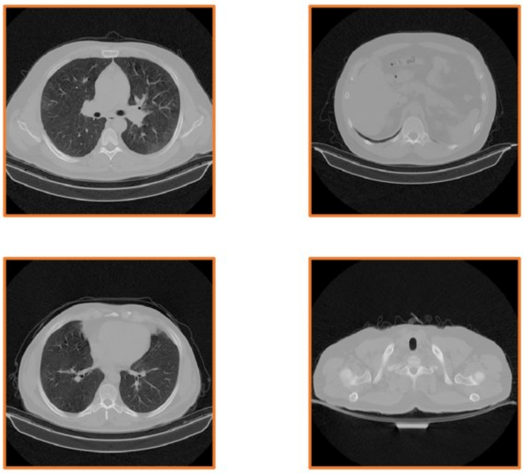

Figure 4.3: Samples of Open/closed lung modes.

4.3 Methods

There are a lot of algorithms that can be used in the medical image classification in the DL field, like K-NN, ANN, SVM and CNN. We will use CNN in our proposed solutions, it offers many advantages such as:

- **Excellent feature extractor:**

  The feature extraction describes image regions. In our case, we will describe the criteria that will be considered in COVID-19 diagnosis, in the learning process an automatic update of values of the filter (characteristic detector) is applied, a filter is used to bring out certain characteristics of a given image such as borders, brightness, etc. Filters are placed on the input image (although their size is much smaller), and moves on this last to cover all of its areas.

After choosing what algorithm we will use, now we move to define what activation function is, also what loss function is, and optimizers.

4.3.1 Activation function

It is a function[2] used in artificial neural networks which outputs a small value for small inputs, and a larger value if its inputs exceed a threshold. If the inputs are large enough, the activation function "fires", otherwise it does nothing. In other words, an activation function is like a gate that checks that an incoming value is greater than a critical number.

Used activation functions:

1. **The rectified linear activation function or ReLU**[3] for short is a piecewise linear function that will output the input directly if it is positive, otherwise, it will output zero. It has become the default activation function for many types of neural networks because a model that uses it is easier to train and often achieves better performance. We used ReLU because it overcomes the vanishing gradient problem, allowing our model to learn faster and perform better. Also it is the default activation when developing multilayer Perceptron and convolutional neural networks.

2. **Softmax:**[4] it is a very interesting activation function because it not only maps our output to a [0, 1] range but also maps each output in such a way that the total sum is 1. The output of Softmax is therefore a probability distribution. The softmax function is often used in the final layer of a neural network-based classifier (as we will do).

4.3.2 Optimizers & loss function

Optimizers update the weight parameters to minimize the loss function. Loss function acts as guides to the terrain telling optimizer if it is moving in the right direction to reach the bottom of the valley, the global minimum [33].

[2]https://deepai.org/machine-learning-glossary-and-terms/activation-function

[3]https://machinelearningmastery.com/rectified-linearactivation-function-for-deep-learning-neural-networks/

[4]https://medium.com/@himanshuxd/activation-functions-sigmoid-relu-leaky-relu-and-softmaxbasics-for-neural-networks-and-deep-8d9c70eed91e

Used loss function:

- **Categorical cross entropy:** it is a loss function that is used in multi-class classification tasks. These are tasks where an example can only belong to one out of many possible categories, and the model must decide which one. Formally, it is designed to quantify the difference between two probability distributions [34].

Used optimizer:

- **Nadam:** it is an acronym for Nesterov and Adam optimiser. The Nesterov component, however, is a more efficient modification than its original implementation [35].

4.3.3 Proposed approaches

In our project we are going to propose three approaches, in each of them a model will be created and trained, the summary of our propositions is as follows:

1. **Using CNN from scratch:** we will create a CNN model from scratch.
2. **Using ResNet50V2 architecture:** we will create a CNN model based on ResNet50V2 architecture.
3. **Using Xception architecture:** we will create a CNN model based on Xception architecture.

1. **Basic model:**

   In this model, we will build a CNN architecture from scratch, then test our model and see results we will get. An overview of our model is shown in Figure 4.4.

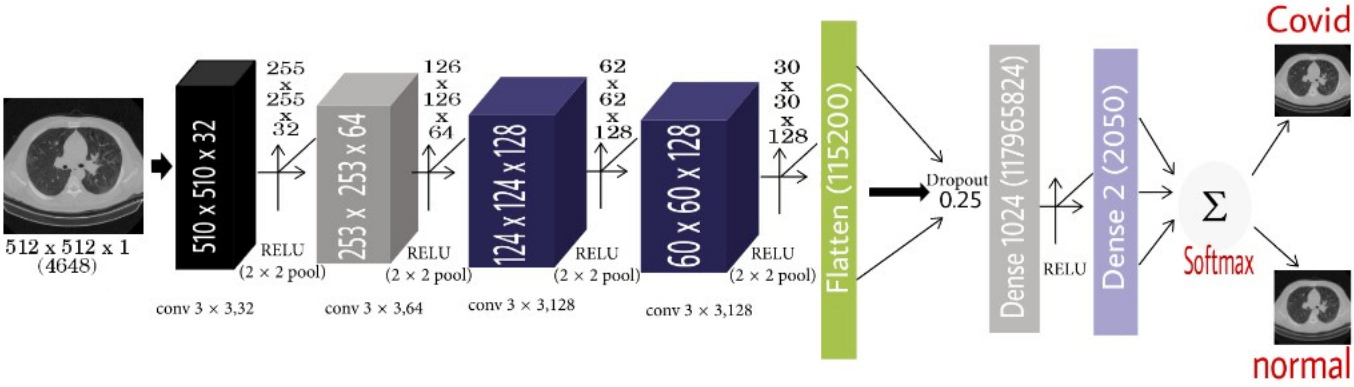

Figure 4.4: Basic model architecture.

Description of the model:

- **Features extraction part:**

  The purpose of this part is to extract high level features, such as edges from the input image. CNN does not need to be limited to a single convolutional layer. In our model we will use four convolutional layers, the first layer is responsible for capturing low level characteristics. The convolution layer applies a filter or feature detector to the input image and creates a feature map for all of the images.

  After each convolutional layer, we're going to use Max Pooling layer to reduce the computational power required to process the data. In addition, it is useful for extracting dominant characteristics, which also works as a noise suppressor. It completely eliminates noisy activations and also performs noise reduction.

  After that it comes the Flatten layer to convert two dimensional matrix of features (Convolutional layer) into a vector that can be fed into a fully connected neural network classifier.

- **Classification part:**

  The classification process is carried out by taking the flattened weighted characteristic obtained from the flattened layer, then drop out 0.25 of its parameters to prevent all the neurons from converging to the same goal, and helps the activations of the hidden units to become sparse which is also desirable characteristic. A dense layer with a size of 1024, receives an input vector and produces a new output vector. To do this, it applies an activation function to the values received as input. This layer makes it possible to classify the image at the input of the network: it returns a vector of size two (two neurons). Each element of the vector indicates the probability for the input image to belong to a class (COVID, NORMAL).

To calculate the probabilities, the fully connected layer therefore multiplies each input element by a weight, adds up, and then applies Softmax activation function.

2. **ResNet50v2 model:**

After we built a basic model, now we will try to implement a CNN model based on **ResNet50v2** architecture, we first need to have a close view at this last.

- **ResNet50v2:**

  Residual Network (ResNet)[5] is a Convolutional Neural Network (CNN) architecture which was designed to enable hundreds or thousands of convolutional layers. While previous CNN architectures had a drop off in the effectiveness of additional layers, ResNet can add a large number of layers with strong performance.

The architecture of ResNet50 has **4 stages** as shown in the figures below. The network can take the input image having height, width as multiples of 32 and 3 as channel width. For the sake of explanation, we will consider the input size as 224 x 224 x 3. Every ResNet architecture performs the initial convolution and max-pooling using 7×7 and 3×3 kernel sizes respectively. Afterward, Stage 1 of the network starts and it has 3 Residual blocks containing 3 layers each. The size of kernels used to perform the convolution operation in all 3 layers of the block of stage 1 are 64, 64 and 128 respectively. The curved arrows refer to the identity connection. The dashed connected arrow represents that the convolution operation in the Residual Block is performed with stride 2, hence, the size of input will be

[5]https://cv-tricks.com/keras/understand-implement-resnets/

reduced to half in terms of height and width but the channel width will be doubled. As we progress from one stage to another, the channel width is doubled and the size of the input is reduced to half [36].

For deeper networks like ResNet50, ResNet152, etc, bottleneck design is used. For each residual function F, 3 layers are stacked one over the other. The three layers are 1×1, 3×3, 1×1 convolutions. The 1×1 convolution layers are responsible for reducing and then restoring the dimensions. The 3×3 layer is left as a bottleneck with smaller input/output dimensions [36].

Finally, the network has an Average Pooling layer followed by a fully connected layer having 1000 neurons (ImageNet class output) [36].

