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DESIGN OF WHEEZING SOUND DETECTION WEARABLE DEVICE BASED ON INTERNET OF THINGS

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ABSTRACT

Introduction: Wheezing is one of the most common manifestations of airway obstruction. The use of a stethoscope in the wheezing examination has several disadvantages such as subjective results and depends on the auditor's hearing sensitivity. So an easy device is needed that helps determine the wheezing sound precisely. This study assembled a single tool to detect wheezing sounds based on the internet of things.
Method: This tool is designed with a microprocessor hardware connected to an electric stethoscope so that it can be attached to the patient's chest wall. Collection of chest breathing voice data accessed on kaggle.com. The creation of algorithms with Convolutional Neural Networks (CNN) was later changed to Mel Frequency Cepstral Coefficients (MFCC). This model will be implanted in a microprocessor and use python language to be able to record the sound of chest wall vibrations. The recorded sound is converted into MFCC to make it easier to perform wheezing sound detection. MFCC image results and detection results are sent to the database via the firebase database feature which stores MFCC photos in real-time as they are detected. Designing android application software using Flutter builds communication between android applications and firebase databases that allows applications to retrieve MFCC images as the final result.
Result: The results of the tool trial on five volunteers, three exacerbation asthma patients and two healthy people showed the device can detect wheezing sounds at a frequency of 400Hz with 80% accuracy through CNN and MFCC algorithms Internet of things based.
Conclusion: This tool can help health workers to accurately determine wheezing sounds, enforce the diagnosis faster, the prognosis of the disease to be better, so as to reduce the number morbidity and mortality of diseases with airway abnormalities in Indonesia

Keywords: Wheezing, Detection, Internet of Things

INTRODUCTION

Wheezing or wheezing sounds are sounds that appear during expiration of the respiratory tract [1]. *Wheezing* is produced in the larynx until the bronchioles are distal during inspiration or expiration and can be heard through a stethoscope [2]. *Wheezing* is a sign that the lungs are unhealthy and can be detected through sinusoidal waves that appear continuously over a period of time. *Wheezing*, which has a characteristic high tone, occurs due to the narrowing of the airway which results in limited airflow [3]. According to *Computerized Respiratory Sound Analysis* (CORSA), *wheezing* is a sound that has a frequency between 100-1000Hz with a duration of more than 100ms by displaying a narrow band trajectory and peaks spectrum over time[4]. Some other studies say that the minimum duration of *wheezing* is usually between 80-100ms[5]. *Wheezing* is also commonly referred to as a musical sound with a variation of three harmonic frequencies. Usually this sound can be heard through a stethoscope at a frequency higher than 400Hz and a duration longer than 250ms. Meanwhile, normal breathing sounds themselves are usually in the frequency range of 60-1000Hz [6].

In establishing the diagnosis, it is necessary to carry out preliminary detection of listening to the sound of breathing with the technique of auscultation using a stethoscope. The use of a stethoscope in helping to establish the diagnosis has several disadvantages. Weaknesses such as the results obtained tend to be subjective, where the results of the diagnosis depend on the sensitivity of the doctor's hearing and the experience of the doctor himself [7]. In addition, the results of the sound obtained cannot be stored and listened to together with other doctors to be considered for the actual diagnosis[8].

Therefore, a technological innovation is needed by making a tool that will make it easier for health workers to detect wheezing sounds that are a marker of obstruction abnormalities in the channel breathing.

Previously, a breath sound sensor device using Normalized Spectral Integration (NSI) and integrated via Bluetooth was designed and developed [9]. However, this creation is different as it is designed using the Deep Learning for Audio Classification method to detect wheezing at certain frequencies and very long distances based on the Internet of things. It is believed that at the end of this study, a tool capable of assisting health workers in finding abnormalities in the airways is developed.

