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Low cost Covid-19 preliminary diagnosis utilizing cough samples and keenly intellective deep learning approaches

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Received 7 June 2020; revised 21 September 2020; accepted 23 September 2020
Available online 29 September 2020

KEYWORDS
Deep learning; Covid 19; SVM; Feature extraction; Cough samples; Health care; Prescreening

Abstract Covid19 an ecumenical pandemic perpetuates to take lakhs of lives and consistently taking its shape as major threat. Skeptically and turmoil in divergent perspectives perpetuate to grow. The most prominent contributing factor to all this is the lack of methodologies to test Covid samples at a more immensely colossal scale. Highly scalable, cost efficacious and flexible diagnosis methodology can contribute greatly towards handling this arduous situation in a more controlled manner. Working towards this the major symptom found among the covid patients is cough. With the avail of Deep learning approaches, this cough is processed to understand the distinctions between the conventional and covid cough. One of the major arduousness to address this quandary is the right amplitude of data to build a deep learning model that can authentically take decisions about the cough recordings. We have extracted some of the recordings from the public platforms and performed deep learning predicated analysis. This gave us the prognostication precision of 94% thus authoritatively mandating a better cough dataset to further carry out the research at a more immensely colossal scale. This paper accommodates as a baseline to cerebrate beyond the customary clinical diagnosis and identify the disease at least in the preliminary in fraction of seconds thus requiring the buildup of covid cough data.

1. Introduction

Self-Isolation, sanitizer, and masks are mandated to keep one away from this pernicious disease. In spite, tremendous increment in the number of cases reported ecumenically. On May 27, 2020, the WHO Covid-19 dashboard reports 5,406,282 recording a death number as 343,562 [1]. Along with the precautionary measures, the timely diagnosis will contribute towards controlling the spread rate. A few countries that taken after a strict regimen towards early location has appeared noteworthy changes within the increased bend. This requests tremendous requirements for an asymptotic framework that can act as a prescreening machine that can aid the specialists to be mindful of all the patients who are most likely to be influenced and influenced. This contributes towards confining the concerned patients at the most punctual inevitable decreasing the community spread. Not as it were the carelessness of

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Peer review under responsibility of Faculty of Engineering, Alexandria University.

https://doi.org/10.1016/j.aej.2020.09.032
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individuals contributed towards the higher cases, but the conventional strategy to kill the illness by following the essential, auxiliary, and another auxiliary fizzled as there was not enough procedure taken after to prevent it at the prior stages. Be that as it may, nations taken after this observing entirely succeeded in controlling this widespread [1,2]. Right presently the circumstance is as of now compounded and the routine way of following every single person of one essential doesn’t holds great. Another point of concern is precarcousness in recognizing COVID and for a few patients, the ailment appeared as it were at the ultimate organize do have a coordinate effect on the passing rate [3].

A few of the reasons why routine testing may not offer assistance in controlling spreading are as follows:

- Restorative experts doing this test are profoundly inclined to disease independent of different safety measures considered. Gambling one and sparing numerous isn’t the procedure and each human life holds centrality and we are similarly capable to spare them. Not as it were that once more from this restorative proficient the community spread might be ended up more powerless as numerous cases detailed of this sort [4].
- The endorsed Nucleic Corrosive Enhancement Tests (NAAT) such as real-time Turn around Translation Polymerase Chain Response (rRT-PCR) requires in individual visit to clinic/lab additionally taken a toll is exceptionally tall.
- One exceptionally vital powerful point that increments the spreading rate is the individuals who don’t create any indications at the prior arrange but a slight cough.[5]
- This diagnosis is still complicated in low to centre financial nations as the wellbeing care framework isn’t robust enough to supply superior execution in atomic testing [6].
- There are various endeavours made to decrease the time taken for distinguishing COVID 19 [7]. Tremendous endeavours are made to extend the number of tests that appeared per hour and have expanded up to 100–200 tests per hour. In any case, this cannot contribute generally as the number of individuals been tried has coordinate effect on the number of positive cases.
- These tests are not taken a toll viable not as it were for the low to middle created nations but also developed nations claim this to be not fetched compelling for all the citizens.

The over said focuses requests a low fetched viable testing methodology which utilized artificial intelligence methodologies utilized X-ray [8] and CT check pictures [9] have given higher exactness as compared to the clinical tests. Once more these strategies required visits to clinical facilities. The genuine complexity of this widespread is its spreading rate which needs genuine consideration. The spreading must be controlled at moo taken a toll, early arrange and without gambling the lives of the adjacent. This requires honest to goodness pre-screening strategies fuelled by made experiences methods that can help individuals to by and by screen themselves and because it was required would visit the healing centre.

