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Defecation Prediction System Using Bowl Sound

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Abstract: Fecal incontinence is a serious but popular problem for elderly people since it not only degrades their quality of physical and mental life but also increases the work of care givers. One promising tool to solve this problem is a defecation prediction system since a patient can go to toilet if he/she knows the time of excretion in advance. Our approach to develop such a system is to measure bowel sounds (BSs) using a wearable device, to predict the defecation time, and to informs the user before defecation. As a first step to the development, in this paper, it is shown that BSs include information of the defecation time by classifying the BSs before/after defecation. The classification is possible by detect the change of the power in the spectrogram of the BSs.

Keywords: Defecation incontinence, Defecation prediction, Quality of life

1. Introduction

Although life expectancy continues to increase globally in developed countries, including Japan, there is a difference between life expectancy and a healthy life expectancy [1]. One of the major diseases in community-dwelling older adults is fecal incontinence. In fact, the reported median prevalence of fecal incontinence in [2] was 7.7% (range, 2.0%-20.7%), which increased with age (15-34 years, 5.7%; ¿90 years, 15.9%), and the reported prevalence of fecal incontinence in Japan in [3] was 8.7% in men and 6.6% in women. In addition, the multivariate analyses therein revealed that dementia and no participation in social activities were independent risk factors for both urinary and fecal incontinence. Thus, fecal incontinence is a serious problem for elderly people.

Although medical treatment for fecal incontinence has been studied intensively [4], non-medical treatment such as bowl habit and training is recommended as a first step [5].

As a non-medical treatment, defecation prediction is a promising tool for community-dwelling adults. An excretion-aid system that predict defecation can avoid fecal incontinence by noticing them the time of excretion in advance. It can also improve the quality of life of nursed people, who need to be treated for excretion, from not only the physical viewpoint but also the mental one.

Several attempts have been trying to develop such a system, however, none of them have succeeded. For example, Helppad system detects excretion using an odor sensor and reduces the uncomfortable time of the user [6] but it cannot predict excretion in advance. Prediction of excretion itself is possible by using ultrasonic sensors [7], however, the sensors must be located just on the intestine with stool, which is not realistic.

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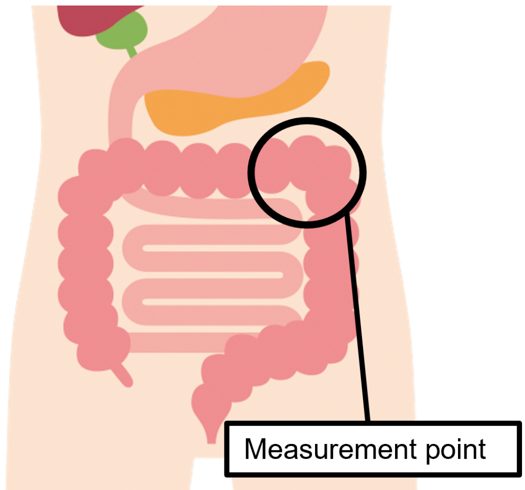


Fig. 1 Location of the stethoscope for data collection.

We tackle this problem using bowel sounds (BSs) since the sounds are easier to measure using wearable devices compared to the ultrasonic signals. BSs stem from the movement of gas or a mixture in the bowel lumen, with gas as the major component [8] and thus are used diagnosis of bowel diseases [9]. These facts imply that BSs include information of bowel status and that they are useful for a defecation prediction system.

As a first step to develop a defecation prediction system, in this paper, we show that the BSs include information of defecation, that is, the sounds before/after defecation are different, by making a classifier based on the spectrogram. By virtue of our result, we will develop a defecation prediction system using BSs in the future.

