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ORIGINAL ARTICLE

A Novel Cascaded-Deep Learning Classifier for Diagnosis of Covid19 and Pneumonia Disease in Chest X-Ray

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Abstract

Computer-aided diagnosis (CAD) systems are considered a powerful tool forphysicians to support identification of the novel Coronavirus Disease 2019(COVID-19) using medical imaging modalities. Therefore, this article proposes anew framework of cascaded deep learning classifiers to enhance the performanceof these CAD systems for highly suspected COVID-19 and pneumonia diseases inX-ray images. Our proposed deep learning framework constitutes two majoradvancements as follows. First, complicated multi-label classification of X-rayimages have been simplified using a series of binary classifiers for each testedcase of the health status.**KEYWORDS:**

Semi-Markov Decision Process (SMDP), Reinforcement Learning(RL) Algorithm, Vehicular Cloud System, Neural-Network, Quality ofExperience (QoE), Quality of Service (QoS).

1. Introduction

The COVID-19is named by the World Health Organization (WHO) as a novel infectious disease,and it belongs to Coronaviruses (CoV) and perilous viruses [2, 3]. It results insome cases a critical care respiratory condition such as Severe Acute RespiratorySyndrome (SARS-CoV), leading to failure in breathing and the death eventually.Recently, situation report no. 74 of the WHO announced that the risk assessmentof COVID-19 is very high at the global level on 3 April

2020 [4, 5]. In addition,the total number of cases has become 972,303 confirmed COVID-19 patients and50,322 deaths worldwide. Also, other common lung infections like viral andbacterial pneumonia lead to thousands of deaths every year [6]. These pneumoniadiseases cause fungal infection of one or both sides of the lungs by the formationof pus and other liquids in the air sacs. Symptoms of the viral pneumonia occurgradually and are mild. But bacterial pneumonia is more severe, especially amongchildren [7]. This type of pneumonia can affect many lobes of the lung.The gold standard for diagnosing common pneumonia diseases and

Coronavirusesis the real-time polymerase chain reaction (RT-PCR) assay of the sputum [8].However, these RT-PCR tests showed high false-negative levels to confirmpositive COVID-19 cases. Alternatively, radiological examinations using chest X-ray and computed tomography (CT) scans are now being used to identify thehealth status of infected patients including children and pregnant women [9, 10],regardless of potential side effects of ionizing radiation exposure. The CT imagingpresents an effective method for screening, diagnosis, and progress assessment ofpatients with COVID-19 [11]. Nevertheless, clinical studies demonstrated that apositive chest X-ray may obviate the need for CT scans and reducing clinicalburden on CT suites during this pandemic outbreak [12, 13]. The AmericanCollege of Radiology (ACR) recommended the utilization of portable chestradiography to minimize the risk of Coronavirus infection, because thedecontamination of CT rooms after scanning COVID-19 patients may causeinterruption of this radiological service [14]. Also, chest CT screening requireshigh-dose exposure to scan patients and relatively expensive hospital bills out[15]. In contrast, conventional X-ray machines are always available and portablein hospitals and clinical centers to give a quick scan for the patients' lungs as two-dimensional (2D) images. Therefore, the chest X-ray scans present the first toolfor clinicians to confirm positive COVID-19 cases [10, 16].

