Jurnal Teknokes
International: Rapid Review: Open Access Journal **Vol. 16, No. 3, Sept. 2023, pp. 164-169** **e-ISSN 2407-8964; p-ISSN 1907-7904**

RESEARCH ARTICLE

OPEN ACCESS

Manuscripts received July 18, 2023; revised August 10, 2023; accepted August 12, 2023; Publish date: 25 September 2023
Digital Object Identifier (**DOI**): https://doi.org/10.35882/teknokes.v16i3.629

How to cite : Fani Febrianti, Endang Dian Setioningsih, Bedjo Utomo, and Sumber "Pulmonary Sound Design Using Max 9814 Sensor With Nextion View", Journal of Teknokes, vol. 16, no. 3, p. 164–169, September. 2023.

Pulmonary Sound Design Using Max 9814 Sensor with Nextion View

Fani Febrianti, Endang Dian Setioningsih, Bedjo Utomo, and Sumber
Department of Medical Electronics Technology, Poltekkes Kemenkes Surabaya, Indonesia

Corresponding author: Bedjo Utomo (email : bedjoutomo123@gmail.com).

ABSTRACT This study aims to develop a tool that can assist nurses in examining patients by displaying sounds and signals on a TFT LCD screen. This tool uses the MAX 9814 sound sensor, which converts sound into an electrical signal. This sensor will generate a voltage when the diaphragm inside it moves back and forth. To design this tool, researchers used a series of high pass filters and low pass filters with a cut-off frequency of 333 Hz - 714 kHz. During testing of this tool using the MAX 9814 sensor mounted on a stethoscope, the signal appears stable on the TFT LCD screen and sound can be played properly. However, if the placement of the stethoscope is not correct during the examination, this can also affect the signal and sound produced. This tool should not produce a clear and loud sound when checking, because if this happens, the inspection cannot be carried out optimally. This research also produces a signal shape that is almost similar to the signal on the phantom. It is important to note that the MAX 9814 can work optimally if it is not exposed to environmental noise. Therefore, if this equipment is used in a noisy environment, the signal and sound produced may be disturbed by environmental noise. This research was conducted with the aim of making it easier for doctors and nurses to carry out portable examinations, as well as to monitor signals and sounds easily.

INDEX TERMS Pulmonary sound, MAX 9814, HPF, LPF, Noise

I. INTRODUCTION

The stethoscope is a medical instrument that utilizes sound to examine the internal sounds of both humans and animals. It is commonly employed to listen to the sounds of the lungs and heart [1][2][3]. The effectiveness of the stethoscope in clinical practice is constrained by differences in how different listeners interpret lung sounds, leading to variability and subjectivity. Moreover, its usefulness is primarily limited to controlled medical environments, as background noise can interfere with the quality of lung auscultations and potentially hide abnormalities in the detected signals [4][5].

The traditional stethoscope is an acoustic instrument that conveys chest sounds from the chest piece to the listener's ears through a hollow tube filled with air. It was originally invented in the 1800s by the French physician René Laennec[6]. In recent years, different types of digital stethoscopes have emerged in the market, replacing the conventional stethoscopes [7]. With the use of machine learning and deep learning algorithms and the use of a digital stethoscope, several new technologies can be developed to provide more intellectual analysis to consumers, providing an immediate diagnostic for respiratory-related diseases. For quite some time, listening to lung sounds has been a fundamental aspect of diagnosing respiratory conditions in healthcare. Despite recent progress in electronic auscultation and signal processing, these advances have not been widely adopted in clinical settings. Nevertheless, computerized lung sound analysis could prove beneficial in pediatric populations, particularly in areas where qualified healthcare professionals are scarce. In our study, we utilized a novel signal processing technique to identify characteristics of normal lung sounds in young children. This research aims to establish a basis for detecting abnormal respiratory sounds in the future.[8][9][10].

The digital auscultation sub study was nested within the PERCH study and was conducted at all sites except for Mali. The digital auscultation sub study was a convenience subset of cases and controls which began during the second half of PERCH enrolment; there were no additional criteria for enrolment[11]. The objective is to develop a sound amplification system that strikes a balance between preserving the accuracy of automatic sound recognition algorithms for diagnosing conditions like crackles, wheezes, and heart murmurs, while also maintaining sound characteristics that medical practitioners are familiar with. The aim is to enhance sound clarity for effective diagnosis while ensuring that the amplified sounds remain recognizable and relevant to healthcare professionals. The lungs are one of the vital human organs that have a role in the respiratory system, because they can meet the oxygen needs of the human body. Lungs that are experiencing interference will have an impact on the performance of the respiratory system which, if not taken seriously, can cause death. So, one way doctors use to diagnose lung disease is by using a stethoscope[12][13].

