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# Remote monitoring of Covid-19 patients using IoT and AI

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***Abstract*— The covid-19 pandemic has brought changes in various sectors like healthcare, business, education and economy. Due to the large spread of covid-19 in a lot of countries there is shortage of hospital beds, oxygen supply and healthcare workers. So, the pandemic generated need to use smart pioneering technologies like Artificial Intelligence and Internet of Things to monitor patient in an effective way. In this research paper a prototype is proposed based on IoT and AI for monitoring home quarantine covid-19 patients. Wearable IoT devices automatically collect information like oxygen level, temperature of body, etc. with the help of integrated sensors. Coughing is one of the most noticeable symptoms of people infected with covid-19. Frequency of cough is detected using Tensor flow library of Deep learning model. This prototype is a way to make IoT sensors smarter enough to detect coughs with the help of a trained model. Coughing dataset is collected and labelled manually. Dataset is self-created and categorized into cough and noise. Cough detection is based on MFCC features using DNN and CNN. The use of these technologies can bring a quick transition in healthcare to avoid risks caused with the life of human beings.**

**Keywords— Artificial Intelligence, Covid-19, cough detection, Internet of Things, MFCC.**

## I. INTRODUCTION

Several technological inventions and applications have been developed to combat the Covid-19 pandemic. The pandemic created inference for the design strategy, application development and use of technologies. There is an crucial necessity for a better understanding of the role that technology and information systems researchers can play in this worldwide pandemic. In March 2020, the World Health Organisation announced that covid-19 had been spread all over the world. And from that day technology started helping world in many different ways. Use of technology for contact tracing of infected people, keeping them in isolation helped world to break down the chain of spread [1].

Covid-19 Pandemic has put life of every human being under threat. It's hard to predict how long scenario of lockdowns, social distancing, mask wearing will going to end. It has affected functioning of every organisation. No any countries' health sector was prepared to tackle this unpredicted pandemic. It showed need of robust health care sector and highlighted need of sustainable investment in health system. Mutated corona viruses triggering more infectious wave in many countries put further pressure on health system. Contact tracing, quarantine, isolation have become difficult because of higher number of patients. Doctors, health workers are unable to keep vigil on every patient. But technology is playing major role in this pandemic. It's providing awareness, online work, education and many more things in this hard time and will assist to control the coronavirus spread [2].

The Internet of Things is playing vital role in healthcare monitoring [19]. Internet of Things is way to connect physical devices to internet so we can handle them from any location. The potential development of smart monitoring wearable devices has changing the way to deal with this pandemic [20]. After contact tracing and testing patient the biggest concern is to monitor patient with proper healthcare attention. Due to shortage of healthcare workers and availability of beds in hospital the people with less symptoms are being quarantined at their homes. It's being difficult to monitor each and every person's health parameters like SpO2 level, pulse rate, etc. To reduce the pressures on health care systems IoT is one of the potential solution. Patient can have proper monitoring system that can do physiological measurements like oxygen level, coughing detection, pulse rate, etc. without human intervention. Thus, implementation of this technology can improve the efficiency of healthcare workers by decreasing their work-pressure [1][2]. This IoT technology can help healthcare organisation to capture real-time health status of infected person from remote location[2].

Coughing is one of the major frequent symptom in covid-19 infected person. The coughing may cause many other respiratory diseases. Phlegm production found in 33% of cases and a dry cough in 67% of total covid-19 cases detected [3]. There is no any IoT sensor developed yet which can directly detect cough by capturing sound. So, we need to take help of Artificial Intelligence here. Deep neural network can process these sound waves and classify this sound into coughing sound for normal noise. Artificial Neural networks is a trained model of perceptive based on the human brain which is a computing system considered by a learning capability. The Artificial neural networks do not need a user to postulate any problem-solving algorithm; rather than this it learns from examples like humans [9].

Every country is now facing shortage of doctors, nurses and health workers in this pandemic period. Hence effective health-care monitoring system can play crucial part in reducing physical contact, need of hospitalization, and cost for patients while it will also reduce stress, workload and burden on medical staff. Smart bands are already in Market for

