MATLAB Image Processing

By Bruce Tannenbaum
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Who uses MATLAB?

Key Industries

- Aerospace and defense
- Automotive
- Biotech and pharmaceutical
- Communications
- Computers
- Education
- Electronics and semiconductors
- Energy production
- Industrial automation and machinery
- Medical devices

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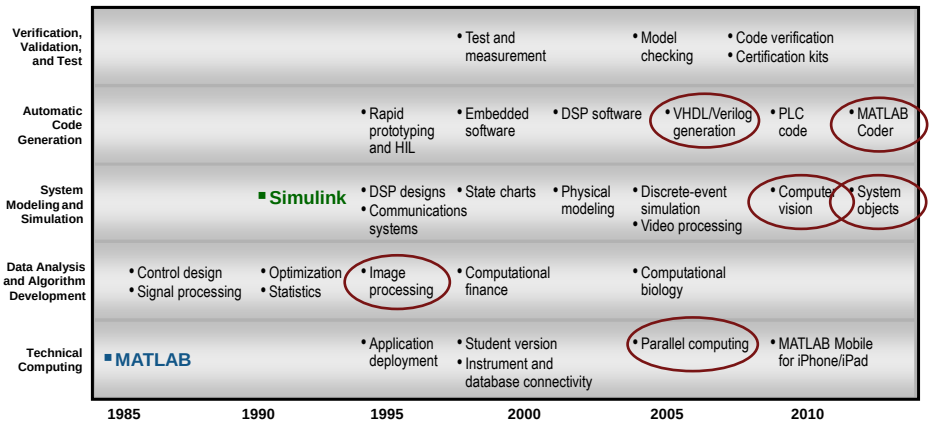
Key Capabilities Drive MathWorks Business



Founded in 1984

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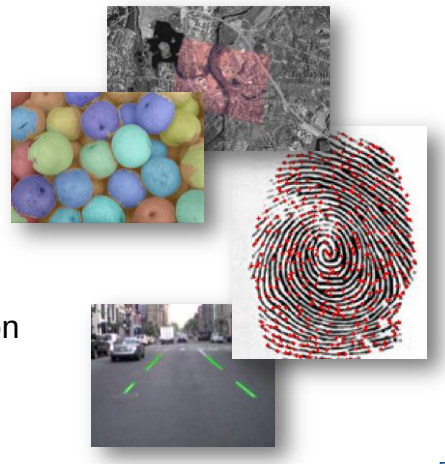
Image Processing Toolbox

Perform image processing, analysis, visualization, and algorithm development

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



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Imaging-related MATLAB Toolboxes

- Image Acquisition Toolbox
- Image Processing Toolbox

- Computer Vision System Toolbox
  - Also supports video processing
- Parallel Computing Toolbox
  - For multicore computers, GPUs, and computer clusters
- Statistics Toolbox
  - Clustering, statistics, and machine learning

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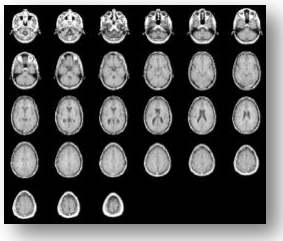
Agenda

- Working with large data sets
  - Block processing
  - Parallel processing
- Image registration
  - Intensity-based
  - Feature-based
- Video processing

