High-Performance Compressive Sensing

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Herschel Space Telescope

- Sensitive to the far infrared and submillimeter wavebands
- Capable of seeing the coldest and most obscure objects in space
- Projects approximate cost over 450 million (4 yr mission)

Taking measurements

- Why go through all the effort of aquiring data that will be lost anyway?
- Why can we not just measure the parts that are not thrown away?
- Is there a way to take advantage of structure and redundancy?

Compressive Sensing (CS)

- CS encodes a signal into a relatively small number of linear measurements.
- Exploits structure and redundancy in the majority of interested signal.
- Recovers sparse compressible signals using $k <$ **Shannon-Nyquist** sample rate.
  - No information loss if we sample at 2x the bandwidth

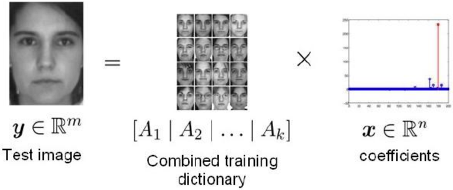
Applications of *Compressive Sensing*

Advantages:

- faster sampling
- higher-dimensional data
- lower energy consumption

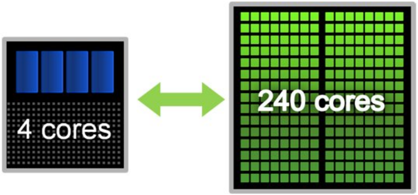
Real-World applications:

- MRI images
- Image reconstruction
- Face recognition
- Infared spectroscopy



GPU computation

- Use of a GPU (graphics processing unit) to do general purpose computing.
- Use a CPU and GPU together in a heterogeneous computing model.
- Major difference:



Jacket

- Brings speed and visual computing capability of GPUs to MATLAB programs.
- NOT a collection of GPU functions.
- Allows the use of multiple GPUs simultaneously.

Disadvantages of the GPU

- Recursion is not allowed.
- Double precision computation CANNOT reach card peak performance (78 v. 933).
- The bus bandwidth and latency between the CPU and the GPU becomes a **bottleneck**.
- Branching may impact performance *significantly*.

Reconstruction from Partial Fourier data (RecPF)

$$\min_u TV(u) + \lambda\|\Psi u\| + \mu\|\mathcal{F}_p(u) - f_p\|^2$$

where we have

- u is the signal/image to be reconstructed
- TV(u) is the total variation regularization term
- Ψ is a sparsifying basis
- $\mathcal{F}_p$ is a partial Fourier matrix
- f_p is a vector of partial Fourier coefficients

RecPF using ciculant matrices (RecPC)

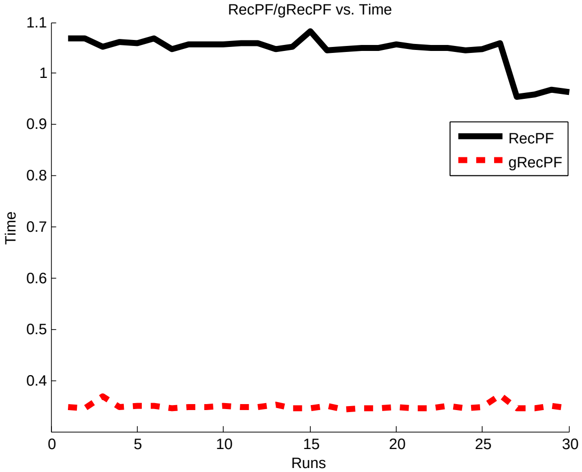
$$\min_u TV(u) + \lambda\|\Psi u\| + \frac{\mu}{2}\|PCu - b\|^2$$