TABLE I. LITERATURE SURVEY

| *Reference Paper* | *Objectives* | *Used Methods* | *Used Parameters* | *Remark* |
|---|---|---|---|---|
| [1] | An android based prototype for evaluation of SpO2, heart rate of covid-19 infected person. | Multiple IoT sensors, IoT gateway and server application. | Heart rate, SpO2, Body temperature. | Mobile application act as IoT gateway sending data related to heart rate, SpO2, temperature to the server. |
| [2] | Develop IoT application to overcome Covid-19 pandemic. | Multiple IoT sensors, Wireless body network sensor and BLE (Bluetooth low energy). | SPO2, Blood pressure, Glucose level. | All sensor connects to internet and at critical situation it sends alert to server. |
| [5] | Find the best algorithm for Covid-19 situation and use of IoT framework to decrease the influence of infectious diseases. | Support vector machine, deep neural network, , K-star, naive bayes algorithm, decision stump and decision table. | Real time data collection, Data analysis and Healthcare, Physical and Cloud infrastructure. | IoT framework with combination of Support vector machine, Naive Bayes algorithm, K-star, Neural network, Decision table and decision stump algorithm and give more than 90% accuracy. |
| [6] | Develop a tool to measure the SpO2 level in blood and pulse oximeter kit by utilizing Internet of Things. | ESPDUINO-32, NodeMCU, GPS-neo-6M and Cloud database server. | Heart rate, Oxygen level | A kit which measures dissolved oxygen and pulse rate of patient using ESPDUINO-32 and database server. |
| [7] | Automatic cough detection technique using various features and android application for collection of data with built in data security. | MFCC, STFT, liftered-MFCC, and Monochrome Frame Buffer, Deep Neural Network, Convolutional Neural Network and Long-short Time Memory. | Audio sample with categories cough, speech, sneeze, etc. | Single large audio segment during feature calculation provides better performance than smaller overlapping segments. |
| [8] | Develop model for automatic cough detection and count of cough frequency. | Microphone, Machine Learning and Android studio. | Audio sample, android application. | A model which detects cough and count cough frequency having accuracy between 90% and 99.5% of the specified specificity. |
| [9] | Develop model for cough detection. | Principal Component Analysis (PCB), Deep Learning and TensorFlow. | Use of different activation function. | The trained model shows with the help of Deep Learning Network with PCA coughing can be prominently detected. |
| [10] | Use of ML and deep learning model to overcome effect of worldwide pandemic of covid-19 disease. | IoT, ML and DNN(Deep Neural Network). | Image file, audio file, disease data, number of new cases of Covid-19, drug's data. | IoT with machine learning application which tackle Covid-19 and track Covid-19 patient. |
| [4] | Health monitor system to reducing workload on doctors and medical staff in pandemic. | IoT Network, IoT Gateway, Wi-Fi module and Android Studio. | Blood pressure, sugar level, body temperature. | Mobile application which shows the data to doctor by IoT kit from patient. |
| [11] | Health monitor system solve some of the problems encountered in covid-19 | Big data, Recommendation systems and Digital transformation. | Disease data, drug's data. | A System which takes data of health issue from user and give him relative medicine with resource. |
| [22] | Deep net model for detection of covid-19 using radiographs based on roc analysis | Inception- ResNetV2, InceptionV3 and ResNet50 | Chest X-ray radiographs | A framework based on CNN models apploed on X-ray images of the chest region to predict the Covid-19 infection. |
| [23] | COVID-19 Risk Minimization Decision Making Strategy Using Data-Driven Model | Smartphone based Digital Proximity Tracing Technology | SEIR (Susceptible–Exposed–Infectious–Recovered) model | SEIR based model categorzed to population into 10 compartments for public health policymakers. |
| [24] | Health status of the patients through message and e-mail using IoT and computer vision | Imrovement in the IoT model is achieved by incorporating AI layer between network and cloud layer. AWS algorithm is used. | Throughput | The AWS algorithm performs better as compared to the FRR, MAS and ODA in terms of throughut |

various purposes which includes measuring steps, pulse rate, temperature, burnt calories. This type of devices with modification will prove effective for monitoring health status of covid-19 patients. So, in this paper, we propose a health status monitoring band for covid-19 patients which will track the temperature, pulse rate, oxygen level and coughing of patients and collected data will be sent to medical staff for further treatment [4].

The contributions of the paper are listed as follows:

1.Proposed a prototype for monitoring covid-19 symptotic and asymptotic patients. The various aspects such as body temperature, SpO2 level and Cough Frequency is determined periodically.

2.Cough frequency detection dataset is designed. Cough frequency detection model is proposed using MFCC based on ANN and CNN architecture.

3.Performance analysis of cough detection model is analysed using various parameters such as precision, recall, accuracy, F1 score and compared with [7].

The paper is organised as follows, the detailed critical literature is introduced in the section 2. Methodology and design implementation of the proposed work is discussed in section 3. Section 4 focuses on mathematical model of our proposed system. The section 5 has emphasis on experimentation and section 6 describes the result analysis. Last section describes conclusion and future scope.

## II. LITERATURE SURVEY

From the perspective of Rinto Priambodo et. al., self-isolated COVID-19 patient monitoring system for monitoring physiological data and heart rate and patient location information. Develop a healthcare monitoring system depends on the IoT, which has a network of human sensors and a gateway through which data can be collected and transmitted. The system also uses an application server on which data can be stored, analysed, and visualized. The prototype monitoring system uses a home pulse oximeter and an Android application that acts as an IoT gateway to collect sensor data and send the data to the server. In this way, they can monitor the condition of patients who are trying to recover self-isolation at any time and take necessary preventive measures [1].

