Least Square Reverse Time Migration

Wenyi Hu

Advanced Geophysical Technology

ADVANCED GEOPHYSICAL TECHNOLOGY
SEISMIC IMAGING BELOW + BEYOND

Conventional RTM

Main features

- *Based on full-wave wave equation based propagator*
- *Zero-lag cross-correlation between source & receiver-side wavefields*
- *Earth imaging method for complex geological settings*

Disadvantages

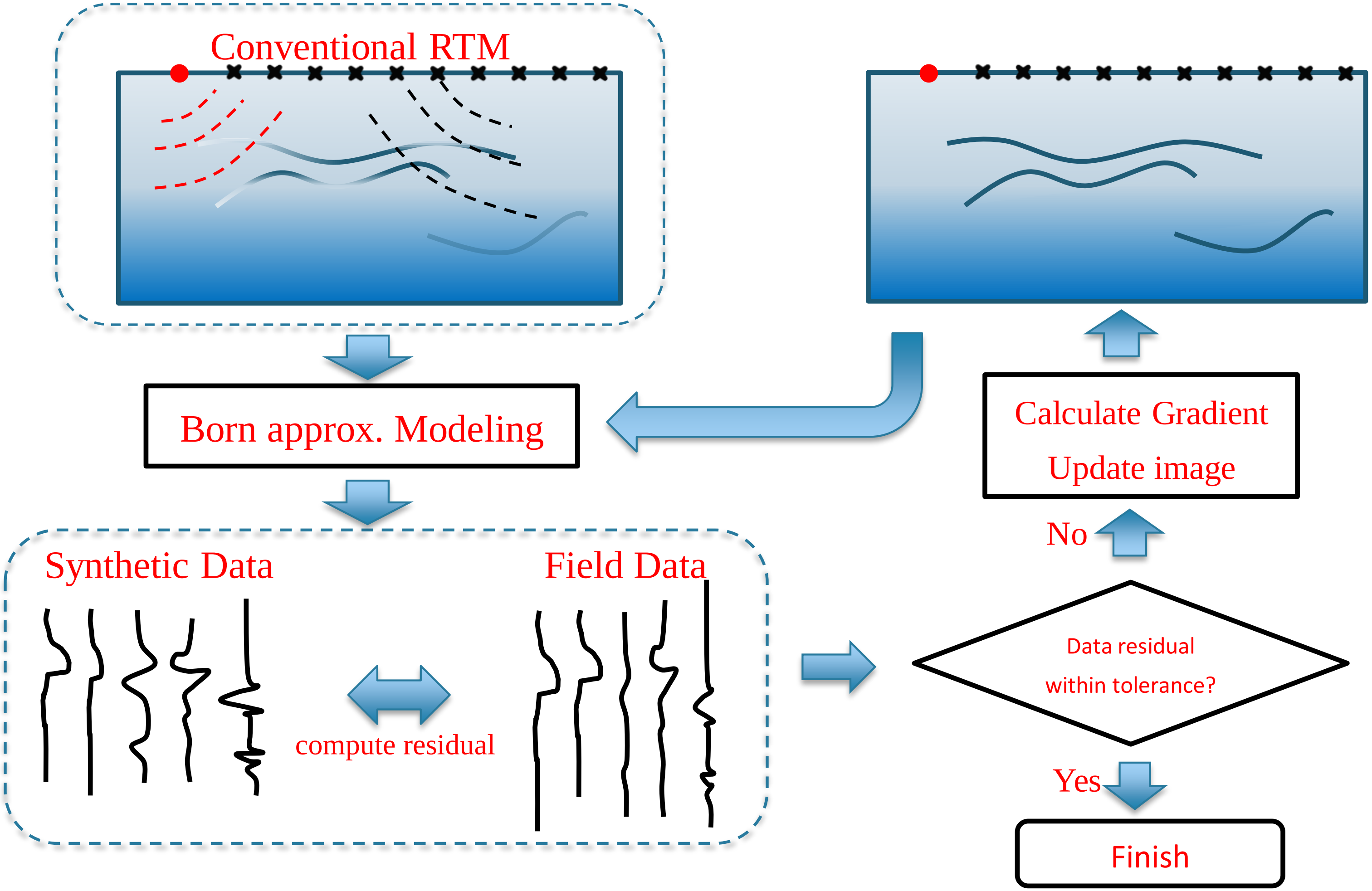
- *Image does not represent reflectivity*
- *Migration artifacts*
- *Image is source wavelet dependent*
- *Image quality depends on survey geometry*
- *Image amplitude dependent on illumination and depth*

Goal of least square RTM (LS-RTM)

- Suppress migration artifacts
- Compensate unbalanced illumination issue caused by survey geometry and geological structures
- Enhance image resolution
- Improve image lateral continuity

→ Image = reflectivity

RTM vs. LS-RTM



RTM – one step procedure

LS-RTM – iterative procedure

Background velocity & reflectivity

- Two modeling involved in LS-RTM
- Model splits into background velocity model (v_g) & reflectivity (m)
- v_g is for RTM propagator
- m is for scattered data simulation for reflectivity update

$$\nabla^2 p_0 + \omega^2 s_0{}^2 p_0 = -i\omega\rho Q$$ → RTM propagator

$$\nabla^2 \delta p + \omega^2 s_0{}^2 \delta p \approx -\omega^2 m p_0(\mathbf{r}', \mathbf{r}_s)$$ → Scattered data simulation