METHOD

This study was a collaborative work by the Electro department and Computer Science of Universitas Syiah Kuala. Following subsequent steps in design thinking, all collaborators teamed up to develop the best device application solution to detect the wheezing sound. Participants were patients with obstructive diseases such as asthma and COPD. This study aims to see the device's functionality so that it only uses three asthmatic patients and two healthy people. Study was conducted in four stages of design: hardware device design, program design, *android* application design and whole device assembly. In the context of developing application, design thinking is an analytical and imaginative method for resolving issues or meeting user wants. The specifics of programming flow gathered in Figure 1.

Hardware Device Design

This section consists of *a Jetson Nano* with a power input of 5V as *a microprocessor*, *head stethoscope* and electronic stethoscope. *The Jetson Nano* is connected to the *stethoscope head* using an *audio jack* as an inputting breathing sound and then it will be processed into the *Jetson Nano*. The display of the installation of the tool on the patient uses a chest belt that is flexible and easy for the patient to use so that it is not tight when used. (Figure 1)

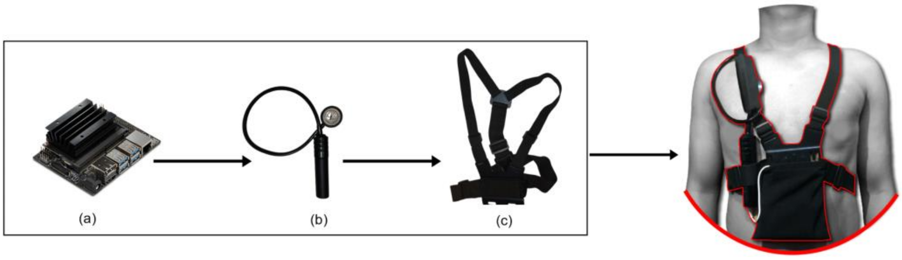

Figure 1. Hardware component design

Program Design

The creation of the program begins with collecting a dataset of human respiratory sounds that can be accessed through https://www.kaggle.com/, then the separation of normal breathing sounds with sounds indicated *wheezing.* After grouping the voices, the next step is to do voice processing using an algorithm with *a Convolutional Neural Network* then changed to *Mel Frequency Cepstral Coefficients* (MFCC). This model will be implanted in a *microprocessor* and use *python* language to be able to perform breathing sound recording. (Figure 2)

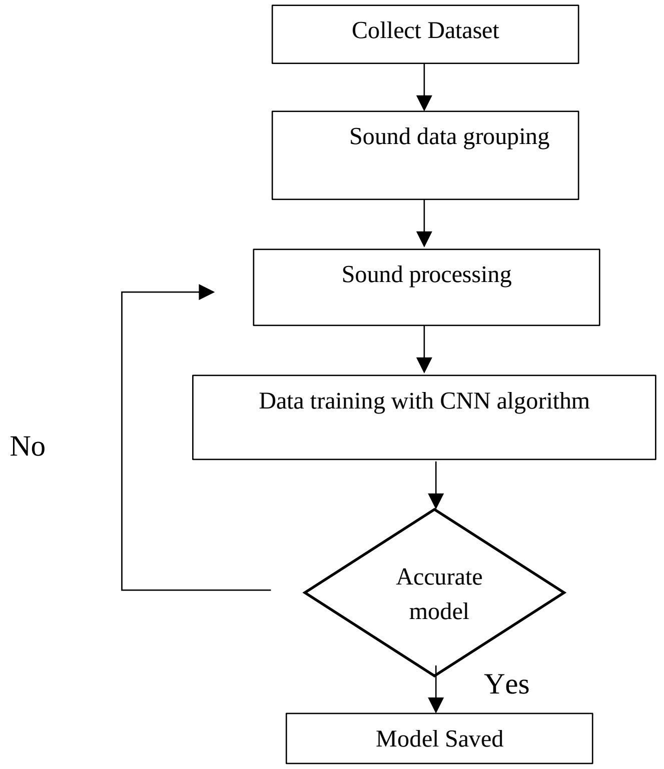

Figure 2. Programing Flow

The result of processing voice data in the form of MFCC already has the characteristic of sound extraction. The next step is to conduct data training using the CNN algorithm and the *pytorch* framework. *Training* data using Epoch as many as 200 and getting an accuracy result of 80% with a loss value of 0.1858. The result of this accuracy is able to detect wheezing sounds precisely. (Figure 3)

