Improving the seismic image in Reverse time migration by analyzing of wavefields and post processing the zero lag Cross Correlation imaging condition

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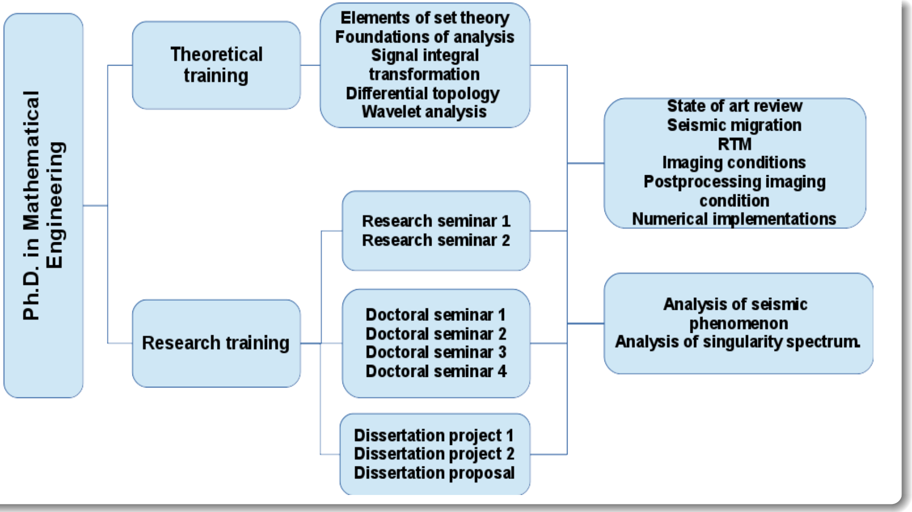
Outline

Introduction

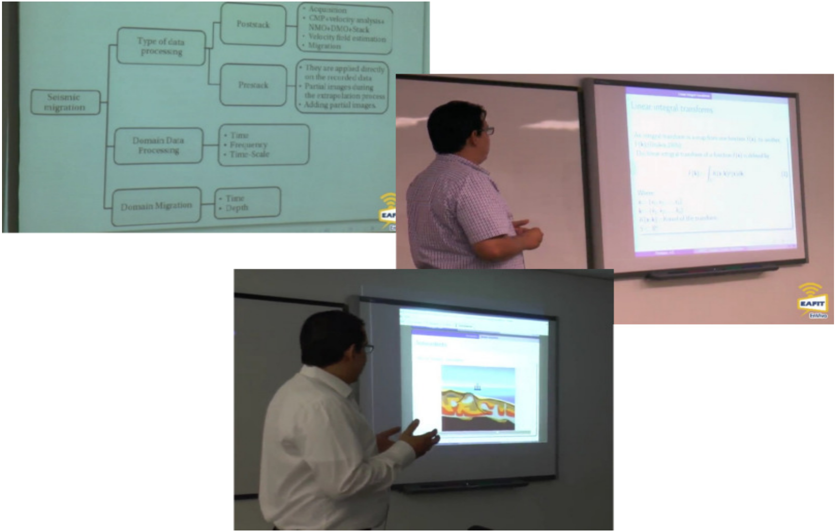
Research project ECOPETROL-COLCIENCIAS

Develop algorithms of seismic migration using wave field extrapolation in the direction of time (RTM-Reverse Time Migration), evaluating the preservation of amplitudes and frequencies as well as the conditions of stability, numerical dispersion and computational cost.

Introduction

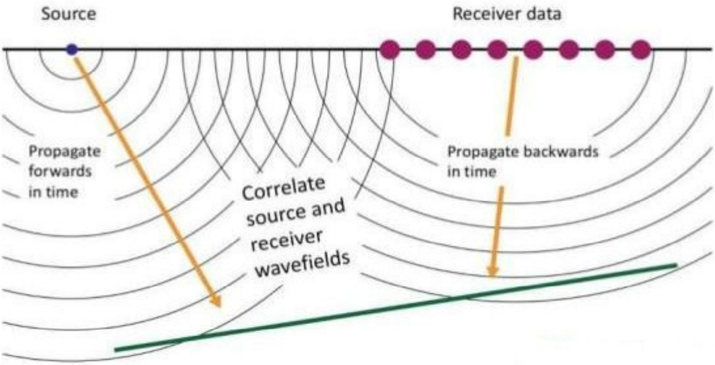


Introduction



Problem statement

Reverse time migration (RTM)



Problem statement

Cross correlation imaging condition

$$I_{CC}(x,z) = \sum_{j=1}^{s_{max}} \sum_{i=1}^{t_{max}} S(x,z;t_i;s_j)R(x,z;t_i;s_j) \tag{1}$$

