Saliency Detection for Seismic Applications Using Multi-dimensional Spectral Projections and Directional Comparisons

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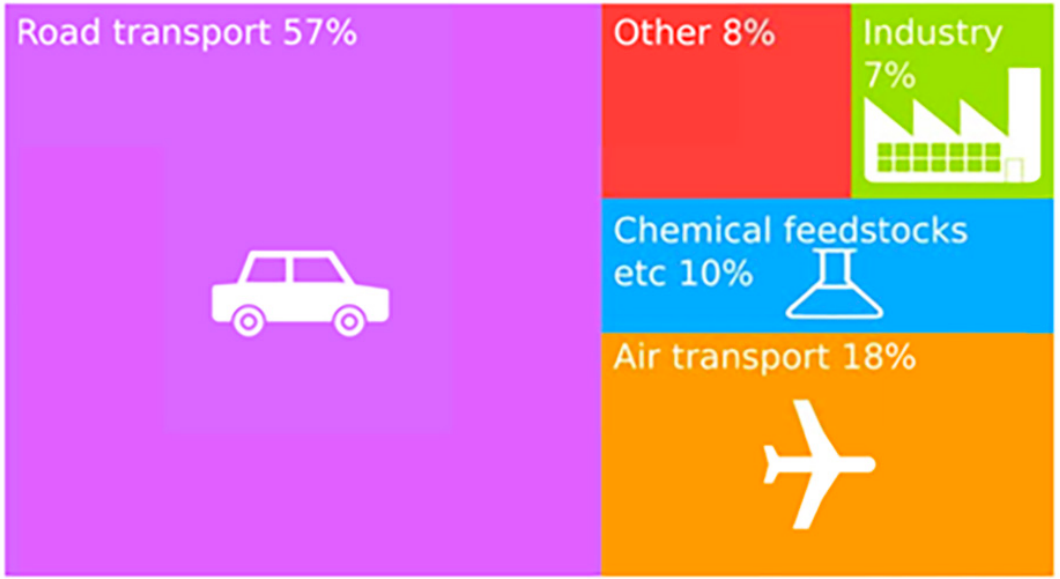
Outline

I. Introduction
II. Literature Survey
III. Seismic Saliency
IV. Proposed Method
V. Experimental Results
VI. Conclusions

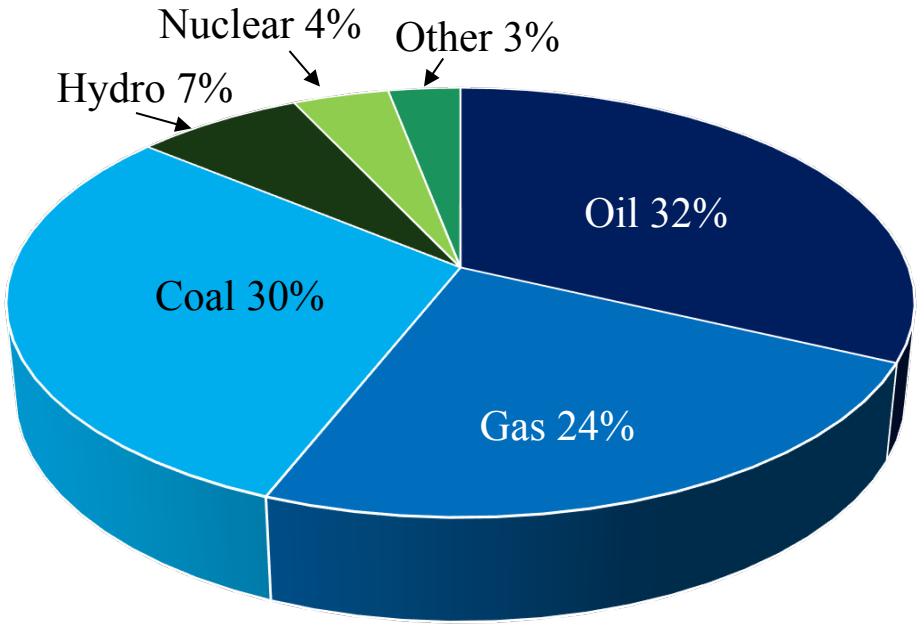
Outline

I. Introduction

- Petroleum products and natural gas account for 99.99% of powered transportation around the globe and oil is directly responsible for about 2.5% of world GDP
- In 2010, petroleum produced over 5.7/15 terawatts of power. In comparison, the same year, wind and solar energy produced 34 and 3.4 gigawatts, respectively.



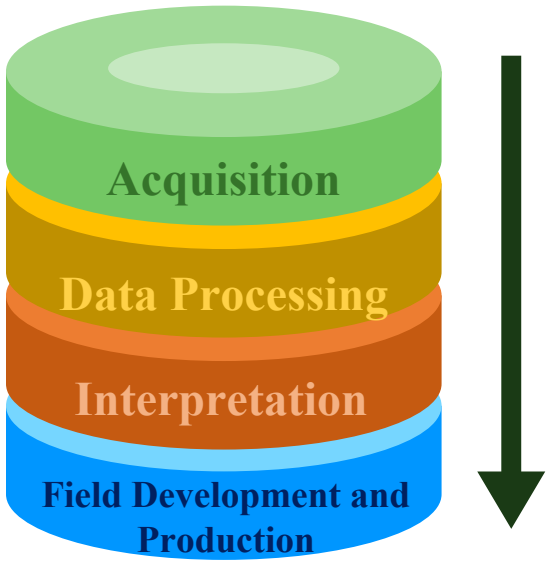
Industry Usage of Oil and Gas. [1]

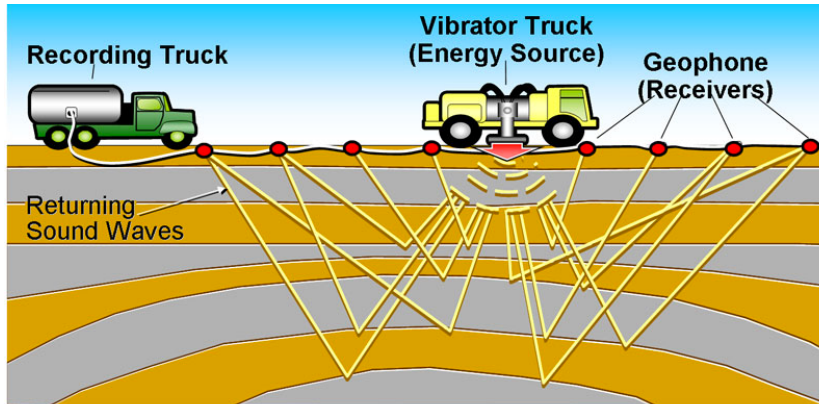


Global Energy Consumption 2015 [2]

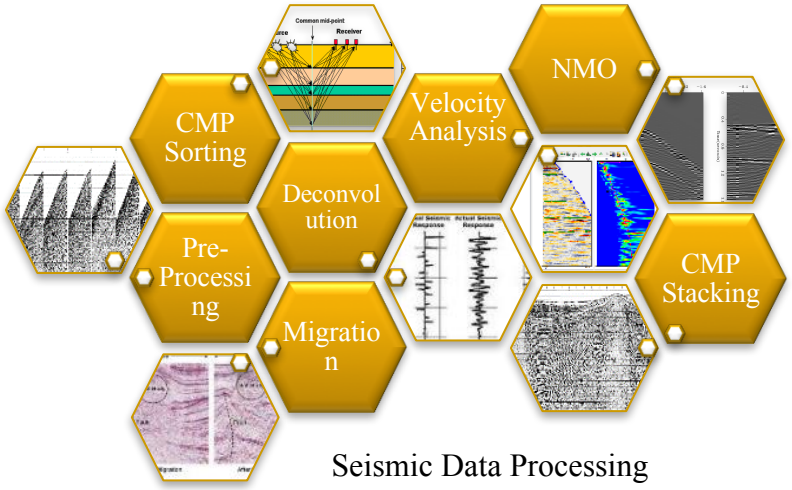
[1] http://www.world-petroleum.org/edu/221-why-are-oil-and-gas-important
[2] http://euanmearns.com/global-energy-trends-bp-statistical-review-2015/

I. Introduction
- Exploration and Production Workflow

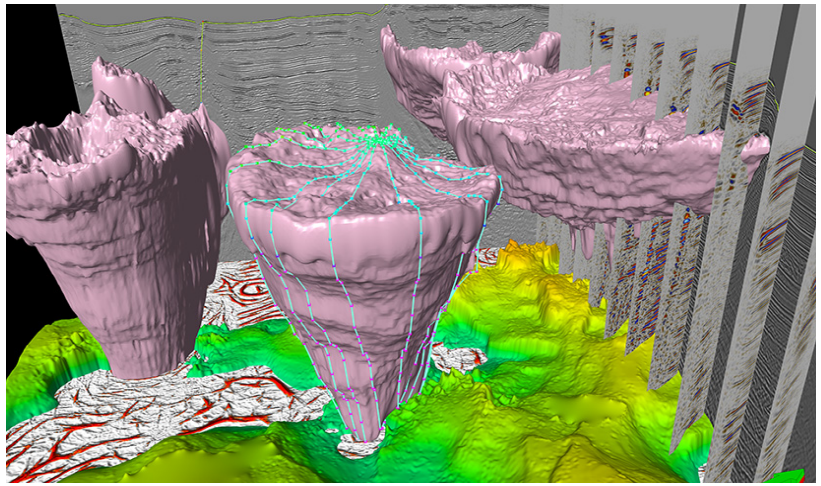




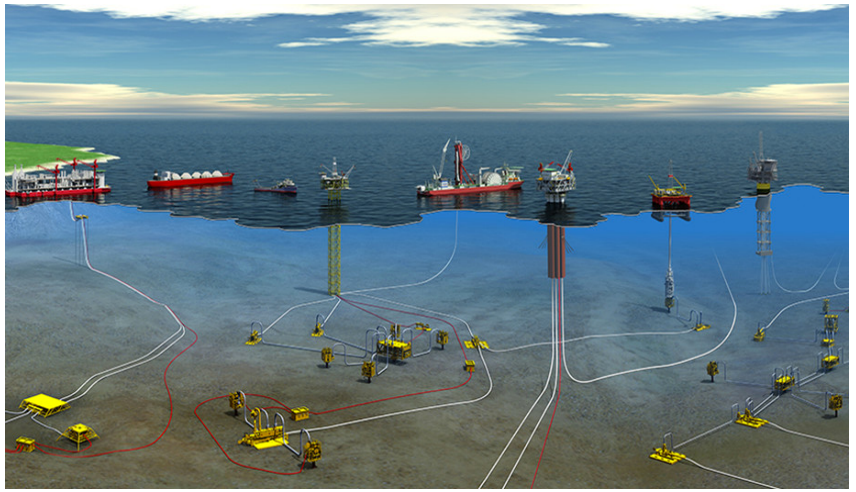
Seismic Acquisition on Land.



