Newton-Marchenko-Rose Imaging: Image reconstruction based on inverse scattering theory

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Ideal RTM
RTM with internal multiples

Behura et al. (CSM,Delft)
Change the experiment...
Change the experiment...
Anti-causal and causal Green’s functions

\[ G^- \quad \text{incoming} \]

\[ G^+ \quad \text{outgoing} \]
Focus-point not on reflector $\rightarrow g^- \neq g^+$

$g^-$ incoming

$g^+$ outgoing
Focus-point on reflector $\rightarrow \mathcal{G}^- = \mathcal{G}^+$

$G^-$ incoming

$G^+$ outgoing
**NMRI algorithm**

```
for any x,y,z in image space do
    build wavefields (Newton,Marchenko,Rose)
    compute \( G^- \) and \( G^+ \) (Wapenaar)
    apply imaging condition on \( G^- \) and \( G^+ \)
end for
```
Data/information used in NMRI

- surface reflection data
- direct arrivals (background velocity model)
- source signature
NMRI = obtain image from $g^-$ and $g^+$
Layer-cake model

![Layer-cake model diagram](image-url)
Layer-cake model
$G^-$ and $G^+$ at $z = 500\text{m}$
$G^-$ and $G^+$ at $z = 660m$
...and the image
Velocity used in imaging

![Velocity Field](image_url)
...and the image
Shot gather

Behura et al. (CSM, Delft)

NMRI
...and the image
Is NMRI worth it?
Limitations

- **computational cost:**
  - high if disk-space limited
  - low if large disk-space
  - low if ray-tracing used

- **number of iterations:**
  - small if multiple scattering is weak
  - large for strong multiple scattering
Advantages over RTM

- multiples imaged
- illumination compensation (potentially)
- targeted imaging
- computationally cheap (potentially)
- all frequencies imaged
- efficient anisotropy imaging
- highly parallelizable
Image after 1 iteration
Contribution of internal multiples

Behura et al. (CSM,Delft)
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Image with illumination compensation
Advantages over RTM

- multiples imaged
- illumination compensation (potentially)
- targeted imaging
- computationally cheap (potentially)
- all frequencies imaged
- efficient anisotropy imaging
- highly parallelizable
Lena’s right eye
Advantages over RTM

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Backup slides
NMRI algorithm

for any x,y,z in image space do
  Compute first arrivals $u^{i_0}$
  Initialize: $u^{i_1}_{1,2} \leftarrow u^{i_0}$, $u^{r}_{1,2} \leftarrow 0$
repeat
  Mute $u^{r}_{1,2}$ beyond first arrivals
  Update incident wavefield:
  \[ u^{i_1} \leftarrow u^{i_0} - u^{r,-t}_{1}, \quad u^{i_2} \leftarrow u^{i_0} + u^{r,-t}_{2} \]
  Update reflected wavefield:
  \[ u^{r}_{1} \leftarrow u^{i}_{1} \ast R, \quad u^{r}_{2} \leftarrow u^{i}_{2} \ast R \]
until $u^{r}_{1,2}$ converge
  \[ g^{+} + g^{-} = u^{r}_{1} + u^{i,-t}_{1} \]
  \[ g^{+} - g^{-} = u^{r}_{2} - u^{i,-t}_{2} \]
i.c. on $g^{-}$ and $g^{+}$
end for
...after low-cut filter