Image processing with MATLAB
@INAF

Giuseppe Ridinò - gridino@mathworks.com
Senior Application Engineer

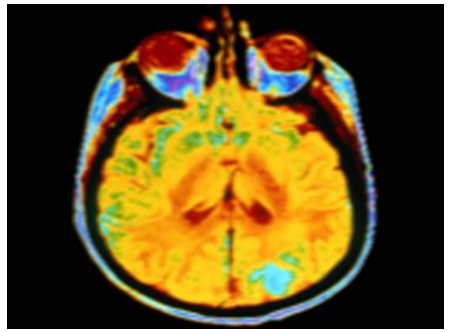
22 Maggio 2019

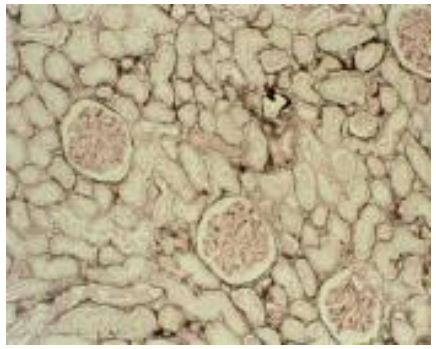
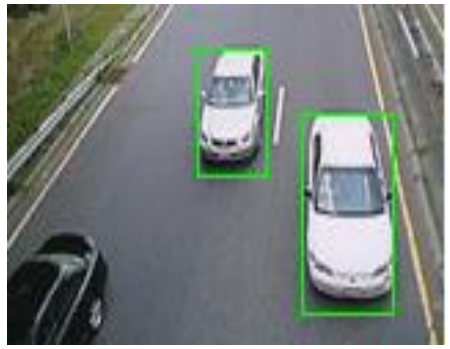
Agenda

- Introduction
- Quick intro to MATLAB
- Image Processing with MATLAB
- Managing large image sets
- What's New
- Wrap-up

Applications: Image and Video Processing

- Medical imaging
- Surveillance
- Robotics
- Automotive safety
- Consumer electronics
- Geospatial computing
- Machine vision
- Science research
- and more…

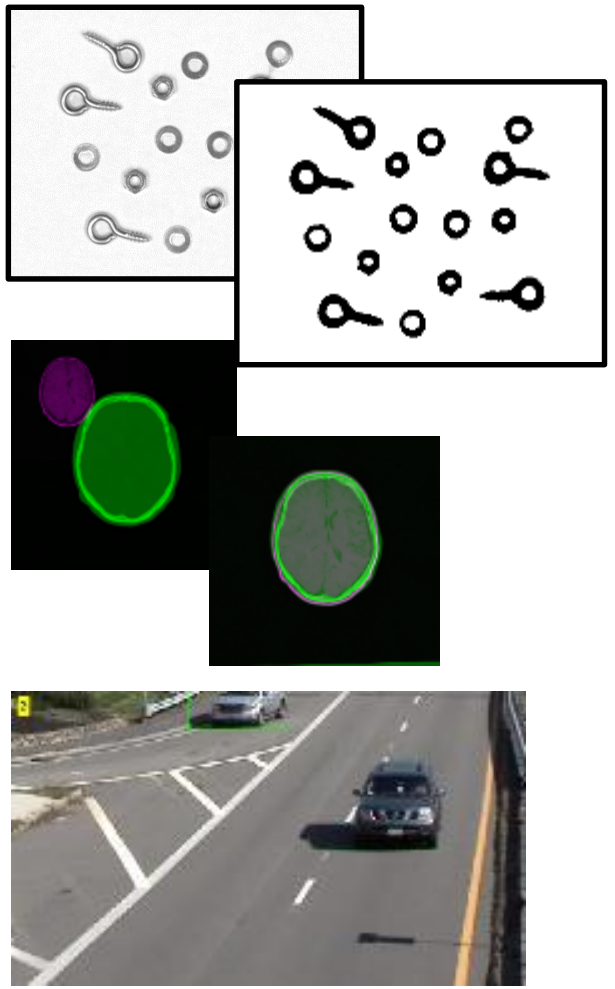





Challenges with Imaging and Vision Systems

- Reading and writing to various file formats
- Create and test algorithms with what-if scenarios
- Identifying causes of algorithm failure
- Visualizing images and intermediate results
- Processing large images with limited memory
- Executing algorithms faster



MATLAB & Simulink in Research

https://www.mathworks.com/academia/research.html

MathWorks® Products Solutions Academia Support Community Events

Academia

Search MathWorks.com

Research with MATLAB and Simulink

Researchers in engineering and science require platforms that let them explore and express new ideas, solve difficult problems, and create tools, leveraging a robust and flexible computational foundation. MATLAB and Simulink are widely used across industries for research and product development, so you can apply your research to interesting and challenging real-world examples.

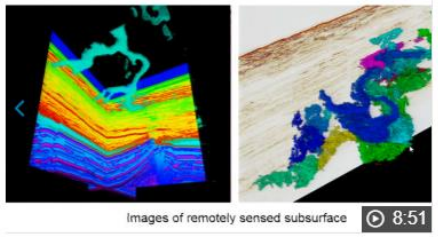
» 7 Reasons to Use MATLAB

Get MATLAB and Simulink for Academic Research

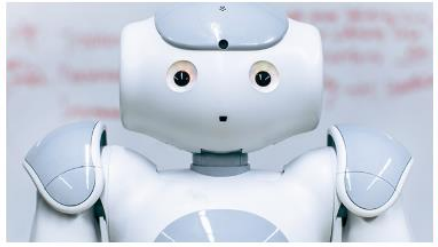
» See if you have a campus license

Get a trial

Research Highlights



MATLAB Analysis of Prestack Seismic: Using MATLAB Beyond the Geophysicist's Sandbox (Highlights)



The Robot Made Me Do It: How Robots are Changing the Lives of Children with Disabilities

Read story

MIT resea... magnify n...

Read sto...

Accelerating Your Research Activities

Featured Research Areas

MathWorks® Products Solutions Academia Support Community Events

Biological Sciences

Search MathWorks.com

Overview | Microscopy and Biomedical Imaging | Electrophysiology | Genomics and Next Generation Sequencing

Trial software | Contact s...

MathWorks® Products Solutions Academia Support Com...

Earth, Ocean, and Atmospheric Sciences

Overview | Working with Geoscience Data | Teaching Geoscience with MATLAB | Seis...

Seismology: An Active MATLAB Community

Seismologists around the world use MATLAB to study seismic events, from eart... analysis of data from sensor sites.

Explore how scientists use MATLAB in seismology, download the code, and lea...

GISMO: MATLAB Toolbox for Scientific Research in Seismology and Infrasound (File Exchange)

MATLAB for Analyzing and Visualizing Geospatial Data (Video)

BRTT Technologies Antelope Software (Tool...

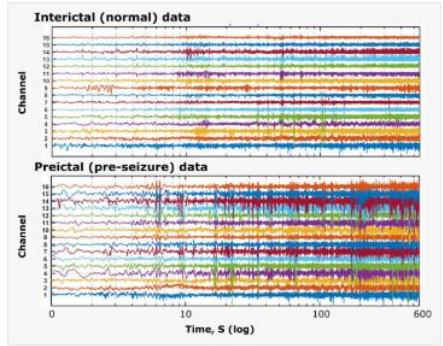
MathWorks® Products Solutions Academia Support...

Neuroscience

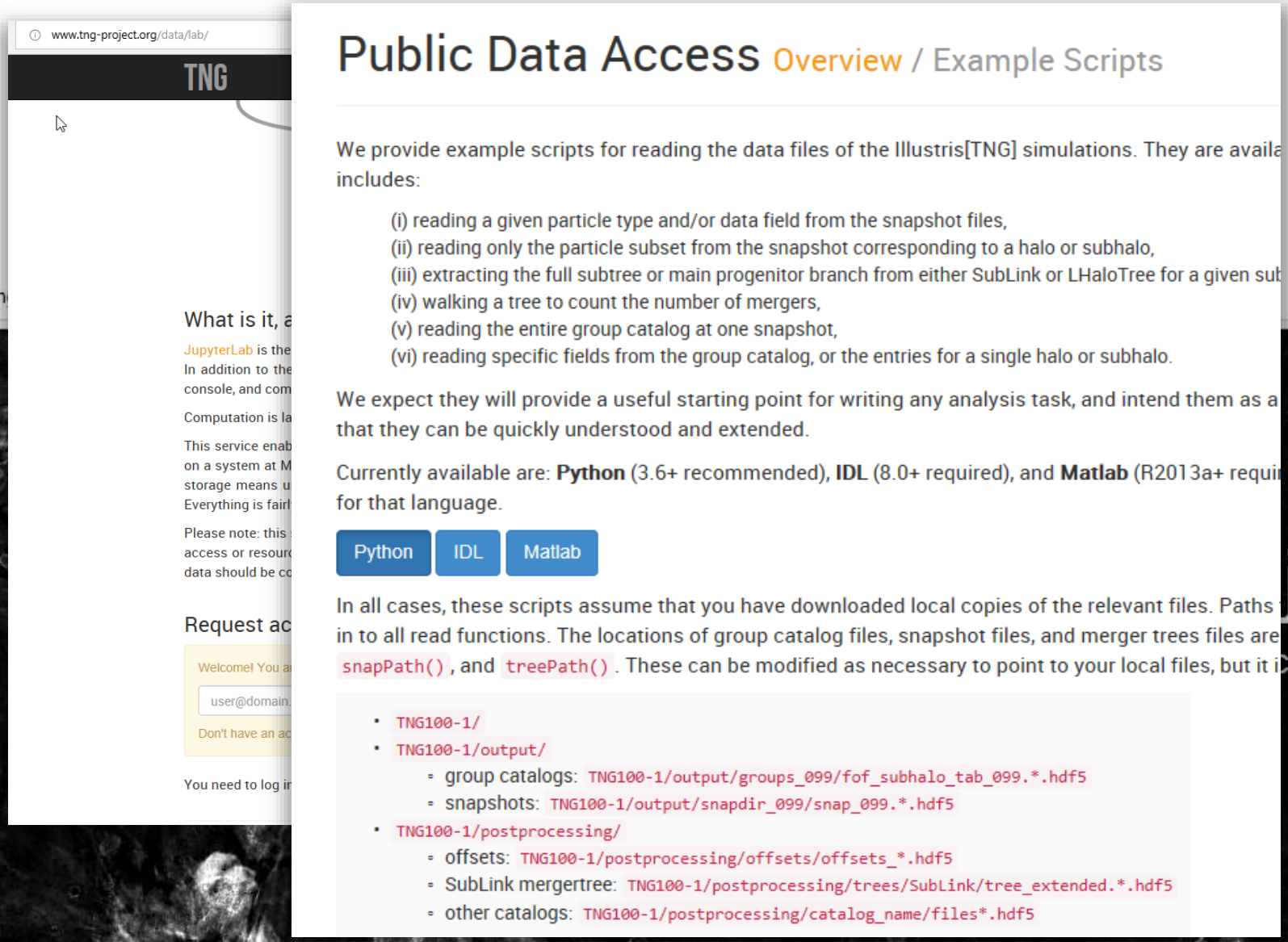
Overview | Use Cases | Resources | Latest Features

Human Brain Mapping

Use cases illustrating analysis of macroscopic data modalities,



TNG Data Project and Jupyterlab Interface



Public Data Access Overview / Example Scripts

We provide example scripts for reading the data files of the Illustris[TNG] simulations. They are availa
includes:

(i) reading a given particle type and/or data field from the snapshot files,
(ii) reading only the particle subset from the snapshot corresponding to a halo or subhalo,
(iii) extracting the full subtree or main progenitor branch from either SubLink or LHaloTree for a given sub
(iv) walking a tree to count the number of mergers,
(v) reading the entire group catalog at one snapshot,
(vi) reading specific fields from the group catalog, or the entries for a single halo or subhalo.

We expect they will provide a useful starting point for writing any analysis task, and intend them as a
that they can be quickly understood and extended.

Currently available are: **Python** (3.6+ recommended), **IDL** (8.0+ required), and **Matlab** (R2013a+ requi
for that language.

Python | IDL | Matlab

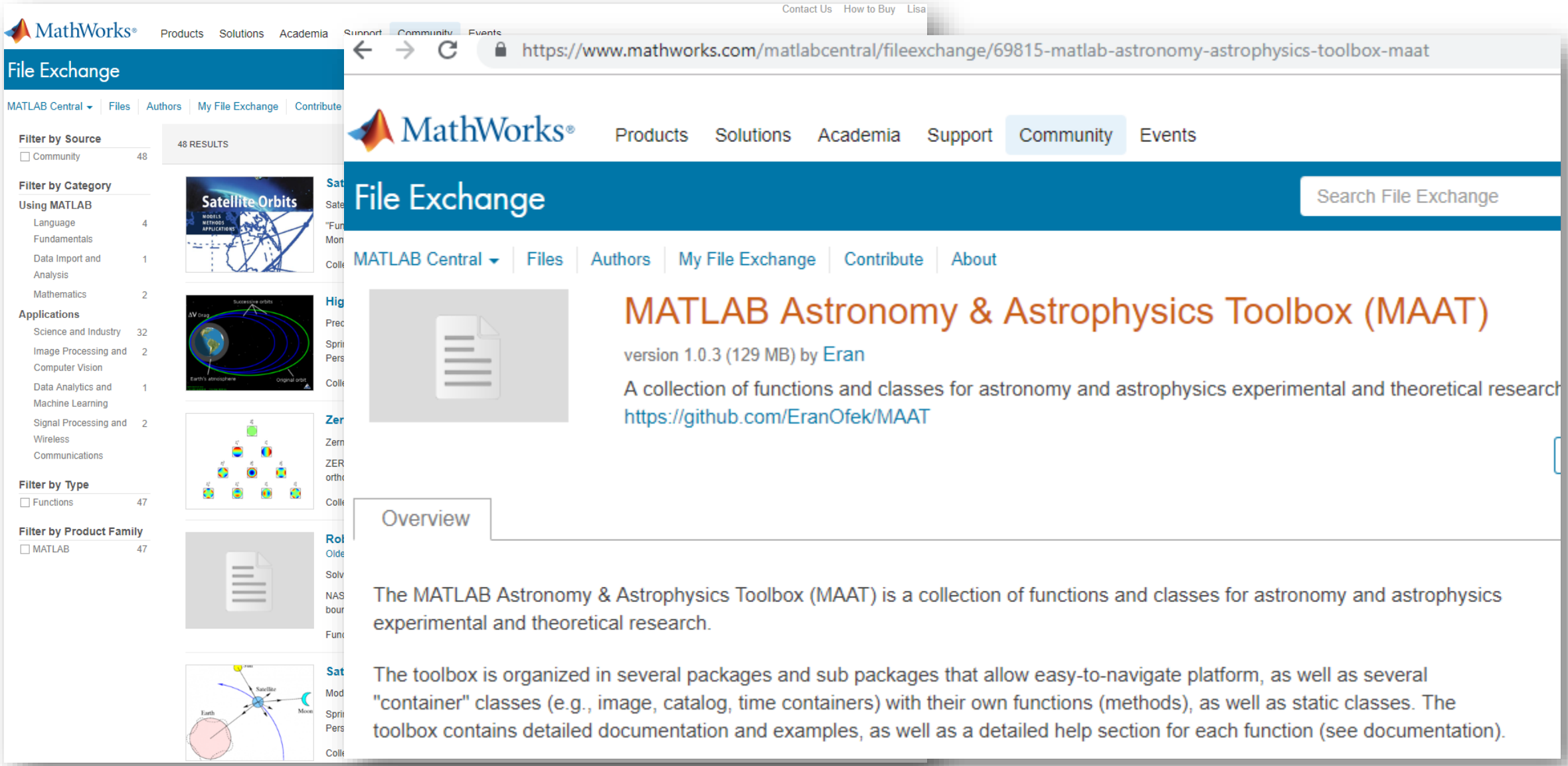
In all cases, these scripts assume that you have downloaded local copies of the relevant files. Paths
in to all read functions. The locations of group catalog files, snapshot files, and merger trees files are
`snapPath()`, and `treePath()`. These can be modified as necessary to point to your local files, but it i

- `TNG100-1/`
- `TNG100-1/output/`
  - group catalogs: `TNG100-1/output/groups_099/fof_subhalo_tab_099.*.hdf5`
  - snapshots: `TNG100-1/output/snapdir_099/snap_099.*.hdf5`
- `TNG100-1/postprocessing/`
  - offsets: `TNG100-1/postprocessing/offsets/offsets_*.hdf5`
  - SubLink mergertree: `TNG100-1/postprocessing/trees/SubLink/tree_extended.*.hdf5`
  - other catalogs: `TNG100-1/postprocessing/catalog_name/files*.hdf5`

Project: http://www.tng-project.org/
Jupyterlab: tng-project.org/data/lab/
Scripts: http://www.tng-project.org/data/docs/scripts/

MATLAB Community Tools for Astronomy

https://www.mathworks.com/matlabcentral/fileexchange?sort=downloads_desc&q=astronomy



LIGO: Spot 1st-Ever Gravitational Waves with MATLAB

MathWorks® Products Solutions Academia Support Community Events

Technical Articles and Newsletters

Search Technical Articles

Overview | Search Technical Articles | Newsletters | Cleve's Corner Collection | Sign Up

Confirming the First-Ever Detection of Gravitational Waves by Analyzing Laser Interferometer Data

By Matthew Evans, MIT

At about 7 a.m. on September 14, 2015, I received an email from my colleagues in Europe notifying me of an extraordinary event: Two detectors in the Laser Interferometer Gravitational-Wave Observatory (LIGO) had simultaneously identified what appeared to be a transient gravitational-wave signal—a "ripple" in space-time.

