TEXAS A&M UNIVERSITY

ELECTRICAL & COMPUTER ENGINEERING

BOWEL SOUND ESTIMATION METHODS

Ayca AYGUN

UIN: 626008308

INSTRUCTOR: Prof. Jean-Francois Chamberland-Tremblay

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Overview

Abdominal auscultation is a crucial method to analyze and obtain a meaningful information about the health of bowels. Studies, focusing on understanding the mechanism of bowels by auscultation are old fashion and are not leveraging from current technological advances[2, 5]. This study includes a denoising and clustering method to obtain bowel sounds and comparison of three estimation methods to classify bowel sounds as before and after dinner.

Materials and Methods

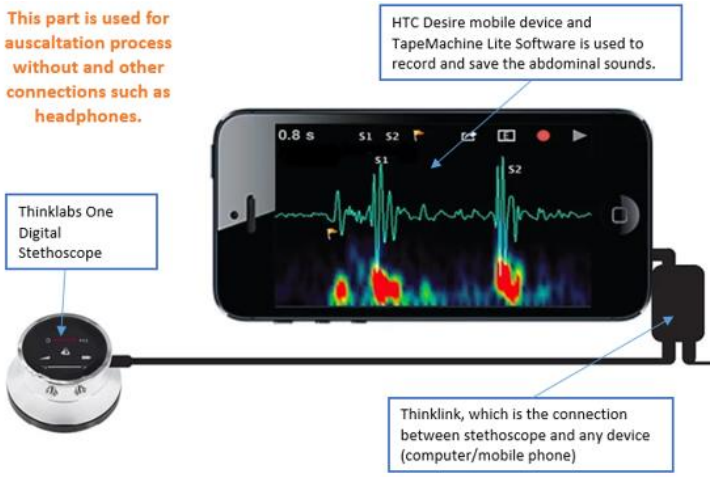

FIGURE 1: AUSCALTATION MECHANISM

In this work, abdominal sounds are auscultated by Thinklabs One Digital Stethoscope [**Figure 1**]. The stethoscope is connected to the mobile device via Thinlink part. To record and save the sounds, TapeMachine Lite software is used. The stethoscope is fastened by a basic belt to be stationary for eliminating any sliding effect.

The abdominal region has mainly nine parts. Many research indicates that the best location for bowel sounds to be heard is **"Right Iliac Region"** [1, 2]. Some studies claim that the whole lower abdominal region (right iliac, left iliac and hypogastrium) is proper for the auscultation of bowel sounds [3].

The right iliac region is chosen for this study after many recordings as I have realized that the location is most proper to record bowel sounds. Abdominal regions are shown in **Figure 2**.

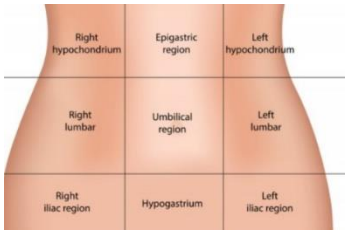

FIGURE 2: ABDOMINAL REGION

Denoising, Clustering and Segmentation of Bowel Sounds

In the literature, there are some studies for denoising bowel sounds such as Wavelet-based denoising [4], Low-power event elimination [3], concatenation [3] and Modified IKD [6]. In this study, a novel denoising method is proposed by using a proper threshold.

Proposed Method

To obtain bowel sounds from the raw data, I proposed a method [**Figure 3**].

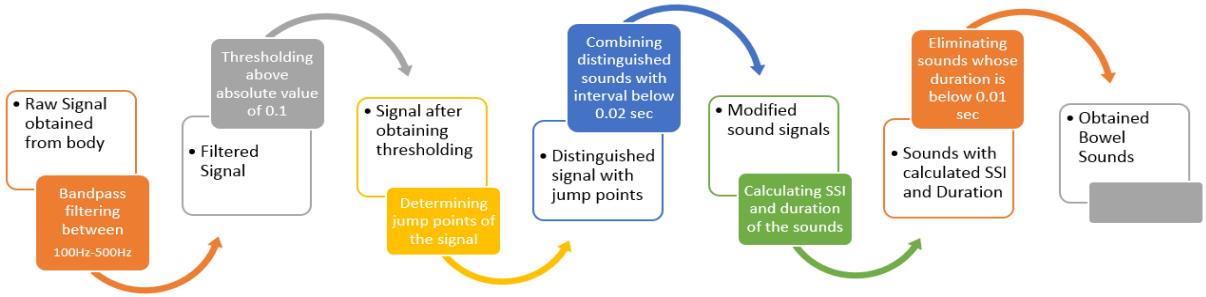

FIGURE 3: STEPS OF THE PROPOSED METHOD

An important part of this study is to choose the proper frequency interval. Most research indicates that bowel activity is best heard between 100Hz – 500Hz. For abdominal sounds, approximately 0.5% of the signal energy

lies above $1000\ Hz$; and approximately of 2% of the signal energy lies beyond $500\ Hz$ [7]. Thinklabs One has the frequency range of $20\ Hz - 2000\ Hz$. In this study, $100Hz - 500Hz$ **bandpass filtering** is applied to the raw data to eliminate the noises for the first step. Then, the absolute values of the magnitude of the filtered signal are calculated and the threshold, 0.1, is used to eliminate weak signals.

