NON-INVASIVE MULTI-CHANNELS BOWEL SOUND MEASUREMENT SYSTEM IN DIAGNOSIS OF GUT FUNCTION

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Abstract - Abdominal auscultation is a simple and noninvasive way to provide clinical diagnosis for gastrointestinal disease. However, auscultation of bowel sound needs patience and time consuming work for a doctor. The previous bowel sound measurement system only measured one channel data of bowel sound and this data is not enough to diagnose the entire intestinal tract. Therefore, it is necessary to develop a multi-channel bowel sound detection system for recording the entire gut and for comparing bowel sound signal in every different position.

We have developed a two dimensional bowel sound measurement system. We use microphone array to measure bowel sounds at the same time. We make display the multi-channel signals in a window on real time, and the analog signal could be transform to frequency domain to inspect their power spectral distribution. We use "Delay-and-Sum Beam forming" and "Cross-Correlation Based" array signal algorithms (4) that can clearly distinguish the position of the bowel sounds and enhance the bowel sound signals. The collected data will assist doctor to make the diagnosis of bowel peristaltic conditions.

In the preliminary results, we can detect the transmit time of bowel sound in the large intestine, and provide the frequency features of bowel sound. These information can be used to functional gut diseases such as irritable bowel syndrome and dyspepsia.

Introduction

The traditional bowel sound measurement methods usually measure one location for every detection, like the use of stethoscope to detect heart sound. The common detecting position is always on the pylorus or the ileo-cecal valve because these two positions have velve and their physiology structures are different. When chime pass through the valve, sound is being produced. Because this sound come from one position, its information is local, so using this signal cannot provide significant information of the digestive system.

The normal bowel peristalsis is a gurgling sound. It happens every five to fifteen seconds. Each time the bowel sound can last for several seconds or less then one second. The creation of the bowel sound mainly by the air and the liquid as the bowel wriggles pass through the bowel path. The phonation rate of the bowel sound is related with the swollen food inside the bowel way and the degree of the food digested.

In clinical diagnosis for the bowel sound, the criterion is to classify detection result into two groups: one is an absence of bowel sound and the other is a borborygmus. Absence of bowel sound is defined as for over one minutes, there is no any sound detected and the detecting time must be over five minutes. In absence of bowel sound the disease types may be peritonitis, enteritis, the last phase of the bowel jams or after belly surgical operation. The bowel sound acceleration may be related to gastroenteritis. But if it has the high frequency sound, then we may doubt for early bowel jams. For bowel jams, the bowel sound usually sound like horselaugh, sometimes we also can hear "Succussion splash "or the voice that sound like the water pours out from the polyfoam.

Bowel sound research is not common. Most the detecting methods explore one site one time and it cannot get so many useful information and it need a long time to measure. Thus the detecting method is seldom use in clinical diagnosis. Dr.Brian L. Craine [1][2][3] did a series of research in bowel sound. For the first two year of his research, he focus on time series analysis and frequency power distribute. He build a S-S (sound-sound interval) index for IBS(Irritable Bowel Syndrome) and Crohn's Disease. In 2002 Dr.Brian explores three sites at the same time and accumulate their sound power to building a two dimensional positional mapping of gastrointestinal sounds in control and functional bowel syndrome patients. Thought they used two dimension concept, they only know knowledge about sound power changes. They do not investigate correlation between the sites, and not use the multi-sites information to do any signal enhancement or analysis.

In our proposal, we try to develop a bowel sound measurement system to evaluate the digestive system

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active situation. We use microphone array to get the two dimension information of the digestive system. With this information we hope to define some factors or use two dimensional mapping image to evaluate the digestive system's active situation. From the two dimension sound power distributed field, we can use the intestinal peristalsis to known the intestinal obstruction position or evaluate the functional disease for digestive system, having peritonitis, intestinal, acute abdomen and Irritable bowel syndrome. We can use the detection system to localize the approximate disorder position and help the clinical doctor quickly and effectively to locate the pathological change position. In the preliminary results, we can find the bowel sound transmits time in the large intestine, and assure the frequency features of the bowel sound..

