Quickest Meal Detection Using Statistical Machine Learning

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Abstract

One of the challenges for diabetic patients is to regulate the amount of glucose in the blood. Quick and reliable meal detection represents one relevant issue to develop more effective treatments. This work presents a statistical machine learning approach for quickest meal detection using abdominal sounds. The data presented in the paper is obtained using Electronic Stethoscope Model 3200 produced by 3M Littmann. The results show an average detection delay lower than 25 seconds with no false detections. Early and reliable meal detection eases the mental burden of diabetic patients in documenting every meal in the controller and also reduces the risk of hypoglycemia.

Introduction

In subjects with Type 1 Diabetes Mellitus (T1DM), the pancreas produces little or no insulin. To regulate the blood glucose level (BGL) for TIDM patients, the insulin is infused externally. These infusions must be administered closely, which is a major concern for people with TIDM [1]. Continuous glucose monitoring (CGM) systems are used nowadays, where a controller administers the insulin infusions based on the glucose amount observed in the subcutaneous (SC) tissue. Due to the slow absorption of glucose in the SC tissues, the CGM systems incur a delay of around 40 min in detecting the meal [2]. In addition, the current systems relies on the patients to input the meal or some information about it. The patients often forget this and the controller struggles to maintain the glucose levels. This work provides an effective and energy-efficient algorithm for meal detection by processing the bowel sound captured by a sensor. Such a method is based on statistical techniques leading to explainable, robust, and results. This technology can help make sure an appropriate insulin administration is attained. Its performance is evaluated based on the *average detection delay* and the *false positive rate*.

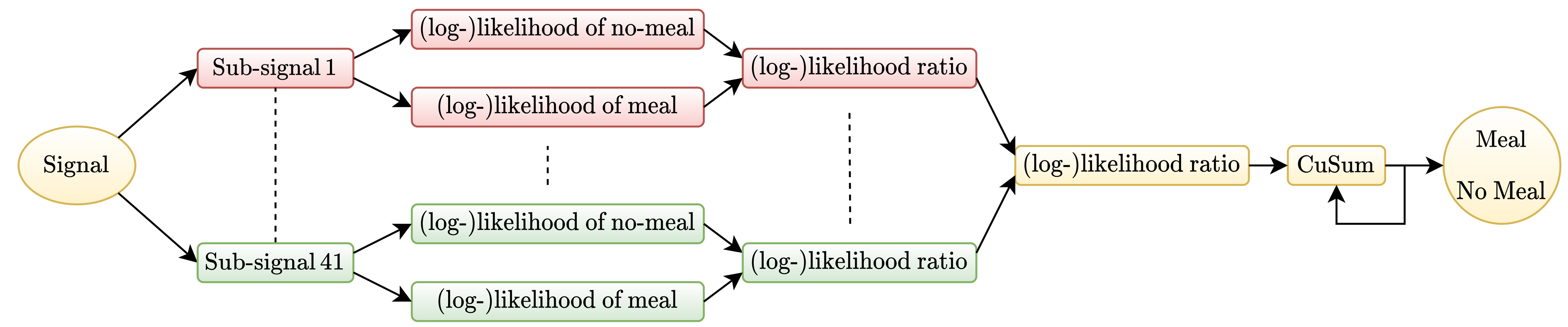

Figure 1: Algorithm Block Diagram.

Experimental Setup

The data presented in the poster were collected from Electronic Stethoscope Model 3200 produced by 3M Littmann, which supports single channel data acquisition. The sampling frequency of this device is 4 kHz. It was applied to the lower abdomen of the subject under the umbilicus using medical tape.

A *training* stage is needed to compute the sub-signals' likelihoods. The sub-signals are assumed *Gaussian* and *statistically independent* (ensuring low *computational complexity*). Therefore the training consists of estimating the *mean* and *variance* of each sub-signal via *maximum likelihood estimation* for both scenarios (meal and no-meal).

Data Acquisition

Five recordings were collected using a Littmann stethoscope that were all from the same subject. The subject remained seated during each recording. For all the recordings, the subject fasted at least 10 hours before the recording session. Each recording lasted a total of approximately 60 minutes. Four meals started 15 minutes after the start of the recording, while the last one started after 21 minutes of recording.

Methodology

The algorithm comprises three steps (see Fig. 1):

1. 41 sub-signals (*features*) are extracted from the acquired acoustic signal.
2. *Likelihood* values for each sub-signal being in one of the 2 hypotheses (*meal* and *no-meal*) is computed, and then their ratio. All the *log-likelihood ratios* (LLRs) are then combined to assign the original signal its value of LLR.
3. The last result is processed via CuSum recursive algorithm and its result is compared to a threshold for quickest meal detection.

