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Advanced software tools for parametric identification based on quantized data

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***Abstract* – Parametric estimation of signals, based on quantized data, is often carried out by means of least squares (LS) or averaging techniques. Such an approach often leads to optimal performance, resulting in almost unbiased estimators when the quantization error can approximately be modeled as an additive white Gaussian noise, or when other additive white Gaussian noise sources are larger than the quantization error. When such hypotheses are not satisfied, however, averaging may produce suboptimal, and biased estimators. In such a case, maximum likelihood or quantile based identification techniques can be shown to lead to more performing estimators, mostly unbiased and with a lower mean square error than that of an LS estimator. A software tool is presented, capable of estimating a DC level, a DC level corrupted by** Additive White Gaussian Noise **(AWGN), and sinewave parameters when the frequency is known, using data quantized by a nonuniform ADC.**

I. INTRODUCTION

The presented software tools consist of three Matlab scriptswhich run as console applications with a small set of auxiliary source files, designed to assess the performance of quantile based estimators fed with quantized data [1]. To this aim, the tools simulate the estimation of a signal, affected by Additive White Gaussian Noise (AWGN). The first routine implements the estimator of a DC signal affected by an AWGN with known standard deviation σ, while the second routine implements the estimator of a DC signal affected by an AWGN with unknown variance, also estimated using the quantile based algorithm. The third script implements the estimator of amplitude, phase and offset of a sinewave with known frequency, affected by AWGN with known variance. The structure of each of the 3 scripts is summarized by the flow chart of Fig. 1.

Each algorithm assumes that the quantized data are obtained from an instantaneous Analog-to-Digital Converter (ADC), bipolar in a range [-*FS*,*FS*], with known transition levels and a resolution of *b* bits. The simulated ADC features a gain G_{ADC}, an offset O_{ADC}, and is affected by Integral Nonlinearity, such that the INL of each transition level is taken from an uniform distribution taking values in $[-\alpha\Delta,\alpha\Delta]$, where Δ is the ADC quantization step and $0\leq\alpha<1$.

