GPU Computing with MATLAB

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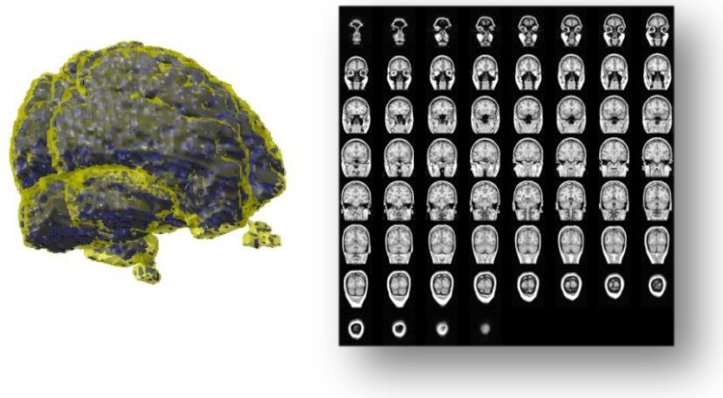
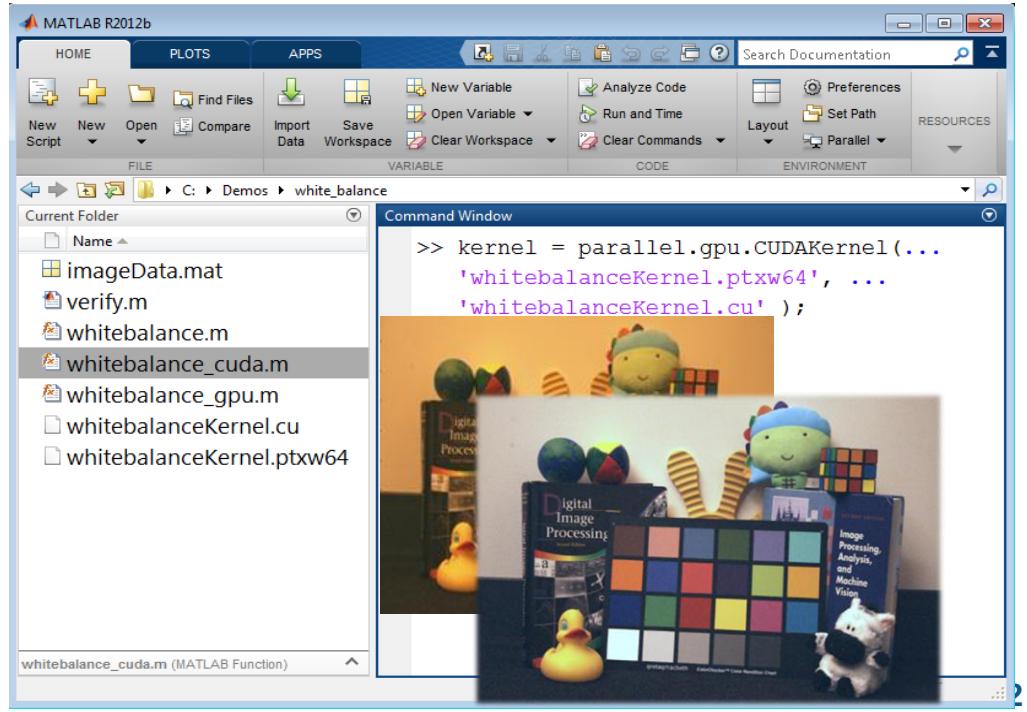
Product Marketing Manager
Image Processing Applications

GPU Computing with MATLAB

- For MATLAB Programmers
  - Acceleration MATLAB Code with GPUs
  - Minimal code changes



- For CUDA Programmers
  - Create test harnesses for your kernels
  - Quickly explore algorithm parameters
  - Analyze and visualize kernel results

