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The long-term goal of this project is to improve the modeling of high performance clocks by taking advantage of methodological advances in statistical modeling and analysis.

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Stochastic Models and Statistical Analysis for Clock Noise

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LONG-TERM GOALS

The long-term goal of this project is to improve the modeling of high performance clocks by taking advantage of methodological advances in statistical modeling and analysis.

OBJECTIVES

The objective of this particular study is to demonstrate the advantages of modern statistical models and analysis techniques by applying them to a collection of clock noises that are representative of what is commonly encountered in the precise time and time interval (PTTI) community. The models and techniques to be included are (i) the formulation of fractionally differenced (FD) processes by Granger and Joyeux [1] and Hosking [2] as tractable models for processes with stationary increments (these are superior analytically to the power law models in common use today); (ii) the development of multitaper spectral analysis, which offers stable estimates of the power spectrum with low bias [3,4]; and (iii) the development of wavelet variance analysis, which offers important generalizations of the well-known Allan variance for characterizing clock noise [5,6].

APPROACH

We will start with the analysis techniques that are described in two recent papers~[7,8], which focus on spectral analysis, wavelet analysis and maximum likelihood estimation as applied to FD processes. As needed to handle particular noise types, we will investigate more complicated models (e.g., composite FD processes and time-varying FD processes) and additional analysis techniques that will serve to complement or extend our basic suite of analysis techniques (e.g., to handle various types of deterministic trends). The emphasis will be on techniques and models now commonly accepted in the statistical community, but that have yet to be commonly used by clock analysts. We will thoroughly document our analyses of the various clock noises, with the intent of offering these as examples of how to bridge the gap between modern statistical theory and practical applications.

In addition to the PI, the other key individuals who will be participating in this work are Charles Greenhall (Jet Propulsion Laboratory) and Lara Schmidt (Rand Corporation). It is our intent to use the results from this study as the basis for a monogram on the statistical analysis of clock noise. Drs. Greenhall and Schmidt will be working primarily on the monogram itself.

WORK COMPLETED

Except for some minor organizational efforts, work has not started on this project. The contract period is from 1 April 2003 to 31 March 2004. The PI has scheduled this work to begin in October 2003 and to be completed by the end of the contract period.

RESULTS

Due to the fact that work has not yet started on this project, there are no results to date.

IMPACT/APPLICATIONS

The results from this project should have a positive impact on the statistical characterization of clock noise, which is a necessary component in evaluating clocks for their use in various systems (including ones associate with the Global Positioning System).

RELATED PROJECTS

None.

REFERENCES

[1] Granger, C.W.J. and Joyeux, R. (1980), "An Introduction to Long-Memory Time Series Models and Fractional Differencing," Journal of Time Series Analysis, vol. 1, pp. 15-29.

[2] Hosking, J.R.M. (1981), "Fractional Differencing," Biometrika, vol. 68, pp. 165-76.

[3] Thomson, D.J. (1982), "Spectrum Estimation and Harmonic Analysis," Proceedings of the IEEE, vol. 70, pp. 1055-96.

[4] Percival, D.B. and Walden, A.T. (1993), Spectral Analysis for Physical Applications: Multitaper and Conventional Univariate Techniques. Cambridge, UK: Cambridge University Press.

[5] Percival, D.B. (1995), "On Estimation of the Wavelet Variance," Biometrika, vol. 82, pp. 619-31.

[6] Percival, D.B. and Walden, A.T. (2000), Wavelet Methods for Time Series Analysis. Cambridge, UK: Cambridge University Press.

[7] Percival, D.B. (2003), "Stochastic Models and Statistical Analysis for Clock Noise," Metrologia, vol. 40, pp. S289-304.

[8] Schmidt, L.S. (2003), "Atomic Clock Models Using Fractionally Integrated Noise Structures," Metrologia, vol. 40, pp. S305-11.