In this proposed work, wefocus only on enhancing the performance of using chest X-ray scans forconfirming the patients with highly suspected COVID-19 or other pneumoniadiseases, namely viral (Non-COVID-19) or bacterial infect.However, X-ray images are still contrast limited because of low-exposure dose tothe patients, leading to difficulties in diagnosing soft tissues or diseased areasin the patient's thorax [15, 17]. Computer-aided diagnosis (CAD) systemspresent a practical solution to overcome these limitations of chest X-rays, andto assist radiologists to automatically detect potential diseases in low-contrastX-ray images [18, 19]. The CAD systems combined advanced components ofcomputer technologies with recent image processing algorithms to performinterventional tasks, e.g. tumor segmentation and 3D visualization of vitalorgans [20, 21]. Now, artificial intelligence (AI) has been widely applied toadvance the diagnostic performance of many CAD systems for various medicalapplications such as brain tumor classification or segmentation [22, 23],minimally invasive aortic valve implantation [17], and detecting pulmonarydiseases [24, 25]. Recently, deep learning approaches become the mostadvanced methods in the field of AI. They can learn patterns and features fromlabeled (or annotated) data to be capable of automatically performing specifictasks based on the previous training, such as human sentiment classification[26] and computer vision applications in surgery [27]. Convolutional neuralnetworks (CNNs) present a major branch of deep learning techniques in manyapplications of computer vision and sensitive medical applications in the lastyears [28]. The CNNs have been used to analyze single and multi-modalmedical images in different applications of radiology, e.g. breast cancerclassification and lung nodule detection [29, 30].

2. LITERATURE SURVEY

Literature survey is that the most vital step in software development process. Before developing the new application or model, it's necessary to work out the time factor, economy and company strength. Once all these factors are confirmed and got an approval then we can start building the application. The literature survey is one which is mainly deal with all the previous work which is done by several users and what are the advantages and limitations in those previous models. This literature survey is mainly used for identifying the list of resources to construct this proposed application.

MOTIVATION

1. Cascaded deep learning classifiers for computer-aided diagnosis ofCOVID-19 and pneumonia diseases in X-ray scan

Human coronaviruses (HCoVs) have long been considered inconsequentialpathogens, causing the “common cold” in otherwise healthy people.However, inthe 21st century, 2 highly pathogenic HCoVs—severe acute respiratory syndromecoronavirus (SARS-CoV) and Middle East respiratory syndrome coronavirus(MERS-CoV)—emerged from animal reservoirs to cause global epidemics withalarming morbidity and mortality. In December 2019, yet another pathogenicHCoV, 2019 novel coronavirus (2019-nCoV), was recognized in Wuhan, China,and has caused serious illness and death. The ultimate scope and effect of thisoutbreak is unclear at present as the situation is rapidly evolving. Coronavirusesare large, enveloped, positivestrand RNA viruses that can be divided into genera: alpha, beta, delta, and gamma, of which alpha and beta CoVs are knownto infect humans.1 Four HCoVs (HCoV 229E, NL63, OC43, and HKU1) areendemic globally and account for 10% to 30% of upper respiratory tract infectionsin adults. Coronaviruses are ecologically diverse with the greatest variety seen inbats, suggesting that they are the reservoirs for many of these viruses.2Peridomestic mammals may serve as intermediate hosts, facilitatingrecombination and mutation events with expansion of genetic diversity. Thesurface spike (S) glycoprotein is critical for binding of host cell receptors and isbelieved to represent a key determinant of host range restriction

1) Until recently, HCoVs received relatively little attention due to their mild phenotypes in humans. This changed in 2002, when cases of severe atypical pneumonia were described in Guangdong Province, China, causing worldwide concern as disease spread via international travel to more than 2 dozen countries.
2) The new disease became known as severe acute respiratory syndrome (SARS), and a beta-HCoV, named SARS-CoV, was identified as the causative agent. Because early cases shared a history of human-animal contact at live game markets, zoonotic transmission of the virus was strongly suspected.
3) Palm civets and raccoon dogs were initially thought to be the animal reservoir(s); however, as more viral sequence data became available, consensus emerged that bats were the natural hosts. Common symptoms of SARS included fever, cough, dyspnea, and occasionally watery diarrhea.2 Of infected patients, 20% to 30% required mechanical ventilation and 10% died, with higher fatality rates in older patients and those with medical comorbidities. Human-to-human transmission was documented, mostly in health care settings.

