Early Meal Detection Based On Chewing, Swallowing and Bowel Sounds

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Abstract

Early meal detection plays a vital role in the lives of type 1 diabetes patients by easing the mental burden of inputting every meal. The reliability of the meal detection is very important because false meal detection may lead to a hypoglycemia. This work compares the meal detection time and its reliability using chewing, swallowing and bowel sounds. The acoustic data is obtained by multi channel acquisition system developed by SINTEF Digital AS. The data are obtained in controlled as well as realistic environment in two subjects. The results show that the meal detection is quicker and more reliable using chewing and swallowing sounds than bowels sounds in both controlled and realistic scenarios.

Introduction

Early meal detection (EMD) based on acoustic sounds can detect the meal quicker than the current systems based on the analysis of continuous glucose monitoring (CGM). It is shown that bowel sounds can detect the meal after about 10 minutes. EMD can inform the patients about a missed meal bolus or can be used as a feed-forward input to an artificial pancreas so that it does not need to rely on patient intervention for meal bolusing.

In the present study, sounds from chewing, swallowing and bowel movements were recorded in non-diabetic subjects. A machine learning model was trained for early meal detection based on these different sounds. The first part of the study was performed in a controlled environment where the subjects were quiet while eating. This work is extended to more realistic environments with normal life activities like talking. The results show that chewing and swallowing sounds are more effective than only bowel sounds for EMD and it is possible to detect the meal in the presence of talking.

Experimental Setup

The hardware used in this work, is developed by SINTEF Digital AS in Trondheim, Norway. A knowles electret condenser microphone (product number FG-23329-P07) is fitted inside a 3D-printed cup-shaped plastic cover. The hardware supports simultaneous multichannel data acquisition up to 4 channels. The sampling frequency of the microphones is 48 kHz, thus it can record variety of body sounds. Four microphones are applied at the mastoid bone, the suprasternal notch and at each side of the stomach below the umbilicus with double sided tape. Fig. 1 shows the cup-shaped cover and the microphone.

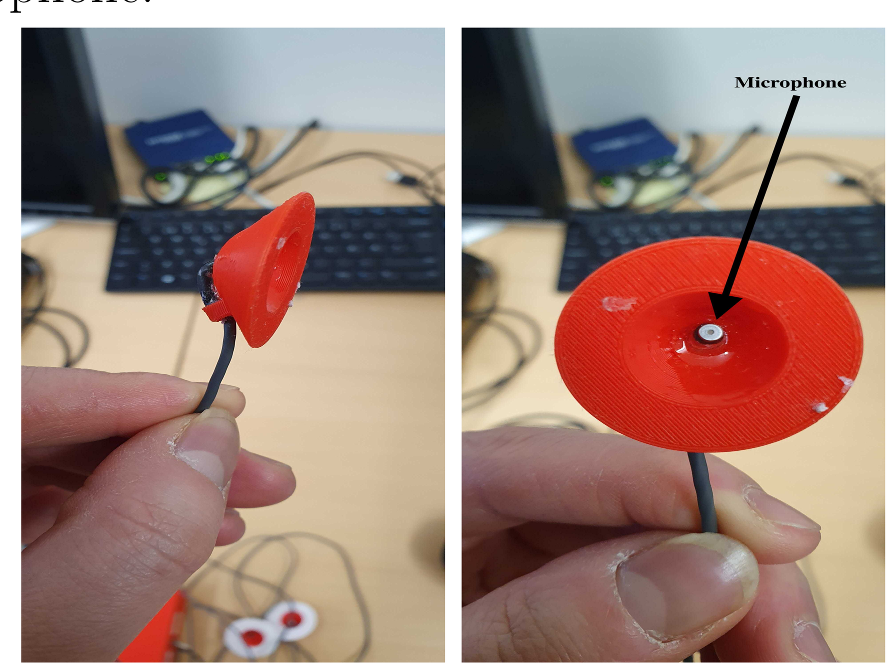

Figure 1: Cup-shaped microphones.