Materials and Methods

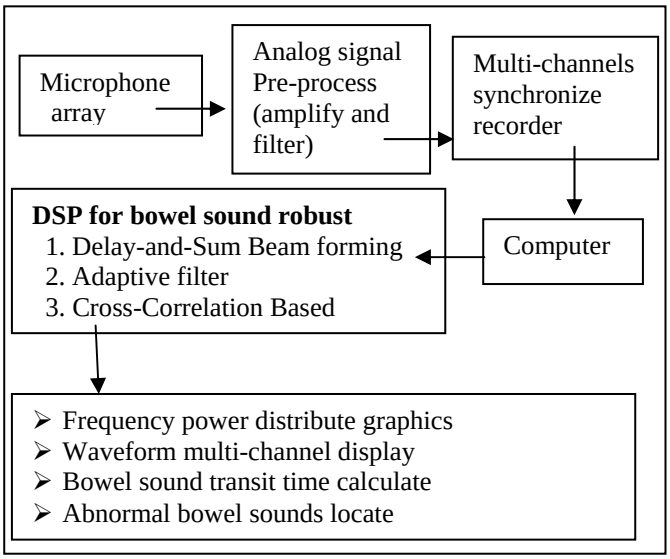

Figure 1: Bowel sound detection system

The system framework is show in figure 1. The entire system includes a analog circuit, a digital circuit, analog to digital converter circuit and an IMC recorder interface device. Using the IMC recorder we transmit digital bowel sound data to the computer, save it and display.

Bowel sound detect system

The detection system includes a hardware system and a software system. The hardware systems include the microphone array sensors and analog signal process circuit and digital signal processor recorder. Research in recent years on the microphone array technique has been using in speech recognition; the method provides a good quality on sound robustness and location. [4] Thus we use few microphone array techniques to process our bowel sounds in DSP algorithms. We use adaptive filter to get clean bowel and use Delay-and-Sum Beamforming and Cross-Correlation Based methods to locate bowel sound position.

The analog signal circuit include an amplifier and a bandpass filter. The original sound signals have to pass the filter circuit to get a clean bowel sound, because in our body there are other sound noises (like heart sound , lung sound, blood flow murmur sound etc.) . In some researches reports[5][6] the bowel sound frequency response is between 300Hz to 800Hz. Thus we design a bandpass filter with frequency response between 100Hz to 1000Hz to cover the bowel sound signal.

As the bowel sound signal is small, in order to observe the wave on monitor or be analysis we need to amplifier it. The signal is micro-volt level so the amplifier will promote it to volt level.

The digital signal recorder SPARTAN is producted by Gemern Company IMC. It is an affordable, multi-channel compact measuring system specially designed to optimize potential-isolated measurement of voltage and temperature. With a sampling rate of up to 10kHz per channel, even highly dynamic processes can be recorded at 16-bit resolution. The combination of 32-bit signal processors and the operating and displaying software enables a real leap in the ability to define real-time functions. Any number of channels can be jointly subjected to computational operations in the scope of real-time analysis.

The DSP software system used is FAMOS 4.0, developed by IMC. Their function for data reduction is in real-time, digital filters. User-defined system responses to specified states are also entered explicitly into the Formula Editor, or parameterized with the help of the Function Assistant's guidance, which makes the procedure as easy as using a pocket calculator. The functions available include basic arithmetic and other basic mathematical operations, trigonometric functions; certain set functions such as power and FFT; and personally defined digital filters.

Detection method

We divide the abdominal surface into 9 regions(see Fig.2): left hypochondriac LH ,left lumbar LL ,left iliac LI ,epigastric E ,umbilical U ,hypogastric H ,
right hypochondriac RH ,right lumbar RL ,right iliac RI,The two horizontal planes are the transpyloric plane TPP and the transtubercular plane TTP. The tubercles are the tubercles of the iliac crests.

Sound were recorded simultaneously from electronic stethoscopes held in these positions , the select positions (see Figure 2) are RI, RH, E, LH, LI and U .We select these positions because when there are some changes on anatomy and these structures can easily produce bowel sound.

According to the Mika Yuki's suggestion[5] for date to be of statistical value, the recording time need to be over two minutes, thus every detected channel in our recording time is 200 seconds.

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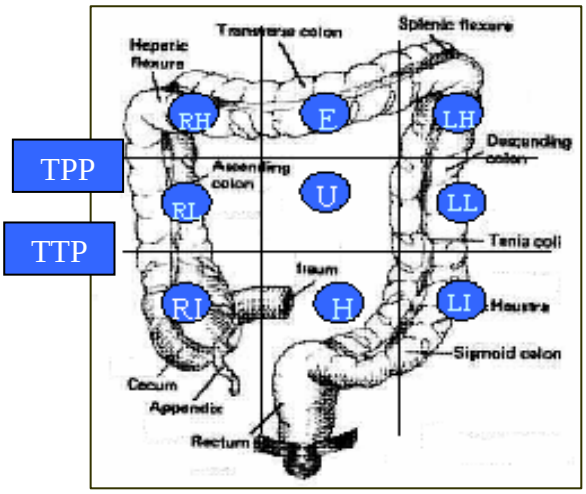

Figure 2: 9 regions of abdominal surface

Results

First we detect a single point bowel sound to calibrate and certificate for our system. Six healthy young men were conducted in our bowel sound measurement, their average age is 25 years old . In figure 3 we can find the bowel sound waveform in time domain (above the figure left). The spectral power in frequency domain is mainly distributed between 150Hz and 500Hz (below the figure left and whit part). These results are the same as related cultural conclusion.