One of the components that can help in pre-screening is, with the hack tests a framework distinguishes if the individual holds COVID or not. A few focuses that hold inconsistencies in taking hack as a pre-screening test are:

1. A few of the COVID-19 patients don’t appear any symptoms of an ailment. There’s clear prove [10] saying that the COVID 19 can as it was being transmitted through beads from the influenced. One way the beads get transmitted is through a hack. In this way, it serves as a fundamental social spreading device for this dangerous illness. More than 60% of the cases [11] appears indication like a hack. Hence in case, a framework fuelled with machine learning calculations can unquestionably cut brief the spreading rate to half.

2. This may prove way better comes about than the normal strategy of recognizing COVID by temperature checking especially for the individuals who don’t appear any affliction. Persuasively, the testing middle can ask an individual to hack to distinguish it indeed there are no signs of fever.

With the tests performed utilizing a negligible dataset is appearing that there’s a completely diverse design of hack sound recording recognizing it from other respiratory sicknesses. So, this methodology of utilizing hack can be considered as a compelling pre-screening technique to distinguish COVID patients at an early arrange keeping in check the number of clients getting influenced. The leftover portion of the work comprises of the taking after areas firstly the thought of utilizing hack for pre-screening is well upheld with therapeutic discoveries to claim that this hack design is distinctive from the other hack designs taken after with the depiction of our information and the distinctive pre-processing procedures. The complexities included with the restricted sum of information to require choices are examined and a few of the ways that can be utilized to make strides this component is talked about. The following segment portrays approximately the different machine learning calculations utilized to perform multiclassification is taken after by reasonable test design, results, and conclusion.

2. Clinical disclosures to appear that COVID hack is distinctive from other respiratory infections:

A major imperfection that can be claimed with this technique is the hack being a common side effect for numerous other contaminations counting respiratory and nonrespiratory contaminations. Unless and until we demonstrate that the hack design of COVID is particular from other diseases, assist investigate on this would take a jump. So, we have chosen to get it the helpful discoveries to appear that the hack design of COVID is particular from other sicknesses. The machine learning-based approach that we are proposing holds truly productive in case the built show is prepared with all the tests of the endless particular hack designs of different illnesses and approving it for its expectation precision. Be that as it may this we considered as a beginning step towards building a pre-screening apparatus, we have considered many lower and upper respiratory afflictions and prepared the show and the results prove that there are varieties within the hack design.

Another way to claim that the hack can be utilized as a pre-screening instrument is to distinguish the hypothetical helpful proofs. The proofs come within the frame of shifting pathomorphological changes compared to other respiratory sicknesses. These proofs are displayed by different creators from [12-19] considering the x-ray pictures and CT filter pictures.
Later aspiratory neurotic think about [17] appears that sometime recently the onset of real COVID 19 side effects a few morphological changes show up with human within the form of varieties within the structure of alveoli signifying harm as well as Receptive alveolar epithelial hyperplasia and fibroblastic expansion.

Consider on CT filter pictures to recognize any critical changes in morphological features [18] reports show inconsistent or segmental unadulterated ground-glass opacities (GGOs) with vascular expansion. There's an expanding run of immeasurable GGOs and association of different projections of lung, combination of injuries and crazy-paving designs amid the dynamic organize. There are diffuse exudative injuries and lung “white-out” amid progressed organize.

Too within the prior stages, it was detailed that the COVID patients are getting near to the sicknesses of pneumonia and it is critical to note in case any eminent neurotic changes show up between pneumonia and COVID. The work displayed in [19] appears that COVID-19 related pneumonia on chest CT filter was more likely to have a peripheral distribution (80% vs. 57%), ground-glass darkness (91% vs. 68%), vascular thickening (59% vs. 22%), invert corona sign (11% vs. 9%) and less likely to have a central + peripheral distribution (14% vs. 35%), discuss bronchogram (14% vs. 23%), pleural thickening (15% vs. 33%), pleural emanation (4% vs. 39%) and lymphadenopathy (2.7% vs. 10.2%)

There are confirmations that major respiratory ailments like flu, bronchitis, asthma, and Pneumonia can be analyzed utilizing hack alone. COVID taking after another respiratory ailment can moreover be distinguished utilizing the hack, be that as it may, advance ponder on typically required as there are no prove appeared. The works on X-ray, CT check on other respiratory afflictions apparent that COVID has a diverse neurotic characteristic that will have an effect on the varieties on the hack design and hence hack utilized as a pre-screening instrument can greatly offer assistance people to track themselves which can impact the spreading rate.