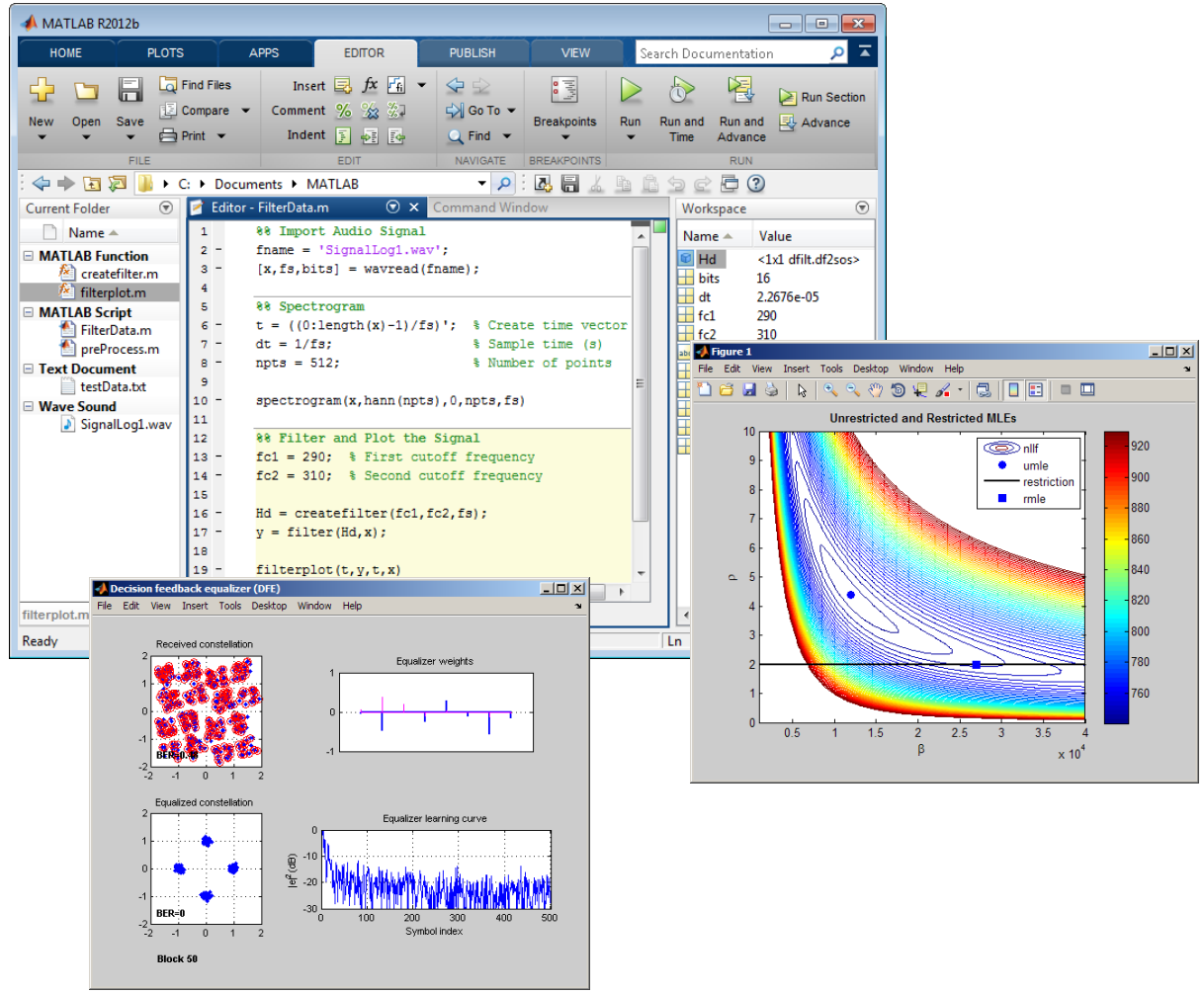


Agenda

What is MATLAB?
Demo: Designing a Camera Pipeline in MATLAB
Demo: Brain Scan Demo – CPU vs GPU
Demo: White Balance Example using CUDA Code
Summary

