POSTER Nº

Th P8 03

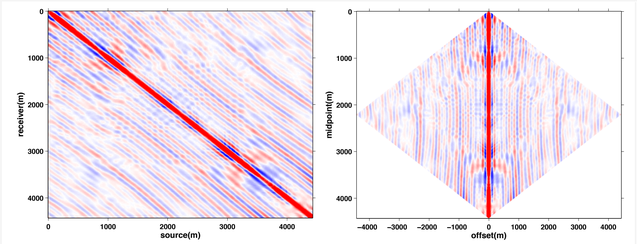
R. Kumar, O. Lopez, E. Esser† & F.J. Herrmann*

Matrix Completion on Unstructured Grids: 2-D Seismic Data Regularization and Interpolation

EAGE 77th EAGE Conference & Exhibition MADRID 2015

Introduction

- *acquisition challenges*
- *need fully sampled data*
- *regularization & interpolation*
- *exploit low-rank structure of seismic data*



Matrix Completion

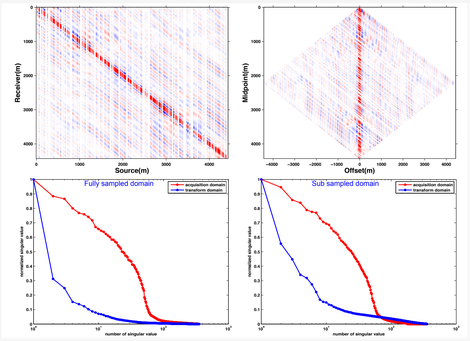
signal structure

- Low rank/fast decay of singular values

sampling scheme

- missing data increase rank in "transform domain"

recovery using rank penalization scheme



Regularization

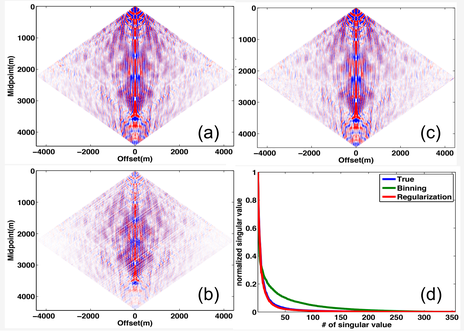


Figure 1: Impact of regularization on singular values decay in the transform-domain. Monochromatic frequency slice at 35 Hz in the midpoint-offset domain, (a) ground truth, (b) binning using nearest-neighbor interpolation, (c) unstructured sampling operator based rank-minimization. (d) Singular values decay in the midpoint-offset domain.

Quantifying regularization error

Let $\mathbf{X_r} \in \mathbb{C}^{n \times m}, \mathbf{b} = \mathbf{RM}(\mathbf{X}_{ir}) + e$ with $\|e\| \leq \eta, \text{and} ||\mathbf{N}(\mathbf{X_r}) - \mathbf{X_{ir}}||_\mathbf{F} \leq \epsilon.$
Let $\tilde{\mathbf{X}}$ be the solution of $\text{BPDN}_{\epsilon+\sigma}$, then

$$||\mathbf{X}_r - \tilde{\mathbf{X}}||_F \leq \frac{C_1}{\sqrt{k}} \underbrace{\sum_{i=k+1}^{l} \sigma_i(\mathbf{X}_r)}_{\text{Rank approximation}} + \underbrace{C_2\epsilon}_{\text{Regularization}} + \underbrace{C_2\eta}_{\text{noise}}$$

where

$$l = min\{n, m\}$$

$$C_1 \text{ and } C_2 > 0$$

Regularization & Interpolation

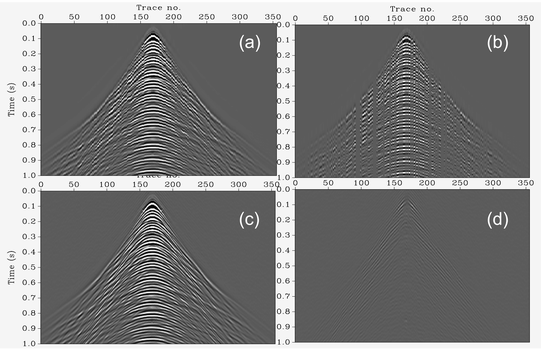


Figure 2: Regularization and Interpolation. Ground truth at (a) irregular grid, (b) and with missing traces.
(c, d) Recovery and difference using proposed rank-minimization on unstructured grids with a SNR of 19.3 dB.

Conclusion

- Binning does not preserve the underlying low-rank structure of seismic data
- Incorporation of grid-irregularity in matrix-completion benefits the regularization & interpolation process and preserve the low-rank structure of seismic data
- Propose matrix-completion framework is computationally affordable for large-scale problems since its SVD-free

†John "Ernie" Esser (May 19th 1980 - March 8th 2015)

We would like to recognize the extraordinary contributions Ernie Esser made to the scientific accomplishments of this paper. It has been a true privilege to have the opportunity to work with Ernie. We will miss him dearly.

Acknowledgements

We would like to thank all of the sponsors of our SINBAD project for their continued support.

References

Abma, R., and J. Claerbout, 1995, Lateral prediction for noise attenuation by t-x and f-x techniques: Geophysics, 60, 1887–1896.
Abma, R., and N. Kabir, 2006, 3d interpolation of irregular data with a pocs algorithm: Geophysics, 71, E91–E97.
Aravkin, A. Y., R. Kumar, H. Mansour, B. Recht, and F. J. Herrmann, 2013, Fast methods for denoising matrix completion formulations, with application to robust seismic data interpolation. SIAM
Hennenfent, G., L. Fenelon, and F. J. Herrmann, 2010, Non-equispaced curvelet transform for seismic data reconstruction: A sparsity-promoting approach: Geophysics, 75, WB203–WB210.
Keys, R., 1981, Cubic convolution interpolation for digital image processing: Acoustics, Speech and Signal Processing, IEEE Transactions on, 29, 1153–1160.
Kumar, R., A. Y. Aravkin, H.Mansour, B. Recht, and F. Herrmann, 2013, Seismic data interpolation and denoising using svd-free low-rank matrix factorization: Presented at the , EAGE.
Kunis, S., 2006, Non-equispaced fft: generalization and inversion: PhD thesis, Lübeck University.
Li, C., C. C. Mosher, and S. T. Kaplan, 2012, Interpolated compressive sensing for seismic data reconstruction: Presented at the Society of Exploration Geophysicists.
Oropeza, V., and M. Sacchi, 2011, Simultaneous seismic data denoising and reconstruction via multichannel singular spectrum analysis: Geophysics, 76, V25–V32.
Potts, D., G. Steidl, and M. Tasche, 2001, Modern Sampling Theory: Mathematics and Applications: 249–274.
Recht, B., M. Fazel, and P. Parrilo, 2010, Guaranteed minimum rank solutions to linear matrix equations via nuclear norm minimization.: SIAM Review, 52, 471–501.
Sacchi, M., T. Ulrych, and C. Walker, 1998, Interpolation and extrapolation using a high-resolution discrete Fourier transform: Signal Processing, IEEE Transactions on, 46, 31 –38.
Spitz, S., 1991, Seismic trace interpolation in the f-x domain: Geophysics, 56, 785–794.