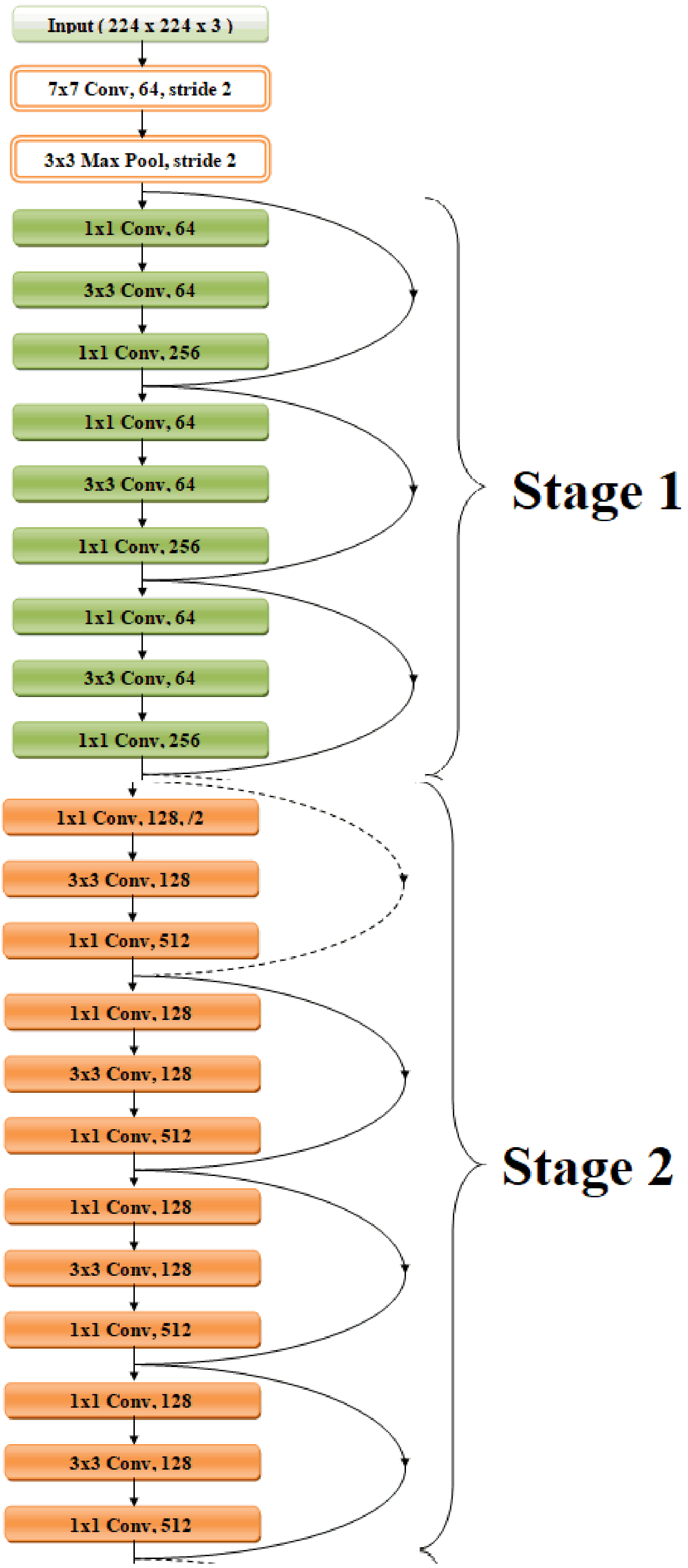

Figure 4.5: Stage 1 and stage 2 of ResNet's aechitecture.

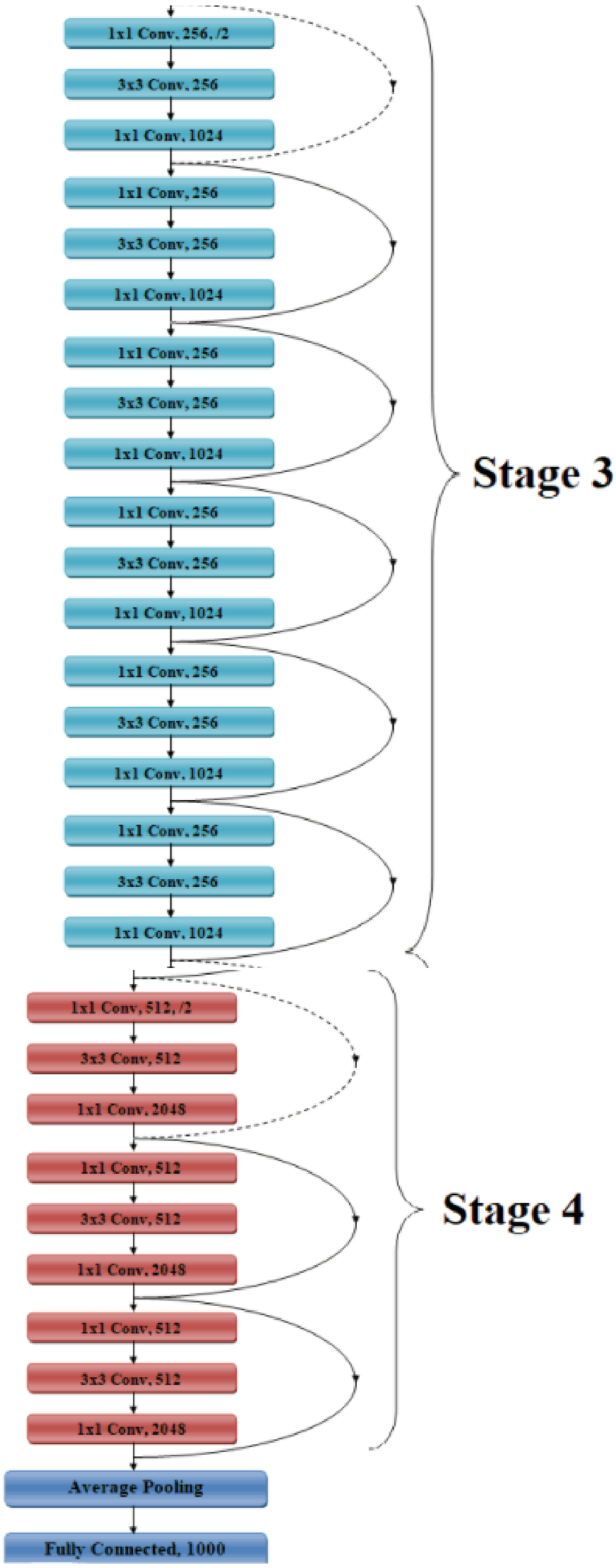

Figure 4.6: Stage 3 and stage 4 of ResNet's aechitecture.

After knowing what ResNet50v2 is, now we will apply some changes on it to have our personalized model (Figure 4.7):

(a) Edit weights of the first layer to (512, 512, 1) because images are 512*512 in grayscale (1 channel only).

(b) Remove ResNet50V2's classifier.

(c) Add a global average pooling layer that will be connected to the last layer of ResNet50V2 architecture.

(d) Add a dense layer of two neurones, applying on them softmax activation function to output our two classes (COVID19/NORMAL), the new classifier of this model will be the combination of the global average pooling layer and the dense layer.

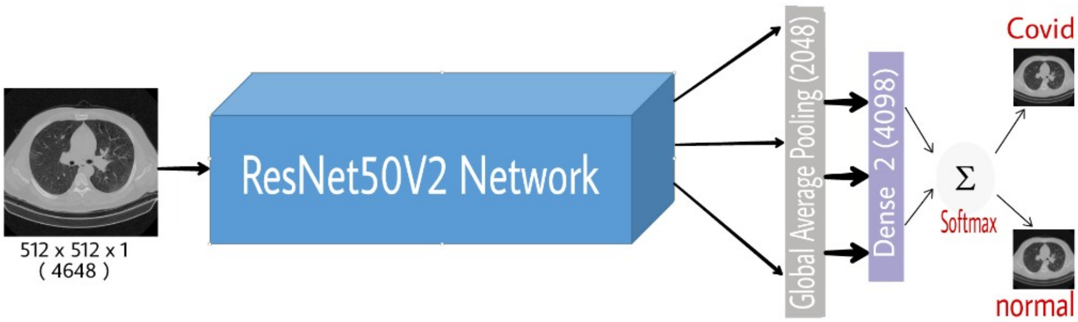

Figure 4.7: CNN model based on ResNet50v2 architecture.

Description of the model:

First, we will give images as input to the ResNet50v2's network, after that the output will pass through the Global average pooling layer, this operation is designed to replace fully connected layers in classical CNNs (dense layer), instead of adding fully connected layers on top of the feature maps generated by the convolutional layers, we take the average of each feature map and the resulting vector is fed directly into the softmax layer.

In the global average pooling layer, there is no parameter to optimize thus overfitting is avoided at this layer.

3. **XCeption model:**

   In this model, we will try to implement CNN model based on **Xception** architecture, we first need to have a close view at this last.

   - **XCeption:**

     XCeption[6] is an efficient architecture that relies on two main points: Depthwise Separable Convolution and shortcuts between Convolution blocks as in ResNet, the data first goes through the entry flow, then through the middle flow which is repeated eight times, and finally through the exit flow.

