Hardware Algorithms for Long-Term Esophagus ECG Signal Decompression and Reconstruction

Degree programme: Master of Science in Engineering | Specialisation: Informations- und Kommunikationstechnologien
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Data compression is a key element in long-term esophagus electrocardiogram (eECG) recording in order to reduce the memory size of the device. Using Hardware/Software Co-Design methodologies, an implementation of the signal decompression and reconstruction algorithms on a system on chip is developed with a throughput of up to 140 MS/s. All computationally intensive tasks are done in parallel, which leads to a processing speed of 2 seconds per 24 hours of recorded eECG data.

Problem Statement

Current algorithms [1] achieve space savings of up to 96% and the decompression and reconstruction systems are challenged with high throughput goals to minimize the delay for the patient and cardiologist. The algorithms allow to process several minutes of compressed multi-channel eECG data in 1 second computation time on a industry-standard computer. The current eECG device [2] holds 15 days of recorded data, which leads to a computation time of several hours. We want a system that allows the cardiologist to disconnect the recording device and to review the recorded data instantly. The signal reconstruction algorithms need thus to be speed up by decades.

Results

Several steps are taken to speed up the decompression and reconstruction algorithms. First, simplifications of the mathematical expressions on a symbolic level are performed. Recursive expressions allow to reuse already computed values, resulting in a reduced number of operations per recursion step. Moreover, matrix operations are decomposed into their components, which allows to drop trivial operations such as multiplications by 0 or 1, or additions by 0. A speed-up factor of x 100 can be achieved by these simplifications.

Second, we model the algorithm in a Data Flow Graph in a sample-based manner and use a system on chip (SoC) as target platform. This makes it possible to perform multiple operations in parallel and to use fast hardware multiplexers to select the corresponding data paths. Constant operands are fix wired into hardware and the use of fixed point operations further reduces the hardware complexity. Pipelining is used to reduce the idle-time of the system.
Third and last, the signals of four channels are processed in parallel. These arrangements lead to an additional speed-up factor of x 300.

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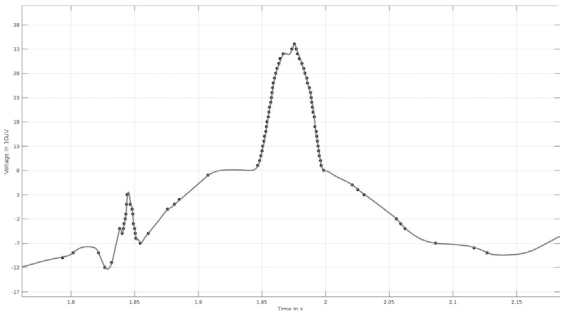
Conclusion

Despite the fact that computationally intensive algorithms are used for the reconstruction of the signals, a speed-up factor of x 30 000 was achieved. This allows to process 15 days of recorded multi-channel eECG data in only 33 seconds, saving time for the cardiologist and the patient during their appointment.

References

[1] D. Robellaz, Compression and Reconstruction Algorithms for Non-equidistantly Sampled Esophagus Signals. MSc Thesis, Jan 2017
[2] C. Baeriswyl, eECG Device Hardware. Project 2, Aug 2016

Esophageal ECG recording device, placed in the patient's nose for 15 days.



Compressed single channel esophageal ECG data (small black dots) and its reconstruction (black line).