This technique is known as the auscultation technique, lung sounds produced in some cases of lung disease show certain patterns that can be recognized. Problems that arise from the process of determining the type of additional sound in lung sounds are lung sounds that occupy a fairly low frequency around 20-2000 Hz, low amplitude, environmental noise problems, ear sensitivity and sound patterns that are relatively the same between one type of sound and the other. another. To determine each type of additional sound requires more expertise from a doctor. Certain studies have indicated that an abnormal heart-rate pattern during exercise and recovery can serve as a predictive factor for sudden death. Considering the rising prevalence of cardiovascular diseases, particularly those related to the heart, it has become a widespread global health concern. With the advancements in wireless technology, the analysis of heart sounds has emerged as a potential new approach for diagnosing cardiovascular conditions. Anh Dinh and Tao Wang conducted research involving the wireless transmission of processed heartbeats using the ZigBee protocol. This method holds promise as an innovative means of diagnosing cardiovascular diseases, therefore in this study a tool will be designed to recognize additional types of sounds in the lungs. The problem that arises in auscultation is that biological sounds usually occupy a fairly low frequency around 20 – 400 Hz, low amplitude, noise problems, environment, ear sensitivity and sound patterns that are similar between one type of heart sound and another. Lung sounds themselves have a frequency range of 150 – 1.7 KHz. Meanwhile, heart sounds The sounds being discussed fall within the frequency range of 20 - 150 Hz, which coincides with the low-frequency range of lung sounds. The method of utilizing a stethoscope to differentiate between normal and abnormal sounds is known as auscultation[14].

The normal frequency range of pulmonary sounds spans from 100 to 1000 Hz. Additionally, wheezing sounds have frequencies between 100 and 5000 Hz, rhonchus has a frequency of 150 Hz, coarse crackle is around 350 Hz, and fine crackle is approximately 650 Hz[15].

Normal tracheal sounds are distinctly audible throughout both phases of the respiratory cycle, whereas normal lung sounds are only heard during the inhalation phase and the initial part of exhalation[16][17][18].

Based on the above problems, researchers are interested in conducting research in conducting normal lung sound recognition and abnormal lung sounds detected. Lung sounds will be classified into four classes, namely voice *tracheal*, voice *vesicular*, voice *crackles*, and sound *wheeze*. Voice *tracheal* and sound *vesicular* indicates normal lungs, while the voice *crackle* and sound *wheeze* indicate abnormalities in the lungs. Wheeze is a type of lung sound that has a high pitch with a frequency of 400 Hz and above, this sound is caused by narrowing of the respiratory tract, so this sound sounds like a whistle. The study aims to explore the potential correlation between the characteristics of forced expiration tracheal sounds and the sound radiation generated by a distinct airflow occurring in the region of dynamic tracheal constriction during forced exhalation[19][20].

Crackles is a type of lung sound that is in the range of 350 Hz to 650 Hz, this sound sometimes sounds like the sound of water bubbles breaking or the sound of fireworks sparkles, which is caused by the sudden opening or ball of gas in the respiratory tract. Wheeze is a type of lung sound that has a high pitch with a frequency of 400 Hz and above, this sound is caused by narrowing of the respiratory tract, so this sound sounds like a whistle. Crackle is a type of lung sound that is in the range of 350 Hz to 650 Hz, this sound sometimes sounds like the sound of water bubbles breaking or the sound of fireworks sparkles, which is caused by the sudden opening or ball of gas in the respiratory tract[21].

Auscultating heart sound and lung sound using an Using an esophageal stethoscope, a medical device designed for listening to internal heart and lung sounds, offers a straightforward, cost-effective, and less noisy approach to auscultate heart and lung sounds. However, achieving accurate results with this method necessitates the expertise and proficiency of highly experienced anesthetists[22].