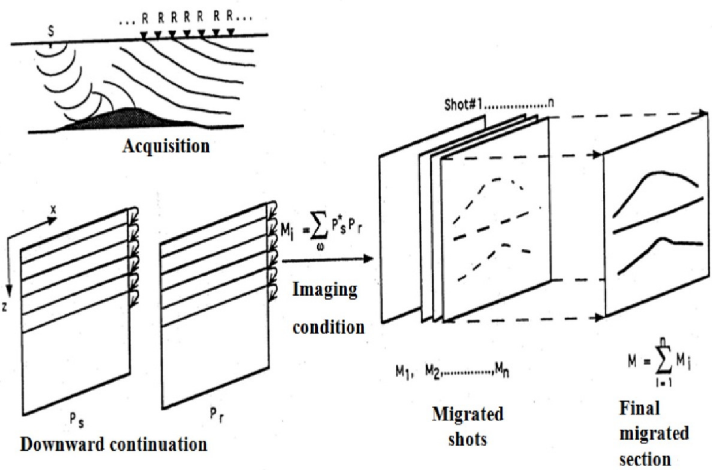
where

S: Source wavefield
R: Receiver wavefield
z: Depth
x: Distance

t: Time
t_{max}: Maximum time
s_{max}: Maximum number of sources

Problem statement

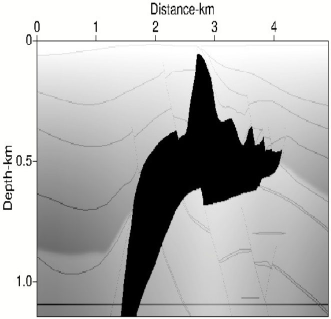
Reverse time migration (RTM)



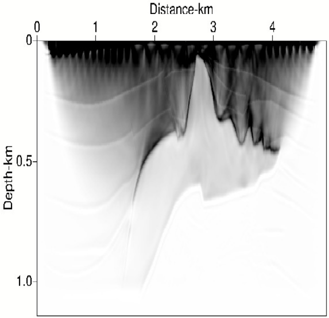
Problem statement

2*D* SEG EAGE model

Velocity model



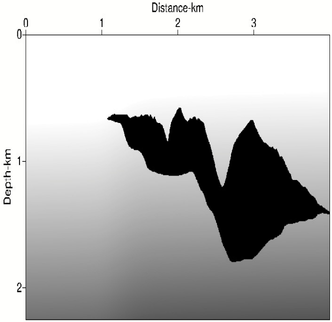
Cross correlation image



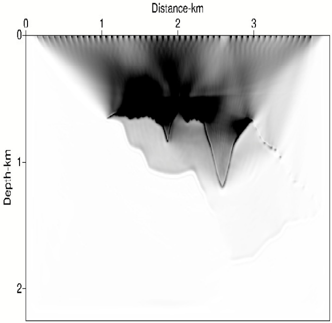
Problem statement

2*D* Sigsbee2A model

Velocity model



Cross correlation image



Problem statement

Methods to eliminate the artifacts

- Wavefield propagation approaches (Loewenthal, 1987,[25], Baysal, 1984, [3], Fletcher, 2005,[12]).
- Imaging condition approaches (Valenciano and Biondi, 2003, [37], Kaelin et al, 2006, [20], Guitton, 2007, [17], Liu, 2011, [22], Whitmore, 2012, [41], Pestana et al, 2014, [30], Shragge, 2014, [34]).
- Post-imaging condition approaches (Youn, 2001, [43], Guitton et al, 2006, [16]).

Problem statement

Imaging condition approaches

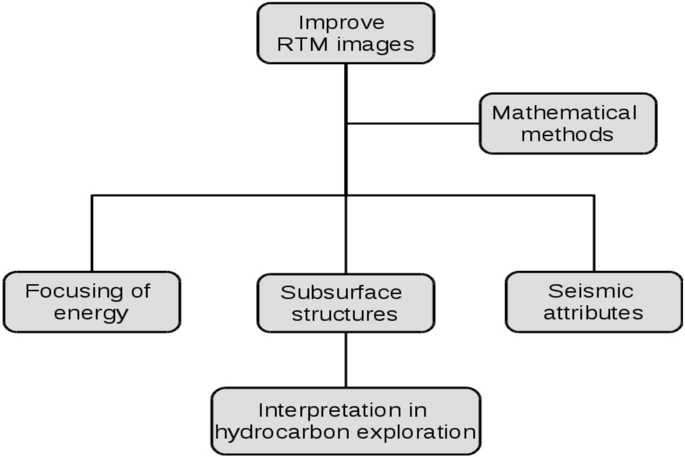
- Source illumination imaging condition
- Receiver illumination imaging condition
- Inverse scattering imaging condition
- Impedance sensitivity kernel imaging condition

