Journal of Applied Geophysics 117 (2015) 42–51

Contents lists available at ScienceDirect

Journal of Applied Geophysics

journal homepage: www.elsevier.com/locate/jappgeo

Simultaneous denoising and preserving of seismic signals by multiscale time-frequency peak filtering

Chao Zhang [a], Yue Li [a,*], Hongbo Lin [a], Baojun Yang [b]

[a] Department of Information, College of Communication Engineering, Jilin University, Changchun 130012, China
[b] Department of Geophysics, Jilin University, Changchun 130026, China

ARTICLE INFO

Article history:
Received 9 October 2014
Received in revised form 19 March 2015
Accepted 20 March 2015
Available online 23 March 2015

Keywords:
Seismic noise attenuation
Signal preservation
Laplacian pyramid
Scale decomposition

ABSTRACT

Time frequency peak filtering has been successfully applied to eliminate pervasive random noise in the time-frequency domain. The linearity of the signal is crucial for denoising in the time frequency peak filtering method. We usually apply pseudo Wigner–Ville distribution to make the signal locally linear in time. However, there is a pair of contradiction in window length selection for pseudo Wigner–Ville distribution. If we choose a short window length for pseudo Wigner–Ville distribution in the time frequency peak filtering, it leads to good preservation for signals, but the denoising performance is relatively poor. So the contradiction between the signal preservation and noise attenuation cannot be solved by a fixed window length. In this paper, we present a multiscale time frequency peak filtering to solve this problem. In the novel method, we adopt a Laplacian pyramid to decompose the seismic data into multiple scale components. These components have different frequencies. Then a short window length can be chosen for signal-dominant scale to preserve the signal and a long window length is applied to noise-dominant scale by the time frequency peak filtering to suppress more noise. We test the performance of our proposed method on both synthetic and real seismic data. Tests demonstrate that the multiscale time frequency peak filtering based on Laplacian pyramid can eliminate the random noise more effectively and preserve events of interest better than the conventional time frequency peak filtering.
© 2015 Elsevier B.V. All rights reserved.

1. Introduction

The seismic signals are affected by various types of noise. Random noise has no rules to be predicted and it is uncorrelated from channel to channel. So it is difficult to remove from the seismic records. The weak reflection events are difficult to be identified clearly when the signal-to-noise ratio (SNR) of the noisy seismic record is low. Time-frequency peak filtering (TFPF) technique is an effective random noise reduction method for non-stationary deterministic band-limited signals (Kahoo and Siahkoohi, 2009), which has been successfully applied to seismic signal processing field (Lin et al., 2008, 2011, 2013; Li et al., 2009; Wu et al., 2011; Liu et al., 2013; Zhang et al., 2013; Tian and Li, 2014). The unbiased estimation condition of the TFPF can be better satisfied if the signal is linear in time (Boashash and Mesbah, 2004). In the conventional TFPF we use pseudo Wigner–Ville distribution to estimate the instantaneous frequency of an analytical signal and realize the local linearity. But it leads to another problem in this method. If we choose a short window length (WL) for pseudo Wigner–Ville distribution, signals can be better preserved but the noise is also left. Conversely, we can achieve a good denoising performance by using a long WL but the amplitudes of signals are also attenuated. Hence, a fixed WL cannot solve the contradiction between signal preservation and noise attenuation. Lin et al. presented a varying-window-length time-frequency peak filtering (Lin et al., 2008). This method chooses different WLs in different sections of a signal in the time domain, but the selection of WL is inaccurate due to the frequency band of the effective signal is unknown before filtering.

To make a good balance between signal preserving and random noise reduction, we separate the seismic data into signal and noise dominant components by multiscale decomposition. In the proposed method, we adopt a Laplacian pyramid (LP) to decompose the seismic data into multiple scales with different frequencies (Do and Vetterli, 2003, 2005). The scales corresponding to the main characteristic of signals are the signal-dominant scales and the scales with high intensity noise are the noise-dominant scales. So we can apply a short WL to signal-dominant scale to preserve signals and for noise-dominant scale we choose a long WL by the TFPF to attenuate more noise. Through simulations of synthetic model and real seismic record, the multiscale TFPF based on Laplacian pyramid method is proved to be more effective in eliminating random noise and preserving the reflection events than the conventional TFPF.

2. The theory analysis of time-frequency peak filtering

The TFPF algorithm realizes seismic signal denoising by encoding the noisy seismic signal as the instantaneous frequency of the analytic signal. Then we can estimate the instantaneous frequency of the analytic

* Corresponding author.
E-mail address: liyue846@sina.com (Y. Li).

http://dx.doi.org/10.1016/j.jappgeo.2015.03.022
0926-9851/© 2015 Elsevier B.V. All rights reserved.