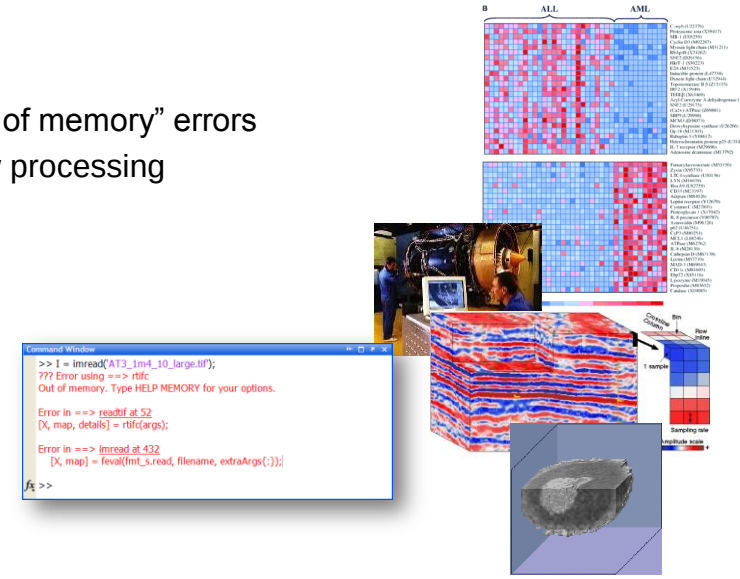
Examples of Large Image Data Sets

- Satellite imagery
- Aerial surveys
- Super-resolution
- Image sequences and stacks
- Volumetric data
- Multispectral and hyperspectral
- Mosaics and panoramic imagery



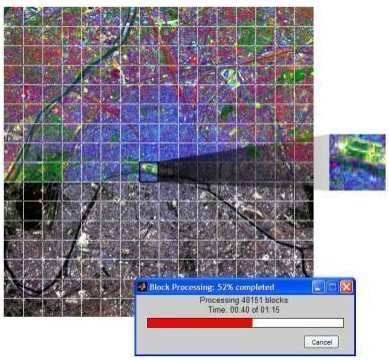
Common Large Image Challenges

- "Out of memory" errors
- Slow processing



`blockproc` and `rsetwrite`

- Block processing
  - Automatically divides an image into blocks for processing
  - Reduces memory usage
  - Processes arbitrarily large images
- Reduced resolution data set
  - Avoids memory demands in visualizing large images



Improving Performance

- MATLAB
  - Preallocate space for variables
  - Identify bottlenecks with Profiler
  - Vectorize code
- Image Processing Toolbox
  - Many toolbox functions are faster as of R2010a
  - Implicit use of multicore processors
- Parallel Computing Toolbox
  - Explicitly use multicore processors, clusters, and GPUs

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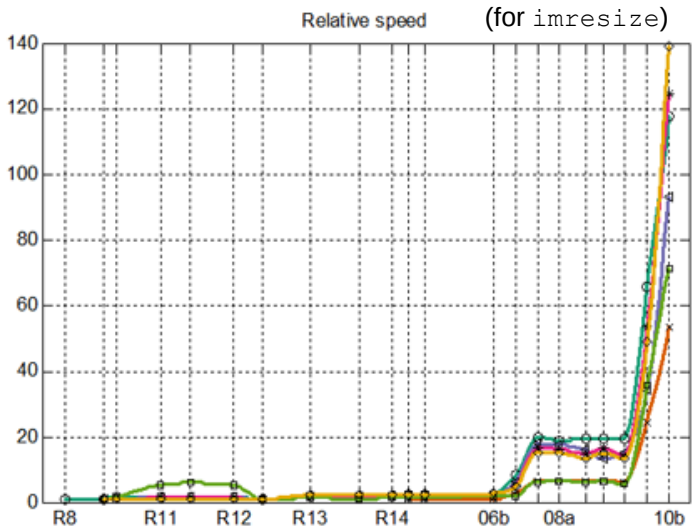
Example of IPT Performance Improvements



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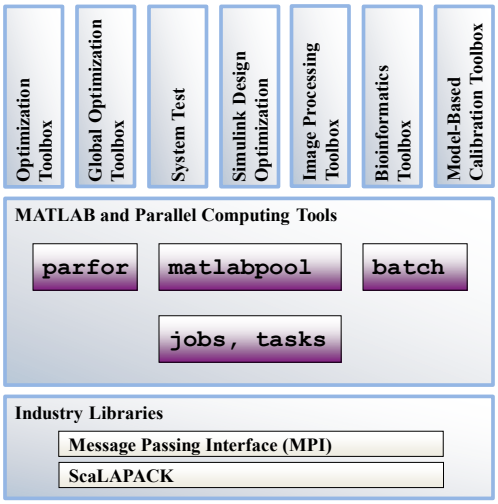
Parallel Computing with MATLAB

