A Hybrid Spatio-Frequency Approach for Delineating Subsurface Structures in Seismic Volumes  
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**Abstract**

Frequency-based edge detection methods such as phase congruency [1] are generally fast and accurate but are sensitive to noise, and cannot capture subtle edges that are marked by a change in texture rather than a change in amplitude. On the other hand, spatial edge detection methods such as Canny Edge Detector [2] are generally fast and accurate but are sensitive to noise, and cannot capture subtle edges that are marked by a change in texture rather than a change in amplitude. In this paper, we share a new hybrid spatio-frequency edge detection method, and show its effectiveness in salt dome delineation on seismic data from the North Sea F3 Block [7].

**Motivation**

- Seismic surveys results in huge amounts of data. For example, a survey of an 50x30 sq. Km area results in about 600 TB of data.
- Manual interpretation and analysis of the data is very time consuming and labor intensive.
- There is increasing interest in automated seismic interpretation tools and algorithms.
- Salt domes are important geological structures spanning over several kilometers under the Earth surface.
- Salt domes are impermeable and thus can potentially trap large quantities of hydrocarbon reservoirs.
- Accurate localization and delineation of salt domes is one of the important steps in seismic data interpretation.

**Background:**

- **GoT**
- **PC**

**Proposed Method**

**Phase Congruency**

PC defines the congruency of the Fourier components of edges in an image. PC varies between 0 and 1, corresponding to no and perfect phase congruency. PC is superior to gradient-based edge detection methods since it is a dimensionless quantity that is not affected by changes in image illumination and contrast.

\[
P_C^*(x) = \frac{E(x)}{\sum_\Delta E_\Delta(x)} \
\]

where \(E(x)\) is sensitive to noise.

\[
PC[x,y] = \sum_{\omega} \sum_{n} W_n(\omega) A_{n,\phi}(\omega) \left( \Delta \Phi_{n,\phi}(\omega) - \Phi_{n,\phi}(\omega) \right) = \sum_{\omega} \sum_{n} A_{n,\phi}(\omega) + \epsilon 
\]

\(A_{n,\phi}(\omega)\) : amplitude and phase of Fourier components at different spatial frequencies and orientations \(\Phi_{n,\phi}(\omega)\) : phase deviation \(\epsilon\) : estimated noise influence at each orientation

- **Gradient of Texture (GoT)**

\[
G(x,y) = \left( \sum_{\omega} \sum_{n} W_n(\omega) A_{n,\phi}(\omega) \left( \Delta \Phi_{n,\phi}(\omega) - \Phi_{n,\phi}(\omega) \right) \right)^2 
\]

\(F(x,y) = \frac{1}{2\pi} \sum_{\omega} \sum_{n} f(x,y) e^{i \omega x} e^{i \phi(x,y)} \)

\(F(x,y)\) is a perceptual dissimilarity measure based on double DFT.

**Results**

We compute the results for delineating salt domes on the real seismic dataset acquired from the Netherlands offshore, F3 block in the North Sea by dGB Earth Sciences [7]. The seismic volume that contains the salt dome structure has an inline number ranging from #151 to #501, a crossline number ranging from #401 to #701, and a time direction ranging from 1,300ms to 3,848ms sampled every 4ms. We objectively compare the results using $\text{SALTIM}$ introduced by Wang et al. [6].

**Salt Dome Similarity:** $\text{SALTIM}(A, B) = \gamma - \frac{\Delta}{\gamma}$  

\(\gamma\) : local term  
\(\Delta\) : global term

**References**


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**Natural vs. Texture Images**

| Spatial: GoT | Frequency: PC | Hybrid: Proposed |

**Seismic Data**

- Salt Domes
- Motivation

**Results**

- Salt Dome Delamination
- Setup

**Seismic Data**

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- Salt domes are impermeable and thus can potentially trap large quantities of hydrocarbon reservoirs.
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**Proposed Method**

- **Phase Congruency**
- **Gradient of Texture (GoT)**

**References**


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