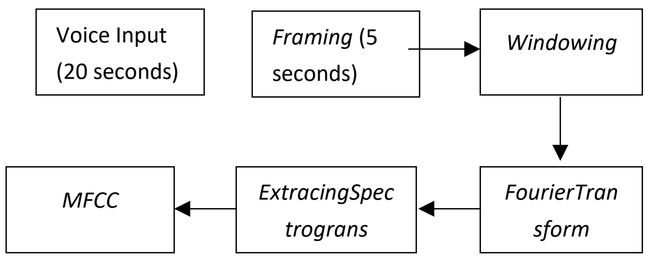

Figure 3. Voice Processing

***Android* Application design**

The application is designed by using the *User Centered Design* method so that users can run the tool and see directly the results of sound detection through an android-based application. App creation is built using *the Flutter* framework with the Dart programming language and continued with the creation of a *database* using *firebase* which is *real-time* so that the application can submit command to the tool to perform voice recording then detect and send the detection results to firebase database. Here's a diagram that describes the Overall Operation of the Device. (Figure 4)

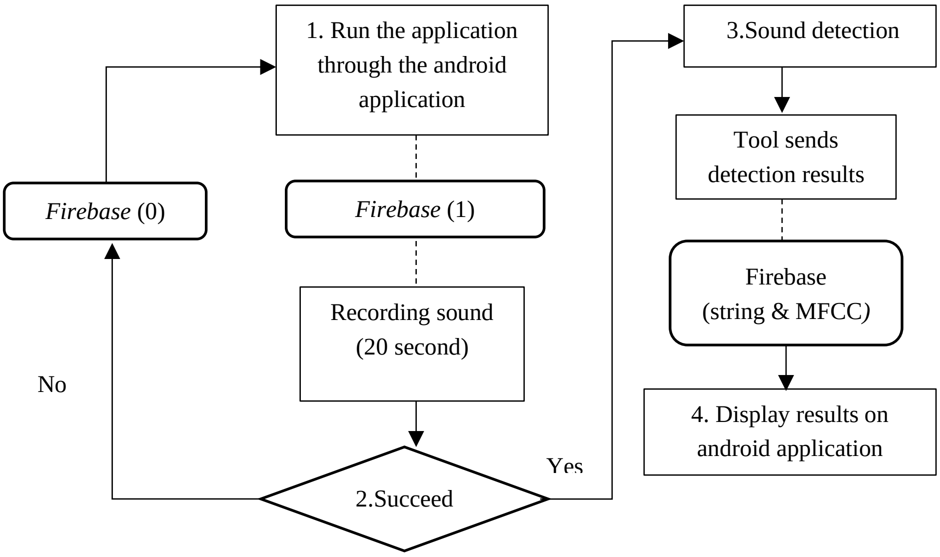

Figure 4. How the Device Works As a Whole

RESULT

After completion of the assembly, this detector tool was then tested on patients with airway abnormalities, namely in three asthma patients and two healthy people. The device is attached to the chest wall of an Asthma patient who is experiencing an exacerbation, as well as in normal people. The tool attached to the chest wall will record the sound on the chest wall and be sent to the application. The application will identify the recorded sound and will output the result of *wheezing* or not *wheezing* sound. From the results of the trial showed that the device can detect the presence of *wheezing* at a frequency of 400 Hz. The application will display a plot image *of Mel Frequency Cepstral Coefficients* (MFCC) created to analyze the sound of breathing so that it can help determine the diagnosis. This test was said to be successful because the device was able to detect wheezing sounds in five trials, namely three exacerbation asthma patients and two healthy people. (Figure 5)