In 2018, Fardhon Danang Prakoso developed an electronic stethoscope called "Wireless-Based Heart and Lung Auscultation." This device enables the reading of heart sound signal data using a personal computer (PC). However, one limitation of this tool is its dependency on a PC during operation. To conduct examinations and display heart sound signals, a PC must be readily available, which can be considered a drawback.

During the year 2017, the International Conference on Biomedical and Health Informatics (ICBHI) released an open dataset to facilitate researchers in exploring and developing models aimed at enhancing classification accuracy. Multiple articles were subsequently published in the conference, showcasing various efforts in this domain. Notably, the highest benchmark score achieved in the contest was 49.86% [23].

It is true that the lungs are vital organs that are in direct contact with the external environment, and they are susceptible to various types of damage. However, it is important to note that lungs are not the only internal organs prone to damage. Other organs, such as the liver, kidneys, heart, and brain, are also susceptible to damage or disease. The primary role of the lungs is to enable the vital exchange of oxygen and carbon dioxide, crucial for the process of respiration[24].

As part of this process, the lungs continuously inhale and exhale air from the outside environment. This constant exposure to the environment makes the lungs vulnerable to various harmful substances, including pollutants, allergens, and infectious agents such as bacteria or viruses. Regarding the use of a stethoscope, it is a common medical tool used to listen to internal sounds of the body, including lung sounds. When listening to the lungs with a stethoscope, healthcare professionals can detect abnormal sounds such as crackles, wheezes, or diminished breath sounds, which may indicate underlying lung conditions or diseases. It is true that lung sounds can be mixed with other sounds, especially the sound of the heartbeat, as the heart and lungs are located in close proximity to each other within the chest cavity. This is why healthcare professionals often need to carefully distinguish between lung sounds and heart sounds to accurately assess the health of these organs[25].

Respiratory conditions like chronic obstructive pulmonary disease and asthma are among the major contributors to global mortality rates. Swift and accurate diagnoses are essential for appropriate treatment, medical care, and preventing respiratory system failure. The World Health Organization's data indicates that approximately 45% of member states report having fewer than 1 physician per 1000 population, underscoring the challenges in providing adequate healthcare access for respiratory-related issues.

In summary, while the lungs are indeed exposed to the external environment and can be susceptible to damage, it is essential to consider the overall vulnerability of various organs in the body. The lungs' proximity to the heart can result in mixed sounds, but medical professionals are trained to differentiate between lung and heart sounds to make accurate diagnoses and assessments. Given the insights from the references mentioned earlier and identified shortcomings in existing tools, the author aims to develop a new tool with the working title. "**PULMONARY SOUND DESIGN USING MAX 9814 SENSOR WITH NEXTION VIEW** "

II. MATERIALS AND METHODS

Based on the information provided, the study titled Pulmonary Sound Design Using Max 9814 Sensor with nextion view was conducted at the Surabaya Electromedical Engineering Campus. The researchers used a phantom mannequin as a tool for comparison in data collection. The research design employed in this study is a Pre - Experimental design with the specific type called One Group Post Test Design.

In this study, the author collected lung sound signals from 5 mannequins and treated them in some way. Unfortunately, the specific details of the treatment (O) are not provided, so it is difficult to comment on the results or implications of the study.

To better understand the study and its outcomes, additional information regarding the treatment and the specific objectives or research questions of the study would be helpful.

In FIGURE 1 It is a block diagram where the input is the sound of the patient's lungs captured by the stethoscope and then detected by the MAX-9814 sound sensor. Then, the output from the sensor enters the non-inverting circuit which has been amplified by 9.3x. Then, after amplifying the sound, it will be processed by a filter circuit to filter out the required sound frequency. Because it has passed through the filter, it is strengthened again with a non-inverting circuit to produce sound output on speakers and headphones. After that, the signal enters the adder circuit to increase the baseline so that it can be read by the microcontroller automatically. Next, we will enter into the programming process using Arduino UNO. And the signal output results will be displayed on the nextion.

