# Voice Analysis Framework for Asthma-COVID-19 Early Diagnosis and Prediction: AI-based Mobile Cloud Computing Application

Alina O. Popadina
*Faculty of Information Measurement and Biotechnical Systems,*
*Saint Petersburg Electrotechnical University "LETI"*
St. Petersburg, Russia
AlinaP-1998@mail.ru

Prof. Al-Majeed Salah
*School of Computer Science*
*University of Lincoln*
Salah.AlMajeed@ieee.org

Prof. Karam Jalal
*Department of Mathematics and Computer Science*
*West Virginia State University*
Joe.Karam@wvstateu.edu

***Abstract*—Asthma patients come through coronavirus with higher risk, where both COVID-19 and asthma cause changes in vocal patterns, which can be detected in different ways. Monitoring systems focused on asthmatic voice quality for diagnosis are essential. However, voice monitoring has the potential to be the most accurate tool for lung early prediction of the disease. Asthma patient has a peak flow meter for daily use as an alternative for disease state monitoring, which has no special devices to detect COVID-19. This paper considers mixture methods of voice analysis for early diseases detection and their perspectives in developing for asthma and COVID-19 application, based diagnostics recognition. Mobile Cloud Computing and Artificial Intelligence used into analysis of voice parameters suitable to design an asthma oriented system for both attack prediction and COVID-19 recognition.**

***Keywords—voice analysis; asthma; COVID-19; early diagnosis; Artificial Intelligence (AI) ; cloud computing.***

## I. INTRODUCTION

The first officially recorded announcement about COVID-19 outbreak appeared on December 31st 2019. Since then, and even nowadays the disease is in progress and not sufficiently studied and understood. There is an urgent need for fast, early and affordable monitoring and detection systems.

The coronavirus infection COVID-19 affects different groups of people to varying degrees, and those among us with respiratory tract disorders are at very high risk. In particular, asthma patients since asthma tends to be chronic with unpredictable disease course. The most dangerous of which are asthmatic attacks.

There are very similar manifestations between worsening asthma and contracting COVID-19 which can be felt the same: cough, weezing, hard breath. For asthma patients it’s very important to have proper and accurate diagnosis for differentiating it from having coronavirus otherwise, they may start wrong a treatment and eventually lose precious curing time.

Voice analysis can present a solution to this problem since respiratory cycle and speech are closely connected. Speech contains inherent information about the physical, physiological, psychological, and emotional status of the speaker. Consequently, there are various studies which conclude that voice disease detection can be used as vocal biomarkers to diagnose health conditions such as heart disease, Parkinson’s, COPD, asthma and COVID-19.

COVID-19 and asthma voice changes are very difficult to be accurately distinguished by human, but they can be detected by AI. Using cloud computing can help to mine and to store patience voice data, which will help to adjust and change the processing algorithm and also to register outbreak in a region.

Smartphones with built-in microphones such as the asthma-COVID-19 monitoring system based on AI and cloud computing can help to determine both COVID-19 and asthma symptoms. The technology is available, simple to use and cheap because users only need a smartphone with a microphone integrated into it.

Asthma is a non-stationary disease and tends to change status. Asthma is usually characterized by chronic airway inflammation. Heterogeneity is a wide asthma course variety which consists of disease severity, age, lifestyle, reaction on treatment and other factors.

Asthma patients usually experience symptoms such as cough, chest tightness, wheeze. Difficulties in breathing caused by airflow limitation connected with various triggers such as exercise, allergen, change in weather.

Triggers and other factors make asthma symptoms worse what are called asthma attacks which can be fatal. It is possible to predict asthma attack and prevent it, because when asthma status are getting worse, breathlessness, coughing and wheezing become more obvious.

Important part of asthma classification is the degree of disease control and asthma attack forthcoming. In pandemic time where there can be problems in availability of medical diagnostics, thus personal monitoring systems are required.

Asthma changes influence on a patient's voice and the changes can be registered [7].

2021 IEEE Conference of Russian Young Researchers in Electrical and Electronic Engineering (ElConRus) | 978-1-6654-0476-1/20/$31.00 ©2021 IEEE | DOI: 10.1109/ElConRus51938.2021.9396367

## II. ASTHMA-COVID-19 DIAGNOSTIC SYSTEM

### A. COVID-19 Impact on Asthma

Investigation of Centers for Disease Control and Prevention showed that asthma has one of the most significant impact on COVID-19 course for children and young people. There are also the correlation between hospitalization time and asthma. Based on the results the hospitalization duration is longer for asthma patients than for people without asthma and that difference is significant for people under 65 year old.

