Productive GPU Software

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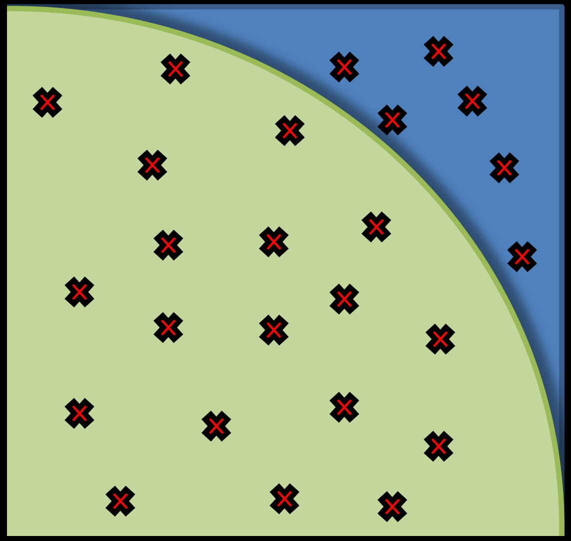
Outline

- Introduction to Jacket for MATLAB®
- GFOR
- Comparison with PCT™ alternative
- Moving into the future
- Case studies and code demos

Easy GPU Acceleration of M code

```
n = 20e6;  % 20 million random samples
X = grand(1,n,'gdouble');
Y = grand(1,n,'gdouble');
distance_to_origin = sqrt( X.*X + Y.*Y );
is_inside = (distance_to_origin <= 1);
pi = 4 * sum(is_inside) / n;
```



