Multiscale Fusion for Improved Instantaneous Attribute Analysis

Motaz Alfarraj, Haibin Di, and Ghassan AlRegib
motaz@gatech.edu, haibin.di@ece.gatech.edu, alregib@gatech.edu

Introduction

• Complex trace analysis has been widely used in 2D/3D seismic interpretation.
• It assumes that a seismic trace \( x(t) \) is the real part of a complex trace, \( z(t) \).
• The complex trace is computed as the Hilbert transform of the seismic trace.

• From the complex trace, a suite of seismic attributes can be extracted to assist seismic data analysis such as the instantaneous amplitude, phase, frequency.
• These attributes tend to be highly sensitive to noise.
• Such limitation is traditionally overcome by:
  • Using a larger processing window
  • Post-processing techniques such as filtering

Instantaneous Attributes

• Complex seismic traces can written as:
  \[ zx(t) = x(t) + jy(t) = A(t)e^{j\theta(t)} \]
• Various attributes can be derived from complex seismic traces such as:
  1. Instantaneous amplitude: \( A(t) = \sqrt{x^2(t) + y^2(t)} \)
  2. Instantaneous phase: \( \theta(t) = \arg(z(t)) = \text{Im}[\ln z(t)] \)
  3. Instantaneous Frequency: \( f(t) = \frac{1}{2\pi} \text{Im}\left[ \frac{z'(t)}{z(t)} \right] \)
  4. Cosine of the phase: \( \cos(\theta(t)) \)
  5. Phase dip angle and Azimuth

Multiscale analysis

• Multiscale analysis has been widely used in image processing for different applications such as image coding, compression, analysis and detection.
• The purpose of multiscale analysis is to exploit features in an image at different scales or resolutions.
• A classical technique is the Gaussian pyramid.
• For an image \( f_0[m,n] \) of size \( M \times N \) constructed as follows:
  • The original image is said to be scale 0 of the pyramid
  • Scale 1 is computed by blurring \( f_0[m,n] \) with a Gaussian kernel then subsampling by a factor of 2
  • The process is repeated for subsequent scales:
    \[ f_i[m,n] = \sum_{k,l} g[k,l]f_{i-1}[2m + k, 2n + l] \]
    where \( g[k,l] \) is a Gaussian kernel defined over \( S \)
• Example:

Method

1. Generate a K-scale Gaussian pyramid for a seismic image.
2. Computed the seismic attribute for each scale in the pyramid as \( A_i[m,n] \).
3. Fuse all attributes to generate a multiscale attribute, \( A_{\text{fused}}[m,n] \).

• Fusion can be done in various ways such as:
  • Simple average: \( A_{\text{Mean}}[m,n] = \frac{1}{K} \sum_{i=1}^{K} A_i[m,n] \)
  • Weighted average: \( A_{\text{WeightedMean}}[m,n] = \frac{1}{K} \sum_{i=1}^{K} A_i[m,n] \)
  • Rank filtering (i.e. median, max, min)

Results

Multiscale attribute with mean fusion
Multiscale attribute with median fusion
Multiscale attribute with weighted mean fusion

Conclusion

• Multiscale fusion enhances the resolution of instantaneous seismic attributes by:
  1. Supressing high-frequency noise.
  2. Preserving small-scale seismic features.
• Multiscale fusion can be seen as filtering in the scale domain as opposed to spatial filtering.
• The proposed workflow can be used for other seismic attributes such as coherence and curvature.