Results

Fig. 2 is obtained using 3 recordings for the *training* stage and the remaining 2 for the *testing* stage. We can see that the lower the threshold, the more sensitive the algorithm will be, hence reducing the detection delay, but in turn, increasing the false positive rate. Preliminary testing results show that we can achieve very low false positive rates if we allow an average detection delay of maximum 25 seconds.

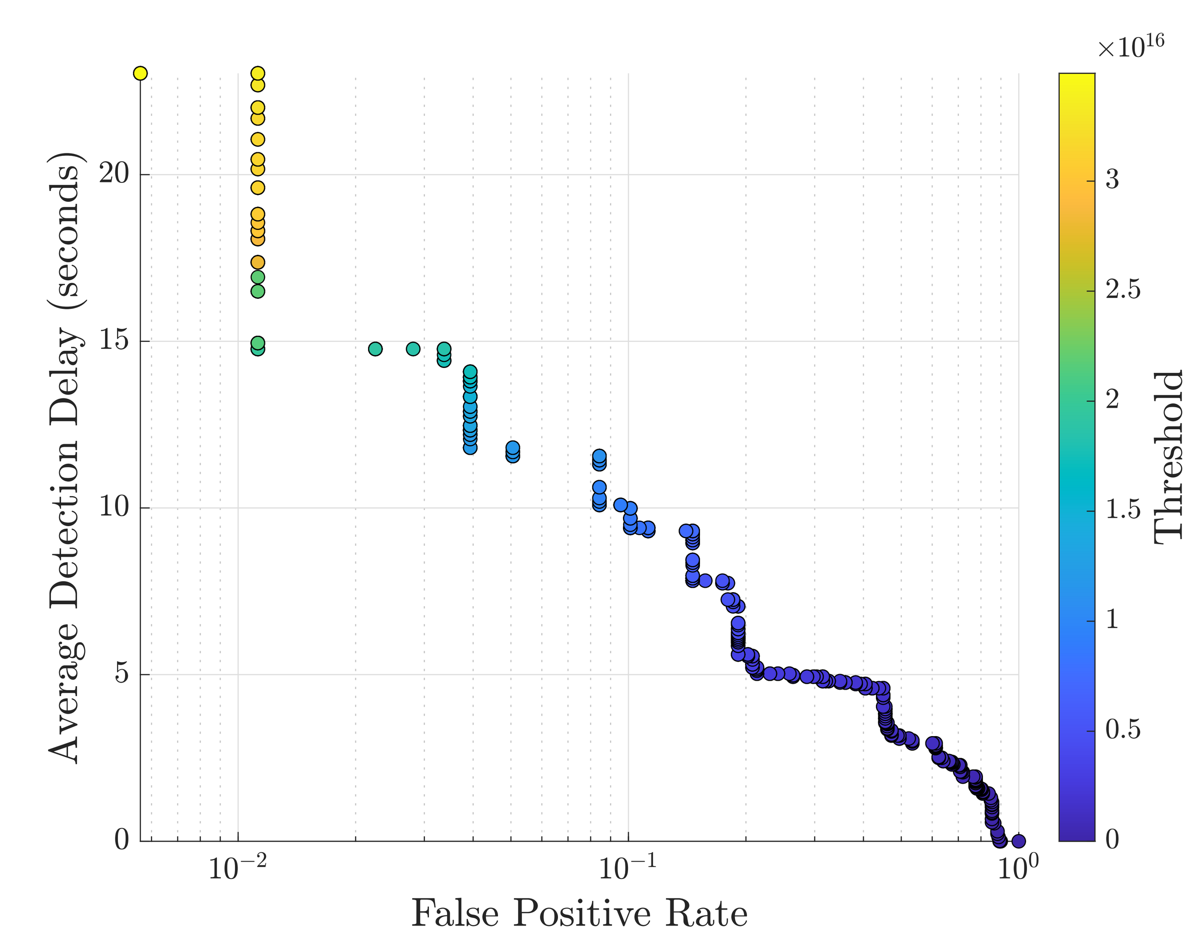

Figure 2: Results of the testing stage.

Conclusion

This work presents a statistical machine learning approach for quick and reliable meal detection. The results show that it is possible to detect the meal within 25 seconds on average with no false positives. In future works, the study will be extended to a bigger dataset and more subjects as well as more realistic scenarios.

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