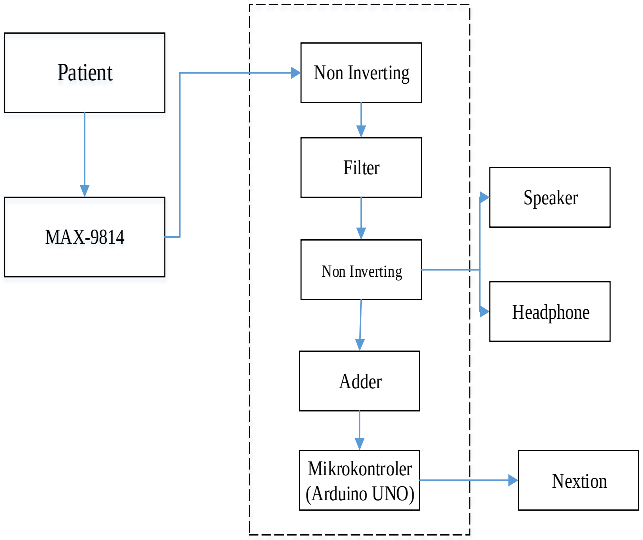

FIGURE 1 System inside block diagram design module digital stethoscope use analog circuit.

In FIGURE 2, the MAX9814 sound sensor serves as the primary source for obtaining lung sound signals, which are then converted into a voltage. This voltage is further processed using an Arduino to refine the signal and extract the relevant information. The processed data is then displayed on the Nextion interface. The pulmonary sound device follows a flow chart, starting with signal acquisition through the MAX9814, subsequent voltage generation, signal processing with Arduino, and finally, presenting the desired output on the Nextion display.

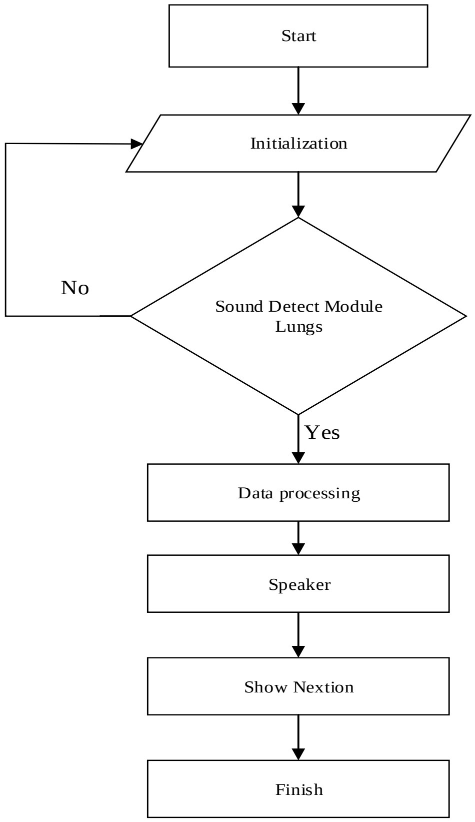

FIGURE 2 System Flowchart on the module Digital stethoscop

A. DATA ANALYSIS

Measurements for each parameter of pulmonary to calculate the overall data collection factor for the phantom mannequins and respondents, we need to consider the number of times data was collected for each. For the phantom mannequins, you mentioned that data was taken 5 times for every 1 kind of sound. So, if there are 4 types of sounds (normal tracheal and bronchial sounds, abnormal wheezes, and crackles)

For the respondents, you did not provide specific information on how many times data was collected. If you could provide that information, I would be able to calculate the total number of data collections for the respondents as well. Regarding the signal results, you mentioned that there is a little difference due to external factors such as cable liaison to the stethoscope swaying and the placement of the stethoscope membrane. These factors can affect the accuracy and consistency of the collected data.

As for the input tool, you mentioned it goes to a non-inverting circuit with a magnification of 9.3x. It seems like you are using some amplification or signal processing technique to enhance the input signals. The magnification factor of 9.3x suggests that the output signal from the circuit would be approximately 9.3 times the magnitude of the input signal.

III . RESULTS

On research This tested using a phantom mannequin . The design is shown in FIGURE 1 . Network part whole consists from Non inverting circuit , Filter Order 2, and Adder .

FIGURE 3 Pulmonary Sound Design Using Max 9814 Sensor With Nextion Display

If you have any specific calculations or further questions, can be shown in the equation (1)

$$Acl = \frac{Rf}{Rin} + 1 \quad (1)$$

on tools This use filter circuit with cut off frequency of 333 Hz – 714 Hz. With calculation under this :
Calculation of the cut off frequency of *the high pass filter* -40 dB order 2 can be shown in the equation (2).

$$Fc = \frac{1}{2\pi\sqrt{R1.R2.C1.C2}} \quad (2)$$

Then, for the image below is the output of several circuits that have been tested point (FIGURE 4).

