Signal Processing of Asynchronous Sampled ECG Signals

Joint Master's Program in Biomedical Engineering, University of Bern and Bern University of Applied Sciences
Subject: Master of Science in Biomedical Engineering
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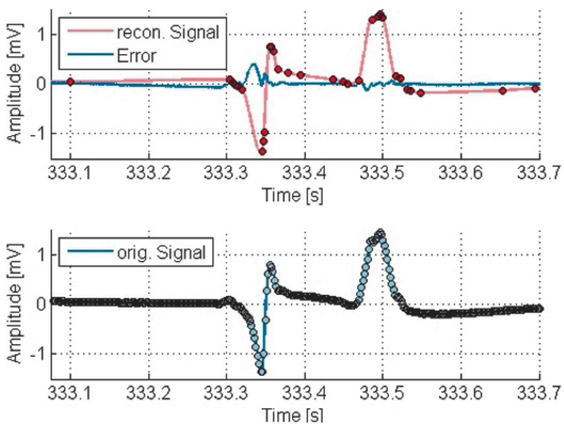
Heart arrhythmias are conditions, where the heartbeat is irregular, either too slow, or too fast. Not all arrhythmias are life threatening, but they can decrease the quality of life of the patient. To diagnose rare occurring arrhythmias, such as paroxysmal atrial fibrillation, the monitoring of the heart rhythm over a longer time period is essential. This is done by long-term surface electrocardiography (sECG).

Introduction

Long-term measurements with a duration of several days/weeks increase the possibility to detect rare occurring arrhythmias. Unfortunately, the sECG has some disadvantages which shorten the maximum recording time.
A potential ECG recording method for long-term measurement is oesophageal ECG (eECG).
The main challenge for developing a long-term implant, is the implementation of a power- and memory-efficient recorder.

Materials and Methods

The focus of this master-thesis is to emulate and investigate the proposed recorder in MATLAB. The recording method is divided into two main steps: the asynchronous sampling of the input signal, and the compression of the asynchronous samples. The asynchronous sampling method is based on a level-crossing analogue-to-digital converter. Samples are generated only when the input signal difference crosses a certain threshold value. A sample consists of the elapsed time since the previous sample and the direction in which the threshold value is crossed (either up or down). The Compression method relies on different slope properties within an ECG signal. Depending on the similarity of asynchronous samples, samples within slopes (e.g. QRS-complex) can be accumulated. This approach leads to a more memory-efficient, and less power consuming recording method compared to a conventional recorder with a fixed sampling rate.



MATLAB simulations with an asynchronous sampling resolution of 5 Bits/mV. (TOP): samples left after compression (red dots), reconstructed signal (red line), and error signal (blue line). (BOTTOM): samples of the original Signal (blue dots), and original signal (blue line)

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Results

The widely used MIT/BIH Arrhythmia Database, containing 48 sECG records, and an eECG Dataset with 13 records were used as test datasets. Different asynchronous sampling resolutions were evaluated.
We can show that with an asynchronous sampling resolution of 5.5 Bits/mV a good compromise between signal reconstruction quality, peak detection performance, and compression ratio is achieved. This resolution leads to a compression ratio of more than 10:1 compared to conventional sampling methods. A recording time of more than 42 days with 1 GByte flash memory, and two eECG channels is possible. We can also show that an eECG signal generates less asynchronous samples. This is because eECG signals are less sensitive to high frequency noise. However, the effect is marginal since, the P-waves in the eECG signal generate more samples compared to the sECG signal.

Discussion

This is the first time that the whole MIT/BIH Arrhythmia Database, and 13 eECG records were analysed with a MATLAB framework, emulating the asynchronous and compression algorithm. Prior to this work, this was done by a PYTHON script which took several hours for only a few minutes of an ECG signal. It is now possible to analyse different parameter settings on a wide range of ECG signals in a feasible time (≈50 ms/Beat).