3. Data depiction and practical trouble in collecting data

The machine learning demonstrates that we are proposing will be great sufficient in case it can take input as a hack from all respiratory and non-respiratory ailments and able to classify each of the illnesses precisely. Since this show was made to trial the utilization of machine learning approaches on COVID discovery, for all intents and purposes collecting and coordination all the tests of different afflictions was not conceivable. In any case, major respiratory ailments and having near likeness on COVID hack are considered as our dataset for building the machine learning-based expectation show. The scope of the dataset built for confirmation was limited to tests from pertussis, pneumonia, COVID and normal hack.

Our proposed machine learning-based framework for hack determination is prepared to utilize 8 COVID hack tests, 28 pneumonia, 15 pertussis, and 30 typical hack sounds. The number of test set is scanty as there were no freely accessible datasets of this sort and the tests we collected are from open stages. The considered dataset is exceptionally little to claim as much better determination instrument, in any case, the forecast exactness is exceptionally great indeed in exceptionally constrained tests. The class distribution of the considered classes are shown with Fig. 1.

The standard way of include extraction in sound signals is well upheld utilizing the Mel scale. Log-based Mel-spectrogram as well as filter banks are tested to include extract the information of the specified 4 classes. The hack flag to begin with experienced a pre-emphasis channel to appropriately increase the higher frequencies so that the flag to clamor proportion is way better. The pre-emphasis channel is connected to the hack flag utilizing the first-order straight condition as indicated underneath:

$$STFT(i, w) = \left[STFT(x(i, w))^2\right]$$

where ‘i’ is the Frame index, x is the input signal and w represent the frame window. The gotten sifted flag was part into short-time outlines so that the Fourier change requires not to be connected to the whole flag. Short-time outline Fourier change can get a great guess of the recurrence forms by concatenating adjoining outlines of the flag. Frames are at that point connected with a Hamming window worked as signified underneath to maintain a strategic distance from any spectral leakage.

$$F_{logmel} = \log(MS(i, w))$$

The logmel features are obtained from the above equation where the Mel scale output is processed. The control range of the flag is gotten by applying the brief time Fourier change taken after by the computation of channel banks ordinarily included applying 40 channels to extricate the recurrence groups. So, the change of the 4 classes of hack information to Mel scale is fulfilled by utilizing the channel banks. The Mel ghastly coefficients for each test are extricated as X*Y matrix that shows MFCC highlights for each outline. These resultant extricated MFCC highlights are displayed under section 5.

4. Proposed hack detection technique

Here we are displaying the framework design (Fig. 2) taken after for distinguishing the 4 classes of the hack. This incorporates a combination of different components to form it seem

Fig. 1 Class Distribution percentage of the considered classes.
doable and holds great enough to be assist utilized as a pre-diagnosis apparatus for identifying COVID.

The stages of determination taken after in our system are delineated underneath along with the flow diagram:

1. The general dataset that we have built alluding to different sources is passed to the channel banks for transformation to its Mel scale.
2. Include extricated information is, to begin with, sent to the pre-filtering instrument which takes care of distinguishing in case the given test is either hack or other shapes of sound.
3. Once the prescreening succeeds, the determination within the frame of classification happens with two built-up models of the considered dataset.
4. The primary classification demonstrates makes utilize of the machine learning-based algorithmic approach for accurately classifying these 4 classes. The technique used here is Support Vector machine with RBF kernel.
5. The following classification show takes after a profound learning-based approach with multi-class names. The technique embraced is LSTM.
6. The comes about of SVM are compared to that of the LSTM and if both delivered indistinguishable comes about at that point the ultimate expectation comes about are displayed.

4.1. Deep learning based multi class classifier (LSTM with attention mechanism):

Attention mechanism proves surprising comes about in speech recognition [20–22]. Attention mechanism as its title means learns the relationship of inputs at different time stages adaptively. Utilizing the weight vector, it predicts the current time arrange. Mathematically for any grouping characterized with a state $h_t$ at each step, a super vector $y_t$ can be computed by the underneath relation:

$$y_t = \sum_{i=1}^{T} \alpha_t h_i$$

where $T$ is the number of steps of the input sequence and $\alpha_t$ denotes the weight vector, computed at step $t$ for each state $h_i$.