Matrix Types

gdouble
double precision

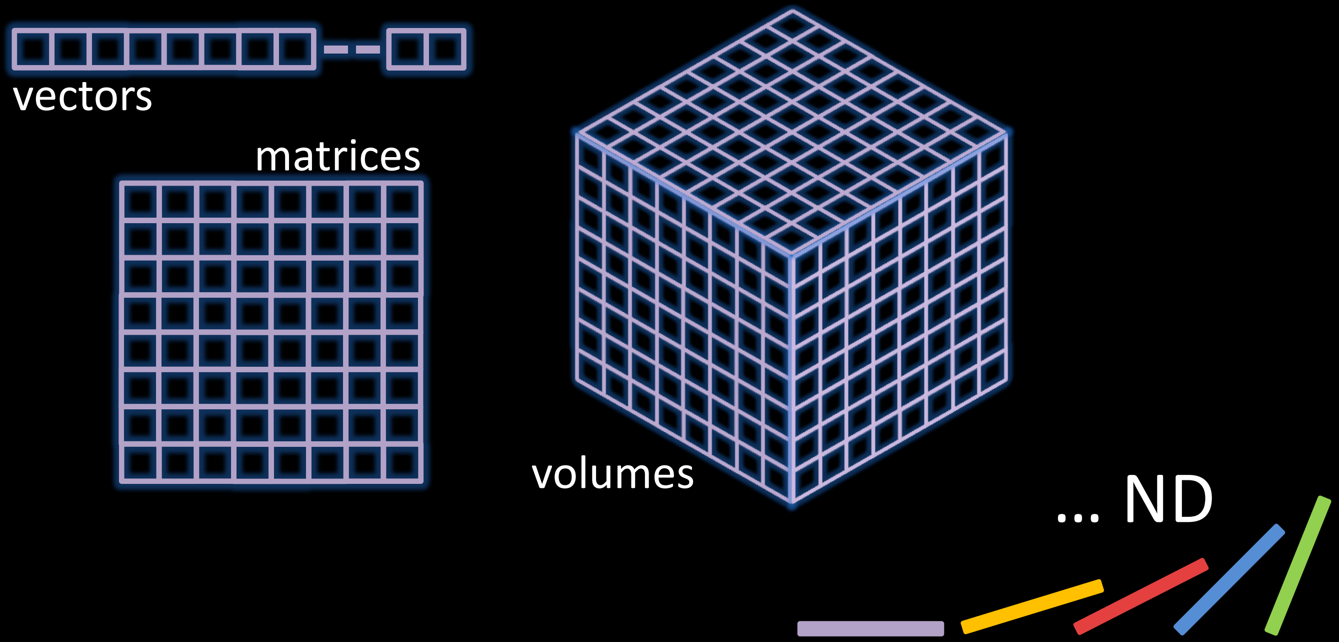
glogical
boolean

guint#
unsigned integers

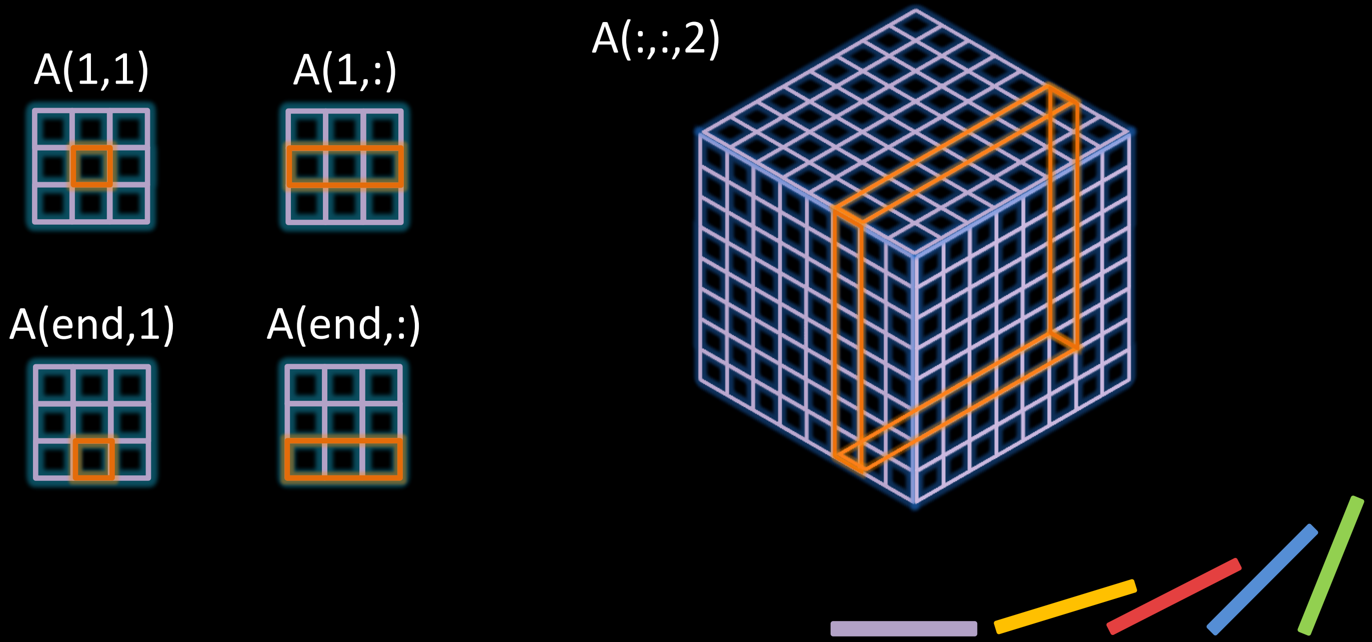
gint#
integers

gsingle
single precision

Matrix Types: ND Support



Matrix Types: Easy Manipulation



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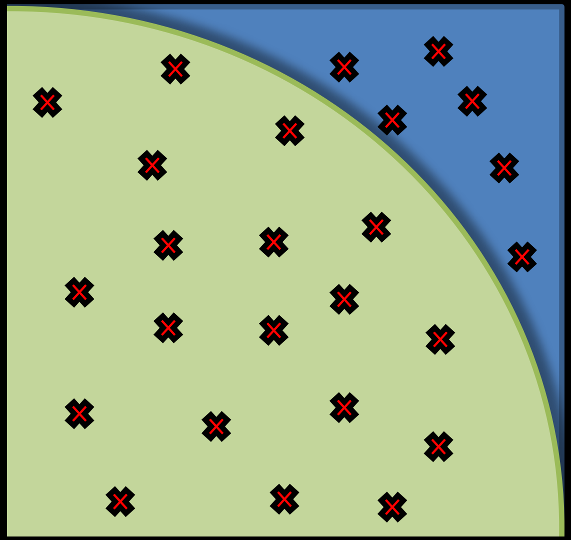


Easy GPU Acceleration of M code

No GPU-specific stuff involved (no kernels, no threads, no blocks, just regular M code)

