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FUNDAMENTAL RESEARCH OF AN EARLY DETECTION SYSTEM TO FIND RESPIRATORY DISEASES FOR PIGS USING BODY-CONDUCTED SOUND

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Abstract. *Early detection of health issues is important in the management of group-housed livestock. This is especially true of respiratory disease in intensively housed pigs, which can cause death and loss of productivity. The purpose of this study was to establish an early detection system that detects the diseases based on respiratory and heart sounds extracted from body-conducted sounds to find respiratory diseases in pigs. As the first step of this conduction, the methods of biological signal collections and experiments to measure the respiratory and heart sounds from body-conducted sounds will be shown.*
Keywords: Body-conducted sound, Wireless recording system, MEMS microphone, Piezoelectric sensor, Respiratory and heart sounds of pig

1. **Introduction.** Early detection of health anomalies is an important issue in the management of group-housed livestock. Especially, regarding respiratory diseases, the issue causes death and loss of productivity, and they are particularly important for intensive pig farming. To minimize damage and loss caused by the diseases, it is necessary to develop technologies to collect and analyze the biological data of the pigs [1]. In previous studies, the diagnoses of respiratory illnesses have been attempted by assessing cough through sound monitoring using a microphone installed in a breeding house [2,3]. In this system, it is easy to make detection with the behavior of pig caused by respiratory diseases, however, when the number of pigs is large, it is difficult to specific individual judgment and the equipment becomes not only expensive but also susceptible to environmental noise. Breath sounds are important indicators of respiratory health and disease. Respiratory diseases usually cause lung disease. Acoustical monitoring of respiratory has been used by researchers for various diagnostic purposes. A few decades ago, physicians relied on their hearing to detect any symptomatic signs in respiratory sounds of their patients [4]. However, with the aid of computer technology and digital signal processing techniques in recent years, breath sound analysis has drawn much attention because of its diagnostic capabilities. Digital signal processing techniques have been widely used to derive characteristics features of the lung sounds for both diagnostic and assessment of treatment purposes [5].

Respiratory sound provides important information regarding the present condition of the lung. Auscultation is the skill of listening to the sounds in the body by using a stethoscope to diagnose abnormalities. Lung sound auscultation gives useful information for diagnosing abnormalities and disorders in the respiratory system [6]. As auscultation

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depends on the skill of the physician, it is subjected to false diagnosis by the untrained physician. Therefore, it requires a professionally well-trained physician to recognize the abnormalities exactly [7,8]. It is the same for the heart sound, using modern advanced artificial intelligence technology; we can train computers to become a well-trained physician to recognize the abnormalities exactly [9].

The purpose of this study was to establish an early detection system that detects the diseases based on respiratory and heart sounds extracted from body-conducted sounds to find respiratory diseases in pigs as shown in Figure 1. The system uses a piezoelectric sensor to record the body-conducted sound of the pigs wirelessly. For realizing the system, we discussed the pickup position of signal extraction with measured signals of respiratory sound. In this study, we aimed to detect and identify the respiratory disease in the early stages using body-conducted sounds of pigs. We employ an FM recording system to collect the body-conducted sounds of the pig. And an extraction method of body-conducted sounds and measurements of respiratory and heart sounds will be discussed on Section 3.2 and Section 3.3.

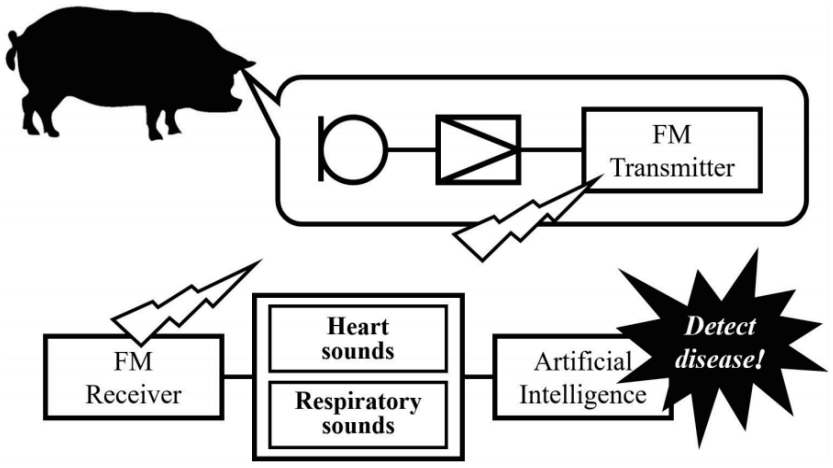


FIGURE 1. Overview of the system for pig's respiratory diseases using body-conducted sound

