

# Active Contour and Seismic Interpretation

---

**Muhammad Amir Shafiq\*, Zhen Wang and Ghassan AlRegib**

Center for Energy and Geo Processing (CeGP) at Georgia Tech and KFUPM

<http://cegp.ece.gatech.edu/>

School of Electrical and Computer Engineering

Georgia Institute of Technology, Atlanta, GA, 30332-0250, USA.

- Motivation
- Active Contour
  - Formulation
  - Proposed Method Overview
- Experimental Results
  - Subjective Evaluation
  - Objective Evaluation
- Summary

- **Motivation**
- Active Contour
  - Formulation
  - Proposed Method Overview
- Experimental Results
  - Subjective Evaluation
  - Objective Evaluation
- Summary

- Seismic Interpretation
  - Impermeable
  - Exploration Planning
  - Drilling Layout
- Delineation Methods
  - Edge based Methods
  - Texture based Methods
  - Graph Cut based Methods
  - 2D vs 3D Methods
  - Active Contours



- Motivation
- **Active Contour**
  - **Formulation**
  - Proposed Method Overview
- Experimental Results
  - Subjective Evaluation
  - Objective Evaluation
- Summary

# Active Contour

- An active contour is an energy minimizing, deformable curves that are governed by two energies
  - External energy
  - Internal energy
    - Penalty on curve length
    - Smoothness
- Energy minimization
- Main types include edge and region based active contours.
- Edge-based geodesic active contour with an arc length penalty

# PDE Formulation

- Energy function

$$E(C(p, t)) = \int_0^L \Phi dp + \int_0^L \frac{1}{2} \lambda \|C_p\|^2 dp$$

- Energy Minimization using gradient descent

$$C_t = -((\nabla \Phi \cdot N)N - (\Phi + \frac{\lambda}{2})\kappa N)$$

- The Edge function should be chosen such that the energy is minimum when active contour lie accurately on the salt dome boundary.

$$\Phi(x, y) = \frac{1}{(\epsilon + \|\nabla I\| * G_\sigma)^p}$$

# Level Set Evolution and Implementation

- The implicit level set evolution of the curve is computed as follows

$$\Psi_t = \widehat{\nabla\Phi} \cdot \nabla\Psi + \left(\widehat{\Phi} + \frac{\lambda}{2}\right) \nabla \cdot \left( \frac{\nabla\Psi}{\|\nabla\Psi\|} \right) \|\nabla\Psi\|$$

- We have used the upwind forward time difference scheme for numerical implementation

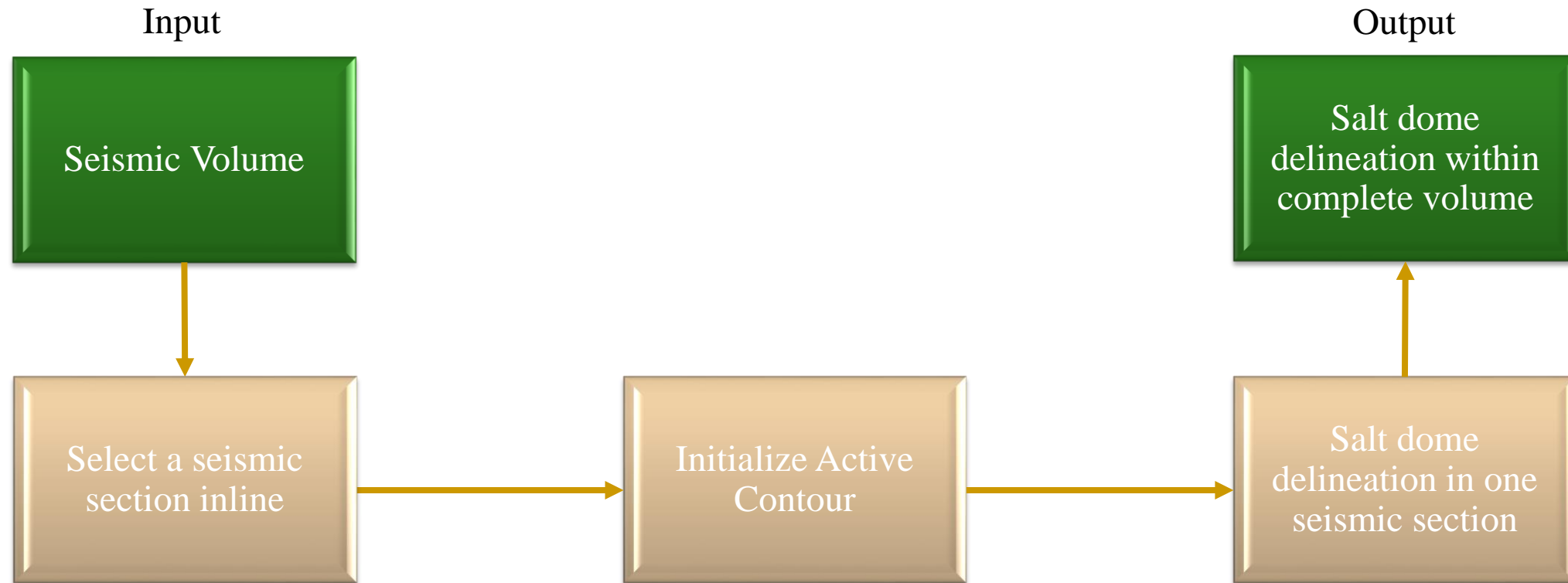
$$\Psi(t + \Delta t) = \Psi(t) + \Delta t \left( \widehat{\nabla\Phi} \cdot \nabla\Psi + \left(\widehat{\Phi} + \frac{\lambda}{2}\right) \nabla \cdot \left( \frac{\nabla\Psi}{\|\nabla\Psi\|} \right) \|\nabla\Psi\| \right)$$