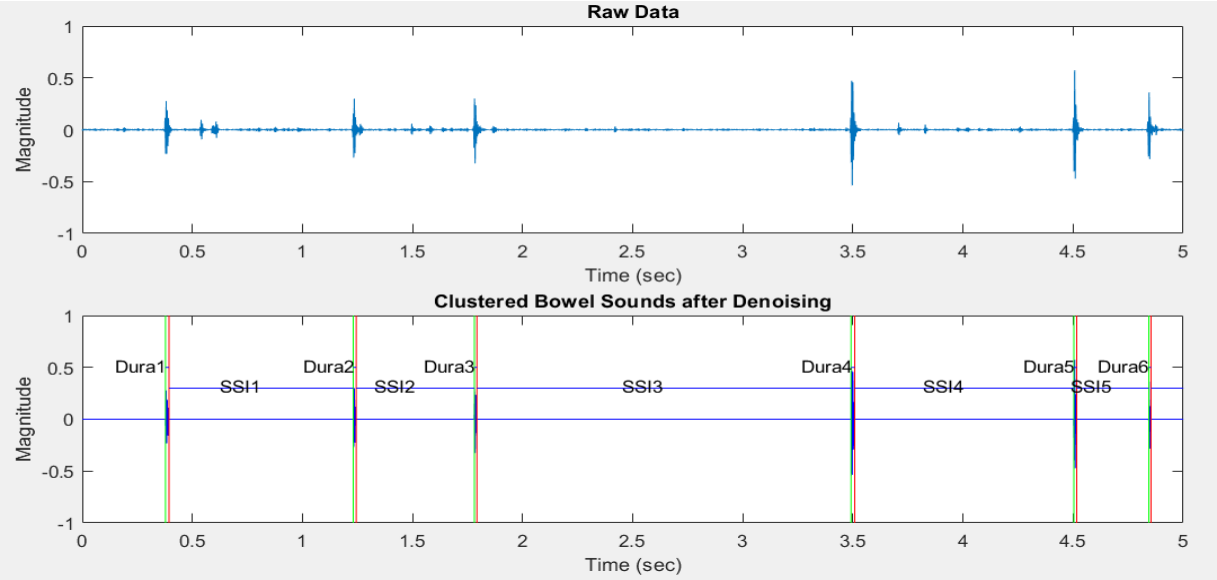

FIGURE 4: CLUSTERED BOWEL SOUNDS BY USING PROPOSED METHOD

After thresholding, the signals are clustered. If the interval between any two of these clusters is less then 20 msec, then they are merged. This step is named as **morphological closing** [3]. Finally, the sounds whose duration is less than 10 msec are dropped out and final bowel sound clusters are obtained. 20 sec sample raw signal and implemented signal after proposed method are seen in **Figure 4**. The final form of the signal is used to calculate the **duration** and the **SSI (sound-to-sound interval)** of each sound. Also, for each of the recording, **total energy** of the sounds are calculated in the frequency range of $100\text{Hz} - 500\text{Hz}$ to obtain the mean of total energy for each sound recordings. Finally, there are four parameters for all of the sound recordings as below:

1. Number of sounds
2. Mean of duration of sounds
3. Mean of SSI of sounds
4. Mean of total energy

Estimation Procedure

Total 76 recordings are used for these experiment. Half of them were recorded before dinner while rest of them were recorded after dinner. There are two classes as **"Before Dinner Recordings"** and **"After Dinner Recordings"**.

	Y0	Y1	Y2	Y3	label
0	98	0.023108	1.756624	3.079291	0
1	155	0.022639	1.133046	4.520234	0
2	60	0.031794	2.991684	3.234910	0
3	146	0.026799	1.213722	4.371807	0
4	102	0.020206	1.725304	3.914631	0
5	109	0.019397	1.505122	3.582319	0
6	84	0.021675	2.009023	3.146961	0
7	36	0.017979	5.078010	1.644905	0

46	121	0.023776	1.428588	3.043341	1
47	238	0.023157	0.726996	5.719740	1
48	308	0.039214	0.545486	9.465036	1
49	259	0.026971	0.663495	8.016043	1
50	171	0.022850	1.033856	6.315806	1
51	133	0.023238	1.250191	4.103950	1
52	190	0.024206	0.921525	6.610611	1
53	144	0.024842	1.197146	4.492414	1
54	215	0.026242	0.813075	6.535723	1

FIGURE 5: LABEL IS EQUAL TO 0 FOR "BEFORE DINNER" AND 1 FOR "AFTER DINNER"

Four parameters are calculated for each of these 76 recordings. Some of these data are seen in **Figure 5**. Y0, Y1, Y2 and Y3 represent number of sounds, mean of duration, mean of SSI and mean of total energy respectively. The problem is to estimate the class of any recordings by using these four informative parameters mentioned above.