2. **Body-Conducted Sound of Pigs.**

2.1. **Wireless recording for body-conducted sound.** In the group-housed livestock, pigs walk around in the piggery, and it is difficult to record the biological signals in the usual way. It is necessary to collect biological signals, such as barks and action sounds of other pigs, for each individual pig separately in noisy environments [10,11]. This recording system is composed of a piezoelectric sensor, an FM transmitter, a Li-ion battery, FM receiver, and a data recorder. The system can wirelessly record the body-conducted sound using a piezoelectric sensor. Biological data is needed to individually observe and detect the pigs that are infected with diseases. There is also a lot of noise such as the grunts of other pigs in the sty. Therefore, we employed the body-conducted sound that is robust to noise. An accelerometer was once used to detect a body-conducted sound in humans [10]; however, the instrument is too expensive to use for pigs. The piezoelectric sensor is more affordable than the accelerometer. Moreover, we employed an FM communication system that enables us to ignore the effects of the movement of the pigs. Near Field Communication (NFC) was used to configure the FM transmitter and receiver within a frequency range of 76.0 to 108.0 MHz in 0.05 MHz steps, to yield 640 bands. The FM transmitter has a suitable size to the ear tags that are used for livestock identification. This makes it easy to introduce this system to farmers. The amplification factor can be

adjusted by 8 steps on the FM transmitter board. Since the frequency range of body-conducted sound is narrow around low-frequencies, the transmitter can emphasize low frequencies (below 100 Hz). The board can record using 2 channels while the amplification factor can be adjusted separately for each channel. Using the proposed system, we aim to extract respiratory and heart sounds from biological signals.

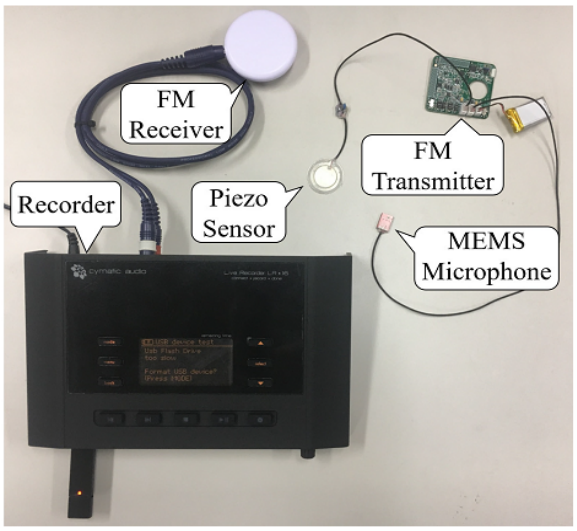


FIGURE 2. Transducers with FM transmitter for the system

2.2. **Respiratory disease determination system.** At the first attempt, the wirelessly recording system not only collected the body-conducted sound using a piezoelectric sensor installed on the skin of a healthy pig, but also wirelessly collected the airborne sound such as respiratory sound from mouth using MEMS (Micro-Electrical-Mechanical Systems) microphone. The MEMS microphone is quite small, does not burden the pig, and has a high acoustic characteristic compared with an ordinary microphone.

3. Detection of Respiratory and Heart Sound.

3.1. **Collection of biological signal.** To extract respiratory and heart sounds from pigs, the body-conducted sound and respiratory sound were recorded simultaneously with the wireless connection. As an experimental subject, a 10-week-old pig at the National Agriculture and Food Research Organization was supine after sedation and then placed on the transducers to the subject. Figure 3 shows the pig with one MEMS microphone as a normal microphone and three piezoelectric sensors. In this experiment, MEMS is used

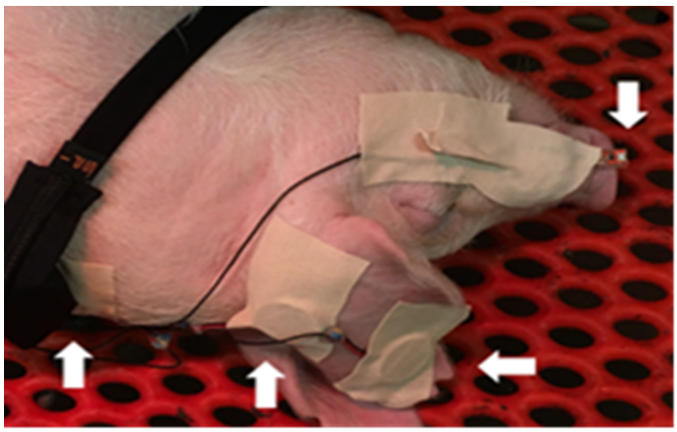
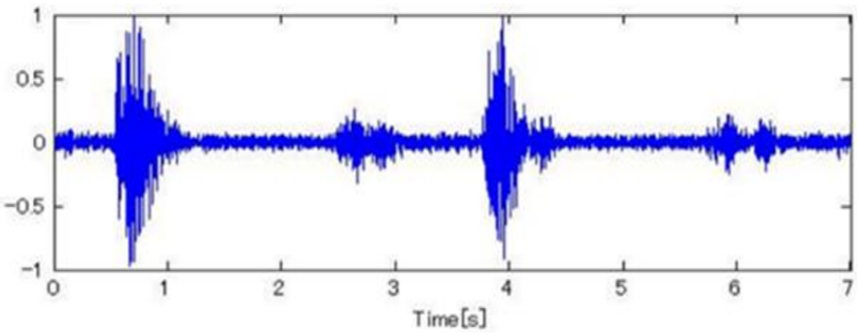


