Deep Learning for Image Processing and Computer Vision with MATLAB

Sarah Hung
**Application Engineer**

2018/11/28

Agenda

- New Features in Image Processing

  – 3-D Image Processing

  – Deep Learning for Image Processing

- Deep Learning for Computer Vision
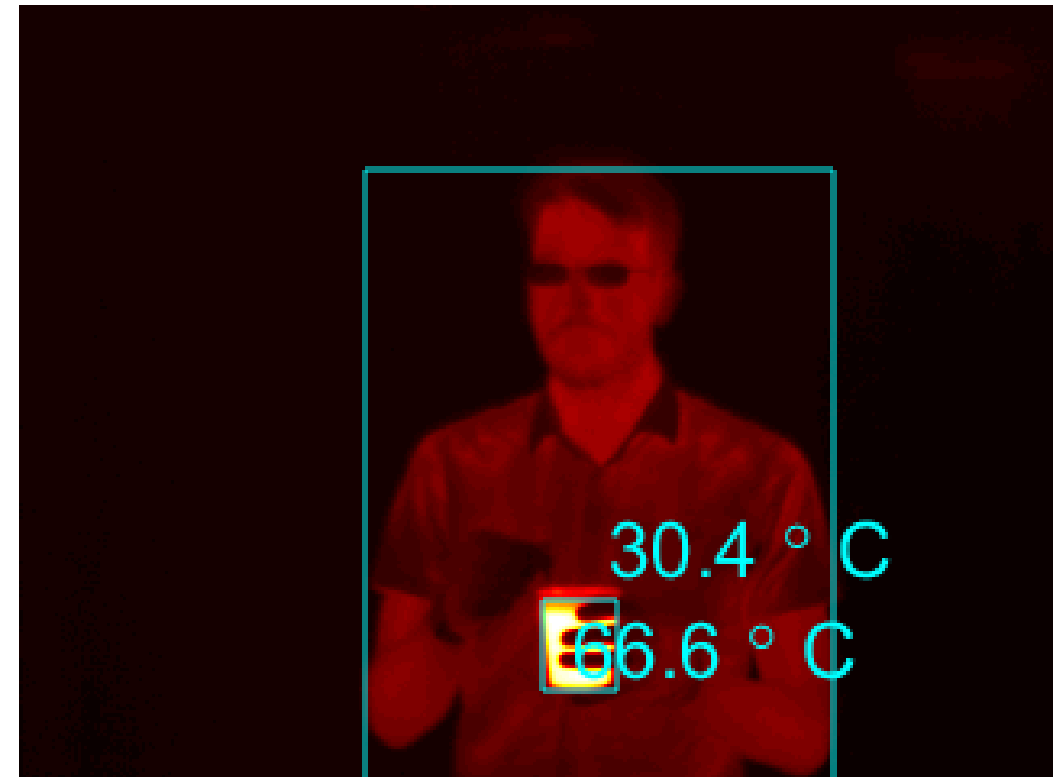
- Deep Learning Network Deployment

Image Processing Toolbox
Accelerate image processing and algorithm development

- Image display and exploration

- Image enhancement

- Image analysis

- Morphological operations

- Image registration
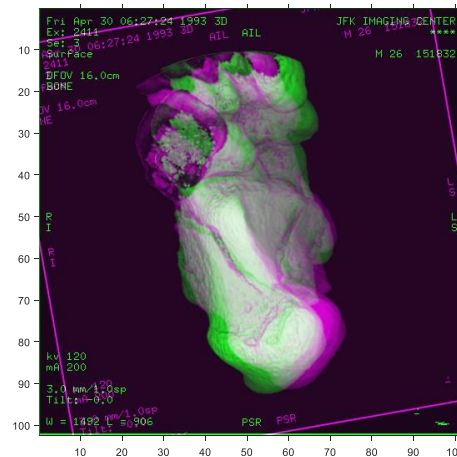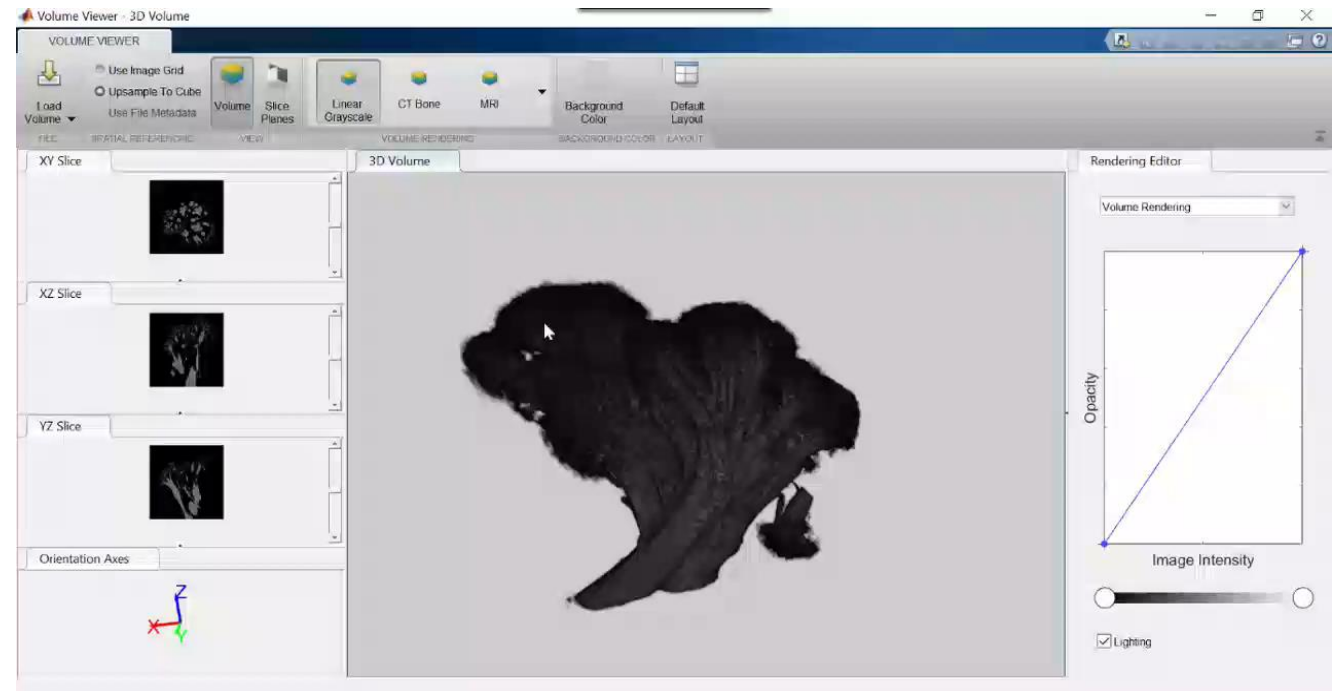
Thermal Image Segmentation

3-D Image Processing

Over _40 functions_ support 3-D volumetric image processing

Capabilities Includes:
- Image arithmetic
- Morphology
- Segmentation
- Geometric transforms
- Enhancement