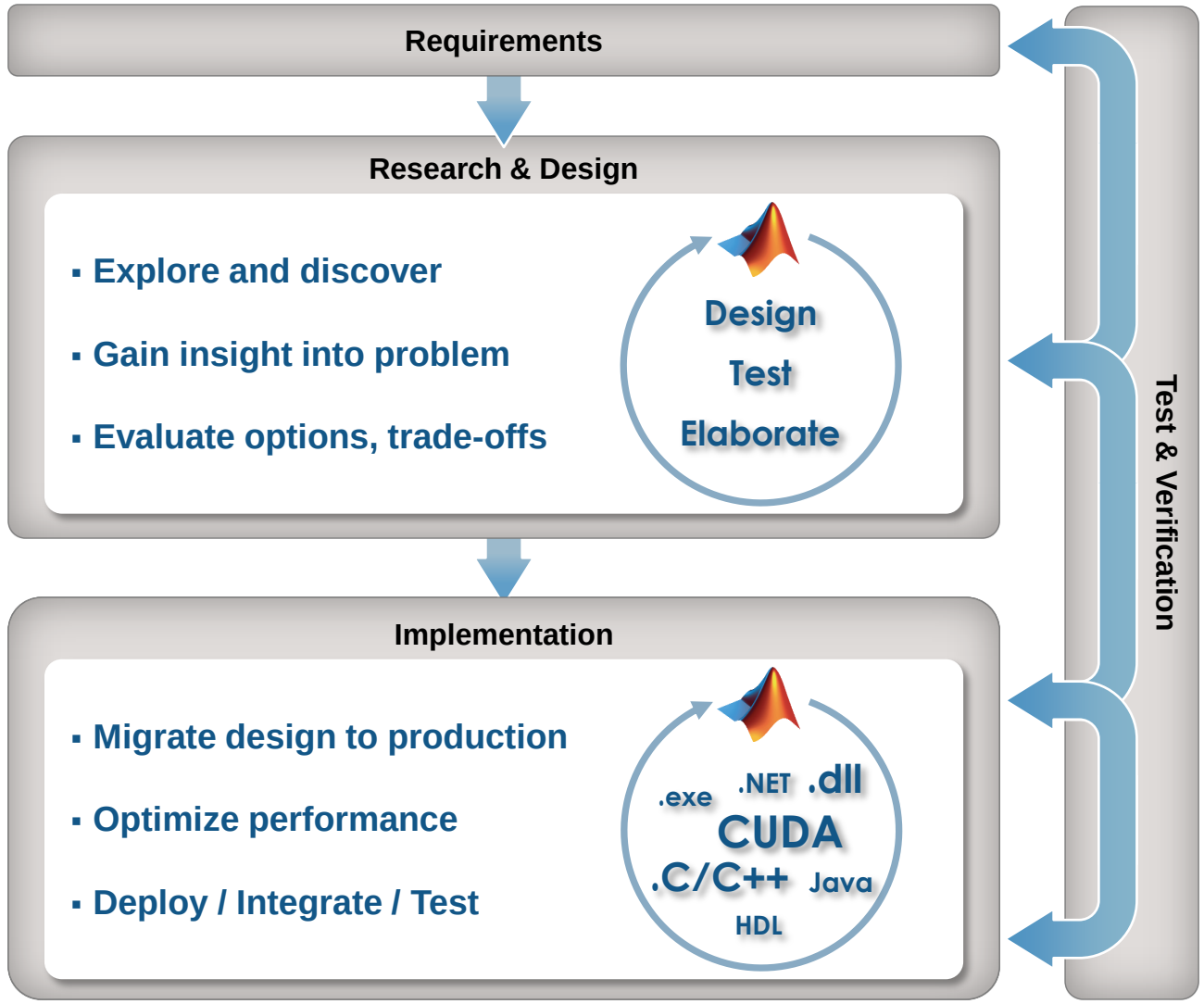
What is MATLAB?