Post-imaging condition approach

- Laplacian filtering

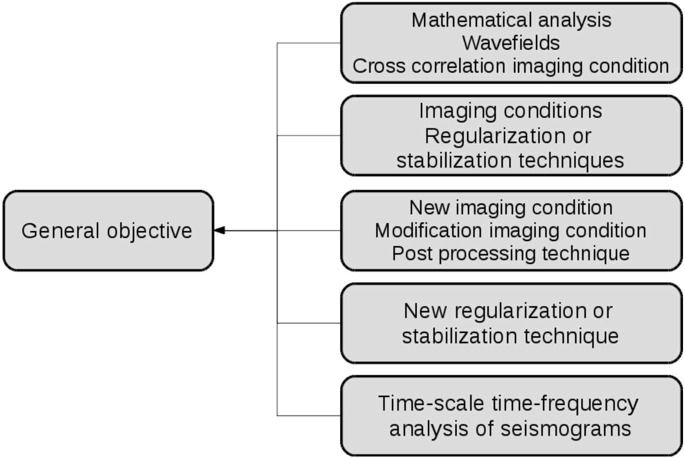
Proposal for thesis research

General objective



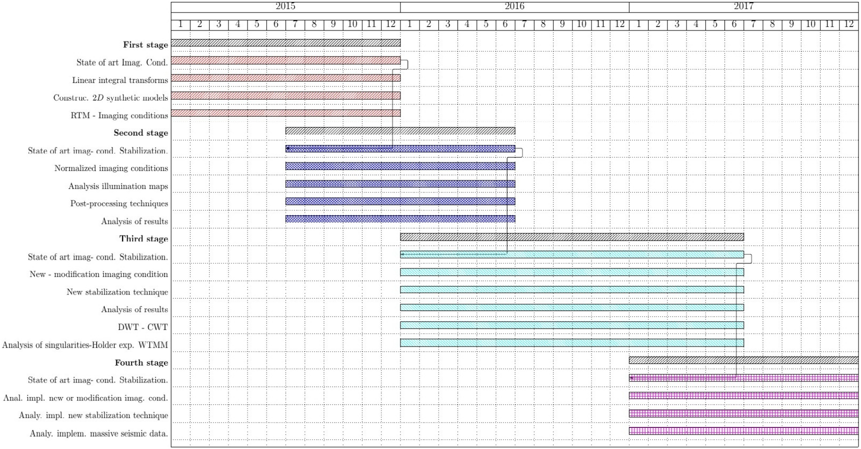
Proposal for thesis research

Specific objectives



Proposal for thesis research

Methodology



Laguerre-Gauss transform

The Laguerre-Gauss transform of $I(x, y)$ is given by (Wang et al, 2006, [39], Guo et al, 2006, [15]):

$$\tilde{I}(x,y) = \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} LG(f_x, f_y) I(f_x, f_y) e^{2\pi i(f_x x, f_y y)} df_x df_y \qquad (2)$$

where

$$LG(f_x, f_y) = (f_x + if_y)e^{-(f_x^2+f_y^2)/\omega^2} = \rho e^{-(\rho^2/\omega^2)} e^{i\beta} \qquad (3)$$

$\rho = \sqrt{f_x^2 + f_y^2}$, $\beta = \tan^{-1}\left(\frac{f_y}{f_x}\right)$ are the polar coordinates in the spatial frequency domain.

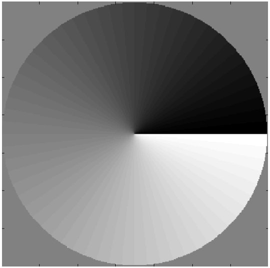
Laguerre-Gauss transform

$$\tilde{I}(x,y) = |\tilde{I}(x,y)|e^{i\theta(x,y)} = I(x,y) * LG(x,y) \qquad (4)$$

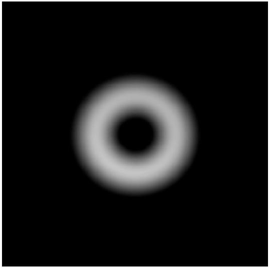
From equation (3) we obtain

$$\begin{aligned} LG(x,y) &= \mathscr{F}^{-1}\{LG(f_x,f_y)\} = (i\pi^2\omega^4)(x+iy)e^{-\pi^2\omega^2(x^2+y^2)} \\ &= (i\pi^2\omega^4)[re^{-\pi^2 r^2\omega^2}e^{i\alpha}] \end{aligned} \qquad (5)$$

