Levels, peaks, slopes. . . which sampling for which purpose?

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Preliminary version

Aim

- Make the best of nonuniformity
- Explore pros and cons of various sampling techniques
  - Level-crossing sampling
  - Peak sampling
  - Level and peak sampling
  - Slope sampling

Level-crossing – principle

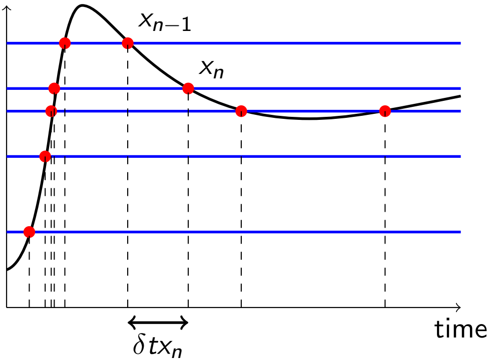

Figure: Principle and notations for level crossing sampling.

Level-crossing – features

Pros ability to adapt to signal variations, no sample during inactive parts, filtering of high-frequency components

Cons over-sampling in large amplitude active parts

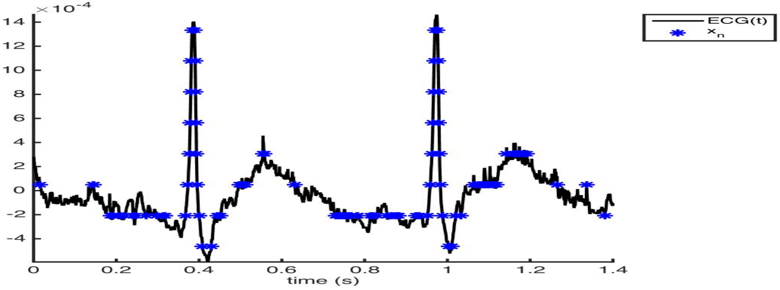

Figure: Level crossing sampling on a small ECG fragment.

Level-crossing – going further

- Decimation of equal amplitude successive samples, in view of further processing where the signal is at most linearly interpolated
- almost the same as send on delta sampling
- Appplication-driven choice of levels

Peak sampling – principle and features

- A sample each time a local minimum or maximum is detected.

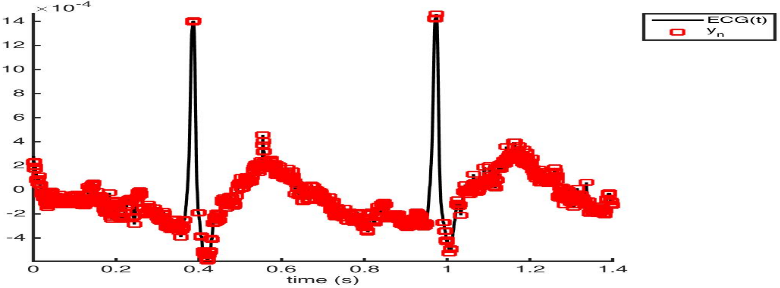

Figure: Peak sampling on a small ECG fragment.

Pros does not depend on extra parameters inactive parts, only relevant data in peaky parts

Cons not adapted to noisy signals, no sample taken if monotonous

Level and peak sampling – principle

- Level crossing
- Detection of local extrema

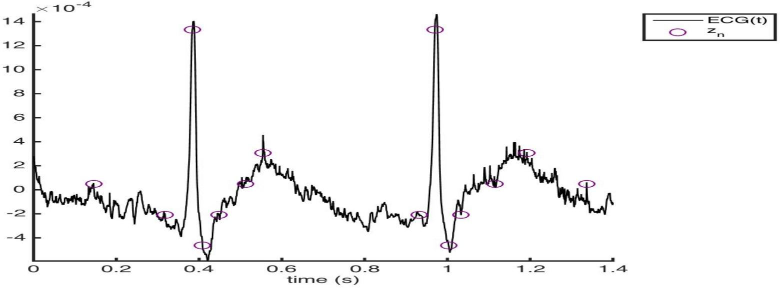

Figure: Demonstration of level and peak sampling on a small ECG fragment.

