A non-parametric generalization of the synchronous average in the cyclo-non-stationary framework

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Abstract

Deterministic-random separation is crucial in machine signal processing. It offers a way to remove the deterministic part and helps in eliminating the interference of the latter in the higher-order analysis of the random part [1]. The most common example is the vibration signal of a power transmission chain comprising a gear and a bearing. In this context, the synchronous average is a widely used tool that separates the deterministic contribution from the random one [2]. This tool consists on averaging the cycles of the vibration signal. In fact, it uses the cyclo-ergodicity hypothesis that assumes that, for a given location in the cycle, the associated samples share the same probability density function. This makes it possible to estimate the signal mean through the synchronous average, i.e. by averaging the samples associated with each position in the cycle. Once the synchronous average is performed, a differential diagnosis of the gears and the bearings can be unambiguously made. However, in many practical applications, the cycle-to-cycle statistics can change according to many factors such as the speed, torque, load, etc. The resulting signal is widely referred in the literature as cyclo-non-stationary [3] [4]. This jeopardizes the cyclo-ergodicity of the signal and, in consequence, the efficiency of the synchronous average. This paper addresses this issue by proposing a new non-parametric generalization of the synchronous average. The proposed method takes advantage of the smoothness of the probability function (in particular the mean) variation with respect to cycles. Instead of computing the mean of the samples located at a given angular location, it proposes to optimally fit the data with an appropriate curve. An efficient way to do this is the use of the Savitzky–Golay filter [5] that smooths the data, for a given position in the cycle, without distorting the general tendency. This is achieved by fitting sub-sets of adjacent data points (of pre-defined width) with a low-degree polynomial by the linear least squares method. In this paper, the theoretical basics of this technique is provided and its efficiency is demonstrated on real vibration signals acquired under nonstationary operating conditions.

Keywords: gearbox, bearing, diagnosis, vibration signal, nonstationary conditions, Savitzky–Golay filter.

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References

[1] R. Randall, N. Sawalhi et M. Coats, «A comparison of methods for separation of deterministic and random signals,» *International Journal of Condition Monitoring,* vol. 1, no. 1, pp. 11-19, 2011.

[2] S. Braun, "The extraction of periodic waveforms by time domain averaging," *Acta Acustica United with Acustica,* vol. 32, no. 2, pp. 69-77, 1975.

[3] D. Elia, Z. Daher et J. Antoni, «A novel approach for the cyclo-non-stationary analysis of speed varying signals,» chez *ISMA2010 international conference on noise and vibration engineering,* Leuven, 2010.

[4] J. Antoni, «Separation of combustion noise in IC engines under cyclo-non-stationary regime,» *Mechanical Systems and Signal Processing,* vol. 38, no. 1 , pp. 223-236, 2013.

[5] A. &. G. M. Savitzky, "Smoothing and differentiation of data by simplified least squares procedures," *Analytical chemistry,* vol. 36, no. 8, pp. 1627-1639, 1964.