1. World Health Organization (WHO), Coronavirus disease 2019 (COVID-19) Situation Report-74.

An unprecedented outbreak of pneumonia of unknown aetiology in Wuhan City, Hubei province in China emerged in December 2019. A novel coronavirus was identified as the causative agent and was subsequently termed COVID-19 by the World Health Organization

(WHO). Considered a relative of severe acute respiratory syndrome (SARS) and Middle East respiratory syndrome (MERS), COVID-19 is caused by a betacoronavirus named SARS-CoV-2 that affects the lower respiratory tract and manifests as pneumonia in humans. Despite rigorous global containment and quarantine efforts, the incidence of COVID-19 continues to rise, with 90,870 laboratory-confirmed cases and over 3,000 deaths worldwide. In response to this global outbreak, we summaries the current state of knowledge surrounding COVID-1.

3. Reyad O (2020) Novel Coronavirus COVID-19 Strike on Arab untries and Territories: A Situation Report I. arXiv:2003.09501 [cs.CY]

The novel Coronavirus (COVID-19) is an infectious disease caused by a newvirus called COVID-19 or 2019- nCoV that first identified in Wuhan, China. Thedisease causes respiratory illness (such as the flu) with other symptoms such as acough, fever, and in more severe cases, difficulty breathing. This new Coronavirusseems to be very infectious and has spread quickly and globally. In this work,information about COVID-19 is provided and the situation in Arab countries andterritories regarding the COVID-19 strike is presented. The next few weeks mainexpectations is also given. The well-known Coronaviruses such as MERS-CoV, SARSCoV and COVID-19 are a group of viruses that infects both birds andmammals which meaning that they are transmitted between people and animals.

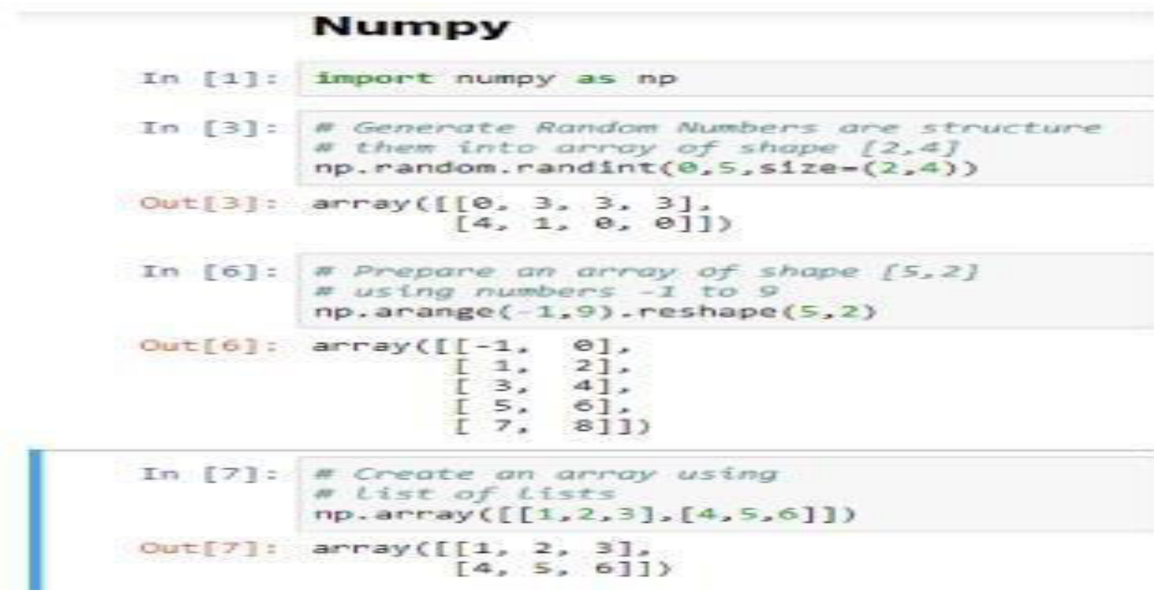
These set of Coronaviruses cause infections that are related to the common coldand flu in humans where symptoms vary according to the infected species [1], [2].The COVID-19 has reported being a novel Coronavirus of a typical pneumoniasince the date 31/12/2019. The COVID-19 started in Wuhan city in China andthen spread around the world very fast. Covid-19 is considered as the secondCoronavirus outbreak that affects the Middle East region, following the MERS-CoV which was reported in Saudi Arabia in the year 2012. United Arab Emirates(UAE) was the first Middle East Arab country to report a Coronaviruspositivecase, following the Wuhan city Coronavirus outbreak in China. Recently, on11/03/2020, the World Health Organization (WHO) stated that the global COVID-19 outbreak is a pandemic because of the speed and scale of transmission of thevirus. From the 195 countries in the world today, there are more than 266,100oronavirus total cases reported to Coronavirus resource center until now [3].Moreover, the number of total deaths are more than 11,200 cases and the numberof total recovered are more than 87,300 cases. Figure 1 shows the CoronavirusCOVID-19 global cases presented by the center for systems science andengineering (CSSE) at Johns Hopkins University

