Paper ID :69

Identification of Related Technologies Associated with Asthmatic Wheeze Detection Systems: A Review

DP Deraniyagala[1#], GAI Uwanthika[1] and MKP Madushanka[1]

[1]*Department of Computer Science, Faculty of Computing, General Sir John Kotelawala Defence University, Rathmalana, Sri Lanka*

[#]37-se-0004@kdu.ac.lk, uwanthika.gai@kdu.ac.lk, pavithram@kdu.ac.lk

Abstract **– Breathing difficulties are a common symptom of lung disorders such as chronic obstructive pulmonary diseases and asthma. Your airways may narrow, swell, and create additional mucus if you have asthma. This may obstruct your airways and cause shortness of breath, coughing, a whistling sound when you exhale, and wheezing. Therefore, wheezing can be used as a crucial diagnostic tool for the identification of various diseases. An individual's respiratory rate increases when they wheeze, and as a result, their lungs are more likely to work harder than they normally would. The presence of low blood oxygen levels, elevated heart rates, increased breathing sounds, increased breathing rates, and coughing can all be utilized to diagnose wheezing in a person. In this study, the aforementioned characteristics are used to identify wheezing in an asthmatic patient. Asthma, a widespread health condition affecting individuals of all ages, poses a significant risk as it claims the lives of many people daily, making it essential to raise awareness, research, and improve management strategies to reduce its impact on public health. With the proper treatment and care, almost all of these fatalities may be prevented. Therefore, this review study contains the study of such systems to determine what technologies can be best in developing this kind of system while considering the accuracy of the systems. After studying these technologies, we have identified that Neural Networks can be used to develop this kind of system due to its high accuracy of it.**

Keywords—Chronic obstructive pulmonary diseases, Asthma, Wheezing, Neural Networks

INTRODUCTION

Monitoring health conditions is becoming more and more popular as people's quality of life improves. Continuous and automatic monitoring of the respiratory status is necessary for individuals with chronic illnesses like asthma since everyday symptoms are vital to the medical diagnosis of these conditions. Unfortunately, unless the patients are hospitalized, such information is not easily accessible. Asthma is classified as a common, persistent respiratory disorder that impairs breathing.

In the world's population, there are around 300 million people who have asthma, according to statistics provided by the World Health Organization (WHO) [13]. By 2025, it is predicted that this number could rise by up to 400 million. While it is not an important statistic for Sri Lanka, over 11% of the population in India suffers from chronic lung conditions like asthma. Adults, newborns, toddlers, and pregnant women are the populations most at risk for developing these lung conditions.

The elderly in particular suffered greatly, and if they hadn't received timely aid, they may have ended themselves in dangerous situations. The patient-to-nurse ratio is likewise subpar at various hospitals throughout Sri Lanka. Not all of the patients are in timely monitored. The monitoring of the patient's status may be done easily without the assistance of the nurses thanks to technology. The rapid growth of information technology is contributing to the development of such kind of health monitoring systems.

Several systems are being developed for this purpose by using various technologies in different countries. These applications try to address this gap of patients and real-time monitoring them to get various information. In-depth information regarding wheeze detection systems that have been established for the benefit of patients and other related medical assistants globally is enhanced in this review study. Through the comparison of the developed systems, a review of the system modules, features, and technologies for giving timely information on wheeze detection is highlighted.

The rest of this paper is organized as follows. Section II includes a comprehensive literature review of the available applications for wheeze detection. Section III of the paper discusses the methodology used in this research. Section IV discusses the results obtained through the review. Finally, section V concludes the overall research indicating the importance of this research.

LITERATURE REVIEW

The research's chosen detecting applications include several asthmatic disease-based systems. Such systems, which use various types of methods to overcome this issue, have been discovered by numerous people. While some of these software's were created just to identify wheezes, others also offer numerous other extra functionalities.

These applications have a variety of features that are necessary to meet both functional and non-functional criteria. These systems utilize a multitude of cutting-edge technologies for a variety of purposes, including frontend, and back-end frameworks, The technologies being employed and the many features offered by the chosen systems are the main topics of this review.

