Compression and Reconstruction Algorithms for Non-Equidistantly Sampled Esophagus Signals

Degree programme: Master of Science in Engineering | Specialization: Industrial Technologies
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The long-term esophageal ECG is a research project to develop a medical device, located in the nose and connected to an esophageal catheter nearby the heart, recording up to 30 days of ECG data. Due to the limited space in the nasopharynx, the available battery capacity is very limited and thus, new low power compress methods are developed. Furthermore, a new approach to smoothly interpolate the decompressed data with respect to the qualities of ECG signals is introduced. 1

Background
Recording of esophageal electro-cardiogram (eECG) has a long history, but is hardly ever used in everyday clinical practice. Nevertheless, esophageal ECG signals show, due to its proximity to the atria, high quality atrial signals. The main challenge of an implantable eECG device is the highly limited space in the catheter and thus, the limited memory size and power resources. Low-power data reduction and compaction is therefore a key element of such a device.

Challenges
This thesis deals with the data path of eECG signals, starting at the binary analog to digital converter (ADC) output on an application-specific integrated circuit (ASIC) level, then storing the data in a highly compressed format on a FLASH memory and in the end decompressing the content of the FLASH memory and interpolating the original eECG signal. The challenges of this work are therefore: a close to memoryless and low power compression algorithm, qualified for ASIC implementation, a corresponding reference decompression algorithm on a standard PC environment and finally, a new efficient interpolation algorithm.

Methods / Results
The compression is performed in two steps. First the captured data is sampled voltage discrete (non-uniform sampling). In other words events are only stored whenever a predefined voltage threshold is crossed. The method follows the idea to only store information when in the input signal alters. This first compression step leads to a compression rate of approximately 90% compared to the equidistantly sampled input signal. The second compression step accumulates the generated events with respect to an accumulation scheme. In our case these schemes are either linear or parabolic. Two consecutive samples will only accumulate (compress) if the signal shape follows one of those classes of shapes. Due to this second compression method we additionally save 60% of memory. Overall, we store the captured data reduced to 4% of its original size, tolerating a maximal predefined error. The decompression is straight forward. The subsequent interpolation of the decompressed data is model based, using a state space representation of the signal and finally solves a quadratic optimization problem, depending on weighted and windowed samples.

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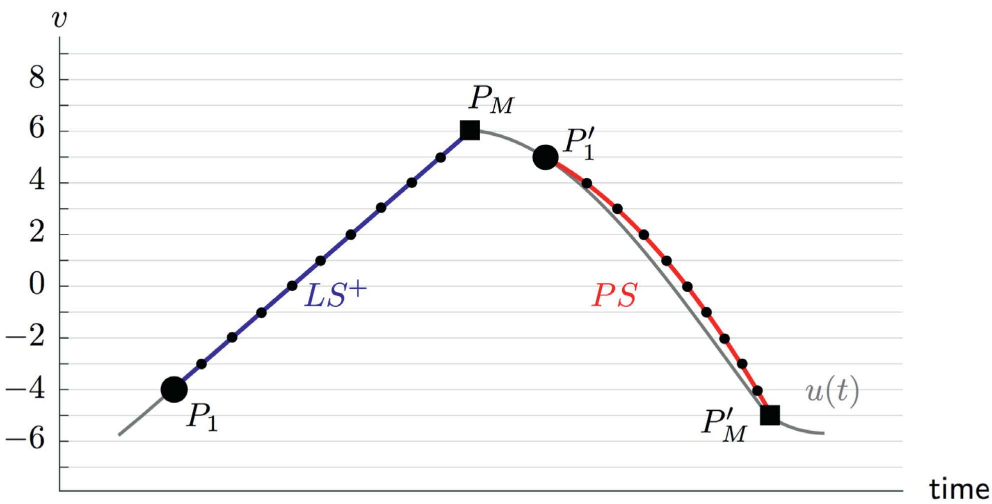

Linear (b) and parable (r) accumulation schemes with stored events (big dots/squares) and original signal (g).