- High level language and development environment for:
  - Algorithm and application development
  - Data analysis
  - Mathematical modeling
  - Multicore and GPU computing*
- Extensive math, engineering, and plotting functionality
- Add-on products for image and video processing, communications, signal processing, financial modeling, and more
- Over 1.3 million COM & EDU users



* Requires Parallel Computing Toolbox

Algorithm Development Process



Running MATLAB code on the GPU

- 200+ MATLAB functions that are GPU enabled
  - Random number generation
  - FFT
  - Matrix multiplications
  - Solvers
  - Convolutions
  - Min/max
  - SVD
  - Cholesky and LU factorization

- Additional support in toolboxes

Image Processing
- Morphological filtering, 2-D filtering, …

Communications
- Turbo, LDPC, and Viterbi decoders, …

Signal Processing
- Cross correlation, FIR filtering, …

Neural Networks
- Network training and simulation

- Ability to launch CUDA kernels

- Ability to deploy MATLAB GPU applications

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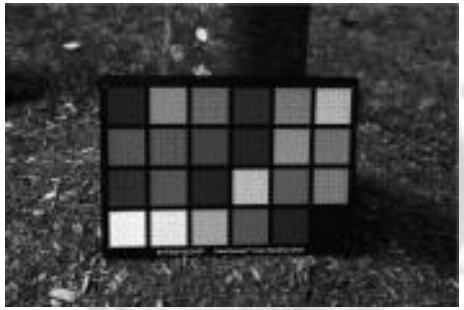
Demo: Digital Camera Pipeline

From Sensor Data to Image

Scene

Image



Noise Reduction

Demosaic

Tone Mapping

White Balance

Gamma Correction

Stages of the Camera Pipeline

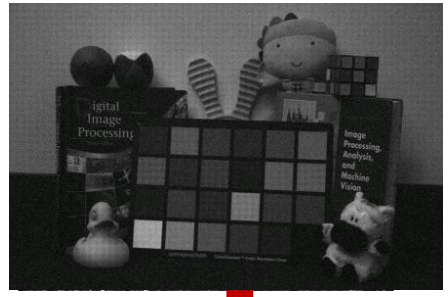
1. **Noise Reduction** : Reduce noise in the raw data

2. **Demosaic**: Interpolate the raw image into an RGB image

3. **Tone Mapping**: Convert sensor RGB values to RGB values

4. **White Balance**: Adjust color of image to compensate for different lighting conditions

5. **Gamma Correction**: Adjust color of image for display



1.	Noise Reduction
2.	Demosaic
3.	Tone Mapping
4.	White Balance
5.	Gamma Correction

Approaches to GPU Computing in MATLAB

Ease of Use

- GPU enabled functions
- Simple programming constructs: `gpuArray, gather`
- Advanced programming constructs: `arrayfun`
- Interface for experts: `CUDAKernel, MEX support`

Greater Control

http://www.mathworks.com/help/distcomp/run-cuda-or-ptx-code-on-gpu.htmll

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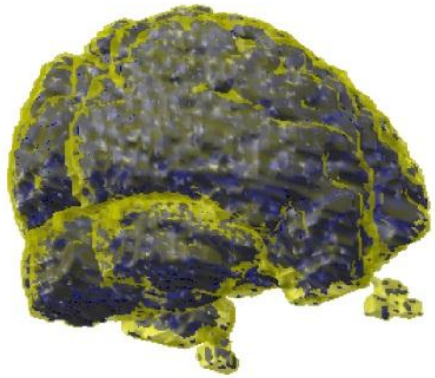
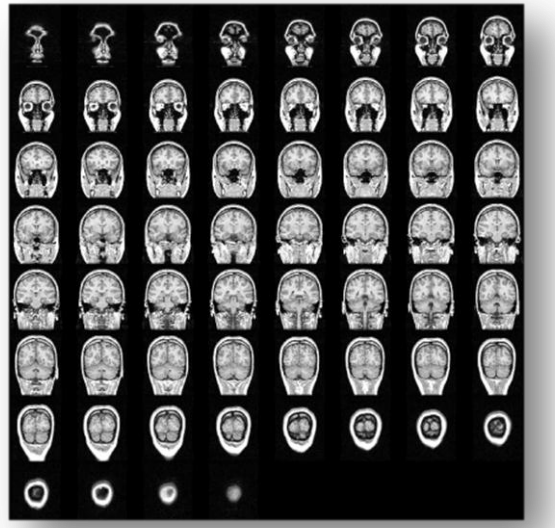
Demo: Brain Scan
CPU vs GPU





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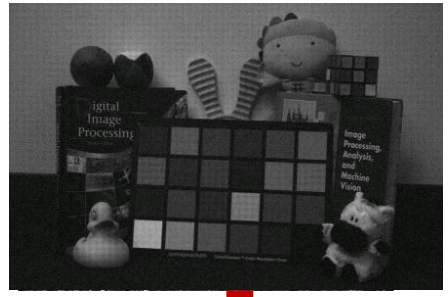

1. Noise Reduction
2. Demosaic
3. Tone Mapping
4. White Balance
5. Gamma Correction

Demonstration: White balance algorithm

- Goal: Deliver algorithm as CUDA C/C++

Before

After

- How can MATLAB support the CUDA development process?