From a view of R. P. Singh et. al., the emergence of the Internet of Things has had an impact on reducing healthcare costs and improving the treatment of Covid-19 infected patients. Twelve important IoT applications were identified and discussed for Covid-19 disease. Ultimately, this forces researchers, scholars and scientists to find effective solutions to help overcome this pandemic. With the help of technology, researchers, doctors, governments and scientists can create a better environment for fighting this disease [2].

M. Otoom et. al. addressed, the Internet of Things infrastructure consists of some main components like gathering and sending symptom data, isolation centre, collected data analysis centre, doctors, and cloud infrastructure. There are eight machine learning algorithms in actual coronavirus dataset are SVM, neural network, decision line, naive Bayes algorithm, KNN, decision table ZeroR and OneR. The results show that, except Decision Stump, OneR and ZeroR, all these algorithms have reached an accuracy of more than 90%. The use of the five most important algorithms ensures nominal and precise detection of Covid-19 cases [5].

A. Hidayat et. al., performed study and found that current pulse oximeter can't track and record the real-time results which is required for the treatment of Covid-19 patients. Taking physical distance and social media protocols into consideration, a pulse oximeter kit using Internet of Things technology to develop tools to remotely monitor Covid-19 patients via smartphones. The fortitude of the dissolved O2 level in the blood is conducted with the help of healthcare workers and is carried out individually. We can measure O2 level with the help of BLE pulse oximeter sensor. Further, collected data is processed with the help of ESPDUINO-32 then the NodeMCU forwards data to database server [6].

Igor D. S. Miranda et. al., compared study of features for acoustic cough detection using Deep Architectures. This study research provided the different acoustic feature for training model to detect cough from sound wave., liftered-MFCC, STFT, Mel-frequency cepstral coefficients and Monochrome Frame Buffer features are compared using Convolutional Neural Network, Deep Neural Network and Long-short Time Memory. According results obtained in this research long audio segment during feature extraction provide better results. STFT and MFB provided the best results for coughing detection. MFCC haven't been tested well for coughing detection [7].

Lucia Kvapilova et. al., perform study on continuous sound collection using smartphones and Machine Learning to Measure Cough. This research article deals with technology which can automatically detect cough. 24 hours recording with devices with numerous microphones for spontaneous and automatic detection and count of cough frequency. Smart application is developed to collect sound samples. Data security was important integral part in any application so data from smart application is always encrypted and only authorised peoples can hear recording. Classification of sound waves has been done. Noise and cough are the two classes in classification. Extensive steps have been taken to maximize privacy and safety of application [8].

S. Khomsay et. al. addressed, a coughing detection approach with the help of Principal Component Analysis and Deep Learning Networks which is primarily dependent on Tensor Flow. Principal Component Analysis uses feature extraction before sending it's logs to teach version by Deep Learning Networks. Graphical version to make calculations that are quite green in practice. The eight volunteers' data are collected for the experiment. The consequences show that cough indicators can be competently detected with the help of DLN with PCA [9].

From the perspective of Awishkar Ghimir et. al., artificial intelligence and machine learning getting to know were very a success at tackling the numerous issues that stand up in healthcare systems, it has additionally been effectively used to address the issues bobbing up because of Covid-19. The distinct programs consist of diagnosis, mortality price prediction, vaccine development, drug development, sentiment evaluation concerning Covid-19 remarks and incorrect information detection [10].

O. Taiwo et. al. addressed, use off technology can help in reducing workload on doctors and medical staff in pandemic. the y developed application of IoT in smart home automation which consists of various sensors and WiFi module that provides real time health related updates of patients to the healthcare workers and doctors. Significances of their study is that, self-isolated or self-quarantined patients can send daily updates of their symptoms to doctors through mobile platform and get the required guidance from them. This mechanism save money, time, stress of patients and reduce burden of health system in pandemic [4].

From a view of Mateus Gonçalo do Nascimento et. al., there are gaps in the use of recent technologies as tools in the battle with Covid-19. They proposed a case study to solve some of the problems encountered in covid-19, for example, different types of volunteer groups used smart bracelets, and then developed a recommendation algorithm system to understand user behaviour. Use simulator software to detect personnel activities and predictable Covid-19 scenarios. Essentially, they proposed a work to

support the recording of vital signs in the form of digital data for use in public primary health care institutions [11].

## III. Methodology

In this section, primary design of prototype for monitoring covid-19 infected patient will be described.