2. Materials and Methods

2.1 Bowel sounds

The BSs in our experiments were collected from one healthy male subject (50 y.o.) for 30 seconds, two hours after a meal and ten minutes after the corresponding defecation, three times for

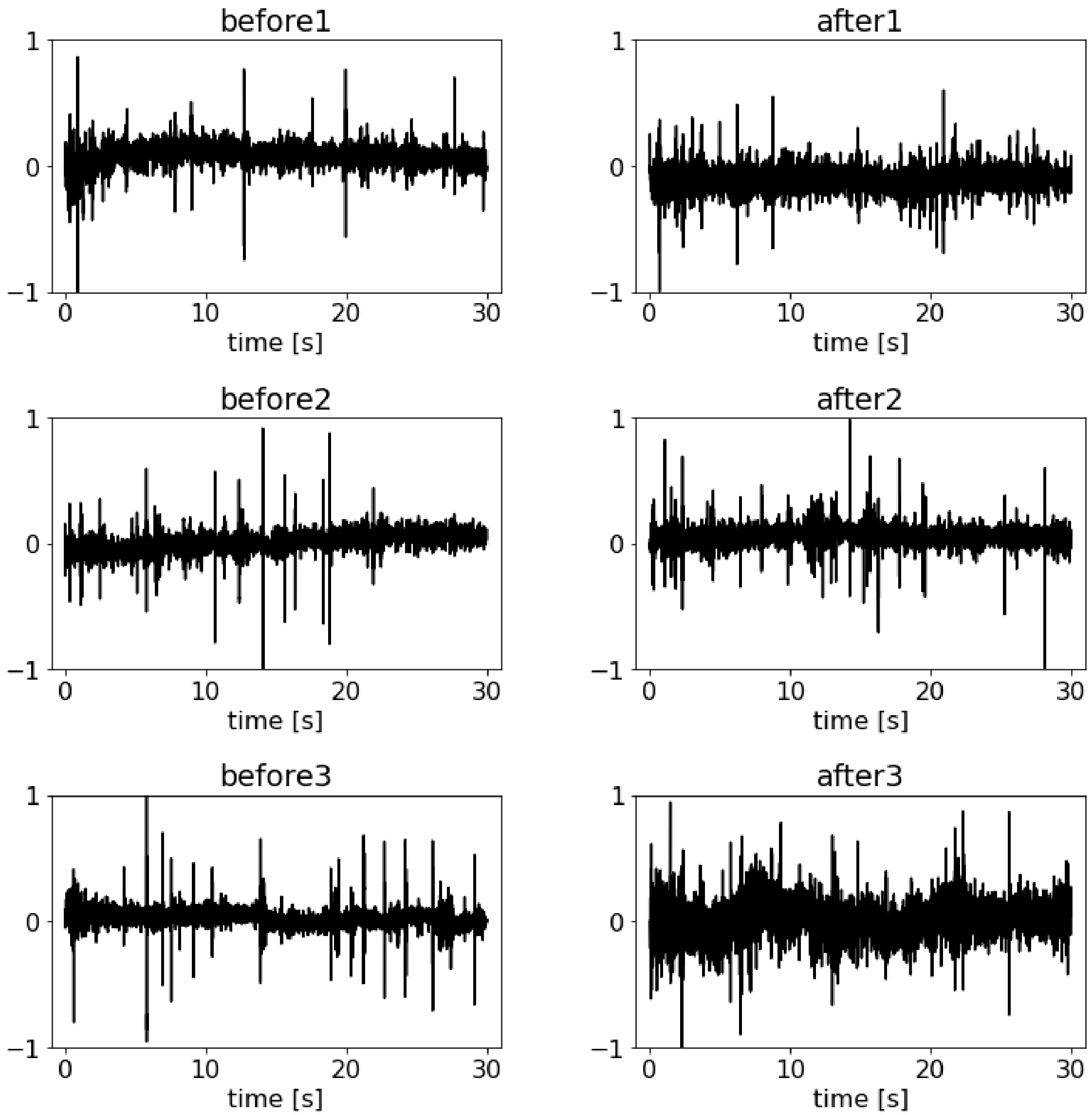


Fig. 2 Collected bowel sounds.

each, using an electronic stethoscope (3M Littmann Stethoscope Model 3200) with a control software (3M Littmann StethAssist Heart and Lung Sound Visualization Software). The electronic stethoscope was placed at the junction of the transverse and descending colons (Fig. 1).

2.2 Preprocessing

The collected bowl sounds were preprocessed using a band-pass filter (100 Hz–1 kHz) and short-time Fourier transform (STFT) with 10-msec sliding window of 100-msec window length. These parameters were determined so that 99.5 % of the signal energy is kept [10] and that each time-window includes at least one single burst or multiple burst [11].