Xception which stands for “Extreme Inception” is a convolutional neural network architecture based entirely on depthwise separable convolution layers. In effect, the mapping of cross-channels correlations and spatial correlations in the feature maps of convolutional neural networks can be entirely decoupled. This hypothesis is a stronger version of the hypothesis underlying the Inception architecture noting that Xception is an interpretation of Inception modules and this is where its name came from [37].

A complete description of the specifications of the Xception network is given in figure 4.8

[6] https://maelfabien.github.io/deeplearning/xception/

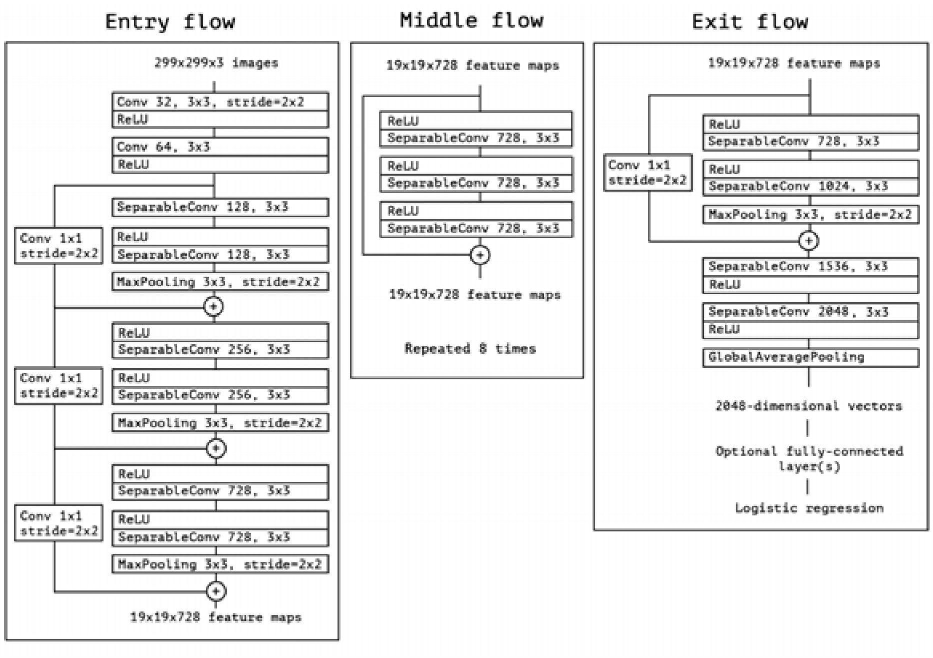

Figure 4.8: The Xception architecture.

The Xception architecture has 36 convolutional layers forming the feature extraction base of the network. The 36 convolutional layers are structured into 14 modules, all of which have linear residual connections around them, except for the first and last modules. In short, the Xception architecture is a linear stack of depthwise separable convolution layers with residual connections. This makes the architecture very easy to define and modify, an open-source implementation of Xception using Keras and TensorFlow is provided as part of the Keras Applications module2, under the MIT license [37].

The data first goes through the entry flow, then through the middle flow, which is repeated eight times, and finally through the exit flow [37].

Xception slightly outperforms Inception v3 on the ImageNet dataset, and vastly outperforms it on a larger image classification dataset with 17,000 classes. Since the Xception architecture has less number of parameters as Inception V3 (figure 4.9), the performance gains are not due to increased capacity but rather to a more efficient use of model parameters [37].

	Parameter count
Inception V3	23,626,728
Xception	22,855,952

Figure 4.9: Parameters count of Inception V3 and XCeption.

To customize our model so it fits our purpose, same modifications as the previous model will be made too (Figure 4.10).

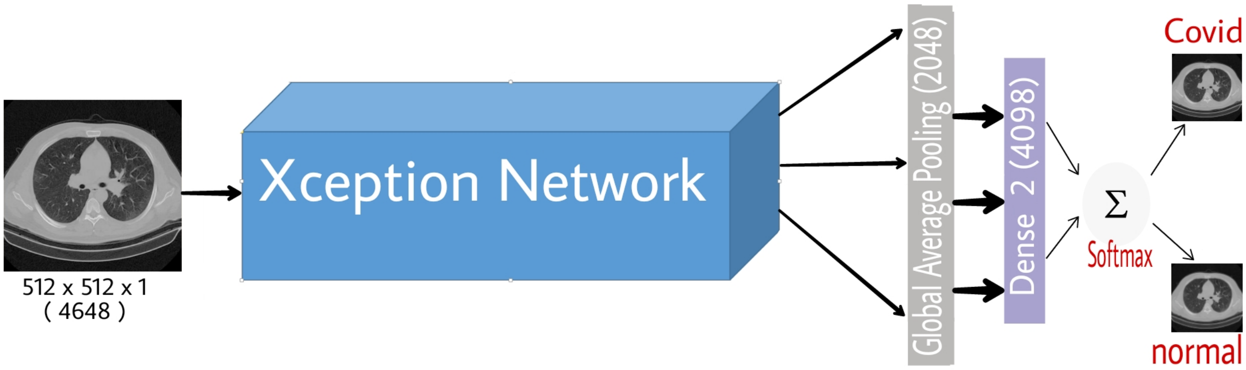

Figure 4.10: Final XCeption architecture.

Description of the model:

First, we will give images as input to the XCeption's netwrok, after that the output will pass through the Global average pooling layer, this operation is designed to replace fully connected layers in classical CNNs (dense layer), instead of adding fully connected layers on top of the feature maps generated by the convolutional layers, we take the average of each feature map and the resulting vector is fed directly into the softmax layer.

4.4 Conclusion

In this chapter, we have discussed the dataset that we are going to use in our work. Then we mentioned the preparation phase of this last. In the end, we have proposed solutions to extend our objective. The results and the tools of this implementation will be presented in the next chapter.

Chapter 5

Implementation and Tests

5.1 Introduction

In this chapter, we will talk about the different libraries used, environment and the programming language chosen to implement our model. We will also present the classification performance indicators. Next, we describe the implementation of our models and present its training on the dataset, after that in the test and prediction phase. We will evaluate our trained models. At the end, we will discuss the results obtained.

5.2 Programming language, libraries and used environment

In order to implement several models, different libraries, development environment and language were used.

5.2.1 Programming language

The programming language chosen for our method presented previously focused on the python language and the models we created in this chapter are also carried on the python language.

Python[1] is a powerful and easy to learn programming language. It has high level data structures and allows a simple but efficient approach to object oriented programming.

[1] https://docs.python.org/3/tutorial/

Python is an interpreted programming language, a scripting language and is a bit slow compared to other languages compiled as C or C ++ to do calculations. Python offers several libraries (packages) for data processing, matrix calculations, analysis and data visualization. For Deep Learning, python has working environments like caffe, tensorow, keras, pytorch. These working environments are very useful because they allow to easily manage the back propagation algorithm for large neural networks, CNNs, RNNs, etc. They also ensure the parallelization of calculations on the GPU. Python and its packages are available: in source or in binary without charge for the majority of platforms and can be redistributed for free.

The choice of this language has the following advantages:

- It is completely free.
- It is easy to learn, read, understand, use and write.
- It is object oriented but does not impose this type of programming.
- It works on all major operating systems and computer platforms.
- It creates professional quality software.

5.2.2 Developing environment

All training of the neuron network requires strong computing power. Our method is based on a deep convolutional network, which involves a large number of points to train. Training on the laptop PC would also have taken a long time. We used the Google Colab notebook environment.

Google Colab:

Google Colab or “the Colaboratory”[2] is a free cloud service hosted by Google to encourage Machine Learning and Artificial Intelligence research, where often the barrier to learning and success is the requirement of tremendous computational power.

Besides being easy to use, the Colab is fairly flexible in its configuration and does much of the heavy lifting for you.

[2] https://medium.com/lean-in-women-in-tech-india/google-colab-the-beginnersguide-5ad3b417dfa

- Python 2.7 and Python 3.6 support.
- Free GPU acceleration.
- Pre-installed libraries: All major Python libraries like TensorFlow, Numpy, Matplotlib among many others are pre-installed and ready to be imported.
- Allows developers to use and share notebook among each other without having to download, install, or run anything other than a browser.
- Google Colab notebooks are stored on the drive.

5.2.3 Used libraries

Several libraries have been used. In our work we need the following libraries:

TensorFlow

TensorFlow[3] is an end-to-end open source platform for machine learning. It has a comprehensive, flexible ecosystem of tools, libraries and community resources that lets researchers push the state-of-the-art in ML and developers easily build and deploy ML powered applications.

Many companies are using TensorFlow such as Google, Twitter, Intel, and Coca-Cola, it is very popular for its many benefits which we list below:

- Multi-platform (Linux, Mac OS, Windows and even Android and iOS).
- Very short compilation times.
- APIs in Python, C ++, Java.
- Extremely well supplied documentation with many examples and tutorials.
- Efficiently executing low-level tensor operations on CPU, GPU, or TPU.