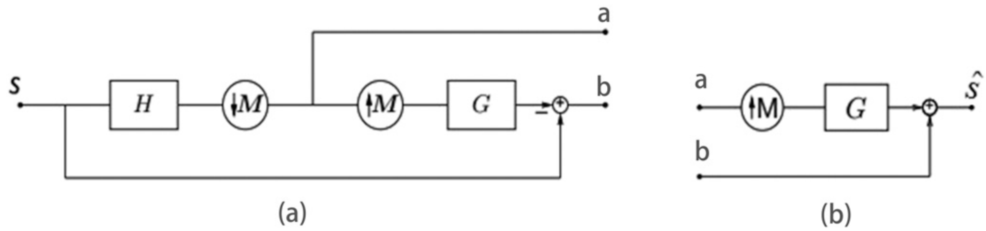

Fig. 1. Laplacian pyramid scheme. (a) One level LP decomposition. H and G are called low-pass analysis and synthesis filters, M is the sampling matrix. Output a is a coarse approximation and b is a difference between the original signal and the predicted signal. (b) The reconstruction scheme for the Laplacian pyramid.

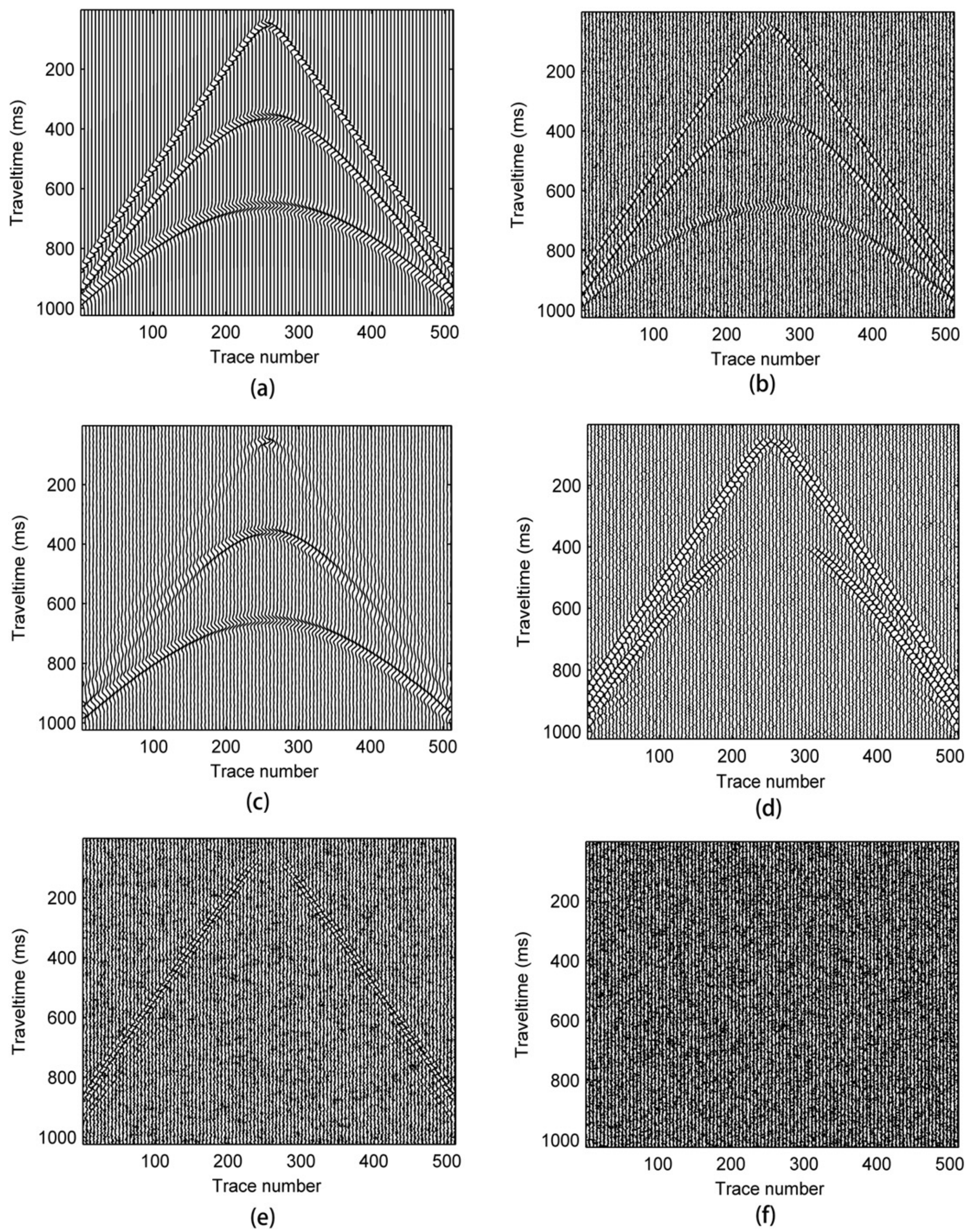

Fig. 2. Scale decomposition of synthetic seismic data. (a) Three synthetic hyperbolic events. Three Ricker wavelets of dominant frequencies 30, 25 and 20 Hz were considered to simulate synthetic waveforms as natural events. (b) Noisy synthetic seismic data (SNR = −5 dB). The synthetic data were contaminated with white Gaussian noise. (c–f) The noisy synthetic seismic data in four scales (j = 1 to j = 4).

Download English Version:

https://daneshyari.com/en/article/4739932

Download Persian Version:

https://daneshyari.com/article/4739932

Daneshyari.com