### A. Proposed Architecture

Using IoT system can be built, that contains various IoT sensors which help to gather different health related parameters of covid-19 infected person. With the help of IoT gateway collected data can be sent over internet. Web-view will display data and doctor can monitor patient based on data displayed. The server application provides analysis and visualization of health parameters [1]. The different IoT sensors can collect health parameters like body temperature, SpO2 level, pulse rate, etc. But IoT sensor can't able to detect the coughing level of patient. So, we trained deep learning model to detect cough. The continues sound input is taken by Arduino 33BLE and passed as input to deep neural networks. If coughing sound is detected then coughing frequency is calculated and sent over internet.

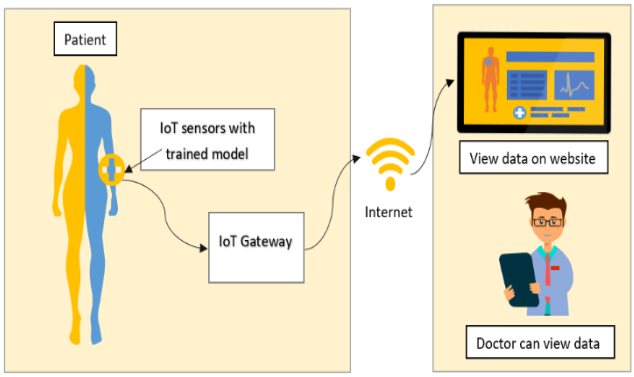


Fig. 1. System Architecture

### B. Data collection

IoT makes data collection task so easy. The different IoT sensors run on very low power supply and able to collect and send data continuously. Decrease in SpO2 level is biggest cause of the covid-19. So, keeping eye on patient's oxygen level is important. Measurement of SpO2 level is routine procedure for self-isolated covid-19 patients. This can be helpful in detection "silent hypoxemia" in covid-19 patient [12]. Other important health parameter is pulse rate. We have used Max30102 pulse oximeter sensor which is capable to measure both SpO2 level and pulse rate. To measure temperature of patient's body we have used infrared temperature. These IoT sensors helps us to collect and send data to IoT gateway as shown in Fig 1. The sensor data model is represented in fig 2, that will provide the inputs to Arduino modules. For coughing detection Arduino 33BLE is used which has inbuilt microphone to record audio. This recorded audio can be fended as input to trained model to check is there any coughing sound is present or not.

| SpO2 | Heart Rate | Temperature |
|---|---|---|

Fig. 2. Sensor data Model

### C. Data Transmission

The data transmission sensors from IoT are responsible for transmission of data from patient house to the health care organization data centre. IoT makes it possible to transmit data from any remote location [12]. After data is received from sensors and collected at cloud-based database, data is visualized on web application. We are using Firebase as database. Firebase provides some unique features like user authentication, NoSQL real-time database, remote configuration, hosting and it can be integrated with any kind of mobile application or web application.

## IV. Mathematical Model

In mathematical modelling, we assume S be our proposed system acquiring I inputs $i_1$-temparature, $i_2$- heart rate, $i_3$- SpO2 level, performing functions F such as data collection, data transmission, cough detection. Our system S will provide the output O of all collected data on web application that will be useful for doctors to monitor the health of covid patients. The proposed system S is described as follows-

$$S = \{I, F, O, C\}$$

Where S is our proposed system. I is an input to the system, F is a set of functions performed by the system, O is the output generated by the system, and C is the constraints of the system like internet connectivity, status of sensors.

## V. Design Methodology

### A. Internal Logic

All sensors are mounted on breadboard for making connections easy. Pulse oximeter is one of the globally used for monitoring ill patient in intensive care [13]. We have used Max30102 pulse oximeter in our prototype which is capable to measure pulse rate and oxygen level. Infrared temperature used to capture temperature of patient's body. Both Max30102 and infrared temperature are mounted on Arduino Uno. Cough detection is done by trained model which is deployed in Arduino 33BLE sense. Arduino 33BLE sense has internal microphone which records sounds. This support tensorflow lite so we can easily deploy deep learning model in it [14]. All collected data is sent to firebase database using Wi-Fi module. Web application will display all the collected data.