Level and peak sampling – features

Pros less samples as levelcrossing sampling
no oversampling in active parts: competitive with Nyquist sampling
possible to add levels, with the same number of final samples
less peak clipping

Cons as peak sampling: no sample taken if monotonous

Slope sampling – principle

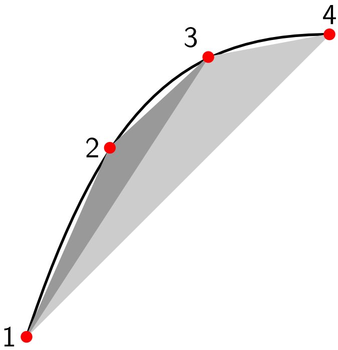

Figure: Principle and notations for "slope sampling".

Slope sampling – features

Pros filters small amplitude noise

eventually takes samples if the signal has only small variations, since small errors accumulate

Cons as peak sampling: no sample taken if monotonous

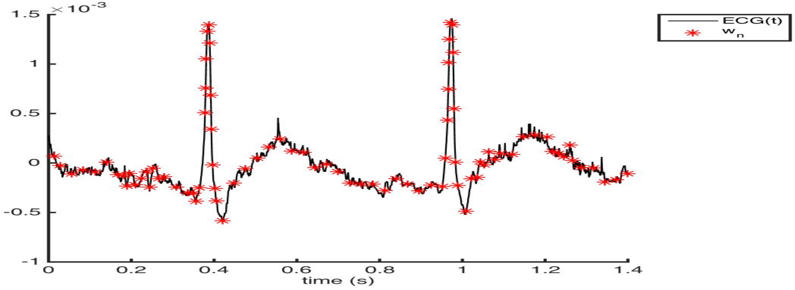

Figure: Slope sampling on a small ECG fragment.

Number of samples – ECG example

- ECG, regularly sampled with $t_s = 5\ 10^{-4}$ s period, leading to 2801 samples
- noisy biological signal

signal	number of samples	compression
x_n	141	95%
y_n	1179	58%
z_n	14	99.5%
w_n	86	97%

Table: Number of samples and compression for an ECG fragment.

Number of samples – discussion

- Theoretical results for level crossing sampling obtained under prescribed Hölder regularity, worst case study
- Analogue impossible for peak sampling
- level and peak sampling always better in terms of compression than simple level crossing sampling.
- To study: impact of extra parameters: levels, L^1-norm

Impact of noise – Number of samples

Input signal: $$f(t) = \frac{1}{2} + \frac{1}{2}\sin(2\pi t).$$

- Not a sporadic signal
- initially: 100 periods, uniformly sampled at 100 Hz, thus yielding 10000 samples
- additive noise with zero mean and standard deviation σ: $\sigma = \alpha q$ for $\alpha \in [0, 1]$

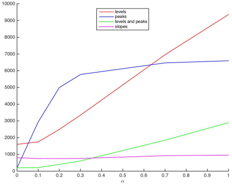

Figure: Number of samples in terms of α.

- Slope sampling: N constant
- Level-based sampling: N linear for large α
- Peak sampling: N saturates for large α.

Impact of noise – Reconstruction

- Same test case
- L^1-error between the noisy input signal and the nonuniform signal

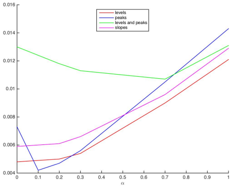

Figure: L^1 error in terms of α.

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- Methods equivalent for large values of α
- Level crossing, peak and slope sampling: linear behavior away from $\alpha = 0$.
- Expect slope sampling to saturate for larger α
- A little noise is quite favorable for peak sampling
- Level and peak sampling bad for small α.

Applications

Pattern recognition Correct pattern analysis vs. good reconstruction.
Main issue: good placement of the levels.

System activity detection Time delays in nonuniform signal allow to detect activity regions.
The regions are regularly resampled, and treated with usual algorithms.

Applications of slope sampling Introduced to test for the main frequency of a signal in a specific industry collaboration.
Very costly procedure for nonuniform samples since there is no FFT-like algorithm at hand.
High compression with slope sampling needed.

Embedded systems Low number of samples needed
Capability of implementing the sampling and the subsequent processing.

Conclusion

- Comparison from the point of view of the number of samples and the robustness of this criterion when noise is added, as well as the reconstruction error.
- Possibility to integrate in electronic systems
- Positioning of levels
- Security issues

Event-driven community in Grenoble

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Goal: use the less possible samples

- to process signal and images in asynchronous systems,
- to control event-based systems.

Applications: embedded systems (medical implants, bee-robots. . .)


THANKS!
Thanks for your attention