(JHU) up-to-the-date20/03/2020 [4]. In this work, the up-to-date information about COVID-19 isprovided and the situation in Arab countries and territories regarding the COVID-19 outbreak is presented4. ACR recommendations for the use of chest radiography and computedtomography (CT) for suspected COVID-19 infection|American College ofRadiology (2020). https://www. acr.org/Advocacy-and-Economics/ACR-Position-Statements/ Recommendations-for-Chest-Radiography-and-CT-forSuspected-COVID19-Infection. Accessed 9 Sept 2020As COVID-19 spreads in the U.S., there is growing interest in the role andappropriateness of chest radiographs (CXR) and computed tomography (CT) forthe screening, diagnosis and management of patients with suspected or knownCOVID-19 infection. Contributing to this interest are limited availability of viraltesting kits to date, concern for test sensitivity from earlier reports in China, andthe growing number of publications describing the CXR and CT appearance in thesetting of known or suspected COVID-19 infection.To date, most of the radiologic data comes from China. Some studies suggest thatchest CT in particular may be positive in the setting of a negative test. We wantto emphasize that knowledge of this new condition is rapidly evolving, andnot all of the published and publicly available information is complete or up-to-date.

3. PROPOSED METHODOLOGY

This study aims at proposing a new deep learning framework as a radiological toolto support clinicians for automated diagnosis of COVID-19 and pneumoniadiseases using chest X-rays.Our preliminary work (COVIDX-Net) [36] introduceddeep learning models to confirm only positive or negative COVID-19 cases. Inthis article, we present a new version of our deep learning framework to constitutethe following advancements

Developing a new cascaded form of deep learning image classifiers for confirming COVID-19, viral and bacterial pneumonia diseases.Using multiple selective and reliable deep learning models to achieve the best classification performance of pulmonary diseases in X-ray images. Proposed architecture of cascaded classifiers based on deploying different deeplearning models allows to obtain better performance than could be obtainedfrom other multi-label classifiers in previous studies. Extensive tests and evaluation of eleven deep learning models have beenconducted on a public X-ray dataset to verify the best performance of proposedclassifiers for detecting COVID-19 and other pneumonia diseases. Demonstrating the feasibility of applying our final recommended classifiers toenhance image-guided diagnosis of COVID-19,viral pneumonia, and bacterialpneumonia infections during the pandemic time.



Numpy

```
In [1]: import numpy as np

In [3]: # Generate Random Numbers are structure
        # them into array of shape [2,4]
        np.random.randint(0,5,size=(2,4))

Out[3]: array([[0, 3, 3, 3],
               [4, 1, 0, 0]])

In [6]: # Prepare an array of shape [5,2]
        # using numbers -1 to 9
        np.arange(-1,9).reshape(5,2)

Out[6]: array([[-1,  0],
               [ 1,  2],
               [ 3,  4],
               [ 5,  6],
               [ 7,  8]])

In [7]: # Create an array using
        # list of lists
        np.array([[1,2,3],[4,5,6]])

Out[7]: array([[1, 2, 3],
               [4, 5, 6]])
```

4. EXPERIMENTAL RESULTS

NUMPY

Python has a strong set of data types and data structures. Yet it wasn't designed forMachineLearning per say. Enter numpy (pronounced as num-pee). Numpy is a data handling library,particularly one which allows us to handle large multi-dimensional arrays along with a hugecollectionofmathematical operations.Thefollowingis aquick snippetofnumpyin action.

