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 acquiring 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 $k < \textbf{Shannon-Nyquist}$ 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
- \( \Psi \) is a sparsifying basis
- \( \mathcal{F}_p \) is a partial Fourier matrix
- \( f_p \) is a vector of partial Fourier coefficients
RecPF using circulant 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
- $\Psi$ is a sparsifying basis
- $P$ is a selection operator
- $C$ is a block-circulant matrix
RecPF $\Rightarrow$ 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 instantiation
RecPC $\Rightarrow$ 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.
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Using only 22% of measurements we can reconstruct images to single precision.