Volume Viewer App for exploration
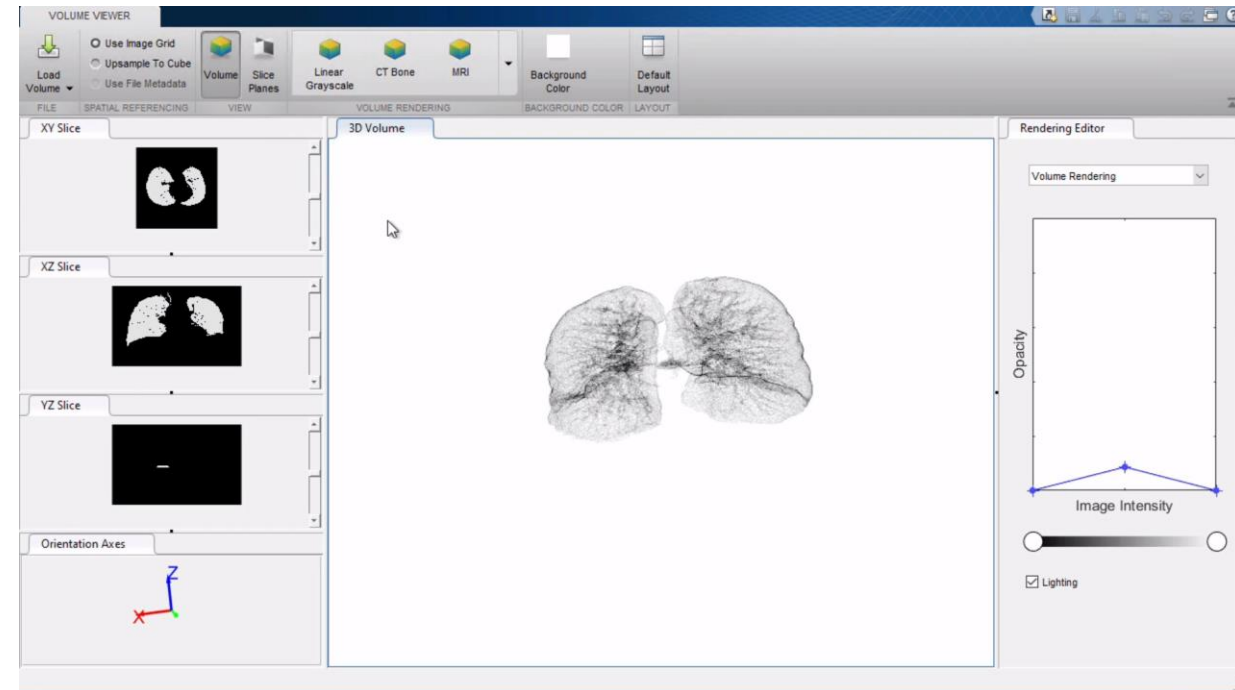
Segment Lungs from 3-D Chest Scan
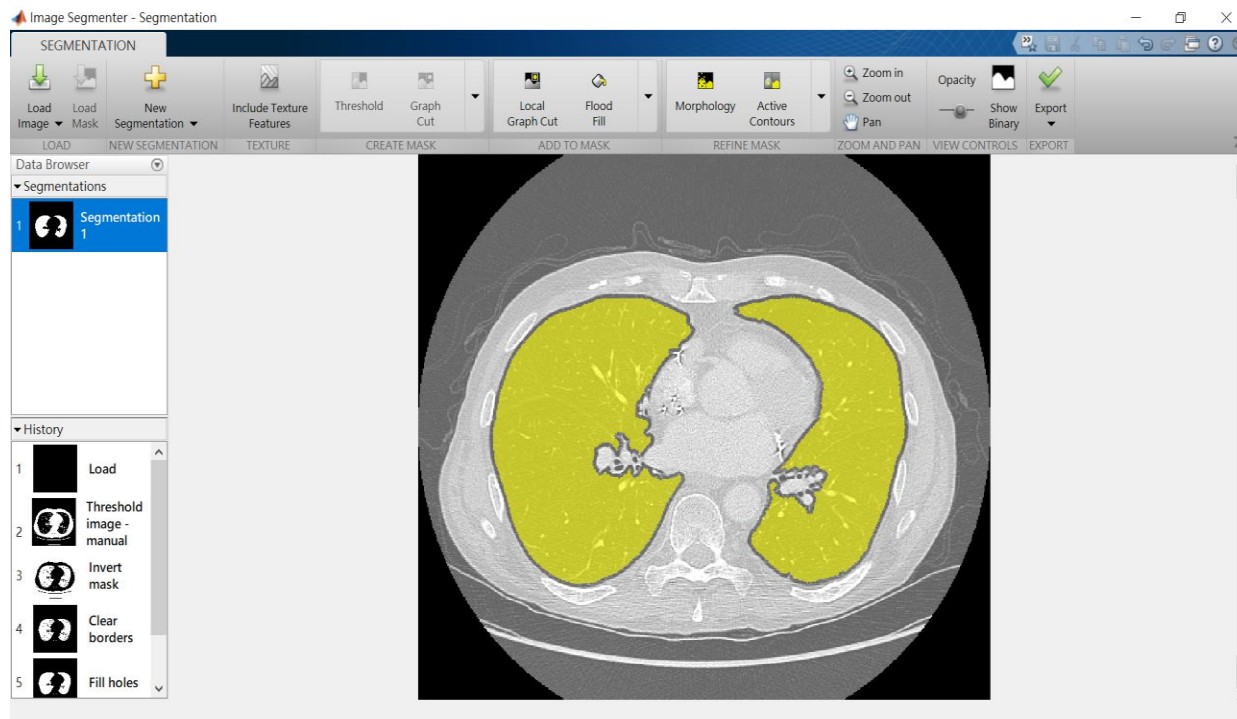
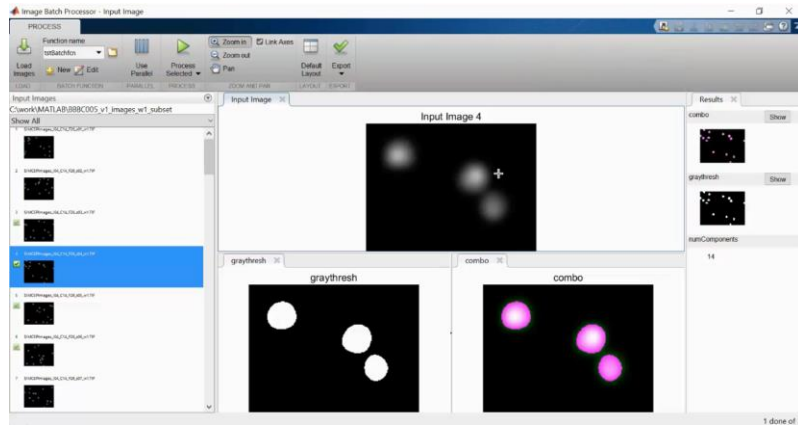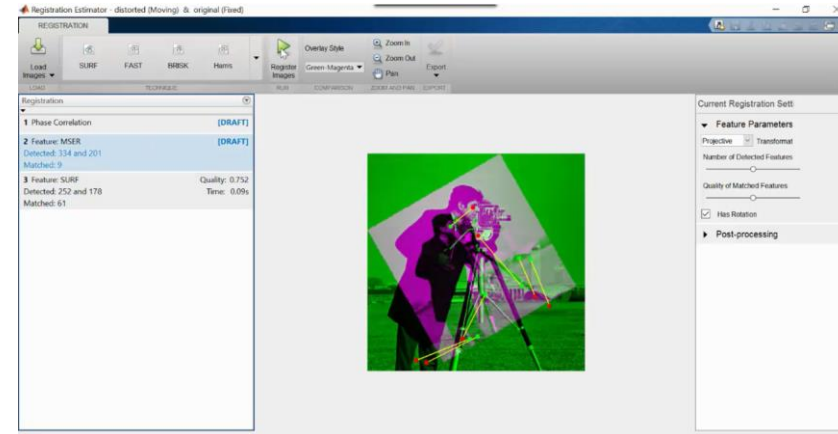- Create seed mask
- Active contour technique

Image Segmenter & Volume Viewer App

https://www.mathworks.com/help/images/segment-lungs-from-3-d-chest-mri-data.html
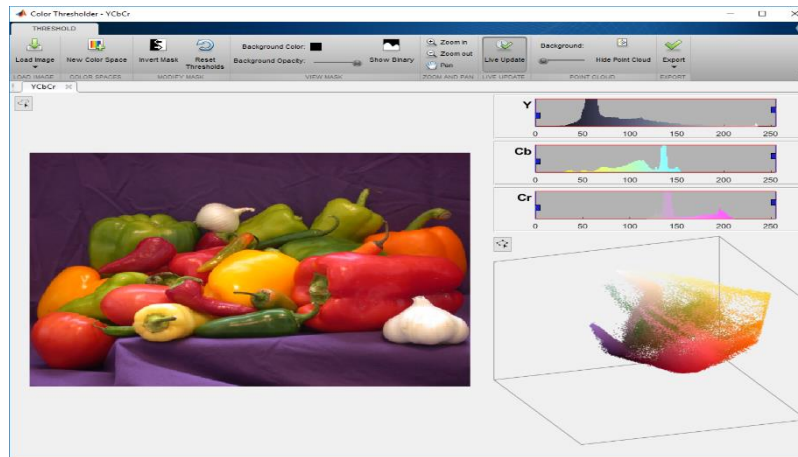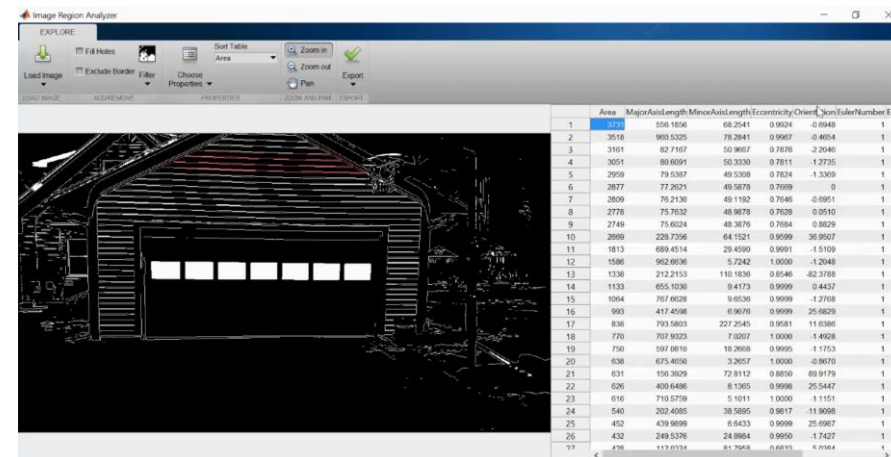
Image Processing Apps

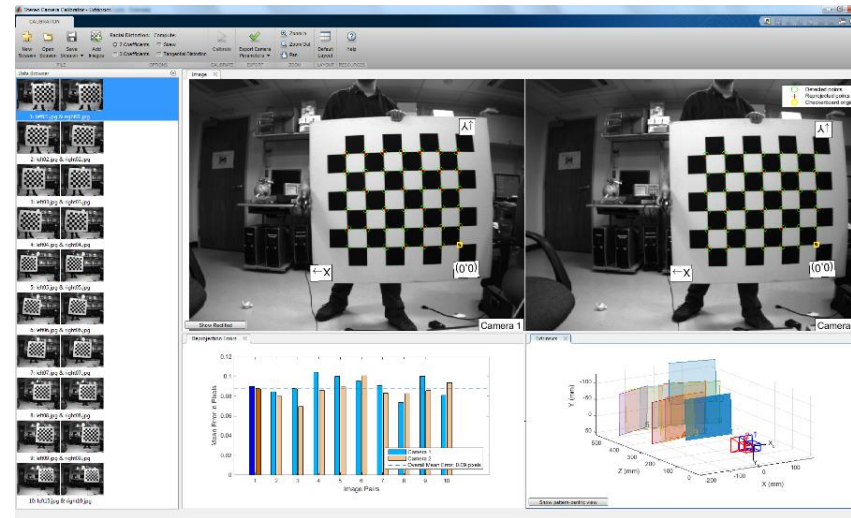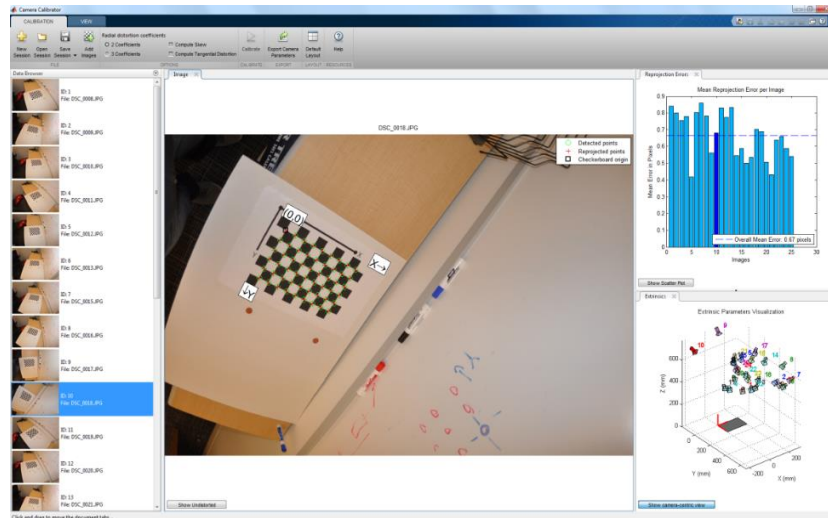Batch Processing