$$\downarrow \frac{\Psi_x^2 \Psi_{yy} - 2\Psi_x \Psi_y \Psi_{xy} + \Psi_y^2 \Psi_{xx}}{\Psi_x^2 + \Psi_y^2}$$



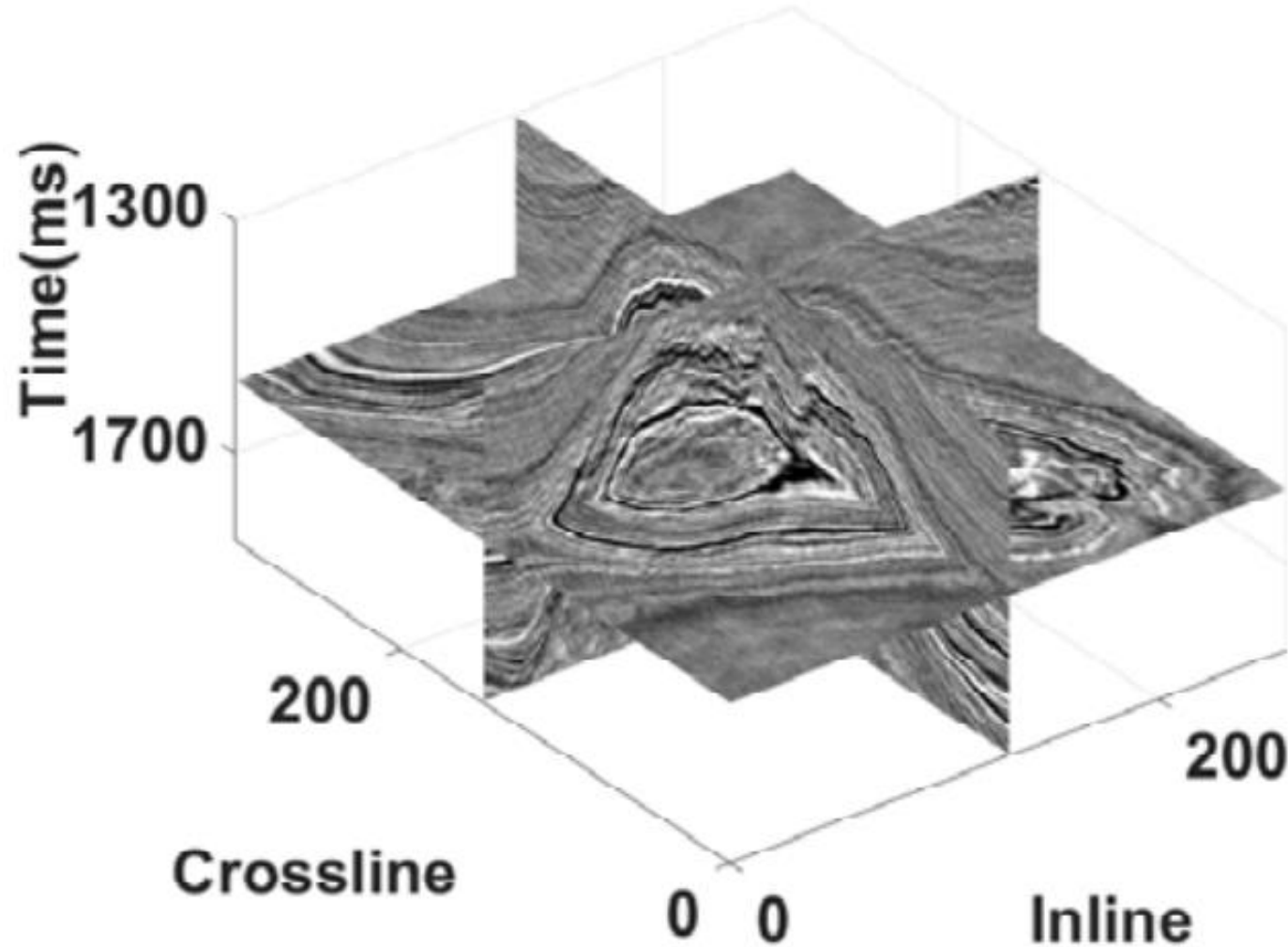
- Motivation
- **Active Contour**
  - Formulation
  - **Proposed Method Overview**
- Experimental Results
  - Subjective Evaluation
  - Objective Evaluation
- Summary