Seismic Data Processing



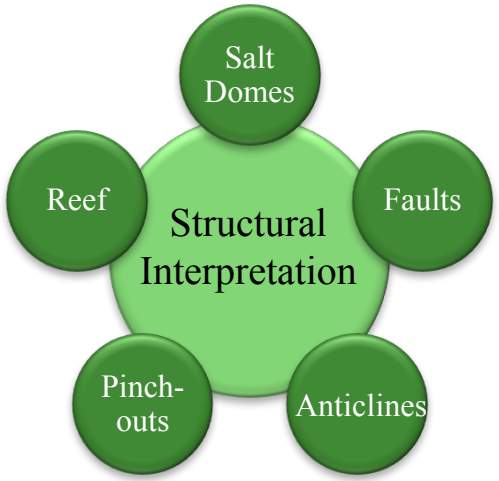
Seismic Data Interpretation

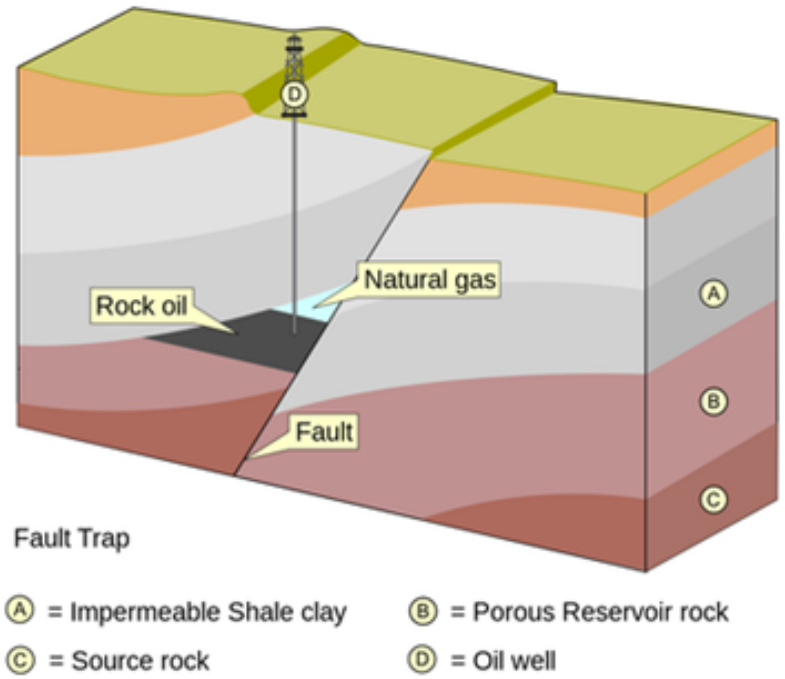


Oil and Gas Production from the Field

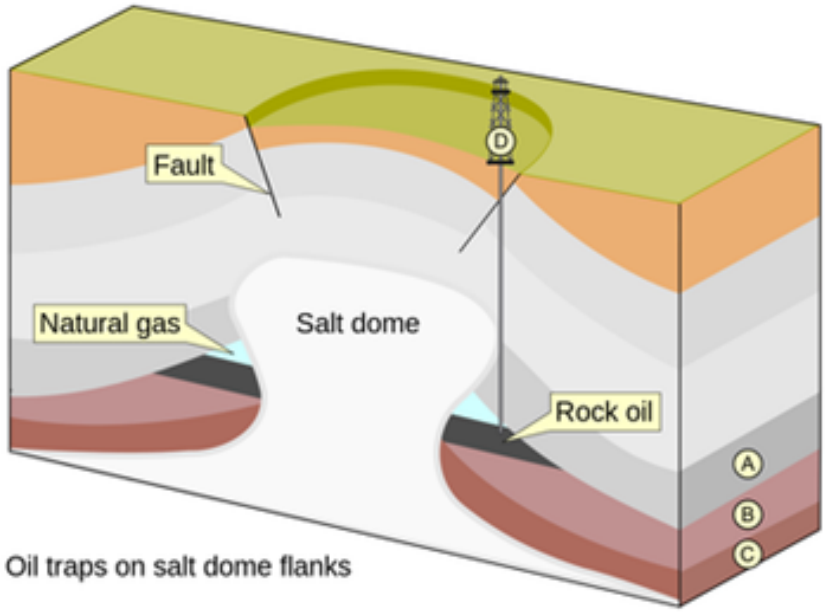
I. Introduction
- Structural Interpretation (Faults)

- Different structures are closely related to the formation of oil and gas reservoirs
  - Faults: *Discontinuity, Line-like or curved shapes*
  - Salt Domes: *Texture, Dome-like structure*





Fault Trap



Salt Dome Trap

I. Introduction
- Challenges in Interpretation

- Large-scale Seismic Data Acquisition
- Manual Interpretation
  - Time consuming
  - Labor intensive
- Automated Seismic Interpretation

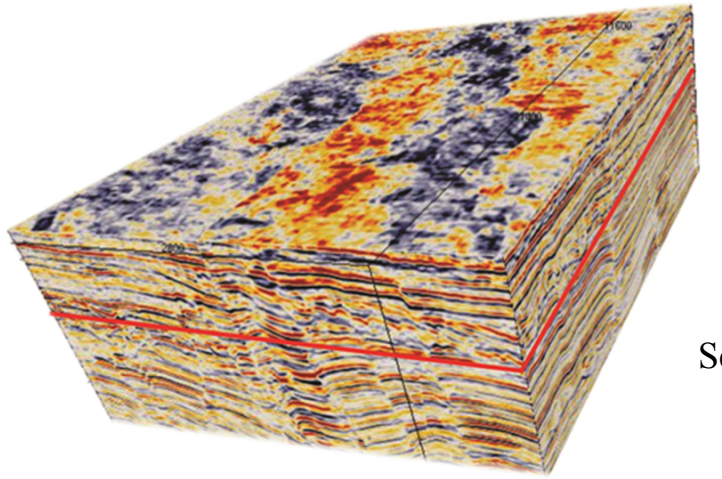
1 km^2 seismic survey for one hour → Seismic surveys: Peta Bytes of data → Generate 1TB migrated data → Years for manual interpretation

Up to 160 shots/1 km^2

20,000 traces per shot, every 10s

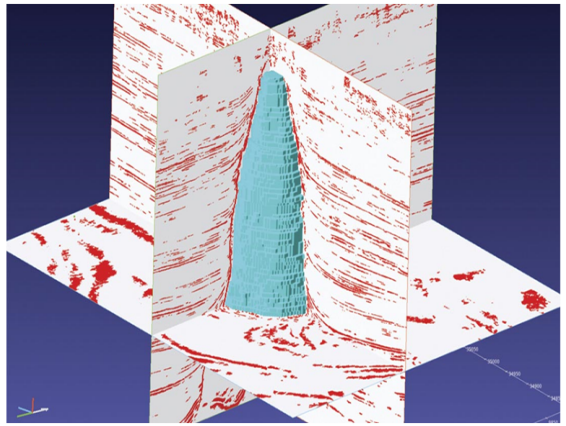
500 samples per trace per second

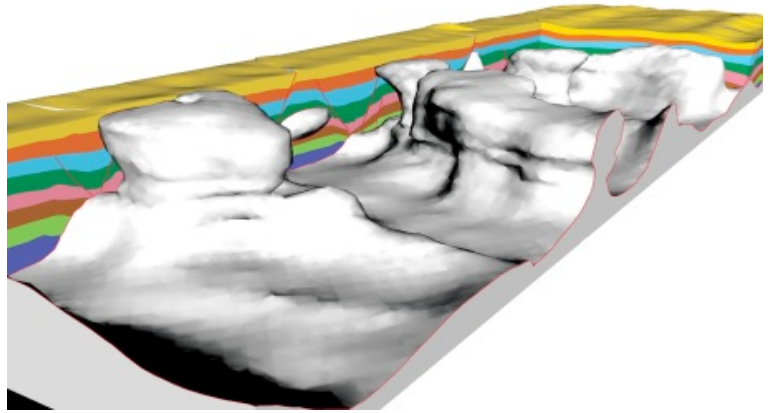
Generate 600GB data



Migrated Seismic Volume

Computational Seismic Interpretation





Seismic Interpretation [1-2]

[1] http://csegrecorder.com/articles/view/advances-in-true-volume-interpretation-of-structure-and-stratigraphy-in-3d
[2] http://www.dgi.com/earthvision/evnews/evnews.html

Outline

II. Literature Survey

Salt Domes

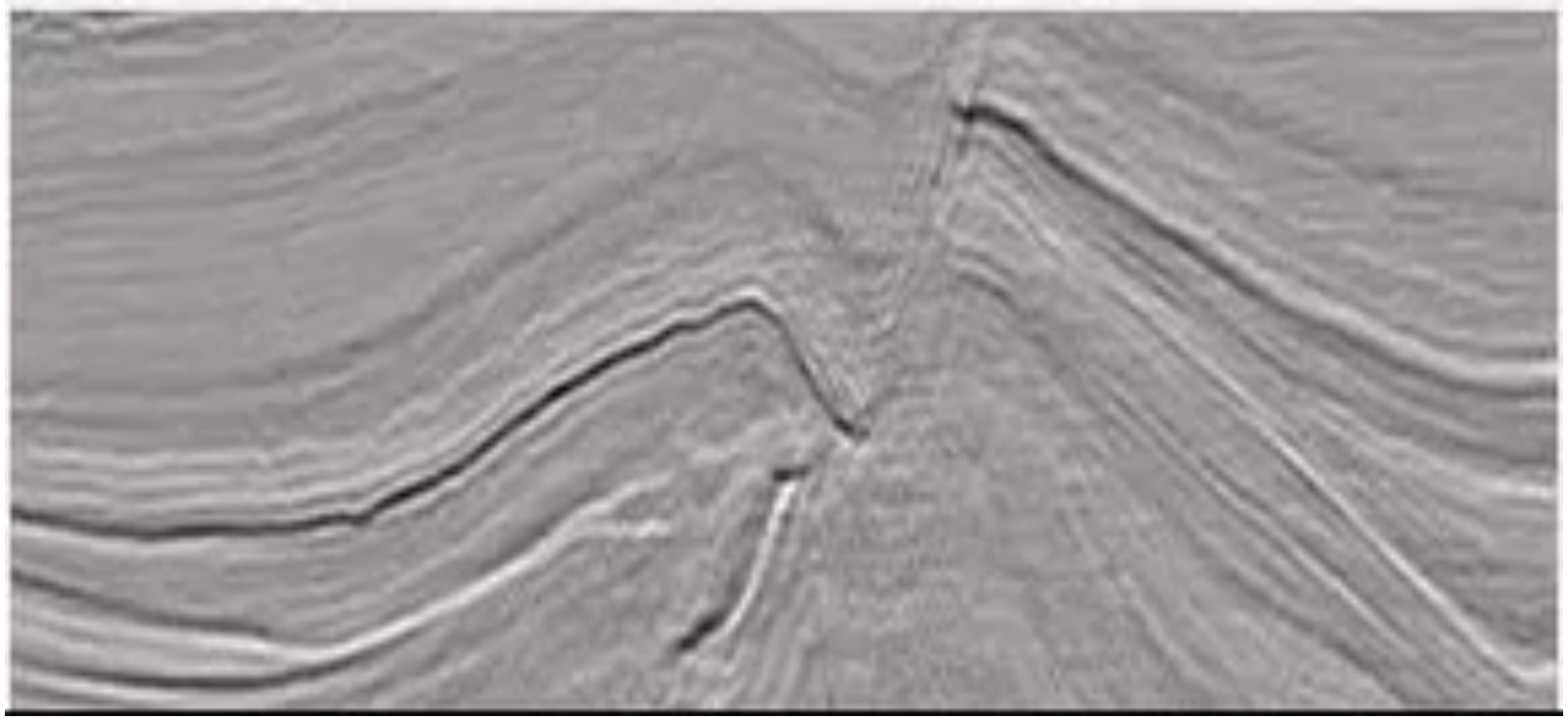
Methods/Year	Before 2007	2007	2008	2011	2012	2013	2014	2015			2016	
Edge	Bahorich and Farmer 1995	Jing *et al.*		Aqrawi *et al*	Alabbasi	Laake *et al.*			Amin and Deriche	Amin and Deriche		
Texture	Haralick *et al.* 1973					Berthelot *et al.*	Hegazy and AlRegib	Wang *et al.*	Amin and Deriche	Guillen *et al.*		Ferreira *et al.*
Graph Theory		Lomask *et al.*	Halpert *et al.*				Halpert *et al.*					
Level set					Winston *et al.*	Haukås *et al.*						
Machine Learning							Larrazabal *et al.*	Amin *et al.*	Larrazabal *et al.*	Guillen *et al.*	Qi *et al.; Wu*	Amin *et al.*
Attributes	Randen *et al.*2003; Kovesi *et al.*1999				Anna *et al.*	Briain *et al.*	Keith e*t al.*					

Faults

Methods/Year	Before 2005	2005		2006	2007	2013		2014		2015	2016
Hough Transform		Jacquemin and Mallet							Wang and AlRegib		Wang *et al.*
Ant tracking	Randen *et al.*		Pedersen *et al.*		Cox and Seitz	Yan *et al.*	Basir *et al.*		Hanif *et al.*		
Attributes	Meldahl *et al.*; Kristofer *et al.*	Chopra and Marfurt	Dorn *et al.*	Goff *et al.;* Cohen *et al.*		Hale	Qi and Castagna	Zhang *et al.*		Wu and Hale	Kluesner and Brothers
Color									Wang *et al.*		
Machine Learning	Meldahl *et al.*						Basir *et al.*	Wang *et al.*	Zhang *et al.*	Barna *et al.*	