In Figure 4, we detect bowel sounds using three channels and display them at the same time. We can find transit time of the bowel sound on different abdominal positions. Between the RI (Right Lumbar) and E (Epigastria), the transit time is about 60 seconds. Between E and LI (Left Lumbar) its transit time is about 40 seconds.

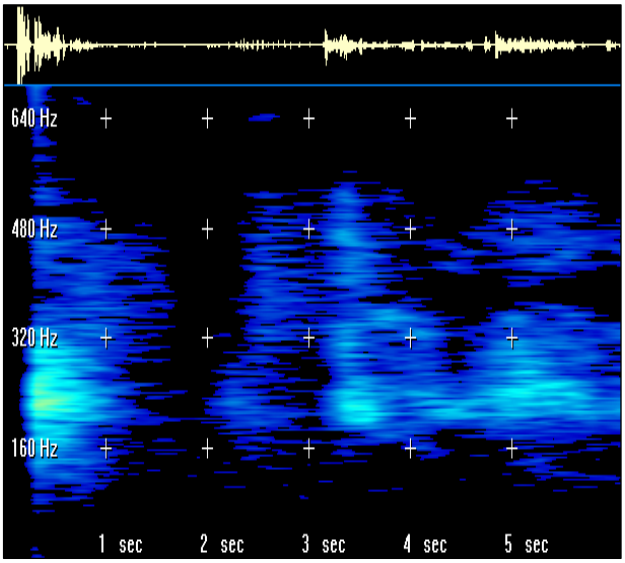

Figure 3: bowel sound waveform in time domain and Spectral power in frequency domain

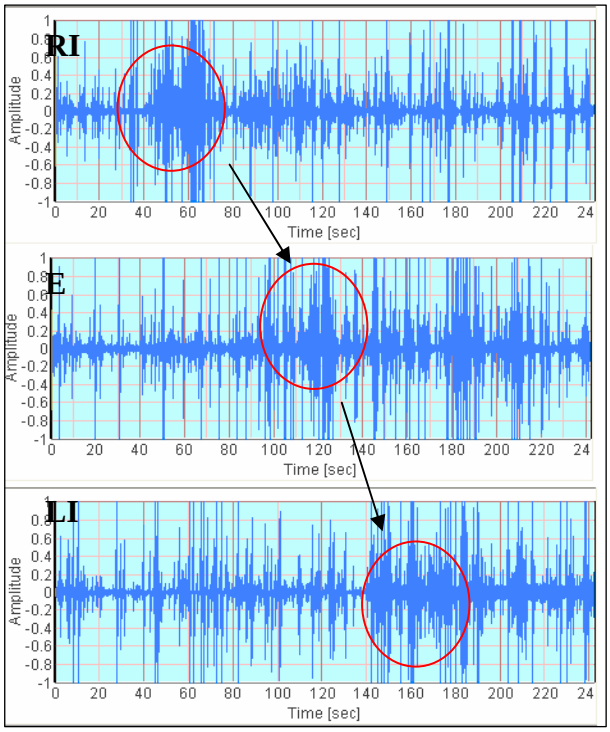

Figure 4: RI,E,LI three points bowel sound waveforms were detected in same time

Discussion

From the result we find that the bowel sound is not a regular pattern. We also need the serious doctor's experiences to hear the sound and confirm it. Thought it is irregular, it also have some unique voiceprint. Using pattern recognition in large the data set, we can use them to set up system an expert system and provide an auto recognition.

Another important result is that we can use multi-channel system to observe bowel sound transiting track and find some information about the intestinal peristalsis. We can use the information to evaluate the digestive system activity.(from the numbers of bowel sound) and find the block position of intestinal obstruction (from the bowel sound disappear detect site).

Conclusions

In future we will select specific symptom like IBS (Irritable bowel syndrome) or intestinal obstruction or dyspepsia to find useful information for digestion system diagnosis. Besides, we will redesign the sensor devices, because they can easily product a lot of noise if sensors and abdominal surface are not close together.

When our lives are wealthier, appetite diseases may also increase immediately. Our final goal is to provide a

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home care device to help people living a good life and we believe the multi-channels bowel sound measurement system will help doctor or related researcher to be more understandable our digestive system.

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