Registration Estimation

Color Thresholder

Region Analysis

Computer Vision Apps

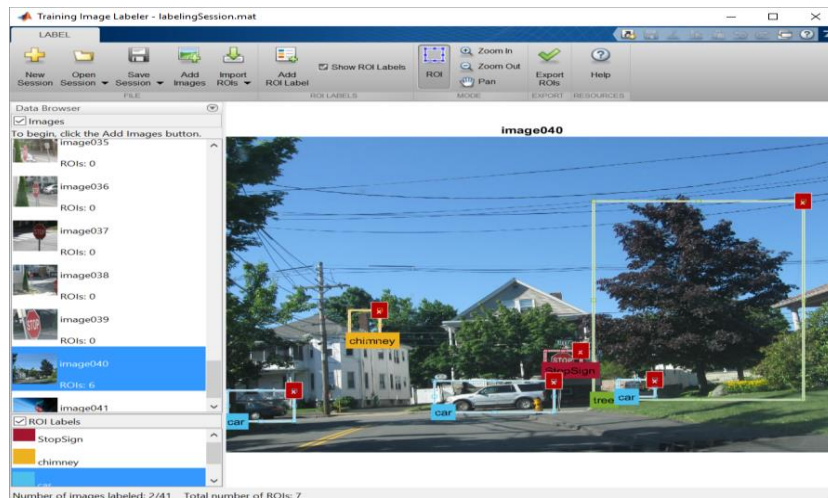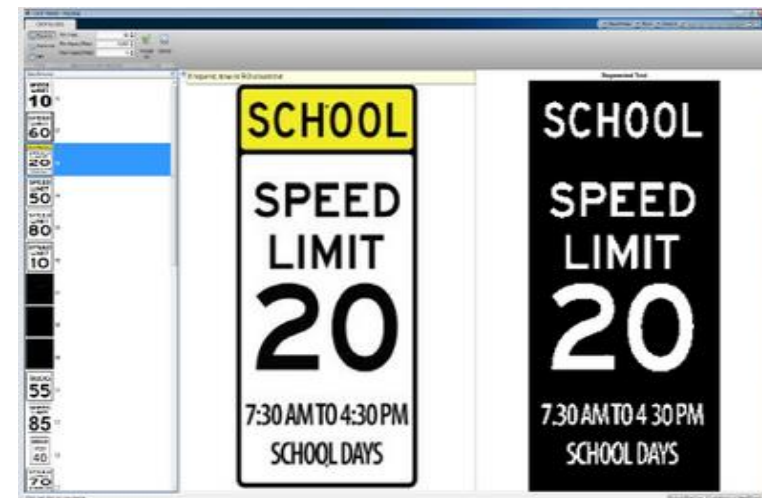Single and Stereo Camera Calibration

Image and Video Labeler

OCR Training

Deep Learning for Image Processing
Perform image processing using convolutional neural networks

Documentation   All   Examples   Functions   Apps

≡ CONTENTS

R2018**b**

Image Processing Toolbox

Perform image processing, analysis, and algorithm development

Image Processing Toolbox™ provides a comprehensive set of reference-standard algorithms and workflow apps for image processing, analysis, visualization, and algorithm development. You can perform image segmentation, image enhancement, noise reduction, geometric transformations, image registration, and 3D image processing.

Image Processing Toolbox apps let you automate common image processing workflows. You can interactively segment image data, compare image registration techniques, and batch-process large datasets. Visualization functions and apps let you explore images, 3D volumes, and videos; adjust contrast; create histograms; and manipulate regions of interest (ROIs).

You can accelerate your algorithms by running them on multicore processors and GPUs. Many toolbox functions support C/C++ code generation for desktop prototyping and embedded vision system deployment.

Getting Started
Learn the basics of Image Processing Toolbox

Import, Export, and Conversion
Image data import and export, conversion of image types and classes

Display and Exploration
Interactive tools for image display and exploration

Geometric Transformation and Image Registration
Scale, rotate, perform other N-D transformations, and align images using intensity correlation, feature matching, or control point mapping

Image Filtering and Enhancement
Contrast adjustment, morphological filtering, deblurring, ROI-based processing
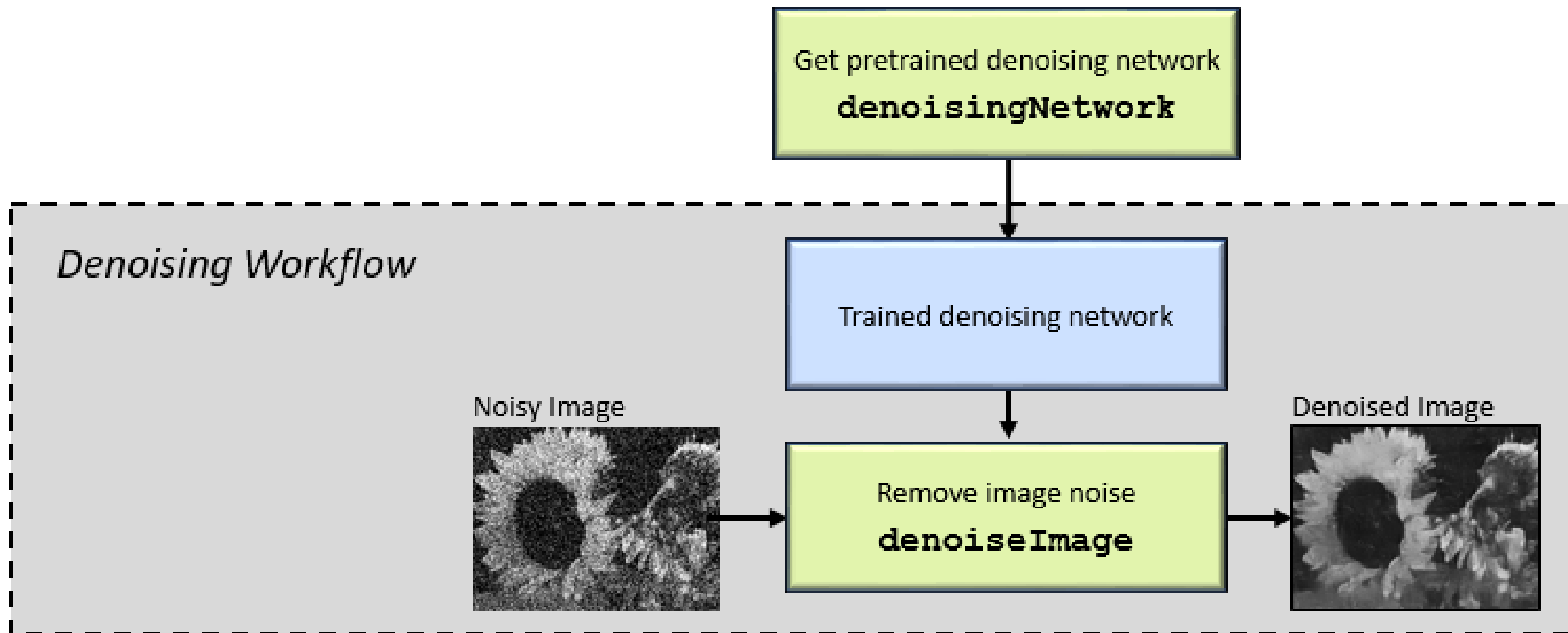
Image Segmentation and Analysis
Region analysis, texture analysis, pixel and image statistics

Deep Learning for Image Processing

Apply Denoising Neural Networks

- Built-in pretrained **DnCNN network** to remove Gaussian noise.

Train Denoising Neural Networks

https://www.mathworks.com/help/images/train-and-apply-denoising-neural-networks.html
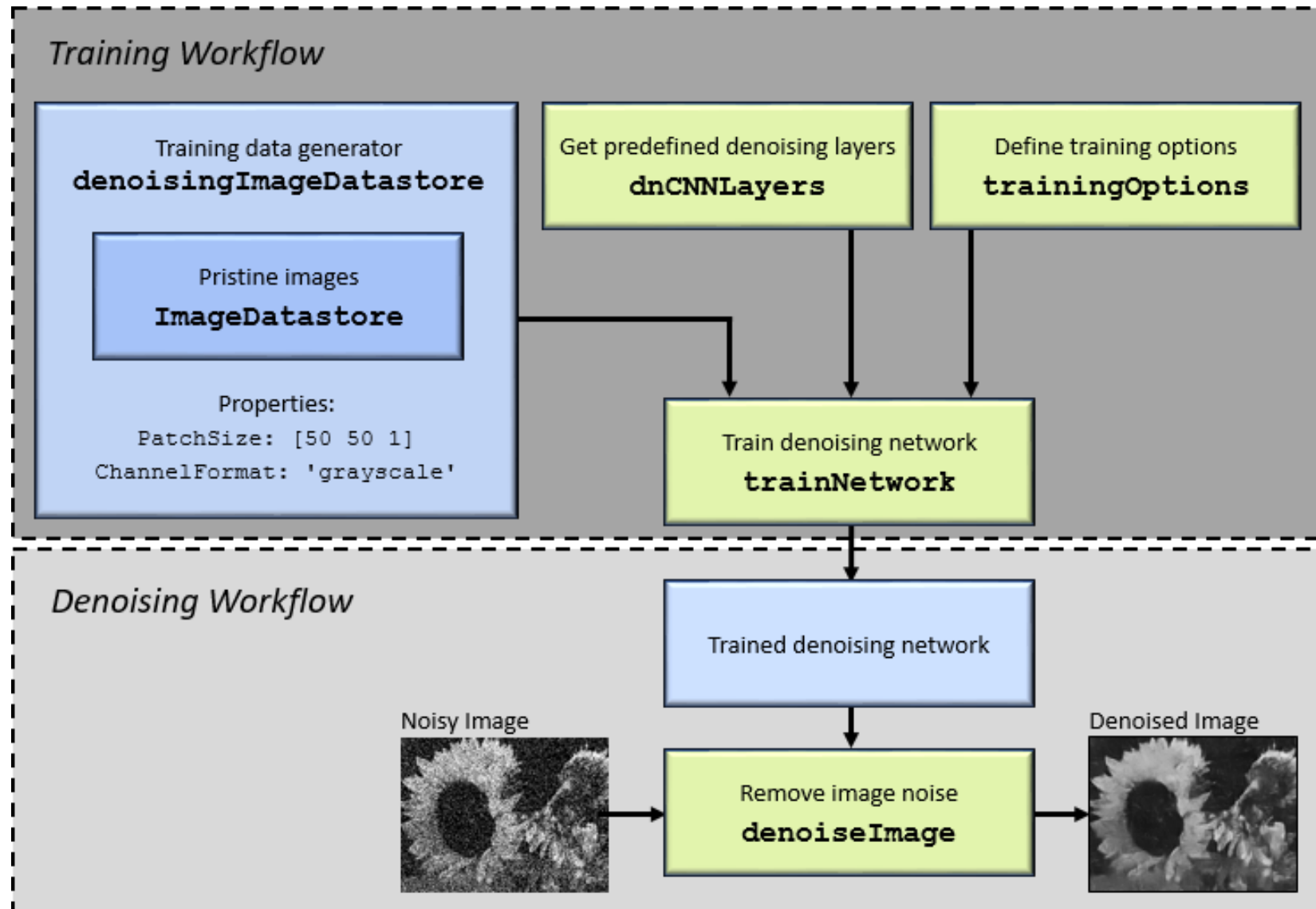
Image Super-Resolution – (1)