Asthma is an inflammatory disease of the airways resulting

in a number of symptoms including obstruction of the airways, chest discomfort or pain, cough, and wheezes or other peculiar sounds during breathing [1].

Symptoms of asthma and COVID-19 can be felt alike, so it makes difficulties for asthma patients to recognize if they are having asthma impairment or they are ill with coronavirus, this way they can start treatment wrong. Nowadays there are no methods to solve this problem of division manifestations of asthma and COVID-19.

To register asthma degree condition patients are recommended to use peak flow meter for daily monitoring. Peak flow meter measures exhale rate of volume flow. Such devices are quite cheap and simple to use, but need strict hygiene which damages flow sensors at the same time.

The other device respiratory disease monitoring is spirometry which is more informative and can register several parameters such as exhale flow rate, lung capacity, tidal volume and others. Spirometry is the most common pulmonary function test which measures the severity of asthma [1], however it may cause difficulties in exploitation because of the amount and the parameters meaning. For this reason, spirometry is majorly used in medical practice.

GINA's report of 2020 has stated interim guidance on asthma monitoring during the COVID-19. There is advice to be careful using spirometers and peak flow meters as these devices can dissipate viral particles when you blow into the mouthpiece. The report strongly recommends avoiding such measurements without urgent need.

Coronavirus is mostly detected by SARS-CoV-2 test or IgM\IgG rapid test. But for an asthma patient it's important to get results as fast as possible and methods described above can't solve this goal.

### B. Asthma-COVID-19 Detection System

Voice analysis can be a diagnostic method for asthma-COVID-19 detection, because both asthma and COVID-19 causes significant voice changes [1-10].

Voice changes caused by asthma and COVID-19 can be detected by AI. Cloud computing technologies are helpful with collection, analysis and storage of big data. It's enough to have a smartphone with an integrated microphone to implement such an algorithm. By installing the mobile app patients can be monitored even when they do not remember about it. The app can be run in the background when a person uses voice search or calls, it's enough to have short voice recording several seconds long.

The volume of voice calls has shown significant growth amid the coronavirus epidemic. According to the largest US mobile operator Verizon, the number of daily calls reached 800 million. Moreover, people actively use voice search. Google states that 20% of all searches are voice searches and 41% of adults and 55% of teens use voice search every day thus, getting data became quite easy.

The system principle shown in figure 1. When a patient uses voice search, voice messages or calls anyone the App makes short recordings of several second length. Recorded data are then sent to the cloud for calculations, signal processing and features extraction. Cloud based technologies form a database which updates constantly with new received data and therefore can present a wealth of database to be uses for training and testing AI systems.

There are several projects based on AI which can predict if patients are having COVID-19 and 'Cough against COVID' is one of these projects. The University of Cambridge developed a COVID-19 sounds App which processes patients' voices, their breathing and coughing. Similar projects are 'Coughvid' by EPFL and Subirana's team project. Aforementioned projects offer patients to cough or to make a sound and collect this information. Also this system requests if patients have had COVID-19 tests and what were the outcomes.

Another interesting project is AI4COVID-19. It's a collaboration of AI4Networks and Allergy, Asthma & Immunology center PC. The research is in the developing stage and the goal is to get a system for distinguishing COVID-19 and asthma by using cough recordings.

The last mentioned project considers mostly cough recorded signals, and we see that this approach can be used to build the asthma-COVID-19 detection system by voice analysis. Using voice recordings helps to collect data about one patient more regularly, because nowadays systems need patients to do special tasks, and some people can forget to use the App regularly for constant data feed. If the App works in background mode, it can select daily recordings and this can help display the dynamics of the disease.

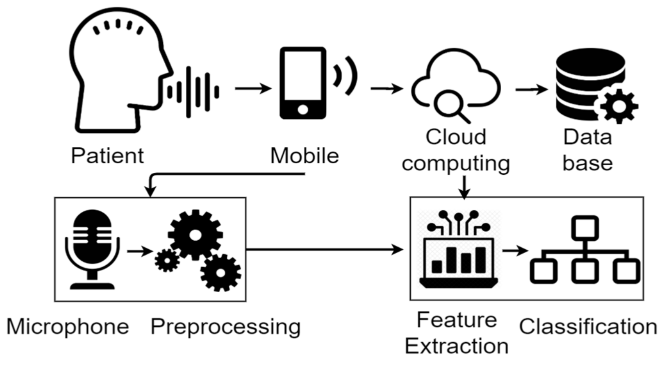


Fig.1 Principle of the mobile voice detection system

*C. Breath and Speech Connection*

The vocal speech production is directly connected to and impacted by the respiratory functions. Moreover, peripheral organs of speech are respiratory organs at the same time. That means voice analysis can be utilized as an indicator of respiratory diseases.