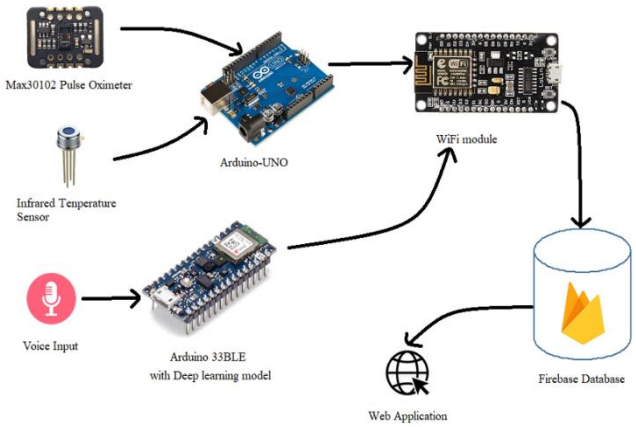


Fig. 3. Sensor Integrations

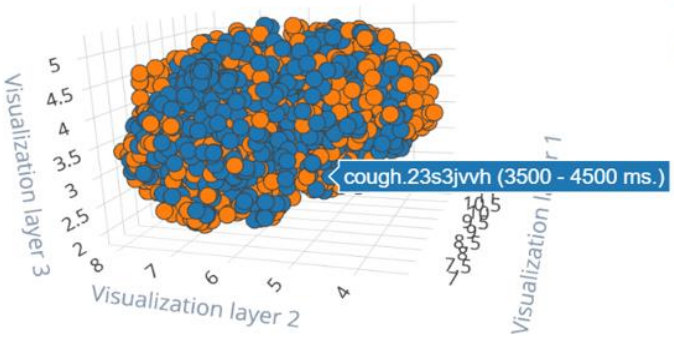


Fig. 4. 3D visualization using mplot3d

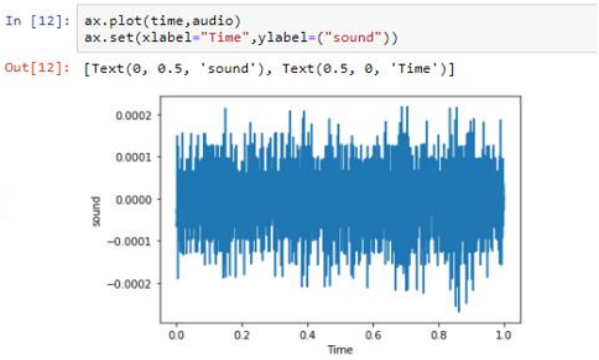


Fig. 5. Single waveform visualization

## B. Model Training for Cough Detection

*a) Data Acquisition:* Our dataset is collected and labelled manually. Also some samples we have collected from YouTube videos. Dataset contain two labels, “cough” and “noise”. We have collected samples of coughing sounds from various age groups. Because as per age and gender pitch of speech sound changes. Coughing sound of children, young ones and elders has been included in dataset along with some samples of female. Audio dataset contain 5 secs .WAV (Waveform Audio Files) extension files. Wav files are lossless and uncompressed. Wav files header contains the information about PCM (Pulse Code Modulation). Our prototype is specially targeted on covid-19 patient who are being home quarantined. So we may encounter with unwanted sound like human speech, air conditioner sound, whistle, fan, mixer grinder. We have categorised all this unwanted sound into “Noise” class. All other sounds are categories into noise class because we only want to concentrate on coughing sound. Thus, our dataset only consists of two classes noise and cough. The final dataset consists of total 363 files out of which there are total 223 files with label “cough” and remaining 140 files with label “noise”. As data samples are from different people with different age and gender so we have achieved diversity in dataset. Also, generalization of noise class has been done. The dataset composition is as shows in table II.

TABLE II. STRUCTURE OF COUGHING DATASET

| *Sr. No* | *Class Name* | *Count of files* |
|---|---|---|
| 1. | Cough | 223 |
| 2. | Noise | 140 |
| Total | | 363 |

In comparison with other studies our dataset contains samples from diversity of more than 20 individuals [15], [7]. Using mplot3d package in python all data points are scattered as shown in fig. 4. All blue coloured data points denotes coughing data points and orange denotes noise data points. 2D plot of single data sample in dataset as shown in fig. 5. In this figure x-axis denotes time scale and y-axis is sound amplitude factor.

*b) Feature Extraction:* After collection of data the first step is to make data trainable by extracting features out of it. Parametric representation has been generated with the help of audio data which define every frame sample in dataset. Acoustic features of sound help to detection of cough from recorded audio file. Properties of sound are depending upon physiological production, acoustic features, auditory perception. For training deep learning model for audio classification typically concern modelling task where input files are audio files. Short-time Fourier transform (STFT), Monochrome Frame Buffer Mel-frequency cepstral coefficients (MFCC) and liftered-MFCC (MFB) are the features which are being used widely for successful speech recognition model training. MFB and STFT are common choice for training model for speech recognition [7]. We are using MFCC and comparing performance using both DNN and CNN. MFCC includes various steps. First step is Pre-emphasis which refers to emphasizing higher frequencies. This step helps to balance audio signal which contain high frequency peaks. Next step includes frame blocking and windowing speech analysis over very small segment of a sound. As sound contain time variance data so it is necessary to examine each and every time spectrum. Next step is DFT (Discrete Fourier Transform). Each frame converted into magnitude spectrum using DFT. Then Mel spectrum is computed using band-pass filters in Mel-Filter bank. Mel is unit to measure human ear perceive frequency. Discrete Cosine Transform (DCT) is applied over Mel spectrum to produce set of cepstral coefficients. Cepstral coefficient means static representation of data in each frame. Block diagram is as shown in fig. 6 refers from [16]. Python inbuilt modules makes feature extraction so easy. Librosa predefined library contain various extraction features and MFCC is one of them.