Numpy isn't just a data handling library known for its capability to handle multidimensionaldata. It is also known for its speed of execution and vectorization capabilities. It providesMATLABstylefunctionalityandhencerequiressomelearningbeforeyoucangetcomfortable.It is also a core dependency for other majorly used libraries like pandas, matplotlib and so on.It'sdocumentation itselfis a good startingpoint.

PANDAS

Think of relational data, think pandas. Yes, pandas is a python library that provides flexibleand expressive data structures (like dataframes and series) for data manipulation. Built on topofnumpy, pandas is as fast andyeteasierto use.

Scipy

```
In [16]: from scipy import linalg
         from scipy import integrate
         import numpy as np

In [17]: # Perform definite integral of a function
         # take f(x) function as f
         f = lambda x : x**4

         # integration with a(lower limit) = 2 & b(upper limit) = 5
         integration = integrate.quad(f, 2 , 4)

         # integral, error
         print(integration)

         (198.4, 2.2026824808563106e-12)

In [18]: #define square matrix
         two_d_array = np.array([ [8,10],
                                  [4,20] ])

         # Get determinant of matrix
         print(linalg.det( two_d_array ))

         120.0
```

Pandas provides capabilities to read and write data from different sources like CSVs, Excel,SQL Databases, HDFS and many more. It provides functionality to add, update and deletecolumns, combine or split dataframes/series, handle datetime objects, impute null/missingvalues, handle time series data, conversion to and from numpy objects and so on. If you areworking on a real-world Machine Learning use case, chances are, you would need pandassooner than later. Similar to numpy, pandas is also an important component of the SciPy orScientificPython Stack .

Pandas

```
In [8]:  import pandas as pd

In [10]: pd_series = pd.Series(data=['Val1','Val2','Val3'],index=range(0,3),name='Series_object')

In [11]: pd_series
Out[11]: 0    Val1
         1    Val2
         2    Val3
         Name: Series_object, dtype: object

In [14]: df = pd.DataFrame(data={'col_1':[1,2,3,4],
                                 'col_2':['A','B','C','D']})

In [15]: df
Out[15]:
```

	col_1	col_2
0	1	A
1	2	B
2	3	C
3	4	D

SCIPY

Pronounced as Sigh-Pie, this is one of the most important python libraries of all time. Scipy isa scientific computing library for python. It is also built on top of numpy and is a part of theScipyStack.Thisisyetanother*behindthescenes*librarywhichdoesawholelotofheavylifting.Itprovidesmodules/algorithmsforlinearalgebra,integration,imageprocessing,optimizations,clustering,sparsematrixmanipulation and manymore..

MATPLOTLIB

AnothercomponentoftheSciPystack,matplotlibisessentiallyavisualizationlibrary.Itworksseamlesslywithnumpyobjects(anditshigh-levelderivativeslikepandas).Matplotlibprovidesa MATLAB like plotting environment to prepare high-quality figures/charts for publications,notebooks,web applications and so on.