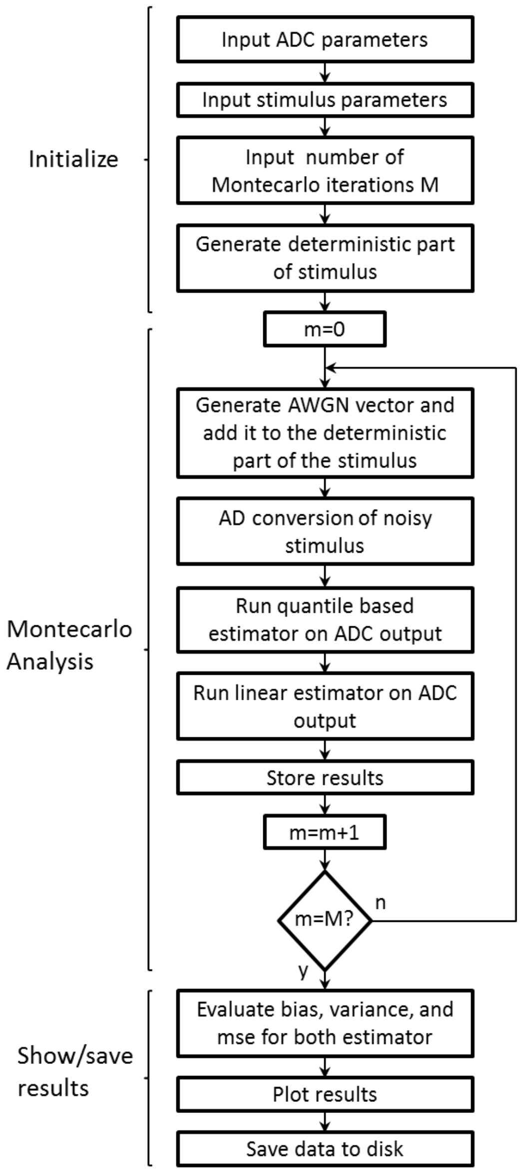

Figure 1 Framework of the 3 developed analysis tools

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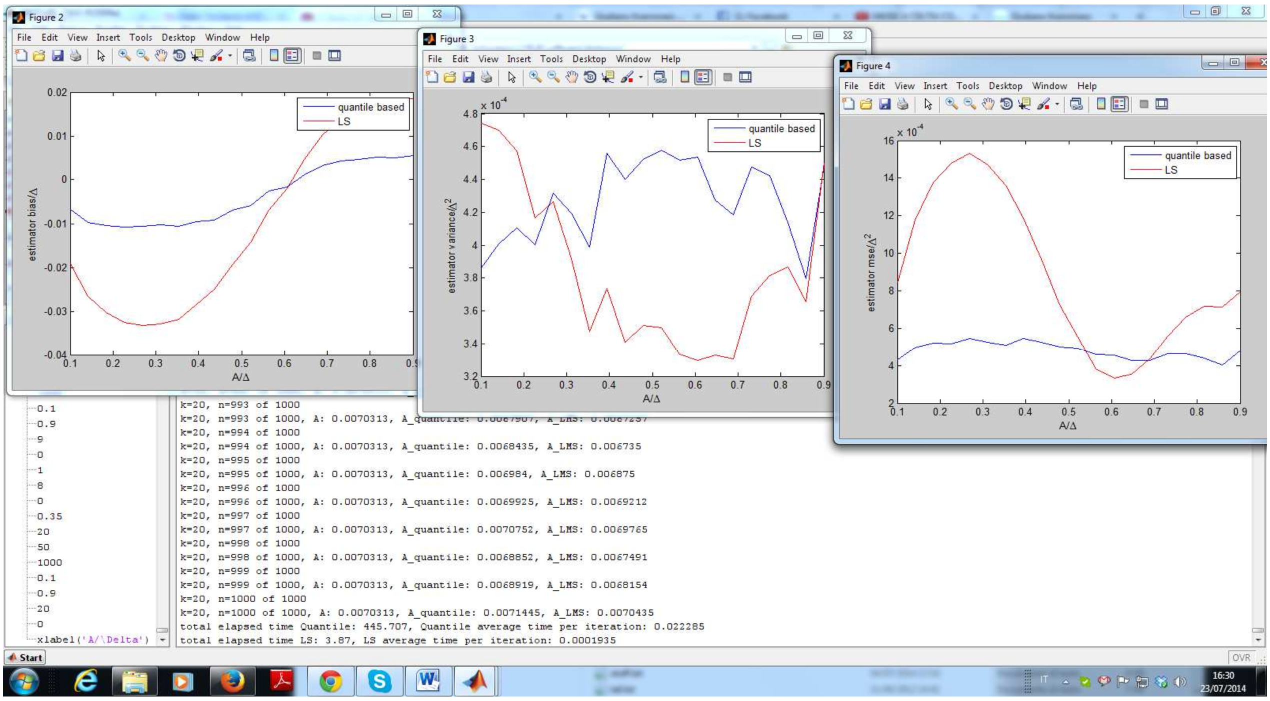

Figure 2. A screenshot of the third tool, used to compare the quantile based algorithm to the IEEE 1057/1241 3 parameter sine fit, assuming a 8 bit ADC with FS=1 and a record length of 1000 samples, when the sinewave amplitude ranges from 0.1Δ *to* 0.9Δ.

Each estimator compares the performance of the quantile based algorithm against that of a more conventional linear estimator. In particular, the first two routines also implement an arithmetic average estimator of the DC signal, while the third routine also implements a Least Squares (LS) 3 parameter sine fitting algorithm, as described in [2][3]. Each software runs a Monte-Carlo analysis, with an assigned number of iterations *M*. For each iteration, a noisy stimulus is generated and fed to an ADC, the output codes being stored and converted into equivalent output voltages. Then, the codes are fed to the quantile based estimator, while the equivalent output voltages are fed to the linear estimator. Thus, the quantile based estimator and the linear one operate on the same data. After completing the *M* cycles, the results are used to compute sample mean and variance, of both estimators' results, subsequently used to compute estimators' bias and mean square error (mse). In order to perform the comparison under various conditions, the user can define a range of DC levels to be considered. Similarly for the third routine, a sinewave amplitude range $[A_{min},A_{max}]$ is entered. Due to the practical significance of the sinewave case, the program also evaluates the overall processing time and the average processing time per iteration, both for the quantile based and for the LS estimators.

A software screenshot is shown in Fig. 2, obtained using the third tool. The plots in Fig. 2 show that, as expected, the quantile based solutions, compared to linear algorithms, remove estimator bias while featuring a comparable variance. Hence, the proposed algorithms feature a reduced mean mse, at a price of an increased processing time.

The implementation of the three scripts is fairly modular, and may easily be extended to keep into account other estimators, such as the Maximum Likelihood ones, or embedded into a Graphical User Interface (GUI) based program. Moreover, the estimator routine may easily be adapted to process real data, obtaining a working system.

II. REFERENCES

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