As a member of the team that developed the LIGO instrumentation, I was excited but also slightly apprehensive. I was excited because if the signal was authentic, it would mark the first time that a gravitational wave had ever been directly observed, confirming Albert Einstein's prediction of their existence, made a century ago. It would also mark the first observation of a pair of black holes merging to form a single black hole. My colleagues and I were apprehensive, however, because we did not yet know whether the signal came from a genuine gravitational wave or was merely the result of some error in the LIGO control system and instrumentation.

I immediately downloaded the LIGO data onto my laptop, opened MATLAB®, and began analyzing the recorded signals and visualizing the data. In the months that followed, my LIGO colleagues and I confirmed that we had, in fact, detected a gravitational wave, and identified its source: the cataclysmic collision of two black holes with a combined mass 60 times greater than our sun in a galaxy more than one billion light years away (Figure 1).

MathWorks® Products Solutions Academia Support Community Events

Blogs

MATLAB Central | All MathWorks Blogs | Subscribe

Cleve's Corner: Cleve Moler on Mathematics and Computing

Scientific computing, math & more

Recent Posts Archive

1 APR Biorhythms and Energy Vortices Near Sedona, Arizona

18 MAR Benchmarking a GPU

4 MAR Amaze, A Maze Generator

18 FEB Experiments with Variable Format Half Precision

18 JAN Floating Point Arithmetic Before IEEE 754

Categories

History	104
Precision	18
People	60
Eigenvalues	29
Numerical Analysis	61

more

Dark Energy Gravitational Waves

Posted by Cleve Moler, April 1, 2016

Recent theoretical, observational and computational results establish the dawn of the universe affect the clock rate of silicon digital process

Contents

- Ed Plum
- LIGO
- LIGO Labs
- LIGO Gravitational Waves
- Dark Energy Gravitational Waves
- The signal
- The sound
- The spectrogram
- Expectations

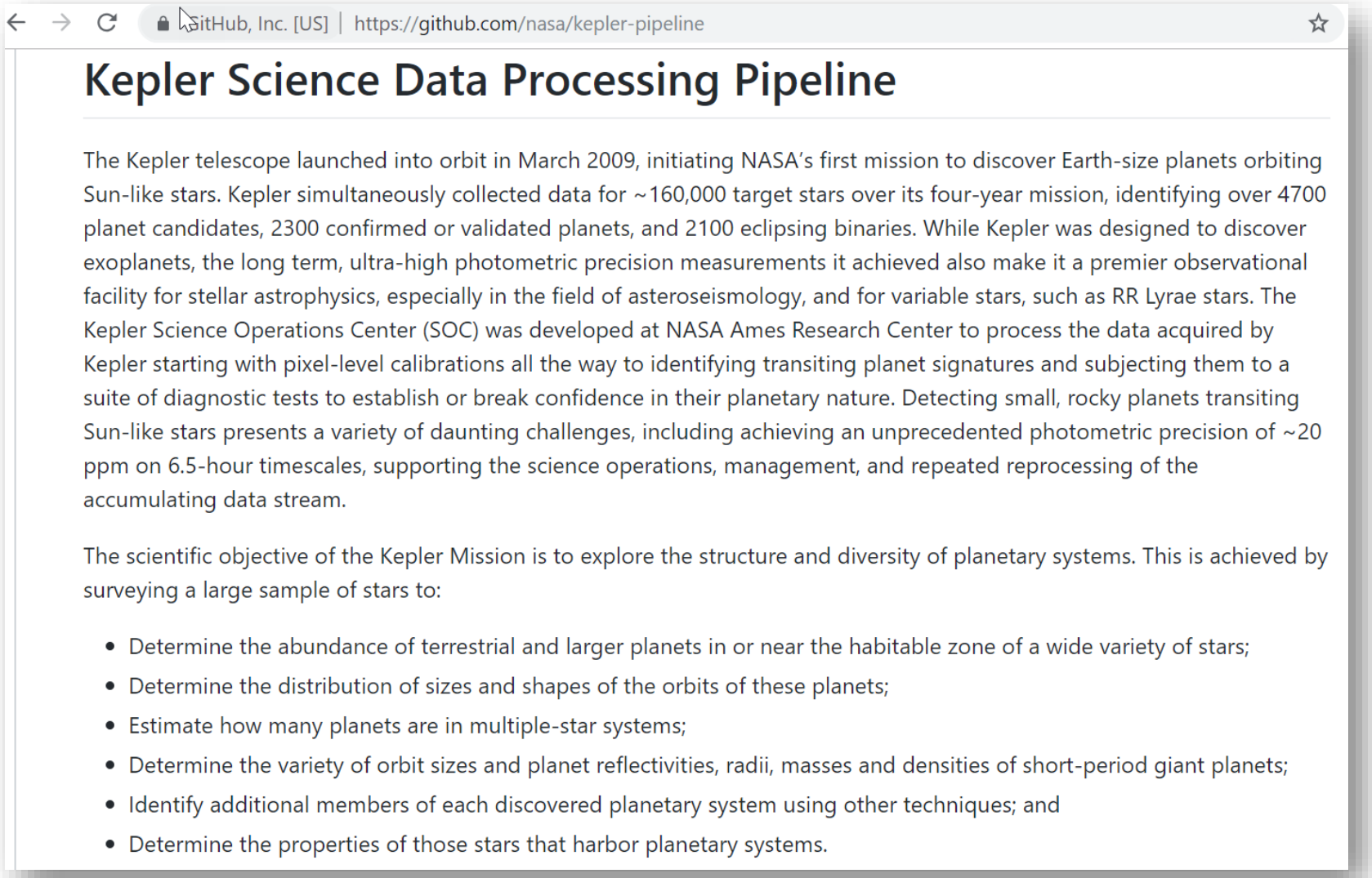
Ed Plum

[Article]

[Blog post]

NASA Build Kepler Pipeline tools with MATLAB

download: github.com/nasa/kepler-pipeline

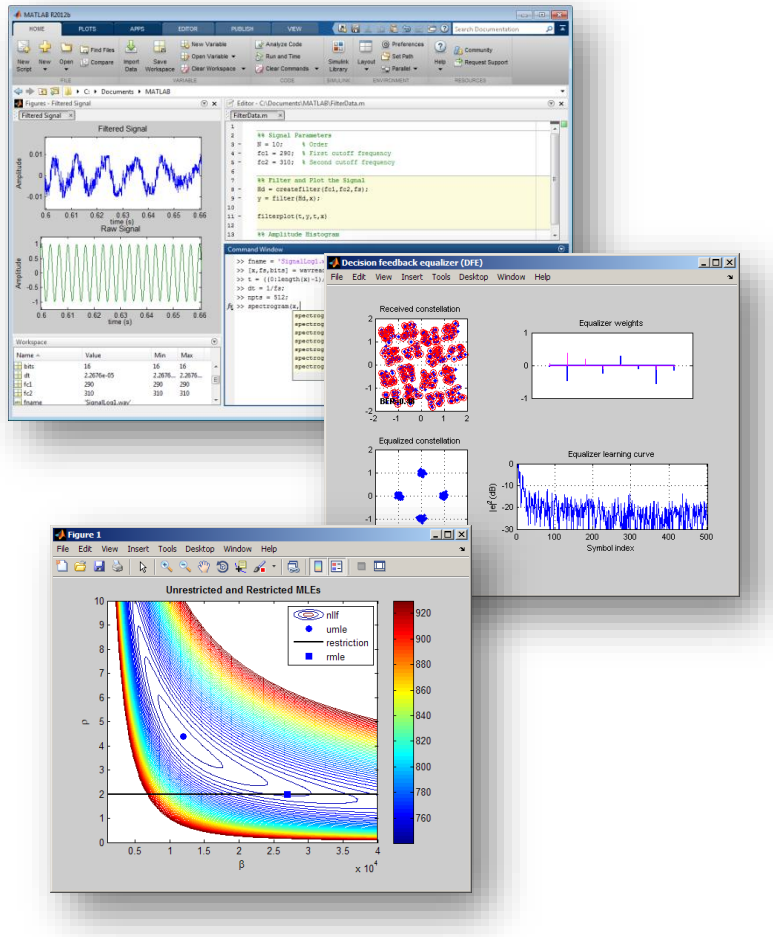


Agenda

- Introduction
- Quick intro to MATLAB
- Image Processing with MATLAB
- Managing large image sets
- What's New
- Wrap-up

What is MATLAB?

- High-level language
- Interactive development environment
- Used for:
  - Numerical computation
  - Data analysis and visualization
  - Algorithm development and programming
  - Application development and deployment

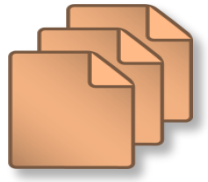


Workflow: Image and Video Processing

Access

Hardware

Files

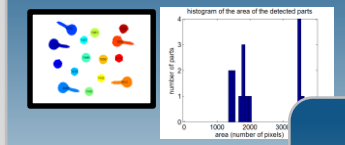


Software

Code & Applications

Explore and Discover

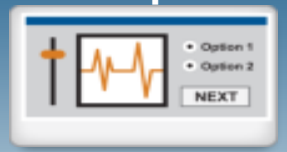
Data Analysis & Modeling



Algorithm Development

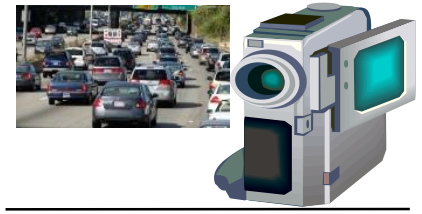
```
for k=1:max
 x = fft(dat
 y = 20*log1
```

Application Development



Share

Outputs for design



Reporting and Documentation

Deployment

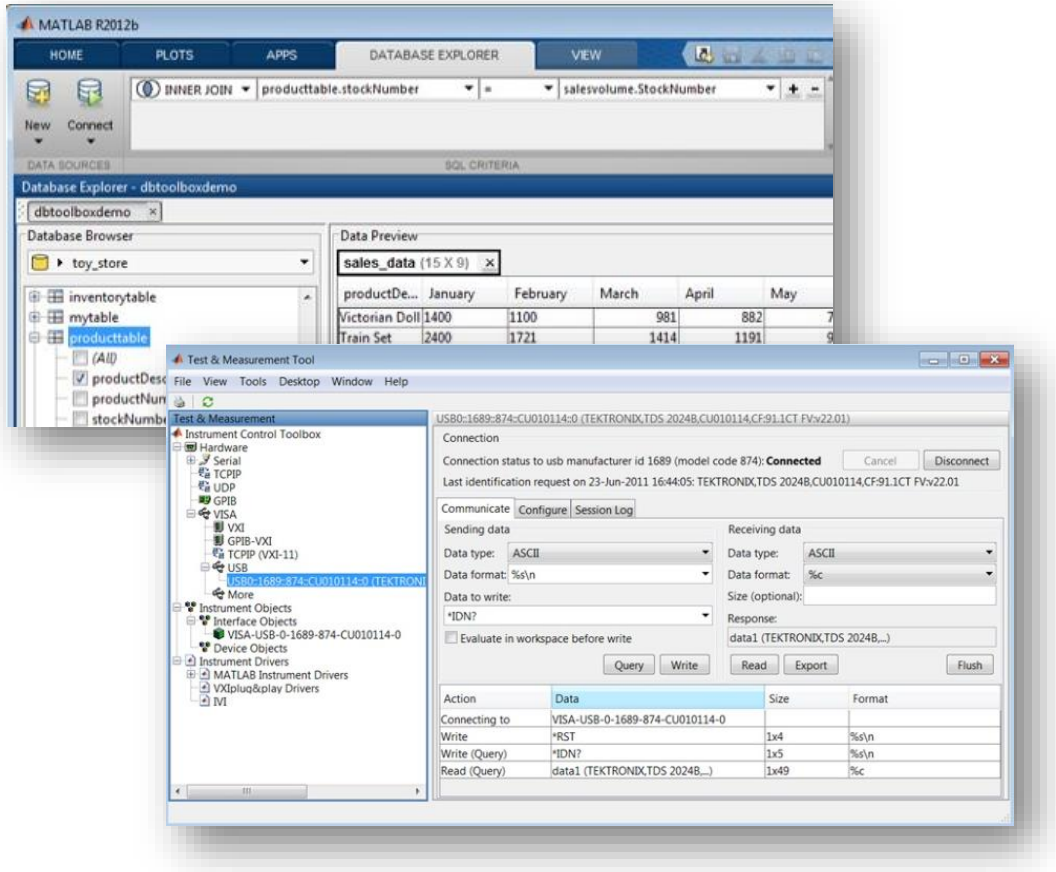
MATLAB Excel .NET .exe C/C++ Java .dll

Automate

Accessing Data from MATLAB

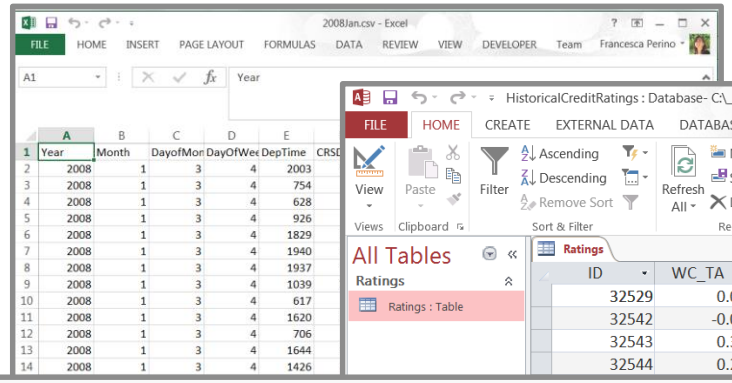
Access | Explore & Discover | Share

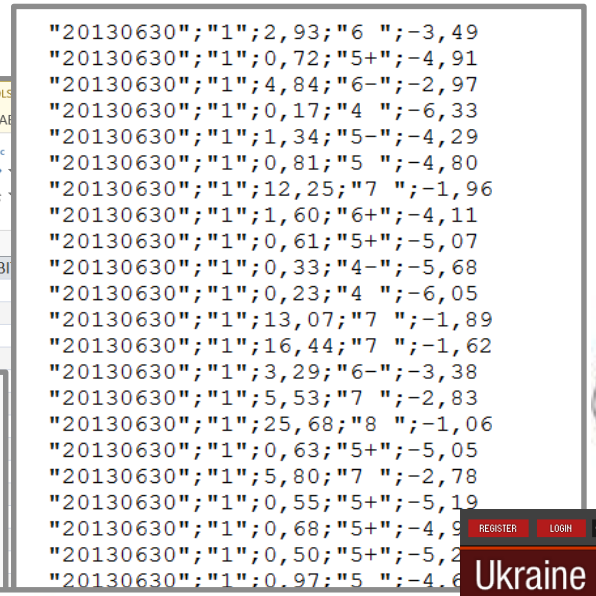
- Files
  - Excel, text, or binary
  - Audio and video, image
  - Scientific formats and XML
- Applications and languages
  - C/C++, Java, FORTRAN, Python
  - COM, .NET, shared libraries
  - Databases (*Database Toolbox*)
- Measurement hardware
  - Data acquisition hardware *(Data Acquisition Toolbox)*
  - Stand-alone instruments and devices *(Instrument Control Toolbox)*

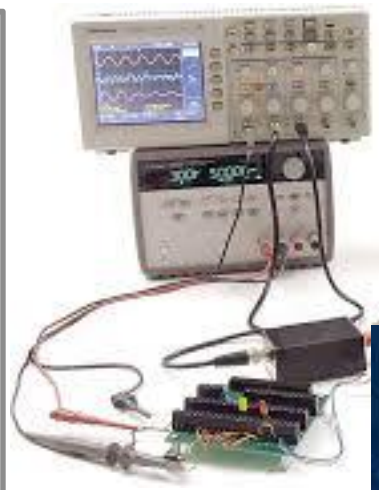


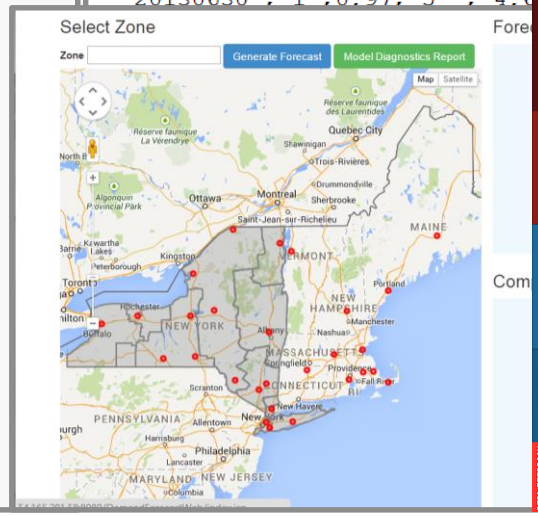
What do data look like?

