PASSIVE STOCHASTIC MATCHED FILTER: APPLICATION TO SCUBA DIVERS DETECTION

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ABSTRACT

Due to its inherent discretion, passive detection is a convenient way for acoustic monitoring of maritime zone. In a context of harbour protection, one of the stakes is intruders detection e.g. scuba divers. However, the need for instantaneous reaction opens a field of research to improve the human operators' detection tools. This article proposes a new approach of the SMF as a real-time passive detection method. The feasibility has been demonstrated on scuba divers signals recorded in a tank. This first tests show that the original SMF assumptions can be relaxed and that the use of this method can drastically improve the output Sound to Noise Ratio (SNR).

Index Terms— Stochastic Matched Filter, Passive Acoustics, Detection, Scuba divers

1. INTRODUCTION

Because of its discretion and robustness, passive acoustic monitoring is nowadays one of the most common and privileged way to underwater detection of noisy threats and targets. However, due to ambient noise and propagation issues, the SNR of received signals is often low, especially when dealing with scuba divers detection [1]. Signal processing tools, improving human operators' response are needed. The best achievement realised during this first year of PhD is presented as a passive version of the Stochastic Matched Filter (SMF), fitted to this problematic. It requires a clear identification of the method's pillars and then an adaptation to passive detection. Finally, results are presented for a scuba diver record.

2. PROBLEM FORMULATION

The SMF, introduced by Cavassillas [2], is an extension of the matched filter for random signal in coloured noise. Different improvements have been reported in [3], where the SMF is presented as a time-varying linear filter. In addition of being used as an active sonar signal processing method, recent works [4] [5] deal with impulsive noise detection e.g. whales clicks, suggesting the possibility of a passive approach.

The interest for the use of the SMF instead of a classical approach as DEMON or cyclostationarity is that ideally, the SMF is able to achieve both detection and classification at once : this method searches through time for spectral similarities between a reference signal and the observation. In addition, it is based on SNR maximisation for the output of the filter and it is also a real-time embedded method. On the other hand, an accurate background noise estimation is needed, that can be tricky in a passive context. The following development presents the principle of the technique when used as a passive detection tool.

3. PASSIVE SMF PRINCIPLE

The observation, of size M, is considered as an additive superposition of the signal and the noise as $Z[m] = \sigma_S S_0[m] + \sigma_N N_0[m]$, with respectively $S_0[m]$ and $N_0[m]$ their zero-mean centred realisations and $\sigma^2_{S,N}$ the square root of the power [3]. This section develops a new application of the SMF as a passive signal processing method. Fig. 1 presents the pre-processing block diagram while Fig. 2 illustrates the real-time procedure. According to Fig. 1, the method re-

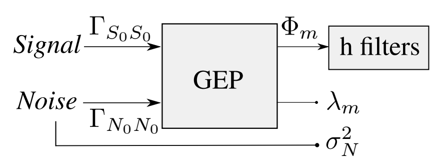

Fig. 1. Scheme of the SMF pre-processing.

quires both signal and noise references for the preprocessing stage such as $\Gamma_{S_0S_0}$ and $\Gamma_{N_0N_0}$, respectively the signal's and noise's covariance matrices. These inputs are used in the following generalized eigenvalue problem (GEP) [3] :

$$\Gamma_{S_0S_0}\Phi_m = \lambda_m \Gamma_{N_0N_0}\Phi_m,$$

to calculate the linear filter bank h using Φ_m eigenvectors as well as the λ_m eigenvalues. The current observation Z_k, where k denotes the sliding window's index, and the previously computed parameters, are then performing in real-time to estimate the reconstructed observation $\tilde{S}_{Q[k]}[k]$ (Fig. 2). It is important to notice that here, the time-dependant SNR, is estimated from the power ratio $\mathrm{SNR}_k = \dfrac{\sigma^2_{Z_k} - \sigma^2_N}{\sigma^2_N}$.

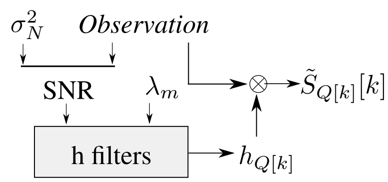

Fig. 2. Scheme of the SMF real-time processing.

So basically, a passive application of the SMF requires :

- a background noise sample, long enough to be considered as a reference or an equivalent noise simulation,
- a prior knowledge of the expected signal's spectral content and,
- estimation tools.

4. EXPERIMENTAL RESULTS

A standing-still scuba diver breathing sound, recorded with a Reson TC4034 hydrophone, sampled at $f_s = 44.1$ kHz has been used. The spectrogram of a thirty second long record can be seen on Fig. 3. It presents several short broadband noises, corresponding to the scuba diver's inhalations with two narrowbands highlighted at 6 kHz and 11 kHz, due to the pressure regulator.

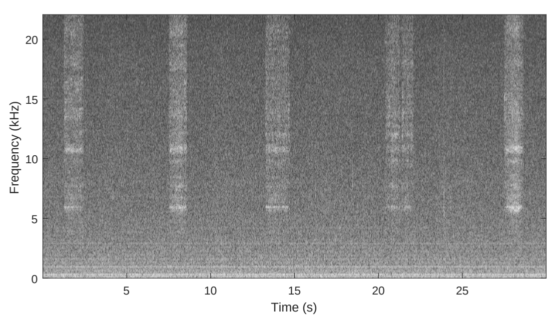

Fig. 3. Scuba diver's inhalation spectrogram.

Fig. 4 presents both the input (the observation Z_k) and the output (the reconstructed observation $\tilde{S}_{Q[k]}[k]$) of the SMF when the noise's reference described in 3 is a white noise elevated to the background noise level and the signals' reference is a synthetic signal with maximum spectral amplitude in the prior indicated frequency bands. Maximum Likelihood Estimator is the chosen noise estimator. Fig. 4 stresses the noise-cancelling property of the SMF : a strong filtering operation occurs when the signal is absent in the observation. *A contrario* a high input SNR will engender the quasi-total reconstruction of the observation. To achieve this kind of filtering, the method's keystone stands in SNR estimation. It can be drawn from those results that the application of the SMF on a scuba diver record can drastically improve the output SNR of the global observation and so enhance their exhalation cycle. Also, this procedure can be seen as the first step of a detection technique (regarding a proper decision criterion) or as a classification process : the output of the filter keeps only what matched the signal reference.

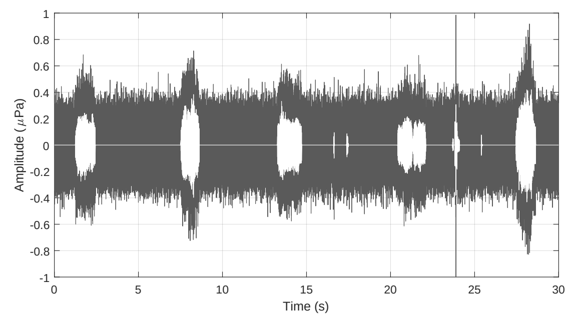

Fig. 4. Input (dark grey) and output (white) of the SMF.

5. CONCLUSION

This article deals with a passive approach of the SMF applied to scuba diver detection. Theory has shown that the SMF only needs a background noise estimation and an *a priori* knowledge about the expected signal to be effective. The stages to perform SMF as a real-time passive processing method have been succinctly presented. Results are then shown on a scuba diver record in a tank, demonstrating the feasibility of the process and highlighting the benefits of the method for SNR maximisation, detection and classification. Next step to this study is to test the method on noisier signals e.g. swimming-pool or marine records.

6. REFERENCES

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