# Proposed Method Overview



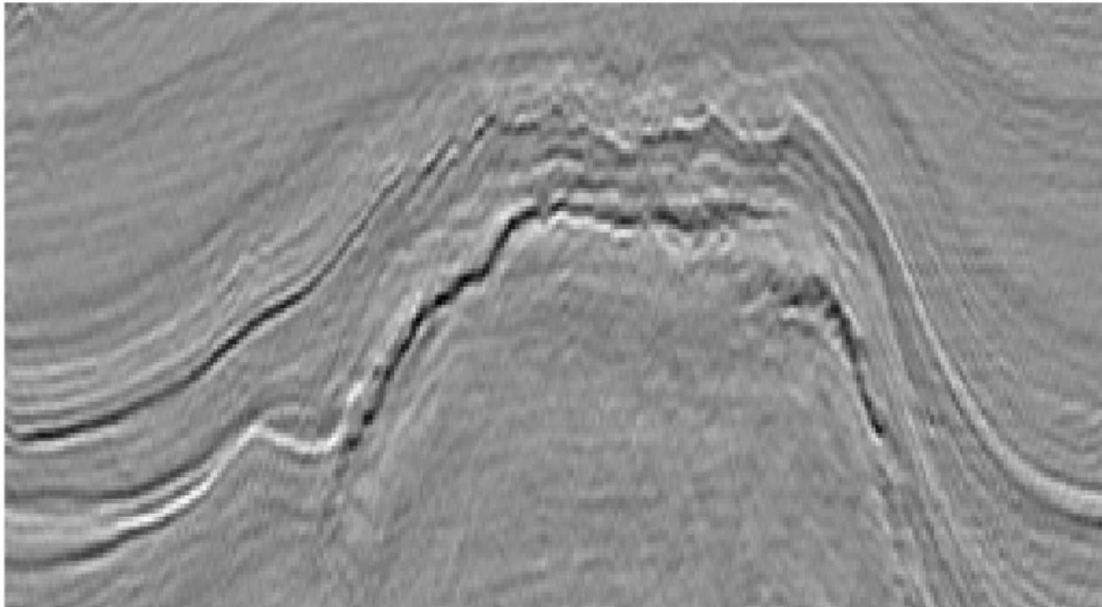
- Motivation
- Active Contour
  - Formulation
  - Proposed Method Overview
- **Experimental Results**
  - Subjective Evaluation
  - Objective Evaluation
- Summary