- Built in parallel functionality within specific toolboxes
- High level parallel functions
- Low level parallel functions
- Built on industry standard libraries



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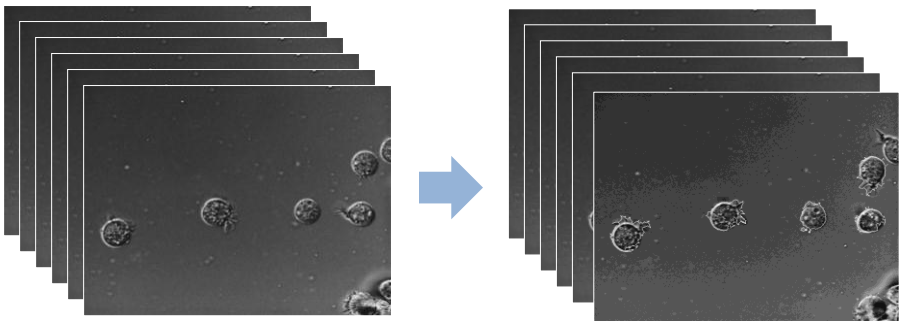
Parallelized Image Segmentation with `parfor`



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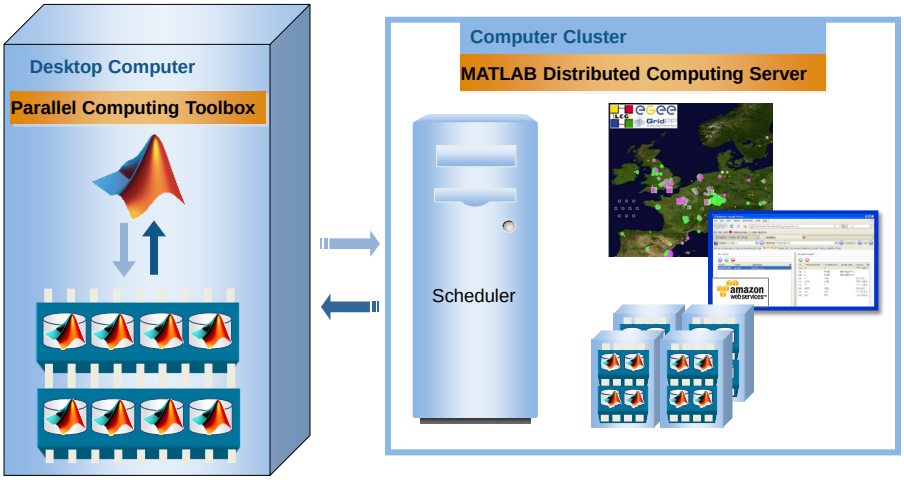
Scale Up to Clusters, Grids and Clouds



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GPU Support with Parallel Computing Toolbox

- Run supported MATLAB code on the GPU
  - Includes functions such as `conv2, filter2`
- Create kernels from existing CUDA code and PTX files
- Run kernels on the GPU from MATLAB

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Agenda

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  - Intensity-based
  - Feature-based
- Video processing

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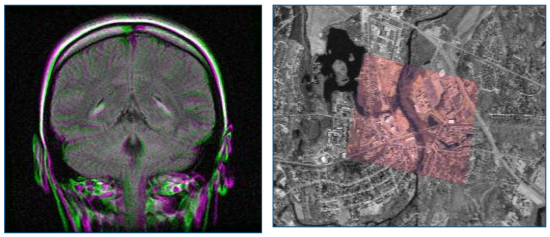
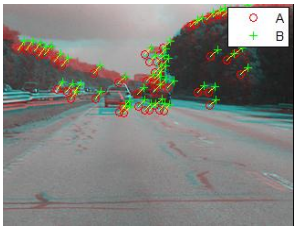
Automatic Image Registration

Intensity-based



Feature-based



Two new registration types supported:

- Intensity-based (Image Processing Toolbox)
- Feature-based (Computer Vision System Toolbox)