Sound production consist of several steps: airflow from the lungs through the larynx, vocal cords vibration and resonance in the oral and nasal cavities. Lung infections such as asthma tend to impact the lung airways and significantly affect natural sound since asthma influence on lung volume and voice source is a function of lung capacity [2].

Speech production and its implementation counterpart is depicted in Figure 2.

Breathing during speech is very common and differs from that of silence in a normal respiratory cycle. During speech, the respiratory organs not only perform their main biological function of gas exchange but also execute voice-forming and articulatory functions. Special requirements for the respiratory act during speech causes significant variations of parameters, in comparison with ordinary calm breathing. The main differences are shown in Table 1.

TABLE I. . SPEECH BREATHING FEATURES

| **Parameter** | **Breathing Type** | |
|---|---|---|
| | ***Ordinary Breathing*** | ***Speech Breathing*** |
| inspiration and expiration duration ratio | 1:1.25 | 1:5 – 1:8 |
| respirations | 12 – 16 | 8 – 10 |
| exhaled air volume, $cm^3$ | 500 | 1500 – 2000 |

Speech is formed in the expiratory phase. For a continuous pronunciation, an extended exhalation is required. That way, stored air volume must be greater than during normal breathing.

Respiratory pathologies cause both breath and voice changes. The voice changes can be significant in voice analysis disease diagnosis. The research conducted [2] and [3] shows the use of voice patterns to identify pulmonary disease. In [4] and [5], acoustic voice parameter analysis was considered for laryngeal pathologies including larynx cancer. Authors of [6] through [9], worked on algorithms of voice analysis to classify heathy people and asthma patients and established asthma degree of severity. Diseases such as Parkinson's and depression can be detected by voice analysis to the same extent as shown in [10]. There are similar works about asthma and COVID-19 recognition. These studies helped to extract features which suit asthma and coronavirus detection.

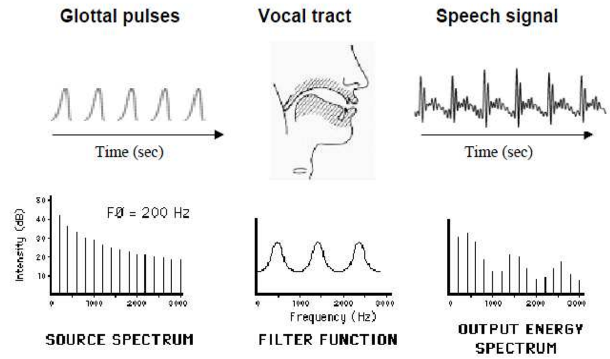


Fig. 2 Modeling of Speech Production

## III. VOICE FEATURES ANALYSIS

There are various studies that compare voice features and selection decisions on the most suitable ones for particular tasks. Mostly used in literature are jitter and harmonics-to-noise ratio (HNR) and jitter they used to distinguish asthma patients from health persons in [2, 4, 6] and they are displayed in Table 2.

The goal is to find features which suit for COVID-19 too, this way it is important to take into account the following criteria: significant differences between asthma and COVID-19, sensitivity to changes in asthma status and minimal influence on factors not related to diagnosed diseases.

Most previous studies connected to asthma and COVID-19 recognition used voice analysis made by PRAAT software. The audio samples are recorded at a sampling frequency around 40 kHz [1, 6].

TABLE II. . VOICE FEATURES

| **Feature** | **Revealing, differences significance** | |
|---|---|---|
| | Asthma | Health |
| **Harmonics-to-Noise Ratio (HNR)** | lower than 20dB | 20dB - 40dB |
| **Jitter** | 1.5% - 6% | 0.1% - 1% |
| **Shimmer** | > 3.8% | < 3.8% |

It is shown in [2] that different features are more significant for different phonations. For vowels, the best result of accuracy is achieved with Mel Frequency Cepstral Coefficients (MFCC). For fricative phoneme, such as /s/, /z/ the most suitable features are HNR and spectral analysis. Consequently, the App diagnostic system needs to process diversified parameters.