Programming Parallel Applications (GPU)

Ease of Use

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Summary Part 1: Apply Scaling Factors on GPU

Code run entirely on CPU

```
function imageData = whitebalance(imageData)
% WHITEBALANCE forces average image color to be gray.

% Find the average values for each channel.
avg_rgb = mean(mean(imageData));

% Find average gray value and compute scaling factor.
factors = max(mean(avg_rgb), 128)./avg_rgb;



% Adjust the image to the new gray value.
imageData(:,:,1) = uint8(imageData(:,:,1)*factors(1));
imageData(:,:,2) = uint8(imageData(:,:,2)*factors(2));
imageData(:,:,3) = uint8(imageData(:,:,3)*factors(3));
```

Execution time on CPU: **120 ms**

Applying Scaling Factors on GPU

```
function adjustedImage = whitebalance_gpu(imageData)



...


%  Load the Kernel
kernel =
parallel.gpu.CUDAKernel('applyScaleFactors.ptxw64',
'applyScaleFactors.cu' );
...
%  Copy our Image to the GPU
imageDataGPU = gpuArray( imageData );
...
%  Apply kernel to scale the color values
adjustedImageGPU = feval( kernel, adjustedImageGPU,
imageDataGPU, factors, nRows, nCols );
```

Execution time on GPU: **2.2 ms**
50x Faster

Summary Part 2: Compute Scaling Factors on GPU

Code run entirely on CPU

```
function imageData = whitebalance(imageData)
% WHITEBALANCE forces average image color to be gray.

% Find the average values for each channel.
avg_rgb = mean(mean(imageData));

% Find average gray value and compute scaling fact
factors = max(mean(avg_rgb), 128)./avg_rgb;



% Adjust the image to the new gray value.
imageData(:,:,1) = uint8(imageData(:,:,1)*factors(1));
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imageData(:,:,3) = uint8(imageData(:,:,3)*factors(3));
```

Computing Scaling Factors on GPU

```
function imageData = whitebalance(imageData)
% WHITEBALANCE forces average image color to be gray.

...


% Compute the factors from the mean.
computeFactorsKernel = parallel.gpu.CUDAKernel( ...
  'computeScaleFactors.ptxw64','computeScaleFactors.cu'
);

% 3 doubles of shared memory
computeFactorsKernel.SharedMemorySize = 3*8;
computeFactorsKernel.ThreadBlockSize = [3 1 1];
factors = feval( computeFactorsKernel, avg_rgb


...
```

Summary Part 3: Compute Mean on GPU with NPP

Code run entirely on CPU

```
function imageData = whitebalance(imageData)
% WHITEBALANCE forces average image color to be gray.

% Find the average values for each channel.
avg_rgb = mean(mean(imageData));

% Find average gray value and compute scaling factor.
factors = max(mean(avg_rgb), 128)./avg_rgb;



% Adjust the image to the new gray value.
imageData(:,:,1) = uint8(imageData(:,:,1)*factors(1));
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imageData(:,:,3) = uint8(imageData(:,:,3)*factors(3));
```

Implementing NPP through MEX

```
function adjustedImage = whitebalance_gpu(imageData)
...
%*************************************
% Find the average values for each channel.

avg_rgb = computeMeanMEX(imageDataGPU);

%*************************************

%  Copy our Image to the GPU
imageDataGPU = gpuArray( imageData );
...
%  Apply kernel to scale the color values
adjustedImageGPU = feval( kernel, adjustedImageGPU,
imageDataGPU, factors, nRows, nCols );
```