[3] https://www.tensorflow.org/

Keras

Keras[4] is a deep learning API written in Python, running on top of the machine learning platform TensorFlow. It was developed with a focus on enabling fast experimentation. Being able to go from idea to result as fast as possible is key to doing good research.It provides essential abstractions and building blocks for developing and shipping machine learning solutions with high iteration velocity.

Matplotlib

Matplotlib[5] is a 2D Python tracking library that produces publication-quality images in various hardcopy formats and interactive environments on all platforms.

NumPy

NumPy is a library for the Python programming language, adding support for large, multi-dimensional arrays and matrices, along with a large collection of high level mathematical functions to operate on these arrays [38].

OpenCV

OpenCV (Open Source Computer Vision Library)[6] is an open source computer vision and machine learning software library. OpenCV was built to provide a common infrastructure for computer vision applications and to accelerate the use of machine perception in the commercial products. Being a BSD-licensed product, OpenCV makes it easy for businesses to utilize and modify the code.

Pandas

Pandas[7] is a fast, powerful, flexible and easy to use open source data analysis and manipulation tool, built on top of the Python programming language.

[4] https://keras.io/
[5] https://matplotlib.org/
[6] https://opencv.org/
[7] https://opencv.org/

Scikit-learn

Scikit-learn[8] is a library in Python which provides many learning algorithms. It includes functions for estimating logistic regressions, classification algorithms, and support vector machines.

5.3 Classification performance metrics

In order to perform experimental evaluation of the models under consideration, various performance metrics like Accuracy, F1-Score, Specificity, Precision, and Recall (Sensitivity) are used in this work. These evaluation metrics are particularly useful while evaluating a medical screening system, which is why they are chosen for the task of COVID19 prediction.

To measure performance, it is customary to distinguish four types of items classified for the desired class:

1. **TP (True positive):** Prediction is positive and the patient has COVID19.
2. **TN (True Negative):** Prediction is negative and the patient is healthy.
3. **FP (False Positive):** Prediction is positive and the patient is healthy.
4. **FN (False Negative):** Prediction is negative and the patient has COVID19.

All used metrics are explained in the table down below

[8]https://scikitlearn.org/

Indicator	Description	Equation
Accuracy	It's the ratio of the correctly labeled subjects to the whole pool of subjects. Accuracy is the most intuitive one.	$\boldsymbol{Acc} = \frac{TP + TN}{TP + FP + TN + FN}$
Precision	Precision is the ratio of the correctly positive labeled by our program to all positive labeled.	$\boldsymbol{Pre} = \frac{TP}{TP + FP}$
Recall (aka sensitivity)	Recall is the ratio of the correctly positive labeled by our program to all who are infected in reality.	$\boldsymbol{Recall} = \frac{TP}{TP + FN}$
F1-Score	It is the harmonic mean (average) of the precision and recall.	$\boldsymbol{FScore} = \frac{2 * (Recall * Precision)}{Recall + Precision}$

Table 5.1: Metrics evaluations.

5.4 Implementation

In this section, we will talk about the implementation of our project, it is divided into two subsections. In the first one, we will describe the filtering algorithm we used to clean our dataset and choose only good images to train our models on (open lung images). Second subsection will basically be oriented to describe the creation of our models.

5.4.1 Filtering algorithm

Our dataset contains many different images for each patient, these images differ from closed lung to open lung.

The main difference between an open lung and closed lung is that the open lung image has lower pixel values (near to black) in the middle of the image, for that this algorithm is used to calculate the pixel values in the middle of CT scan to determine whether it's an open lung or not.

The implementation of the filtering algorithm is illustrated down below in the Figure 5.1

```
for r,d,f in os.walk(original_path): #Take the addresses of the TIFF files for each patient in the dataset
    for file in f:
        if'.tif' in file:
            full_add=os.path.join(r,file)
            indexes=find_inds('/',full_add)
            index=indexes[-1]
            if full_add[:index+1] not in adds:
                adds[full_add[:index+1]]=[]
            adds[full_add[:index+1]].append(full_add[index+1:])

for key in adds:
    zero=[]
    names=[]
    for value in adds[key]:
        names.append(value)
        address=key+value
        pixel=cv2.imread(address,cv2.IMREAD_UNCHANGED ) #read the TIFF file
        sp=pixel[240:340,120:370] #Crop the region
        counted_zero=0
        for i in np.reshape(sp,(sp.shape[0]*sp.shape[1],1)):
            if i<300: #count the number of pixel values in the region less than 300
                counted_zero+=1
        zero.append(counted_zero)
    min_zero=min(zero)
    max_zero=max(zero)
    threshold=(max_zero-min_zero)/1.5 #Set the threshold
    indices=np.where(np.array(zero)>threshold) #Find the images that have more dark pixels in the region than the calculated threshold
    selected_names=np.array(names)[indices]
    selected[key]=list(selected_names) #Add the selected images of each patient
```

Figure 5.1: Filtering algorithm.

5.4.2 Created models

During our experiments, we have created several models with different architectures based on the proposed approaches.

The architecture of the models are illustrated down below:

1. **Basic model:**

   The architecture of this model is represented in the table below:

Model: "sequential_1"

Layer (type)	Output Shape	Param #
conv2d_4 (Conv2D)	(None, 510, 510, 32)	320
max_pooling2d_4 (MaxPooling2	(None, 255, 255, 32)	0
conv2d_5 (Conv2D)	(None, 253, 253, 64)	18496
max_pooling2d_5 (MaxPooling2	(None, 126, 126, 64)	0
conv2d_6 (Conv2D)	(None, 124, 124, 128)	73856
max_pooling2d_6 (MaxPooling2	(None, 62, 62, 128)	0
conv2d_7 (Conv2D)	(None, 60, 60, 128)	147584
max_pooling2d_7 (MaxPooling2	(None, 30, 30, 128)	0
flatten_1 (Flatten)	(None, 115200)	0
dropout_1 (Dropout)	(None, 115200)	0
dense_2 (Dense)	(None, 1024)	117965824
dense_3 (Dense)	(None, 2)	2050

Total params: 118,208,130
Trainable params: 118,208,130
Non-trainable params: 0

Table 5.2: Basic model summary.

2. **ResNet50v2 model:**

   The architecture of this model is summarized in the table as it follows:

Model: "sequential"

Layer (type)	Output Shape	Param #
resnet50v2 (Functional)	(None, 16, 16, 2048)	23558528
global_average_pooling2d (Gl	(None, 2048)	0
dense (Dense)	(None, 2)	4098

Total params: 23,562,626
Trainable params: 23,517,186
Non-trainable params: 45,440

Table 5.3: ResNet50V2 model summary.

Description of the model:

ResNet50V2 model consists of five stages each with a convolution and Identity block. Each convolution block has three convolution layers and each identity block also has 3 convolution layers. The ResNet50V2 has over 23 million trainable parameters (table 5.3). After that comes the Global Average Pooling that replaces the dense layer of the classification.

Then the final dense layer of two neurons outputs the final class results (COVID19/Normal).

3. **XCeption model:**

   The architecture of this model is summarized in the table as it follows:

```
Model: "sequential"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
xception (Functional)        (None, 16, 16, 2048)      20860904
_________________________________________________________________
global_average_pooling2d (Gl (None, 2048)              0
_________________________________________________________________
dense (Dense)                (None, 2)                 4098
=================================================================
Total params: 20,865,002
Trainable params: 20,810,474
Non-trainable params: 54,528
_________________________________________________________________
```

Table 5.4: XCeption model summary.

Description of the model:

Xception is a convolutional neural network that is 126 layers deep, after that comes Global Average Pooling that replaces the dense layer of the classification.

Then the final dense layer of two neurons outputs the final class results (COVID19/Normal).

5.5 Training and tests

In this section, we will talk about training and testing phases of our models. It is divided into two subsections, first subsection will be dedicated for the training of our models using train images set, note that our models are trained on different number of epochs (10, 30, 50) , and the second one will contain the test of our models using test images set.

5.5.1 Training

All models are trained on a portion of the dataset (4GB) due to technical resources problems, 112 patients (50 positive cases, 62 negative cases) with 5654 images as it is summarized in the table down below.

Dataset	Images number
Training set	3736
Testing set	1006
Validation set	912
Total	5654

Table 5.5: Used dataset representation.

All results (accuracy and lose values) obtained from training phase are shown down below for each model.

1. **Basic model:**

Basic Model			
Number of epochs	10	30	50
Accuracy	60.86%	72.04%	62.50%
Loss	2.74	0.67	5.57
Time	44min 36s	1h 3min	1h 45min 24s

Table 5.6: Accuracy/Loss/Time for basic model.