Data Acquisition

Two set of recordings are performed in this work. The first set of five recordings were performed in the controlled environment. The recordings were done on two subjects. In the second set of ten recordings, the subjects were asked to read out loud from a book or a newspaper. Fig. 2 shows the protocols for the two sets of recordings.

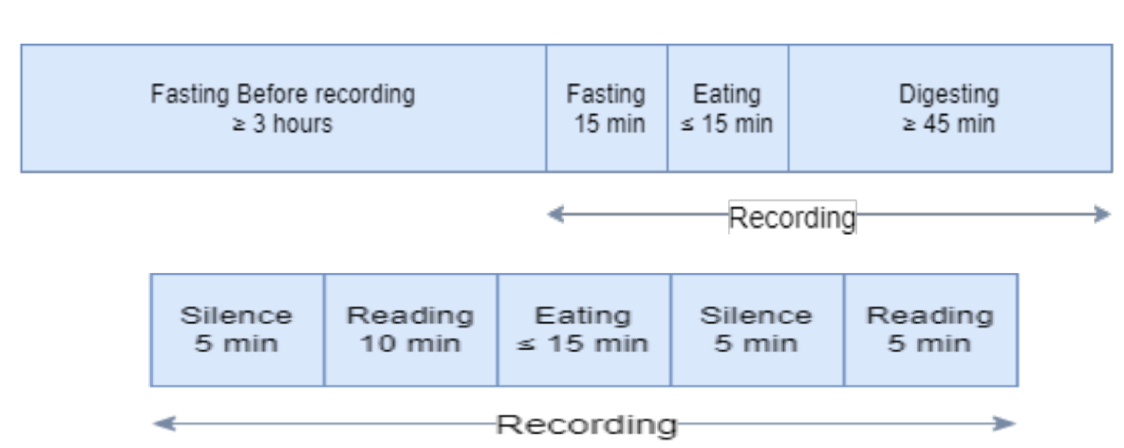

Figure 2: Protocols for the recordings in controlled (top) and realistic environment(bottom).

Methodology

1. 41 power-based features are extracted from the acoustic signal.
2. The best 21 features are selected based on the f_score method.
3. In the controlled environment, an SVM based model is trained and tested for chewing, swallowing and bowel sounds.
4. For the realistic scenario, SVM-based model is unable to differentiate between talking and meal. Hence, a Neural Network is trained and tested.

Results

Table. 1 shows the detection time and false positives in the controlled environment. A false positive is observed when the meal is detected before the start of the actual meal. With this data set, the SVM-based model is unable to detect the meal using bowel sounds. Both test meals are falsely detected, hence, detection time is not applicable (NA). The meals are detected instantly using chewing and swallowing sounds. Table. 2 shows the meal detection results using the neural network in realistic scenario. Two out of three test meals are detected using chewing and swallowing with the average detection times of 2 and 5 minutes, respectively. The results show that is possible to detect the meal in the presence of talking.

Table 1:Meal Detection time (DT) Result for recording set 1

Body sounds	Chewing	Swallowing	Bowel
Training Meals	3	2	2
Validation Meals	1	1	1
Testing Meals	2	2	2
False Alarms (Test)	0	0	2
DT (Min) (Test)	0	0	NA

Table 2:Meal Detection time (DT) Result for recording set 2

Body sounds	Chewing	Swallowing	Bowel
Training Meals	6	6	6
Validation Meals	1	1	1
Testing Meals	3	3	3
False Alarms (Test)	1	1	3
DT (Min) (Test)	2	5	NA

Conclusion

This work compares the meal detection using chewing, swallowing and bowel sounds in controlled as well as realistic environment. The results show that meal detection is possible using chewing and swallowing sounds in both scenarios. In future studies, the chewing and swallowing sounds may be exploited further to determine the type or size of a meal.

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