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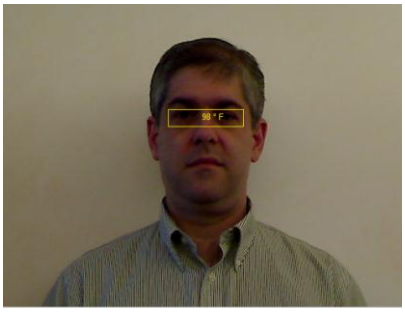
Demo: Intensity-based Image Registration



Goal:

- Detect febrile symptoms off an image

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Demo: Intensity-based Image Registration

Step 1: Register the image pair to detect the eyes

Step 2: Read temperature near eyes & issue alert in case of fever

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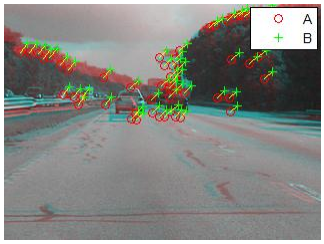
Feature-based Registration

- Aligning data from multiple sources
- Applications
  - Stabilization
  - Mosaicking, panoramas
  - Stereo vision
  - Data fusion
- Key capabilities
  - Feature detection and extraction
  - Feature matching
  - RANSAC for estimating geometric transformation or fundamental matrix



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Demo: Feature-based Image Registration

- Workflow
  - Feature detection and extraction
  - Feature matching
  - Geometric transformation estimation with RANSAC

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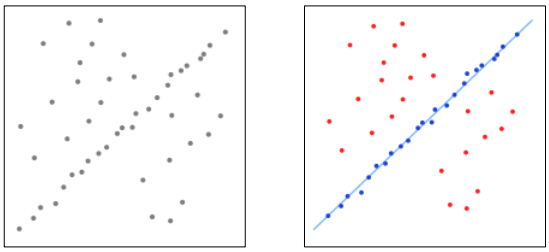
RANSAC for Estimation

- Random Sample Consensus
  - Iterative estimation of parameters to a mathematical model from a set of observed data that contains outliers
- Our uses of RANSAC
  - Estimate Geometric Transformation
  - Estimate Fundamental Matrix (useful for stereo vision)



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Video Processing in MATLAB

```
myVid = VideoReader('myvideofile.avi');
numFrames = myVid.NumberOfFrames;
numIter = 10;
opticalFlowIn = zeros([size(currentFrame) 5]);
opticalFlowOutput = zeros([size(currentFrame) numFrames]);

i = 1;
while i <= numFrames
   opticalFlowIn(:,:,2:end) = opticalFlowIn(:,:,1:end-1);
   opticalFlowIn(:,:,1) = read(myVid,i);

   flow = opticalFlow(opticalFlowIn(:,:,1),opticalFlowIn(:,:,5),…
                  'horn-schunck',numIter,'magitude-squared');

  opticalFlowOutput(:,:,i) = flow;

   i = i+1;
end

implay(opticalFlowOutput,30)
```

Explicit state management

Explicit indexing

Need to maintain buffer

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Video Processing with System Objects

```
reader = vision.VideoFileReader
reader.Filename = 'myvideofile.avi';
viewer = vision.DeployableVideoPlayer('framerate',30);

optical = vision.OpticalFlow
optical.Method = 'horn-schunck';
optical.OutputValue = 'Magitude-squared';
optical.ReferenceFrameDelay = 3;
optical.MaximumIterationCount = 10;
```

Initialize objects

```
while ~isDone(reader)
   currentFrame = step(reader);
   OF = step(optical, currentFrame);
   step(viewer, OF);
end
```

"In-the-loop" code is much simpler

Implicit states, buffering, and indexing

Video player runs in-the-loop

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Demo: Car Detection Using Optical Flow

Use optical flow to detect and count moving vehicles on a road

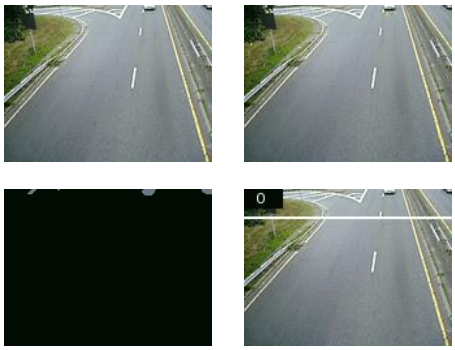

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Image Acquisition Toolbox Hardware Support