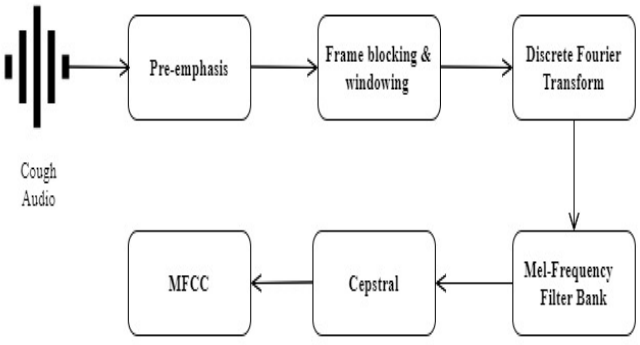


Fig. 6. MFCC extraction steps

*c) Model Training:* For cough detection model has been trained using DNN and CNN to obtain comparative results. Google provide cloud based platform called Google-colab which provide support of CPU, GPU and TPU based training. Support of GPU and TPU makes training and processing very fast as compared to CPU based training. So we have used google colab with runtime type GPU. Also we are using Tensorflow which is open source software library developed by google. Using librosa feature extraction has been done. And using keras with tensorflow, classifier has been trained. Firstly, DNN has been trained for cough detection. Then model layers' structure has been referred from [9] with some modification. The model contains three hidden layers with Relu activation and output layer with softmax activation as shown in table III. As DNN faces overfitting problem due to greater number of parameters. So dropout has been added with initial dropout rate as 0.1 and 0.5 for hidden layers. With Adam as optimiser and binary cross entropy as loss function we obtained accuracy of 89.47 %.

TABLE III. DNN LAYERS STRUCTURE

| *Layer Number* | *Layers Architecture.* | *Activation* |
|---|---|---|
| 1. | Dense layer(100), Dropout(0.1) | relu |
| 2. | Dense layer(200), Dropout(0.5) | relu |
| 3. | Dense layer(200), Dropout(0.5) | relu |
| 4. | Dense layer(2) | softmax |
| Total Params | | 44602 |
| Trainable params | | 44602 |

We also have trained model for cough detection using CNN. CNN are multi-layer neuron structure which can be directly compared with mammalian brain. CNN has many applications in different fields like speech recognition, image processing, NLP and action processing[17]. Our model contains 3 convolution layers, one flatten dense layer and output layer with softmax activation. Every convolution layer have relu as an activation function and valid padding has been used. Maxpooling with stride has been used to keep size of feature matrix valid. The fully connected layer has dropout regularization with rate 0.5. Last fully connected layer i.e. output layer with softmax activation gives necessary output. Network architecture is as shown in table IV.

TABLE IV. CNN LAYERS STRUCTURE

| *Layer Number* | *Layers Architecture.* | *Activation* |
|---|---|---|
| 1. | Conv2D(24,(5,5)) , MaxPooling2D. | swish |
| 2. | Conv2D(48,(5,5)), MaxPooling2D,padding=valid. | swish |
| 3. | Conv2D(48,(5,5)),padding=valid. | swish |
| 4. | Flatten, Dropout rate=0.5 | swish |
| 5. | Dense(64) , Dropout rate=0.5 | swish |
| 6. | Dense(2) | softmax |
| Total Params | | 240914 |
| Trainable params | | 240914 |

We have used Relu as activation function since relu doesn't have problem of vanishing gradient like other activation functions [17]. The Swish activation function which is being designed recently by google can be one of the choice. The convolutional neural network has been trained using categorical cross entropy as loss function and Adam as optimiser. Batch size is 32 and 80 epochs. With 5640 ms runtime using GPU and 0.001 learning rate model produce accuracy of 86.21%. After changing relu activation to swish we are able to increase the accuracy from 86.21 to 93.1%. Swish is performing better because swish is unbounded above and bounded below. Plot for swish is as shown in fig. 7 [18].