Outline

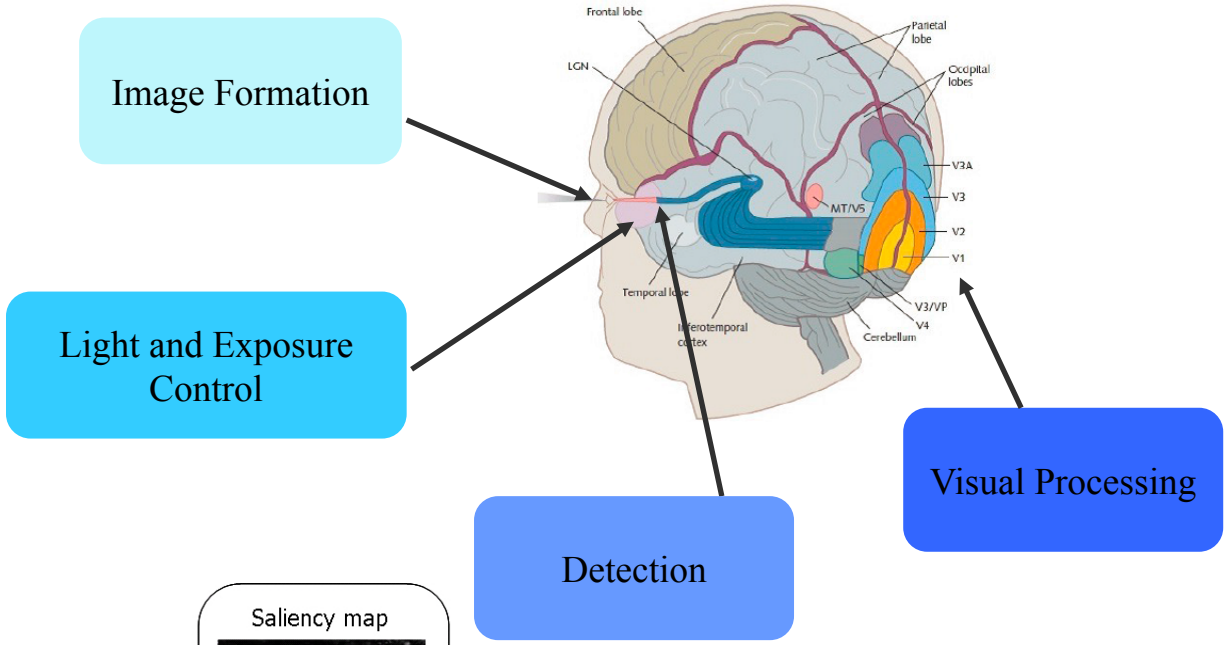
III. Seismic Volume and Visual Saliency



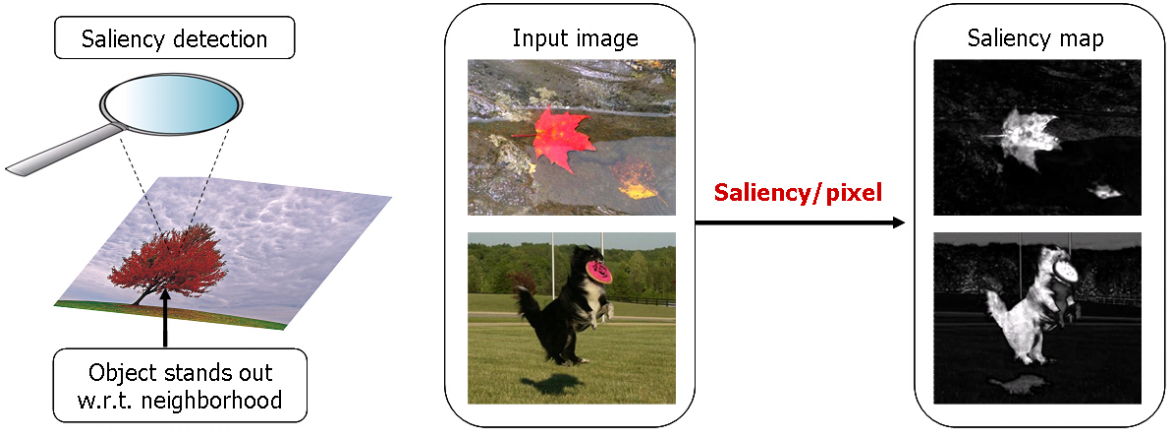
Seismic Volume, F3 Block, North SEA

III. Visual Saliency

- Human visual system (HVS) is sensitive to
  - Structure
  - Motion
  - Surrounding information
- Attention models mimic the behavior of human subjects looking at an image or video



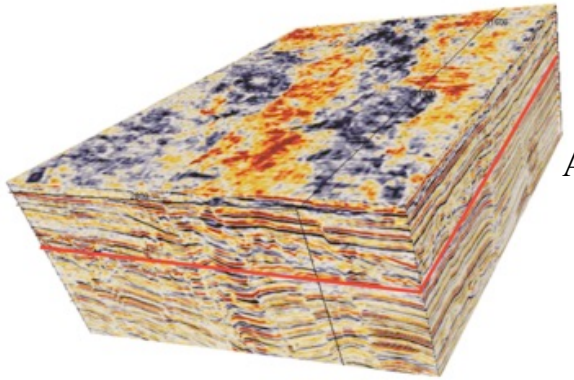
Human Visual System [1]



Saliency Detection [2]

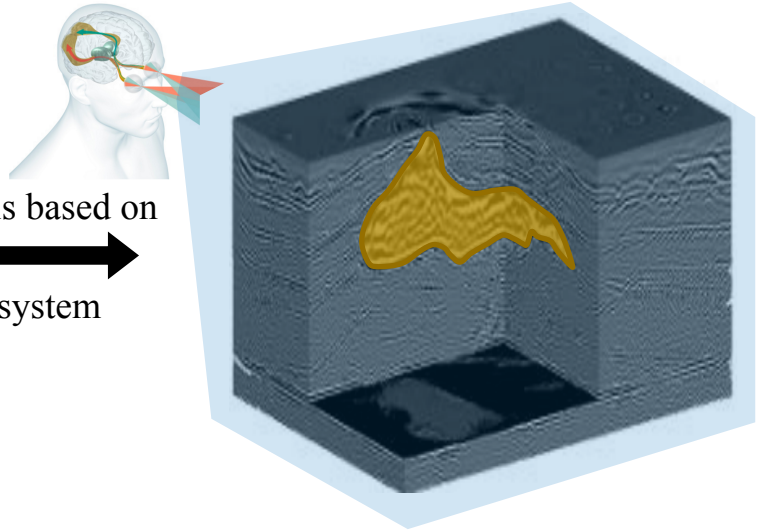
[1] https://www.studyblue.com/notes/note/n/visual-process-and-perception/deck/14629318
[2] http://ivrlwww.epfl.ch/supplementary_material/RK_CVPR09/

III. Seismic Saliency
- Attention Models in Seismic Interpretation



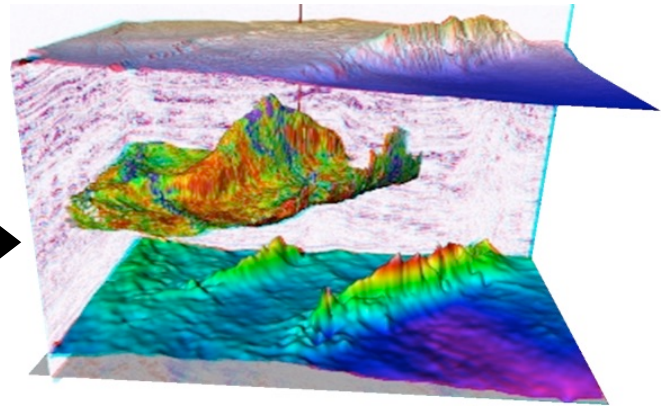
Attention models based on

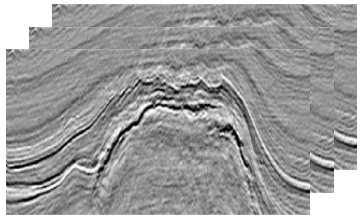
Human visual system



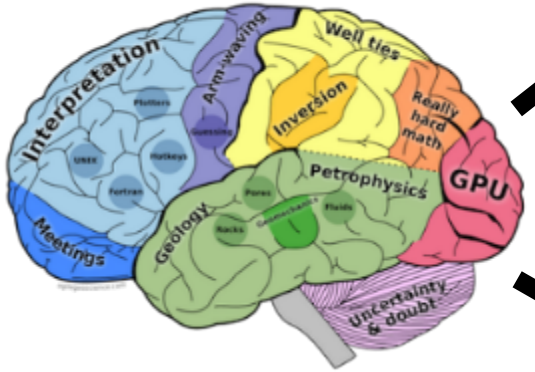
Structural

Interpretation

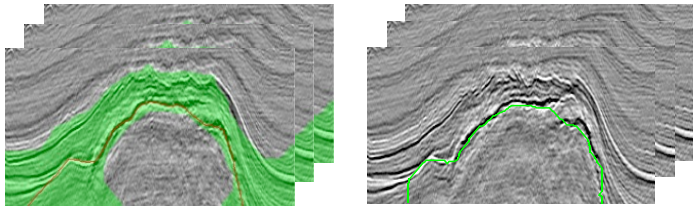




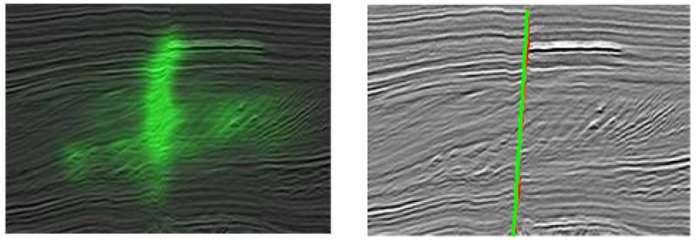
Attention Models based on HVS



Detection and delineation of salt domes



Detection and delineation of faults



[1] https://agilescientific.com/blog/2013/8/6/your-next-employment-contract.html

Outline

I. Introduction

II. Literature Survey

III. Seismic Saliency

- I. Background
- **II. Related Work**
  - Interpreter-assisted interpretation
  - Automated delineation

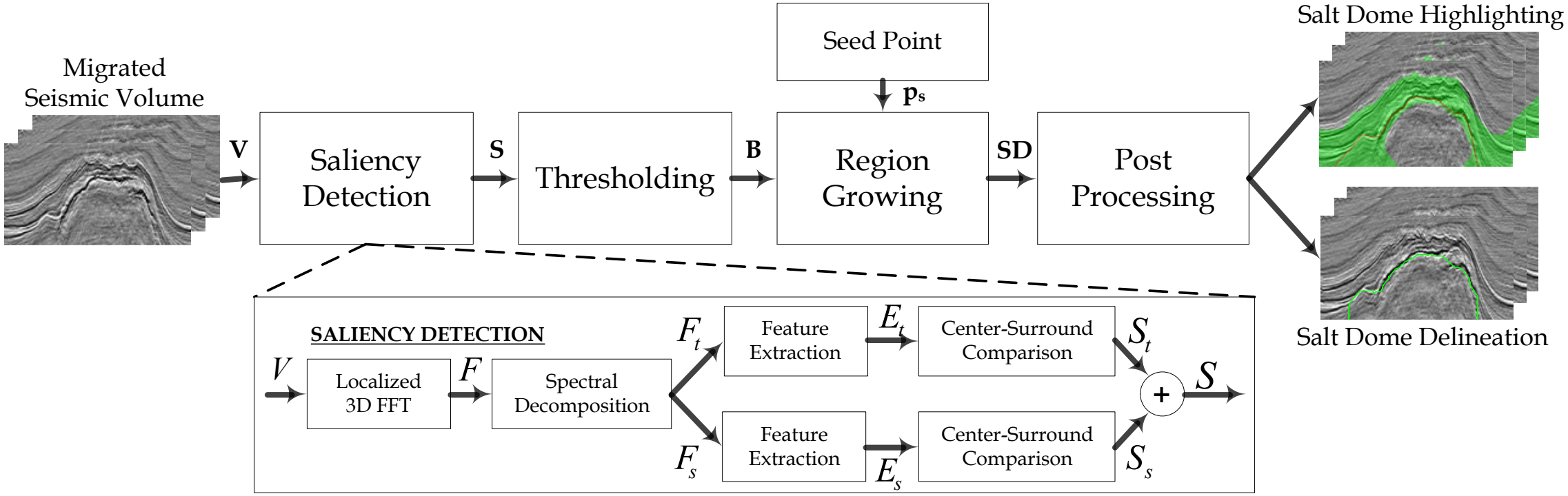
IV. Proposed Method

V. Experimental Results

VI. Conclusions

III. Seismic Saliency
- Saliency in Interpretation

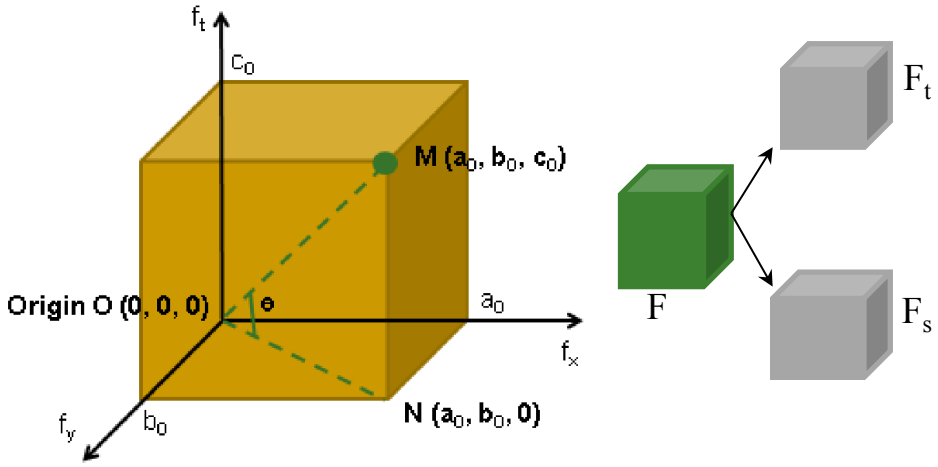
- We proposed workflows based on visual saliency for assisting interpreters and automated delineation of salt domes



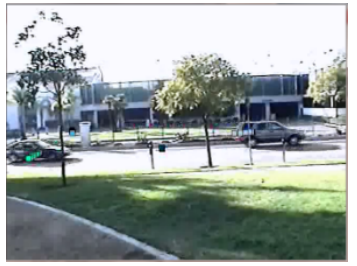
[1] M. Shafiq, T. Alshawi, Z. Long, and G. AlRegib, "SalSi: A New Seismic Attribute For Salt Dome Detection," *IEEE Intl. Conf. on Acoustics, Speech and Signal Processing (ICASSP)*, Shanghai, China, Mar. 20-25, 2016.
[2] M. Shafiq, T. Alshawi, Z. Long, and G. AlRegib, "The role of visual saliency in the automation of seismic interpretation," Geophysical Prospecting, July, 2017.

