Developing Image Processing and Computer Vision Systems Using MATLAB and Simulink

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MathWorks
# Why use MATLAB for Image and Video Processing?

<table>
<thead>
<tr>
<th>Read/Write many image formats</th>
<th>Visualize and explore images interactively</th>
<th>Connect directly to cameras</th>
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<tbody>
<tr>
<td>Use a large library of inbuilt functions</td>
<td>Quickly build custom IP algorithms</td>
<td>Block process large images to avoid memory issues</td>
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<td>Process images faster with multiple cores and clusters</td>
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AGENDA

- Image Acquisition
  - DEMO

- Algorithm Development using Image Processing and Computer Vision System TB
  - DEMO

- Working with Large Images
  - DEMO

- Targeting DSP’s
  - DEMO

- Simulink Workflow
  - DEMO
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    - TB
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Underexposure Photo

Improper Camera Settings??
White Balanced Photo

Much Better!
Image Acquisition Toolbox

Configure, acquire, and preview live video data using a graphical interface

- Acquire images and video directly into MATLAB and Simulink
- Synchronize multimodal devices
- Configure device properties
Image Acquisition Toolbox Hardware Support
From Sensor Data to Image
(Converting raw data from image sensor to color adjusted RGB)

Image Sensor

Bayer pattern
Color Filter

Sensor Arrays

Raw Image

RGB Color Image
Example of digital camera pipeline
(Processes may be different depends on sensors)
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DEMO
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Examples of Computer Vision with MATLAB
Computer Vision System Toolbox

Design and simulate computer vision and video processing systems

- Feature detection, extraction and matching
- Feature-based registration
- Object detection and tracking
- Stereo vision
- Video processing
- Motion estimation
- Video display and graphics
Object Detection and Tracking

Face Detection

People Detection

KLT Tracking
Categorical Object Detection

- How do we detect a category or “general type”
  - Faces
  - People
  - Cars
  - ...

[Image showing facial detection]
Category Detection = Features + Machine Learning

- Typical Features:
  - Histogram of Gradients (HOG)
  - Haar-like Features
  - Local binary patterns

- Machine Learning:
  - Requires input data and known responses
  - Builds a model to predict responses to new data

- Typical Machine learning classifiers:
  - SVM
  - Adaboost
  - Cascade of Adaboost
  - K-nearest neighbour
Histogram of Oriented Gradients (HOG)

- Descriptor to characterize local object appearance
- Compute gradients in image using \([-1, 0, 1]\) mask with no smoothing, divide it into cells
- Compute histogram of gradient orientations on each cell
- Group cells into overlapping blocks, normalize vector of histogram values
- Slide over all relevant windows/regions
Support Vector Machines (SVMs)

- Type of supervised learning
- Represent data as features in ‘feature-space’
- Linear SVM is a classifier that maximizes distance between two classes (margin) in feature-space
- ‘Trained’ SVM accepts test data
Demo: People Detector

- vision.PeopleDetector detects upright people
- Uses HOG features and trained SVM classifier
Demo: Viola-Jones Face Detection

- **Algorithm details**
  - Haar-like features
  - Gentle Adaboost classifiers for feature selection
  - Cascading of classifiers to quickly weed out negative candidates
Cascade of Classifiers in CascadeObjectDetector

Each stage of cascade is Gentle Adaboost, an ensemble of weak learners

Each stage rejects negative samples using a weighted vote of these weak learners

The samples not rejected are passed to the next stage

Positive detection means the sample passed all stages of the cascade
Object Tracking Workflow

1. Detection:
   - First, detect a face (using Viola Jones Algorithm)

2. Tracking:
   - Then, detect features using Minimum eigenvalues (corners)
   - Track Features using vision.PointTracker
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Parallel Computing Products

MATLAB
Distributed Computing Server

Parallel Computing Toolbox

Multicore CPU
GPU
Parallel Computing enables you to …

- Larger Compute Pool
- Larger Memory Pool
- Speed up Computations
- Work with Large Data
GPU Support with Parallel Computing Toolbox