where we have

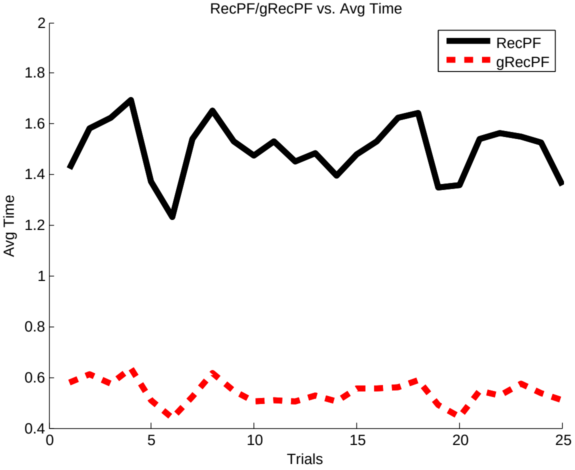
- u is the signal/image to be reconstructed
- TV(u) is the total variation regularization term
- Ψ is a sparsifying basis
- P is a selection operator
- C is a block-circulant matrix

RecPF ⇒ gRecPF (using Jacket)

- RecPF uses an alternating minimization scheme where the main computation involves shrinkage and fast Fourier transforms (FFTs)

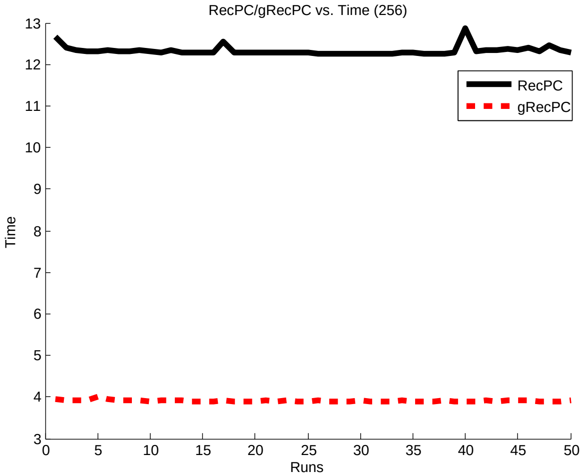


With avg. time taken before instantition



RecPC ⇒ gRecPC (using Jacket)

- However, hardware realizations make it difficult and costly to implement random matrices.
- Sol'n: use circulant matrices as basis matrix



Future work

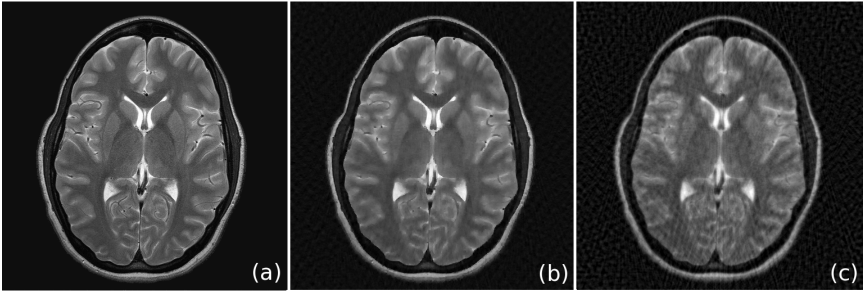
- Need to finish the anisotropic cases for both gRecPF & gRecPC.
- Try and make new algorithms (Median formula).
- Make CUDA prototypes.

Acknowledgements

- Dr. Wotao Yin
- Dr. Zhu Han
- Russell Carden

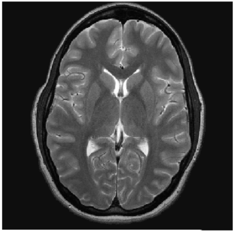
gRecPF

Using only 22% of measurements we can reconstruct images to single precision.

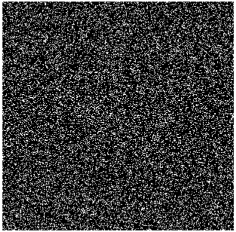


gRecPC

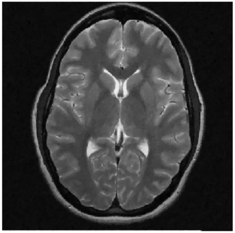
original



sample mask, 20.0%



recovery, SNR 19.1



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