↓

A linear system $d = L(m)$

d – scattered data

L – linear operator

m – reflectivity

Optimization in LS-RTM

- Cost function

$$C = \frac{1}{2}\left\| L(\mathbf{m}) - M \right\|^2 + \lambda R(\mathbf{m})$$

M – recorded field data

L – linear operator

$\mathbf{m}$ – reflectivity

λ – regularization parameter

R – regularization term

γ – step-length

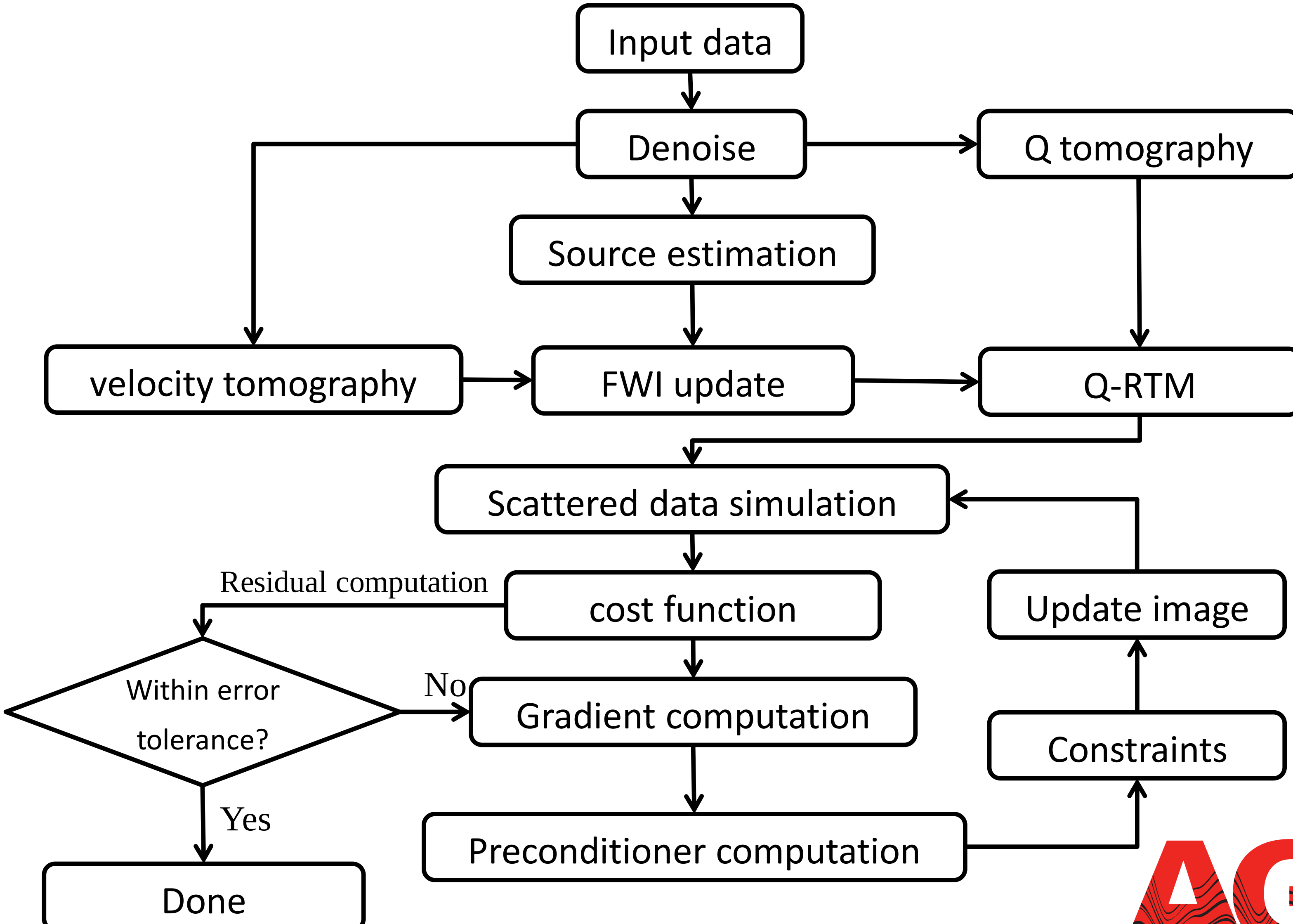
$$g(\mathbf{m}) = \nabla_{\mathbf{m}} C$$
$$= L^T(\mathbf{m})\left[L(\mathbf{m}) - M\right] + \lambda \nabla_{\mathbf{m}} R(\mathbf{m})$$

$$\mathbf{m}^{n+1} = \mathbf{m}^n + \gamma\left\{L^T(\mathbf{m})\left[L(\mathbf{m}) - M\right] + \lambda \nabla_{\mathbf{m}} R(\mathbf{m})\right\}$$

Challenges in field data LS-RTM

- Wave propagator does not take into account full physics
  - Elastic instead of acoustic
  - Q attenuation
  - Noise
- Source wavelet is unknown
- Velocity model is not accurate
  - Defocusing (especially for shallow region, far-offset)

AGT's solution to field data LS-RTM



Unique features of AGT LS-RTM

- Q tomography and Q-RTM are employed to compensate the leakage from Q effect to reflectivity
- FWI is incorporated for accurate velocity model update, especially in shallow region where velocity tomography loses capability
- Cost function is established on phase or cross-correlation to mitigate amplitude overfitting issue
- Effective preconditioner for convergence acceleration
- Constrained inversion is employed to enhance inversion stability and robustness
- Advanced regularization techniques for image quality improvement

AGT
SEISMIC IMAGING BELOW + BEYOND
ADVANCED GEOPHYSICAL TECHNOLOGY