The weight vectors, $\alpha_t$, are then computed by using an intermediate vector, $r_t$

$$r_t = f(O_{t-1}, h_t)$$

Where $f$ is the learned function that learns depending on the output at step $t-1$.

The weight vector $\alpha_t$ is then computed as depicted below:

$$\alpha_t = \frac{exp(r_t)}{\sum_{k=1}^{T} exp(e_{tk})}$$

This consideration instrument can recursively create weight vectors given the state of the current step. A little variety to this conventional consideration conditions are made to create beyond any doubt that the learned work at the middle of the road vector so that a considerable component will put accentuation on the imperative steps to surrender tall values within the super vector $c$ when modelling groupings. LSTM an extraordinary shape of repetitive neural systems having circles to preserve perseverance. The covered-up states of LSTM with the help of a feed-forward consideration instrument was utilized to adaptively calculate the weight of each outline.

The primary classifier employments an LSTM based RNN for classifying the four sorts of hack 1) Normal hack 2) Pneumonia 3) Pertussis 4) COVID. This classifier architecture is proposed within the underneath graph.

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**Fig. 2** System Architecture of Low-cost COVID19 pre-screening mechanism.
The conclusion starts with an input cluster of frameworks each with columns of estimate and column of measure. The yield once more is in the shape of the network of measurements. The dataset is fitted to the model and the plot of the anticipated value is delineated within the underneath figure. This once more is tried with a more complicated LSTM structure with dropout esteem = 0.04 and the number of layers utilized is so that the issue of overfitting is taken care. At last, the yield layer with 6 neurons and actuation work is utilized to classify the input between 6 conceivable diseases.

4.2. Machine learning based SVM classifier:

The next parallel machine learning based classifier is built using support vector machine. SVM may be a discriminative classifier that has been used in numerous genuine world applications. SVMs characterize the “best” separating hyperplane by maximizing the edge between boundary focuses of the classes and the isolating hyperplane. These boundary focuses are alluded to as support vectors. SVMs utilize straight and nonlinear separating hyperplanes for information classification.

Not at all like channel bank extraction in LSTM here in SVM the highlight extraction is done by utilizing the log-based Mel spectrogram that computes the include extricated vector utilizing the underneath condition

\[
m = 2595 \log_{10} \left( 1 + \frac{T}{700} \right)
\]

These logs extricated highlights are bolstered into a multi-class bolster vector machine for classification. With this input vector, SVM show was built with k-fold approval of 4 cycles.

5. Results and discussion

The model is validated using the performance metrics of accuracy, recall, precision, specificity, F1 score and ROC.

\[
\text{Recall} = \frac{TP}{TP + FN}
\]

\[
\text{Accuracy} = \frac{TP + TN}{TP + TN + FP + FN}
\]

\[
\text{Precision} = \frac{TP}{TP + FP}
\]

\[
\text{Specificity} = \frac{TN}{FP + TN}
\]

\[
\text{Area under ROC} = \int_0^1 \frac{TP}{TP + FN} d\frac{FP}{TN + FP}
\]

Fig. 3 Raw audio output of the considered 4 classes.
Here, TP, TN, FP, and FN refer to True Positives, True Negatives, False Positives, and False Negatives, respectively.

The tests gotten for building these classifiers is depicted step by step from the portrayal of the crude tests. The raw audio samples of the considered tests are shown in Fig. 3 below:

The crude tests after been connected with the channel bank extraction. Fig. 4 appears the result of channel bank extraction within the frame of Fourier change.

This variety among the changed esteem in Fig. 3 appears the clear refinement between the COVID and the other 3 names. The varieties within the hack design appear that hack can indeed be considered as a pre-screening instrument.

More standardized Mel scale which is log based spectrogram yield is appeared in Fig. 5:

These performance metrics are based on mean confusion matrices from 2-fold cross validation.

1. The performance metrics for the deep learning-based classifier LSTM results are reported in Table 1 and Fig. 6. The by and large exactness of the built show is 88% with the precision gotten for each of the course is famous in Table 1.

2. For the machine learning based classifier, the Table 2 shows the performance metrics of the classifier. Results indicate an overall accuracy of 94% with RBF kernel and the individual precision for each class is presented in the Table 2.