FIGURE 3. Each position of sensors

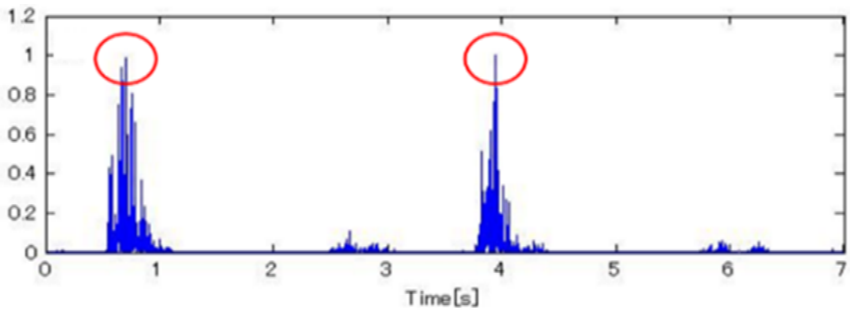
to confirm whether the piezoelectric sensor successfully recorded the biological signals. The respiratory sounds were collected from the MEMS microphone located on the nose of the pig, and the body-conducted sounds were measured from the piezoelectric sensors located on a tip of the ear, root of the ear, and near the cervical vertebra. For farm use, the microphone could be incorporated into an ear tag; usually the ear tag is installed at the tip of the ear if the recorded data from the tip of the ear is irreplaceable in this experiment, the location of the ear root set as a comparison is not used in future data analysis. In our proposal system, we anticipated that the biological signals of the pigs will be reviewed online, it is necessary to identify the optimal position on the pig to improve signal transmission. Sounds were recorded via wireless connection using a recorder (Cymatic Audio LR-16).

3.2. **Extraction of respiratory sound from body-conducted sound.** To detect respiratory disease in pigs, we expected a distinct difference in the characteristics of respiratory sounds between sick and healthy pigs [12]. These differences would include respiratory rate, and beats of breathing, as well as the intensity of the respiratory sounds of breathing. We hypothesized that by observing these respiratory characteristics, we can make an early diagnosis of respiratory disease.

Figure 4 shows the waveform and power of the sound recorded from the nose and Figure 5 shows the waveform and power of body-conducted sounds recorded from the tip of the ear. As Figure 4(b) shows, strong exhalation, and weak inspiration peaks are repeated. Moreover, in the red circle of the body-conducted sounds in Figure 5(b), a strong peak appears at the same time as the red circle in Figure 4(b). Compared with these points of circles, it was confirmed that respiratory sounds can be extracted from the data. And we can find these strong exhalations and weak inspiration peaks are repeated from the data from the root of the ear.