Access Explore & Discover Share

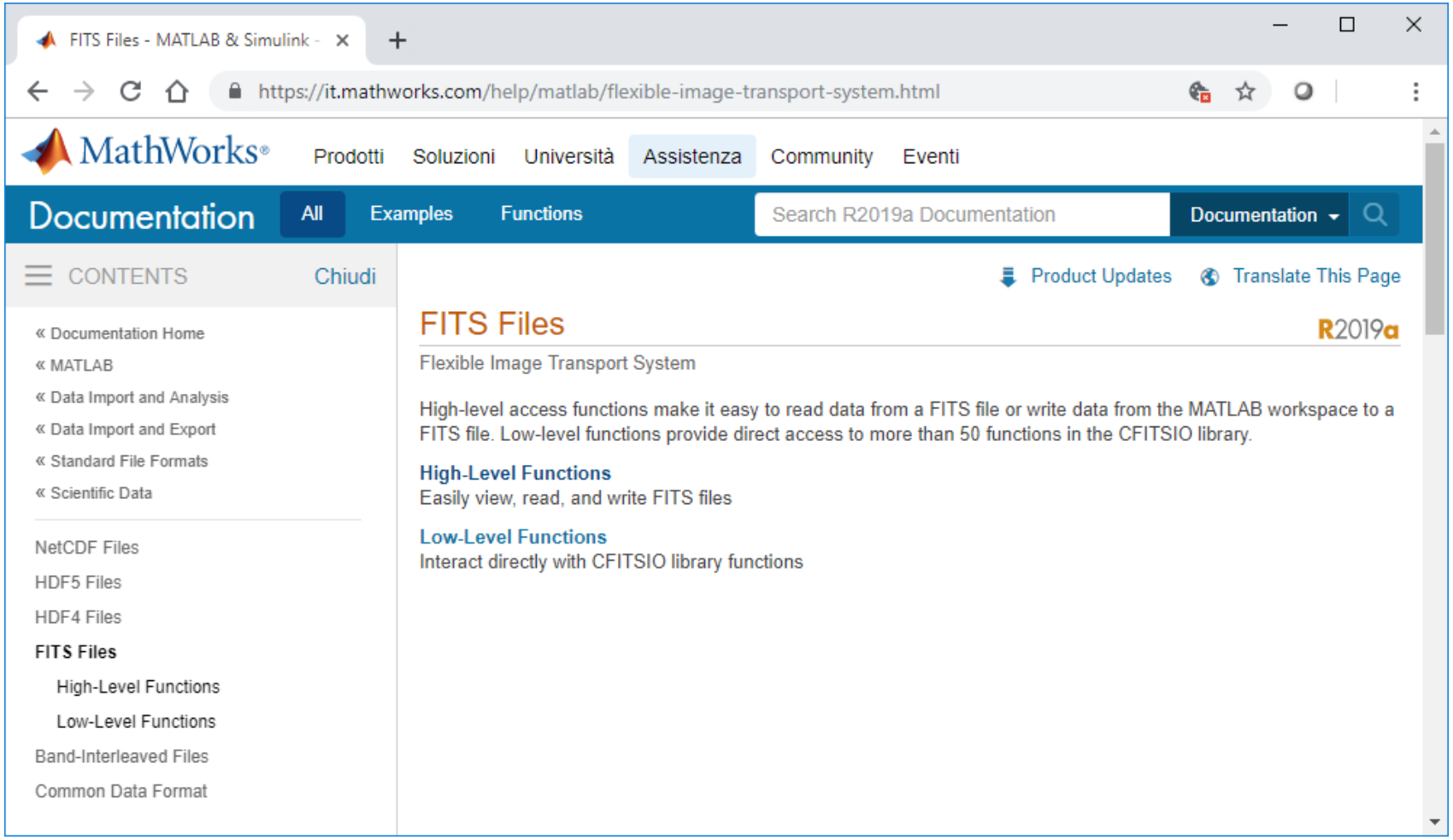








Example: FITS files



MATLAB connects to your hardware

Data Acquisition Toolbox

Plug in data acquisition boards and modules

Instrument Control Toolbox

Instruments and RS-232 devices

Image Acquisition Toolbox™

Image capture devices

Vehicle Network Toolbox

CAN bus interface devices

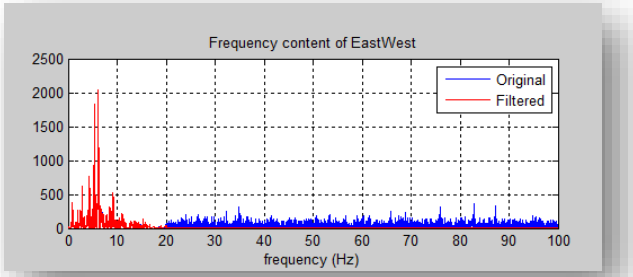
MATLAB

Interfaces for communicating with everything

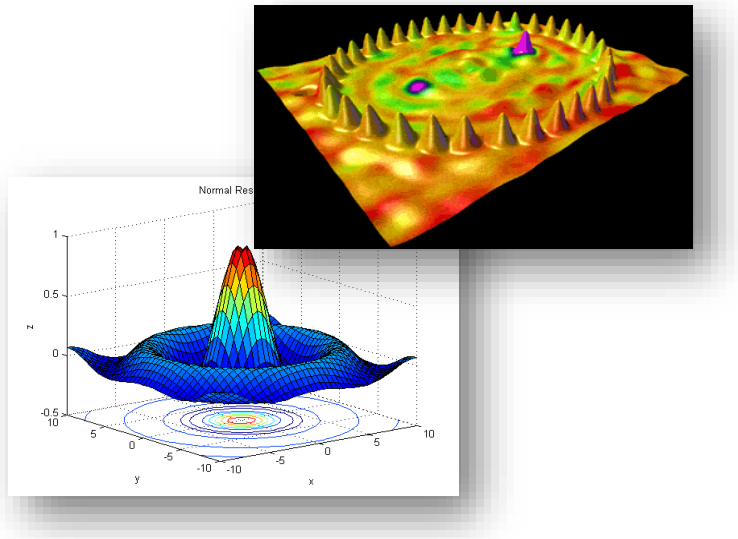
Data Analysis and Visualization in MATLAB

Access | **Explore & Discover** | Share

- Built-in engineering and mathematical functions
  - Interpolation, filtering, smoothing, Fourier analysis



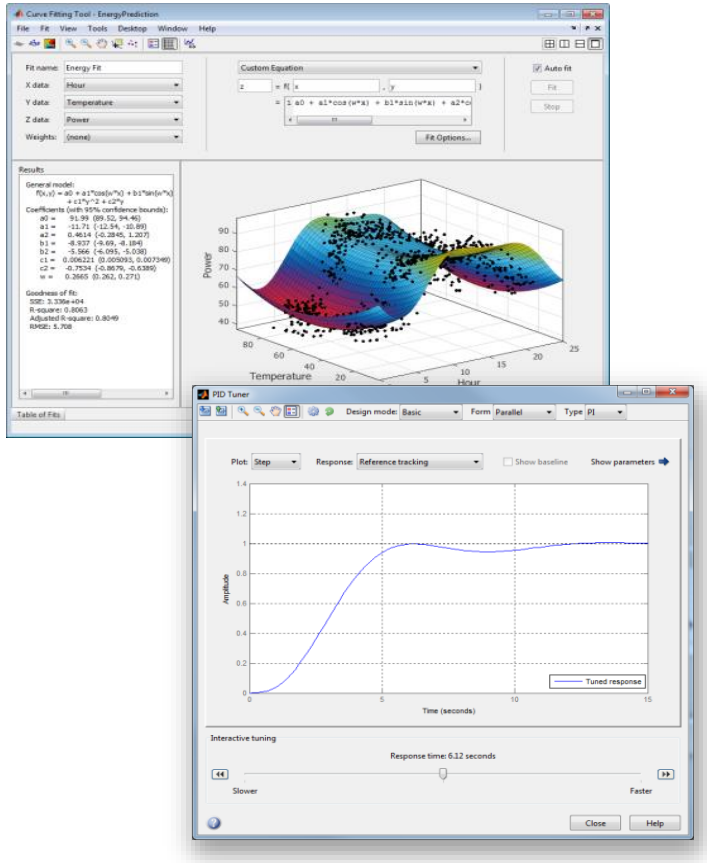
- Extensive plotting capabilities
  - 2-D, 3-D, and volume visualization
  - Tools for creating custom plots



Expanding the Capabilities of MATLAB

Access | **Explore & Discover** | Share

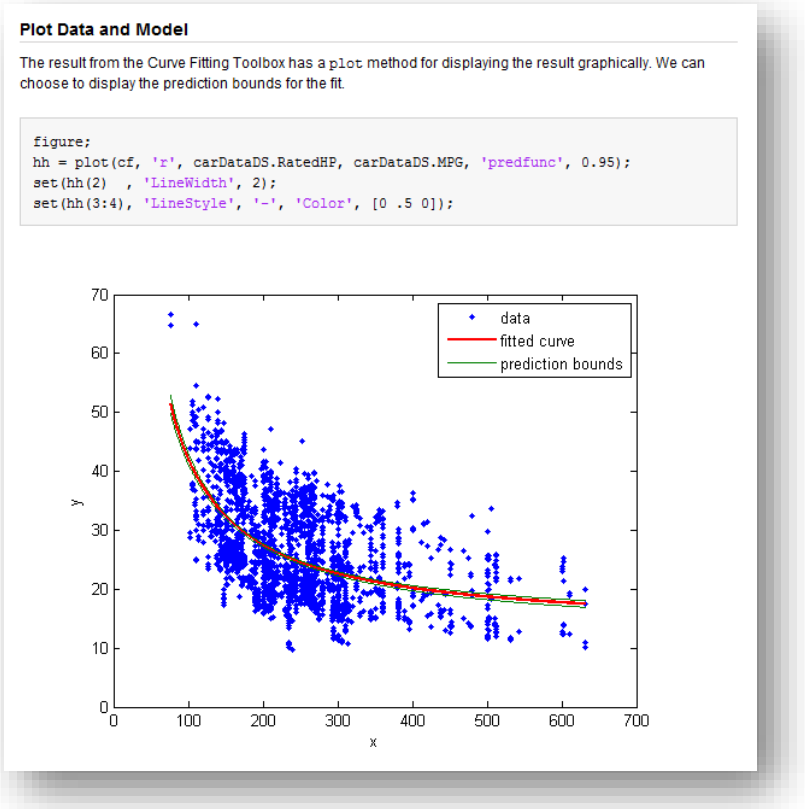
- MathWorks add-on tools for:
  - Math, statistics, and optimization
  - Control system design and analysis
  - Signal processing and communications
  - Image processing and computer vision
  - Parallel computing and more…
- Partner products provide:
  - Additional interfaces
  - Domain-specific analysis
  - Support for niche applications



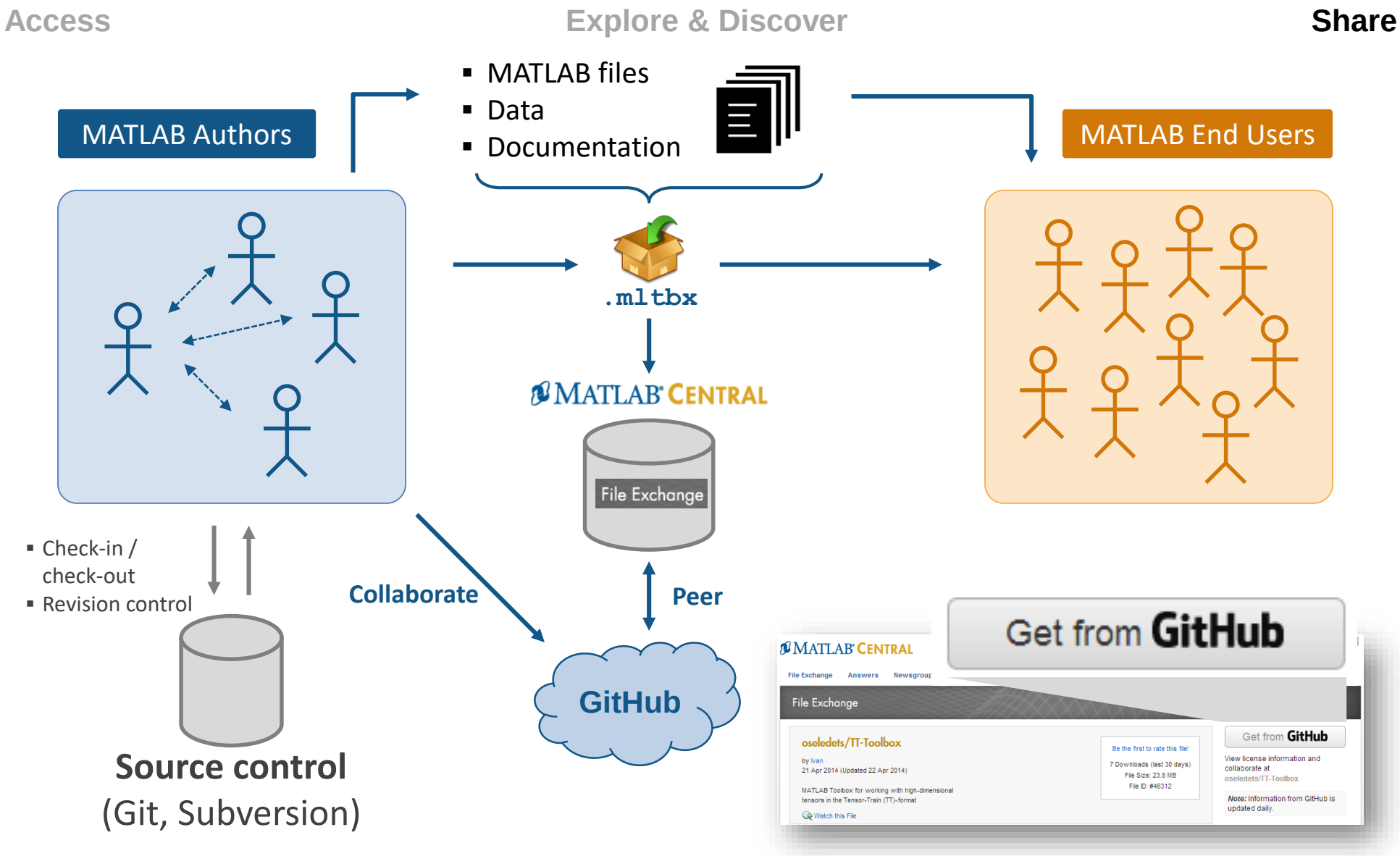
Sharing Results from MATLAB

Access | Explore & Discover | **Share**

- Automatically generate reports
  - Publish MATLAB files
  - Customize reports
    (MATLAB Report Generator)
- Live scripts export
- Deploy applications to other environments

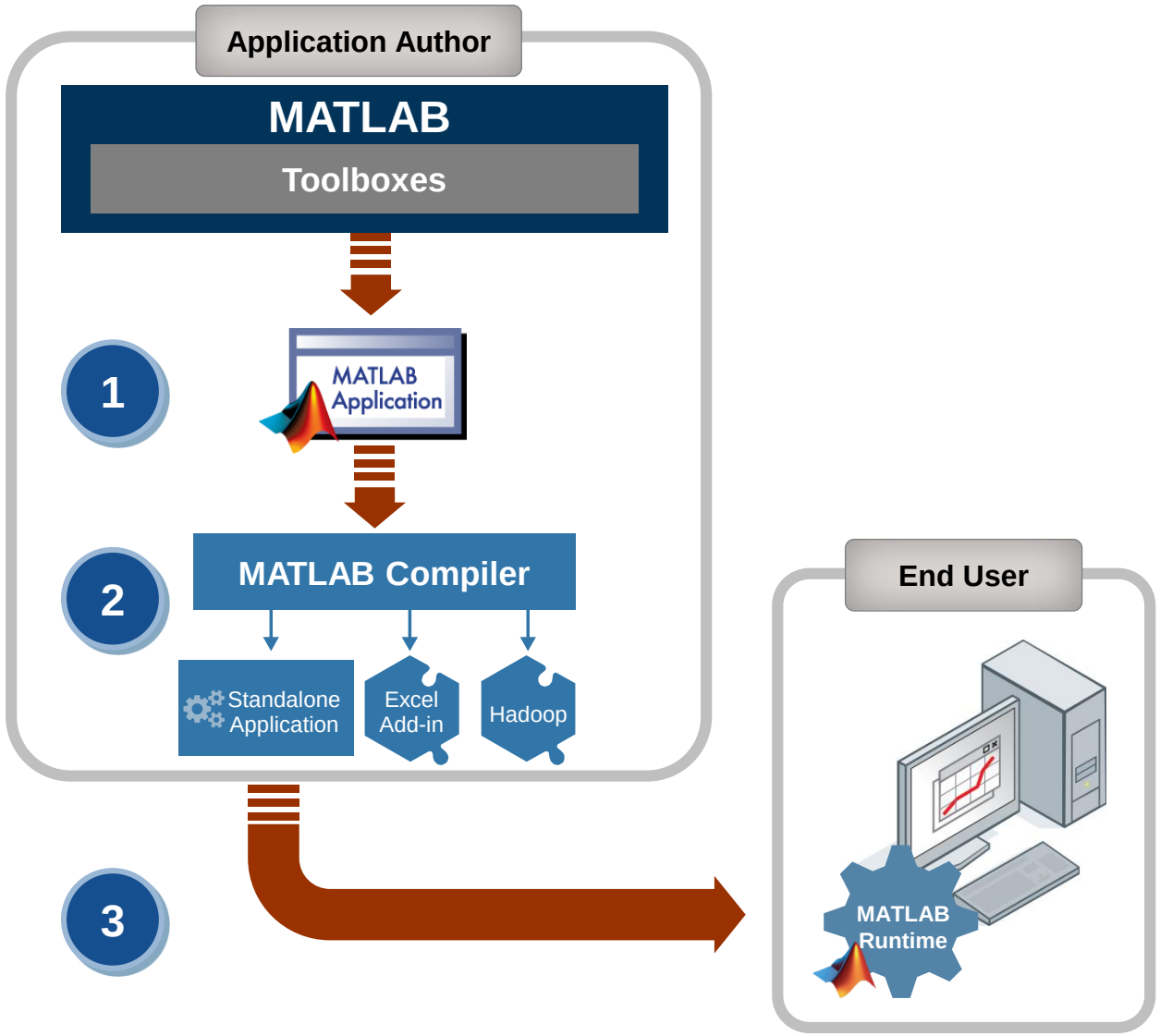


Share MATLAB Code as Toolboxes or Apps



Sharing Standalone Applications

Access | Explore & Discover | **Share**



Agenda

- Introduction
- Quick intro to MATLAB
- Image Processing with MATLAB
- Managing large image sets
- What's New
- Wrap-up