FIGURE 4 Pulmonary sound signal output after passing non inverting.

In FIGURE 4, the measured amplitude is 2.7Vpp. This signal is the output before passing through a filter circuit, which boasts a gain of 9.3 times. In FIGURES 5, the signal output, before being processed through the filter circuit, exhibits an amplitude of 2.24 Vpp. As per theoretical calculations, the filter circuit's cutoff frequency is expected to allow frequencies above 333 Hz to pass through while attenuating frequencies below 714 Hz.

FIGURE 5 **Lung sound signal output after passing non-inverting 2**

In FIGURE 6 The recorded amplitude is 2.52 Vpp. Following its passage through a filter circuit, the output signal displays a gain of 9.3 times.

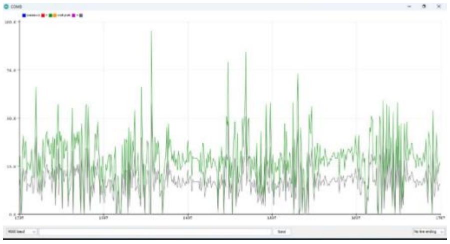

FIGURE 6 **Pulmonary sound signal output on the Arduino serial plotter**

In FIGURE 6, in the mentioned signal, two categories of lung sounds are discernible, namely inspiration and expiration. During the process of inspiration, the muscles between the outer ribs contract, elevating the ribs and expanding the chest cavity, which, in turn, causes the lungs to expand. This results in a lower air pressure inside the lungs compared to the outside, facilitating the intake of air. Conversely, during expiration, the muscles between the outer ribs relax, pulling the ribs back to their original position and increasing the volume of the chest cavity. This leads to higher air pressure in the lungs relative to the outside, causing the air to be expelled. Some of the detection results in various sounds, namely: crackles, wheeze, bronchial, tracheal will be shown in the image below. Some of the detection results in various sounds, namely: crackles, wheeze, bronchial, tracheal will be shown in the image below. The examination results reveal the presence of wheezing, a distinct sound originating from constricted airways. Wheezing produces a noticeable whistling sound that is evident during both inhalation and exhalation. This condition can affect individuals of all ages. The outcomes of the bronchial sound examination indicate a chronic inflammatory ailment affecting the airways, leading to symptoms such as persistent coughing, wheezing, difficulty breathing, and a sensation of tightness in the chest. The tracheal breath sound is characterized by its high pitch and pronounced loudness, with both inspiration and expiration durations being relatively similar. This sound is rarely heard during routine examinations and is typically audible over the trachea. On the other hand, vesicular breath sounds are the most commonly encountered normal breath sounds, found throughout most lung surfaces. They are characterized by their soft and low-pitched nature, with inspiratory sounds being longer than expiratory ones.

IV . DISCUSSION

The implementation of the MAX-9814 sensor as a tapping sensor for lung sounds has proven to be successful in generating a lung sound signal output. The sensor efficiently detects lung-generated sounds, and the device is equipped with an analog filter that has a cutoff frequency ranging between 333-714 Hz. This filter comprises both a High Pass Filter and a Low Pass Filter, effectively attenuating the signal by 40 db. With this setup, the device can effectively isolate and capture lung sounds falling within the desired frequency range.

In conclusion, the authors summarize that the designed tool has effectively detected and recorded lung sounds using the MAX-9814 sensor. Nevertheless, it is crucial to consider factors that can affect the quality of data collection, such as environmental noise and proper placement of the tool. With this understanding, further development of this tool can be pursued to enhance performance and mitigate the effects of unwanted noise.

V. CONCLUSION

Objective from study This is For detect voice lungs used For prove that voice lungs has 2 categories , viz normal and abnormal lungs . For normal lungs themselves that is tracheal and bronchial sounds, then for category abnormal sound ie wheezes and crackles. At a frequency of 500 Hz incl category voice normal lungs. Whereas frequency above 500 Hz category voice abnormal lungs. In terms of classifying lung sounds, there are generally two broad categories: normal and abnormal lung sounds.

Normal lung sounds can be classified into three categories: Vesicular Breath Sounds: These are the typical and healthy sounds heard during regular breathing. They are soft, low-pitched, and can be heard over most of the lung fields. The presence of vesicular breath sounds indicates normal, healthy lung tissue.