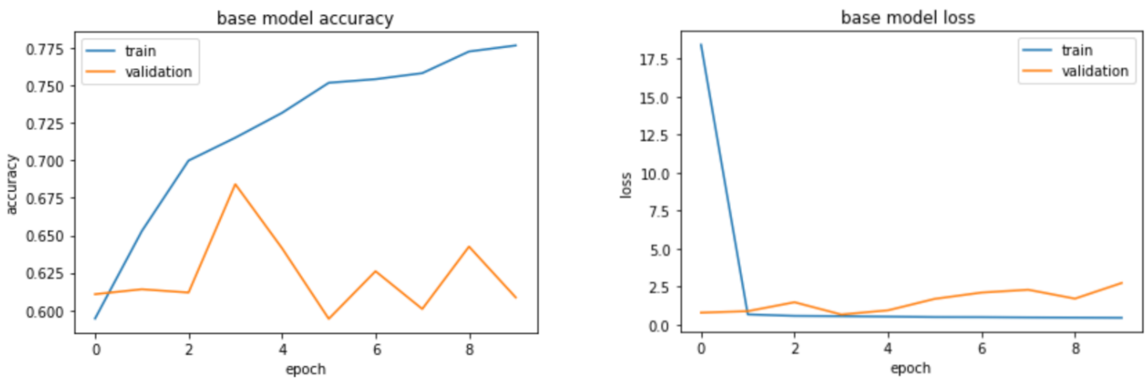

Figure 5.2: Accuracy and loss of the basic model according to 10 epochs.

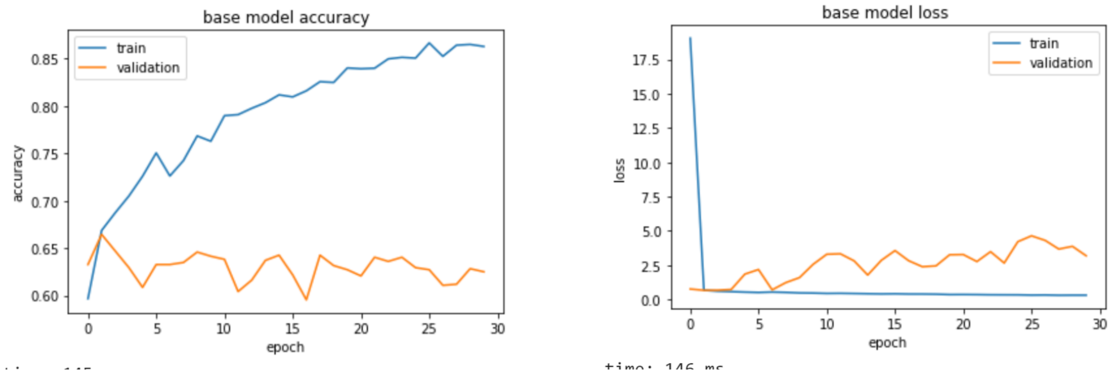

Figure 5.3: Accuracy and loss of the basic model according to 30 epochs.

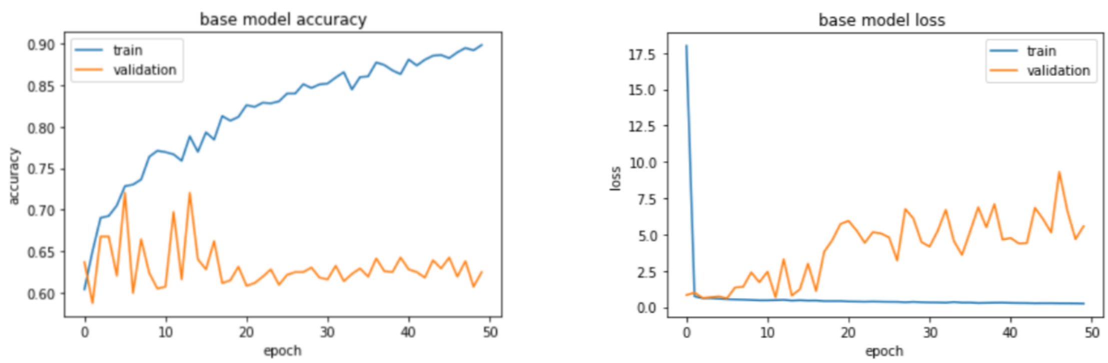

Figure 5.4: Accuracy and loss of the basic model according to 50 epochs.

2. **ResNet50V2 model:**

ResNet50V2 Model			
Number of epochs	10	30	50
Accuracy	98.14%	98.46%	98.57%
Loss	0.19	0.30	0.18
Time	55min 11s	1h 37min 8s	3h 1min 52s

Table 5.7: Accuracy/Loss/Time for ResNet50V2 model.

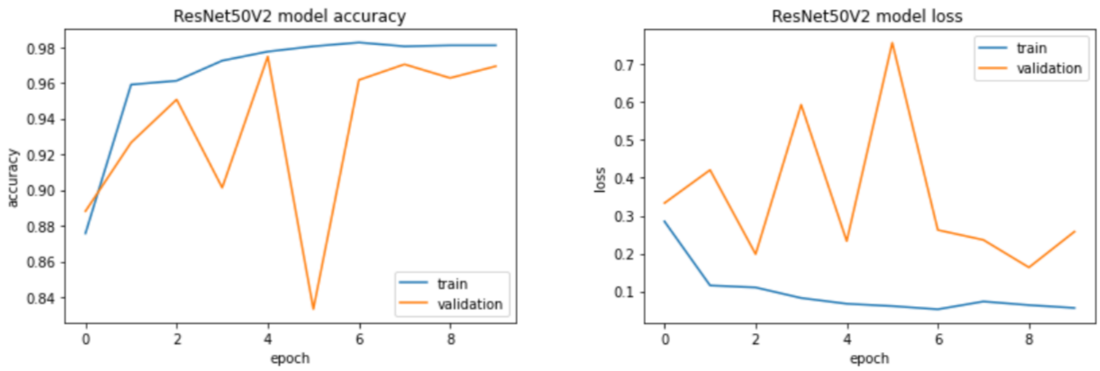

Figure 5.5: Accuracy and loss of the ResNet50V2 model according to 10 epochs.

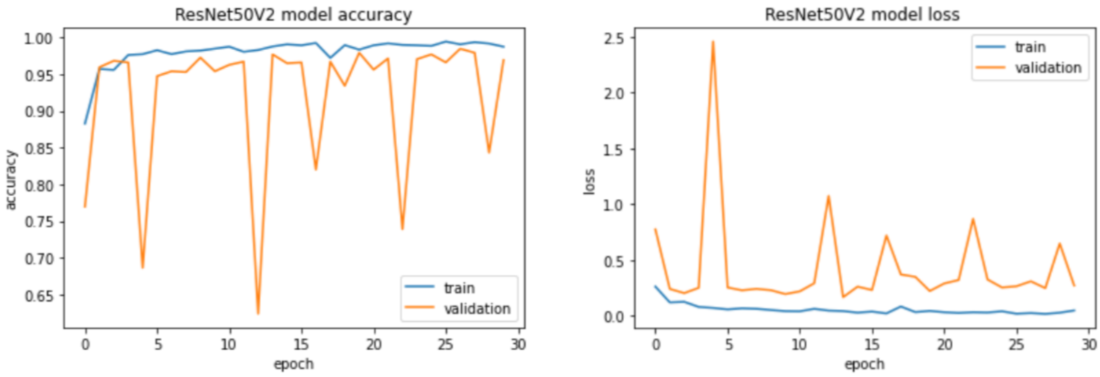

Figure 5.6: Accuracy and loss of the ResNet50V2 model according to 30 epochs.

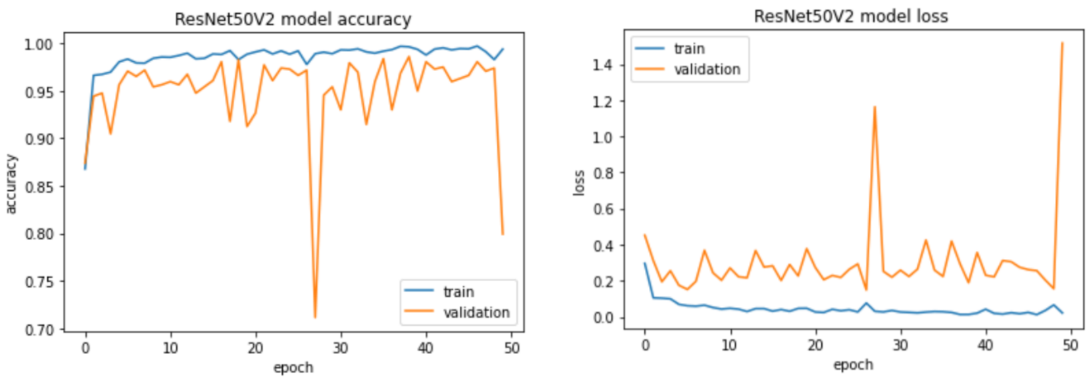

Figure 5.7: Accuracy and loss of the ResNet50V2 model according to 50 epochs.

3. **XCeption model:**

XCeption Model			
Number of epochs	10	30	50
Accuracy	94.74%	97.04%	97.81%
Loss	0.22	0.29	0.26
Time	1h 5min 25s	3h 51min 44s	6h 12min 40s

Table 5.8: Accuracy/Loss/Time for XCeption model.