2.3 Problem formulation

Our final goal is to develop a defecation prediction system. As a first step to the goal, in this paper, we made a classifier that discriminates the BSs before/after defecation.

3. Results

3.1 Bowel sounds collection

The BSs were properly collected using the electronic stethoscope (Fig. 2). The sounds were confirmed by a medical doctor (the second author) that they are surely bowl sounds from the medical viewpoint. In addition, they were confirmed to have single bursts and multiple bursts by their spectrogram, where wide-band signals were included (Fig. 3).

3.2 Power of bowel sounds

The spectrogram in Fig. 3 shows a difference of power of the BSs between before and after defecation. In fact, their distributions differ in the histogram of the power (Fig. 4a), which means that we can make a classifier by just thresholding the cumulative distribution of the power (Fig. 4b).

3.3 Performance of classifier

The simple classifier based on the cumulative distribution of

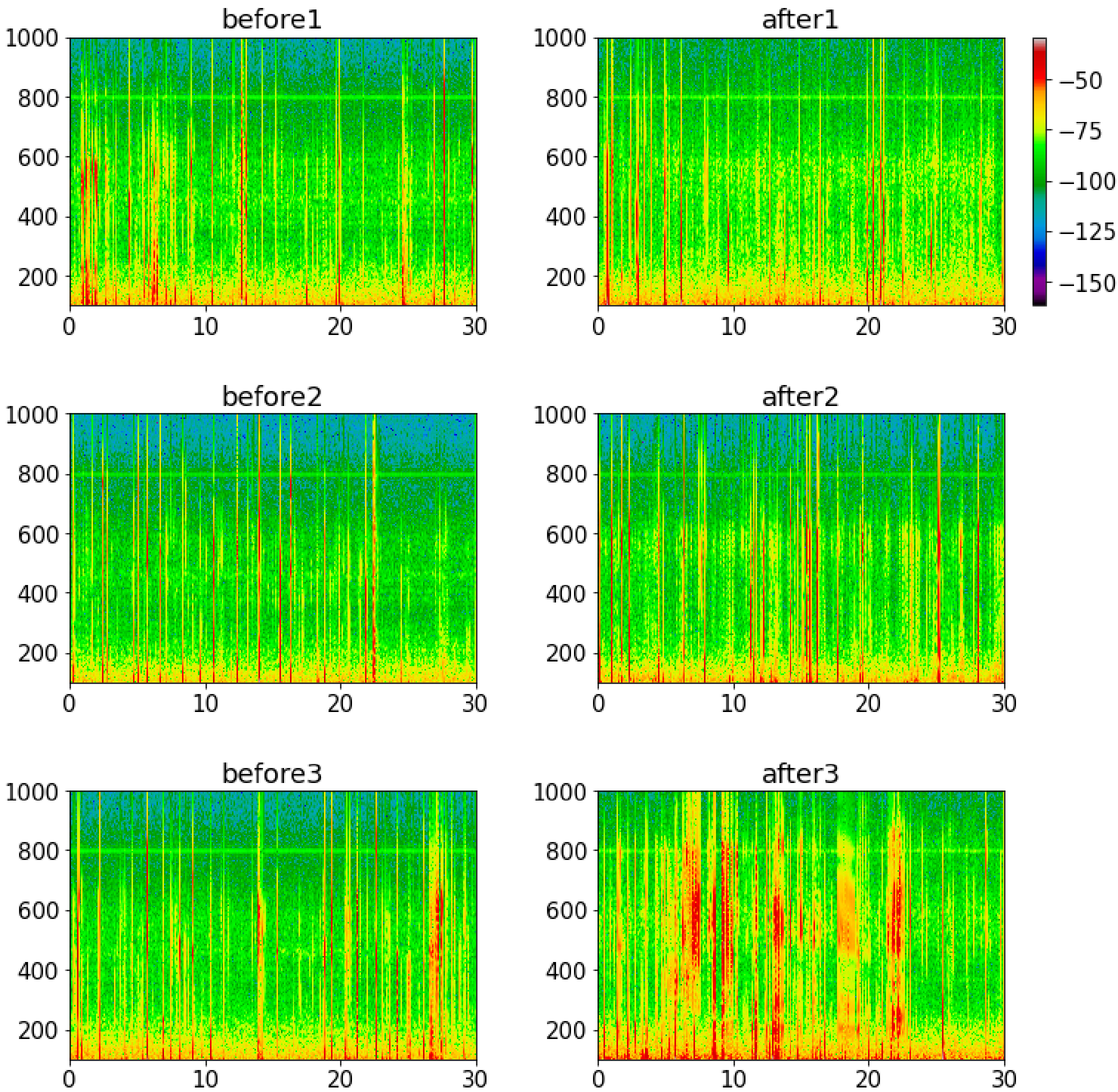


Fig. 3 Spectrogram of bowl sounds.

the power has two parameters, the time-window length L and the percentile p (the horizontal axis in Fig. 4b). To see the performance of the classifier, we calculated the AUC (Area under the curve) with each parameter set, where the curve means the ROC (Receiver Operating characteristic Curve).