Existing Systems for Asthmatic-Based Diseasse Detection

Researchers [1] have done a study which demonstrates a wearable microphone array system for health condition monitoring where they are monitoring the wheeze signals. The research provides a brand-new wheezing signal detection technique for wearable systems in particular. A Digital Signal Processing (DSP) based system has been used to implement the wheeze signal detector. The sampling rate of 1000Hz, which is much lower than the standard sample rate of 44kHz for audio signals, is what the detection method is intended to function at. The proposed approach runs at a sampling rate of 1000Hz, which is significantly lower than the standard sampling rate of 44 kHz for audio signals in order to comply with the low power consumption limitation under the wearable state . The findings demonstrate that the suggested wheeze detection method is resistant to power scaling issues and is capable of detecting wheezes with greater than 90% accuracy even when speech interference is present.

This study [2] introduces a brand-new technique for automatically detecting and classifying wheezes. The frequency spectrum of a wheezing signal is described by the proposed method by employing "entropy" and only either one or two entropy-based features can be used to identify wheezes. As a result, the computational complexity of the suggested solution has been significantly decreased, and it can operate under the wearable condition's low power consumption limitation. Lung sounds of patients and healthy persons were used to assess the effectiveness of the proposed approach at various Signal-to-Noise Ratios (SNR). The single step in this straightforward Entropy-Based Wheeze Detection (EBWD) approach is the estimation of signal entropy. A wearable sound-based respiratory monitoring system has been developed using the suggested methodology. The experimental findings demonstrate that, when the Signal-to-Noise Ratio (SNR) is 6dB, the suggested wheeze detection method is capable of detecting roughly 85% of wheezy samples and achieving its design aim.

This study demonstrated a flexible acoustic sensor that can monitor wheezing [3], which is a frequent asthma symptom, while attached to the chest of the patient. They have used air as the dielectric material in a parallel-plate capacitive arrangement. The upper diaphragm of the framework vibrates as a result of wheezing pressure (acoustic) waves~~-~~, modifying the output capacitance. The sensors are constructed in such a manner that something that resonates in the 100 to 1000 Hz wheezing frequency range, has two advantages. Resonance causes a significant diaphragm deflection, eliminating the need for signal amplifiers (used in microphones). In addition, the design itself functions as a lowpass filter to lessen the impact on background noise, which primarily occurs in the frequency band above 1000 Hz. Aluminum foil, a cheap sustainable material, is used in the sensor's construction, which significantly lowers the cost & complexity of the manufacturing process. When noisy signals coming from the chest that is in the same frequency band as wheezing are present, a reliable wheezing detection (matching filter) method is employed to distinguish between different forms of wheezing noises. The study further enhanced that the sensor may process signals and be further integrated into electronic healthcare electronic systems using the Internet of Things (IoT) as the result of the sensor's Bluetooth connection to a smartphone (IoT). The sensor is put through bending, cyclic pressure, heat, and perspiration testing to gauge how well it performs under a variety of realistically difficult situations.

This research [4] aims to present an Internet of Things (IoT) based early warning system for asthma patients. The suggested system, which measures the air quality, was created using a Raspberry Pi computer and accompanying sensors. The system uses various message-handling protocols, such as IBM's Message Queuing Telemetry Transport Server, to handle message transfers. It also uses various actuators, such as the SIM900A GSM Module, to notify patients and other relevant parties. The system is designed to notify the patients and the appropriate parties to take emergency precautions whenever the values of the said factors, which affect air quality, exceed a pre-identified threshold value. As a conclusion, it could be said that the proposed, tested, and implemented IoT-based solution could early warn asthmatic situations to asthma patients by gathering sensor data (air quality, humidity, etc.), processing them, and issuing some warnings to the patients. Further, the IBM Watson IoT platform with some Artificial Intelligence (AI) techniques like deep learning models are also being used to make certain predictions against some input factors like patient's heart rate, blood pressure, etc.