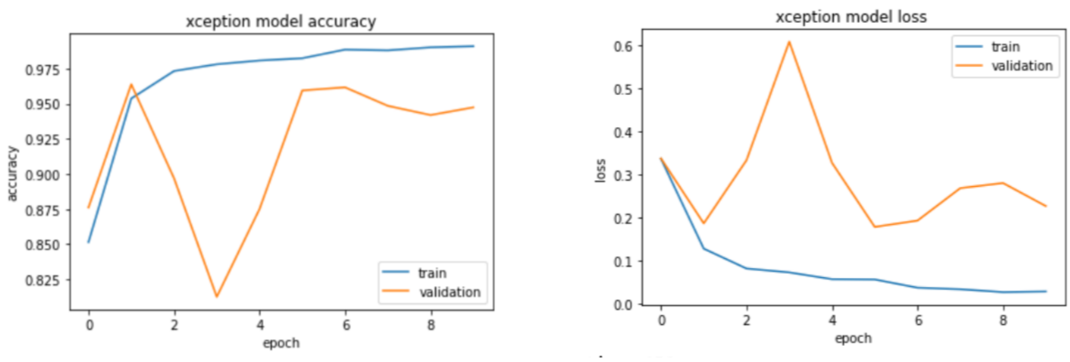

Figure 5.8: Accuracy and loss of the XCeption model according to 10 epochs.

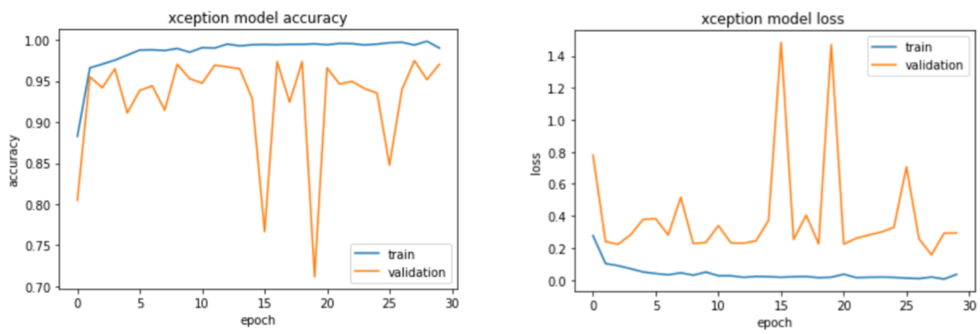

Figure 5.9: Accuracy and loss of the XCeption model according to 30 epochs.

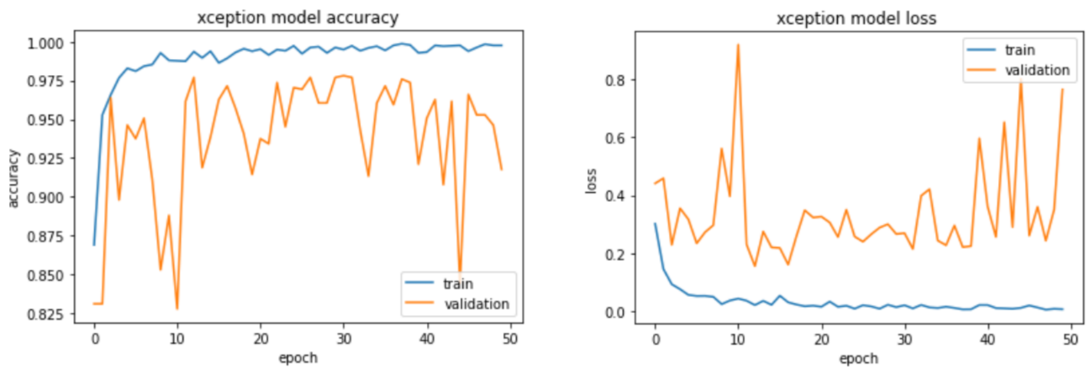

Figure 5.10: Accuracy and loss of the XCeption model according to 50 epochs.

5.5.2 Tests

After training our models, now we pass to the evaluation phase, where we will test our models on the testing set containing 1006 images (49% positive COVID19 cases, and 51% negative cases). All testing results are illustrated in tables down below.

Basic model			
Number of epochs	10	30	50
Accuracy	61.23%	64.01%	67.09%
Recall	55.53%	57.26%	58.59%
Specificity	71.62%	78.61%	79.83%
precision	78.13%	85.28%	87.68%
F1-Score	58.59%	59.72%	64.22%

Table 5.9: Basic model test results.

ResNet50V2 model			
Number of epochs	10	30	50
Accuracy	98.80%	99.60%	99.40%
Recall	99.5%	100%	98.92%
Specificity	98.18%	99.27%	99.81%
precision	97.83%	99.13%	99.78%
F1-Score	98.72%	99.56%	99.43%

Table 5.10: ResNet50V2 model test results.

XCeption model			
Number of epochs	10	30	50
Accuracy	96.42%	98.60%	98.31%
Recall	96.30%	97.86%	97.84%
Specificity	96.52%	99.25%	98.70%
precision	95.88%	99.13%	98.48%
F1-Score	96.37%	98.64%	98.32%

Table 5.11: Xception model test results.

5.6 Analyze and discussion

In this section, we will compare the models based on their results obtained from different epochs of training, and determine which model among them is the best.

5.6.1 Models comparison

First of all, we will choose the best model based on the number of epochs, figures down below illustrate this last.

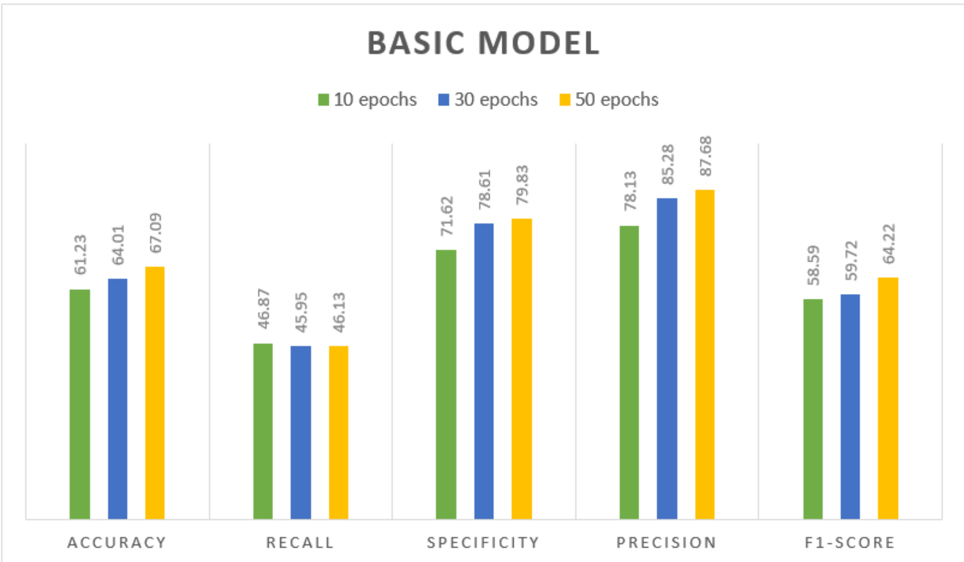

Figure 5.11: Basic model epochs comparison.

From the figure up above, it is obvious that the model with 50 epochs of training has the best values for each metric.

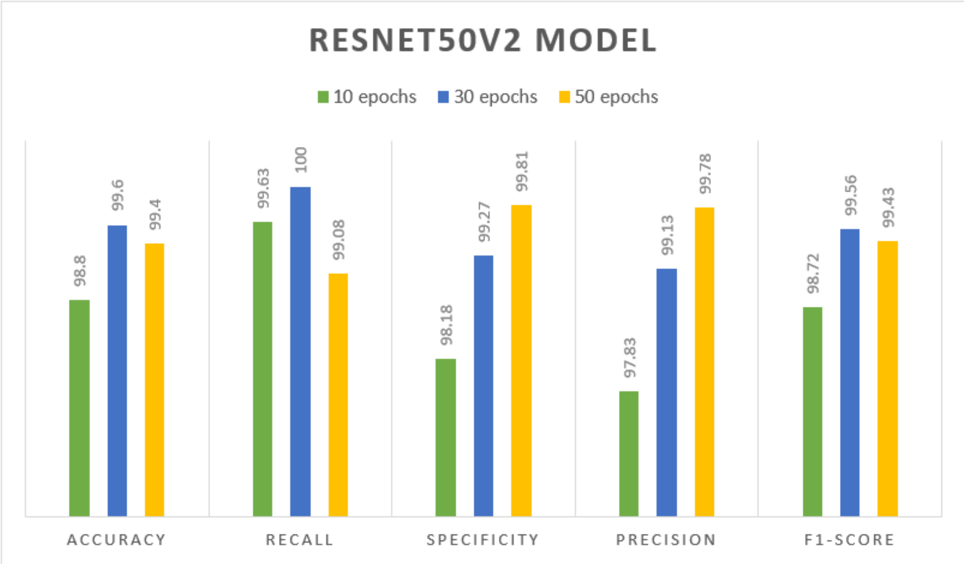

Figure 5.12: ResNet50V2 model epochs comparison.

