inter•noise 25th Anniversary Congress – Liverpool 96

INCE: 56.2

GEOSTATISTICAL ANALYSIS OF TIME SERIES OF SHORT LAEQ VALUES

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1. INTRODUCTION

Professional exposure to noise varies with time under the effect of factors which induce deterministic and random variations within and between days. The study of these variations is necessary for defining data collection strategies for a specific need: to furnish representative estimates of noise exposure on the long run [1]. Already proposed for industrial hygiene [3], this approach sheds new light on the autocorrelation of time series, on the relation between noise integration time and the experimental variance, estimation problems and noise sampling strategies [2]. After a brief presentation of the notion of *variogram* this paper presents the first steps of a geostatistical analysis of two acoustic series and draws a few consequences with respect to the sampling strategy.

2. NOTION OF VARIOGRAM

The variogram is the basic tool of geostatistics. Like the covariance function it measures the time dependence of the data, but in a more general framework.

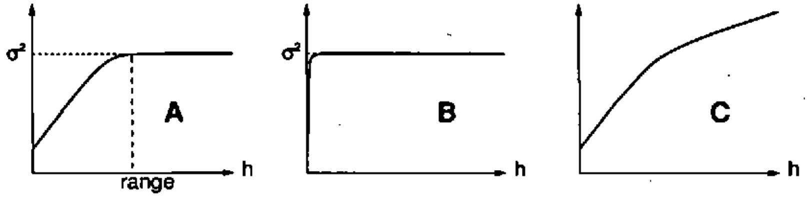

Figure 1: Different types of long-range time dependence.

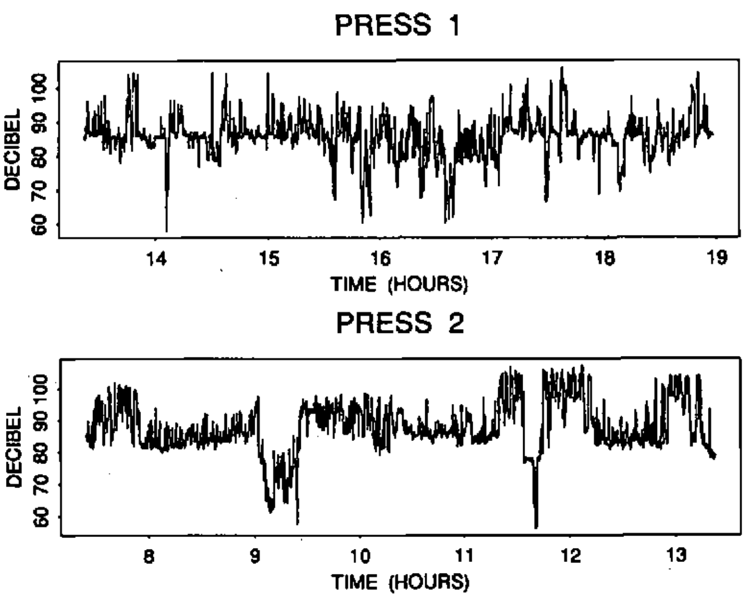

Figure 2: Time series in dB(A) for 10s integration time.

We define the acoustic power $Z(t)$ from noise levels $L(t)$ in decibels by the formula $Z(t) = 10^{-9}\,10^{L(t)/10}$. Note that the acoustic power is divided by a factor of one billion, convenient at the high noise levels to be considered.
The variogram is a function of time lag h defined as

$$\gamma(h) \quad = \quad \text{average}\left(\frac{\big(Z(t+h) - Z(t)\big)^2}{2}\right) \qquad (1)$$

where the average is computed for all data pairs separated by a given time lag. When the series are $L_{Aeq}(t)$ values measured over an integration time Δt, the variogram is made dependent upon this integration time.
The Figure 1 illustrates three types of variograms. The variogram of type A stabilizes with increasing distance at a sill equal to the underlying variance σ^2 soon as the range of autocorrelation is reached. The variogram of type B represents a phenomenon with so short an autocorrelation distance that a hypothesis of independence would be of little harm. The variogram of type C does not stop to grow within the observation interval and we are facing two possible situations: either the autocorrelation distance is larger than the observation interval or no sill can be reached at any distance [3, 4].