- Very-Deep Super-Resolution (VDSR) neural network.
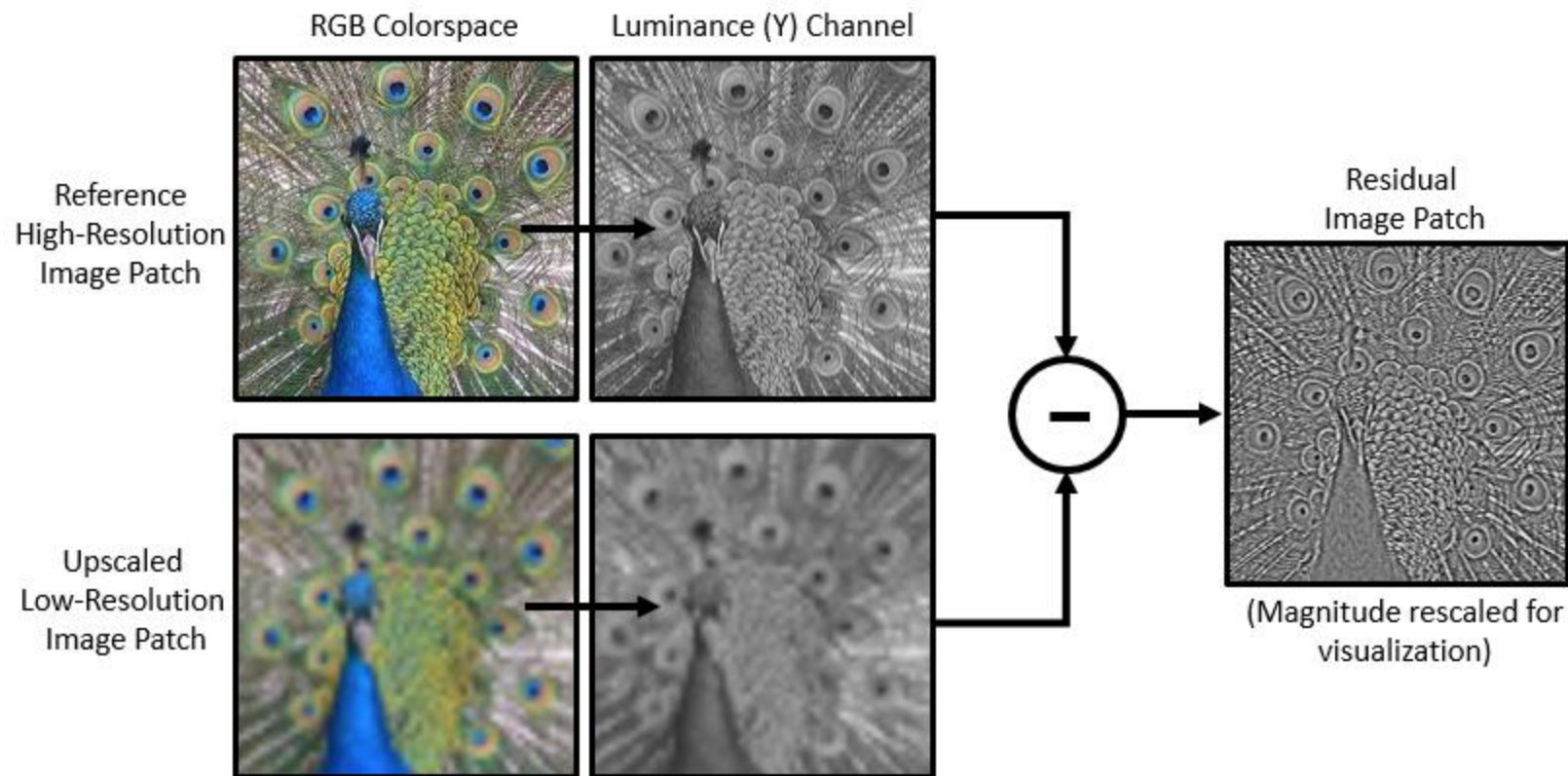- Estimate a high-resolution image from a single low-resolution image.

Image Super-Resolution – (2)

High-Resolution Results Using Bicubic Interpolation (Left) vs. VDSR (Right)

https://www.mathworks.com/help/images/single-image-super-resolution-using-deep-learning.html

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Using Deep Learning to Reduce Radiation Exposure Risk in CT Imaging

By Dr. Ryohei Nakayama, Ritsumeikar

Because they produce 3D images of o
significantly greater diagnostic value th
exposure to potentially harmful radiatio
together by computer software. As a re
7 milliseverts (mSv), 350 times higher
risk; guidelines limit the radiation dose

Medical researchers want to limit radia
approach is the use of ultra-low-dose (
principal drawback of ultra-low-dose C
for physicians to see organs, fat, and i
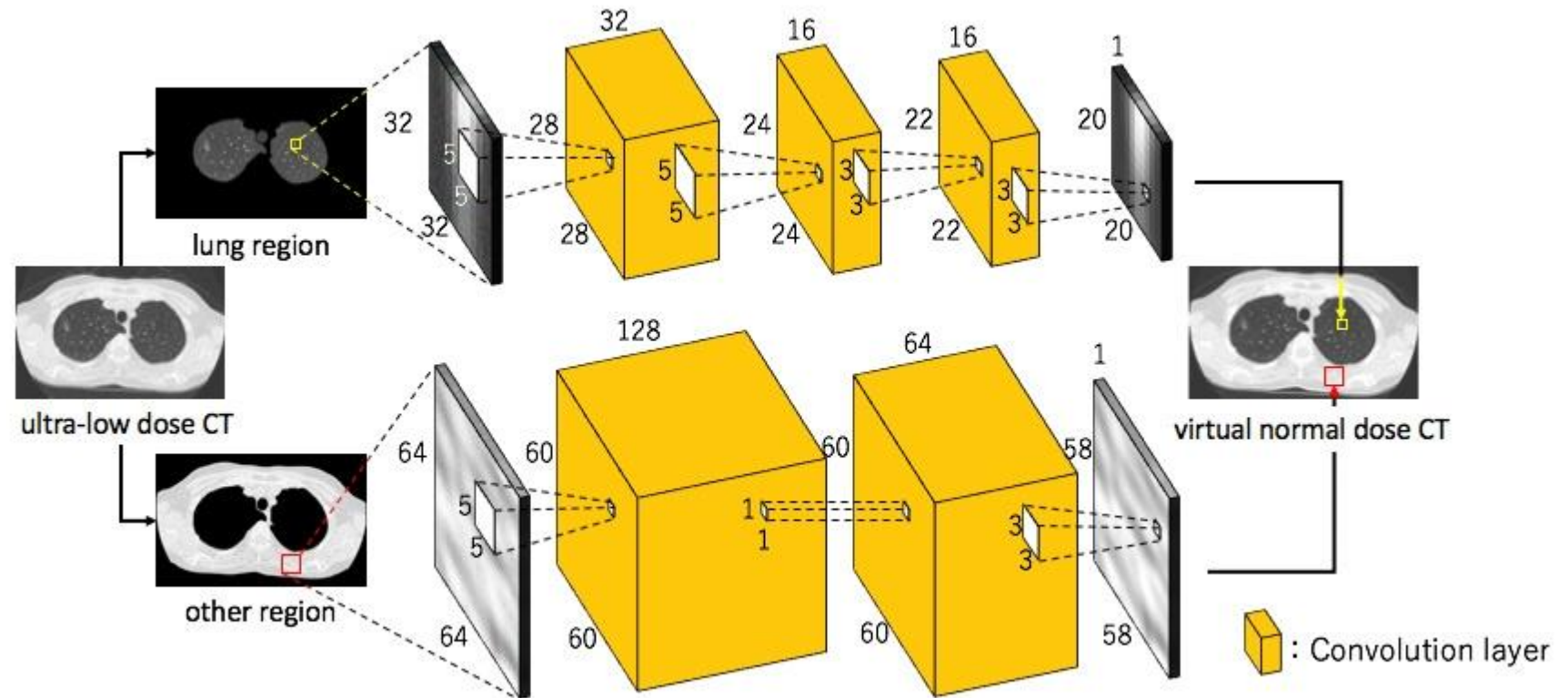
Agenda