This model has shown results as it follows:

- 30 epochs has better Accuracy, Recall, F1-Score compared to 10 and 50 epochs.
- 50 epochs has better Precision and specificity compared to 10 and 30 epochs.

Since Accuracy and F1-Score are the most intuitive metrics, we can say that the model with 30 epochs gave us the highest results.

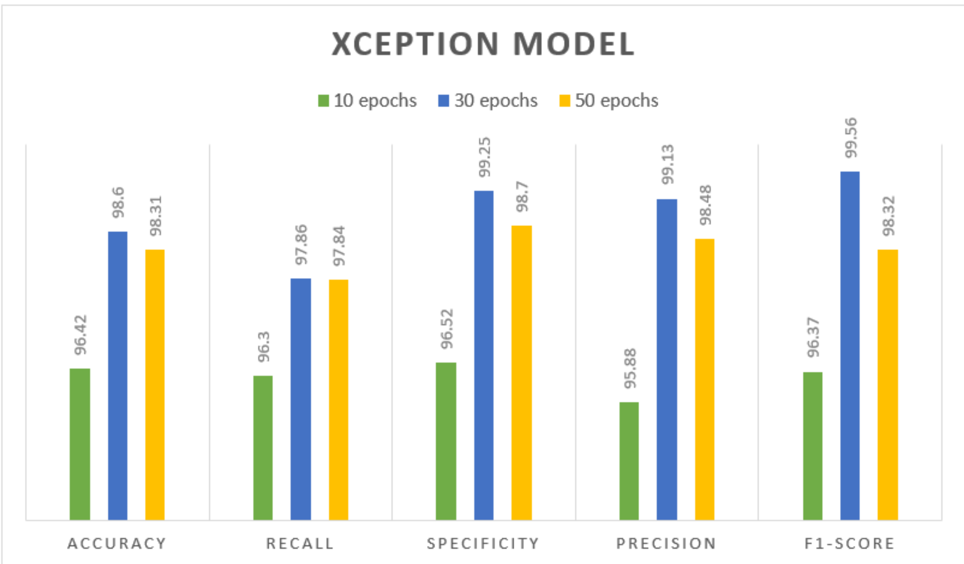

Figure 5.13: XCeption model epochs comparison.

From the figure up above, the model with 30 epochs of training has shown the best results compared to 10 and 50 epochs.

At this point we have 3 models with the highest results, summarized as it follows:

Test Results									
Models	Basic Model			XCeption Model			ResNet50V2 Model		
Epochs	10	30	**50**	10	**30**	50	10	**30**	50
Accuracy	61.23%	64.01%	**67.09%**	96.42%	**98.60%**	98.31%	98.80%	**99.60%**	99.40%
Recall	55.53%	57.26%	**58.59%**	96.30%	**97.86%**	97.84%	99.5%	**100%**	98.92%
Specificity	71.62%	78.61%	**79.83%**	96.52%	**99.25%**	98.70%	98.18%	**99.27%**	99.81%
Precision	78.13%	85.28%	**87.68%**	95.88%	**99.13%**	98.48%	97.83%	**99.13%**	99.78%
F1-Score	58.59%	59.72%	**64.22%**	96.37%	**98.64%**	98.32%	98.72%	**99.56%**	99.43%

Table 5.12: All models results.

The table up above shows that:

- Basic model trained on 50 epochs: 64.22% F1-Score and 67.09% Accuracy.
- ResNet50V2 model trained on 30 epochs: 99.56% F1-Score and 99.60% Accuracy.
- XCeption model trained on 30 epochs: 98.64% F1-Score and 98.60% Accuracy.

Are the best models for each approach.

Now, we compare these three models to choose our best model in all approaches

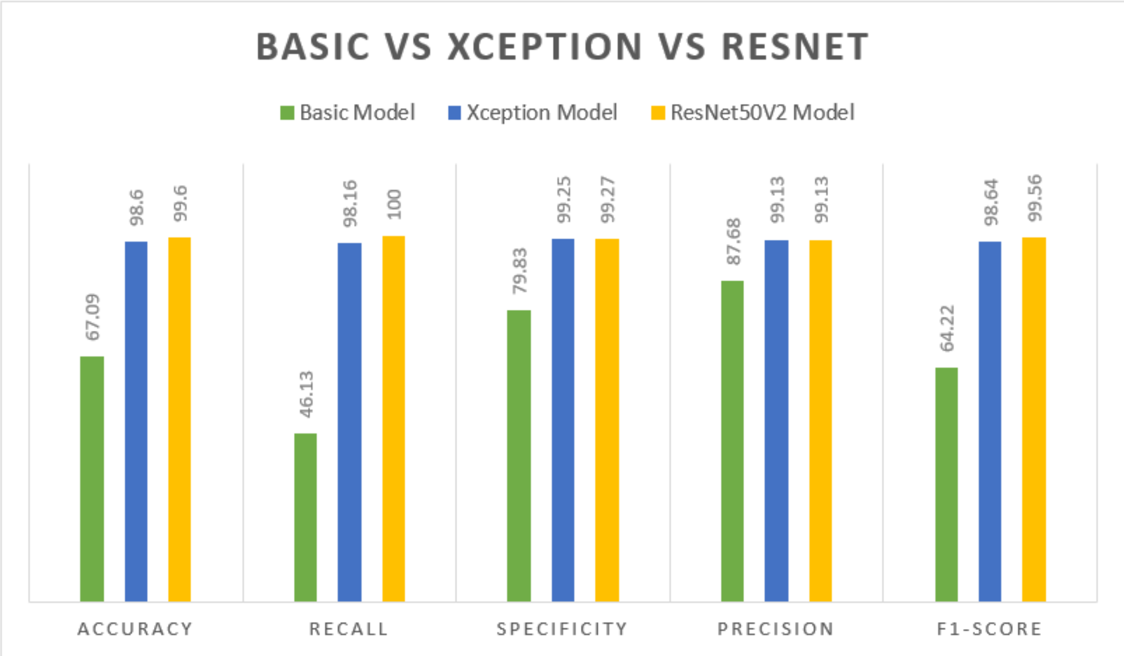

Figure 5.14: All models comparison.

Finally, we can say that in all proposed approaches models, ResNet50V2 trained on 30 epochs has the highest results for COVID-19 detection in all terms of metrics.

5.6.2 Comparison with other works

After knowing the best model we created, now it is time to compare it to another existing project, which is **Identifying COVID19 from Chest CT Images: A Deep Convolutional Neural Networks Based Approach** [34] and their model (Decision Fusion Model) in the table 5.13 and figure 5.15.

ResNet50V2 Model VS Decision Fusion Model		
Models	ResNet50V2 Model	Decision Fusion Model
Accuracy	**99.60%**	89%
Recall	**100%**	89%
Specificity	**99.27%**	90.5%
Precision	**99.13%**	88%
F1-Score	**99.56%**	87.5%

Table 5.13: ResNet50V2 Model VS Decision Fusion Model.

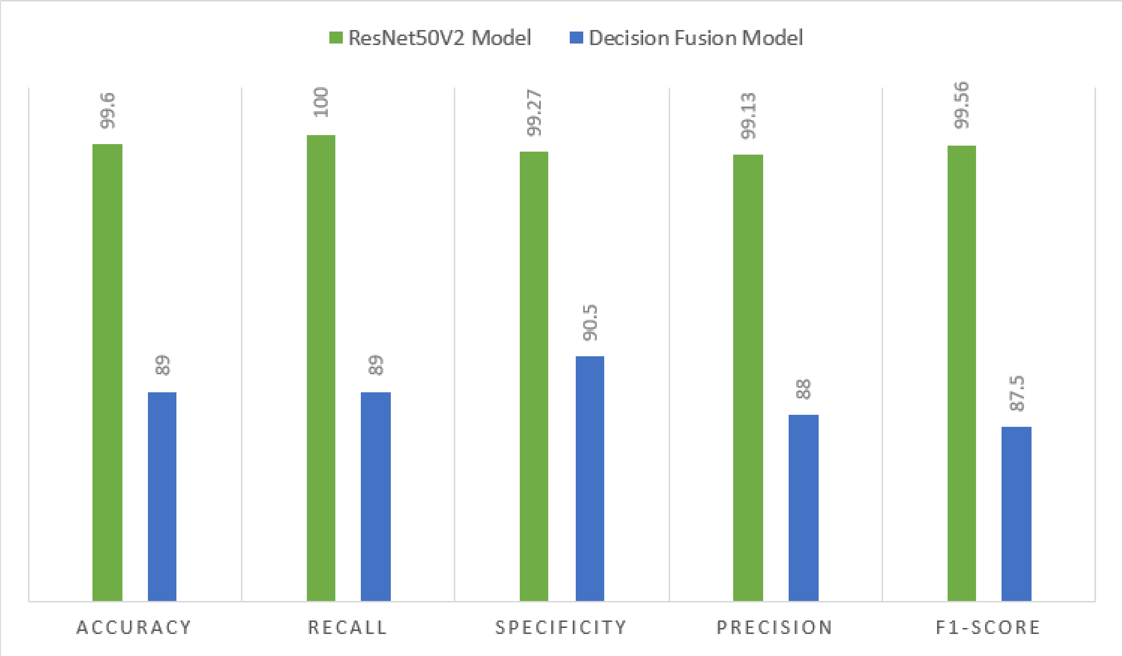

Figure 5.15: ResNet50V2 Model VS Decision Fusion Model.