# Real Seismic Dataset

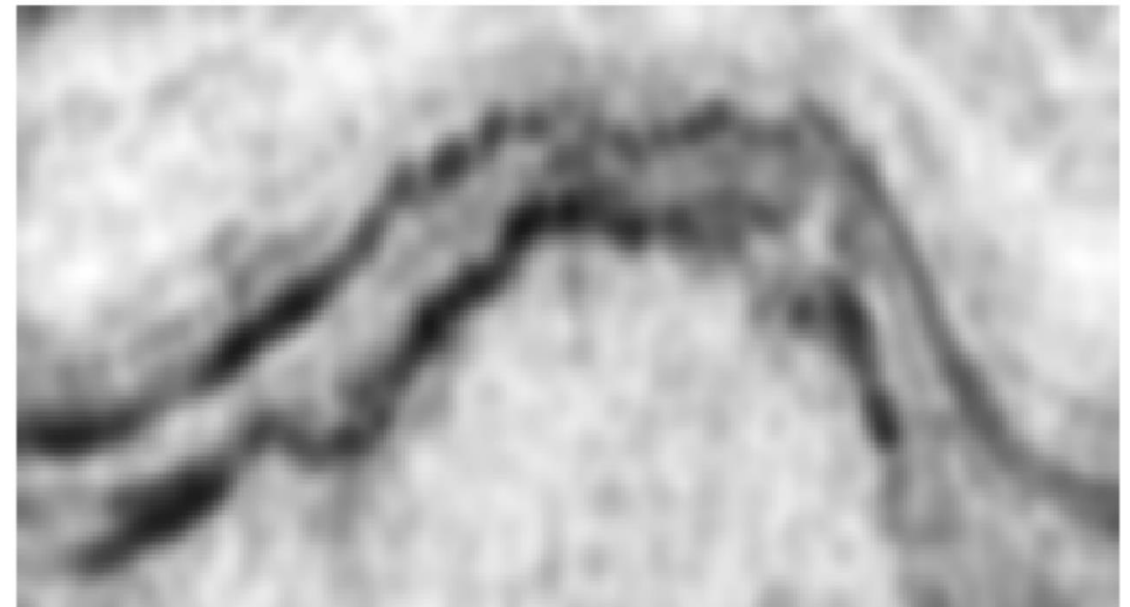


# Edge Function

Seismic Section  
Inline #369



Edge Function  
Inline #369

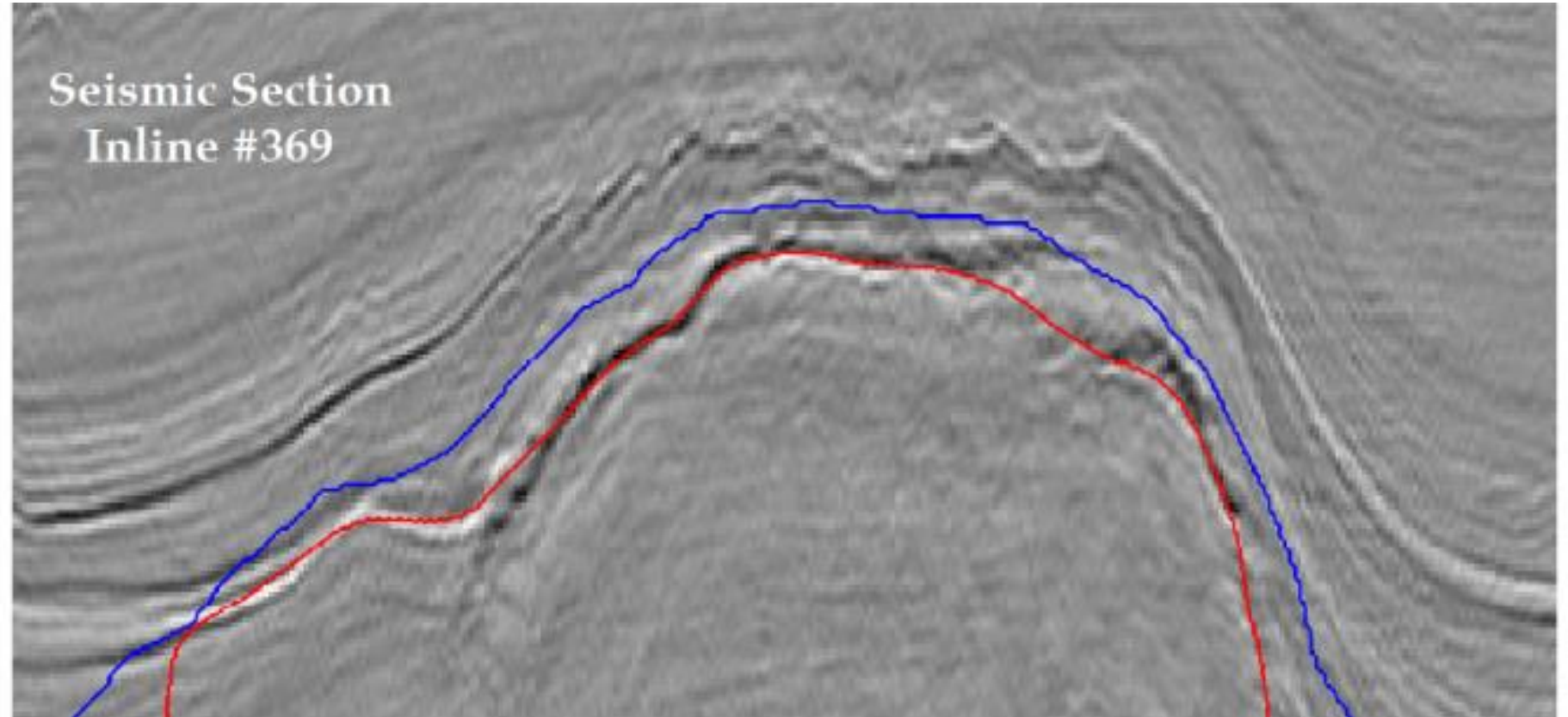


# Experimental Results

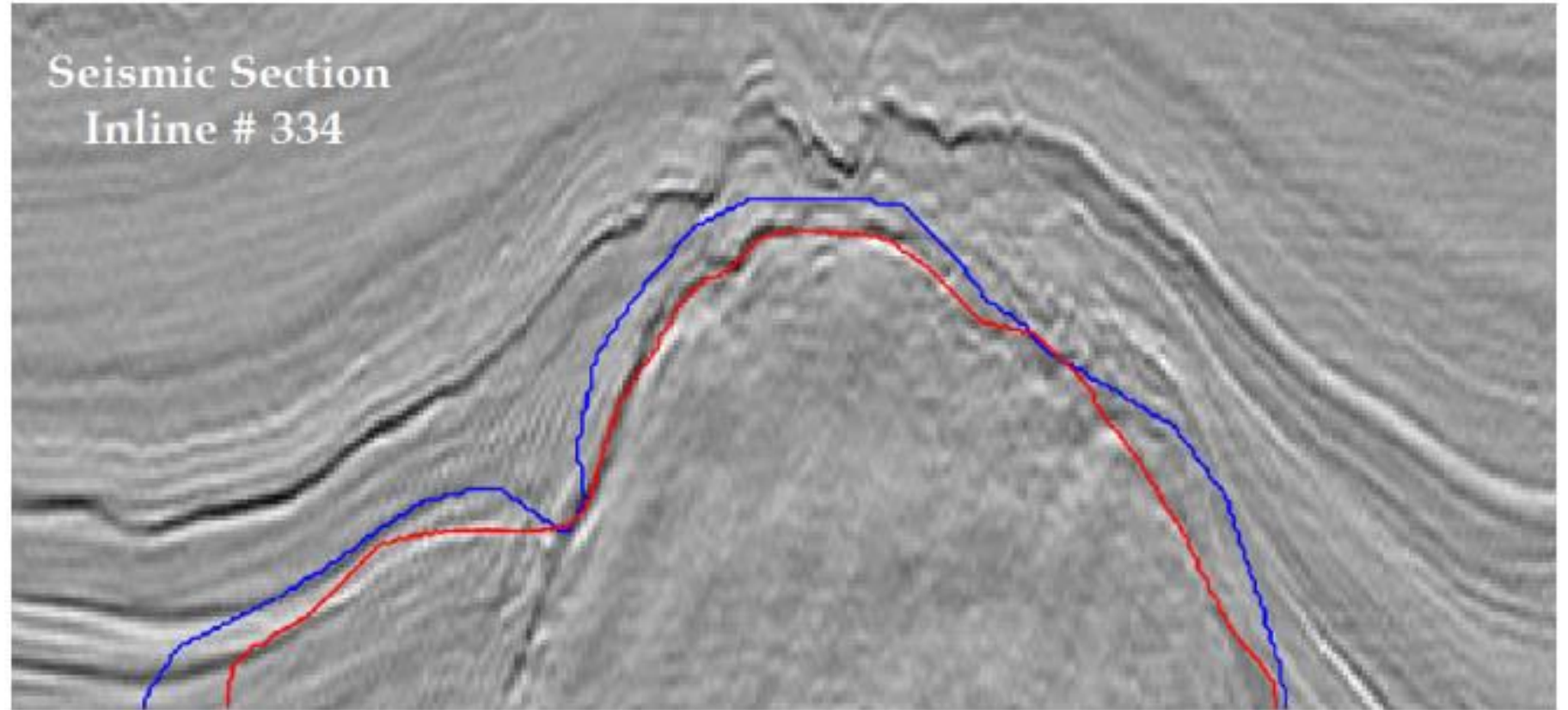
Seismic Section # 369

Blue: Initial Curve

Red: Curve after  
level set evolution