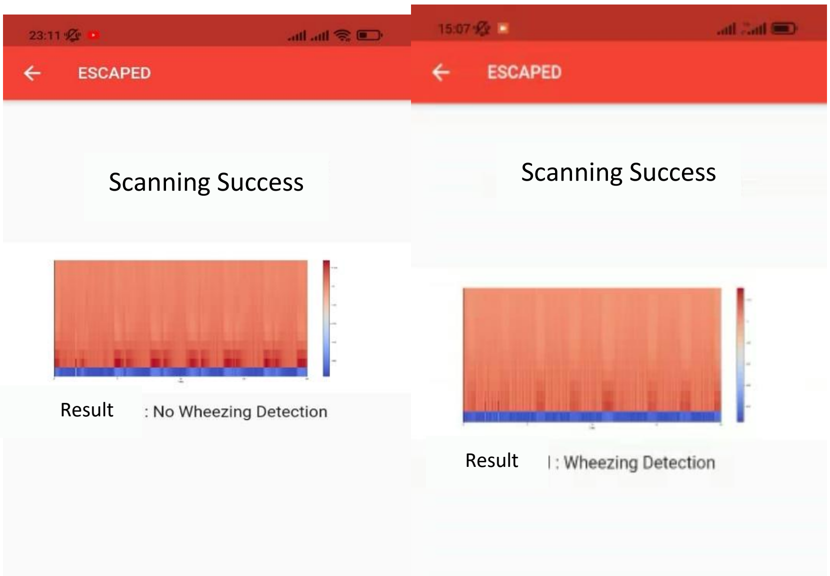

Figure 5. Spectrum *of wheezing* sounds and healthy breathing sounds

DISCUSSION

Wheezing sound is a type of musical sound that has the tone and appearance of sinusoidal waves continuously, resulting from oscillations of airway walls and vortex *shedding* in the airways central. Because the airways are obstructed, the incoming air flow will pass through the narrowed bronchi resulting in a change in the speed of the air flow, and the breathing sound becomes louder as well as the peak intensity of the greater power spectrum[10] of these studies found that *wheezing* sound characteristics have a higher peak frequency and intensity and are greater than normal breathing sounds (about 100 Hz-500 Hz). Similarly, wheezing sounds have a narrower *bandwidth* than normal breathing sounds. These results also correspond to the results of previous studies (more than 150 ms). [11.12].

It is commonly known that the quartile frequencies in the power of the wheezing sound spectrum contain peak frequencies that are above 150 Hz and at least three times higher than the base level, this is found through *Time Frequency Threshold-Dependent* (TFTD) algorithm for detecting *wheezing* sounds in *smartphones* [13]. Jin et al. proposes a time frequency decomposition method to obtain a noise-resistant time frequency contour and detect *wheezing* sounds under the background of noise [14]. Other studies used image processing methods to obtain an extract of *wheezing* sound time frequency features from spectral projection patterns of spectrograms [15.16].

Most of the methods in this study only provide simple information in the frequency domain, such as: peak frequency and median frequency. Using MFCC can provide good performance in detecting wheezing sounds, but still requires more computational complexity. Through the Flutter framework with the Dart programming language and the creation of a database using firebase which is *real-time* the application was able to obtain breathing sounds quickly in this study. In contrast to other methods, which require relatively longer raw data and more computational complexity, this study method shows an extract of time frequency features from easy short-term breathing sounds with lower computational complexity[17,18]. This study method proposes the implementation of wheezing detection easily and in real time on mobile phones or tablets commercially with a relatively low computing system. In addition, using mechanical design innovations based on the internet of things can produce a technological device that is more convenient and freely without being restricted time and distance are able to collect and find wheezing sounds precisely. However, this study suggests that subsequently this wheezing detection tool really needs to be developed to match the *dataset* with the population's respiratory voice data in Indonesia.

CONCLUSION

The device is capable of *detecting wheezing* sounds at a frequency of 400 Hz with the Internet of things-based CNN and MFCC algorithms with 80% accuracy. Therefore, it is hoped that this tool can help health workers to determine *wheezing* sounds accurately, establish the diagnosis of airway abnormalities faster, treatment patients are getting better, and in the end it is expected to improve the prognosis of the disease and reduce the morbidity and mortality rate of diseases with airway disorders in Indonesia.

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