# Optimum Unit Time on Calculating Occurrence Frequency of Bowel Sounds for Real-Time Monitoring of Bowel Peristalsis

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***Abstract*—Long-Term and real-time bowel sound recording/analysis is useful for monitoring activity of bowel peristalsis clinically and industrially. We have studied its application with food design, nutrition management, dietary therapy, critical care and so on in mind. Therefore, we built a BS measurement/analysis system including development of the dedicated sensor for BS and the abdomen audible signal processing method. Although we got some useful knowledge as the result, the matter to consider is still left behind. We had carried out evaluation of peristaltic activity of an intestine, focusing on change of the number of bowel sounds generating per unit time. However we have not examined the optimal length of this unit time yet. Here, based on an easy experimental examination, we report that the optimal unit time length for calculating occurrence frequency of bowel sounds is estimated as one to two minutes.**

***Index Terms*—unit time, bowel sound, occurrence frequency, real-time monitoring**

## I. Introduction

Bowel Sound (BS) is a biological audio signal, stemming from peristaltic activity of an intestine. BS is widely used in medical examinations now. We aim to utilize BS for food design, nutrition management, dietary therapy, and critical care. We have investigated a new method for recording/analyzing bowel sounds based on a new concept, and have developed new equipment suitable for our objectives [1]-[5]. It is a real-time system for recording/analyzing bowel sounds with multi-channel electrical stethoscope. This system can record bowel sounds detecting them by digital signal processing for long time and analyze the BS as soon as the data is recorded. Although there are some researches on long-term bowel sound monitoring [6]-[10], our concept is different from other group's studies. We focus on especially temporal change of occurrence frequency of bowel sounds; that is, transition of the number of bowel sounds generated in a unit time. We believe that it represents the degree of peristalsis activity of a bowel.

Although the core technologies of measurement and analysis of BS were mostly established so far, some required considerations concerning them still remain. One of them is the determination of the unit time length for calculating frequency of generating BS. In our previous researches, although the unit time length of calculating frequency of generating BS has been set as 4 minutes or 1 minute, there is no basis on these numbers. Since clinical trials to accumulate BS data are recently being carried out, consideration on unit time length for calculating occurrence frequency of bowel sounds is needed.

So, in this report, we considered how long the unit time is suitable for calculating frequency of generating BS by sample experiments.

## II. Method of Measurement and Analysis

The long-term bowel sound measurement/analysis system consists of a multi-channel sound sensor sited on an abdominal surface, a data logger (amplifier and A/D-converter), and a PC for recording and analysis. The analytical method of recorded bowel sound data is same as the procedure adopted in the precedent study [1], [3], [4] and is shown in Fig. 1. This is composed of a time frequency analysis by pattern matching and a thresholding. A few templates which are power spectra are used in the pattern matching, which we call standard bowel sound spectra. The outline of bowel sound processing in this study is as follows, which is the same procedure of our previous study [11].

First, abdominal sound signals detected simultaneously by multiple microphones were recorded on the hard disk drive of the personal computer via the data logger.

Next, template matching was performed with these 4 spectrograms, and then the cross-correlation functions of these spectrograms were obtained. The templates of bowel sound power spectrum were obtained by collecting signals that were considered characteristic bowel sounds according to the human ear with a signal length of 0.5 seconds and by determining the average shape of these power spectral density functions. Two types of bowel sound power spectra were identified, and the template-matching process was performed separately on each type.

Template matching for each template produced 4 cross-correlation functions. Since we performed template matching using 2 templates, a total of 8 cross-correlation functions were obtained. This was a variable condition depending on the number of sensors and templates, and we used 4 sensors and 2 templates.

Manuscript received August 15, 2015; accepted May 5, 2016.


doi: 10.18178/ijsps.4.6.465-468

A new sequence with maximum values selected from the 8 cross-correlation functions was then created for each time point and designated as the bowel sound frequency function.

Finally, an appropriate threshold value was determined, and the times when this threshold value of the bowel sound frequency function was exceeded and the duration of the sounds were recorded. The threshold used in this study was a stethoscope-audible threshold. The stethoscope-audible threshold was defined as the lowest intensity sound that could be detected by a trained professional using a stethoscope.

