

Large-Scale Data Recovery with the PWFDCT

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Outline

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- Background
- Idea
- Applications
- Performance & Preliminary Results
- Conclusions & Future Directions

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Background



Some are easy...

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- "Embarrassingly parallel"
 - No communication needed
 - Processes can run independently of one another
- Examples
 - Brute-force search
 - Monte Carlo simulation
- In seismic processing
 - per shot
 - per frequency slice

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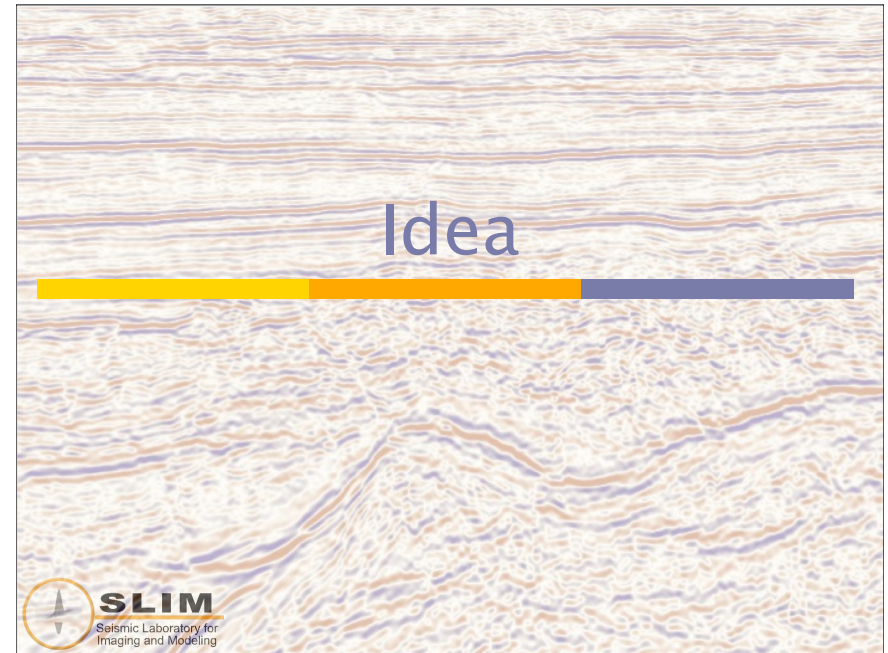
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Some aren't...

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- FFT
 - heavy in communication
- FDCT
 - FFT-based
- Anything FDCT-based
 - Many algorithms used by SLIM



Idea

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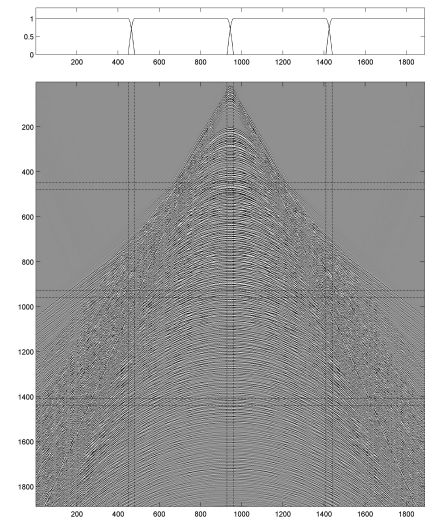
- Window data in some/all directions
 - non-overlapping windows not suitable
 - edge effects from thresholding
- Overlapping, tapered windows
 - only overlapping regions are communicated
 - tapering maintains constant energy
- Regularly update overlapping region
 - maintain continuity between windows



Idea

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- Shows 4 windows along each dimension
- Taper functions shown on top
- Dashed lines show window edges
 - space in between lines is tapered overlap

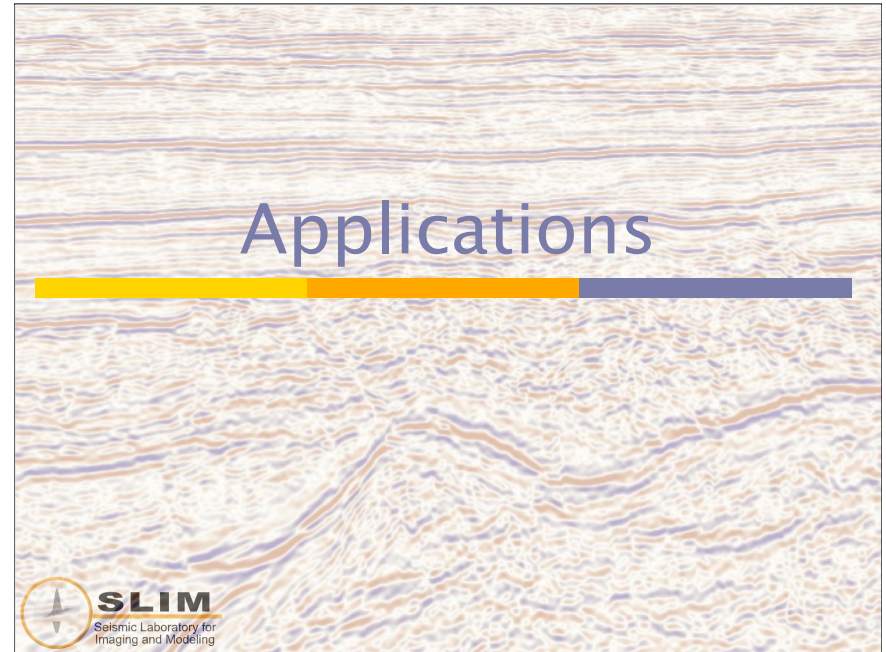




In Mathematical Terms...