The profound learning-based models can superior learn and make choices with a colossal dataset with the classes of all respiratory maladies considered. Indeed, with a really few tests, the accuracy gotten is satisfiable to create this instrument with the supported software to serve as a pre-screening component. This is often turn can serve as a beginning point towards the method of killing COVID.
both the models demonstrates to supply comparative comes about and those tests are analysed as the name.

6. Conclusion and future work:

This approach of screening COVID is not the substitution of conventional restorative determination approaches. But the major trouble confronted all-inclusive to control COVID lies with the failure to accurately follow and giving reasonable restorative care. Each person presently is bothered to create themselves secure against this widespread to defend their life. So, if people are given a self-looking at the framework will incredibly advantage the society. Any innovation is certainly for the wellbeing and dynamic improvement of people. One of the later mechanical developments is within the field of manufactured insights and associated ranges. In this way, it ought to contribute towards the control of this worldwide widespread. With this thought, these prescient approaches are taken after and it demonstrates to be effective in terms of pre-

Table 1 Performance metrics of LSTM.

|                  | F1 score | Sensitivity | Specificity | precision | Accuracy |
|------------------|----------|-------------|-------------|-----------|----------|
| Normal           | 1.00     | 1           | 1           | 1         | 1        |
| Pertussis        | 0.91     | 0.6666      | 1           | 0.86      | 0.9375   |
| Pneumonia        | 0.86     | 1           | 0.8666      | 1         | 0.9375   |
| COVID            | 1.00     | 1           | 1           | 1         | 1        |

Fig. 5 Mel scale output of the 4 classes.

Fig. 6 Confusion matrix of LSTM.
cision. Coming up once more with the moo taken a toll instrument of coordination a basic application in social gatherings for hack tests isn’t a more noteworthy venture. And our work on this does have confinement in terms of the number of tests been utilized for building the prescient demonstrate. This can be fair been utilized as a confirmation of the concept to provide the usability of the machine and profound learning approaches within the preparation of diagnosing COVID.

Way better optimization in terms of counting a greater number of respiratory sickness classes is basic to form this demonstrate usably. At least at this level, this work demonstrates the varieties watched within the major ailment hack designs. This once optimized on the off chance that coordinates with social gatherings can serve as a moo fetched viable pre-screening component to follow and target the COVID populace. And this not as it were on gatherings can too be given within the frame of a kiosk at all open places like air terminals, railroads stations, etc. that can pay attention to people being uncovered to COVID. Towards the battle of the corona, this is often a little piece of work that can contribute in way better building of hack dataset and get it the varieties of hack designs more in fact at that point seeing it as it were within the frame of therapeutic screening.

Declaration of Competing Interest

The authors declared that there is no conflict of interest.

Acknowledgment

This work is to all the specialists who sacrificed their lives within the prepare of sparing people.

References

[1] World Health Organization. (2020) Coronavirus disease (COVID-19) outbreak situation. Accessed on: May 27, 2020. [Online]. Available: https://www.who.int/emergencies/diseases/novel-coronavirus-2019.

[2] BBC. (2020) Coronavirus in South Korea: How ‘trace, test and treat’ may be saving lives. Accessed on: May 29, 2020. [Online]. Available: https://www.bbc.com/news/world-asia-51836898.

[3] M. Cascella, M. Rajnik, A. Cuomo, S.C. Dalebon, R. Di Napoli, “Features, evaluation and treatment coronavirus (COVID-19)”, in StatPearls [Internet], StatPearls Publishing (2020).

[4] Medscape (2020) In memoriam: Health care workers who have died of COVID 19 Accessed on: May, 30, 2020. [Online]. Available: https://www.medscape.com/viewarticle/927976.

[5] World Health Organization. (2020) Coronavirus disease (COVID-19) Q&A on Coronavirus Accessed on : May 30,2020 [online] Available:https://www.who.int/emergencies/diseases/novel-coronavirus-2019/question-and-answers-hub/q-a-detail/q-a-coronaviruses.

[6] J. Hopman, B. Allegranzi, S. Mehtang, Managing COVID-19 in low- and middle-income countries, JAMA (2020), https://doi.org/10.1001/jama.2020.4169.

[7] Abott (2020) Your Covid 19 Testing questions Accessed on : May 30,2020 [online] Available: https://www.abottom.com/coronavirus/covid-19-faq.html

[8] L. Wang and A. Wong, “COVID-Net: A Tailored Deep Convolutional Neural Network Design for Detection of COVID-19 Cases from Chest Radiography Images,” arXiv preprint arXiv:2003.09871v1, 2020.