"Very little recoding was needed to promote our Lattice Boltzmann Model code to run on the GPU." –Dr. Kevin Tubbs, HPTi

GFOR – Parallel FOR-loop for GPUs

- Like a normal FOR-loop, but faster

Regular FOR-loop (3 serial kernel launches)

```
for i = 1:3
    C(:,:,i) = A(:,:,i) * B;
```

Parallel GPU FOR-loop (only **1** kernel launch)

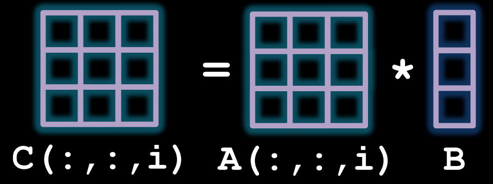
```
gfor i = 1:3
    C(:,:,i) = A(:,:,i) * B;
```

Example: Matrix Multiply

Regular FOR-loop (3 serial kernel launches)

```
for i = 1:3
    C(:,:,i) = A(:,:,i) * B;
```

iteration i = 1



Example: Matrix Multiply

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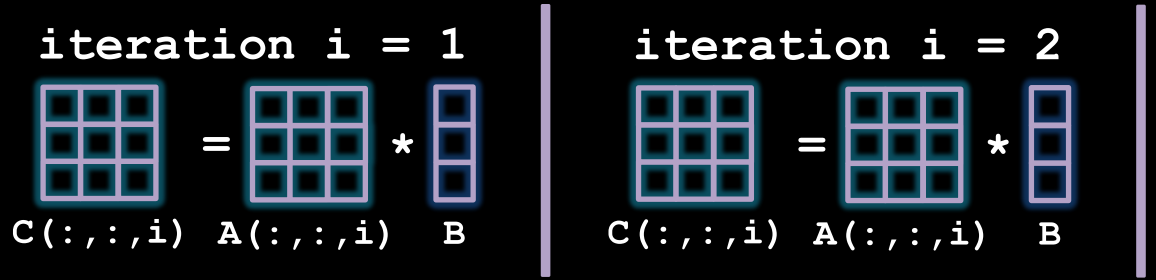

Example: Matrix Multiply

Regular FOR-loop (3 serial kernel launches)

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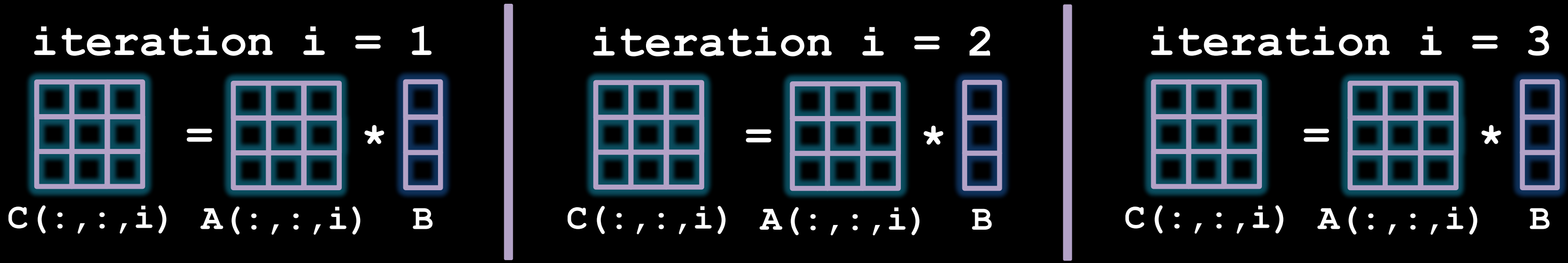
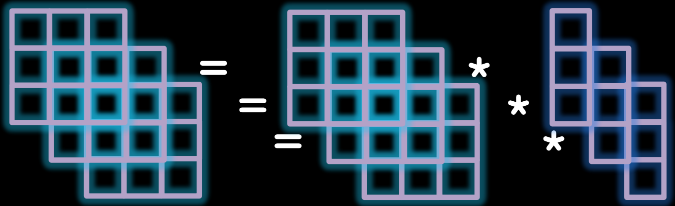