Bronchial Breath Sounds: These sounds are comparatively louder and higher pitched than vesicular breath sounds. They are primarily heard over the trachea and main bronchi. While bronchial breath sounds may be present in certain regions of the lung in healthy individuals, their occurrence in abnormal locations could indicate potential lung pathology.

Bronchovesicular Breath Sounds: These sounds combine the characteristics of both vesicular and bronchial breath sounds. They are audible in the middle areas of the lungs, such as the first and second intercostal spaces.Abnormal lung sounds can be further categorized into various types based on the underlying pathology. Some common abnormal lung sounds include: Crackles (also known as rales): These are intermittent non-musical sounds that can be heard during inspiration or expiration. Crackles can indicate conditions such as pneumonia, pulmonary fibrosis, or heart failure. Rhonchi: Rhonchi are low-pitched, continuous sounds that resemble grunting or gurgling. They are often caused by the presence of mucus or fluid in the larger airways and can be heard during inspiration or expiration. Rhonchi can be an indicator of conditions such as bronchitis or bronchiectasis.

In the classification above, the next researcher must be able to develop and consider the tool so that it can be carried out in a long and long term. While this tool is still classified as a simple tool, therefore for future researchers to be able to develop it again at a higher level, with an example of adding IoT-based storage and adding normal and abnormal categories to the displayed LCD screen.

REFERENCES

[1] N. Bhimani and Z. Shaikh, "Electronic stethoscope designing and use in resource limited Indian setting," *Indian J. Physiol. Pharmacol.*, vol. 62, no. 3, pp. 367–371, 2018.

[2] M. K. P. D. D. and M. S. R. K., "Design of Wireless Electronic Stethoscope," *Airccse.Org*, [Online]. Available: http://airccse.org/journal/ijdps/papers/0112ijdps30.pdf

[3] Y. Ma *et al.*, "Lungbrn: A smart digital stethoscope for detecting respiratory disease using bi-resnet deep learning algorithm," *BioCAS 2019 - Biomed. Circuits Syst. Conf. Proc.*, pp. 1–4, 2019, doi: 10.1109/BIOCAS.2019.8919021.

[4] M. Gold, KJ; Mozurewich, EL; Puder, KS; Treadwell, "乳鼠心肌提取 HHS Public Access," *J. Obstet. Gynaecol. (Lahore).*, vol. 176, no. 1, pp. 139–148, 2016, doi: 10.1109/TBME.2017.2717280.Computerized.

[5] J. C. Aviles-Solis *et al.*, "International perception of lung sounds: A comparison of classification across some European borders," *BMJ Open Respir. Res.*, vol. 4, no. 1, pp. 1–6, 2017, doi: 10.1136/bmjresp-2017-000250.

[6] S. Swarup and A. N. Makaryus, "Digital stethoscope: Technology update," *Med. Devices Evid. Res.*, vol. 11, no. 2018, pp. 29–36, 2018, doi: 10.2147/MDER.S135882.

[7] Y. Ma *et al.*, "Live Demo: LungSys-Automatic Digital Stethoscope System for Adventitious Respiratory Sound Detection," *BioCAS 2019 - Biomed. Circuits Syst. Conf. Proc.*, no. November, 2019, doi: 10.1109/BIOCAS.2019.8918752.

[8] L. E. Ellington *et al.*, "Developing a Reference of Normal Lung Sounds in Healthy Peruvian Children," *Lung*, vol. 192, no. 5, pp. 765–773, 2014, doi: 10.1007/s00408-014-9608-3.

[9] S. Aras, M. Öztürk, and A. Gangal, "Automatic detection of the respiratory cycle from recorded, single-channel sounds from lungs," *Turkish J. Electr. Eng. Comput. Sci.*, vol. 26, no. 1, pp. 11–22, 2018, doi: 10.3906/elk-1705-16.

[10] E. Andrès, S. Reichert, C. Brandt, N. Hill, and R. Gass, "Développement et expérimentation d'un nouveau stéthoscope numérique, communiquant et intelligent," *Eur. Res. Telemed.*, vol. 5, no. 4, pp. 145–155, 2016, doi: 10.1016/j.eurtel.2016.09.003.