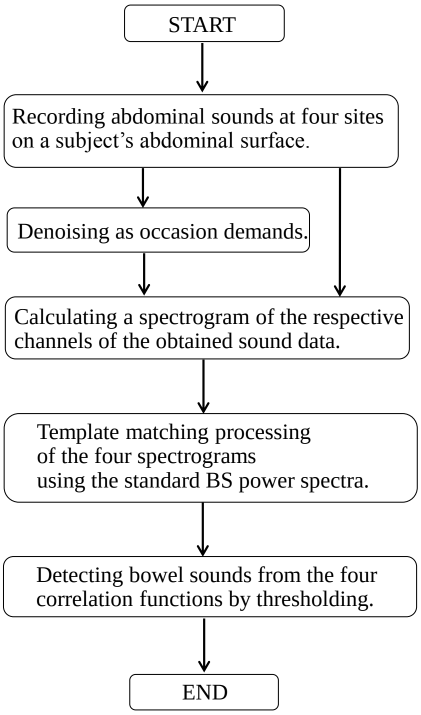


Figure 1. Procedure of BS detection.

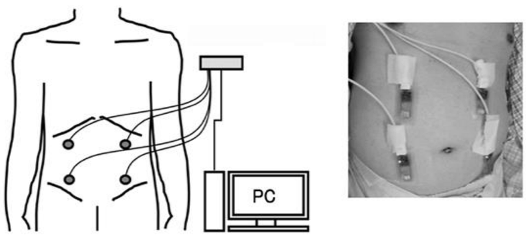


Figure 2. An example of occurrence frequency of bowel sounds.

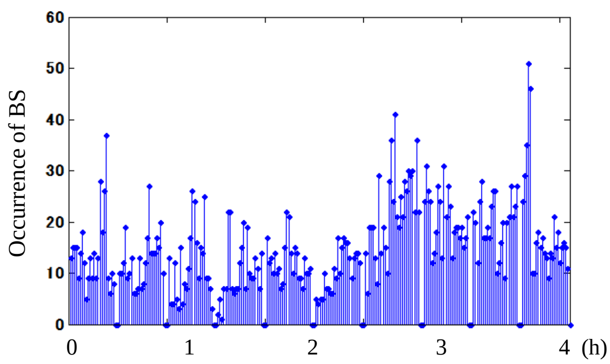


Figure 3. An example of occurrence frequency of bowel sounds.

Moreover, Fig. 2 shows the arrangement of bowel sound sensors on an abdominal surface and an example of transition of bowel sound occurrence is shown in Fig. 3 (a healthy adult subject). Fig. 3 represents that the number of bowel sound per one minute varies with time. In addition, detection time resolution was set to 0.032 s in the BS detection process carried out by this research. This value corresponds to a shift amount of the analytical time window in the pattern matching processing in Fig. 1.

## III. Experimental

Bowel sound measurements around 6 hours long were carried out several times using four 24 years-old healthy male subjects. We started to record bowel sounds after two or three hours of the subject's dinner, which was his ordinary dinner menu. The subject was maintained own supine position at rest during the recording. The method for bowel sound detection is shown as Fig. 1, which was proposed in our previous researches.

New time series of interval of the bowel sound occurrences, histograms of the intervals, and power spectra of the ones were calculated.

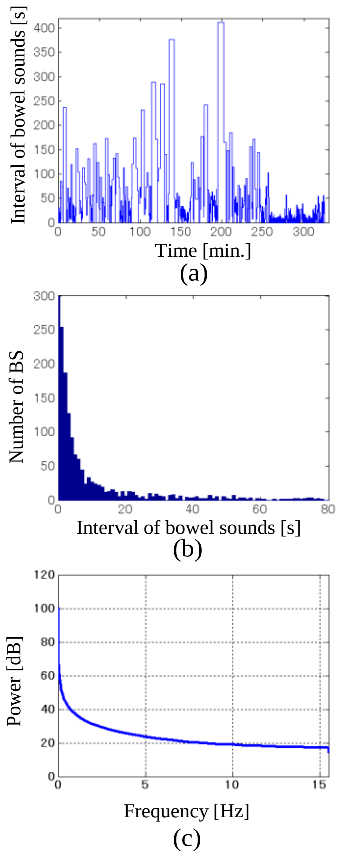


Figure 4. Result of BS analysis (Subject 1). (a) The interval time between occurrences of bowel sounds, (b) the histogram of the interval time, (c) the power spectrum of the interval time.

## IV. Results and Discussions

The results are represented in Fig. 3 to Fig. 6. The interval time between occurrences of bowel sounds is plotted as graph (a) in Fig. 4 to Fig. 7. Each graph (b) and

(c) in Fig. 4 to Fig. 7 show the histogram of the interval time and the power spectrum of the interval time, respectively.

According to our previous works, in the case that a bowel has no disorder, distances between the bowel sounds are probably within a few minutes at the longest regardless of whether the subject is a normal or a serious case. In addition, we know that the bowel sounds of subjects even in their fasting period are always generated [11]. In long-term measurements of bowel sounds, often we can't stably record bowel sounds due to mainly the subject's body movements. There is a possibility that a part of the bowel sound data dealt with in this article was not recorded correctly, in which intervals of bowel sounds were more than several minutes.