Image Processing Toolbox

Perform image processing, analysis, visualization, and algorithm development

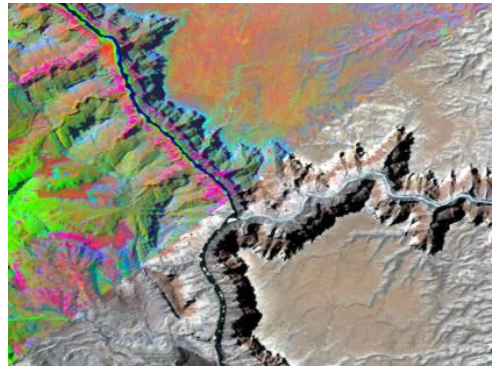
- Image display and exploration
- Image enhancement
- Image analysis
- Morphological operations
- Image registration
- Geometric transformation
- ROI-based processing

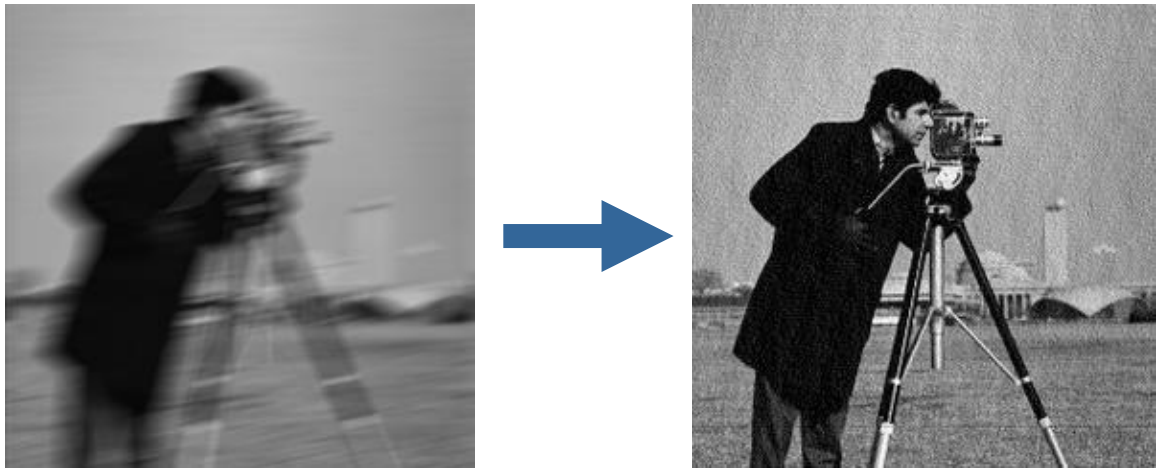
What is image enhancement?

Pre- and Post-Processing

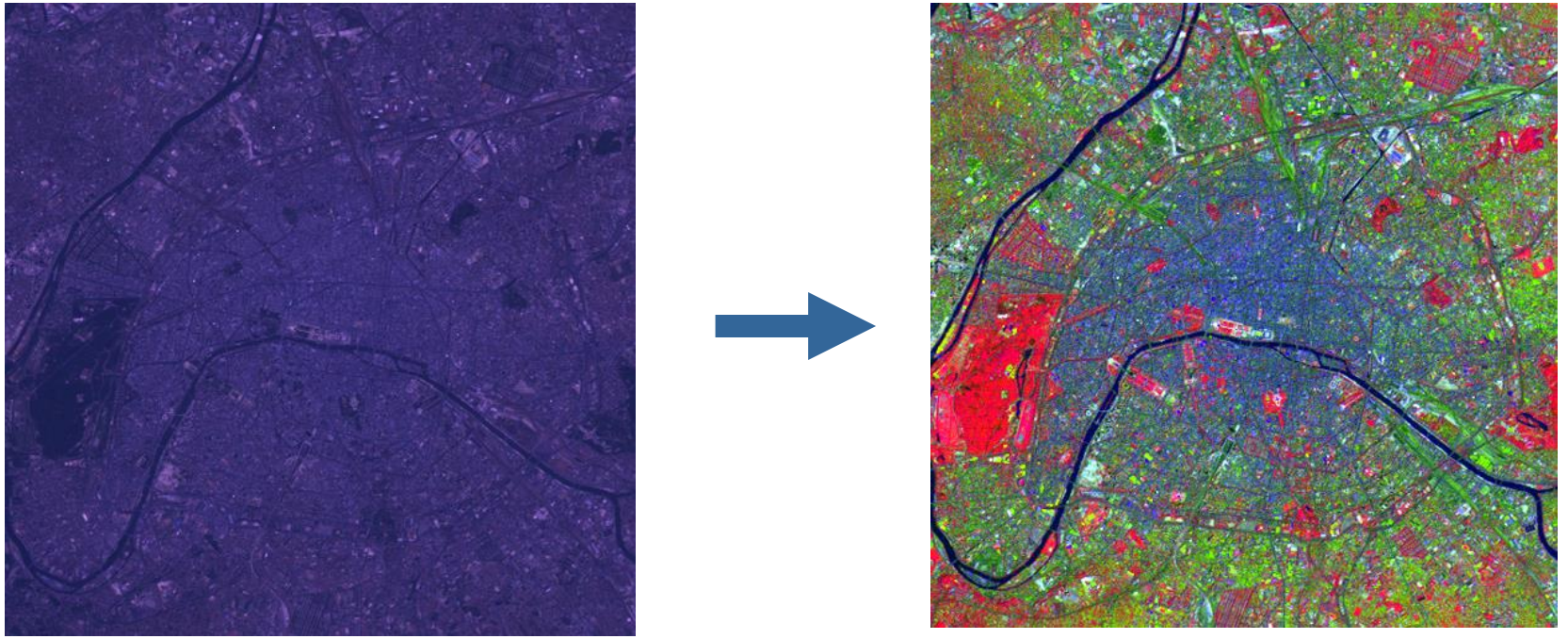
Image enhancement is the process of adjusting digital images so that the results are more suitable for display or further processing.

- Noise removal
- Deblurring
- Filtering





Demo: Image Enhancement



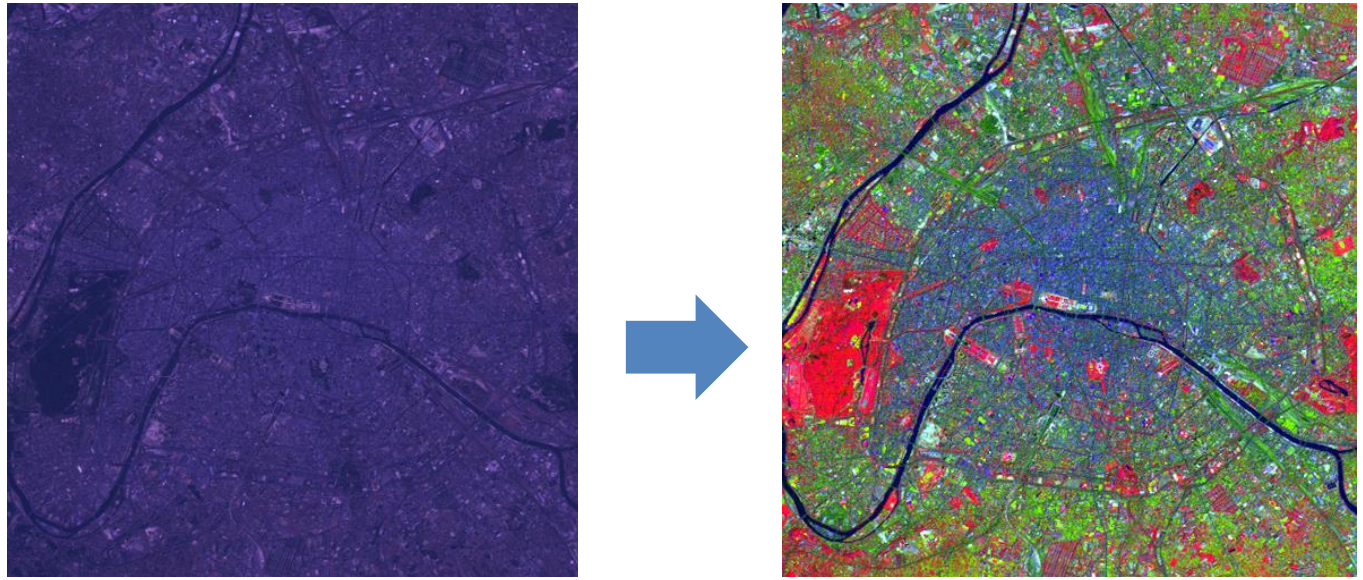
- Import and visualize map of Paris
- Correct for poor contrast and unbalanced colors

```
>> Histogram_Stretch
```

Demo: Image Enhancement

Summary

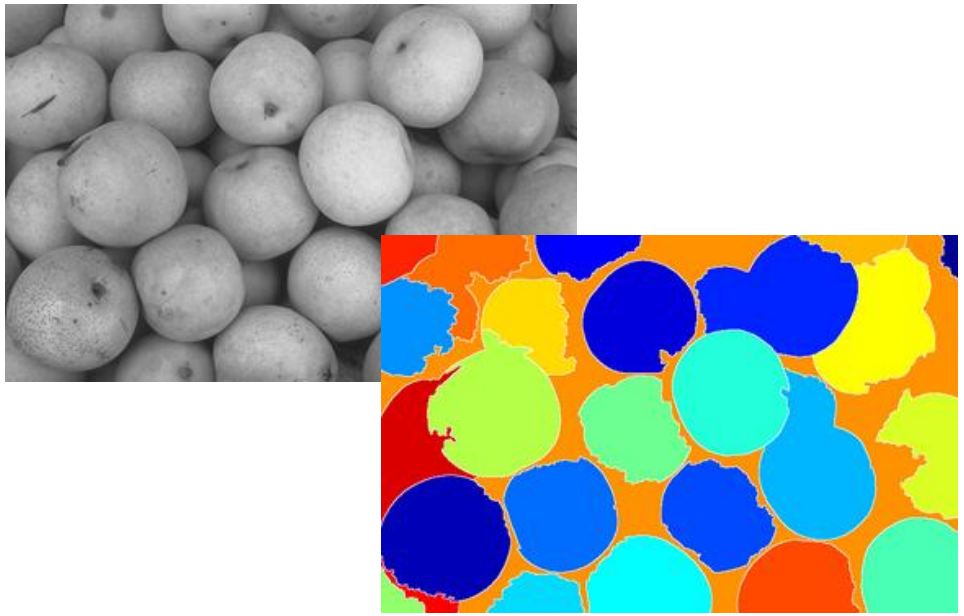
- Visualize images
- Visualize histogram and scatter plot
- Perform contrast and decorrelation stretch

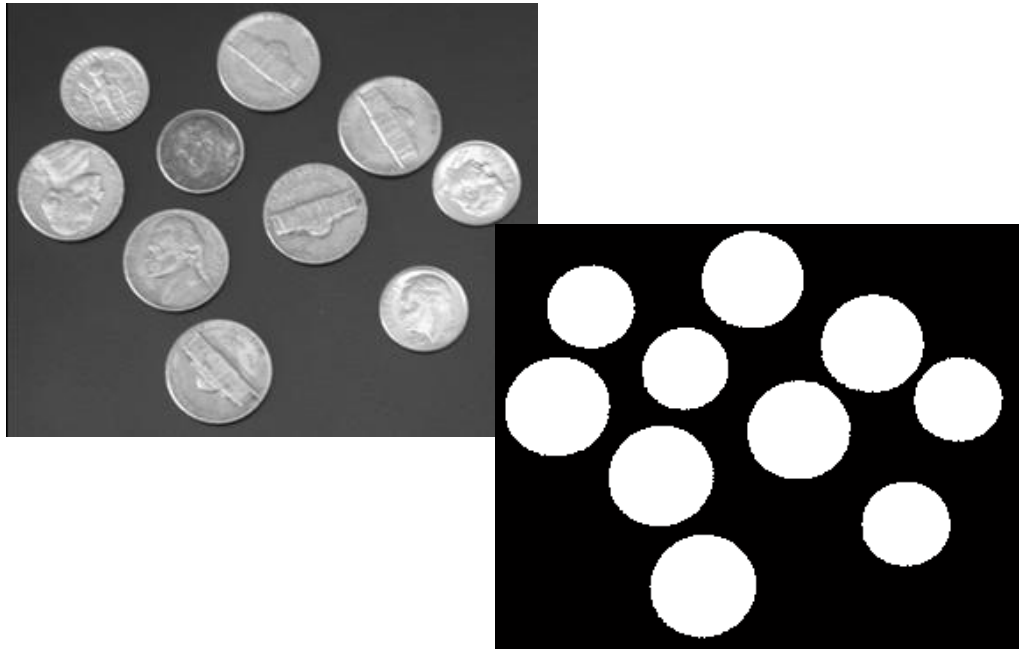


What is image segmentation?

Image processing for detection

- Image segmentation is the process of dividing an image into multiple parts.
  This is typically used to identify objects and other relevant information within an image.

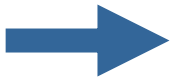




Demo: Image Segmentation

- Objects detection

There are 4 objects in the image!



```
>> cardetection
```

Demo: Image Segmentation

Summary

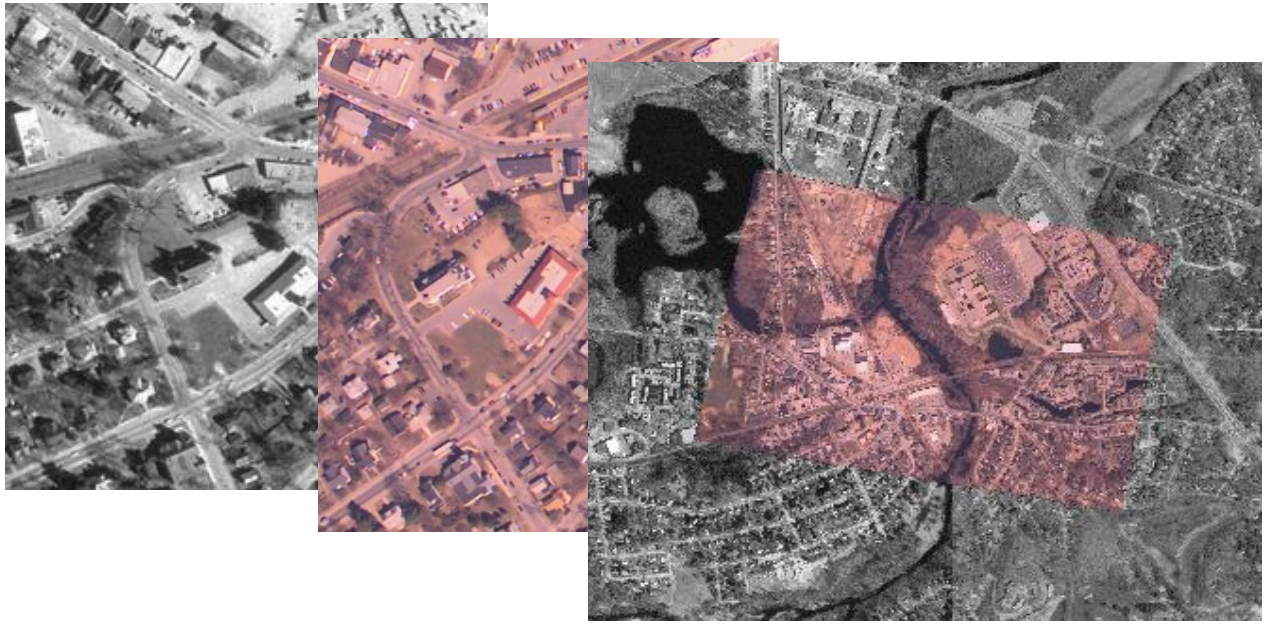
1. Detection concept: Image difference
2. Preprocessing: Enhancements
3. Segmentation: Threshold, Fill in, Morph. Opening
4. Region Properties

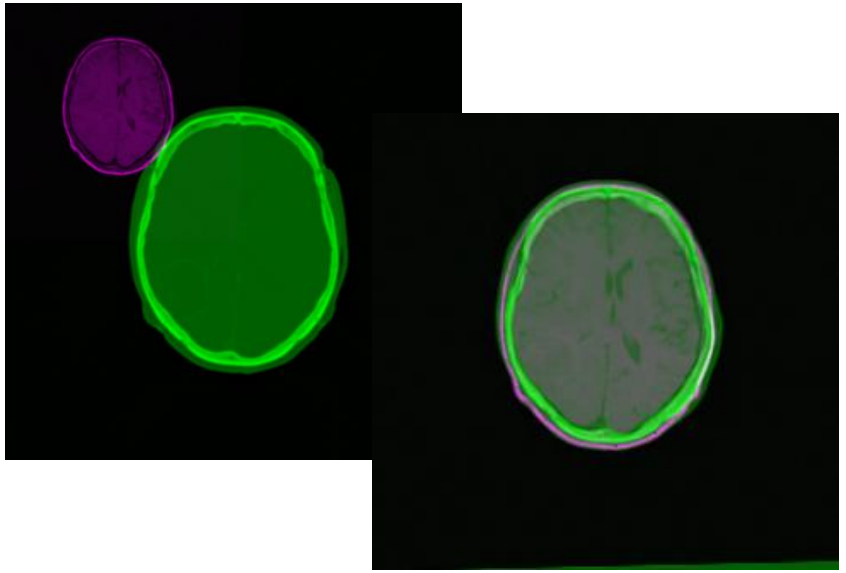
There are 4 objects in the image!