III. Seismic Saliency
- Motion-based Saliency Detection

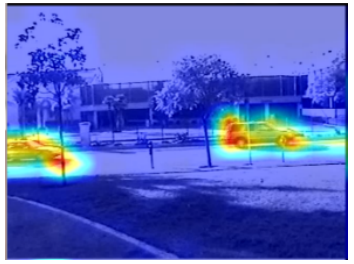
- Advantages of a FFT-based saliency detection method compared to other detection algorithms
  - Effectively captures temporal and spatial saliency
  - Better computational efficiency
  - Few parameters selection



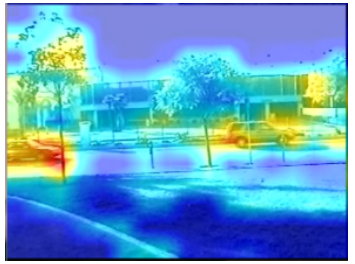
Geometric Decomposition



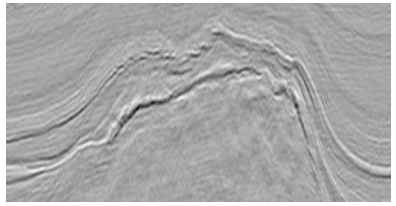
A Video Frame



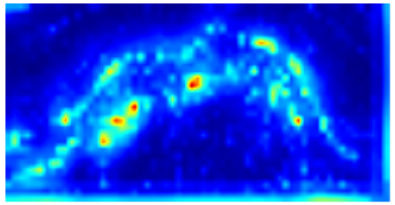
F_t Energy Distribution



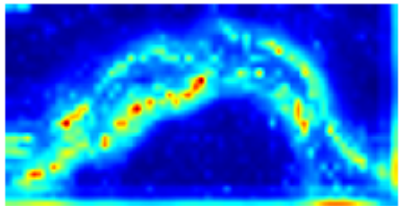
F_s Energy Distribution



Seismic Inline



F_t Energy distribution



F_s Energy distribution

[1] Zhiling Long and Ghassan AlRegib, "Saliency detection for videos using 3D FFT local spectra," *Proc. SPIE*, vol. 9394, pp. 93941G–93941G–6, 2015.

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I. Introduction
II. Literature Survey
III. **Seismic Saliency**
  I. Background
  II. **Related Work**
    - **Interpreter-assisted interpretation**
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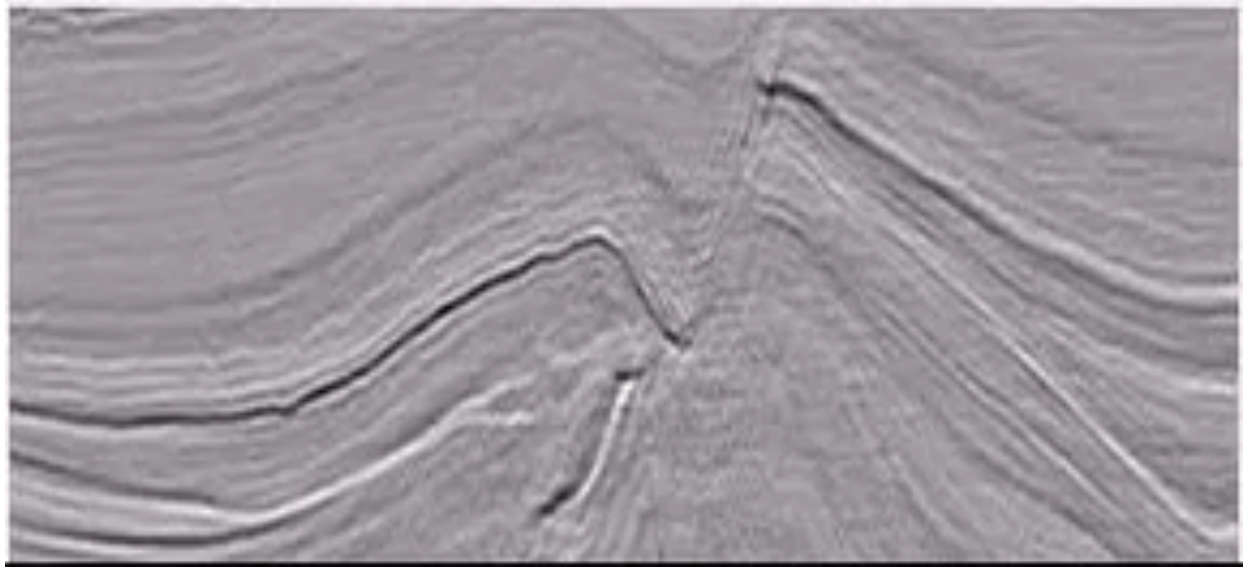
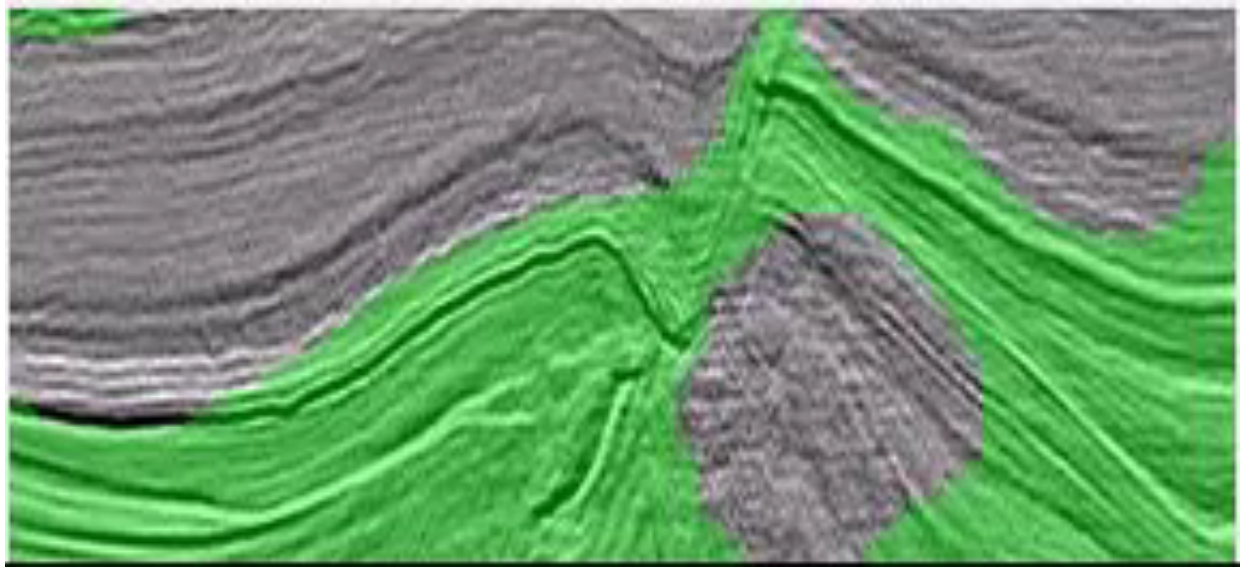
III. Seismic Saliency
- Interpreter-Assisted Interpretation Workflow

- The HVS based interpretation workflow can be used to
  - Assist interpreters during seismic volume interpretation
  - Bring attention of interpreters to important areas within seismic sections
  - Initialize computationally expensive delineation algorithms
  - Track substructures within seismic volumes



Original Seismic Volume



Highlighted salt-dome boundaries

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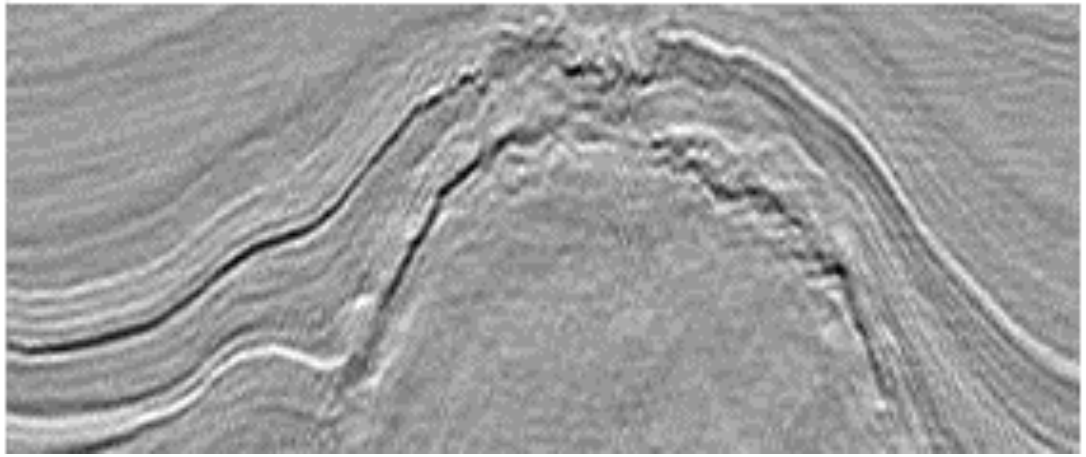
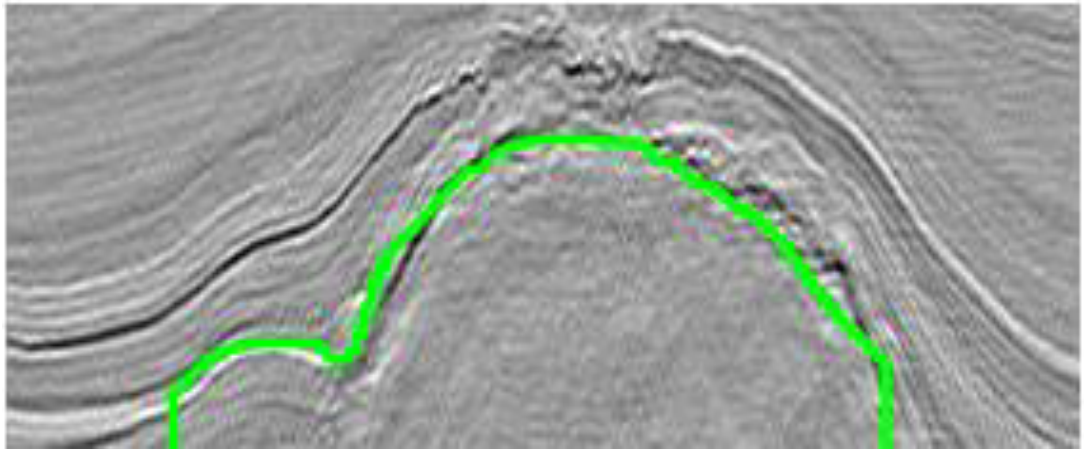
III. Seismic Saliency
- Salt Dome Delineation