Jitter is the average absolute difference between consecutive periods (1).

$$Jitter = \frac{1}{N-1}\sum_{i=1}^{N-1}\left|T_i - T_{i+1}\right| \quad (1)$$

Shimmer (2) is an average absolute difference between the amplitudes of consecutive periods, divided by the average amplitude. Generally, and in the case of healthy speakers, the vibration of vocal fold tissues, displays a low-level jitter. Higher levels of jitter are observed in pathological voices for both asthma and COVID-19 patience [6, 7].

$$Shimmer = \frac{1}{N-1}\sum_{i=1}^{N-1}\left|20\log\left(\frac{A_{i+1}}{A_i}\right)\right| \quad (2)$$

A Harmonicity object represents the degree of acoustic periodicity. It is also called Harmonics-to-Noise Ratio (HNR) and expressed in dB. Harmonicity can be used as a measure for voice quality [7].

For instance, a healthy speaker can produce and sustained vowel "a" with Harmonicity of around 20 dB, and a vowel "u" at around 40 dB; Hoarse speakers will utter the vowel "a" with a Harmonicity much lower than 20 dB. [4].

## IV. AI CLASSIFICATIONS

### A. *Radial Basis Function Artificial Neural Network*

A neuron is defined as the fundamental processing unit of the human brain. Figure 3 shows a model of a neuron that has N inputs (the X's), N weights (the W's), a bias b and an output Y. Where b is an internal threshold or offset, and f is a nonlinear function chosen from one of the ones below (3,4):

(1) *Hard limiter*, where

$$f(x) = \begin{cases} +1 \text{ if } x > 0 \\ -1 \text{ if } x < 0 \end{cases} \quad (3)$$

or,

(2) *Sigmoid functions*, where

$$f(x) = \begin{cases} \tanh(\beta x) \text{ if } \beta > 0 \\ \dfrac{1}{1+e^{-\beta x}} \text{ if } \beta < 0 \end{cases} \quad (4)$$

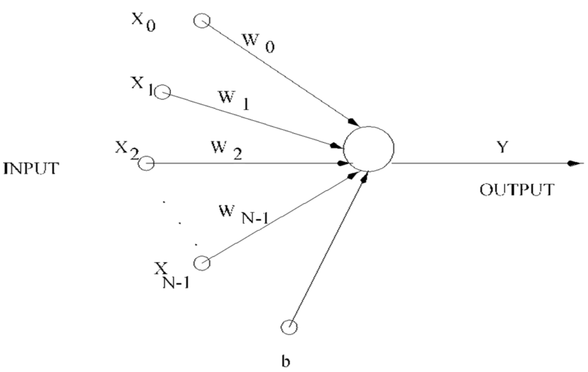


Fig. 3 A computational node of a neural network

The Sigmoid nonlinearities are used often since they are continuous and differentiable. In general, an Artificial Neural Network (ANN) is a network of several simple computational units. It has a great potential for parallel computation since the processing of the units is done independently and are widely used in pattern classification, matching and completion.

The core of a recognition system is the recognition engine. The one chosen in the paper is the Radial Basis Functions Neural Network (RBF). This is a static two neuron layers feed forward network with the first layer, $L_1$, called the hidden layer and the second layer, $L_2$, called the output layer Figure 3. $L_1$ consists of kernel nodes that compute a localized and radially symmetric basis functions Figure 4.

The pattern recognition approach avoids explicit segmentation and labelling of the speech signals. Instead, the recognizer uses the patterns directly. It is based on comparing a given pattern with previously stored ones. The way patterns are formulated in the reference database affects the performance of the recognizer. In general, there are two common representations.

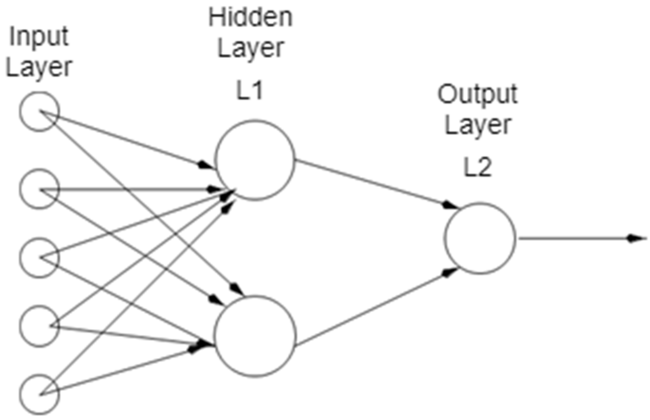


Fig. 4 A multi-layer neural network

The output $y$ of an input vector $x$ to a (RBF) neural network with $H$ nodes in the hidden layer is linked to linear weights $W_h$ and to $\varphi_h$ which are the radial symmetric basis functions. Each one of these functions is characterized by its centre $C_h$ and by its spread or width $\sigma_h$. The range of each of these functions is [0,1].

