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Adapting an Accurate Reverse-time Migration Method to USCT Imaging

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Abstract : Reverse time migration has been widely used in the Petroleum exploration industry to reveal subsurface images and to detect rock and fluid properties since the early 1980s. The seismic technology involves the construction of a velocity model through interpretive model construction, seismic tomography, or full waveform inversion, and the application of the reverse-time propagation of acquired seismic data and the original wavelet used in the acquisition. The methodology has matured from 2D, simple media to present-day to handle full 3D imaging challenges in extremely complex geological conditions. Conventional Ultrasound computed tomography (USCT) utilize travel-time-inversion to reconstruct the velocity structure of an organ. With the velocity structure, USCT data can be migrated with the “bend-ray” method, also known as migration. Its seismic application counterpart is called Kirchhoff depth migration, in which the source of reflective energy is traced by ray-tracing and summed to produce a subsurface image. It is well known that ray-tracing-based migration has severe limitations in strongly heterogeneous media and irregular acquisition geometries. Reverse time migration (RTM), on the other hand, fully accounts for the wave phenomena, including multiple arrives and turning rays due to complex velocity structure. It has the capability to fully reconstruct the image detectable in its acquisition aperture. The RTM algorithms typically require a rather accurate velocity model and demand high computing powers, and may not be applicable to real-time imaging as normally required in day-to-day medical operations. However, with the improvement of computing technology, such a computational bottleneck may not present a challenge in the near future. The present-day (RTM) algorithms are typically implemented from a flat datum for the seismic industry. It can be modified to accommodate any acquisition geometry and aperture, as long as sufficient illumination is provided. Such flexibility of RTM can be conveniently implemented for the application in USCT imaging if the spatial coordinates of the transmitters and receivers are known and enough data is collected to provide full illumination. This paper proposes an implementation of a full 3D RTM algorithm for USCT imaging to produce an accurate 3D acoustic image based on the Phase-shift-plus-interpolation (PSPI) method for wavefield extrapolation. In this method, each acquired data set (shot) is propagated back in time, and a known ultrasound wavelet is propagated forward in time, with PSPI wavefield extrapolation and a piece-wise constant velocity model of the organ (breast). The imaging condition is then applied to produce a partial image. Although each image is subject to the limitation of its own illumination aperture, the stack of multiple partial images will produce a full image of the organ, with a much-reduced noise level if compared with individual partial images.

Keywords : illumination, reverse time migration (RTM), ultrasound computed tomography (USCT), wavefield extrapolation
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