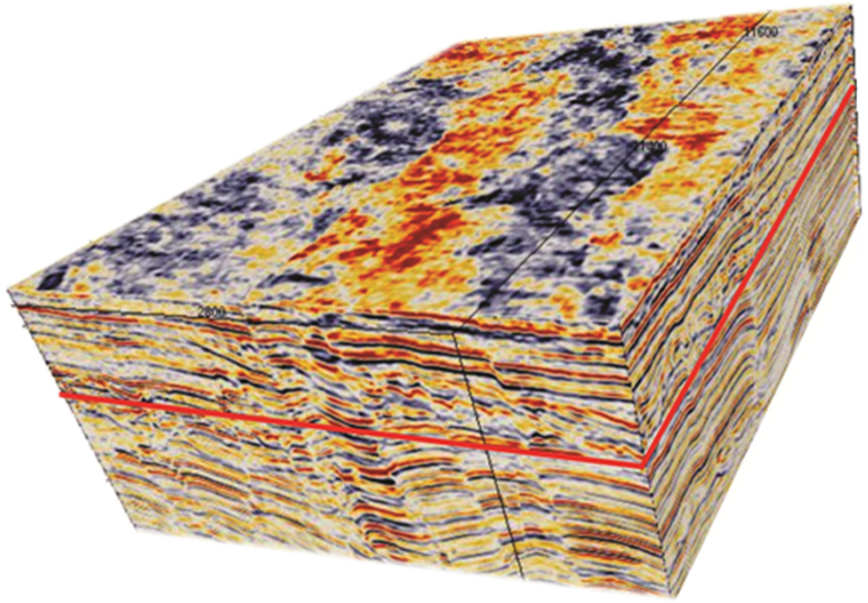
Seismic Volume



Salt Dome Delineation

III. Seismic Saliency
- Shortcomings of current approach

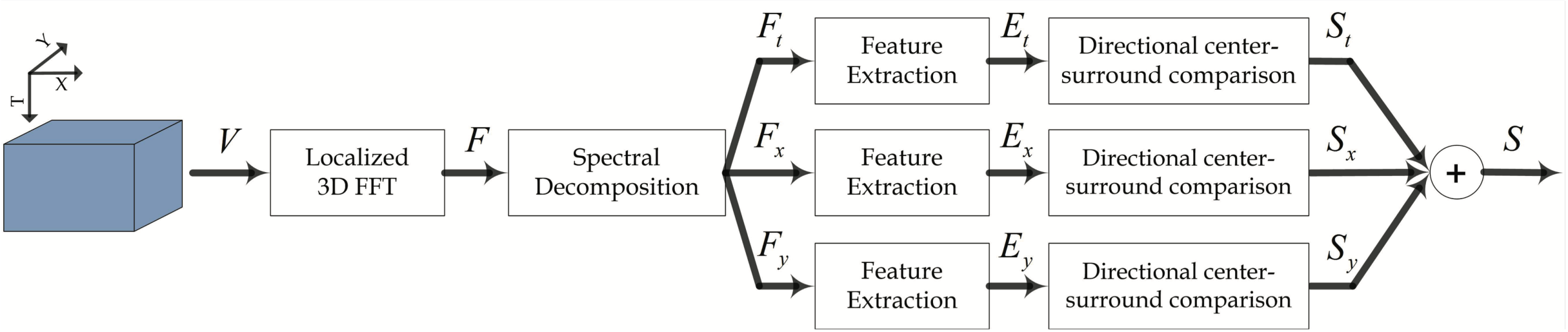
- Temporal domain is defined for videos
  - Temporal direction for seismic!
- Previous approach was based on bottom-up model
  - Assumes no information from data
  - Data-driven
- A priori information to model different structure
  - Top-down
  - Directionality
- Resolution
  - Fine details are required for seismic saliency



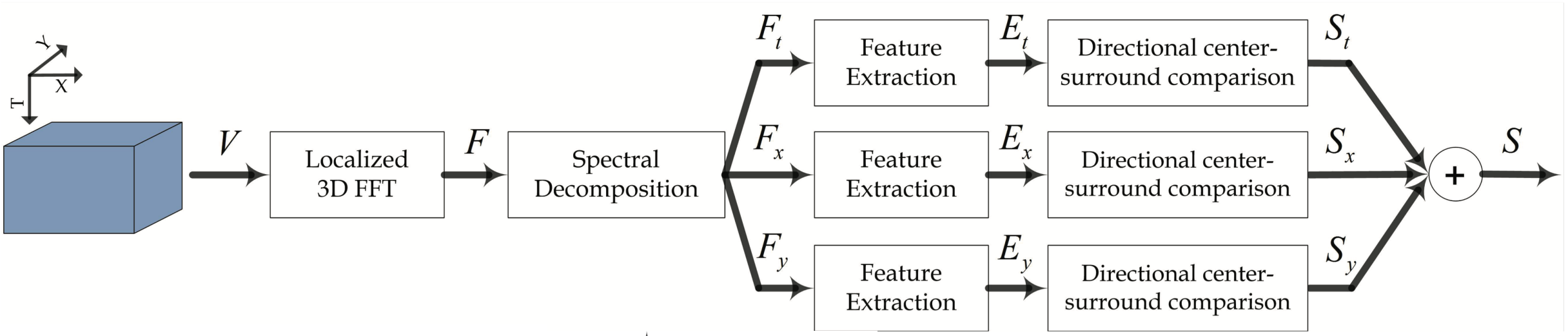
Migrated Seismic Volume

Outline

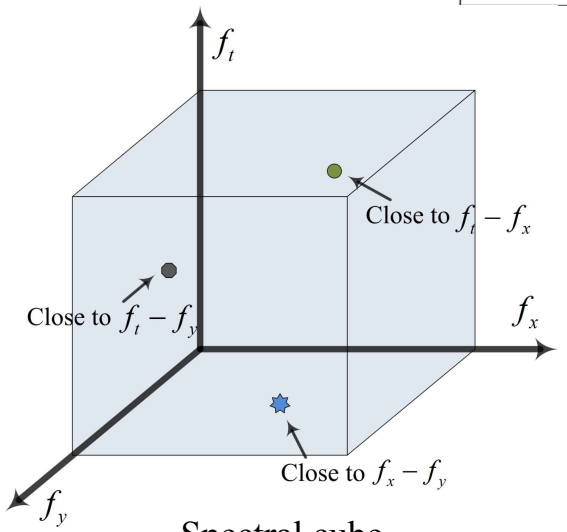
IV. Proposed Method



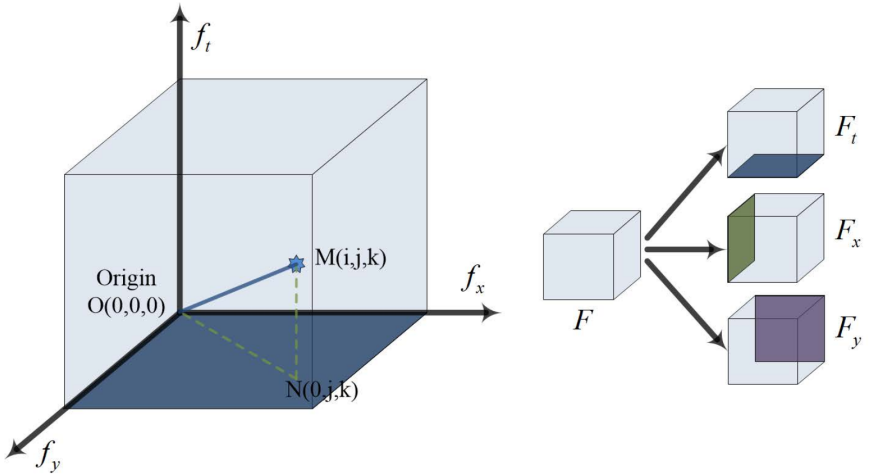
IV. Proposed Method
- Spectral Decomposition



$$\boldsymbol{F_t}[i,j,k] = \boldsymbol{F}[i,j,k] \times \frac{ON}{OM},$$
$$= \boldsymbol{F}[i,j,k] \times \frac{\sqrt{j^2+k^2}}{\sqrt{i^2+j^2+k^2}},$$
$$\boldsymbol{F_x}[i,j,k] = \boldsymbol{F}[i,j,k] \times \frac{\sqrt{i^2+k^2}}{\sqrt{i^2+j^2+k^2}},$$
$$\boldsymbol{F_y}[i,j,k] = \boldsymbol{F}[i,j,k] \times \frac{\sqrt{i^2+j^2}}{\sqrt{i^2+j^2+k^2}}.$$

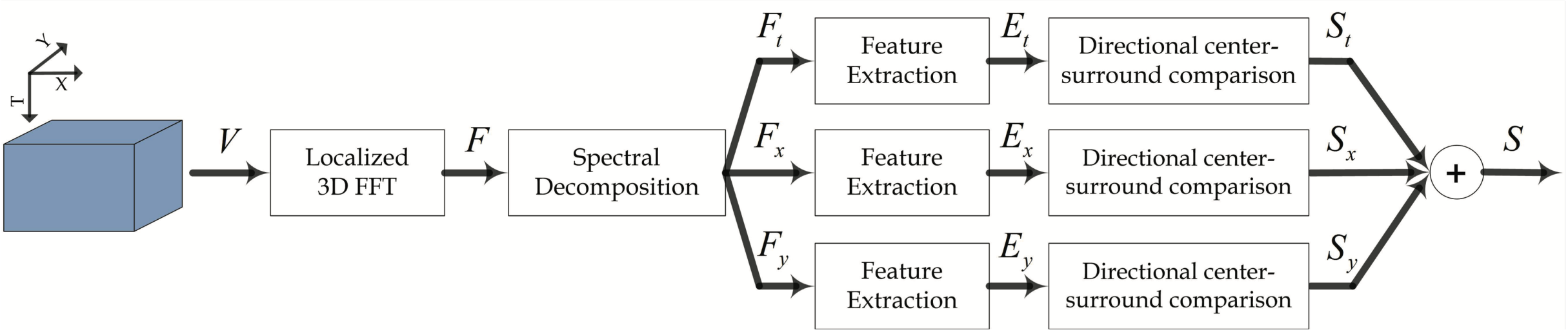


Spectral cube



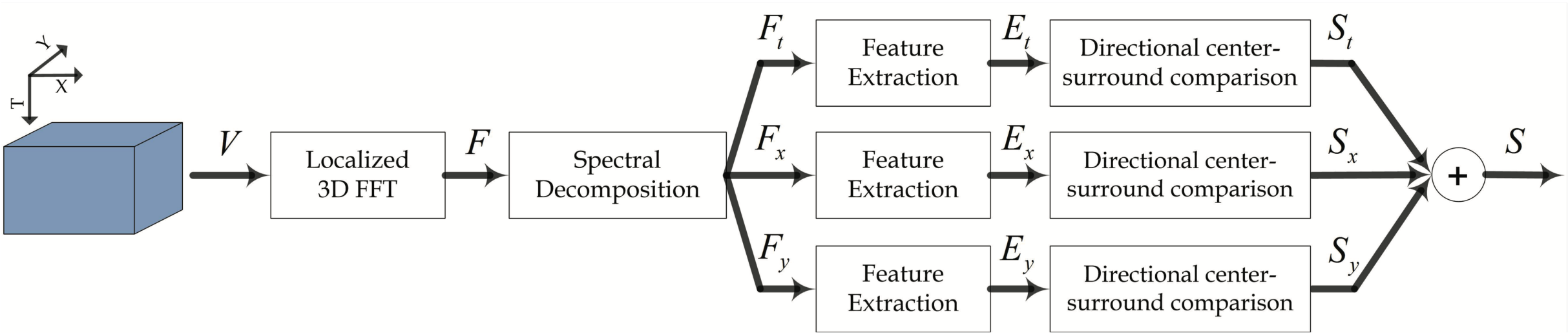
Plane projections

IV. Proposed Method
- Feature Extraction

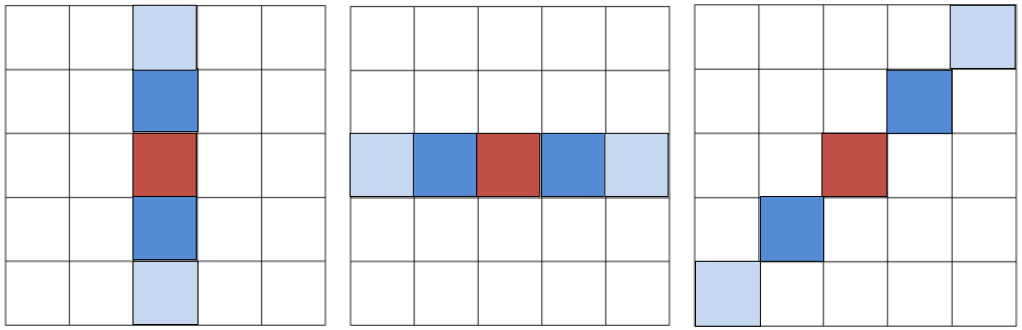


$$\mathbf{E_m}[t,x,y] = \frac{1}{L^3}\sum_{i,j,k}|\mathbf{F_m}|, \quad m \in (t,x,y),$$

IV. Proposed Method
- DCS Comparisons

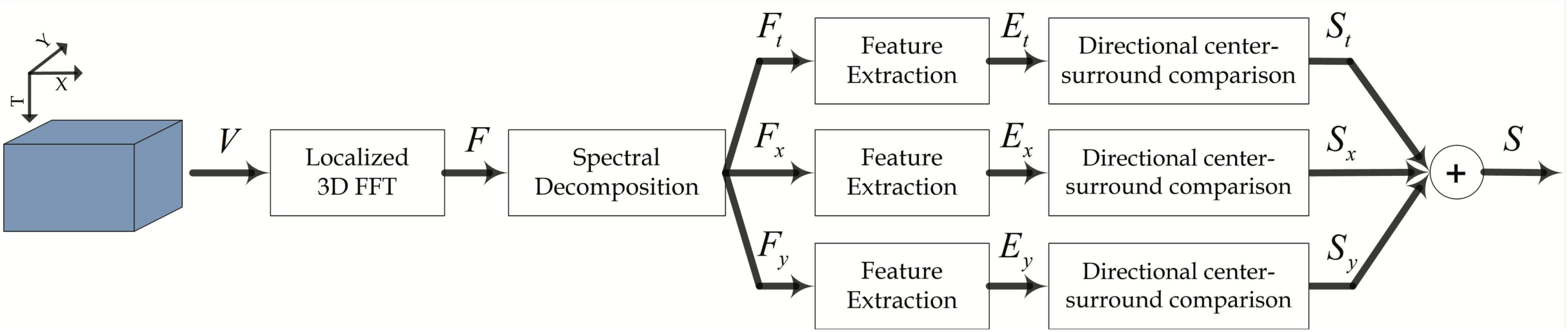


$$\boldsymbol{S_m}[t,x,y] = \frac{1}{Q} \sum_{i_0,j_0,r_0} |\boldsymbol{E_m}[t,x,y] - w.\boldsymbol{E_m}[t+i_0, x+j_0, y+r_0]|, \quad m \in \{t,x,y\},$$



Directional center-surround comparison along *t*, *x*, and *t-x* directions, respectively.