# Experimental Results



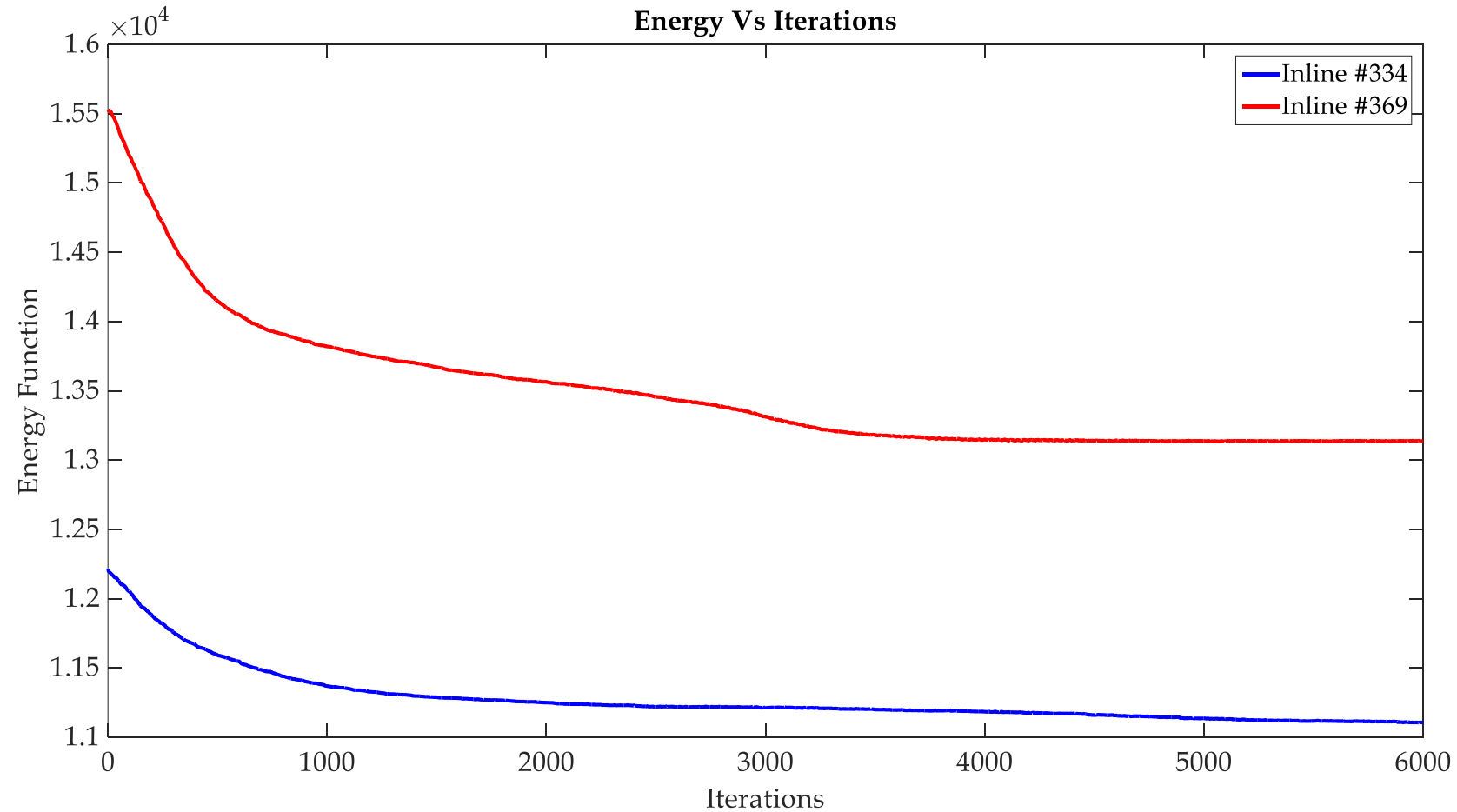
Seismic Section # 334

Blue: Initial Curve

Red: Curve after  
level set evolution



# Energy Minimization

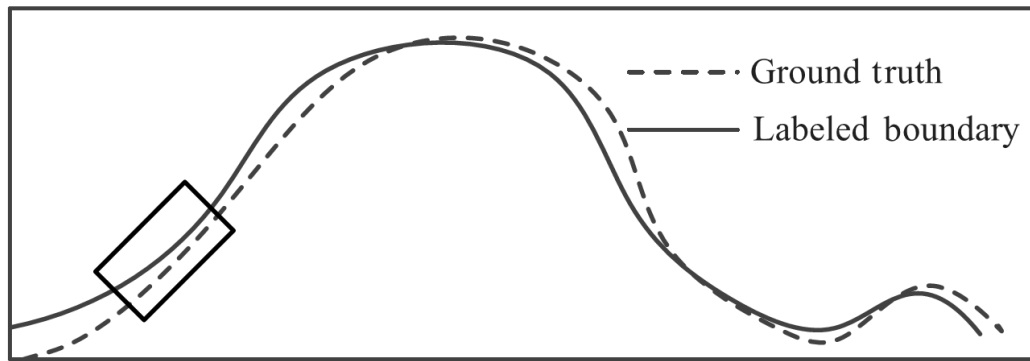




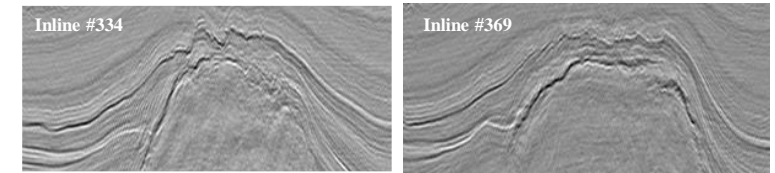
- Motivation
- Active Contour
  - Formulation
  - Proposed Method Overview
- **Experimental Results**
  - **Subjective Evaluation**