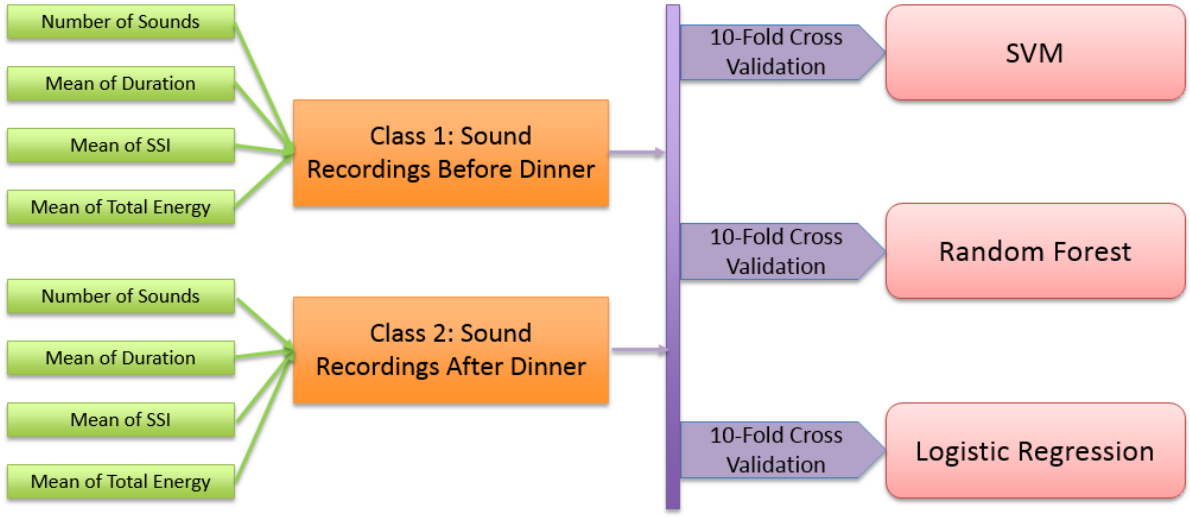

FİGURE 6: SCHEMATİC OF ESTİMATİON METHOD

To distinguish training and test data, **10-Fold Cross Validation** is used. Three estimation methods are used which are **SVM (Support Vector Machine)**, **Random Forest** and **Logistic Regression** respectively. The schematic of estimation method is seen in **Figure 6**.

Results

	SVM	Random Forest	Logistic Regression
Accuracy	78.214%	83.036%	86.071%

(a)

	SVM	Random Forest	Logistic Regression
Accuracy	85.893%	80.357%	87.500%

(b)

FİGURE 7: RESULTS (A) WİTH FOUR PARAMETERS, (B) WİTH TWO PARAMETERS (MEAN OF SSI AND TOTAL ENERGY)

The results of the comparison of three methods by usin all of the four parameters are seen in **Figure 7 (a)**. It seems that the more accurate estimation model for bowel sound is **Logistic Regression** as it has an accuracy rate of $\mathbf{86.071}\%$.

On the other hand, to understand the most important parameters that impact the accuracy, the coefficients of Logistic Regression Model are calculated and compared. The results are -9.91224709e-04, 1.41162326e-05, -1.57621116e+00 and 8.68802283e-01 for number of sounds, mean of duration, mean of SSI and and mean of total energy respectively. It tells us that mean of SSI and mean of total energy are most important parameters. The results indicate that the accuracy rate of Logistic Regression Model increases to $\mathbf{87.500}\%$**.** Also, the accuracy rate of SVM indicates better result while the accuracy rate of Random Forest decreases from 83.036% to 80.357%. The results for two parameters are seen in **Figure 7 (b)**.

As a result, Logistic Regression Model is the best algorithm to estimate bowel sounds among these three estimation algorithms.

Future Plans

I'm planning to get features such as total energy and acoustic features of sounds such as Jitter and Shimmer. These two parameters could be also used to estimate bowel sounds. Estimation of bowel sounds can be used for futher analysis like clustering and classification for diseases.

References

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