- New Features in Image Processing

  – 3-D Image Processing

  – Deep Learning for Image Processing

- **Deep Learning for Computer Vision**

- Deep Learning Network Deployment

Deep Learning is a Neural Network

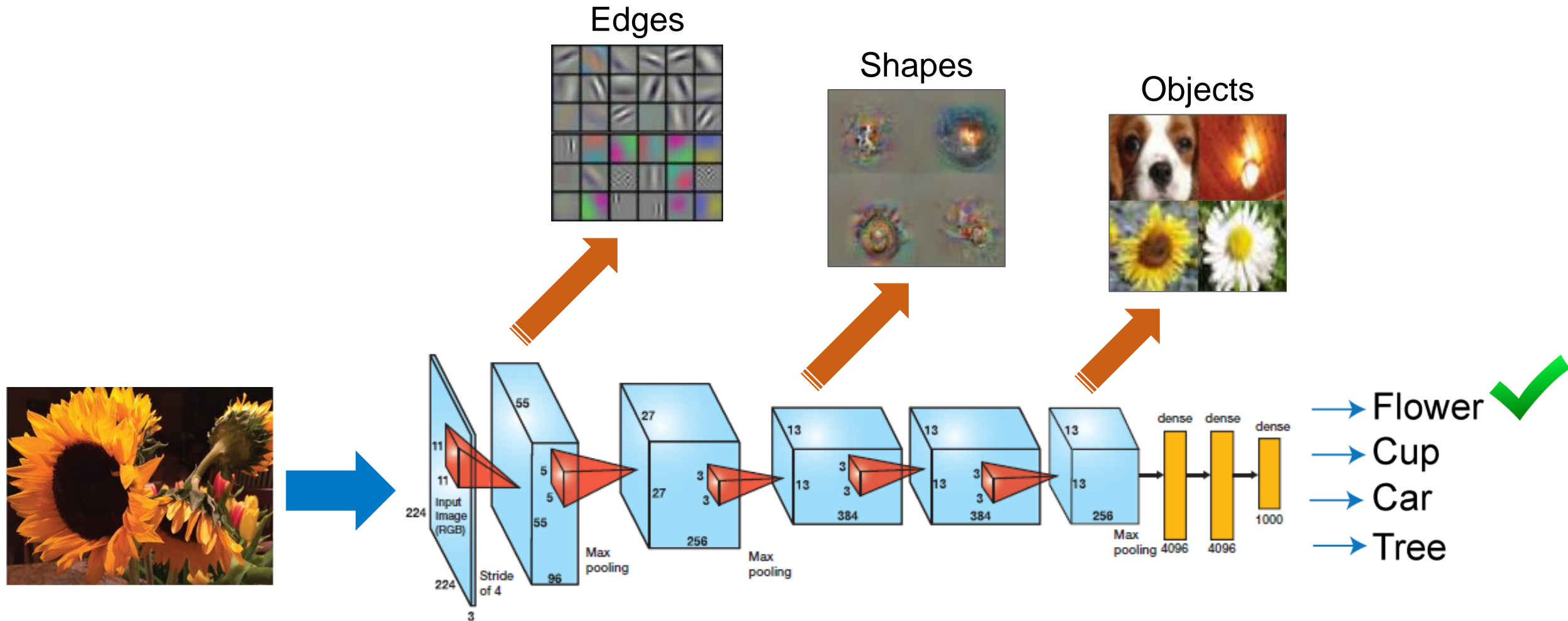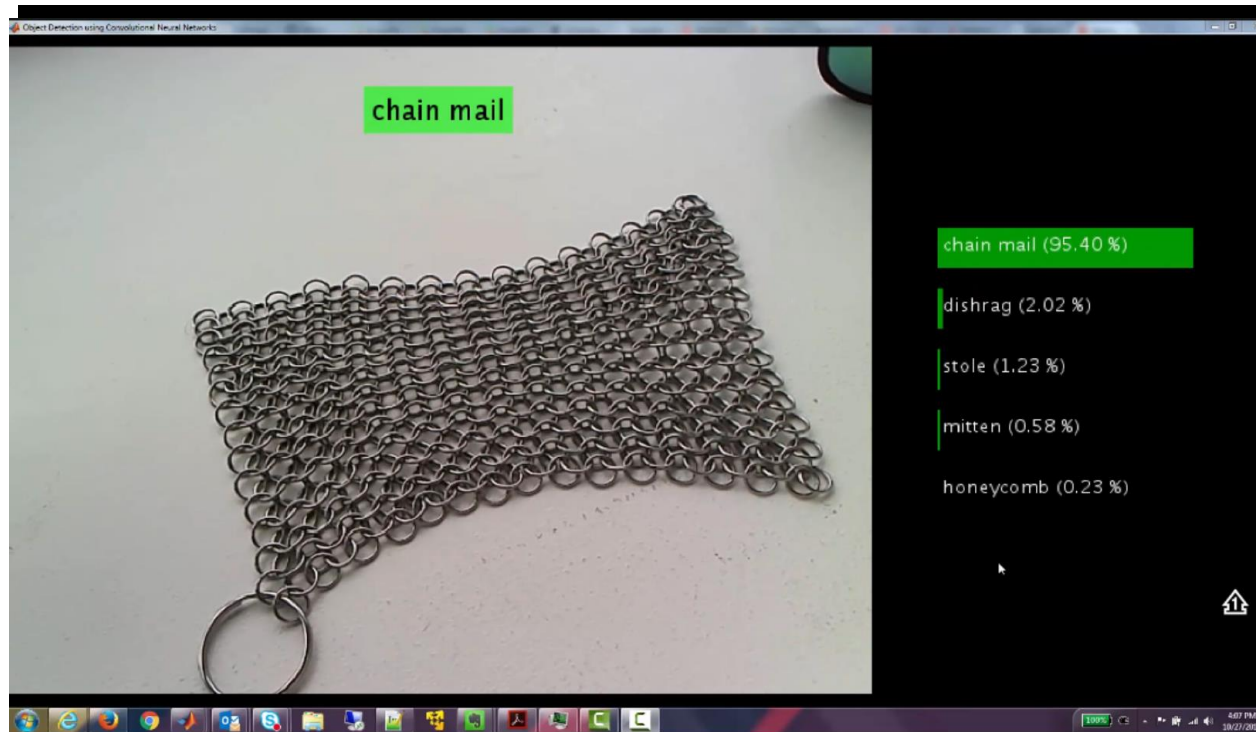Inspired by the structure and function of the brain

Edges

Shapes

Objects

Image Classification using Deep Learning


```matlab
camera = webcam; % Connect to the camera
nnet = alexnet;  % Load the neural net

while true
    picture = camera.snapshot;                % Take a picture
    picture = imresize(picture,[227,227]);    % Resize the picture

    label = classify(nnet, picture);          % Classify the picture

    image(picture);      % Show the picture
    title(char(label));  % Show the label
    drawnow;
end
```

|	
Training (GPU)	Millions of images from 1000 different categories (AlexNet)
Prediction	Real-time object recognition using a webcam connected to a laptop

MATLAB Integrates with Open Source Frameworks

- ▪ **Pretrained Models***
  - AlexNet
  - VGG-16
  - VGG-19
  - GoogLeNet
  - InceptionV3
  - ResNet18
  - ResNet50
  - ResNet101
 - Inception-ResNet-v2
  - SqueezeNet
  - DenseNet-201

  …

  * single line of code to access model

- ▪ **Import Models from Frameworks**
  - Caffe Model Importer
  - TensorFlow-Keras Model Importer

- ▪ **Converter for ONNX Model Format**

AlexNet	**VGG-16**	**ResNet**
PRETRAINED MODEL	PRETRAINED MODEL	PRETRAINED MODEL
Caffe	**GoogLeNet**	**TensorFlow/Keras**
MODELS	PRETRAINED MODEL	MODELS
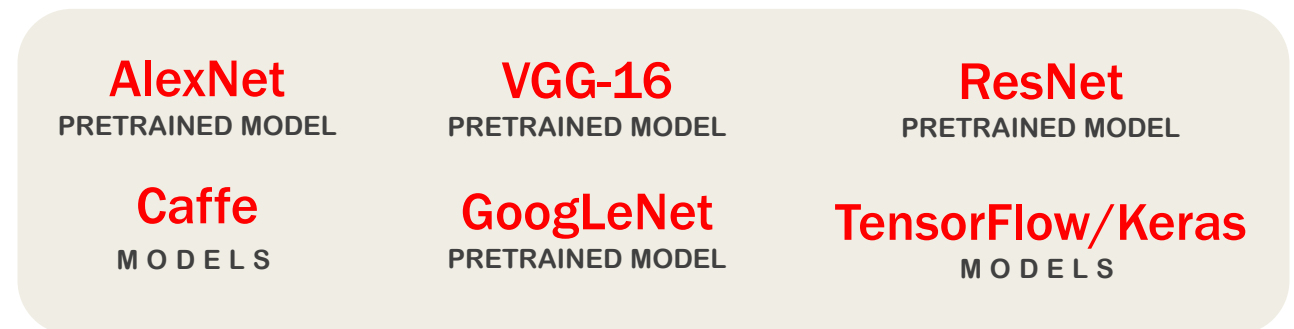
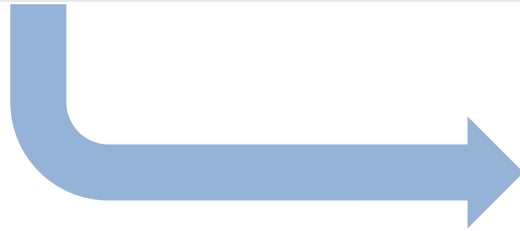# ONNX is an open format to represent deep learning models
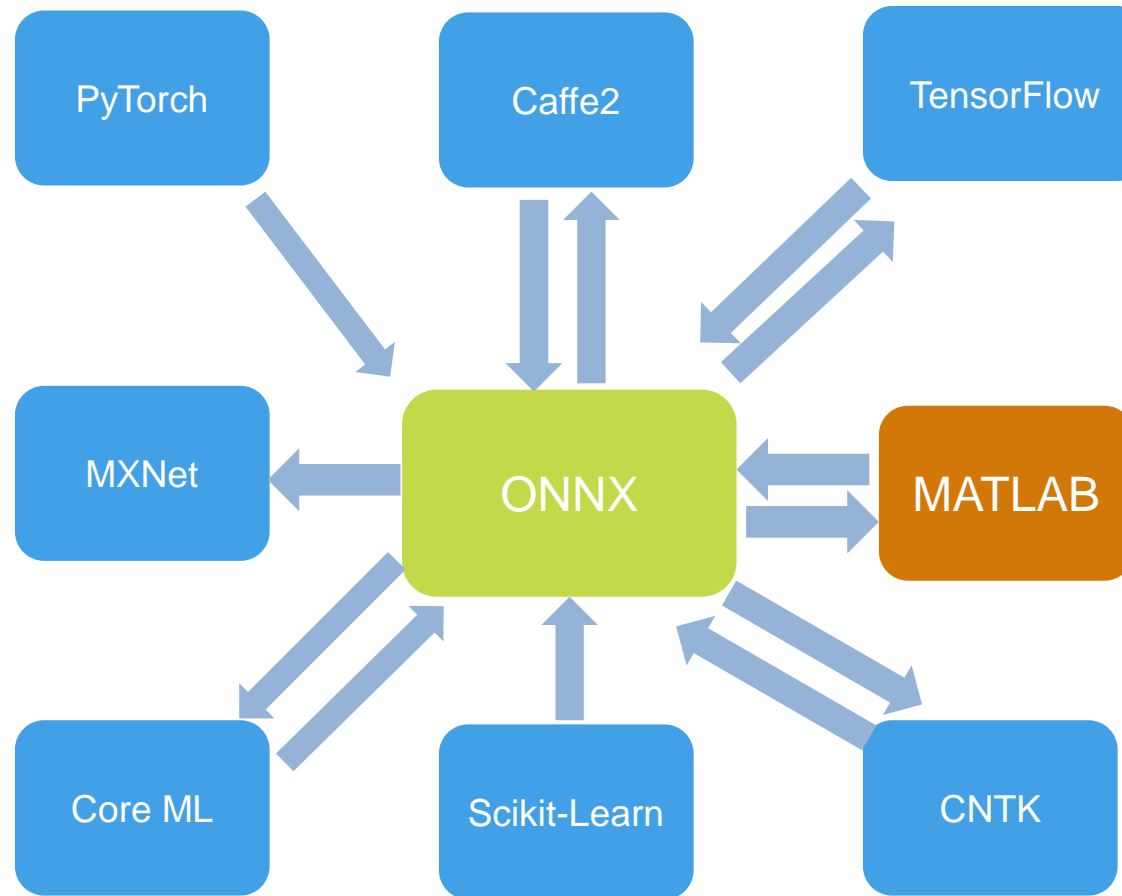
ONNX = Open Neural Network Exchange Format