IV. Proposed Method - Saliency

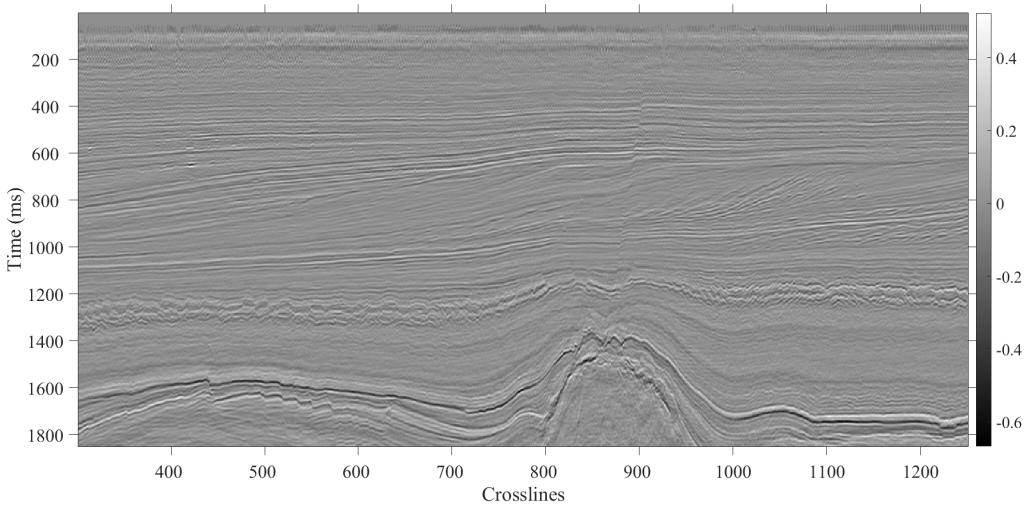


$$\boldsymbol{S}[i,j,k] = a \cdot \boldsymbol{S_t}[i,j,k] + b \cdot \boldsymbol{S_x}[i,j,k] + c \cdot \boldsymbol{S_y}[i,j,k].$$

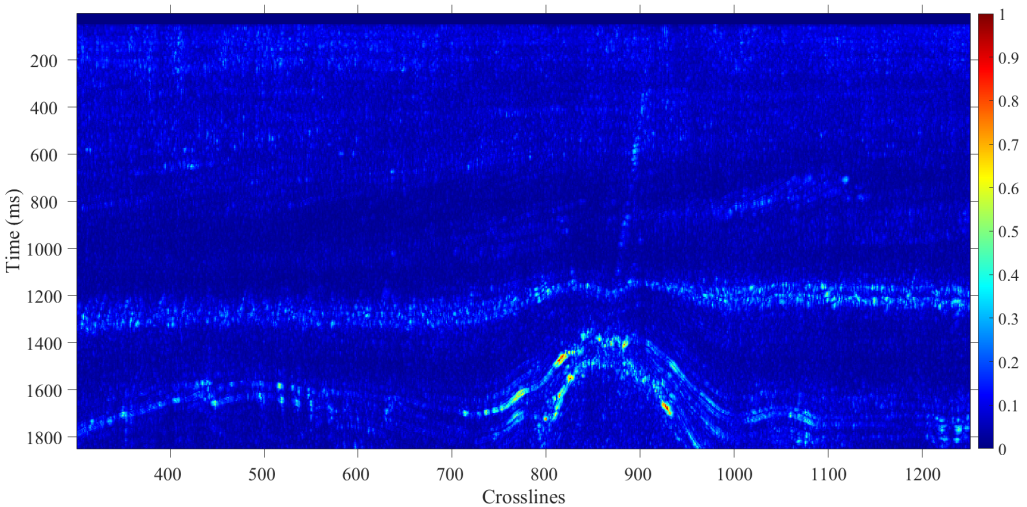
Outline

I. Introduction
II. Literature Survey
III. Seismic Saliency
IV. Proposed Method
V. **Experimental Results**
   I. **Inline**
   II. Crossline
   III. Time
   IV. Comparison with State-of-the-art Algorithms
VI. Conclusions

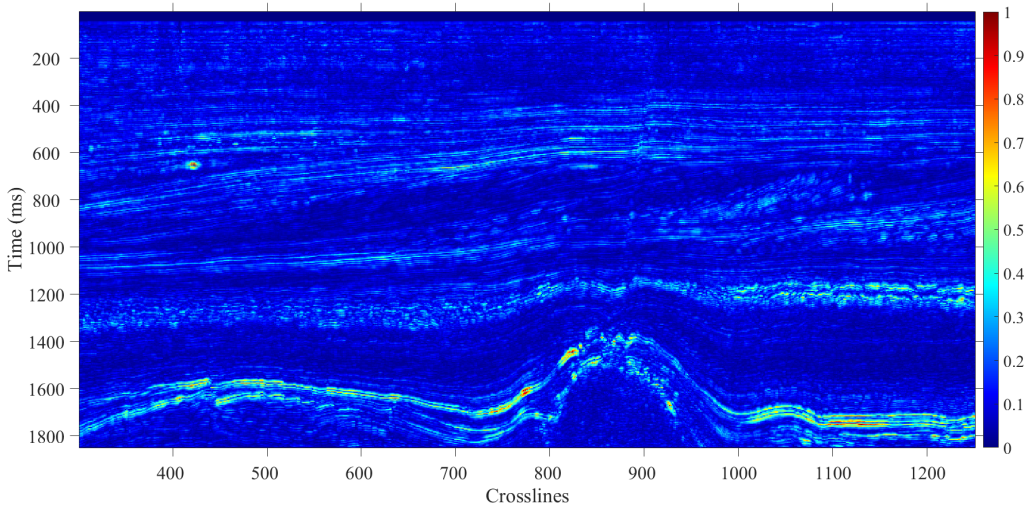
V. Experimental Results
- Inline Section and Spectral Projections