Example: Matrix Multiply

Parallel GPU FOR-loop (only **1** kernel launch)

```
gfor i = 1:3
    C(:,:,i) = A(:,:,i) * B;
```

simultaneous iterations i = 1:3



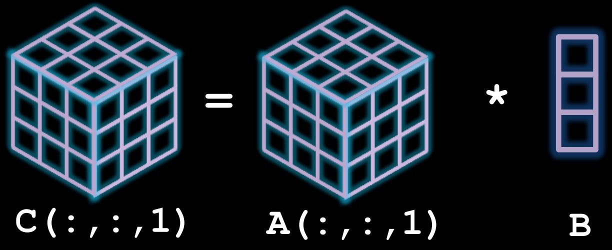
C(:,:,1:3) A(:,:,1:3) B

Example: Matrix Multiply

Parallel GPU FOR-loop (only **1** kernel launch)

```
gfor i = 1:3
    C(:,:,i) = A(:,:,i) * B;
```

`simultaneous iterations i = 1:3`



Example: Summing over Columns

- Think of gfor as "syntactic sugar" to write vectorized code in an iterative style.

Three passes to sum all columns of B

```
for i = 1:3
    A(i) = sum(B(:,i));
```

One pass to sum all columns of B

```
gfor i = 1:3
    A(i) = sum(B(:,i));
```

Both equivalent to "**sum(B)**", but latter is faster (more explicitly written)

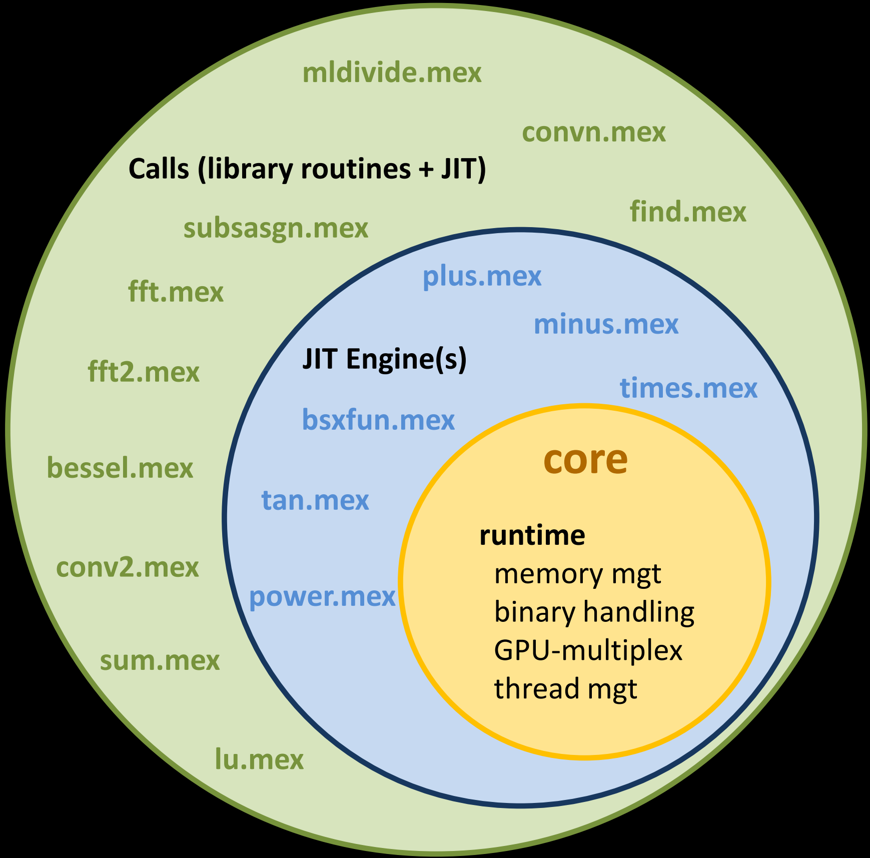
Easy Multi GPU Scaling

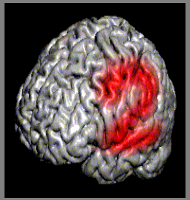
```
y = gzeros( 5, 5, n );
for i = 1:n,
    gselect(i);              % choose GPU for this iteration
    x = grand(5,5);          % add work to GPU's queue
    y(:,:,i) = fft(x);       % more work in queue
end

% all GPUs are now computing simultaneously, until done
```