ONNX Converter

Import from ONNX format

```
modelfile = 'cifarResNet.onnx';
classes = ["airplane" "automobile" "bir
net = importONNXNetwork(modelfile,'Outp
analyzeNetwork(net)
```

Export to ONNX format

```
filename = 'fishdetector.onnx';
exportONNXNetwork(net,filename)
```

Deep Learning Demo
Image Classification

Transfer Learning
Access Reference Models in MATLAB

Transfer Learning

Images →

Labels →

Load Reference Network

Modify Network Structure

Learn New Weights

→ New Classifier
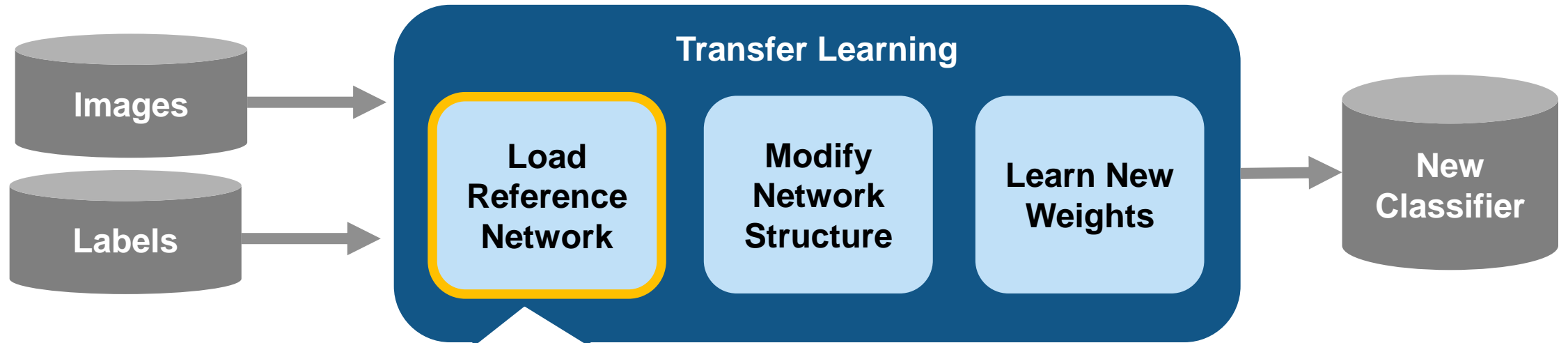
Easily Load Reference Networks

Access Models with 1-line of MATLAB Code

```
Net1 = alexnet
Net2 = vgg16
Net3 = vgg19
```

Transfer Learning
Modify Network Structure
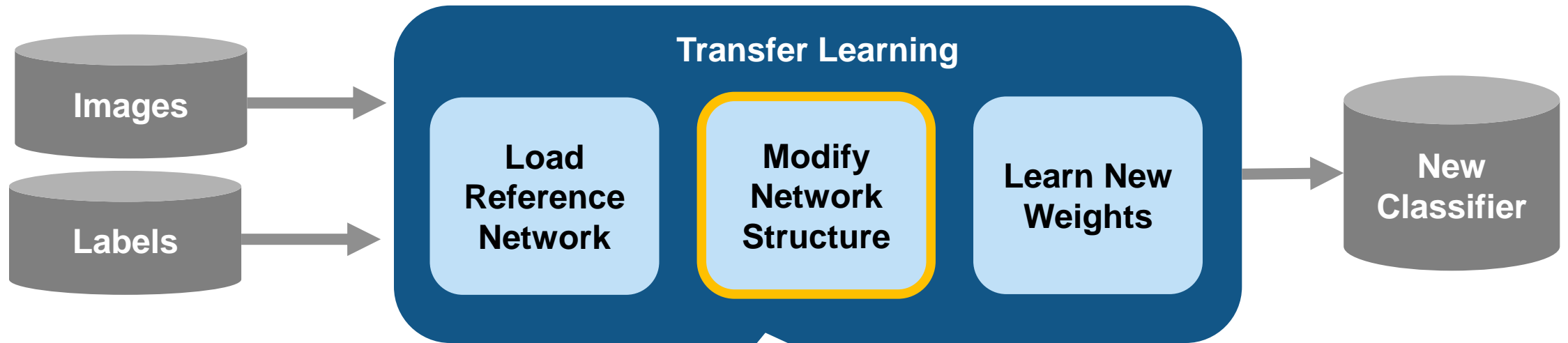
Simple MATLAB API to modify layers:
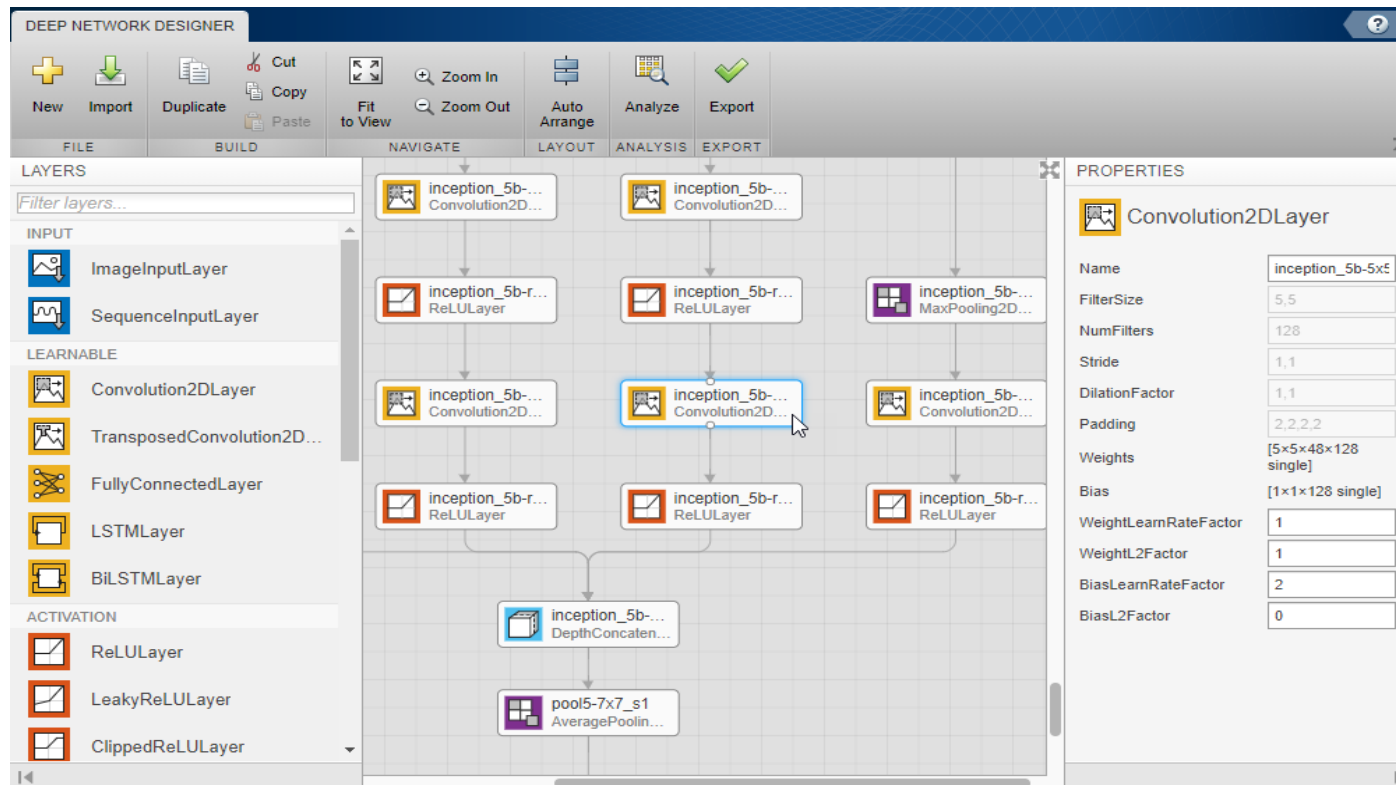
```
layers(23) = fullyConnectedLayer(5, 'Name','fc8');
layers(25) = classificationLayer('Name','VehicleClassifier')
```

Deep Network Designer App

- Graphically design and modify networks
- Check for errors in network architectures

Design deep networks

`>> deepNetworkDesigner`
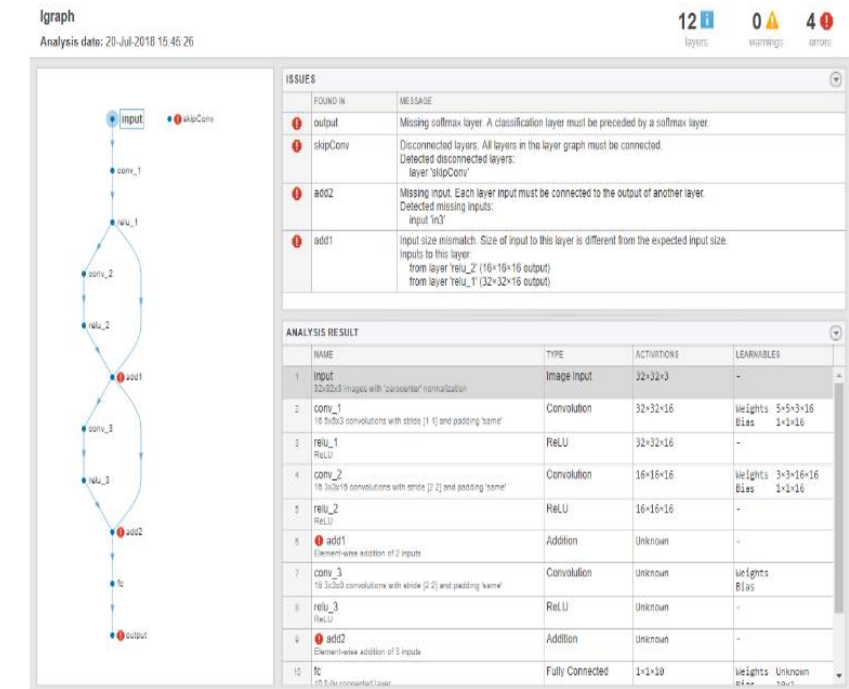
Check for errors