Once the input vector x is presented to the network, each neuron in the layer $L_1$ will output a value according to how close the input vector is to its weight vector. The more similar the input is to the neuron's weight vector, the closer to 1 is the neuron's output and vice versa. If a neuron has an output 1, then its output weights in the second layer $L_2$ pass their values to the neurons of $L_2$. The similarity between the input and the weights is usually measured by a basis function in the hidden nodes. One popular such function is the Gaussian function that uses the Euclidean norm. It measures the distance between the input vector $x$ and the node center $C_h$. It is defined as (5).

$$\varphi_h = e^{\left|x - \frac{C_h}{2\sigma h^2}\right|} \quad (5)$$

## V. CONCLUSION AND FUTURE WORKS

Both asthma and COVID-19 affect the respiratory system and consequently speech. They cause voice changes that can be significantly distinguished from health voice patterns. It is desirable to find features which can match for asthma and COVID-19 recognition and presumably, such features can be shimmer, jitter and HNR which can significantly differentiate amongst healthy and ill patients. It is important to determine if aforementioned parameters can distinguish COVID-19 from asthma. This paper lays down the framework for voice analysis system for detecting COVID-19 patients and especially individuals suffering from asthma. There is a need for them to distinguish asthma degree degradation and COVID-19 among to start right treatment. According to the alleged app speech segments are regularly recorded by smart phone and stored in the clouds for immediate and constant processing and analysis. A radial basis artificial neural network is always available for testing incoming new speech signals against stored database for classifications.

## REFERENCES


[1] Yadav S., NK K., Gope D., Krishnaswamy U.M., Ghosh P.K. Comparison of Cough, Wheeze and Sustained Phonations for Automatic Classification Between Healthy Subjects and Asthmatic Patients. 40th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC). Honolulu, 2018, pp. 1400-1403.

[2] Yadav S., Keerthana M., Gope D., Maheswari U.K., U., Ghosh P.K. Analysis of Acoustic Features for Speech Sound Based Classification of Asthmatic and Healthy Subjects. ICASSP 2020 - 2020 IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP). Barcelona, 2020, pp. 6789-6793.

[3] Sankar U.S.M., Ganesan R., Katiravan J., Ramakrishnan M., Kouser R.R. Mobile application based speech and voice analysis for COVID-19 detection using computational audit techniques. *International Journal of Pervasive Computing and Communications*, 2020, vol. 16 no. 4. Available at https://www.emerald.com/insight/publication/issn/1742-7371/vol/16/iss/4 (Accessed 23 October 2020).

[4] Sonu, Sharma R.K. Disease Detection using Analysis of Voice Parameters. 5th IEEE International Conference on Advanced Computing & Communication Technologies (ICACCT). 2011, pp. 416-420.

[5] Oletic D., Arsenali B., Bilas V. Low-power wearable respiratory sound sensing. *Sensors,* 2014, no. 4, pp. 6535–6566.

[6] Asiaee M., Vahedian-azimi A., Atashi S.S., Keramatfar A., Nourbakhsh M. Voice Quality Evaluation in Patients With COVID-19: An Acoustic Analysis. *Journal of Voice.* 2020, p. 7.

[7] Batra K., Bhasin S., Singh A. Acoustic Analysis of voice samples to differentiate Healthy and Asthmatic persons, *International journal of engineering and computer science*, 2015, vol. 4, no. 7, pp. 13161-13164.

[8] Walia G.S., Sharma R.K. Level of asthma: Mathematical formulation based on acoustic parameters. Conference on Advances in Signal Processing (CASP). Pune, 2016, pp. 24-27.

[9] Dogan M., Eryuksel E., Kocak I., Celikel T., Sehitoglu M.A. Subjective and Objective Evaluation of Voice Quality in Patients With Asthma. *Journal of Voice,* 2007, vol. 21, no. 2, pp. 224-230.

[10] Brown C., Chauhan J., Grammenos A., Han J., Hasthanasombat A., Spathis D., Xia T., Cicuta P., Mascolo C. (2020). Exploring Automatic Diagnosis of COVID-19 from Crowdsourced Respiratory Sound Data. The 26th ACM SIGKDD Conference on Knowledge Discovery and Data Mining. 2020, pp. 3474-3484.