Technology Stack

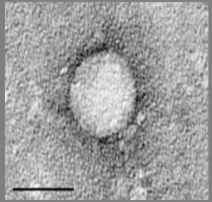
- A full system making optimizations for you
- Including
  - "Core" brains
  - "JIT" speed
  - "Calls" heavy-lifting





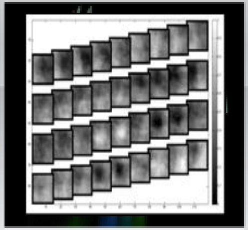
17X

Neuro-imaging
Georgia Tech



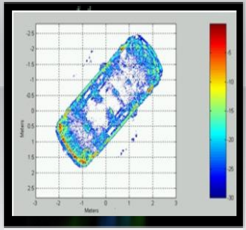
20X

Bio-Research
CDC



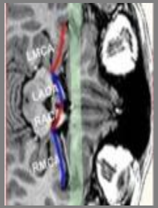
20X

Video Processing
Google



45X

Radar Imaging
System Planning



12X

Medical Devices
Spencer Tech

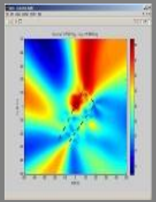
http://www.accelereyes.com/case_studies

5X

Weather Modeling
NCAR

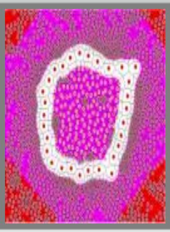
35X

Power Engineering
IIT India



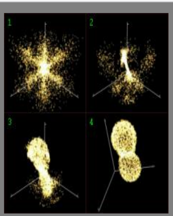