Result has been obtained by tuning hyper parameters in deep neural network. Selection of best parameters has been done to train model for cough detection. Dataset diversity and randomness has been

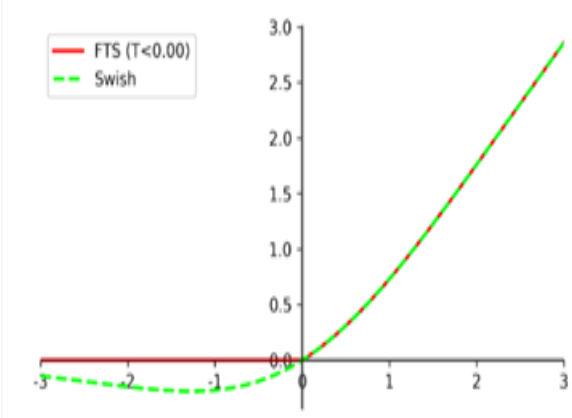


Fig. 7. Swish activation function

maintained and divided into 80/20 train test ratio. To get robust result cross validation scheme has been applied.

## VI. RESULT AND DISCUSSION

### A. Model Training Result

We have represented comparative evaluation using two deep learning architectures. Table V represents the results obtained on training cough detection model using DNN and CNN. To conduct this comparison, we have trained both models using same dataset. We observed that CNN performs better than DNN. In case of DNN it takes greater number of epochs to get well trained model. As CNN performs better in feature extraction so CNN can be better choice for the cough detection.

TABLE V. COMPARISON BETWEEN DNN AND CNN

| *Property* | *Deep Neural Network* | *Convolutional Neural Network* |
|---|---|---|
| Number of Epochs | 100 | 80 |
| Batch Size | 32 | 32 |
| Activation Function for non-output layers | Relu | Swish |
| Accuracy | 89.47% | 93.1% |
| Precision | 89.75% | 93.79% |
| Recall | 89.47% | 93.10% |
| F1 Score | 89.35% | 92.94% |

We first trained CNN model using relu as a activation for non-hidden layers. And we got accuracy of 86.21% which was less than DNN model. Later we changed activation from relu to Swish in CNN model and trained new model. We obtained satisfying results this time. Using swish activation, we are able to increase model accuracy upto 93.1% which was greater than DNN model. So additional better performance was obtained using swish.

Plot of DNN model accuracy with number of epochs is as shown in fig. 8. Fig. 9 shows variation in loss with respect to number of epochs. Similar plots are being plotted for CNN model. Fig. 10 shows plot of model accuracy with number of epochs. And fig. 11 represent variation of loss with respect to number of epochs.