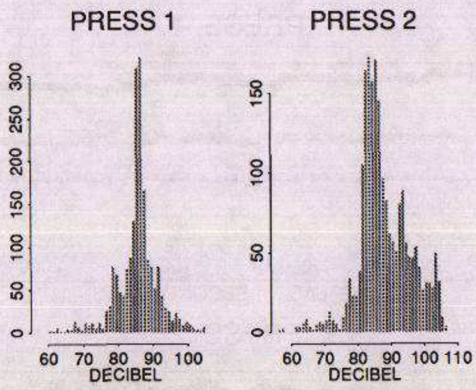

Figure 3: Histograms in dB(A) for 10s integration time.

3. APPLICATION TO TWO TIME SERIES

The data has been collected using personal sound exposure meters carried by two operators of automatic presses, termed PRESS 1 and PRESS 2. The two workers are from different factories with a different job definition and were each monitored continuously during six hours using an integration time of 1 second. The acoustic powers were also averaged over 10s and 60s for comparison of the statistical behavior at different measurement scales. The two time series in dB(A) for 10s integration time are shown on Figure 2 The histograms of the two series, to be seen on Figure 3, show more multimodality for PRESS 2 than for PRESS 1. The L_{Aeq} of the two series are respectively 90 and 94.6 dB(A).

The variograms of the two series are shown on Figure 4. They were computed on the acoustic power for the three integration times. The corresponding sample variances are represented as dashed horizontal lines. The variances drop with an increase of integration time: the upper is for 1s data, the middle for 10s and the lower for 60s. The variograms of PRESS 1 have a range of about 300s, while those of PRESS 2 stabilize only beyond 1500s. Both variograms are of type A. PRESS 1 has a range of 5mn while it is rather of the magnitude of half an hour for PRESS 2. We should thus not try to reduce the observation interval, say below an hour, in the case of the second press, being exposed to the danger of obtaining a variogram of type C, implying a non representative sample variance.

When a long run average exposure is to be estimated from samples, three parameters have to be considered: the number of samples, the integration time and the sample spacing. The variogram model allows for the optimization of these parameters, by providing a measure of efficiency of the

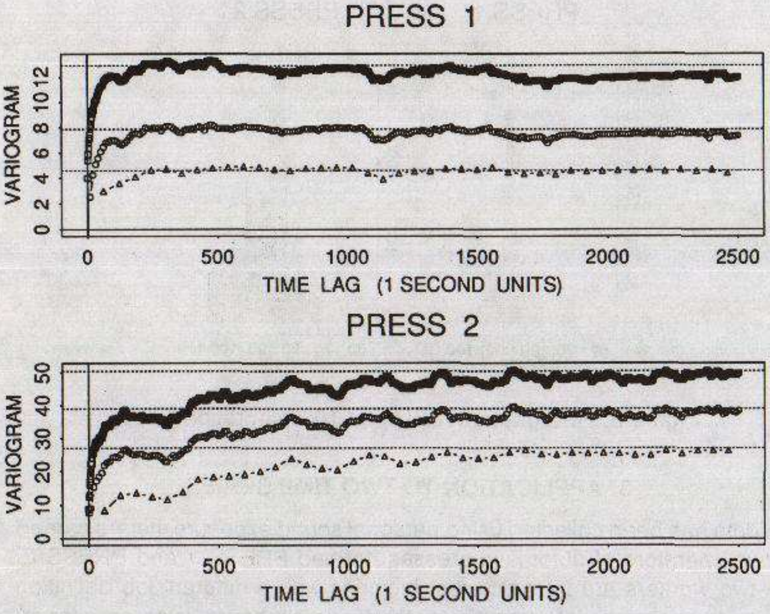

Figure 4: Variograms of acoustic power for integration times of 1s (upper), 10s (middle) and 60s (lower).

estimates for various combinations of these sampling parameters.

4. CONCLUSION

This case study demonstrates the advantage of computing variograms to characterize the variability of professional noise exposure data taking into account two basic parameters of sound monitoring: the integration time and the length of the observation interval. Variograms can be modeled and used to compute dispersion variances for various integration times (see an example on acoustic data in [2, 4]). This research is still going on to describe the variability of different types of noise exposure and to derive adequate sampling strategies.

References

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