17X

Track Bad Guys
BAE
Systems



70X

Drug Delivery
Georgia Tech

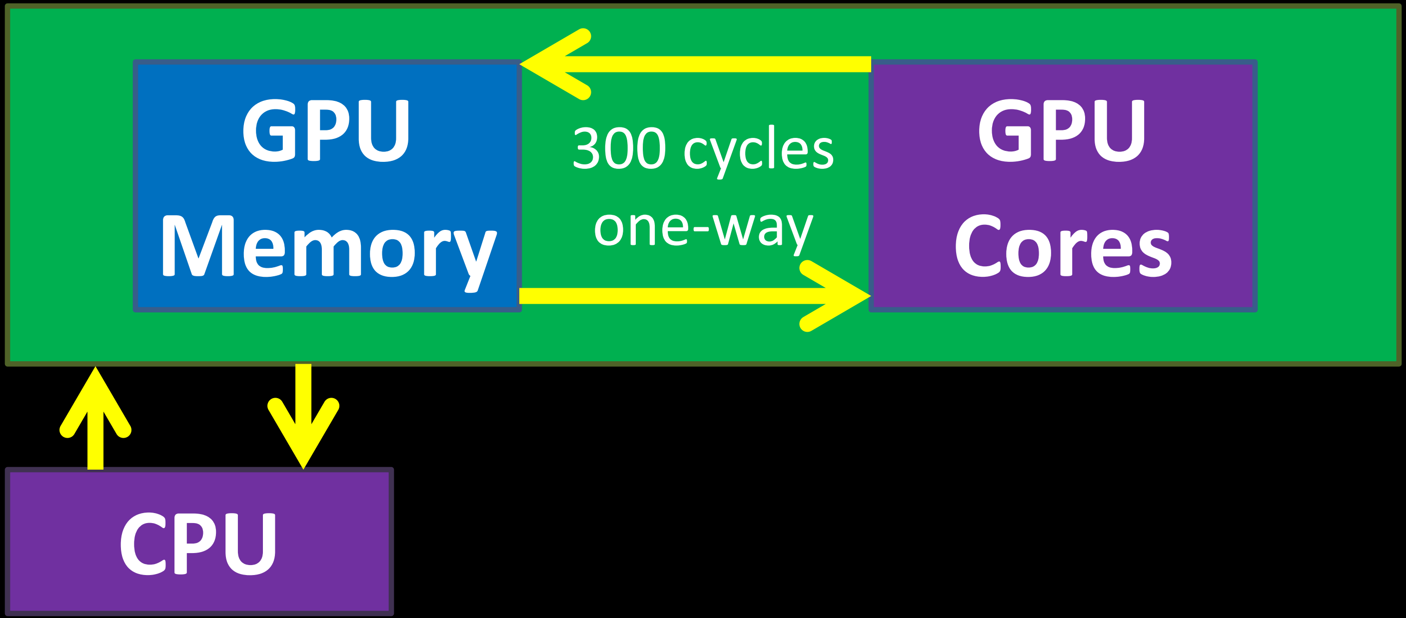


35X

Bioinformatics
Leibniz

Automated Optimizations

```
A = sin( x + y ).^2
```



Automated Optimizations

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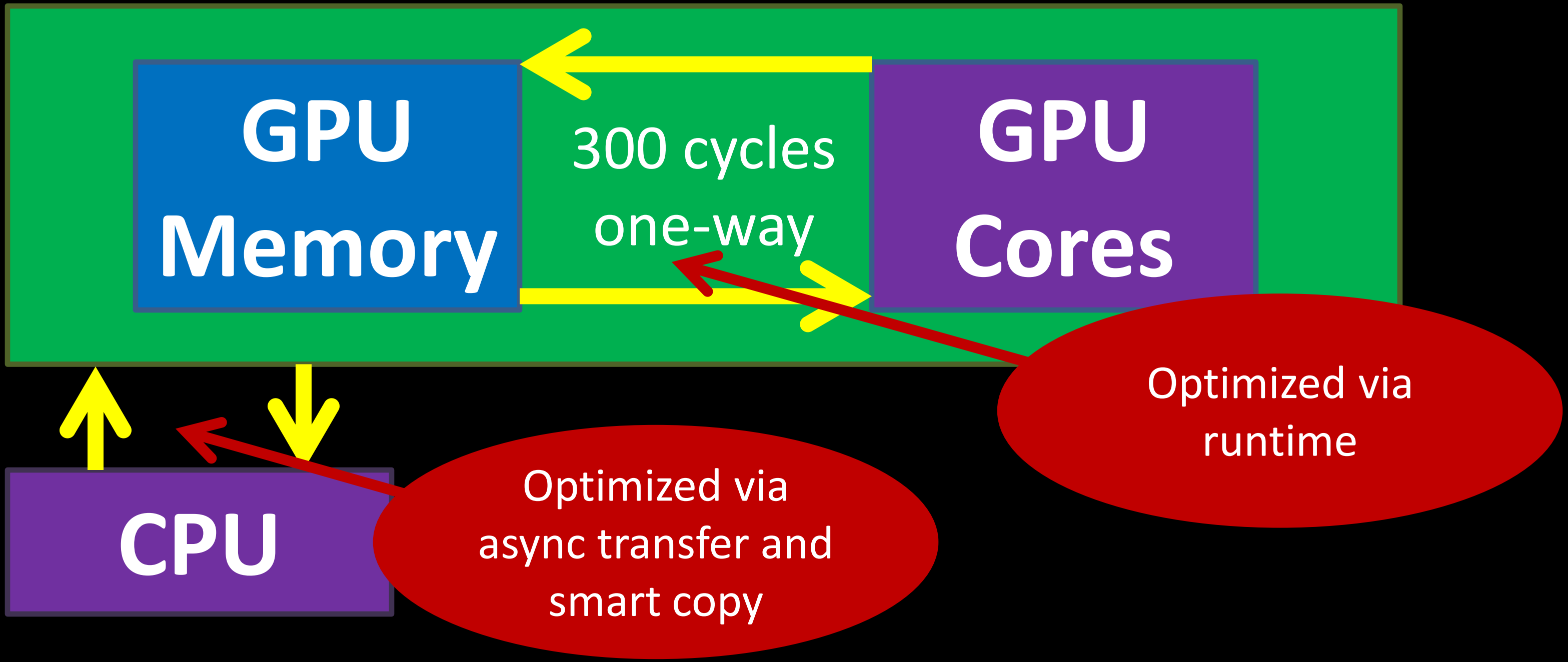

Compare versus PCT { parallel computing toolbox™

$$A = \sin(x + y).\hat{}2$$

<u>PCT</u>
Load x, y (300 cycles)
+ (4 cycles)
Store Temp1 (300 cycles)
Load Temp1 (300 cycles)
Sin (~20 cycles)
Store Temp2 (300 cycles)
Load Temp2 (300 cycles)
.^ (~10 cycles)
Store A (300 cycles)

<u>Jacket</u>
Load x, y (300 cycles)
Sin(x+y).^2 (34 cycles)
Store A (300 cycles)