Matplolib is a high customizable low-level library that provides a whole lot of controls andknobstoprepareanytypeofvisualization/figure.Givenitslow-levelnature,itrequiresabitofgettingusedto - alongwithplentyofcodetogetstuffdone.Its

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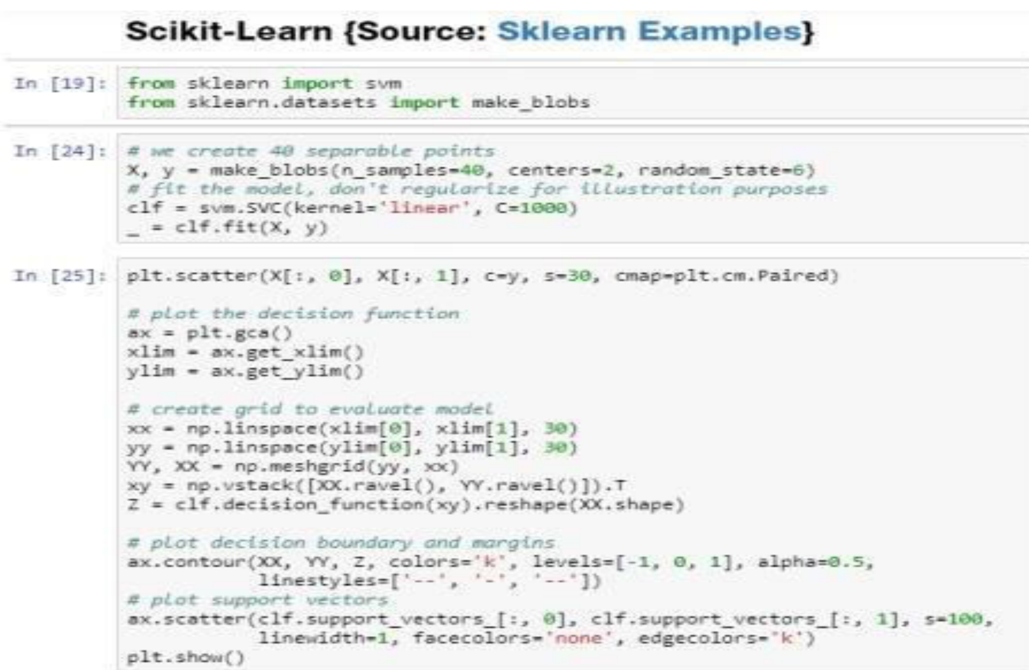
welldocumentedandextensibledesignhasallowedawholelistofhigh-levelvisualizationlibrariestobebuiltontop.Someofwhich,wewill discuss in the comingsections.:

SCIKIT-LEARN

Designed as an extension to the SciPy library, scikit-learn has become the de-facto standardformanyofthemachinelearningtasks.DevelopedaspartofGoogleSummerofCodeproject,ith as nowbecome awidelycontributedopen sourceproject withover 1000contributors.

Scikit-learn provides a simple yet powerful fit-transform and predict paradigm to learn fromdata, transform the data and finally predict. Using this interface, it provides capabilities toprepareclassification,regression,clusteringandensemblemodels.Italsoprovidesamultitudeofutilities for preprocessing, metrics,modelevaluation techniques,etc.