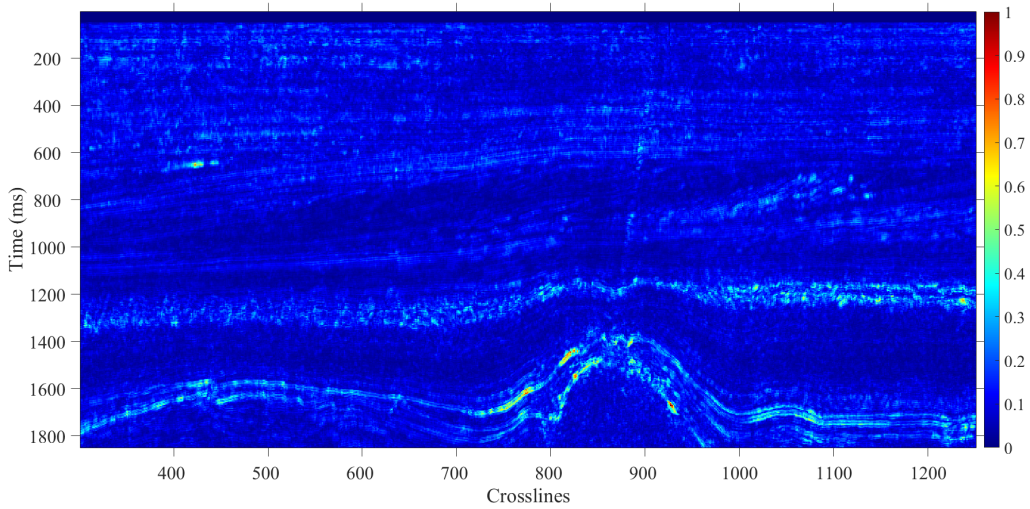
Seismic Inline



Seismic saliency along time direction - S_t

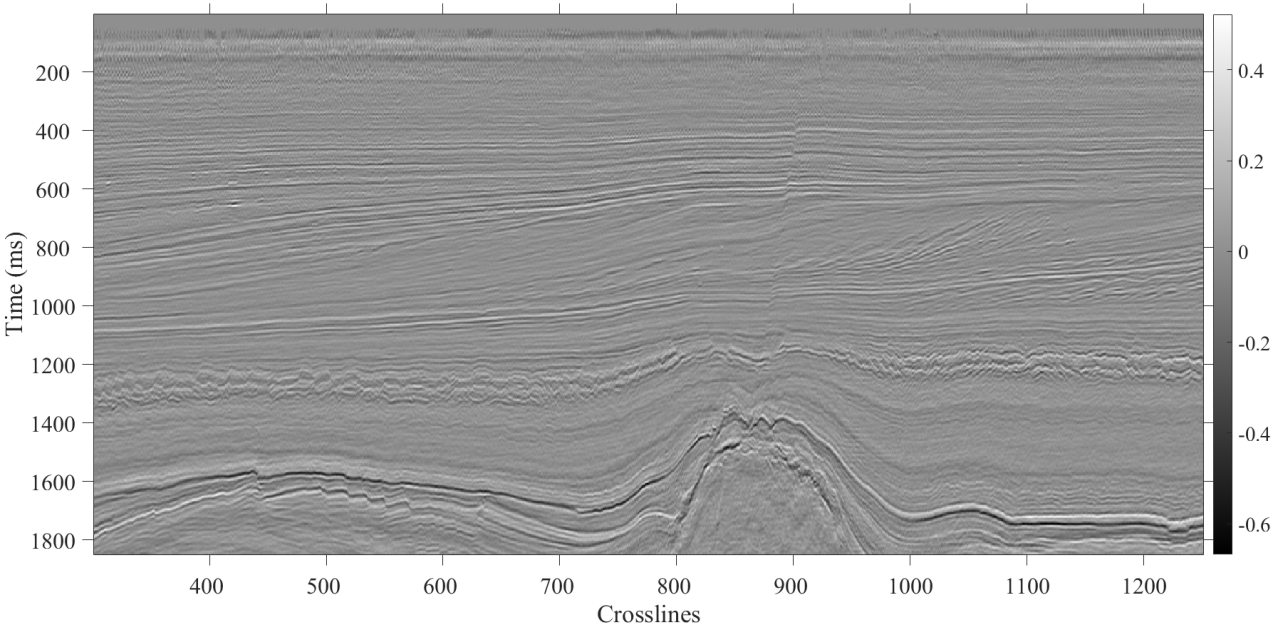


Seismic saliency along crossline direction - S_x

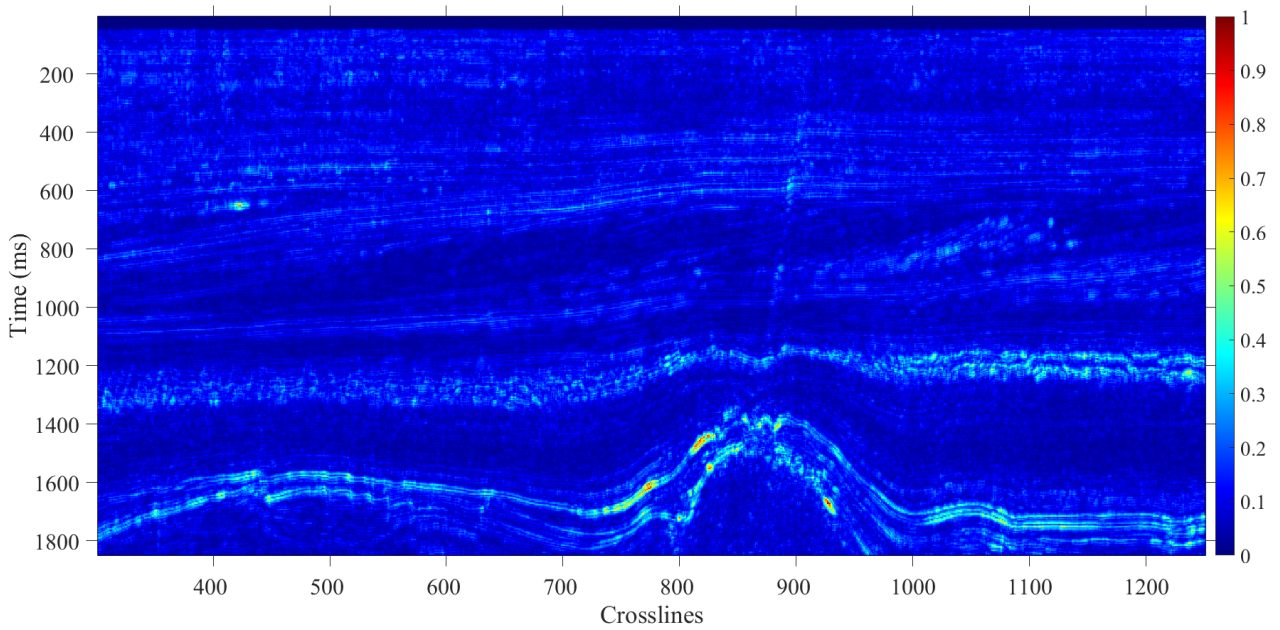


Seismic saliency along inline direction - S_y

V. Experimental Results
- Inline Section and Seismic Saliency



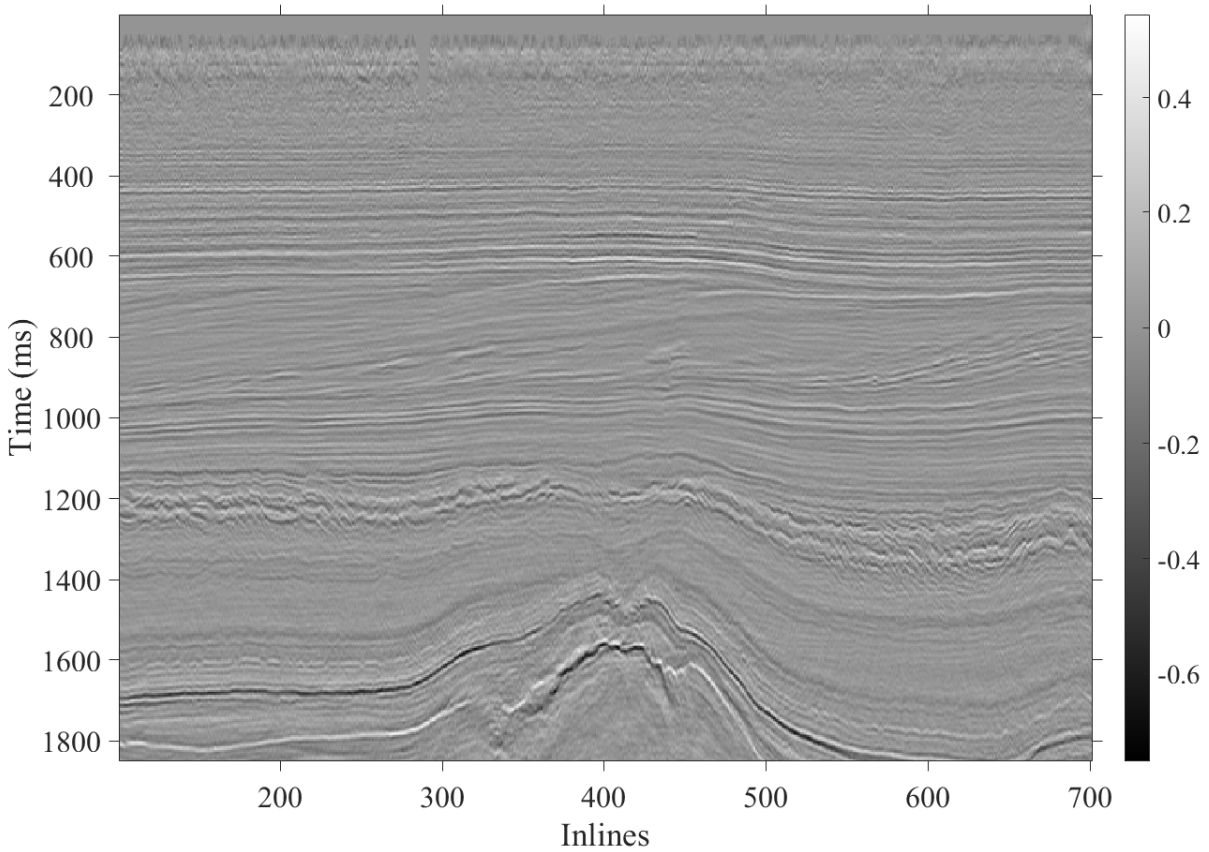
Seismic Inline



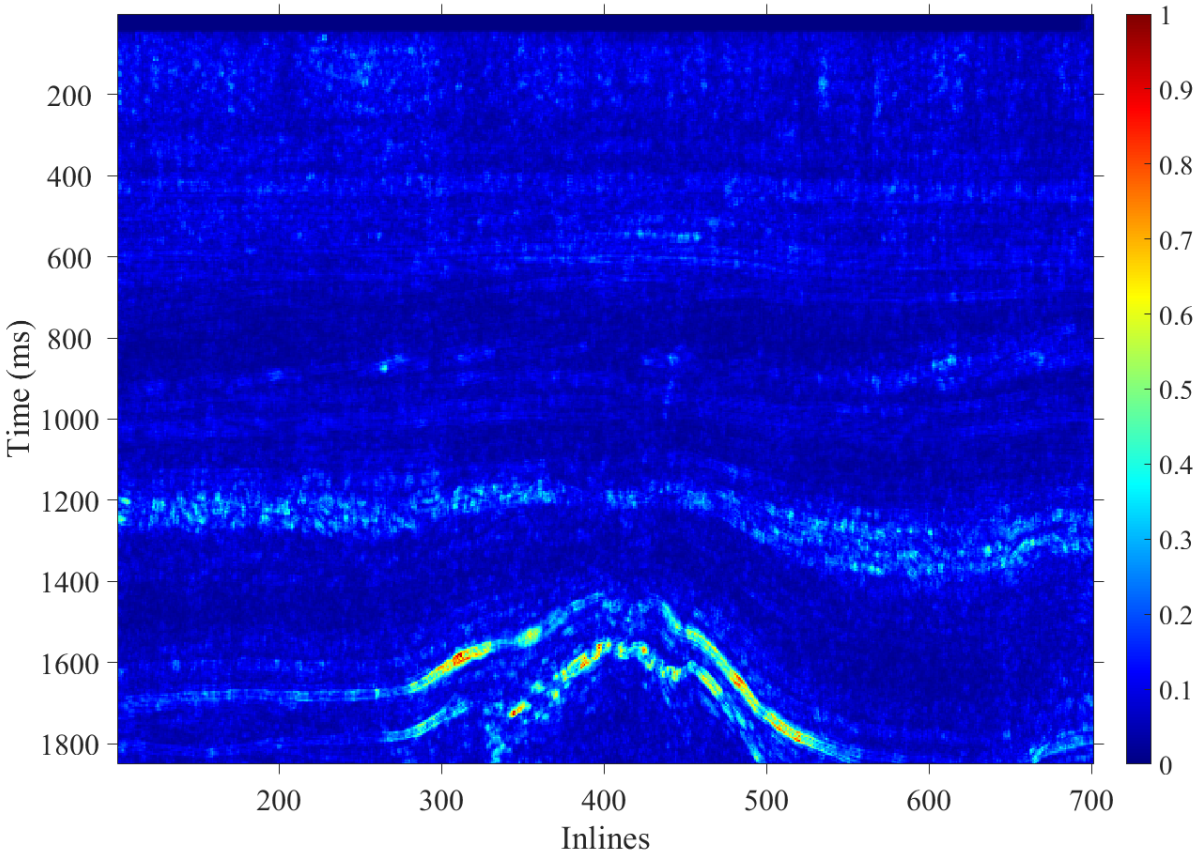
Seismic Saliency

Outline

V. Experimental Results
- Crossline Section and Seismic Saliency



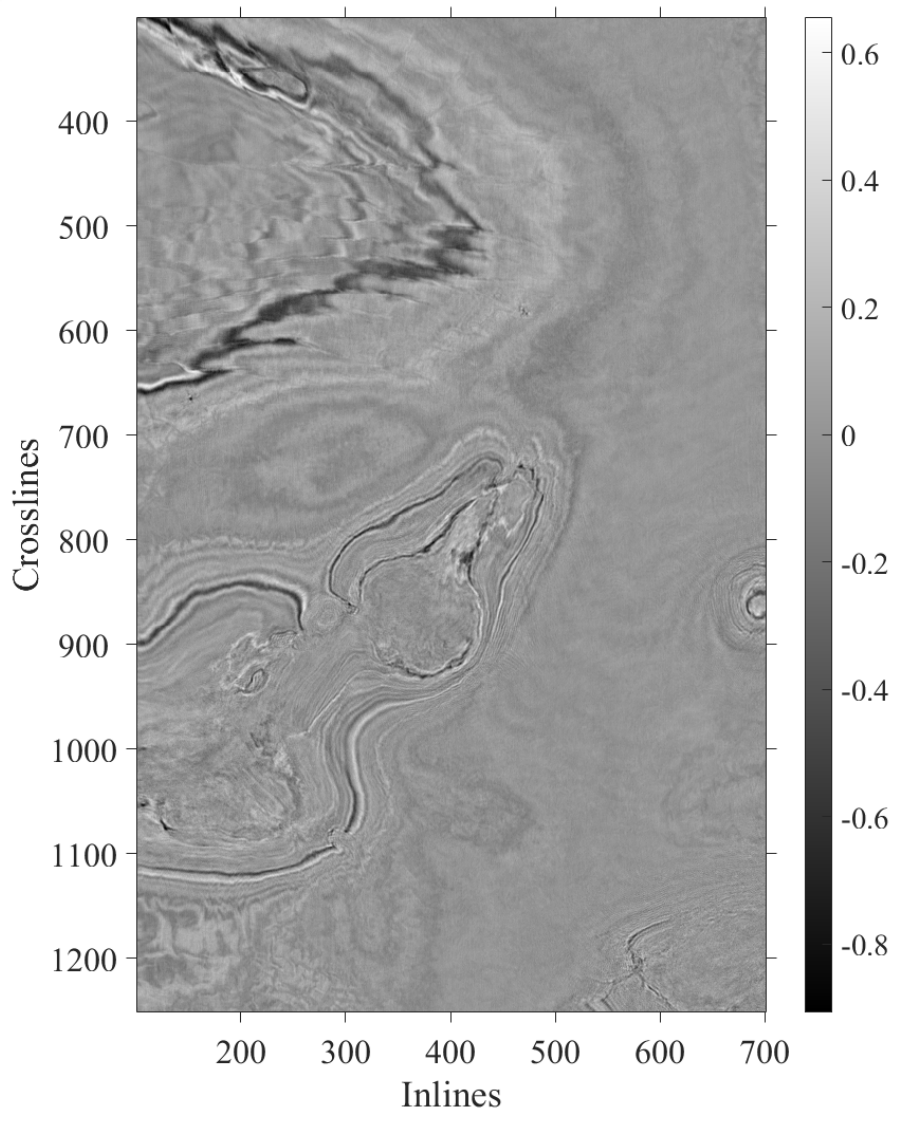
Seismic Crossline



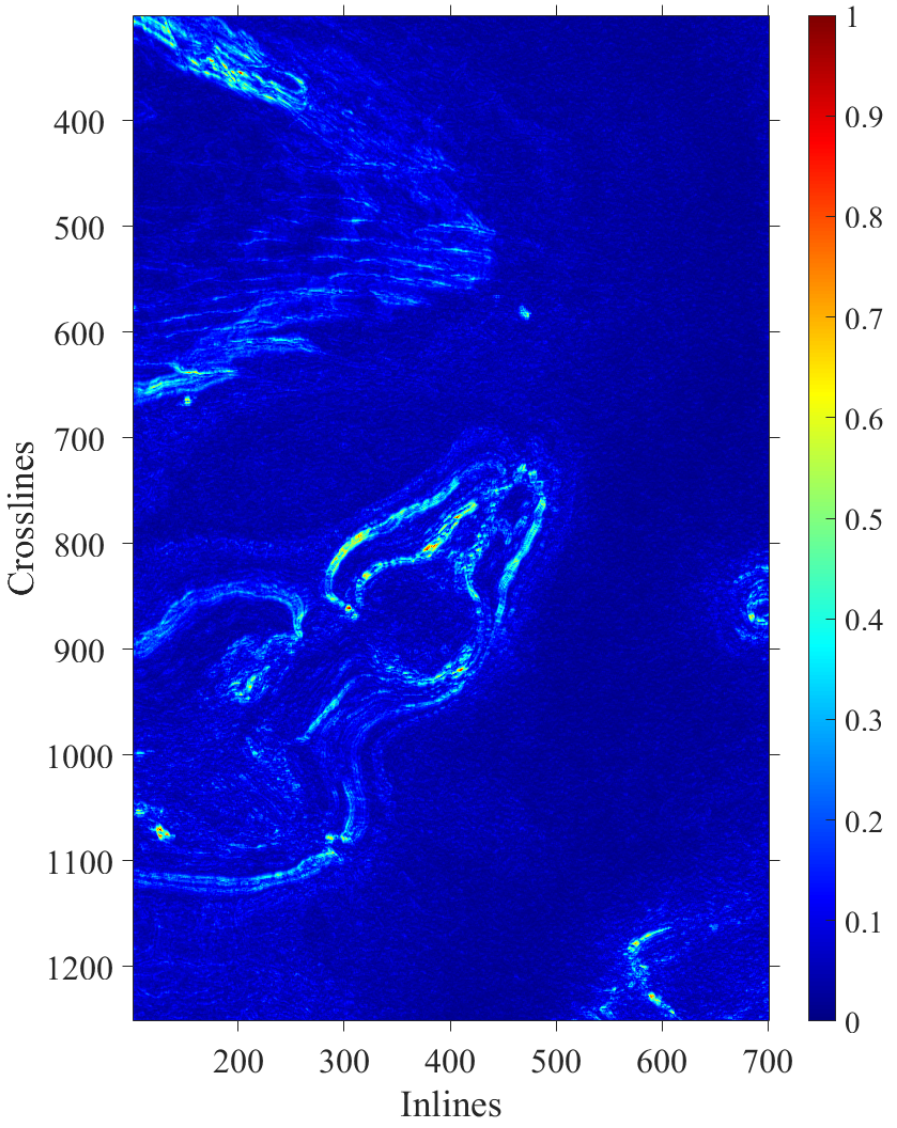
Seismic Saliency

Outline

V. Experimental Results
- Time Section and Seismic Saliency

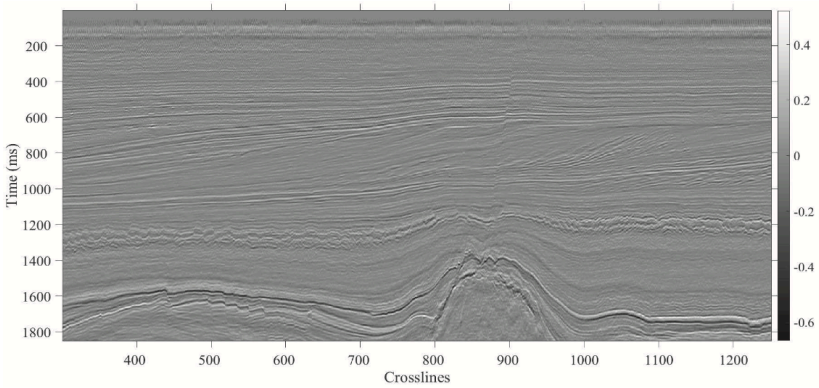


Time Section

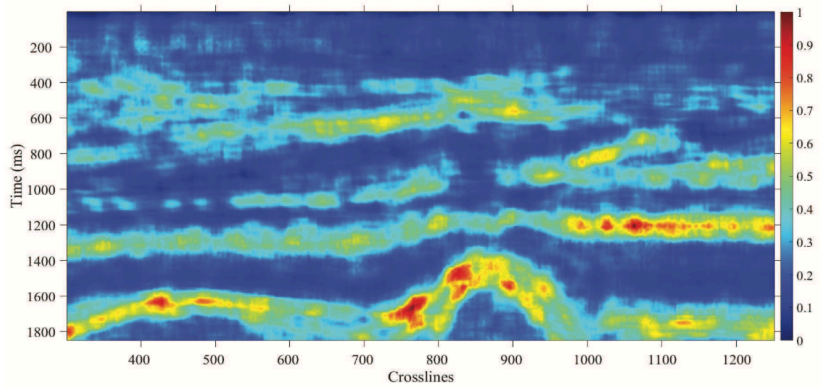


Seismic Saliency

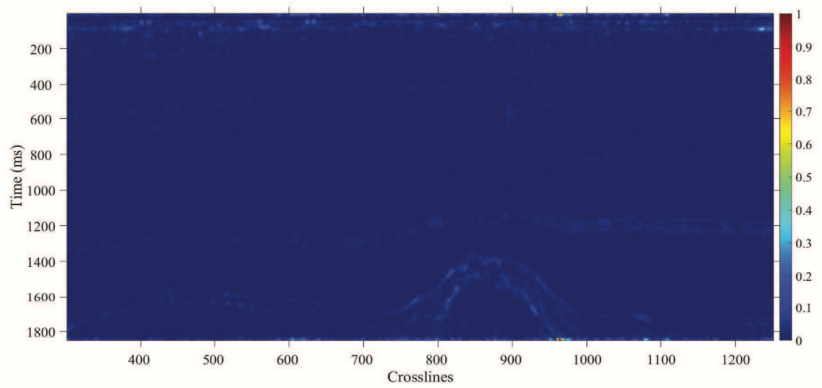
Outline



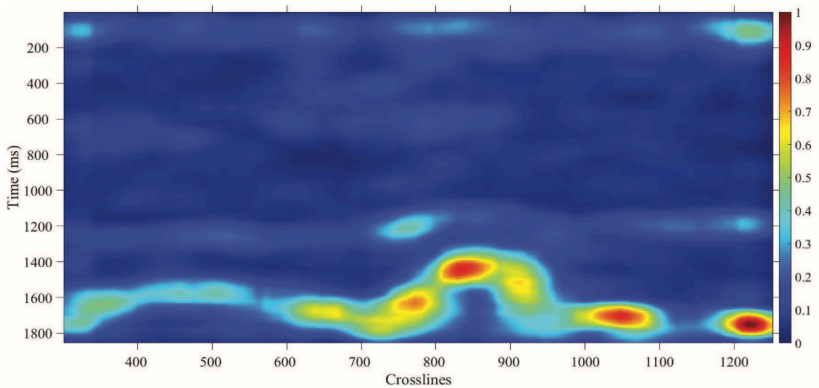
(a) A typical seismic inline image.



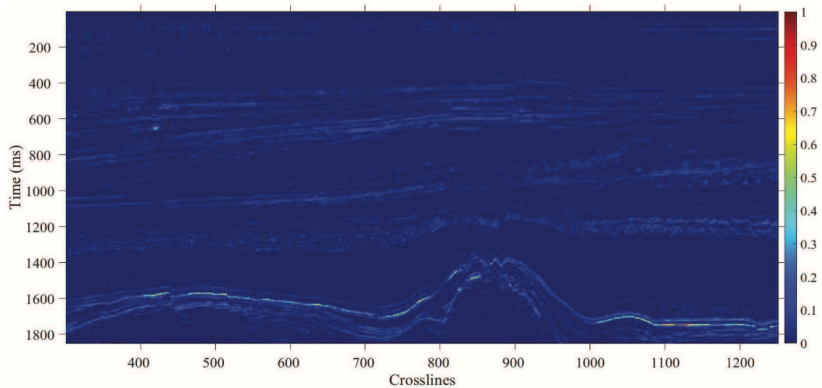
(b) Zhang et al., (2008)



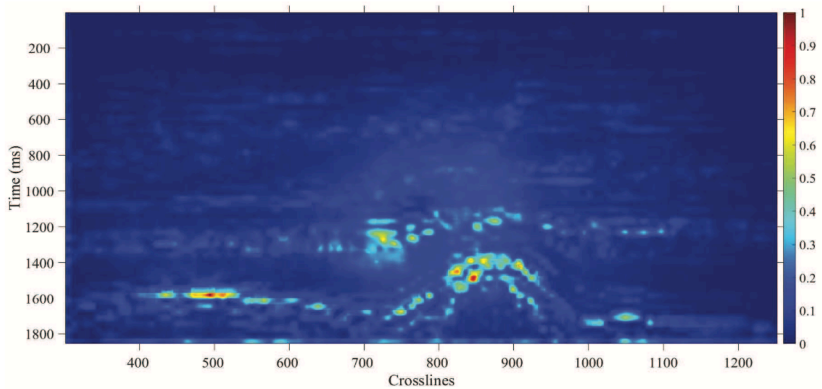