Compare versus PCT { parallel computing toolbox™

```
A = sin( x + y ).^2
```

<u>PCT</u>

Load x, y (300 cycles)
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1834 cycles

<u>Jacket</u>

Load x, y (300 cycles)
Sin(x+y).^2 (34 cycles)
Store A (300 cycles)

634 cycles

Compare versus PCT { parallel computing toolbox™

$$A = \sin(x + y).\hat{}2$$

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1834 cycles

Jacket

Load x, y (300 cycles)
Sin(x+y).^2 (34 cycles)
Store A (300 cycles)

634 cycles

Theoretically, a 3x increase. Actually, a 20x difference:

- **Legacy Java system**
- **Better GPU code**

Jacket has 10X more functions…

gfor (loops)

reductions
- sum, min, max, any, all, nnz, prod
- vectors, columns, rows, etc

dense linear algebra
- LU, QR, Cholesky, SVD, Eigenvalues, Inversion, det, Matrix Power, Solvers

gcompile (fine-grain)

convolutions
- 2D, 3D, ND

FFTs
- 2D, 3D, ND

image processing
- filter, rotate, erode, dilate, bwmorph, resize, rgb2gray
- hist, histeq

gselect (multi-GPU)

interp and rescale
- vectors, matrices
- rescaling

sorting
- along any dimension
- find

help
- gprofview

and many more…

Easy To Maintain

- Write your code once and let Jacket carry you through the coming hardware evolution.
  - Each new Jacket release improves the speed of your code, without any code modification.
  - Each new Jacket release leverages latest GPU hardware (e.g. Fermi, Kepler), without any code modification.

New in Jacket 2.1: Optimization

- Unconstrained Optimization in 2.1
  - Gradient Descent and BFGS methods
  - Jacobian computation with GFOR
- Batched-mode Optimization in 2.2
- Search-based Optimization in 2.2
- Constrained Optimization in 2.3

Sparse Roadmap

Current functions supported:

- Matrix multiply
- Triangular matrix solve
- Iterative solvers with no pre-conditioning.
- Examples: CG, BICG, BICGSTAB, BICGSTABL, GMRES, LSQR

Under development:

- Iterative solvers with pre-conditioning and improved performance
- Examples: CG, BICG, BICGSTAB, GMRES

Move to C/C++, Fortran, or Python

ArrayFire GPU library

- Free version for most users (single GPU usage)
- Pro version (multi-GPU usage)
- Available for CUDA or OpenCL devices

ArrayFire

The World's Largest, Fastest GPU Library

ArrayFire Example (C++)

```
#include <stdio.h>
#include <arrayfire.h>
using namespace af;
int main() {
    // 20 million random samples
    int n = 20e6;
    array x = randu(n,1), y = randu(n,1);
    // how many fell inside unit circle?
    float pi = 4 * sum<float>(sqrt(mul(x,x)+mul(y,y))<1) / n;
    printf("pi = %g\n", pi);
    return 0;
}
```

Case Studies

See more examples:

http://www.accelereyes.com/examples/case_studies

http://blog.accelereyes.com/blog/

Case Study: Australian Brokerage

- Description: Nonlinear regressive model fitting
- Speedup: 115x
- Solution: Jacket, Jacket DLA, ArrayFire Pro, Consulting

Case Study: Australian Brokerage

- Description: Modified conjugate gradient for sparse matrices
- Speedup: 10-30x (Depends on data size. Larger data gives bigger speedups.)
- Solution: Jacket, Jacket SLA, ArrayFire Pro, Consulting

Case Study: Koch Industries

- Description: Option pricing based on Monte-Carlo simulation
- Speedup: 60 - 70x
- Solution: Jacket

Case Study: Bank of America

- Description: Visualization of server utilization and workloads, required to run in MATLAB®
- Focus only on visualization, not computation
- Result: Beautiful OpenGL 3D renderings
- Solution: Jacket with the Graphics Library

Automotive Trader Example

- Description: Algorithmic trading
- Speedup: 37x on 3 GPUs (14x on 1 GPU)
- Solution: Jacket, Jacket MGL for 3 GPUs
- Learn more: http://www.automatedtrader.net/articles/software-review/107768/mashup

Demos

Discussion

jacket

Faster MATLAB® through GPU computing