Summary Part 4: Integrate C with CUDA

Code run entirely on CPU

```
function imageData = whitebalance(imageData)
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% Find the average values for each channel.
avg_rgb = mean(mean(imageData));

% Find average gray value and compute scaling factor.
factors = max(mean(avg_rgb), 128)./avg_rgb;



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imageData(:,:,1) = uint8(imageData(:,:,1)*factors(1));
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imageData(:,:,3) = uint8(imageData(:,:,3)*factors(3));
```

Implementing C++ with CUDA Kernels

```
// dllmain.cpp : Defines the entry point for the DLL
application.
#include <mex.h>
#include <gpu\mxGPUArray.h>
#include "whitebalance.h"

// A function to compute the mean of all the elements
of a uint8 matrix on the GPU.
// Returns a single scalar value on the GPU.

void mexFunction ( const int nlhs, mxArray * plhs[],
const int nrhs,
        const mxArray * const prhs[] )
{

    //Ensure the GPU system is initialized.
    int mwGpuStat = 0;
    mwGpuStat = mxInitGPU();
    if ( mwGpuStat != 0 )
        mexErrMsgTxt( "Error initializing MW GPU
system" );
...
```

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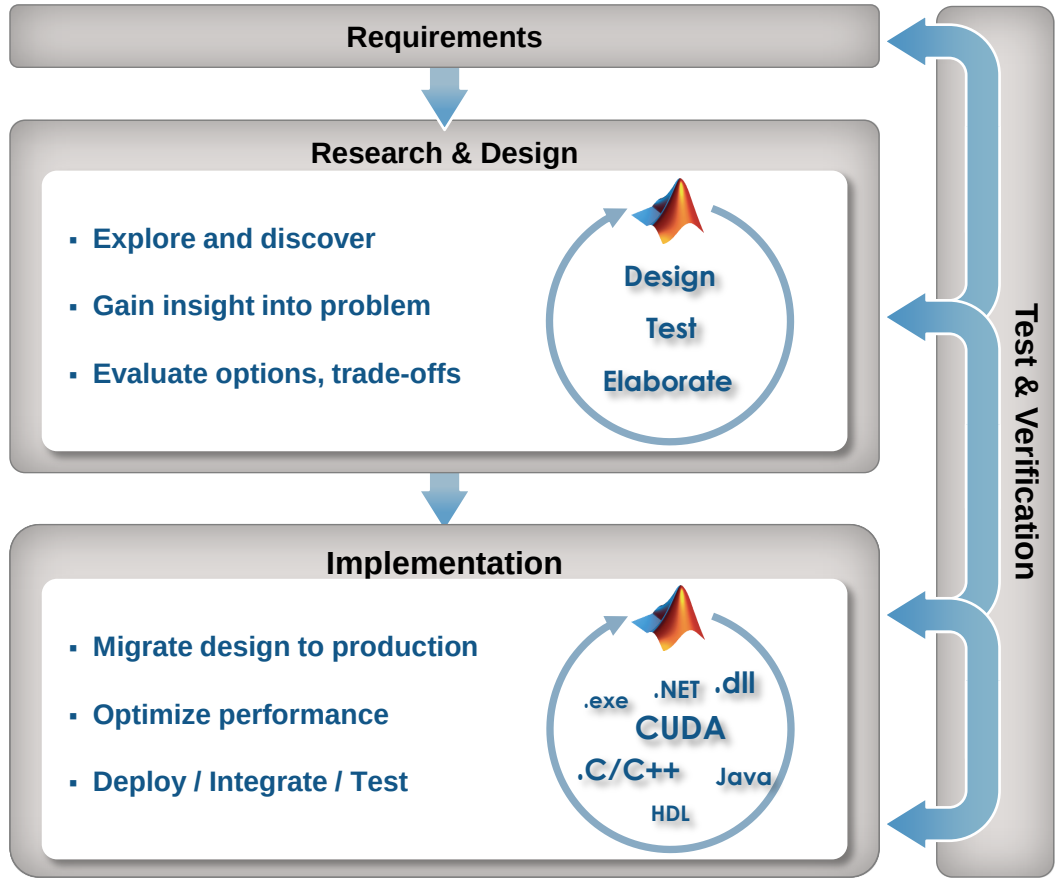
MATLAB Value-add to CUDA Programmers

