Submission code: XPLDLRQ6PL

See this and other abstracts on our website: https://home.sbgf.org.br/Pages/resumos.php

A Memory-Efficient GPU-Based Viscoacoustic Reverse Time Migration

Gabriel Araújo (LAPPS; UFRN; Brazil;), Sergio Da Silva ([1]LAPPS; UFRN; Brazil; [2]CNR; PoliTO; Italy), Tiago Barros (Universidade Federal do Rio Grande do Norte), Samuel Xavier-de-Souza (LAPPS; UFRN; Brazil)

SBGf Conference
18-20 NOV | Rio'25

A Memory-Efficient GPU-Based Viscoacoustic Reverse Time Migration

---

Reverse Time Migration (RTM) is widely used in seismic imaging due to its capacity to produce high-resolution seismic images even in geologically complex settings. However, this accuracy comes at a high computational cost, especially when modeling attenuation effects. When deployed on GPUs—where memory is limited—the conventional approach of storing the entire source or receiver wavefield becomes impractical. Although the use of random boundary conditions (RBC) has been proposed in the literature as an effective memory-saving strategy, its application has been restricted to the acoustic wave equation. In this work, we extend the RBC approach to the viscoacoustic engine, where wavefield reconstruction is more challenging due to attenuation effects. We present an efficient GPU-based viscoacoustic RTM workflow that combines random boundaries with Q-compensation, allowing wavefield reconstruction with minimal storage requirements. This development enables scalable, high-performance Q-compensated RTM with attenuation modeling on a single GPU, offering a practical solution for large-scale seismic imaging in realistic, lossy media.

In this work, we consider the viscoacoustic wave equation introduced by Deng and McMechan (Geophysics 2007, 72:3, S155-S166), in which there is a parameter that controls the direction of propagation: = 1 for forward propagation (with attenuation) and = 1 for backward propagation (with amplitude amplification). To reduce memory usage during RTM on GPUs, we integrate the RBC technique into this viscoacoustic framework. This method pads the physical model with a boundary zone, randomly assigning the velocity values. These values are generated independently for each shot and with randomly chosen boundary thicknesses. The purpose of this padding is to produce incoherent boundary reflections, which do not correlate in the imaging condition and therefore do not generate artifacts in the final image. The key advantage of combining this strategy with the viscoacoustic equation is that it allows wavefield reconstruction with minimal memory usage: only the last two wavefields need to be stored at last time step. This feature is particularly beneficial for GPU-based RTM implementations, where memory constraints are a limiting factor. Although random reflections introduce noise, their incoherent nature ensures they do not degrade image quality significantly, enabling efficient imaging in attenuating media. In addition, we compare two imaging conditions (IC) to evaluate the effectiveness of our approach. The first is the conventional cross-correlation IC, and the second is the Inverse Scattering Imaging Condition (ISIC).

We demonstrate the feasibility of applying RBC to viscoacoustic RTM by successfully reconstructed wavefields at arbitrary time steps while storing only the last two forward-propagated wavefields—substantially reducing memory demands without compromising image quality. Despite the introduction of random noise through the boundaries, the final migrated images remained free of significant artifacts. When compared to conventional implementations using absorbing boundaries such as DAMPING or CPML, the proposed RBC-based approach yielded equivalent imaging results in terms of fidelity. Furthermore, the combination of RBC with the ISIC led to seismic images with higher resolution. From a computational standpoint, the performance gain was substantial. Our GPU implementation achieved speedups of up to 90×compared to the CPU version. These results confirm that RBC is a practical and efficient alternative for viscoacoustic RTM, especially in scenarios where memory limitations are a critical concern.