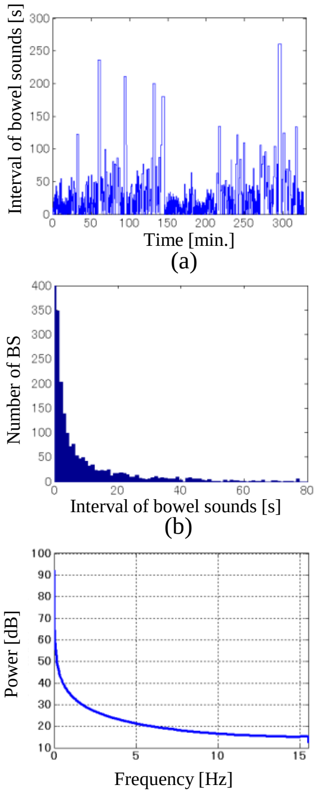


Figure 5. Result of BS analysis (Subject 2). (a) The interval time between occurrences of bowel sounds, (b) the histogram of the interval time, (c) the power spectrum of the interval time.

Also as to the data treated in this paper, measuring or detecting BS might have been unable to perform normally in data sections where BS occurrence intervals beyond some minutes are included. Taking that into consideration, there is probably no meaning in the generating interval of bowel sounds exceeding 60 to 100 seconds.

Seeing Fig. 4-Fig. 7(b) from such a viewpoint, we notice that almost all bowel sounds are included within the range of the BS occurrence interval of 60 to 80 seconds. Incidentally, we also checked that the same tendency can be observed about other several healthy subjects. Therefore, we estimate that that the optimal unit time length for calculating occurrence frequency of bowel sounds is estimated as one to two minutes.

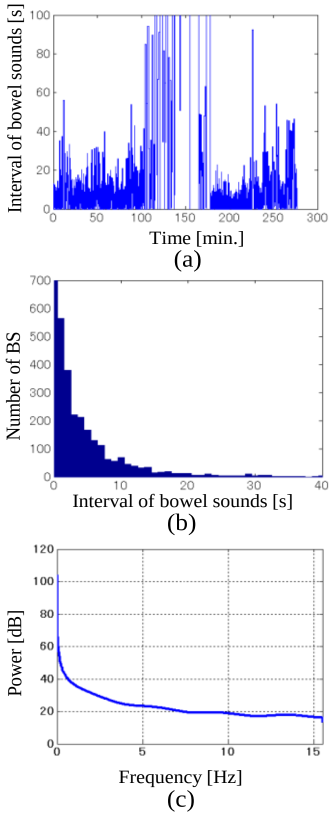


Figure 6. Result of BS analysis (Subject 3). (a) The interval time between occurrences of bowel sounds, (b) the histogram of the interval time, (c) the power spectrum of the interval time.

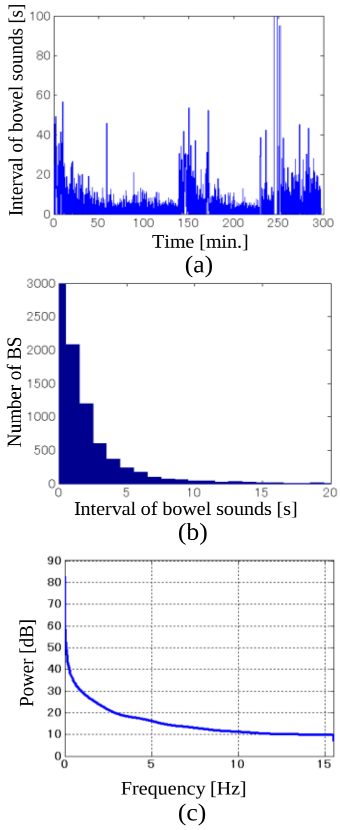


Figure 7. Result of BS analysis (Subject 4). (a) The interval time between occurrences of bowel sounds, (b) the histogram of the interval time, (c) the power spectrum of the interval time.

On the other hand, in Fig. 4-Fig. 7(c), the shape of the curves are similar and show that the main frequency components of fluctuation of the generation interval of BS are very low, that is, this represents the generation interval of BS is stable.

Therefore, we assume that the unit time should be one to two minutes without the overlapping analytical windows. This is a practical number which allows us real-time operation, even when the system is constituted from a low spec data logger and PC.

## V. Conclusion

We considered a proper unit time for calculating the occurrence frequency of bowel sounds based on some normal subjects' bowel sound data recorded by long-term measurement. As a result, we concluded that the proper unit time is approximately one or two minutes.

## Acknowledgment

This work was supported by Grand-in-Aid for Scientific Research (B) 25280098, Japan.

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