- Develop prototype code to explore algorithms
- Manage GPU data and launch kernels using a simple interface
- Incrementally develop and test kernels
- Analyze and visualize kernel results



Scaling to Run on Multiple GPUs

Single GPU

```
N = 1000;  % Number of iterations

A = gpuArray(A); % transfer data to GPU


for ix = 1:M
    % Do the GPU-based calculation
    X = myGPUFunction(ix,A);
    % Gather data
    Xtotal(ix,:)= gather(X);
end
```

Multiple GPUs

```
N = 1000;  % Number of iterations

A = gpuArray(A); % transfer data


parfor ix = 1:M
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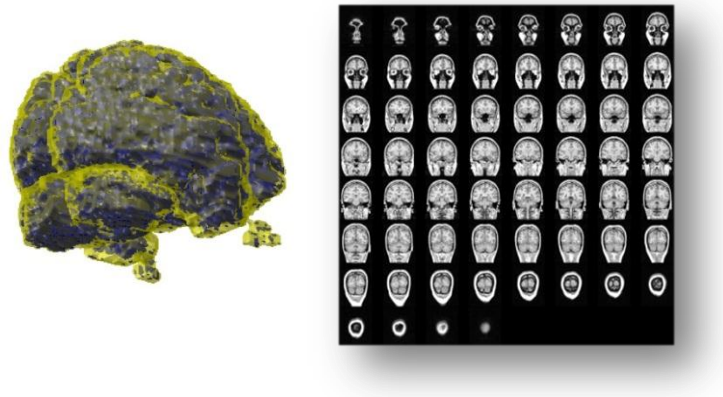

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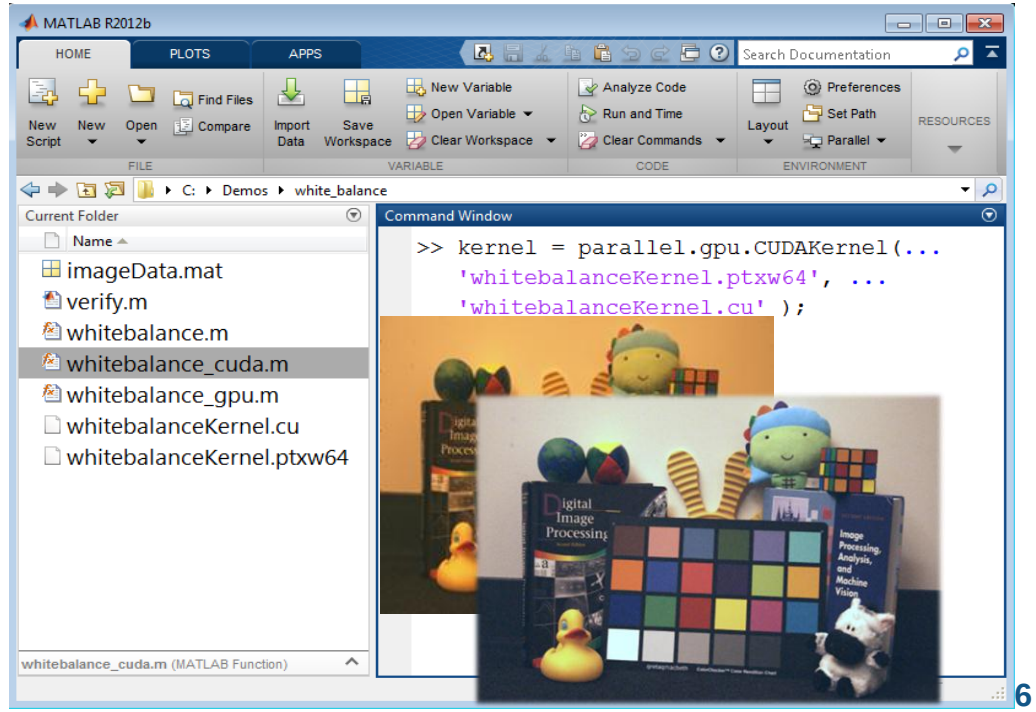

Questions & Answers