From the figure up above, it is obvious that our model (ResNet50V2 Model) is better than Decision Fusion Model in all metrics.

5.7 Obstacles

Deep learning, the spearhead of artificial intelligence, is perhaps one of the most exciting technologies of the decade. It already made his road to many domains such as medical diagnosis.

It is known that the implementing of deep learning algorithms needs some specific resources like large datasets to train models and strong computing hardware resources (CPUs, GPUs and storage space).

During the implementation of our project, we faced many problems due to our limited resources as students from them we mention:

- Scarcity of appropriate Covid-19 datasets because of its recent appearance.
- Some covid-19 datasets are access limited to specific universities and research centers.

- Unavailability of strong computing resources in our university.

Due to the problems mentioned up above the only solution we had is cloud services. There are lot of cloud services that offer the needed resources but most of them are paid like amazon[9] web services and Allibaba[10] cloud, but these are paid services and as students we can't afford them so we went towards free cloud services.

There is many free cloud services like Google Colab and Kaggle[11] Notebooks all of them offers modest computing resources that can implement deep learning algorithms but with limitations.

Google Colab was the most fitting service to implement our project but always with limitations and from them we mention:

- Only 12 continuous working hours per session.
- Using only one GPU per session.
- Limited memory of 12GB.
- One CPU (Intel(R) Xeon(R) CPU @ 2.30GHz)

There is also a premium version of Google Colab that allows to access more resources but its paid.

These limitations caused us some problems, which led us to:

- The filtering process takes much time, so we could not filter all the dataset and this leads to use only one part from the dataset(5654 clear image or after filtering).
- Tweak the algorithm we used to reduce training time.

Colab also needs a stable internet connection as all the cloud services but unfortunately internet in Algeria in unstable, which make implementing our project even more challenging.

[9]https://aws.amazon.com
[10]https://www.alibabacloud.com
[11]https://www.kaggle.com/notebooks

5.8 Conclusion

We have presented in the last chapter the programming language, libraries and environment used to implement our project. After that we presented the classification performance indicators (metrics), then we moved to the implementation describing the filtering algorithm and our created models, after that the training and testing phases as well as the various results obtained of comparisons of each model with itself, then between our three approaches models, finally the final comparison with a related work. We ended this chapter with an important point, which is the obstacles and problems we faced during our implementation of the project.

General conclusion

During Covid-19 world pandemic and the huge increase of infected people because of its fast transmission. The only solution to stand against this virus is to determine infected people in early stages and quarantine them to prevent them from infect more people.

The detection of infected people with COVID-19 using traditional methods such as the process based on reverse transcription-polymerase chain reaction (RT-PCR), which usually takes much time to give results. Moreover, since COVID-19 is a global pandemic the availability of testing kits poses another problem even for developed countries like United States of America. For this, researchers tried to find alternative solutions like detecting COVID-19 virus from chest CT scans across multifocal bilateral patchy ground-glass opacities or consolidation with interlobular septal and vascular thickening, mostly in the peripheral fields of the lungs. This solution needs manual detection by doctors in addition this process is a tedious task, tiring, likely to involve human error and the most important thing is that it takes so much time.

At this point comes the role of Deep Learning more precisely the field of Computer Vision in medical imaging diagnosis, because it is an efficient method and can solve the long time problem in diagnosing COVID-19 in chest CT scans if it is used correctly.

In this dissertation, we proposed three Deep Learning approaches, starting by a basic CNN model developed from scratch, secondly using ResNet50V2 architecture, finally using XCeption architecture. Based on these three approaches we built three models (CNN model from scratch, CNN model based on ResNet50V2 architecture and CNN model based on XCeption architecture).

All these models were trained on a portion of chest CT scans dataset, which contains infected and normal patients, in order to make our models able to classify chest CT scans into COVID-19 and Normal classes.

CNN was the chosen algorithm in our study because it offers an excellent feature extractor and the way it processes images made it a perfect fit to our project. The results we obtained after testing our models proves the efficiency of our proposed models.

In this project, we presented some medical basics passing through defining COVID-19 and covering medical imaging and its types. After that we talked about AI, ML, DL and the way we use deep learning to detect diseases from medical images, then we passed to materials and methods we used to implement our models and a detailed description of this last. Finally, we discussed the results obtained from implementing and testing the three models.

Perspective and future works:

Moving on to future works and perspectives. It is known that there is no perfect work, so it is our work. In the close future we are looking forward to make our models even more accurate and make them applicable in the real world hoping to help the world to make a stop to this global health crisis.

However, none of this is going to happen unless we get rid of the technical resources limitation we already faced in order to train our models on much more data and make the necessary clinical trials in hospitals with the cooperation of specialist doctors.

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Abstract

Currently, the detection of coronavirus disease (COVID-19) is one of the main challenges in the world, given the rapid spread of the disease. Recent statistics indicate that the number of people diagnosed with COVID-19 is increasing exponentially, with more than 1.6 million confirmed cases; the disease is spreading to many countries across the world.

The objective of this work is to propose a Deep Learning approach in the field of epidemiology to detect coronavirus.

To do this, we have chosen to use the Convolutional Neural networks (CNN), where different models have been implemented allowing us to obtain the best results.

In this study, we proposed three Convolutional Neural Network approaches and crated three models based on these approaches, the created models were trained and prove their efficiency by achieving high accuracy and F1-Score in their testing using real-world chest CT scans dataset.

Key words: COVID-19, Coronavirus, Chest CT scans, Medical imaging, Image analysis, Radiology imaging, Artificial intelligence, Machine Learning, Deep Learning, Neural networks, Convolutional neural network, image processing, image classification, ...

Résumé

Actuellement, la détection de coronavirus (COVID-19) est l'un des principaux défis dans le monde, étant donné la propagation rapide de la maladie. Des statistiques récentes indiquent que le nombre de personnes diagnostiquées avec COVID-19 augmente de façon exponentielle, avec plus de 1,6 million de cas confirmés, la maladie s'étend à de nombreux pays dans le monde.

L'objectif de ce travail est de proposer une approche d'apprentissage approfondi dans le domaine l'épidémiologie pour détecter les coronavirus.

Pour ce faire, nous avons choisi d'utiliser les réseaux neuronaux convolutifs (CNN), où différents modèles ont été mis en œuvre, ce qui nous permet d'obtenir les meilleurs résultats.

Dans cette étude, nous avons proposé trois approches de réseau neuronal convolutif et avons créé trois modèles basés sur ces approches. Les modèles créés ont été formés et ont prouvé leur efficacité en obtenant une grande précision et F1-score lors de leurs tests en utilisant des données de scanners thoraciques réels.

Mots clés: COVID-19, Coronavirus, CT scanners, Imagerie médicale, Analyse d'images, Imagerie radiologique, Intelligence Artificielle, Apprentissage Automatique, Apprentissage en profondeur, Réseaux de neurones, Réseau de neurones convolutifs, Traitement d'image, Classification d'images, . . .

ملخص

حاليًا ، يعد اكتشاف مرض فيروس كورونا أحد التحديات الرئيسية في العالم ، نظرًا للانتشار السريع للمرض. تشير الإحصاءات الحديثة إلى أن عدد الأشخاص المصابين بفيروس كورونا يتزايد بشكل كبير ، مع أكثر من ٦٠١ مليون حالة مؤكدة ؛ ينتشر المرض في العديد من البلدان في جميع أنحاء العالم.

الهدف من هذا العمل هو اقتراح نهج التعلم العميق في مجال علم الأوبئة للكشف عن فيروس كورونا.

للقيام بذلك ، اخترنا استخدام الشبكات العصبية التلافيفية ، حيث تم تنفيذ نماذج مختلفة مما يتيح لنا الحصول على أفضل النتائج.

في هذه الدراسة ، اقترحنا ثلاثة مناهج للشبكة العصبية التلافيفية وصممنا ثلاثة نماذج بناءً على هذه الأساليب ، وتم تدريب النماذج التي تم إنشاؤها وإثبات كفاءتها من خلال تحقيق دقة عالية في اختبارها باستخدام مجموعة بيانات مسح الصدر بالأشعة المقطعية.

كلمات مفتاحية، كوفيد١٩ ، فيروس كورونا ، فحوصات الصدر المقطعية ، التصوير الطبي ، تحليل الصور ، التصوير الشعاعي ، الذكاء الاصطناعي ، التعلم الآلي ، التعلم العميق ، الشبكات العصبية ، الشبكة العصبية التلافيفية ، معالجة الصور ، تصنيف الصور ، ...