What is image registration?

Image alignment

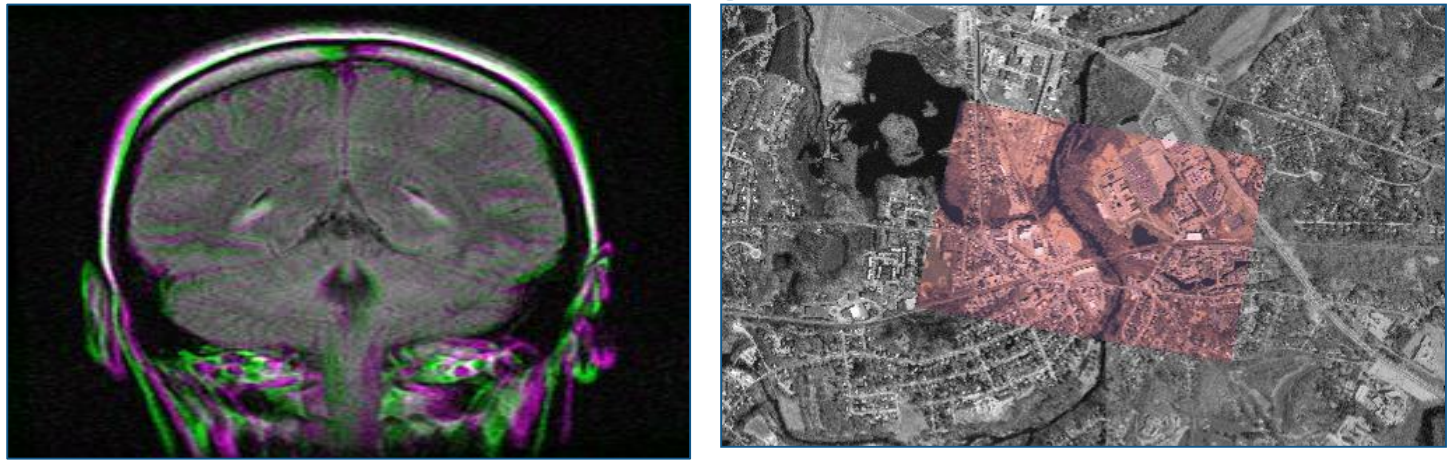
- Process of aligning images from different data sets for visual or computational analysis.
  - Enables quantitative comparison
  - Removes changes due to camera motion



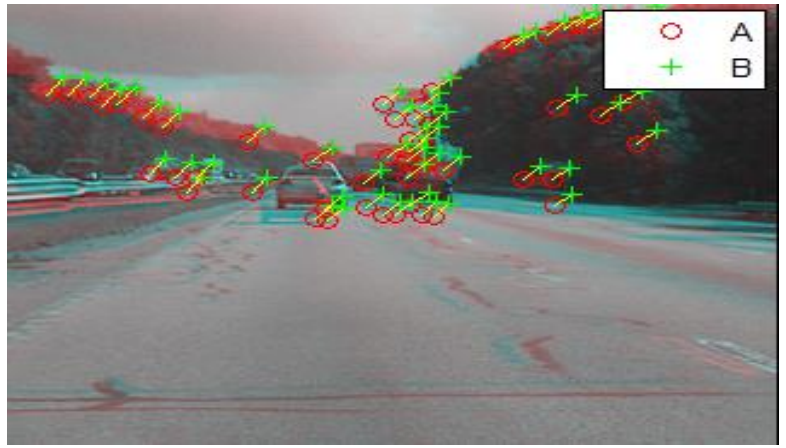


Automatic Image Registration

Intensity-based



Feature-based



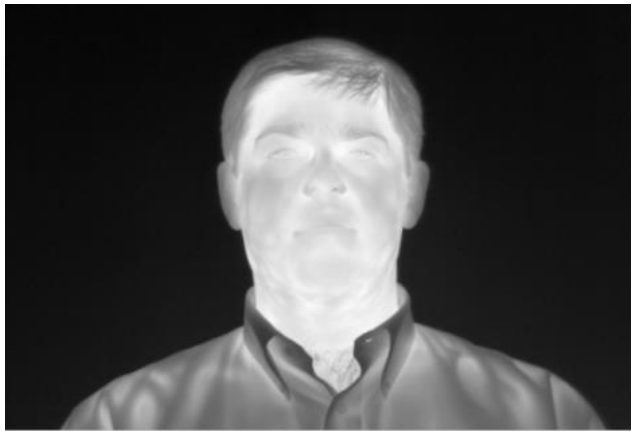
- Two registration types supported:
  - Intensity-based (Image Processing Toolbox)
  - Feature-based (Computer Vision Toolbox)

Demo: Image Registration

- Goal: Register the image pair to detect the eyes and measure body temperature

Webcam image

Thermal IR image



```
>> ThermalScreening
```

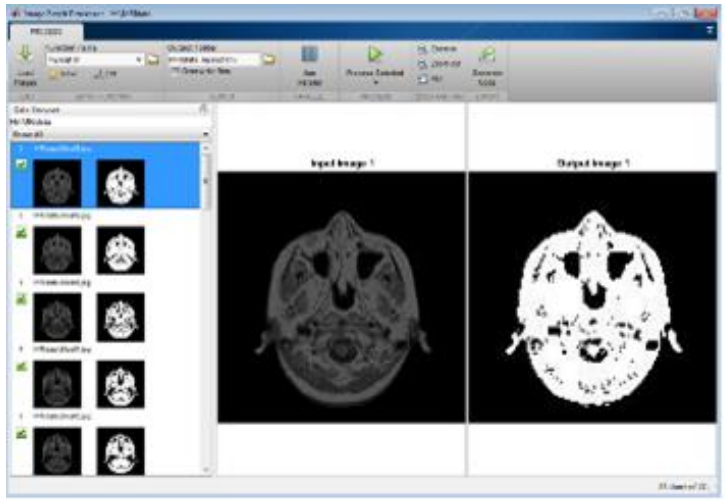
Demo: Image Registration

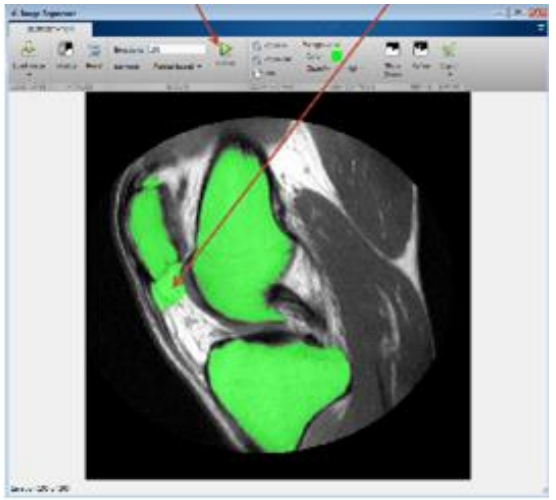
Summary

- Acquire images into MATLAB
- Visualize images
- Automatic image registration
- Feature detection (where are eyes?)
- Text annotation on the image

Use Apps to Quickly Explore Ideas or Find Solutions

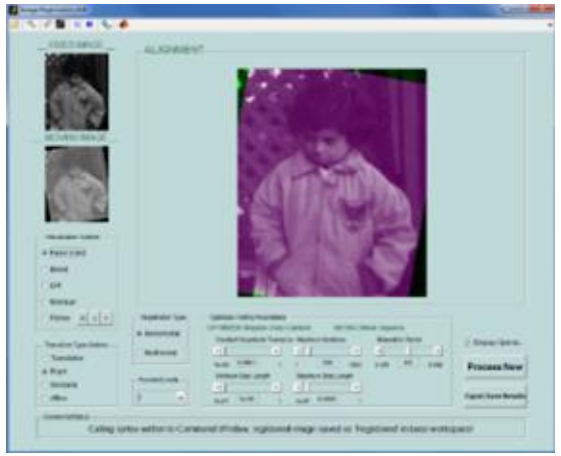
1. Image Batch Processor App
2. Image Segmenter App
3. Region Analyzer App
4. Color Thresholder App

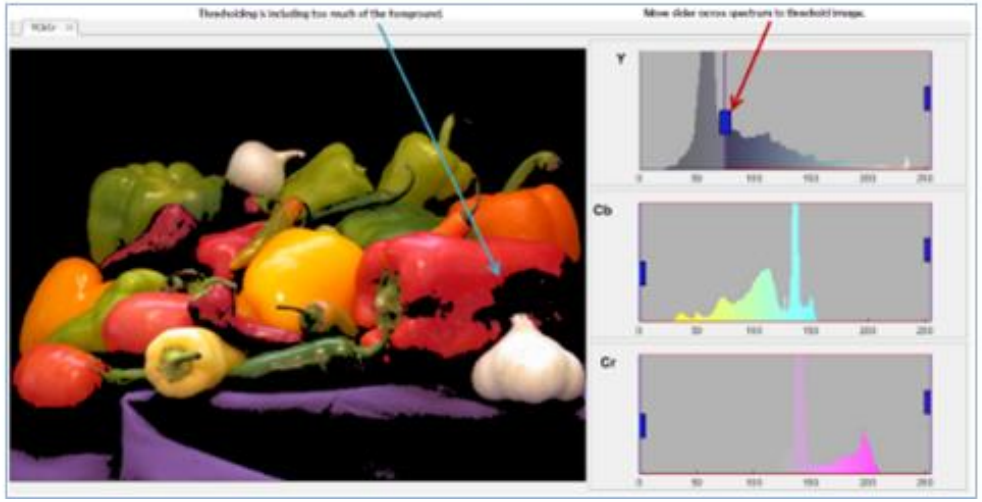




From the Community:

- Image Morphology App
- Image Registration App





File Exchange: http://www.mathworks.com/matlabcentral/fileexchange/

Agenda

- Introduction
- Quick intro to MATLAB
- Image Processing with MATLAB
- Managing large image sets
- What's New
- Wrap-up

Images & Video Applications Have Massive Data Challenges

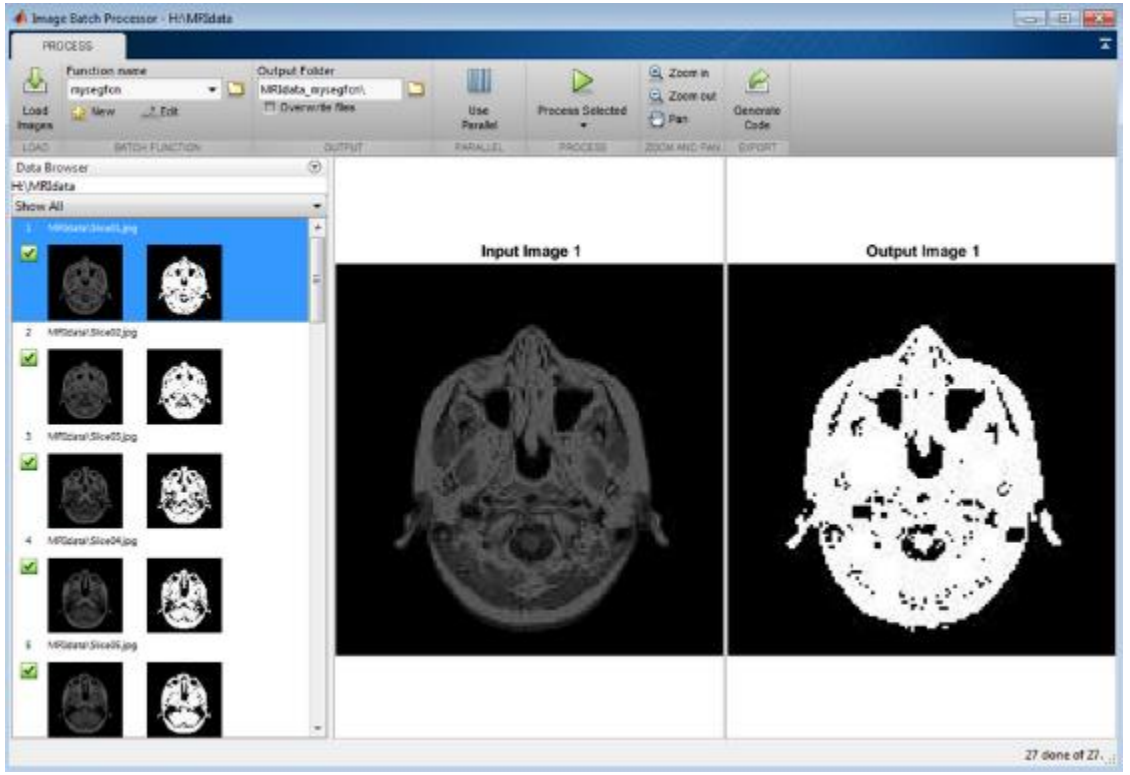
- 20+ Mega Pixel cameras
- 4K or 8K video
- Thousands to millions of images or videos to process



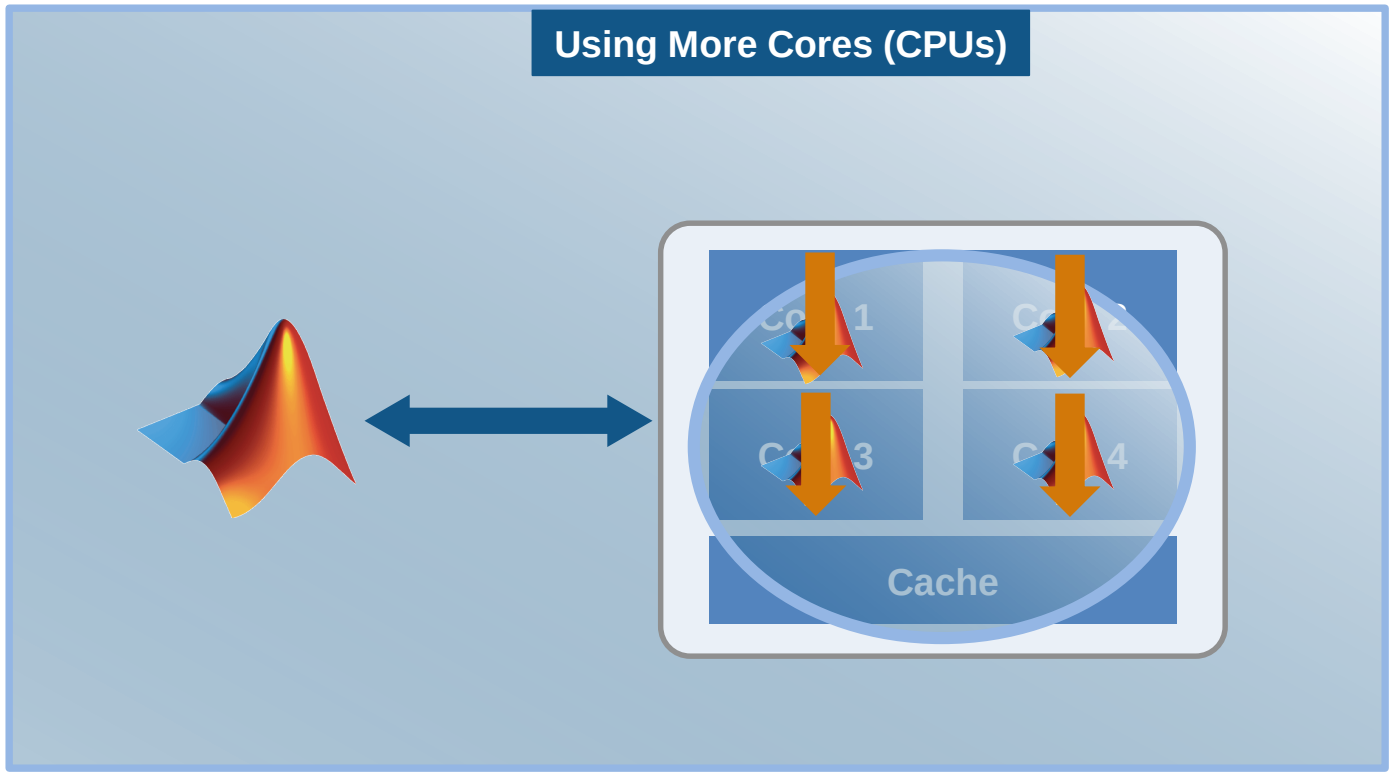
Working with Large Images Sets

- Processing large data sets with `datastore` and `imageSet`
  - Navigate data too large for memory.
  - Process multiple files as a single entity.
  - Works with `mapreduce`

- Image Batch Processor App
  - Apply algorithms to sets of images
  - Interactive interface
  - Support for parallel processing

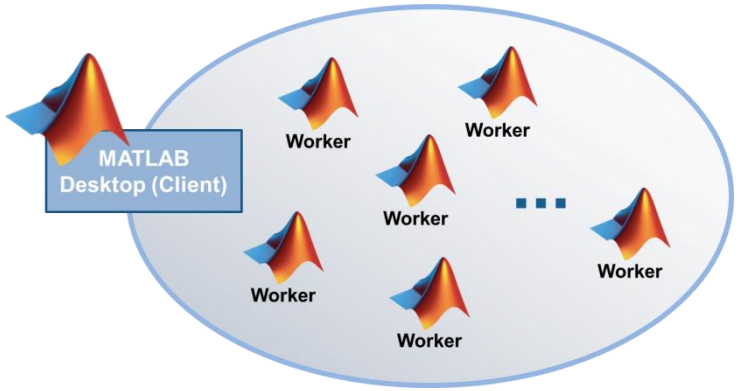


Parallel computing



Parallel computing support for image processing applications

- Option in Batch Image Processor to improve performance with parallel processing.
- Option in `blockproc` function to improve performance of block processing tasks.