Laguerre-Gauss transform



Spiral phase function

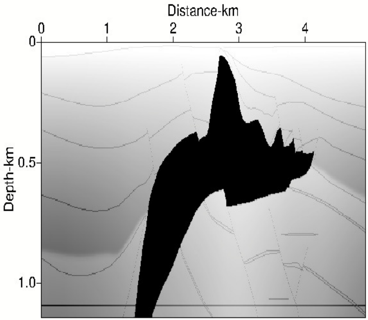


Toroidal amplitude

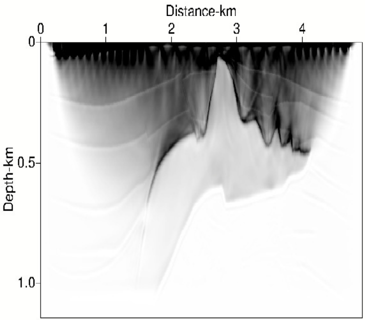
Figure: Laguerre Gauss Filter (Wang et al, 2006, [39])

2*D* SEG EAGE model

Velocity model

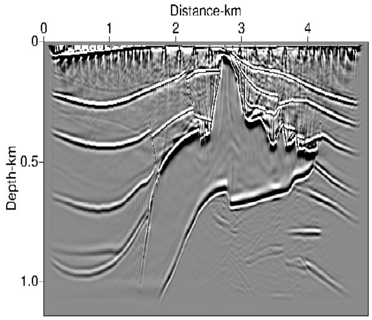


Cross correlation image

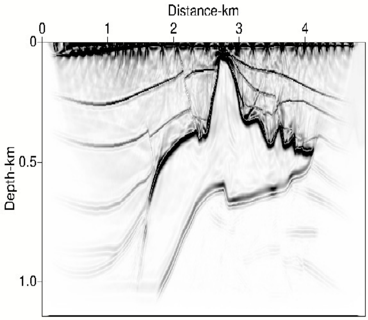


2*D* SEG EAGE model

Laplacian image

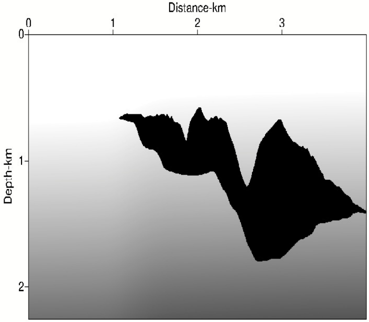


Laguerre Gauss image

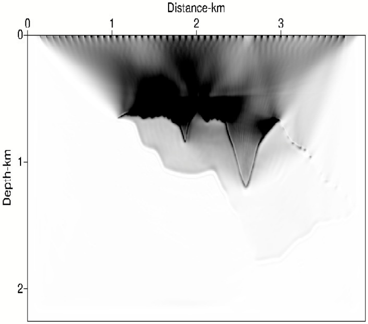


2*D* Sigsbee2A model

Velocity model

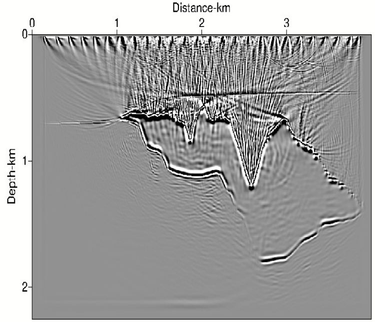


Cross correlation image

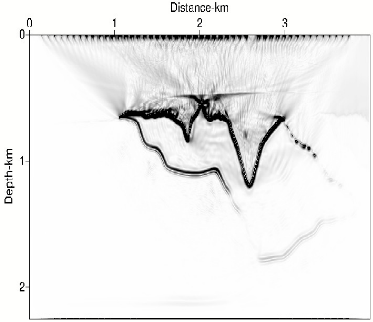


2D Sigsbee2A model

Laplacian image



Laguerre Gauss image



Future work

- Perform a mathematical analysis of the source and receiver wavefields obtained in RTM to study its effects in the cross correlation imaging condition and the illumination maps.
- Analyze the effects of stabilization techniques to avoid division by zero in the frequency domain in order to propose a stabilization technique in time domain.
- Analyze of singularity spectrum of the seismograms, and the source and receiver wavefields in order to obtain additional information to use in RTM imaging.

Future work

- Measure the accuracy of the image obtained by Laguerre-Gauss Filtering compared with the true image.
- Implement the new methodologies proposed about the imaging condition in RTM and analyze the results in different synthetic models and real massive data.

For example, if $\kappa = 1$ Suppose that is the set of all sets of size 1. Then, by the pairing axiom, $\bigcup$ is the set of all sets, which cannot exist by Russel's paradox.

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