- Manufacturers include:
  - Allied Vision Technologies
  - Basler
  - Baumer
  - DALSA
  - FLIR
  - Hamamatsu
  - Lumenera
  - Matrox Imaging
  - National Instruments
  - PixeLINK
  - Point Grey
  - Qimaging
  - Sony
  - And many more
- See Supported Hardware Pages for more information

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Why use MATLAB for Image and Video Processing?

- Read and write many image file formats
- Visualize and explore images interactively
- Connect directly to cameras and frame grabbers
- Use a large library of built-in functions
- Quickly build custom image processing algorithms
- Block-process large images to avoid memory issues
- Process images faster with multiple cores and clusters

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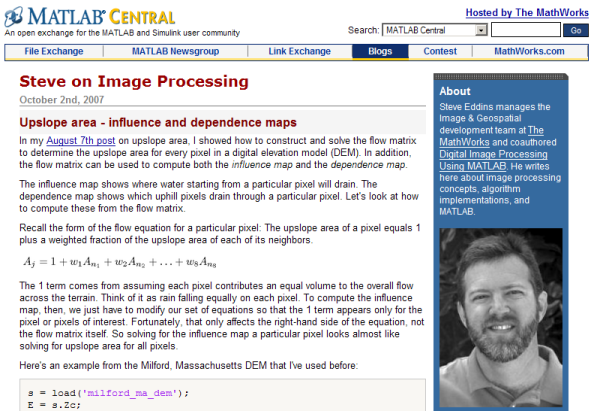
Additional Resources

MATLAB Central Blog: “Steve on Image Processing”

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



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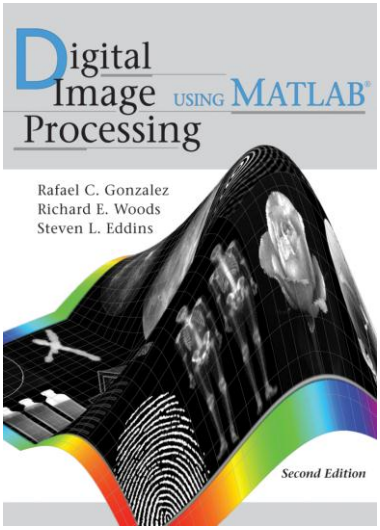
Additional Resources

Digital Image Processing Using MATLAB

Gonzalez, Woods, and Eddins

Gatesmark



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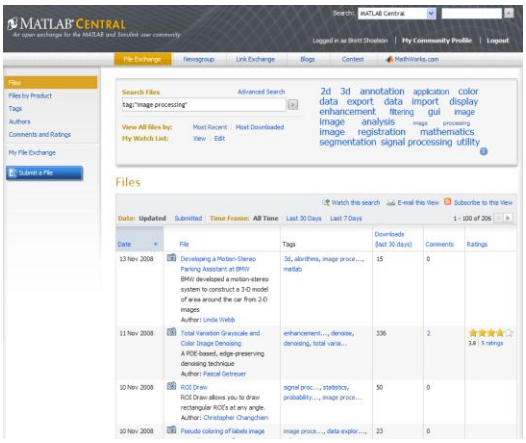
Additional Resources

MATLAB Central File Exchange

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



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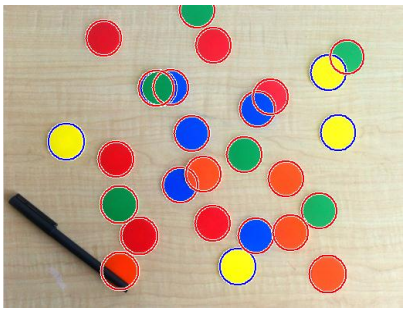
Questions?

If Time Permits.. Find the Circles



Goal:

- Find circles in truecolor image
- Draw edge lines around the circles