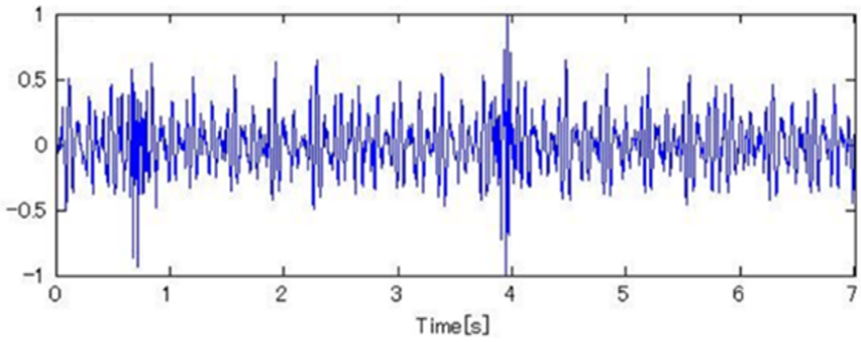


(a) Waveform

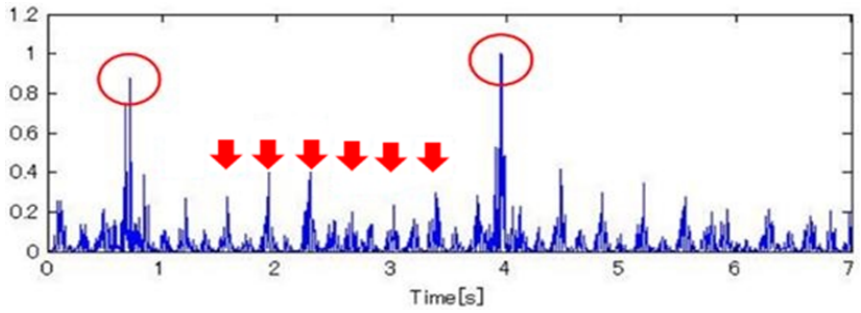


(b) Power

FIGURE 4. Sound from tip of nose

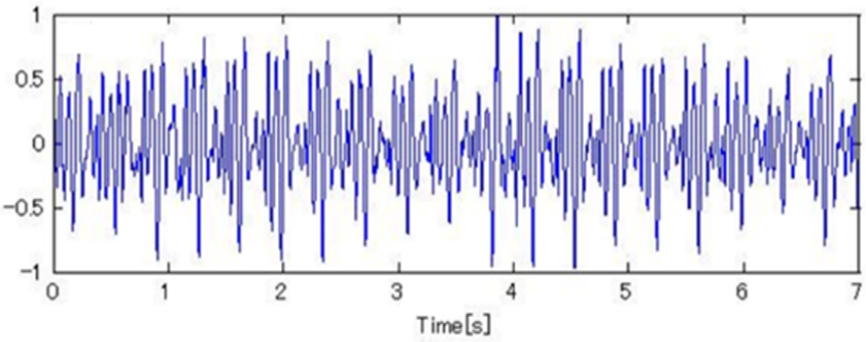


(a) Waveform

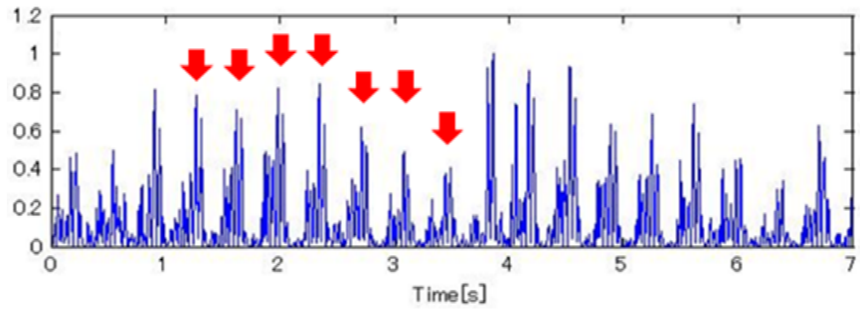


(b) Power

FIGURE 5. Body-conducted sound from tip of ear



(a) Waveform



(b) Power

FIGURE 6. Body-conducted sounds from cervical vertebrae

3.3. **Extraction of heart sound from body-conducted sound.** We hypothesized that irregular heart sounds would be identified in respiratory disease, causing a high mortality after the illness. After suffering from respiratory disease, it will result in systemic disease would be expected to alter cardiac function and heart sounds. These effects can

cause changes in the characteristics of the heart sound. Recording respiratory sounds and heart sounds by the device, and comparing the features of respiratory and heart sounds of pigs before and after disease, will improve the accuracy of early diagnosis of swine respiratory disease.

Figure 6 shows the waveform and power of body-conducted sounds recorded near the cervical vertebrae. The peak appearing in Figure 6(b) can be confirmed as a heart sound based on the time interval. As can be confirmed by the red arrows in Figure 5(b) and Figure 6(b), these peaks can be confirmed with synchronous intervals. It was shown the heart sounds can be extracted from body-conducted sounds collected from the tip of the pig's ear. Based on this result, we found the possibility to identify the heart sounds of a pig.

4. **Conclusions.** In this study, a wireless transmission was developed and respiratory and heart sounds were measured for early detection of pig respiratory diseases. Experimental results showed that body-conducted sounds can express respiratory and heart sounds. In addition, when comparing the signals collected from body-conducted sounds from other data, respiratory and heart sounds can be extracted from the body-conducted sounds from the tip of the ear. By being able to record sounds from the tip of the ear, we expect to make an integrated module installed on ear tags. Since changes in respiratory rate and heart rate are important parameters to identify diseases, it is expected to be utilized for the actual system.

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