Transfer Learning
Training Network

Images → | Transfer Learning | → New Classifier

Labels →

Transfer Learning

| Load Reference Network | Modify Network Structure | Learn New Weights |
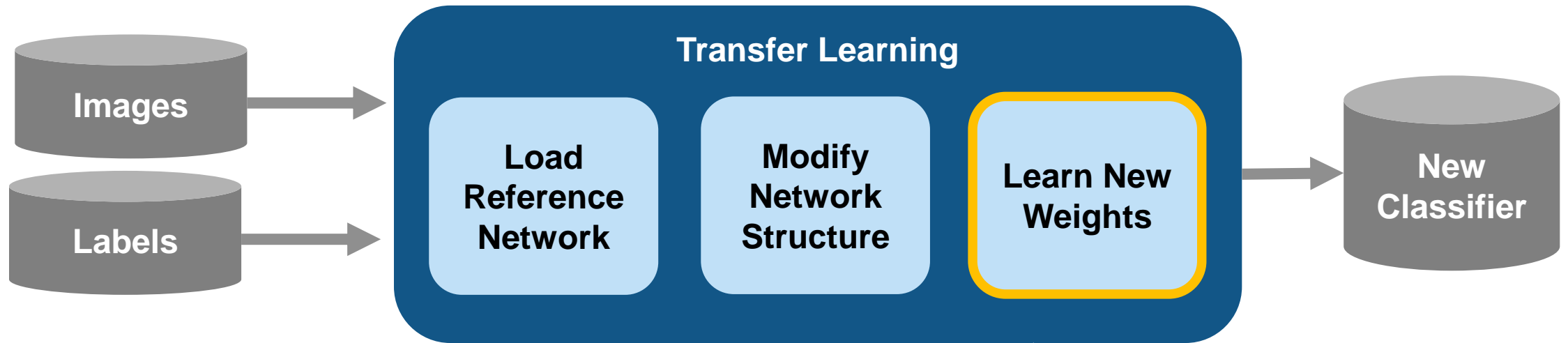
Train Any Network
`trainNetwork(datastore, layers, options)`
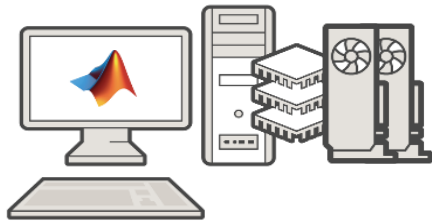
Deep Learning on CPU, GPU, Multi-GPU and Clusters

HOW TO TARGET?

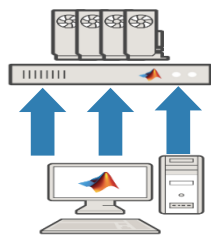Single CPU

Single CPU
Single GPU

```
opts = trainingOptions('sgdm', ...
    'MaxEpochs', 100, ...
    'MiniBatchSize', 250, ...
    'InitialLearnRate', 0.00005, ...
'ExecutionEnvironment', 'auto' );
```


Single CPU, Multiple GPUs

```
opts = trainingOptions('sgdm', ...
    'MaxEpochs', 100, ...
    'MiniBatchSize', 250, ...
    'InitialLearnRate', 0.00005, ...
'ExecutionEnvironment', 'multi-gpu' );
```


On-prem server with GPUs
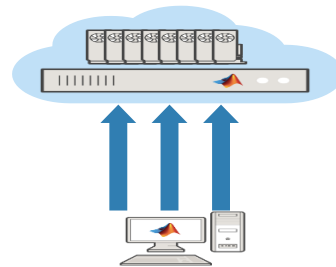
Cloud GPUs (AWS)

```
opts = trainingOptions('sgdm', ...
    'MaxEpochs', 100, ...
    'MiniBatchSize', 250, ...
    'InitialLearnRate', 0.00005, ...
'ExecutionEnvironment', 'parallel' );
```

Object Detection

Original Image

ROI detection
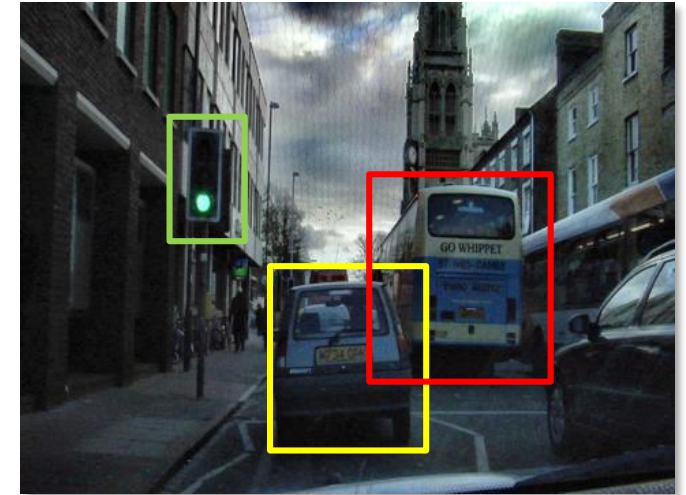
Pixel classification

Semantic Segmentation

CamVid Dataset
1. Segmentation and Recognition Using Structure from Motion Point Clouds, ECCV 2008
2. Semantic Object Classes in Video: A High-Definition Ground Truth Database ,Pattern Recognition Letters

Ground truth Labeling

"How do I *label* my data?"

New App for Ground Truth Labeling

Label pixels and regions for semantic segmentation
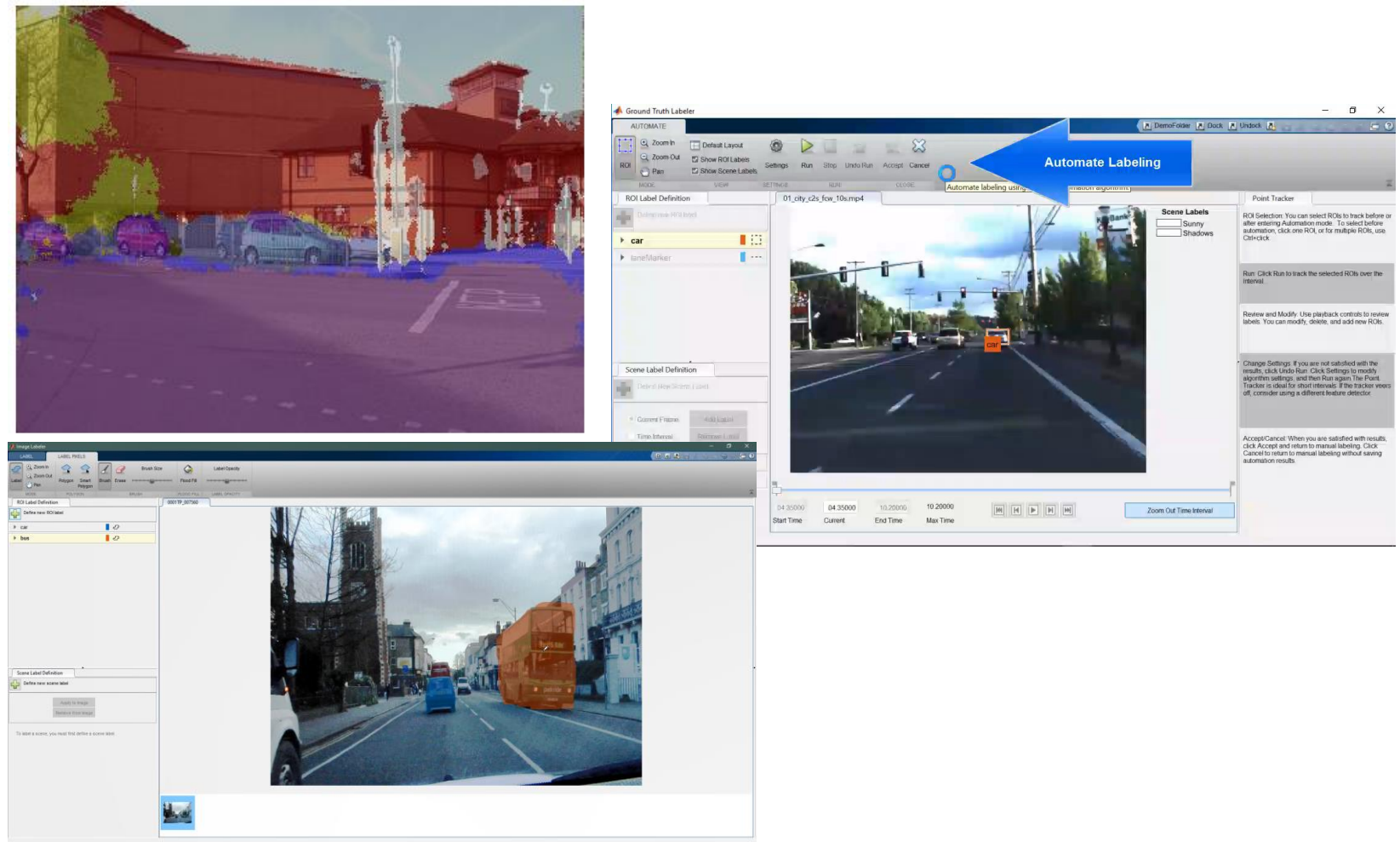
Application for Semantic Segmentation
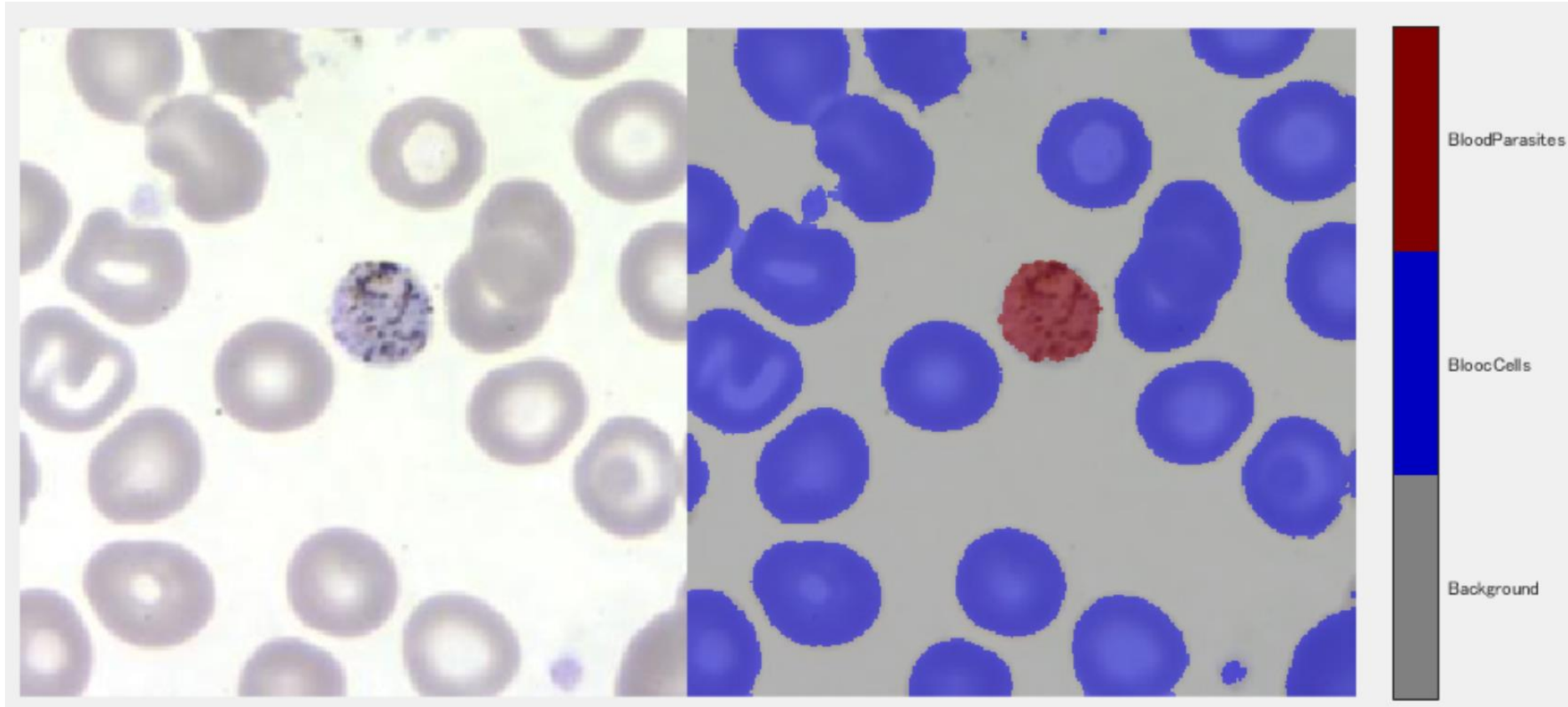
[Medical Image Segmentation Using SegNet](#)