MATLAB supports GPU Acceleration with NVIDIA

- Over 300 MATLAB functions supporting NVIDIA GPUs
- 50 of the most popular Image Processing functions
- Support for functions in bag-of-words workflow
- Constantly adding more GPU functionality

```
bagOfFeatures
bagOfFeatures.encode
trainImageCategoryClassifier
imageCategoryClassifier
imageCategoryClassifier.predict
```


```
bwmorph          imhist
bwlookup         imnoise
corr2            imopen
edge             imresize
histeq           imreconstruct
imadjust         imrotate
imbothat         imshow
imclose          imtophat
imdilate         imwarp
imerode          mean2
imfill           medfilt2
imfilter         padarray
imgradient       rgb2gray
```

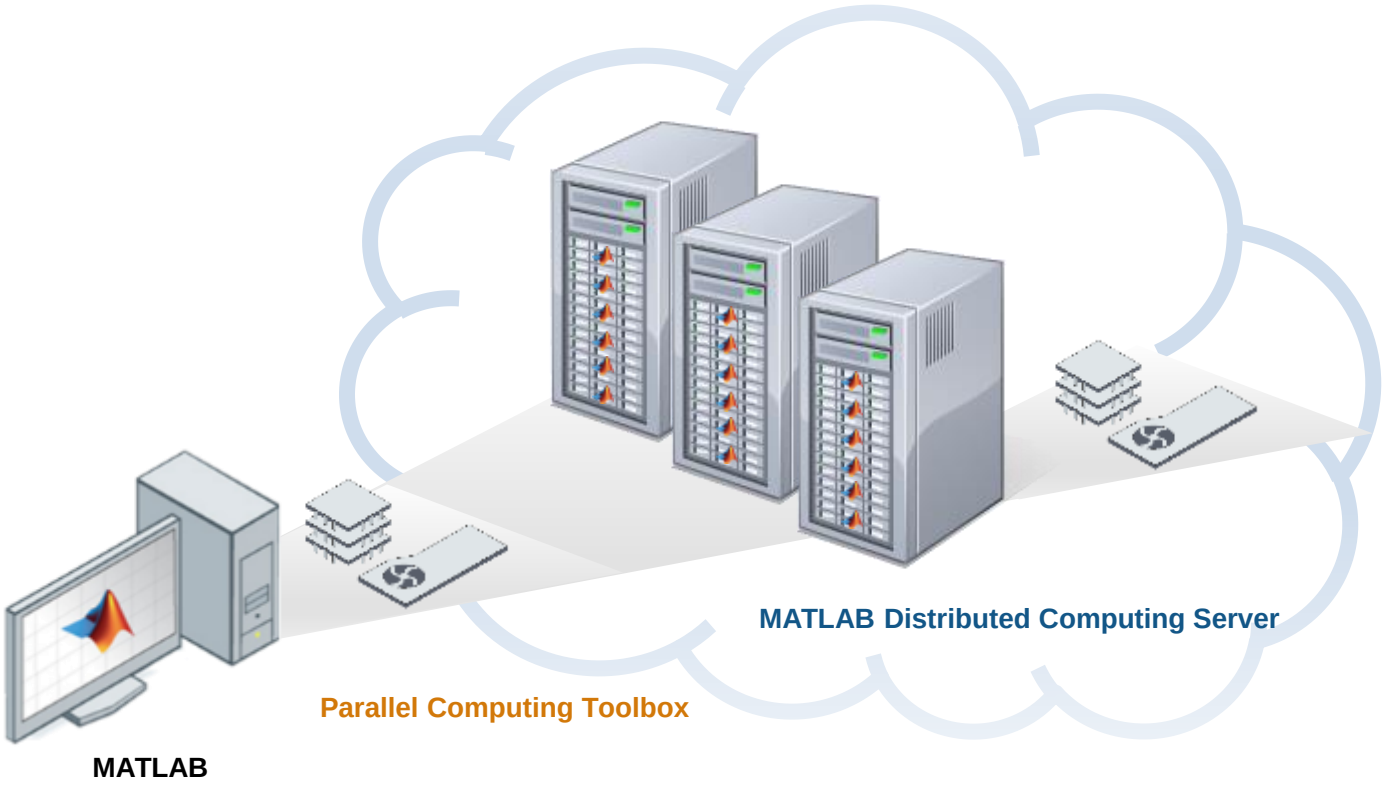
http://www.mathworks.com/discovery/matlab-gpu.htmll

GPU Example - Required Code Changes

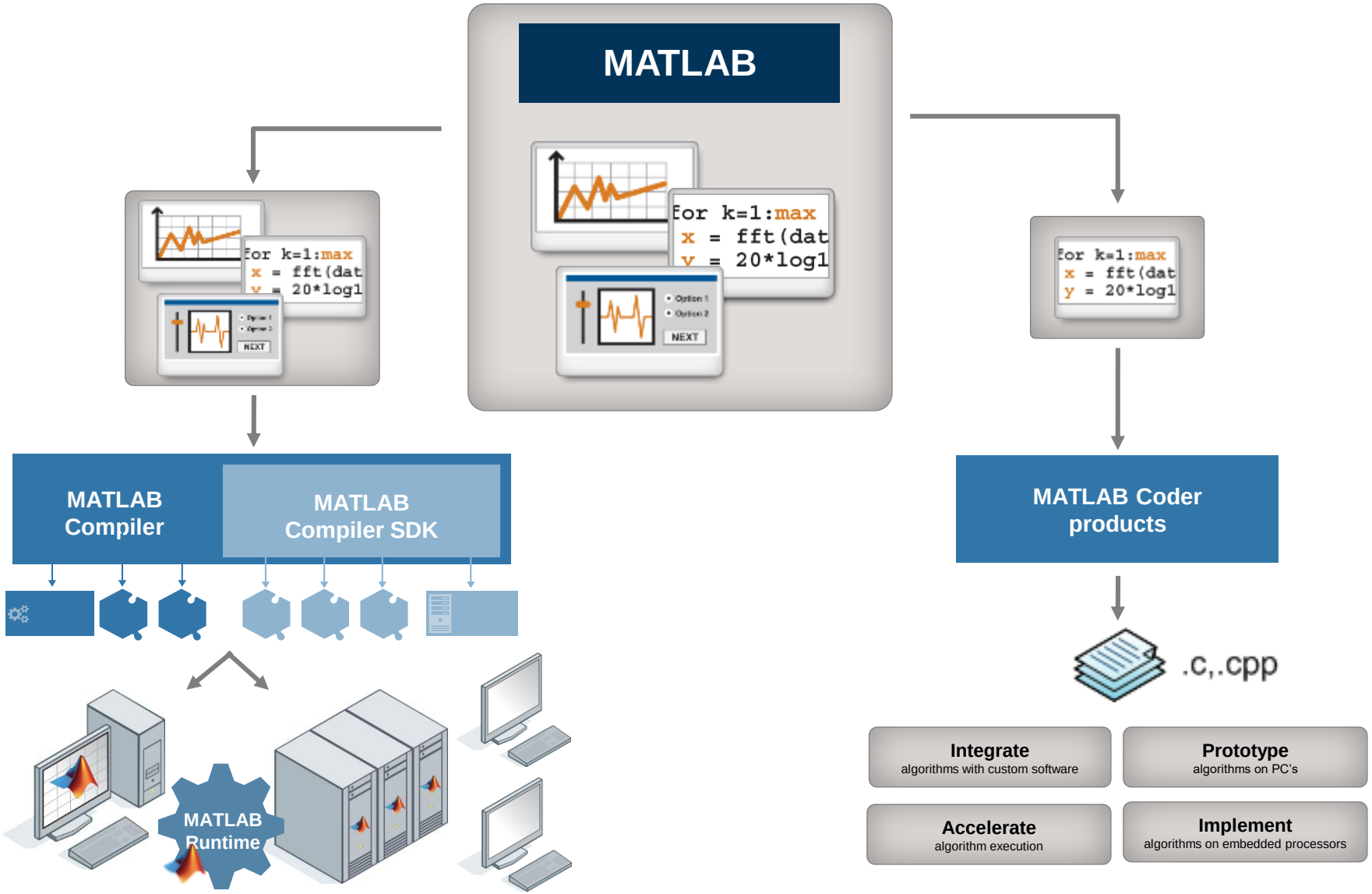
```
function vv = waveEqn(N,Nsteps)
% Initialization / Setup
  vv = exp(-40*((xx-.4).^2 + yy.^2));

% Send data to GPU
  dt = gpuArray(dt);
  vv = gpuArray(vv);
  index1 = gpuArray(index1);

% Processing
  n=0;
  while n < Nsteps
    V = [vv(ii,:) vv(ii,N:-1:2)];
    U = real(fft(V.')).';
    W1test = (U.*W1T).';
    W1 = (real(ifft(W1test))).';

% Gather vvg back from GPU memory when done
  vvg = gather(vv);
```

Scale to Clusters and Clouds

- Offload computation:
  - Free up desktop
  - Access better computers
- Scale speed-up:
  - Use more cores
  - Go from hours to minutes
- Scale memory:
  - Utilize distributed arrays
  - Solve larger problems without re-coding algorithms

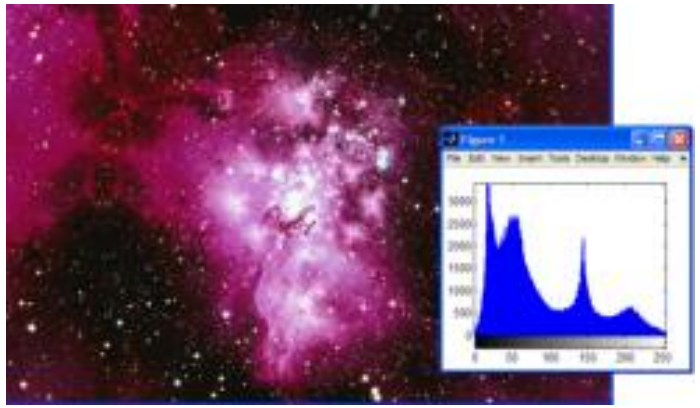


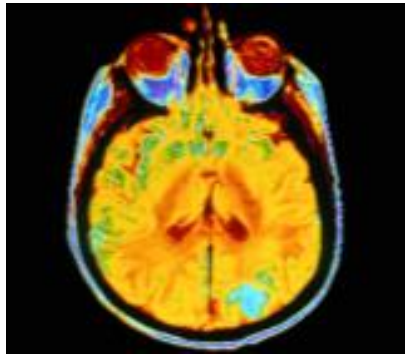
Advising on Deployment or Code Generation



Code Generation for Image Processing Functions

- regionprops
- watershed
- bweuler
- bwlabel
- bwperim
- multithresh
- padarray
- bwmorph
- bwlookup
- Conndef
- fspecial
- bwtraceboundary
- imadjust
- imclearborder
- medfilt2
- imfill
- imhmax
- imhmin
- imreconstruct
- imregionalmax
- iptcheckconn
- …

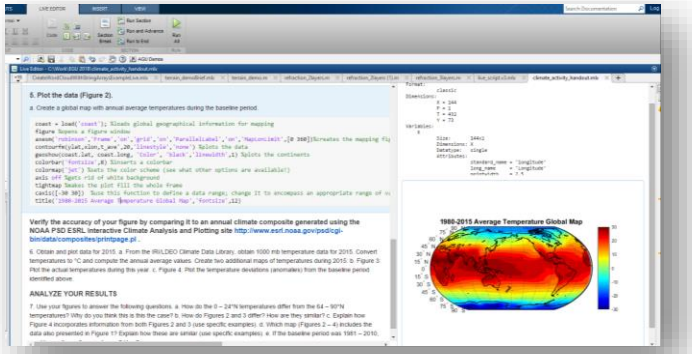




Agenda

- Introduction
- Quick intro to MATLAB
- Image Processing with MATLAB
- Managing large image sets
- What's New
- Wrap-up

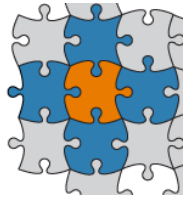
Sustainable Research Software Engineering with MATLAB



- MATLAB Live Script
  - Create computational code stories with Live Editor for papers and teaching
- Source Control
  - Use git and SVN from MATLAB

- MATLAB Projects (R2019a)
  - Organize, manage, and share your work

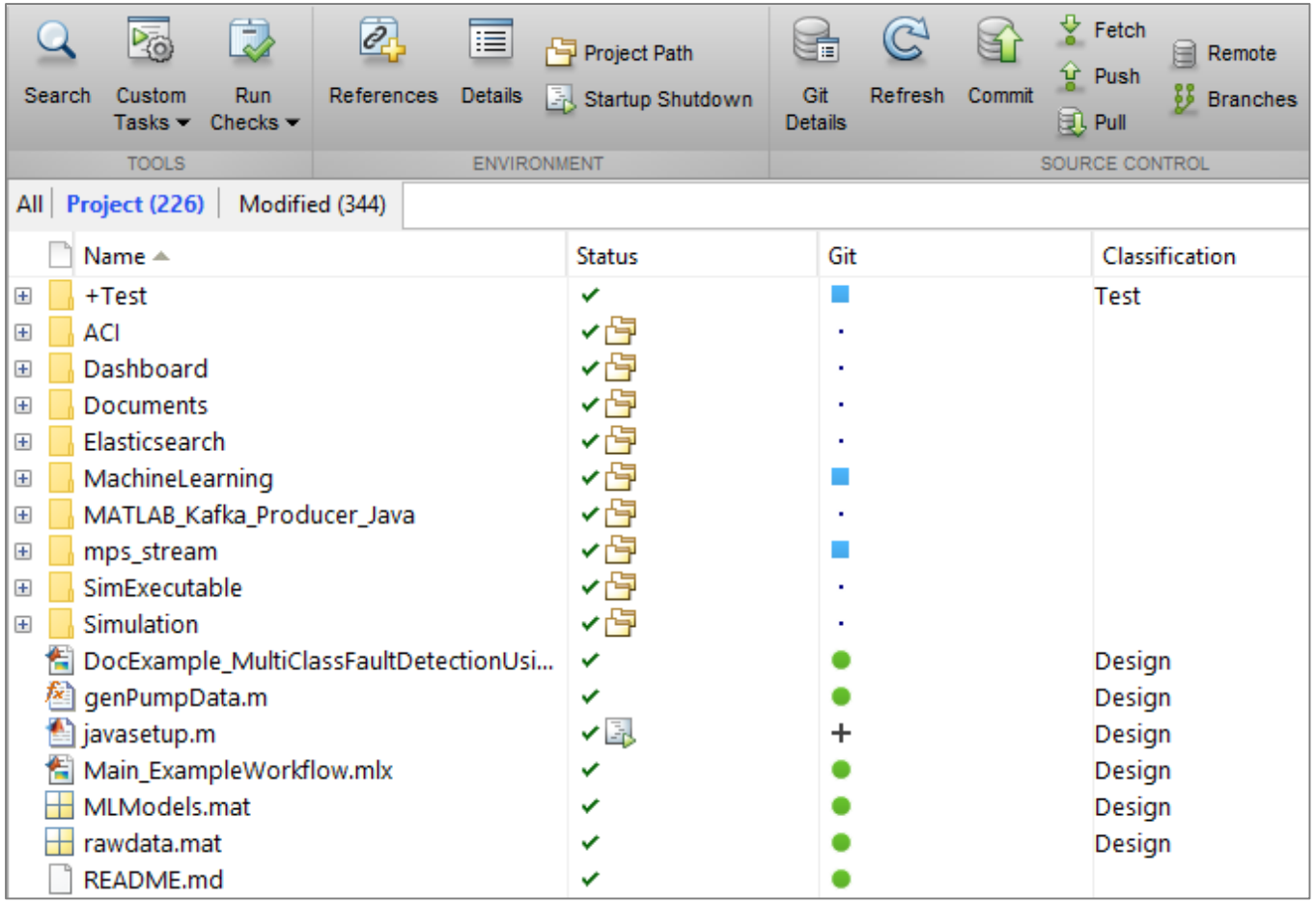
- Test Frameworks
  - Unit Test, Performance Test, App Test, and Mocking Framework tests