The goal of this study [5] is to use Cepstral analysis in Gaussian Mixture Models to categorize normal and abnormal (wheezing) respiratory sounds. The sound stream is separated into overlapped segments, each of which is represented by Mel-Frequency Cepstral Coefficients-based reduced dimension feature vectors. The "speaker" in this investigation is a wheeze. Unknown audio is compared to all of the Gaussian Mixture Model (GMM) models during the test phase, and the classification choice is made using the Maximum Likelihood criterion. Identification in these processes is dependent on a threshold value. The audio is normal if the threshold exceeds zero. Wheeze otherwise can be heard. According to experimental findings, wheeze can be identified with up to 90% accuracy whenever the Gaussian mix number is 16.

The research study [6] suggests a brand-new automatic wheeze identification technique for automatically identifying wheezes by extracting time-frequency aspects of lung sounds. The suggested technique successfully locates wheezing features in a lung sound spectrogram using canonical correlation analysis. Additionally, a neural network technique is employed to distinguish between wheezing and healthy noises. The Canonical Correlation Analysis (CCA) methodology, when compared to previous wheezing analysis methods, could significantly lessen the impact of background breathing sounds and environmental noise. It could also detect wheezing features in a lung sound spectrogram. A majority of the lung sound characteristics for all asthma groups, including the respiratory rate, sound index, breathing cycle period, expiratory duration, maximum peak frequency, wheezing duration, and wheezing frequency, according to the experimental results, were significantly different from those of the healthy group, with the exception of the inspiratory duration. Additionally, the Radial Basis Function Neural Network (RBFNN) with extracted lung sound features performed superbly in differentiating between normal lung sounds and wheezing sounds (accuracy = 96.8%). As a result, the suggested method may effectively detect wheezing in children who have asthma and may one day be used to gauge the severity of wheezing.

In this study [7] they offer a brand-new, reliable algorithm created just for the Compressively Sensed (CS) recovered Short-Term Fourier Spectra (STFT), for wheeze detection. The suggested technique uses a hidden Markov model to detect the presence and monitor numerous distinct wheeze frequency lines (Hidden Markov Model). On Nyquist-rate sampled respiratory sounds STFT, the algorithm produces 89.34% sensitivity, 96.28% specificity, and 94.91% accuracy. When used with STFT that has been recovered by Orthogonal Matching Pursuit (OMP), it allows for a signal compression ratio of up to 4x (classification from only 25% signal samples) with less than a 2% reduction in classification accuracy. It offers good parallelism prospects and has execution speeds comparable to equivalent methods.

Using MATLAB (Matrix Laboratory software), different lung sounds have been studied in this research [8] for wheeze identification and classification to Monophonic (one sound at a time) or Polyphonic (multiple sounds at a time). The American Thoracic Society (ATS) definition of wheeze and earlier studies are used to combine and analyze the set of factors in the provided algorithm. It has an overall sensitivity of 90% for wheezing episode detection and an accuracy of 91%. It is remarkably resilient, computationally simple, and accurate. The system has a sensibility of 91% and an accuracy of 70% for identifying monophonic and polyphonic wheezes. With a 90% specificity, the suggested method prevented other lung sounds from being mistakenly labeled as wheezes. This device can assist doctors in the early detection of lung obstructive disease and based on the analysis of lung sounds, may pinpoint the exact point of the obstruction in the lung. All they have to do is download the MATLAB compiler and launch the study program's executable file to detect respiratory wheeze sounds.

The invention of a quick and effective wheeze recognition system is described in this study [9]. The suggested wheeze detection system is based on back propagation neural networks (BPNN) and order truncate averages (OTA). The trained BPNN is then given some characteristics that were retrieved from the processed spectra. The trained BPNN eventually processes the fresh testing samples to determine whether they are asthmatic noises. The qualitative approach of wheeze recognition exhibits high responsivity of 0.946 and specificity of 1.0 according to experimental data. To address the shortcomings of Homs-Corbera et al's study and to identify wheezes with great sensitivity, a novel modular approach to the OTA technique was created. The program provides doctors with processed data in addition to an automatic diagnosis. Prior to automatic recognition in this application, the processed spectrogram is displayed on a computer screen. The results of the trials show that this method can be highly helpful in clinical diagnostics, particularly when analysis can be performed continuously using a large number of patients breathing cycles.