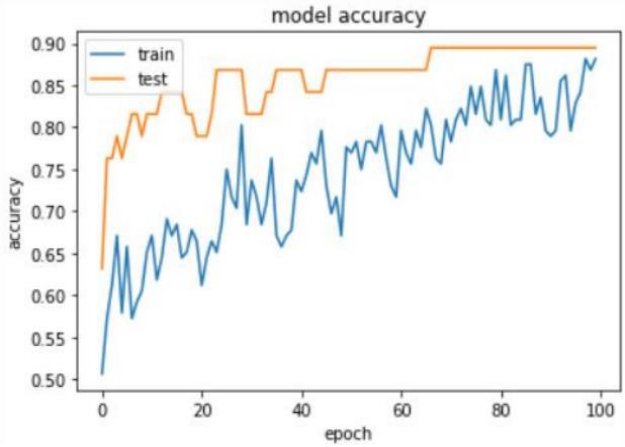


Fig. 8. DNN accuracy vs number of epochs plot

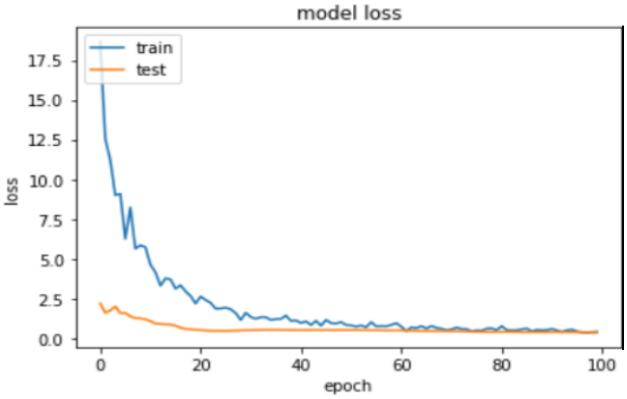


Fig. 9. DNN loss vs epochs plot

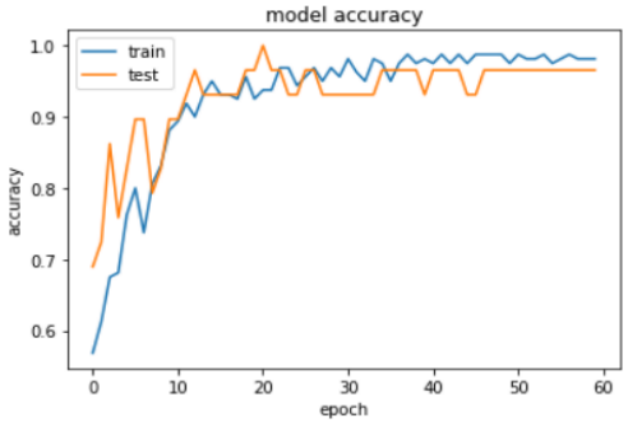


Fig. 10. CNN accuracy vs number of epochs plot

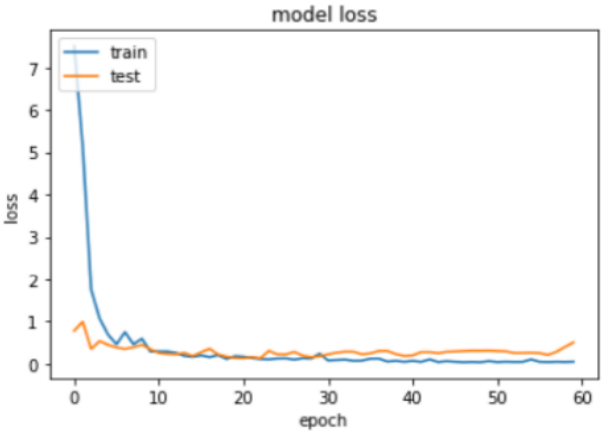


Fig. 11. CNN loss vs epochs plot

## *B. Results after Integrating all IoT sensors*

In this research paper covid-19 monitoring band prototype has been designed. We have used MAX30102 pulse oximeter sensor and infrared temperature sensor. Infrared temperature sensor used to calculate temperature of body. And Max30102 will detect both pulse rate and SpO2 level of patient. After mounting all sensor on Arduino-uno, we sent all collected data to firebase real-time database using ESP8266 node MCU. The trained deep leaning model for coughing detection has been deployed in Arduino 33BLE sense which has inbuilt support for tensor-flow. The collected data can be visualised using Django web application from any location by healthcare workers or doctors. Fig. 12 shows the data sent by sensors to firebase real-time database. Django web application displays all healthcare parameters as shown in fig. 13.

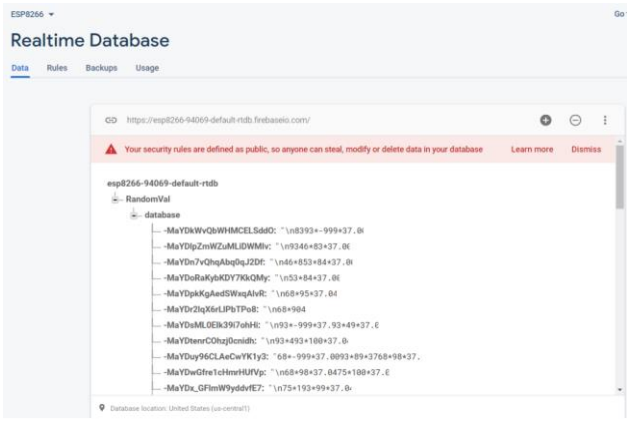


Fig. 12. Firebase real-time Database


Fig. 13. Django web application to visualise collected data

### C. Discussion

We compared our results with [7]. Using MFCC and DNN architecture [7] obtained accuracy of 80.5%. Our model performs better with accuracy 89.47%. But model performance proposed in [7] using MFB and DNN is equal to our model using MFCC and DNN. In case of CNN architecture and MFCC our model performance is better. But CNN using MFB model provides almost equal performance like our model. The one of the reason for difference in results is may be due to change in sample audio file input size. [7] used audio with 10-second long and we have used audio with 5–second long.

## VII. Conclusion

In this research paper we have developed a prototype that contain wearable IoT sensors with trained deep learning model for monitoring covid-19 patients. We have performed comparative study of CNN and DNN for cough detection using different evaluation parameters. We also compared our results with previously available work.

It can be concluded that IOT and AI based band can constantly track self-isolated or quarantined covid-19 patients. The band system is developed to monitor health traits of covid-19 patients such as oxygen level, temperature, pulse rate and coughing. The band system is capable of acquiring data from different sensors and transmit a data to the doctors or healthcare workers using Wi-Fi module for monitoring patient's condition. From this system patient can automatically send their health updates to doctors without visiting them. This will avoid contact of covid-19 patients with outside world and lower the risk of virus spread along with this it will also reduce burden on health system.

## VIII. Future Scope

The developed band can be accommodated with more sensors and features for example shivering sensor, emergency button to make it more effective and useful for monitoring covid-19 patients. This band can be further used to monitor patients of asthma, tuberculosis ands chest cold. It is also possible that such kind of bands or devices can be further extended to monitor health status of pet animals and farm animals so that veterinary doctors can guide farmers to diagnosis, prescription and treatment of disease. Overall, this type of bands will facilitate easy monitoring of patients and reduce burden on health system.

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