- Object Oriented Programming
  - Validate object properties by their type, size, shape, or other attributes (R2017a)
- Continuous Integration
  - Use MATLAB with Jenkins

MATLAB Projects: Organize, manage, and share your code

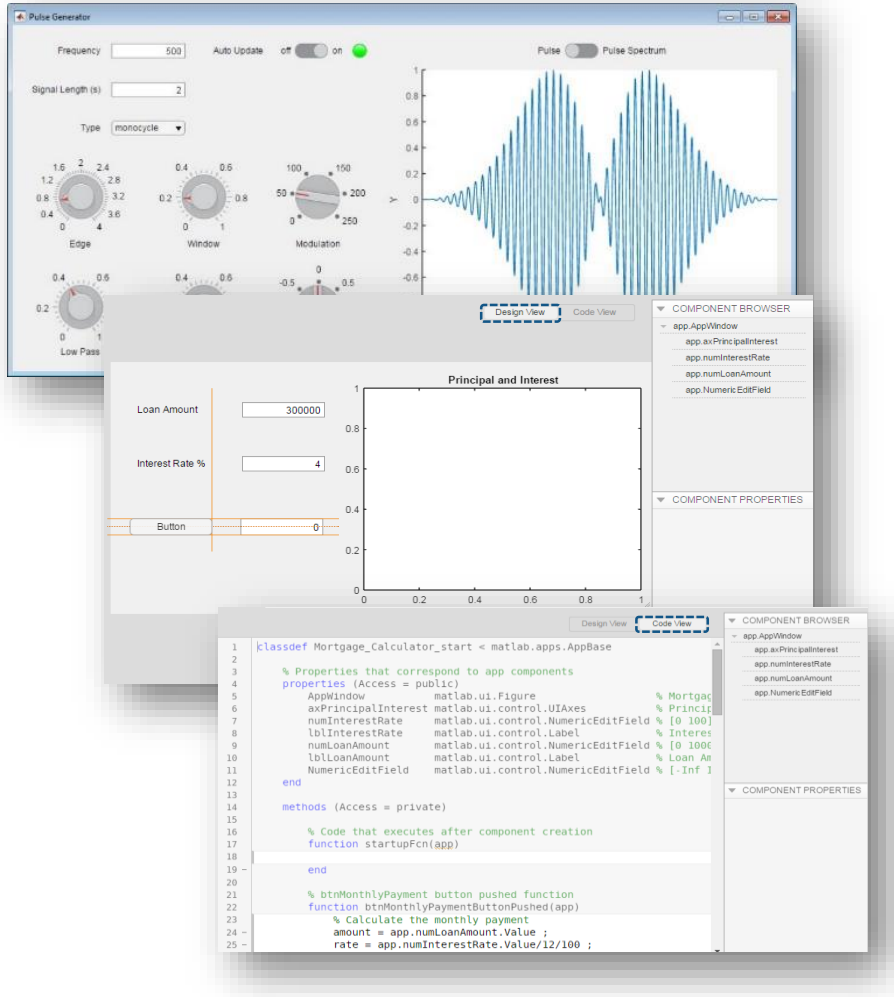
- Configure your environment
- Analyze dependencies
- Track and control changes
- Package and share projects



App Designer

Create professional Apps for no professional software developer

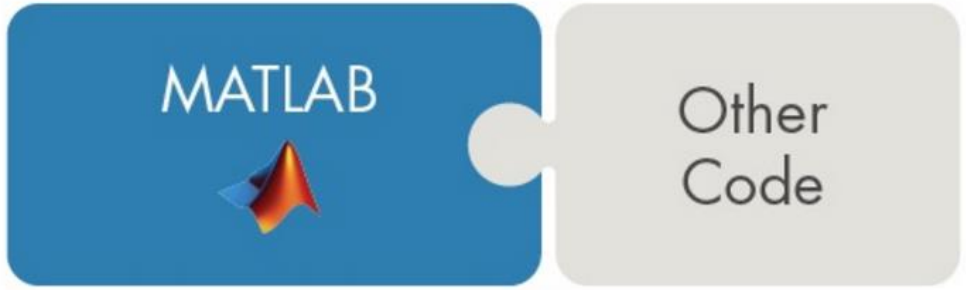
- Enhanced design environment
- New UI components: gauges, dials, tabbed interfaces, and more…
- Improved object-based code and coding tools
- Deploy apps to the web



Working with Other Languages

Interoperate with Python, C, and more from MATLAB

Call Other-Language Libraries from MATLAB



- Java
- Python
- C/C++
- Fortran
- COM components and ActiveX® controls
- RESTful, HTTP, and WSDL web services

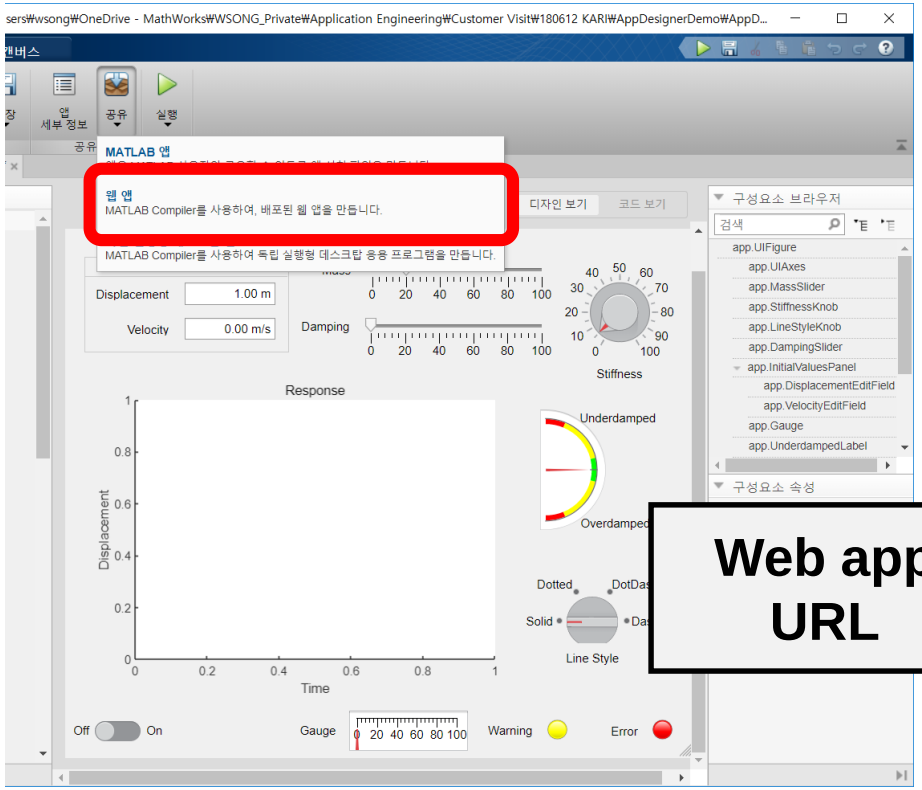
Call C++ libraries directly from MATLAB R2019a

Call MATLAB from Another Language

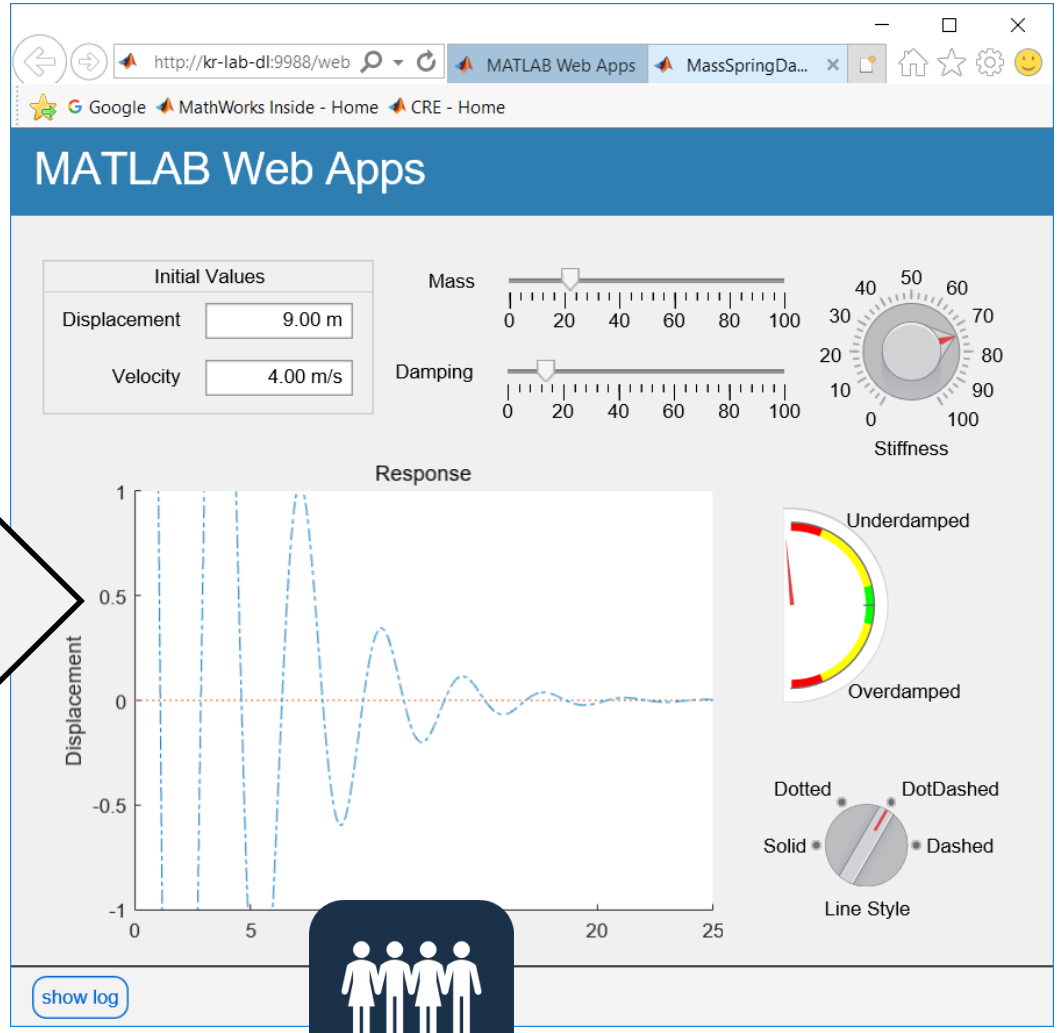
- Java
- Python
- C/C++
  - Updated C++ API
- Fortran
- COM Automation server

MATLAB Programs Can be Shared With Anyone

Standalone desktop app & Web Deploy



Web app URL



MATLAB User

End-Users

Deep Learning Toolbox

Create, analyze, and train deep learning networks

Interoperability with other deep learning frameworks

ONNX

PyTorch mxnet TensorFlow

Deep Network Designer app

Improved inference performance

NVIDIA

Domain-specific workflow support

- Ground truth labeling apps for audio and video
- Application-specific datastores

Network training performance

NVIDIA GPU CLOUD

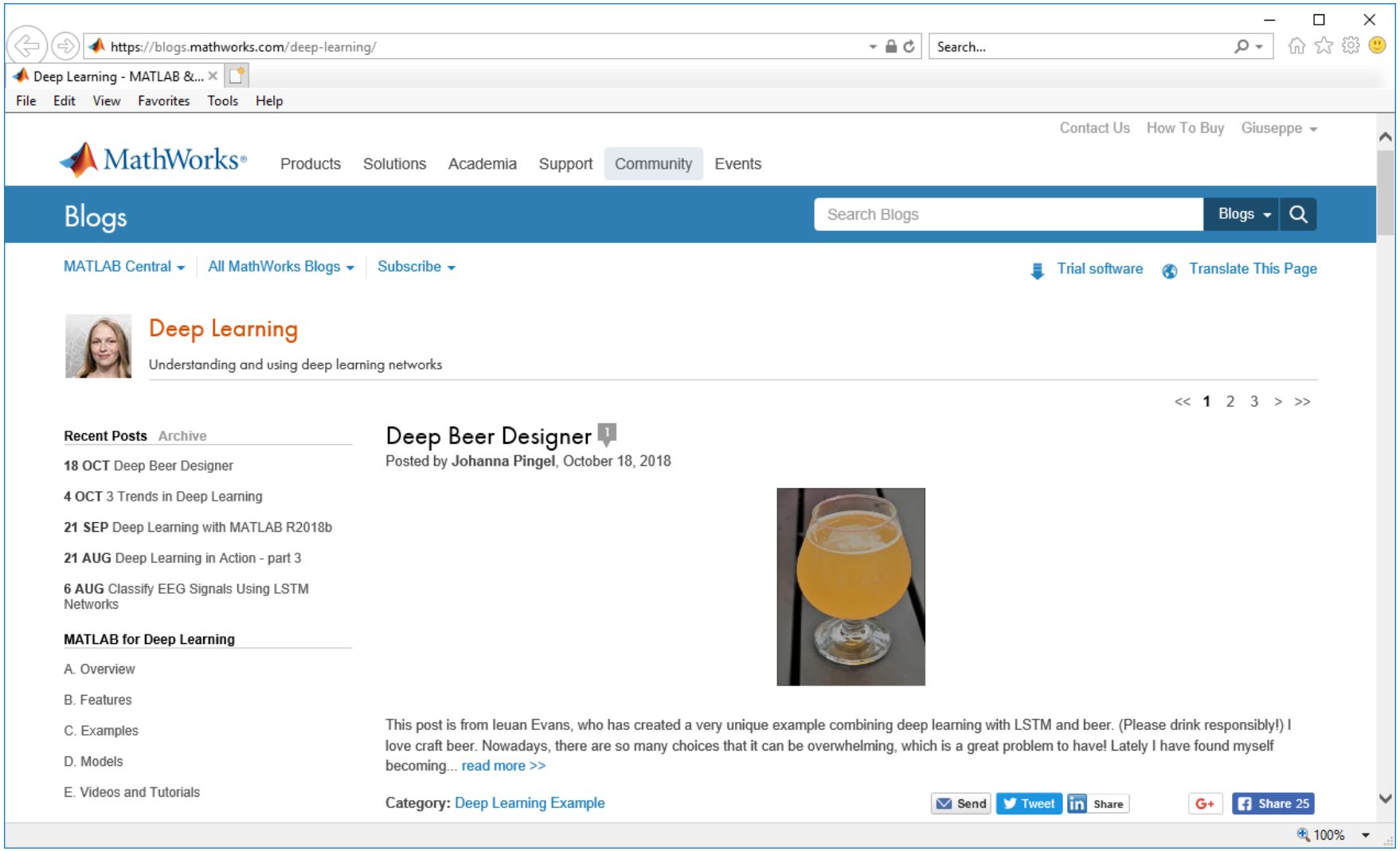
Azure

amazon web services™

Expanded deployment support

intel ARM

Blog: Deep Learning



http://blogs.mathworks.com/deep-learning/

Agenda

- Introduction
- Quick intro to MATLAB
- Image Processing with MATLAB
- Managing large image sets
- What's New
- Wrap-up

Why use MATLAB for Image Processing?

Key takeaways

- Complete environment
- Verified and trusted algorithms
- Faster than hand-coding algorithms in C/C++
- Open and flexible architecture enables a customized workflow

Download Image Processing Tips, Techniques, and Code

Author and developer Steve Eddins shares excerpts from his blog, featuring the most popular tips and techniques for image processing and image segmentation with MATLAB®.