- NVIDIA GPUs with compute capability 1.3 or greater
  - Includes Tesla 10-series and 20-series products
    (e.g., NVIDIA Tesla C2075 GPU: 448 processors, 6 GB memory)

- GPU enabled Image Processing Toolbox functions:
  - imrotate(), imfilter(), imdilate(), imerode(), imopen(), imclose(), imtophat(), imbothat(), imshow(), padarray(), bwlookup()

Example: imfilter : 37x37 Filter on 3840 x 5120 pixels image
13 seconds (CPU Only) ➔ 1 seconds (GPU: Tesla C2050)
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DEMO

DEMO
Targeting DSPs and FPGAs

MATLAB and Simulink
• Algorithm development
• Debugging and profiling
• System design

Fixed-Point Modeling

Generate code
Verify design

Link to Embedded Software

Integrated Development Environment
• Compiler
• Build automation tools
• Debugger
Fixed-Point Analysis

- Convert floating point to **optimized** fixed-point models
  - Automatic tracking of signal range (also intermediate quantities)
  - Word / Fraction lengths recommendation
- Bit-true models in the same environment

Automatically identify and solve fixed-point issues
With MATLAB Coder, design engineers can

- Maintain one design in MATLAB
- Design faster and get to C/C++ quickly
- Test more systematically and frequently
- Spend more time improving algorithms in MATLAB
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Simulink Workflow → DEMO
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Simulink: The Simulation Platform

- Hierarchical block diagram design and simulation tool
- Built-in notion of time
- Visualize Signals
- Co-develop with C / M / HDL code
- Integrated with MATLAB
Simulink System Design Environment

Input from Hardware

EDA Connection
(Ex: Xilinx, Altera, Mentor Graphics, Cadence)

Co-Simulation with FPGA

Co-Simulation with CPU/DSP

IDE Connection
(Ex: Texas Instruments, Analog Devices, Green Hills, Altium, Eclipse)
Run on Target Hardware
What is it?

- A Simulink feature that generates an executable application from a model and runs it on supported target hardware

- Available from the model’s **Tools** menu
  
  Tools → Run on Target Hardware

- Includes a **Target Installer** to select and install target hardware support packages
BeagleBoard

- An open-source **single-board “laptop”**
- Compatible with **USB devices** like keyboard, mouse, and web cam
- Stereo audio in and out
Installing a Target Hardware Support Package

MATLAB R2013a

Command Window

>> targetinstaller

Support Package Installer

Select a support package based on your hardware needs.
Target Hardware Support Packages

- Target hardware support packages provide a collection of software components for the specified target hardware.
Workflow
How does it work?

1. Connect target hardware to host computer
2. Install Target Hardware Support Package
3. Create a model
4. Prepare to Run
5. Run
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DEMO
What you saw today

- A typical workflow for building a system using the Image Processing and Computer Vision System Toolbox.
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<td>Statistical Methods in MATLAB</td>
<td>Bangalore</td>
<td>02-03 Sep 2013</td>
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<tr>
<td>MATLAB based Optimization Techniques</td>
<td>Bangalore</td>
<td>04 Sep 2013</td>
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<td>Physical Modeling of Multi-Domain Systems using Simscape</td>
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<td>MATLAB Fundamentals</td>
<td>Delhi</td>
<td>23-25 Sep 2013</td>
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<td>MATLAB for Building Graphical User Interface</td>
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<td>21 Nov 2013</td>
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<tr>
<td>Generating HDL Code from Simulink</td>
<td>Bangalore</td>
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MathWorks Certified MATLAB Associate Exam

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- Can help accelerate professional growth
- Can help increase productivity and project success and thereby prove to be a strategic investment
- Certification exam administered in English at MathWorks facilities in Bangalore on Nov 27, 2013

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Thank you!