In this study [10], they created the first step in creating a computational model for respiratory phase-based wheeze identification, known as WheezeD [10]. First, they create an algorithm to identify the breathing phase from audio data. This is the first part of WheezeD [10]. They next turn the audio into a 2-D Spectro-temporal picture and create a model for wheeze identification based on a convolutional neural network (CNN). They assess model performance and contrast it with traditional methods. The results of experiments on a publicly available dataset demonstrate that their model can identify wheezing events with an accuracy of 96.99%, specificity of 97.96%, and sensitivity of 96.08%.

Since all these applications developed are not directly addressing the wheeze detection techniques the technologies, features, and concepts of them can be effectively used to improve the effectiveness in developing this kind of a system.

METHODOLOGY

The purpose of this research is to review technologies used to develop asthmatic wheeze detection systems based on their functionalities and effectiveness. This research followed a systematic search strategy to find such studies that have been done already as depicted in Figure 1. The research findings are summarized and discussed in this paper.

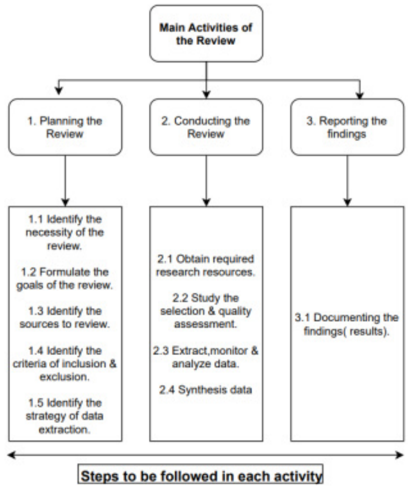

Figure 1: Research Methodology followed for the Review

Selected applications represent different technologies used, and different functionalities using different approaches. Breathing-related diseases are a common problem for people which causes high fatality rates as well. Therefore, this review is done to evaluate the technologies of such existing systems and to identify the best technologies that can be used to develop this kind of system. The main sources of information were ieee.org. After studying such systems, we have identified five factors that can be used to diagnose wheezing conditions. They are low blood oxygen levels, elevated heart rates, increased breathing sounds, increased breathing rates, and coughing can all be utilized to diagnose wheezing in a person. Therefore, the data is extracted according to the technologies used, features used, equipment used, and accuracy rates and presented in the discussion section. Applications are critically reviewed based on these criteria.

DISCUSSION

The review of systems for predicting asthmatic wheeze and other similar systems revealed many types of systems that have been built using various technologies. The systems have been reviewed according to the technologies used, equipment used, features addressed, and their accuracies.

Table 1: Comparison of Technologies, Equipment, Features, and Accuracy of the Revised Systems

Research Paper	A	B	C	D	E	F	G	H	I	J
Technology	DSP-based technology	Using LABVIEW	IOT	IOT & Deep learning models	Cepstral analysis in gaussian mixture models	Canonical correlation analysis & Neural networks	Hidden Markov model	DSP techniques	Order truncate average(OTA) and back-propagation neural network(BPNN)	Acoustic Data From Pulmonary Patients Under Attack
Equipment	Wearable microphone array system	Sensors, Signal conditioning circuits & PDA platform.	Acoustic sensors, filters	Raspberry Pi sensors, actuators	Sensor, amplifier and bandpass filters	Self assembled lung sound recorder	Wearable sensors	Collected from available databases	ECM wrapped inside the tube, filters, amplifiers	Collected from available databases
Feature	Sampling rate	Entropy-base features	Wheezing sounds	Air quality	Sound stream	Time frequency aspects of lung sounds	Wheeze signal frequencies	Monophonic wheezes and Polyphonic wheezes	OTA filtering of spectrogram	Breathing signal phase
Accuracy	In the presence of a speech interfering source, the accuracy is still above 90%	When SNR is 6dB 85% of accuracy	Low cost, low complexity design of the system	Early warning system to send warnings to authorities has a good accuracy	90% accuracy when gaussian mix number is 16	Accuracy 96.8%	89.34% sensitivity 96.28% sensitivity, 94.91% accuracy	90% sensitivity & 91% accuracy	High sensitivity of 0.946 and a specificity of 1.0 in qualitative analysis	accuracy of 96.99%, specificity of 97.96%, and sensitivity of 96.08%