(c) Hou and Zhang, (2007)



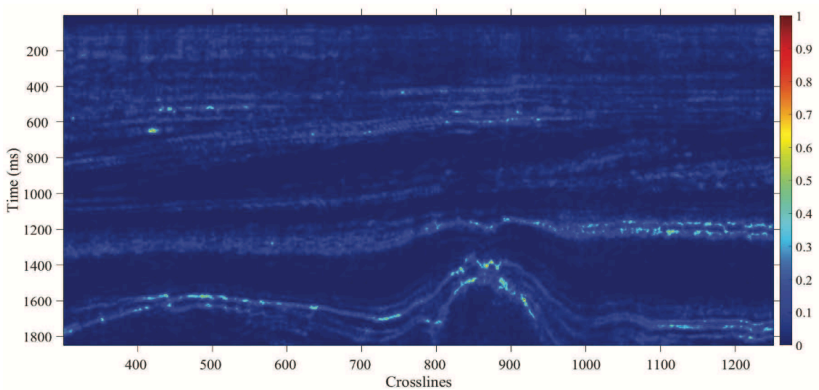
(d) Guo and Zhang, (2010)



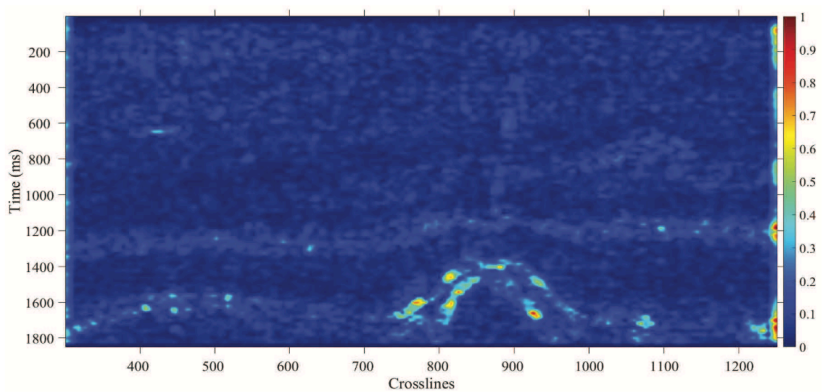
(e) Achanta et al., (2008)



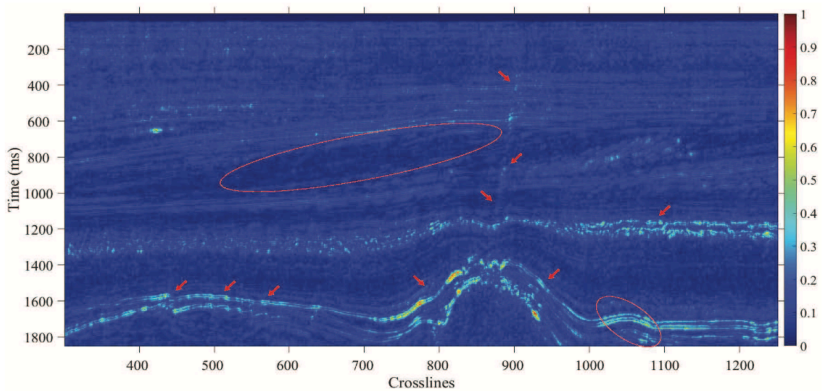
(f) Fang et al., (2014)



(g) Seo and Milanfar, (2009)



(h) Long and AlRegib, (2015)



(i) Proposed Method

Outline

V. Conclusions

- Proposed seismic saliency based on 3D-FFT, spectral projections and DCS comparisons.
- Models the behavior of Interpreters looking at seismic volumes.
- We can embed apriori information into saliency models using directional comparisons and various templates of different shape, sizes, and orientations etc.
- Attention models based saliency can not only model Interpreters' knowledge but can also automate the seismic interpretation.
- We show the effectiveness of the proposed scheme on the F3 block from the North Sea.
- Outperforms the state-of-the-art methods for saliency computation.
- Holds the potential of becoming a very promising attribute in the seismic interpretation.

THANK YOU

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