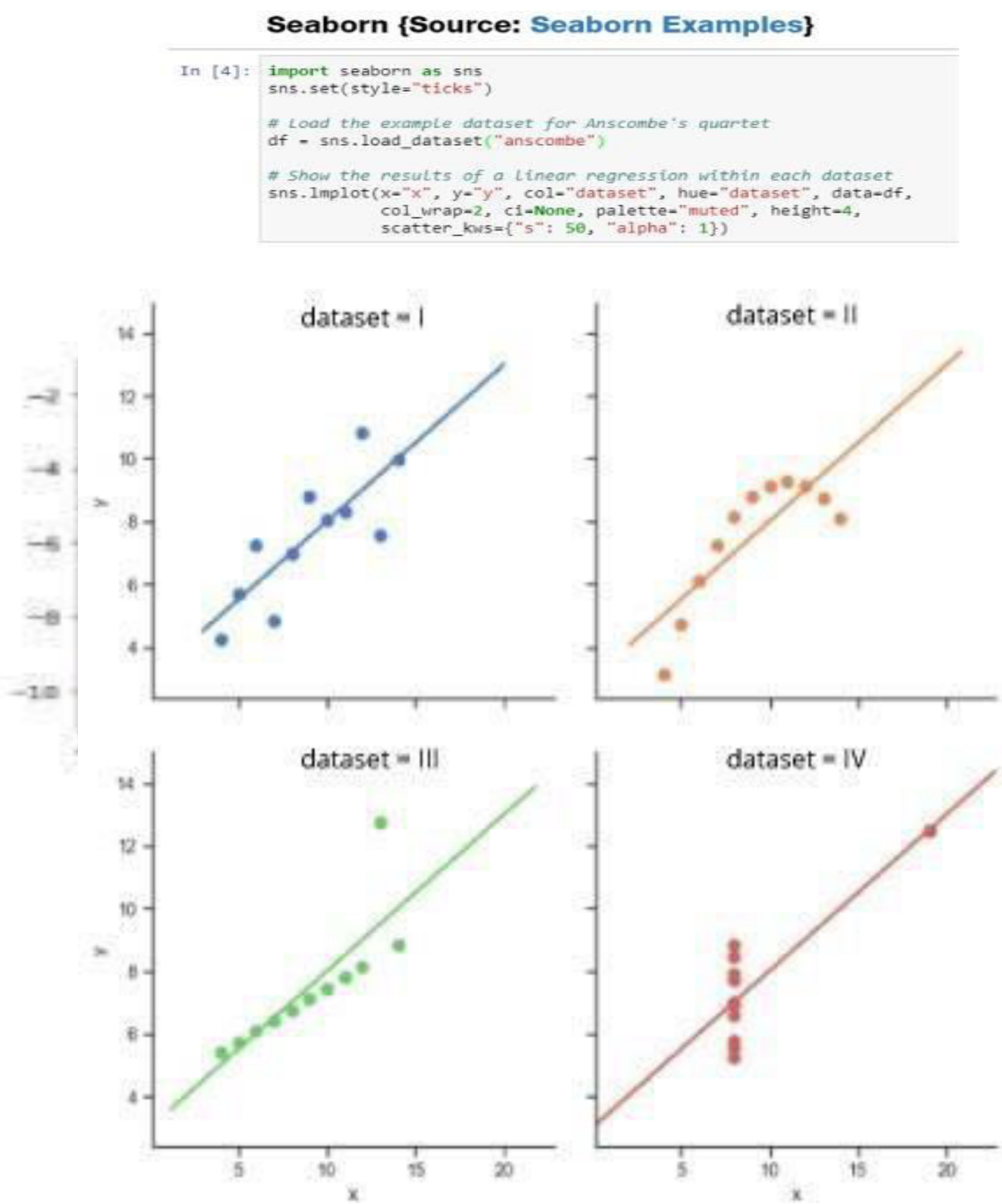


Scikit-Learn {Source: Sklearn Examples}

```
In [19]: from sklearn import svm
         from sklearn.datasets import make_blobs

In [24]: # we create 40 separable points
         X, y = make_blobs(n_samples=40, centers=2, random_state=6)
         # fit the model, don't regularize for illustration purposes
         clf = svm.SVC(kernel='linear', C=1000)
         _ = clf.fit(X, y)

In [25]: plt.scatter(X[:, 0], X[:, 1], c=y, s=30, cmap=plt.cm.Paired)

         # plot the decision function
         ax = plt.gca()
         xlim = ax.get_xlim()
         ylim = ax.get_ylim()

         # create grid to evaluate model
         xx = np.linspace(xlim[0], xlim[1], 30)
         yy = np.linspace(ylim[0], ylim[1], 30)
         YY, XX = np.meshgrid(yy, xx)
         xy = np.vstack([XX.ravel(), YY.ravel()]).T
         Z = clf.decision_function(xy).reshape(XX.shape)

         # plot decision boundary and margins
         ax.contour(XX, YY, Z, colors='k', levels=[-1, 0, 1], alpha=0.5,
                    linestyles=['--', '-', '--'])
         # plot support vectors
         ax.scatter(clf.support_vectors_[:, 0], clf.support_vectors_[:, 1], s=100,
                    linewidth=1, facecolors='none', edgecolors='k')
         plt.show()
```