[9] X. Xu, X. Jiang, C. Ma, P. Du, X. Li, S. Lv, L. Yu, Y. Chen, J. Su, G. Lang et al., “Deep Learning System to Screen Coronavirus Disease 2019 Pneumonia,” arXiv preprint arXiv:2002.09334, 2020.

[10] Science. (2020) Not wearing masks to protect against coronavirus is a ’big mistake,’ top Chinese scientist says. Accessed on: June 2, 2020. [Online]. Available: https://www.sciencemag.org/news/2020/03/not-wearing-masksprotect-against-coronavirus-big-mistake-top-chinese-scientist-says.

[11] World Health Organization, “Report of the WHO-China Joint Mission on Coronavirus Disease 2019 (COVID-19),” 2020.

[12] L. Wang and A. Wong, “COVID-Net: A Tailored Deep Convolutional Neural Network Design for Detection of COVID-19 Cases from Chest Radiography Images,” arXiv preprint arXiv:2003.09871v1, 2020.

[13] J. Zhang, Y. Xie, Y. Li, C. Shen, and Y. Xia, “COVID-19 Screening on Chest X-ray Images Using Deep Learning based Anomaly Detection,” arXiv preprint arXiv:2003.12338, 2020.

[14] A. Narin, C. Kaya, and Z. Pamiluk, “Automatic Detection of Coronavirus Disease (COVID-19) Using X-ray Images and Deep Convolutional Neural Networks,” arXiv preprint arXiv:2003.10849, 2020.

[15] W. Zhao, Z. Zhong, X. Xie, Q. Yu, J. Liu, Relation between chest ct findings and clinical conditions of coronavirus disease (COVID-19) pneumonia: a multicenter study, Am. J. Roentgenology (2020) 1–6.

[16] L. Li, L. Qin, Z. Xu, Y. Yin, X. Wang, B. Kong, J. Bai, Y. Lu, Z. Fang, Q. Song et al., “Artificial intelligence distinguishes COVID-19 from community acquired pneumonia on chest ct,” Radiology, p. 200905, 2020.

[17] S. Tian, W. Hu, L. Niu, H. Liu, H. Xu, S.-Y. Xiao, Pulmonary pathology of early phase 2019 novel coronavirus (COVID-19) pneumonia in two patients with lung cancer, J. Thoracic Oncology (2020).

[18] W.-c. Dai, H.-w. Zhang, J. Yu, H.-j. Xu, H. Chen, S.-p. Luo, H. Zhang, L.-h. Liang, X.-l. Wu, Y. Lei et al., “CT imaging and differential diagnosis of COVID-19,” Canadian Association of Radiologists Journal, p. 0846537120913033, 2020.

Table 2 Performance metrics of SVM.

|            | F1 score | Sensitivity | Specificity | precision | Accuracy |
|------------|----------|-------------|-------------|-----------|----------|
| Normal     | 1.00     | 1           | 1           | 1         | 1        |
| Pertussis  | 0.80     | 1           | 0.9166      | 1         | 0.875    |
| Pneumonia  | 0.75     | 0.75        | 1           | 0.60      | 0.875    |
| Covid      | 1.00     | 1           | 1           | 1         | 1        |
[19] H. X. Bai, B. Hsieh, Z. Xiong, K. Halsey, J. W. Choi, T. M. L. Tran, I. Pan, L.-B. Shi, D.-C. Wang, J. Mei et al., “Performance of radiologists in differentiating COVID-19 from viral pneumonia on chest CT,” Radiology, p. 200823, 2020.

[20] Chan, W.; Jaitly, N.; Le, Q.V.; Vinyals, O. Listen, attend and spell: A neural network for large vocabulary conversational speech recognition. In Proceedings of the IEEE International Conference on Acoustics Speech & Signal Processing (ICASSP), Shanghai, China, 20–25 March 2016.

[21] J. Chorowski, D. Bahdanau, D. Serdyuk, K. Cho, Y. Bengio, Attention-based models for speech recognition, Comput. Sci. 10 (2015) 429–439.

[22] Zhang, S.; Chen, Z.; Zhao, Y.; Li, J.; Gong, Y. End-to-end attention based text-dependent speaker verification. In Proceedings of the IEEE Spoken Language Technology Workshop (SLT), San Diego, CA, USA, 13–16 December 2016.