As the results, the classifier has AUCs of more than 0.80, up to 0.974 when $L = 15$, if the percentile p is appropriately chosen (Fig. 5).

4. Discussion

We have succeeded to discriminate the bowel sounds before/after defecation using a simple classifier based on the power distribution as a first step to a defecation prediction system. In short, the power of BSs increases after defecation.

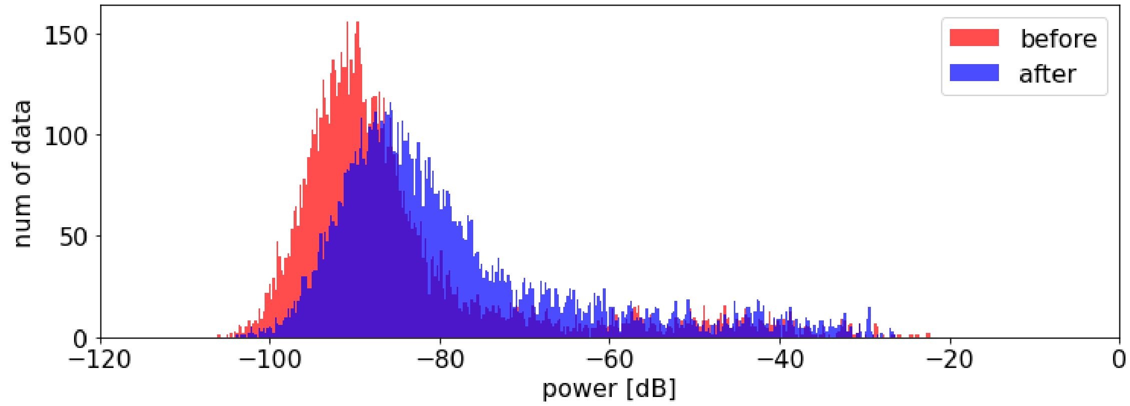
BSs are related to migrating motor complex (MMC), which is a regular cyclic activity of intestines during fasting and vanishes after eating [12]. Our result that the power of BSs increases after defecation is consistent with the knowledge if we can regard defecation as a kind of fasting since the intestine gets empty.

One of the next steps is to extend the classifier to the predictor. This will not be a difficult task if we can collect bowel sounds continuously. For example, we can apply the sequential Bayesian inference technique to the prediction problem, as was done for cell division prediction [13], since the task is not to show when defecation occurs but to alert the user five minutes before defecation.