According to the first system it has used DSP-based technology to implement a wearable array system to identify wheezing using the sampling rate of the respiratory signals with an accuracy of 90%. Using the LABVIEW software and hardware equipment such as sensors, signal processing circuits, and Personal Digital Assistant (PDA) platform in the second system they have used entropy-based features to measure the frequency spectrum of the wheezing signals with an accuracy of 85% when the Signal-to-Noise Ratio is 6dB. In the next system, they used IoT technologies using acoustic sensors and filters to analyze wheezing sounds. Due to the low complexity of the design of the system low cost is spent to build such a system. The next system uses IOT & Deep learning models using Raspberry Pi sensors, and actuators to measure the air quality of the air which circulates the patient, and it has achieved good accuracy while it is an early warning system to send warnings to relevant authorities about the patient. The next system uses cepstral analysis in gaussian mixture models using sensors, amplifiers, and bandpass filters to analyze the sound stream of the person and has achieved an accuracy of 90% when the gaussian mix number is 16. In the sixth system, canonical correlation analysis & neural networks has being used as technologies, and a self-assembled lung sound recorder to analyze time frequency aspects of lung sounds with a total accuracy of the system of 96.8%. Hidden Markov Model is used in this system where they have used wearable sensors to detect wheeze signal frequencies with an accuracy rate for the system of 94.91%. In the next system, DSP techniques have been used to collect data from already available databases without collecting signals or data in a real-time procedure and mainly it categorizes wheezes into two categories monophonic and polyphonic. It has achieved an accuracy rate of 90%. Order truncate average (OTA) and back-propagation neural network (BPNN) has used in this system while using ECM wrapped inside the tube, filters, and amplifiers to analyze the Order truncate average (OTA) filtering of the spectrogram. The final system used acoustic data from pulmonary patients under attack collected from already available databases to analyze the breathing signal phase which has achieved an accuracy of 96.99%. The features, technologies, and concepts used in these systems can be used for the development of these kinds of wheeze detection systems.

CONCLUSION

Insights into the current systems utilized for wheeze detection operations are provided in this review study. We can derive the following findings from our study. According to the above findings, neural networks provide better accuracy when compared with the other studies provided in this review study. Even though some systems like IoT-based systems provide easy implementation and low cost using neural networks a higher accuracy rate can be achieved hence these systems should be highly critical and should be reliable and safe because these systems are dealing with patients, and risks their life's when using this kind of systems. When measuring respiratory signals as input for these systems there can be sound interference too. To omit such scenarios, we can identify techniques mentioned in the above studies to overcome them. In the first study which is reviewed the system achieved a 90% accuracy rate even when sound interference is present. So, we can use those techniques when developing the system because we will get sound interference too when measuring the respiratory signals of the patients. But using neural networks we can achieve an accuracy above 90% for the system therefore we can use neural networks to develop the system. Studying more systems linked to various respiratory sound detection and classification procedures in the medical area in future research, as this study largely concentrated on systems used for wheeze detection will be very beneficial.

REFERENCES

[1] Wee Ser, Zhu-Liang Yu, Jianmin Zhang and Jufeng Yu, "Wearable system design with wheeze signal detection,"

2008 5th International Summer School and Symposium on Medical Devices and Biosensors, 2008, pp. 260-263, doi: 10.1109/ISSMDBS.2008.4575069.

[2] J. Zhang, W. Ser, J. Yu and T. T. Zhang, "A Novel Wheeze Detection Method for Wearable Monitoring Systems," 2009 International Symposium on Intelligent Ubiquitous Computing and Education, 2009, pp. 331-334, doi: 10.1109/IUCE.2009.66.