  - **Objective Evaluation**
- Summary

# Comparison: Objective Evaluation

- SalSIM: Frechet distance-based similarity index



$$\text{SalSIM} = \underbrace{e^{-\alpha \cdot (\mu_d + \sigma_d)}}_{\text{Local item}} \cdot \underbrace{e^{-\beta \cdot d_{\max}}}_{\text{Global item}}$$



Methods	Inline #334	Inline #369
Aqrawi et al.	0.7048	0.9351
Berthelot et al	0.8463	0.9194
Shafiq et al.	0.8595	0.9378
Active Contour	0.9470	0.9640

# Software Demonstration

<http://cegp.ece.gatech.edu/>

## INTERACTIVE SEISMIC INTERPRETATION

Seismic Section #369

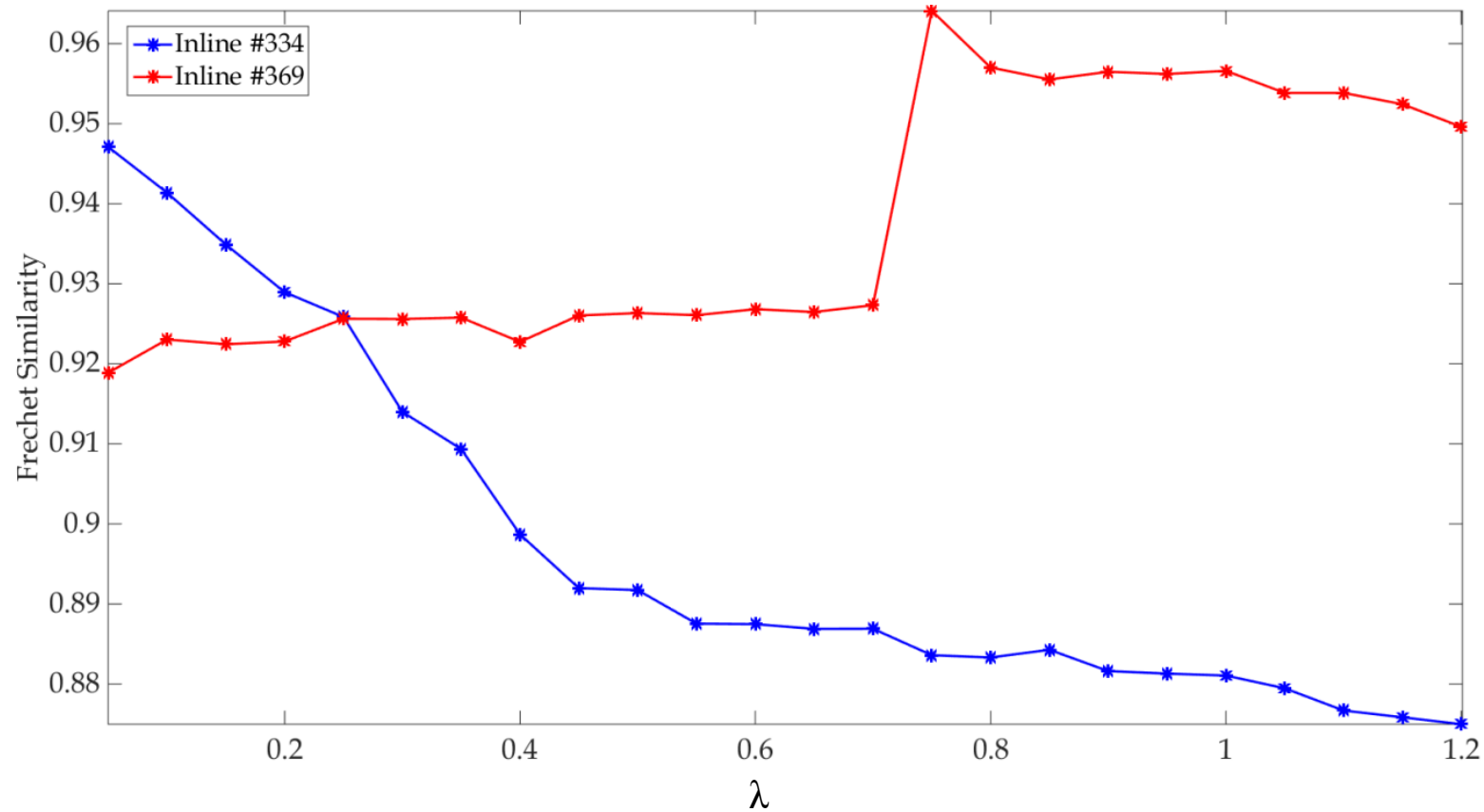
The screenshot displays the 'Interactive Seismic Interpretation' software interface. On the left, there are several control panels:

- Select Mode:** Radio buttons for 'Salt Dome Segmentation Algorithms' (selected), 'Three Dimensional (3D) Salt Dome', 'Frechet Similarity with Ground Truth', and 'Interactive SD Boundary Correction'.
- Segmentation Algorithms:** Checkboxes for 'Ground Truth', 'Aqrawi', 'Berthelot', 'Active Contour', '2D GoT', '3D GoT', and 'Codebook', all of which are checked.
- Seismic Image:** Radio buttons for 'Original' (selected) and 'Enhanced'.
- View Seismic Section:** A text input field for 'Seismic Section #' containing '369', with 'Prev' and 'Next' buttons.
- Loop Seismic Sections:** Input fields for 'Start' (349), 'Stop' (409), and 'Delay' (1), with 'Start' and 'Stop' buttons.
- References:** A button labeled 'References'.
- About/Exit:** Buttons labeled 'About' and 'Exit'.

The main display area shows a grayscale seismic section with several colored lines overlaid, representing different interpretation algorithms. A legend on the right side of the image identifies the lines: Active Contour (red), 2D GoT (cyan), 3D GoT (blue), Berthelot (yellow), Aqrawi (magenta), Codebook (black), and Ground Truth (green). The seismic section shows a prominent salt dome structure in the center, with various geological layers and faults visible.

# Curve Length Penalty

## ■ Fréchet similarity vs $\lambda$



- Motivation
- Active Contour
  - Formulation
  - Proposed Method Overview
- Experimental Results
  - Subjective Evaluation
  - Objective Evaluation
- **Summary**

- Geodesic Active contour based method for salt dome delineation.
- Implicit level set implementation using gradient descent.
- Curve length penalty for smoothness and length.
- Experimental results show effectiveness on real dataset of the North Sea, F3 block.
- Better results as compared to the state of the art methods.

- Zhen Wang, Tamir Hegazy, Zhiling Long, and Ghassan AlRegib, “Noise-robust detection and tracking of salt domes in post-migrated volumes using texture, tensors, and subspace learning,” *Geophysics*, 2015.
- Ahmed Adnan Aqrabi, Trond Hellem Boe, and Sergio Barros, “Detecting salt domes using a dip guided 3D Sobel seismic attribute,” in *Expanded Abstracts of the SEG 81st Annual Meeting*. Society of Exploration Geophysicists, 2011, pp. 1014–1018.
- Angelique Berthelot, Anne HS Solberg, and Leiv J. Gelius, “Texture attributes for detection of salt,” *Journal of Applied Geophysics*, vol. 88, pp. 52–69, 2013.
- Muhammad A. Shafiq, Zhen Wang, Asjad Amin, Tamir Hegazy, Mohamed Deriche, and Ghassan AlRegib, “Detection of salt-dome boundary surfaces in migrated seismic volumes using gradient of textures,” in *2015 SEG 85th Annual Meeting, New Orleans, Louisiana, Oct. 18-23, 2015*.
- dGB Earth Sciences B.V., “The Netherlands Offshore, The North Sea, F3 Block - Complete,” <https://opendtect.org/osr/pmwiki.php/Main/NetherlandsOffshoreF3BlockComplete4GB>.
- <https://www.domeenergy.com/wp-content/uploads/2014/06/SaltDomeComplarge.jpg>

# Thank You

---

Questions!

<http://cegp.ece.gatech.edu/>