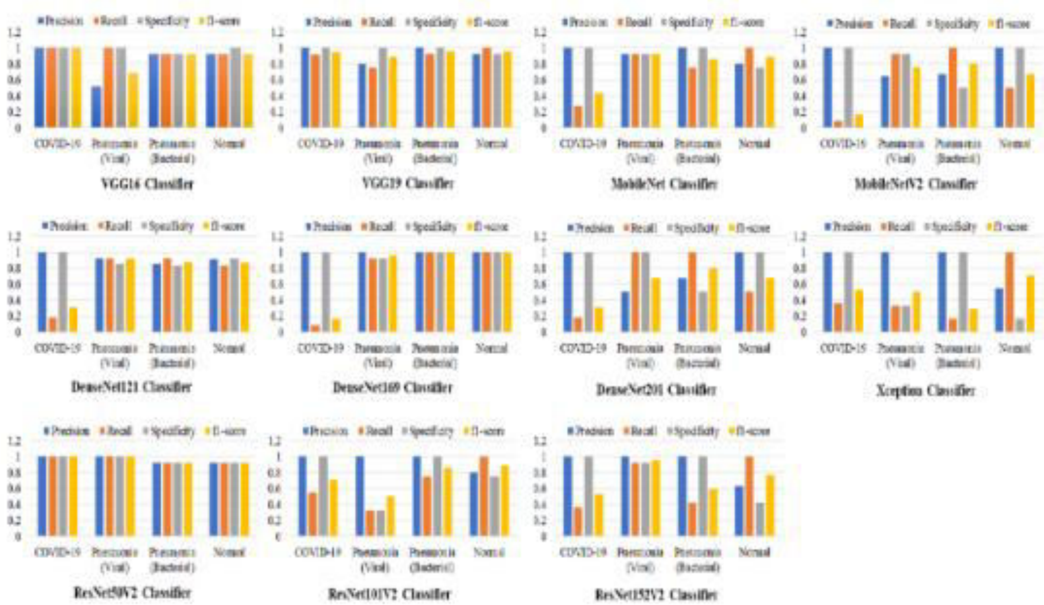
VisualizationSeaborn

Builtontopofmatplotlib,seabornisahigh-levelvisualizationlibrary.Itprovidessophisticatedstyles straight out of the box (which would take some good amount of effort if done usingmatplotlib).



SAMPLEPLOTS USINGSEABORN

Apart from styling prowess and sophisticated color pallets, seaborn provides a range ofvisualizations and capabilities to work with multivariate analysis. It provides capabilities toperformregressionanalysis,handlingofcategorical variablesandaggregatestatistics



5. CONCLUSION

This study presented a new framework for automated computer-aided diagnosis of COVID-19, viral and bacterial pneumonia in chest X-rays, based on three cascaded deep learning classifiers. Compared to previous studies, the proposed cascaded classifiers achieved promising results to confirm positive COVID-19 cases using VGG16 model. Also, the ResNet50V2 and DenseNet169 models identified viral and bacterial diseases successfully, as shown above in Fig. 6. Hence, we are currently working on the clinical implantation of our deep learning framework as a new CAD system in the diagnostic protocol of potential COVID-19 patients with other pneumonia diseases using the cost-effective X-ray imaging modality

6. FUTURE SCOPE

In future improvements furthermore, automated segmentation of COVID-19 infections in chest X-ray scans is the main prospect of this research work. This segmentation task will significantly assist the clinician to follow-up the disease progress in the lung of infected patients, as described in [57]. To satisfy security and privacy requirements for transmitting medical images over general communication networks [58], securing COVID-19 patient data will be also considered in the next version of our developed deep learning framework

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