[3] S. M. Khan, N. Qaiser, S. F. Shaikh and M. M. Hussain, "Design Analysis and Human Tests of Foil-Based Wheezing Monitoring System for Asthma Detection," in IEEE Transactions on Electron Devices, vol. 67, no. 1, pp. 249-257, Jan. 2020, doi: 10.1109/TED.2019.2951580.

[4] W. Premachandra, N. Chathuranga, C. Rathnawardhana, M. Nowfeek, C. Jayawardena, and P. Lanka, “AllY: Early Warning System for Asthma Patients based on IoT and AI,” p. 9, 2019.

[5] J. -C. Chien, H. -D. Wu, F. -C. Chong and C. -I. Li, "Wheeze Detection Using Cepstral Analysis in Gaussian Mixture Models," 2007 29th Annual International Conference of the IEEE Engineering in Medicine and Biology Society, 2007, pp. 3168-3171, doi: 10.1109/IEMBS.2007.4353002.

[6] H. -C. Kuo, B. -S. Lin, Y. -D. Wang and B. -S. Lin, "Development of Automatic Wheeze Detection Algorithm for Children With Asthma," in IEEE Access, vol. 9, pp. 126882-126890, 2021, doi: 10.1109/ACCESS.2021.3111507.

[7] D. Oletic and V. Bilas, "Asthmatic Wheeze Detection From Compressively Sensed Respiratory Sound Spectra," in IEEE Journal of Biomedical and Health Informatics, vol. 22, no. 5, pp. 1406-1414, Sept. 2018, doi: 10.1109/JBHI.2017.2781135.

[8] R. M. Rady, I. M. El Akkary, A. N. Haroun, N. Abd Elmoneum Fasseh and M. M. Azmy, "Respiratory Wheeze Sound Analysis Using Digital Signal Processing Techniques," 2015 7th International Conference on Computational Intelligence, Communication Systems and Networks, 2015, pp. 162-165, doi: 10.1109/CICSyN.2015.38.

[9] B. -S. Lin, H. -D. Wu, S. -J. Chen, G. E. Jan and B. -S. Lin, "Using Back-Propagation Neural Network for Automatic Wheezing Detection," 2015 International Conference on Intelligent Information Hiding and Multimedia Signal Processing (IIH-MSP), 2015, pp. 49-52, doi: 10.1109/IIH-MSP.2015.51.

[10] S. Chatterjee, M. M. Rahman, E. Nemanti, and J. Kuang, “WheezeD: Respiration Phase Based Wheeze Detection Using Acoustic Data From Pulmonary Patients Under Attack,” in Proceedings of the 13th EAI International Conference on Pervasive Computing Technologies for Healthcare - Demos and Posters, Trento, Italy, 2019. doi: 10.4108/eai.20-5-2019.2283516.

[11] Centers for Disease Control and Prevention. (2020). *2019 National Health Interview Survey Data.* U.S. Department of Health & Human Services. https://www.cdc.gov/asthma/nhis/2019/data.htm

[12] National Center for Health Statistics. *National Vital Statistics System: Mortality (1999-2018).* U.S. Department of Health and Human Services, Centers for Disease Control and Prevention. https://wonder.cdc.gov/ucd-icd10.html

[13] “Asthma: Practice Essentials, Background, Anatomy,” *eMedicine*, May 2022, Accessed: Nov. 23, 2022. [Online]. Available: https://emedicine.medscape.com/article/296301-overview#:~:text=Asthma%20affects%20an%20estimated%20300.

AUTHOR BIOGRAPHIES

DP Deraniyagala is a Software Engineering undergraduate at the Department of Computer Science, Faculty of Computing, KDU.

Mrs.GAI Uwanthika is a Lecturer (Probationary) at the Department of Computer Science, Faculty of Computing, KDU.

Ms. MKP Madushanka is a Lecturer (Probationary) at the Department of Computer Science, Faculty of Computing, KDU.