A robust test for detecting non-stationarity

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Abstract. Tests of stationarity that require a statistical model for ambient noise may not be appropriate for huge data sets since, in most cases, the models would have to be estimated from the data itself. An alternative is presented in the form of a *robust* test : its false alarm rate is almost independent of the statistical nature of the ambient noise. Apart from robustness this test is also suitable as an online monitor of stationarity.

I THE PROBLEM

Tests for detecting transient non-stationarity [1,2], or *bursts*, that require a statistical model for the ambient stationary noise present a paradox : In practice, the noise model must be obtained from the data itself. But in order to use a portion of data for this purpose, it is first necessary to certify it as stationary ! Though an iterative procedure may get around this problem, automating it would prove to be difficult. Hence, it may not work for the humungous amount of data that interferometric detectors will produce and especially for the auxillary channels since ambient terrestrial noise is not well understood statistically.

FIGURE 1. Left panel : White Gaussian noise (variance $\sigma^2 = 1$) plus broadband burst (peak amplitude 3σ). Right panel : Output of the test. The black cluster corresponds to the burst. The white areas represent stationarity.

FIGURE 2. False alarm versus threshold curve (right panel: detail from left). Solid : GWN with variance $\sigma^2 = 1$. (G: Gaussian, W: white N: Noise.) Dashed : GWN ($\sigma = 10$), Dotted : Exponential WN ($\sigma = 1$) and Dashed-Dotted : Coloured GN with LIGO-I PSD ($\sigma = 1$).

II A SOLUTION

Use a *robust* test for which the *false alarm rate* at a given threshold depends weakly on the nature of ambient noise. We present such a test which is also computationally trivial and unambiguously provides the time of arrival and bandwidth of a burst. The basic idea behind this test is the detection of a temporary change in the Power Spectral Density (PSD) of the input data that should occur, in general, during a burst. Sample PSDs are computed for two disjoint segments of the data. Student's *t*-test [3] is used to test for a statistically significant difference in the PSDs at each frequency. Fig. 1 shows the output, a time-frequency plot.

The false alarm rate versus threshold curve for this test is estimated for several different types of noise. An example, shown in Fig. 2, demonstrates the robustness of this test (the error bars are at 1σ). The test is surprisingly powerful at detecting a wide variety of bursts. For instance, at a false alarm rate of 1 /hour, bursts centered at 200 Hz with a bandwidth of 20 Hz and embedded in noise with a LIGO-I PSD can be detected with probability 0.8 when their peak amplitude is only $1.6\times$ the r.m.s. of the background ambient noise.

ACKNOWLEDGEMENT

This work was supported by NSF awards PHY 98-00111 and PHY 99-96213 to the Pennsylvania State University.

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