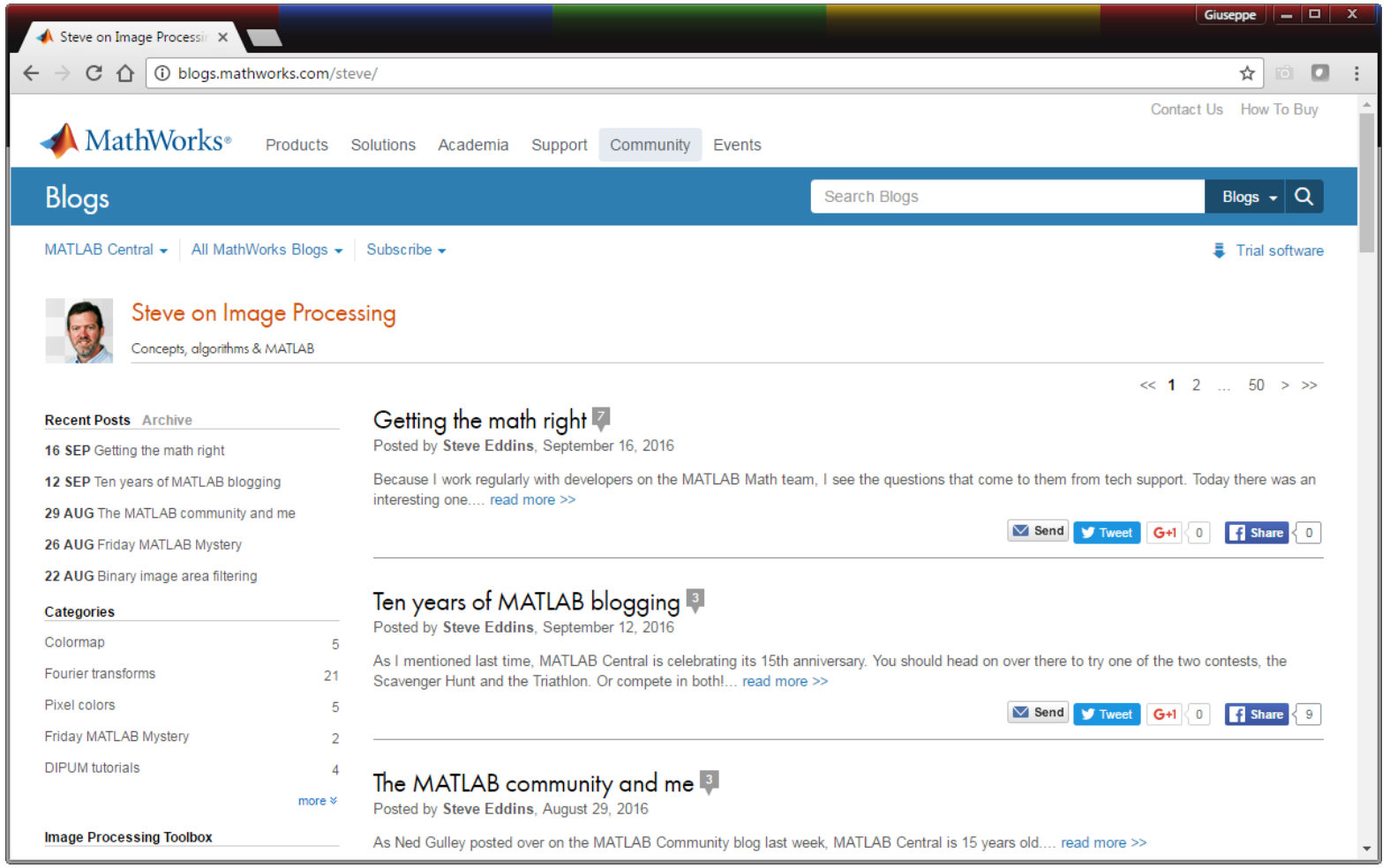
Download the Image Processing Tips and Techniques Kit to get code and step-by-step instructions for implementing these tasks easily in MATLAB:

- ✔ Color Segmentation
- ✔ Image Region Analysis
- ✔ Watershed Segmentation

The kit also includes several bonus techniques that MATLAB users have found helpful.

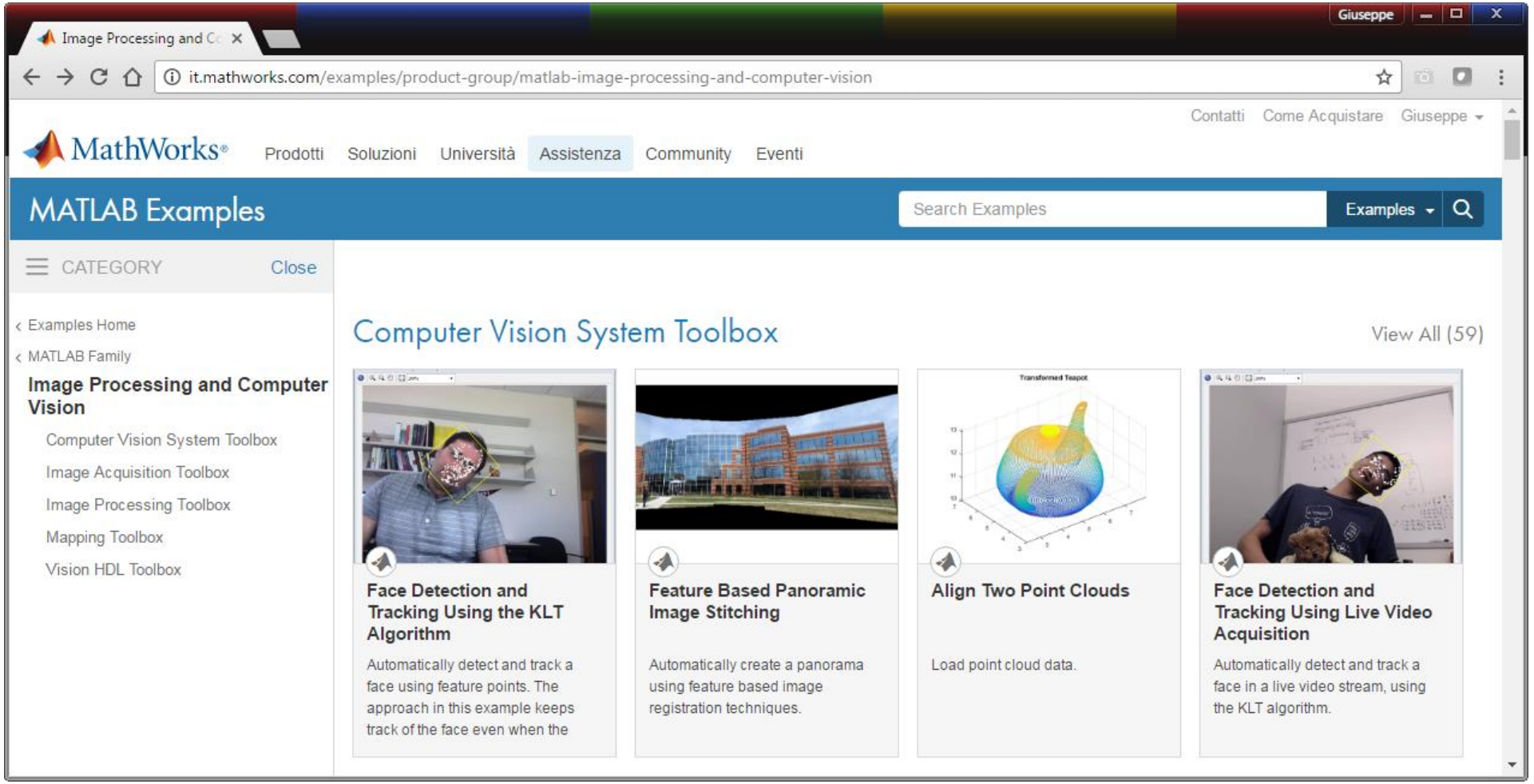
https://it.mathworks.com/campaigns/products/offer/image-processing-tips-and-techniques.html

Blog: Steve on Image Processing



http://blogs.mathworks.com/steve/

MATLAB Examples



http://it.mathworks.com/examples/product-group/matlab-image-processing-and-computer-vision

Hardware Support in MATLAB

- Validate algorithms with live data
- Integrate with webcams and IP cameras
- Access images and video from network cameras
- Webcam and IP Camera support in base MATLAB

Support for Industrial and Scientific Cameras

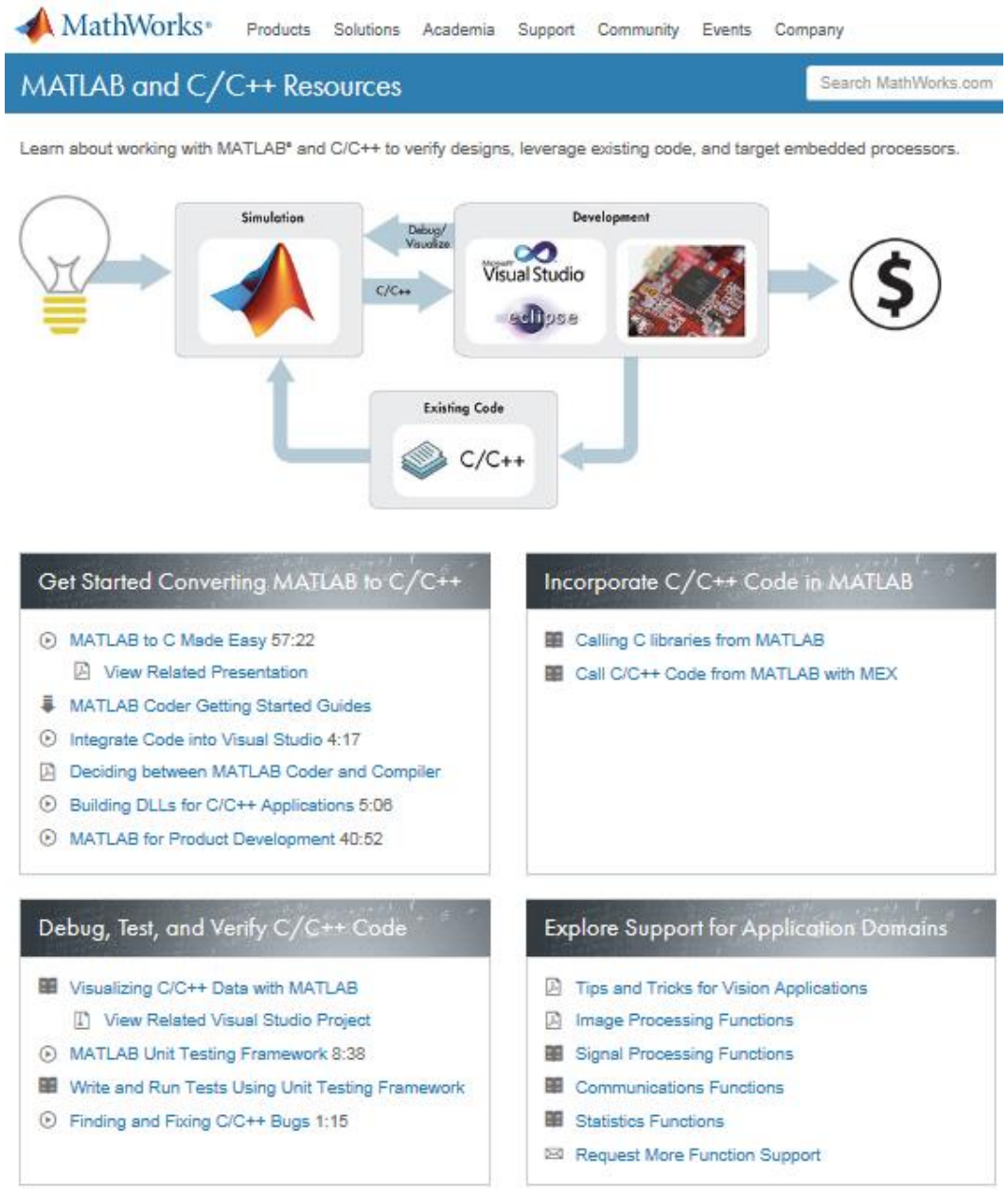
- Acquire images & video from industry-standard hardware:
  - Camera Link
  - DCAM compatible FireWire (IIDC 1394)
  - GigE Vision
  - GenICam Interface
- Manufacturers include:
  - Allied Vision Technologies
  - Basler
  - Baumer
  - FLIR
  - Hamamatsu
  - Point Grey
  - Teledyne DALSA

- See Hardware Catalog for more details: www.mathworks.com/hardware

Getting Started Resources

Web Resource Portal

- **MATLAB and C/C++ Resources**
  - **Videos**
  - **Examples**
  - **Documentation**

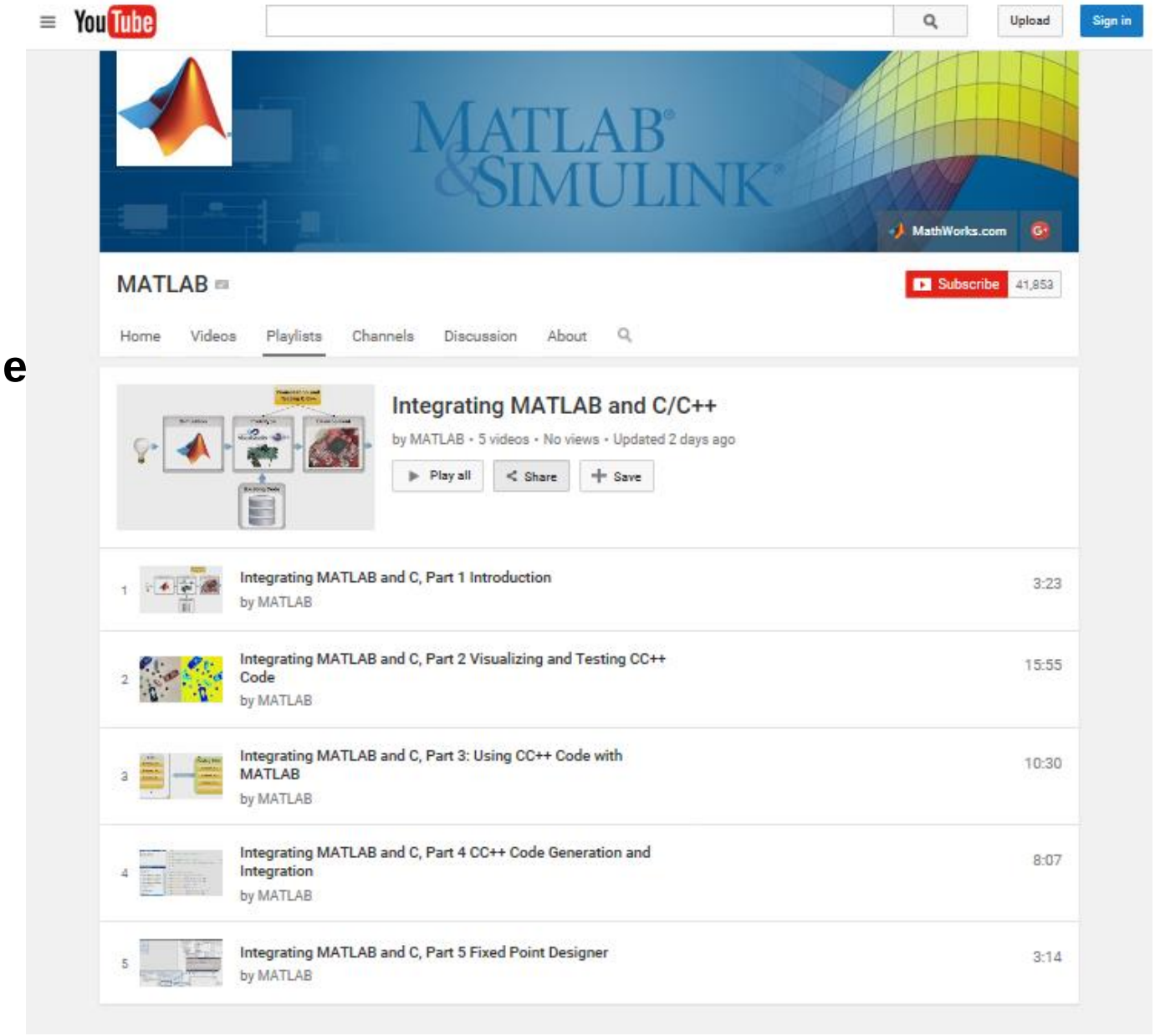


http://it.mathworks.com/matlab-c-resources

Getting Started Video Series

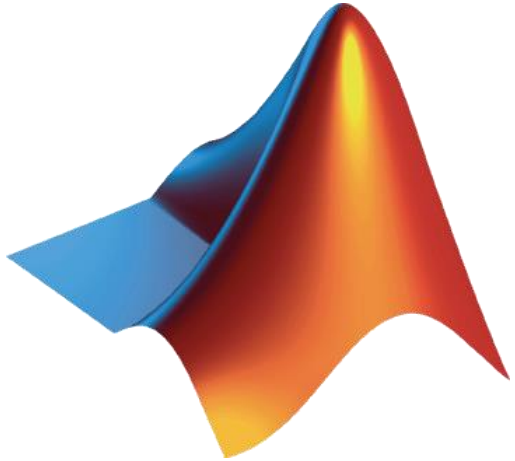
YouTube:

- **Integrating MATLAB and C/C++**
  - **Visualizing and Testing C/C++ Code**
  - **Using C/C++ Code with MATLAB**
  - **Fixed Point Conversion Overview**
  - **…**



https://www.youtube.com/playlist?list=PLn8PRpmsu08rKGu3KgYixmZQV-gYGfE7q

Thank you for your attention!
Questions?



Accelerating the pace of engineering and science