[11] D. E. Park *et al.*, "Digitally recorded and remotely classified lung auscultation compared with conventional stethoscope classifications among children aged 1–59 months enrolled in the Pneumonia Etiology Research for Child Health (PERCH) case–control study," *BMJ Open Respir. Res.*, vol. 9, no. 1, p. e001144, 2022, doi: 10.1136/bmjresp-2021-001144.

[12] S. S. Kraman, "Does the vesicular lung sound come only from the lungs," *Am. Rev. Respir. Dis.*, vol. 128, no. 4, pp. 622–626, 1983, doi: 10.1164/arrd.1983.128.4.622.

[13] C. POKORNY and C. A. HELLWIG, "Diffuse interstitial fibrosis of the lungs.," *A. M. A. Arch. Pathol.*, vol. 59, no. 3, pp. 382–387, 1955, doi: 10.1378/chest.20.4.366.

[14] M. I. Rusydi, E. M. Ningsih, A. Pawawoi, R. Nofendra, and N. Windasari, "Design a Stethoscope Digital to Keep the Medical Practitioner at an Adequate Distance While Examining the Patient," *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 1041, no. 1, p. 012015, 2021, doi: 10.1088/1757-899x/1041/1/012015.

[15] V. I. Korenbaum, A. A. Tagiltcev, S. V. Gorovoy, A. D. Shiryaev, and A. E. Kostiv, "On localization of wheezing respiratory sounds in human lungs by means of intensimetric processing of signals detected on the chest surface," *Acoust. Phys.*, vol. 62, no. 5, pp. 600–607, 2016, doi: 10.1134/S1063771016050055.

[16] S. Swarup and A. N. Makaryus, "Digital stethoscope: Technology update," *Med. Devices Evid. Res.*, vol. 11, pp. 29–36, 2018, doi: 10.2147/MDER.S135882.

[17] R. Sripada, K. Keys, and K. M. Eichholz, "Inability to ventilate the lungs of a patient with tracheal anomaly and in prone position," *J. Clin. Anesth.*, vol. 20, no. 5, pp. 386–388, 2008, doi: 10.1016/j.jclinane.2008.03.007.

[18] R. Sabarinathan, "Development of a Software Application to Extract the Features of Normal Respiratory Sounds from the Lungs and the Trachea," 2006.

[19] A. I. Dyachenko, G. A. Lyubimov, I. M. Skobeleva, and M. M. Strongin, "Generalization of the mathematical model of lungs for describing the intensity of the tracheal sounds during forced expiration," *Fluid Dyn.*, vol. 46, no. 1, pp. 16–23, 2011, doi: 10.1134/S0015462811010029.

[20] Yaseen, G. Y. Son, and S. Kwon, "Classification of heart sound signal using multiple features," *Appl. Sci.*, vol. 8, no. 12, 2018, doi: 10.3390/app8122344.

[21] K. J. Hong *et al.*, "An Analysis of Sounds for Lungs with Excessive Water To cite this version : HAL Id : hal-01644304 An Analysis of Sounds for Lungs with Excessive Water," 2017.

[22] N. Mohamed, H. S. Kim, K. M. Kang, M. Mohamed, S. H. Kim, and J. G. Kim, "Heart and lung sound measurement using an esophageal stethoscope with adaptive noise cancellation," *Sensors*, vol. 21, no. 20, pp. 1–15, 2021, doi: 10.3390/s21206757.

[23] Y. Ma *et al.*, "Lungbrn: A smart digital stethoscope for detecting respiratory disease using bi-resnet deep learning algorithm," *BioCAS 2019 - Biomed. Circuits Syst. Conf. Proc.*, no. November, 2019, doi: 10.1109/BIOCAS.2019.8919021.

[24] J. S. Chorba *et al.*, "Deep learning algorithm for automated cardiac murmur detection via a digital stethoscope platform," *J. Am. Heart Assoc.*, vol. 10, no. 9, 2021, doi: 10.1161/JAHA.120.019905.

[25] D. A. Pratama, N. L. Husni, E. Prihatini, S. Muslimin, and O. F. Homzah, "Implementation of DSK TMS320C6416T Module in Modified Stethoscope for Lung Sound Detection," *J. Phys. Conf. Ser.*, vol. 1500, no. 1, 2020, doi: 10.1088/1742-6596/1500/1/012012.