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- Linear operator **A**
 - communicates overlap
 - converts non-overlapping windows to overlapping ones
- Linear Operator **B**
 - applies taper at edges of windows
- Combined operator **T = BA** satisfies:
 - $\langle \mathbf{T}\mathbf{x}, \mathbf{y} \rangle = \langle \mathbf{x}, \mathbf{T}^H \mathbf{y} \rangle$
 - $\mathbf{T}^H \mathbf{T} = \mathbf{I}$



Algorithms

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- At SLIM: iterative thresholding
 - Generalized thresholded Landweber
 - denoising
 - interpolation
 - Block coordinate relaxation method
 - primary-multiple separation
 - ground roll removal
- Many, many more possibilities



PWFDCT

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- We define a new linear operator
 - $\mathbf{P} = \mathbf{C}\mathbf{T}$
 - $\mathbf{P}^H \mathbf{P} = \mathbf{I}$
- Takes the place of **C**
 - requires no changes to algorithms
- Minor differences between **C** and **P**
 - **P** ignores lowest frequencies / largest curvelet scales



Thresholding

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- Tapering impacts thresholding
 - coefficients removed when they shouldn't be
- Taper-corrected threshold weighting required
 - need (diagonal) operator **D** that satisfies:
 - $C^HDCx = Tx$
 - apply **D** to a threshold value or vector
- **D** can be approximated several ways
 - Monte Carlo sampling
 - Evaluating taper at curvelet locations



Performance

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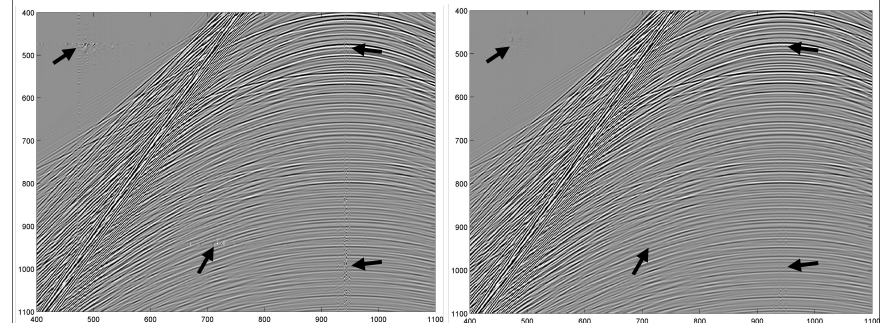
- Simple benchmark test
 - 10 forward/transpose PWFDCCT's

Decomposition	Global Size	Local Size	Overlap	Execution Time
2x2	1024x1024	544x544	16	51.97
		630x630	64	66.94
	2048x2048	1056x1056	16	201.85
4x4	2048x2048	544x544	16	52.67
		630x630	64	67.26
	4096x4096	1056x1056	16	202.53
8x8	4096x4096	544x544	16	61.89
		630x630	64	87.84
	8192x8192	1056x1056	16	220.68
		1152x1152	64	257.50



Importance of Overlap

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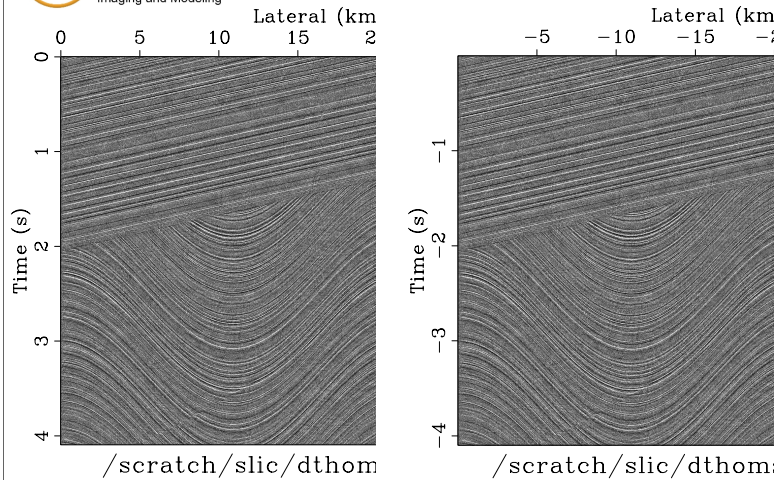


- Interpolation results from 30% missing seismic traces



Serial vs. Parallel

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Conclusions & Future Directions



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Summary

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- PWFDCCT can replace FDCT
 - highly scalable
 - share similar mathematical properties
 - suitable for many iterative algorithms
 - including several used by SLIM
- Overlapping windowing generalizable
 - can define "PW" versions of many operators
 - i.e. FFT, Wave Atom, etc.
- Preliminary testing complete
 - performs as expected

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Where to next?

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- Further testing
 - very large scale runs
- Application to new algorithms, transforms
 - block solver
 - STOMP
 - Wave Atom

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The End!

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- For more, see:
 - D. Thomson, G. Hennenfent, H. Modzelewski and F.J. Herrmann. A parallel windowed fast discrete curvelet transform applied to seismic processing. 2006. (accepted to SEG 2006 annual meeting)