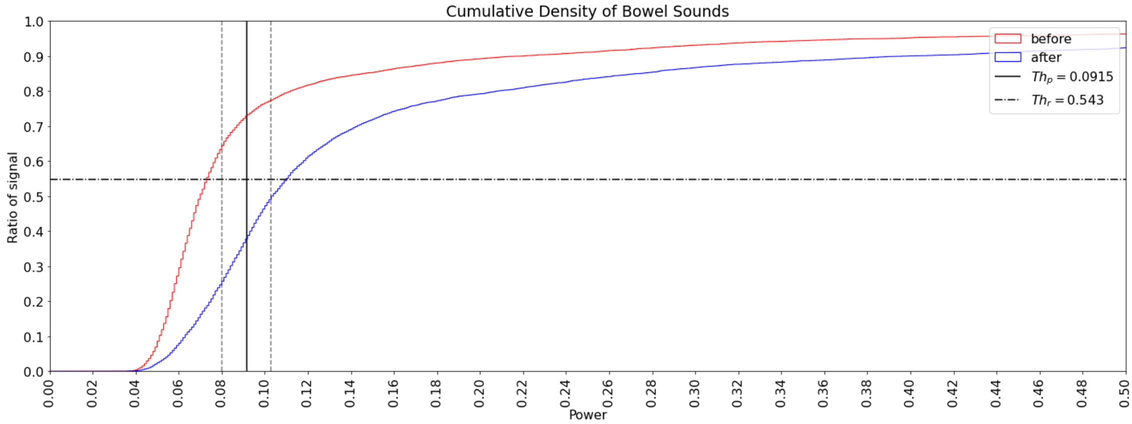
Another step is to develop a wearable device. Fortunately, this is promising since bowel sounds are rather easy to collect [12], [14] compared to ultrasonic imaging although ultrasonic imaging techniques have also been developed [15].

5. Concluding Remarks

As a first step to developing a defecation prediction system using a wearable device, we confirmed that bowel sounds include the information on defecation by constructing a classifier that discriminate the bowel sounds before/after defecation. The bowel sounds before/after defecation have different power distributions and thus the simple thresholding method of the cumulative distributions classified them with the AUC of up to 0.974 when the time-window length and the percentile were appropriately cho-



a) Histogram of the BS power before/after defecation.



b) Cummurative histogram of the powers.

Fig. 4 Histogram of bowl-sound power.

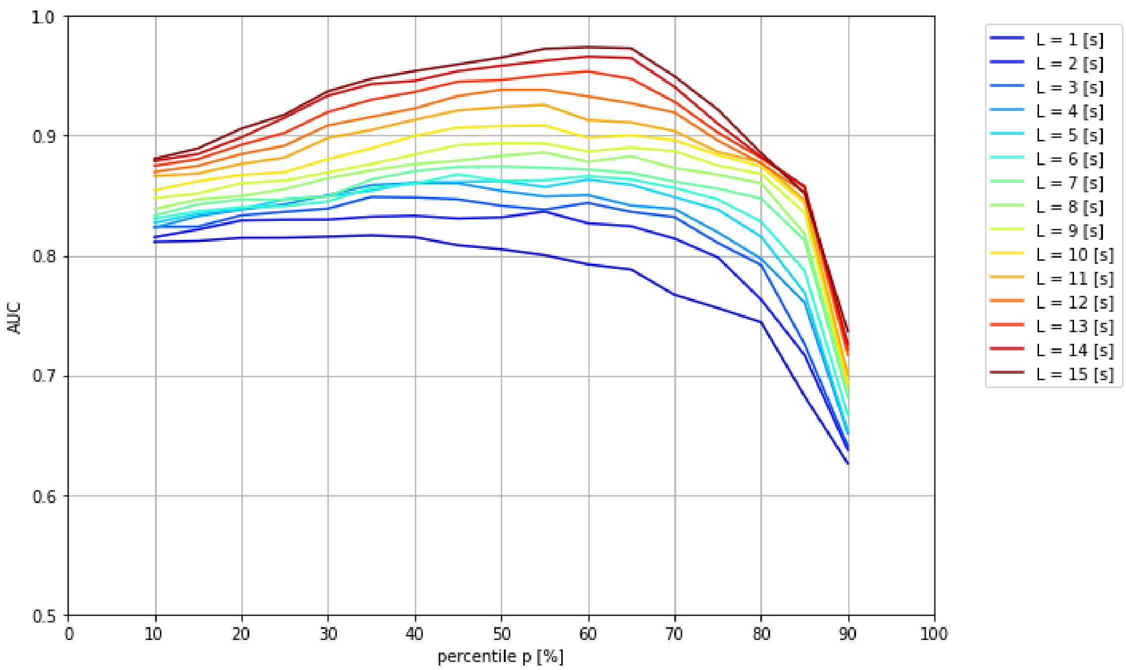


Fig. 5 AUC scores of the thresholding of the power.

sen. The results suggest the possibility of constructing a defecation prediction system using bowel sounds.

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