Agenda

- New Features in Image Processing

  - 3-D Image Processing

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- Deep Learning for Computer Vision

- **Deep Learning Network Deployment**

MATLAB is Fast for Deployment

- Target a GPU for optimal performance

- NVIDIA GPUs use CUDA code

- We only have MATLAB code.

  Can we translate this?
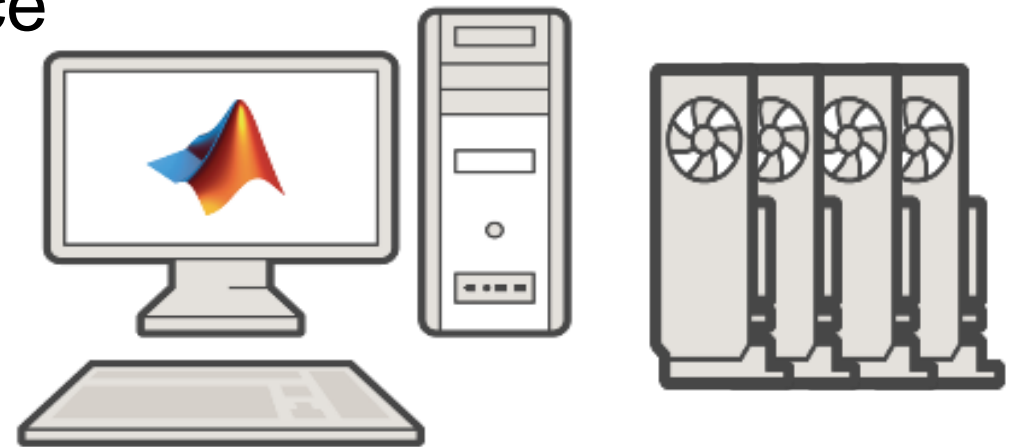
GPU Coder

- Automatically generates **CUDA** Code from MATLAB Code
  - can be used on NVIDIA GPUs

- CUDA extends C/C++ code with constructs for parallel computing

How to Use GPU Coder? Workflow to Embedded Tegra GPU

MATLAB algorithm
(functional reference)

GPU Coder

Build type

Call CUDA from MATLAB directly
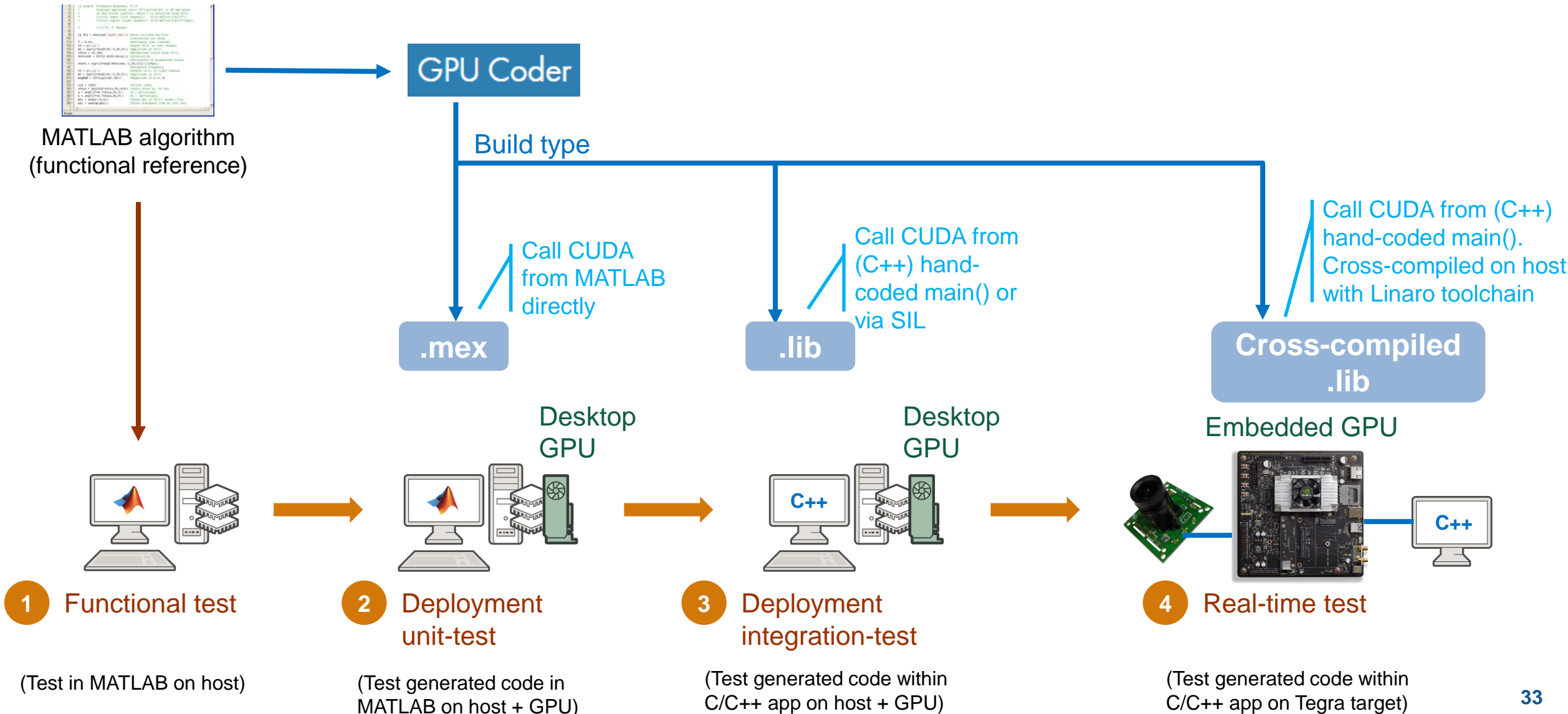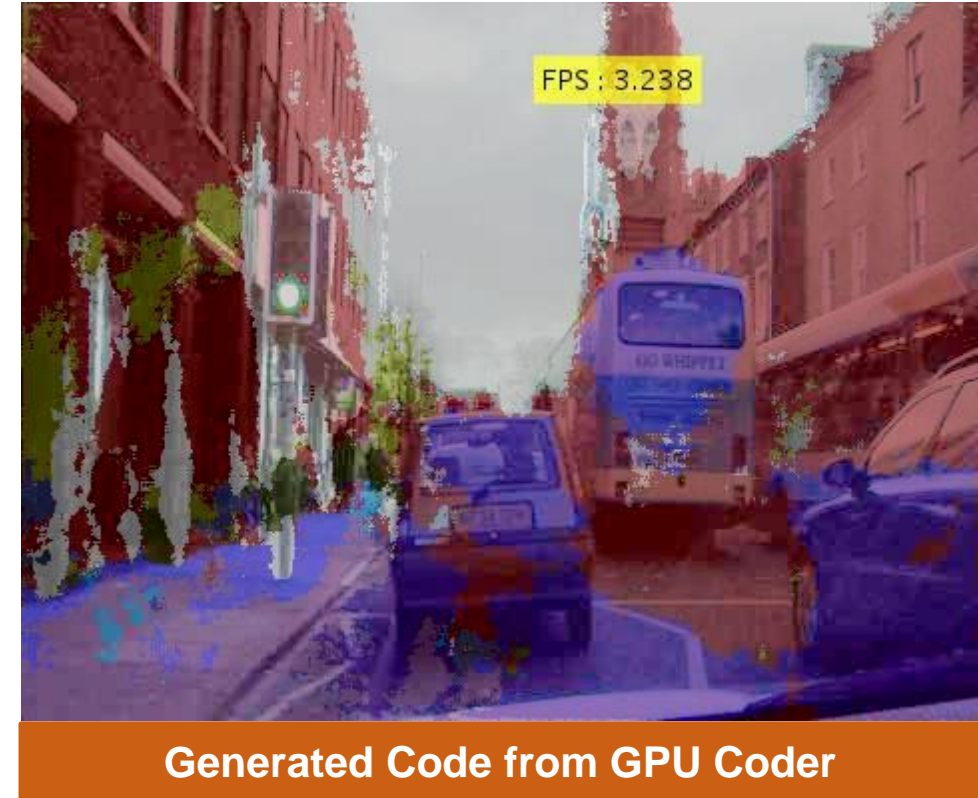
Call CUDA from (C++) hand-coded main() or via SIL

Call CUDA from (C++) hand-coded main(). Cross-compiled on host with Linaro toolchain

.mex

.lib

Cross-compiled .lib

Desktop GPU

Desktop GPU

Embedded GPU

C++

C++

1 Functional test

2 Deployment unit-test

3 Deployment integration-test

4 Real-time test

(Test in MATLAB on host)

(Test generated code in MATLAB on host + GPU)

(Test generated code within C/C++ app on host + GPU)

(Test generated code within C/C++ app on Tegra target)

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GPU Coder Performance

Running in MATLAB

FPS : 0.012235

Generated Code from GPU Coder

FPS : 3.238

Prediction Performance: Fast with GPU Coder

Images/Sec

Prediction (V100 GPU)

AlexNet   **ResNet-50**   **VGG-16**
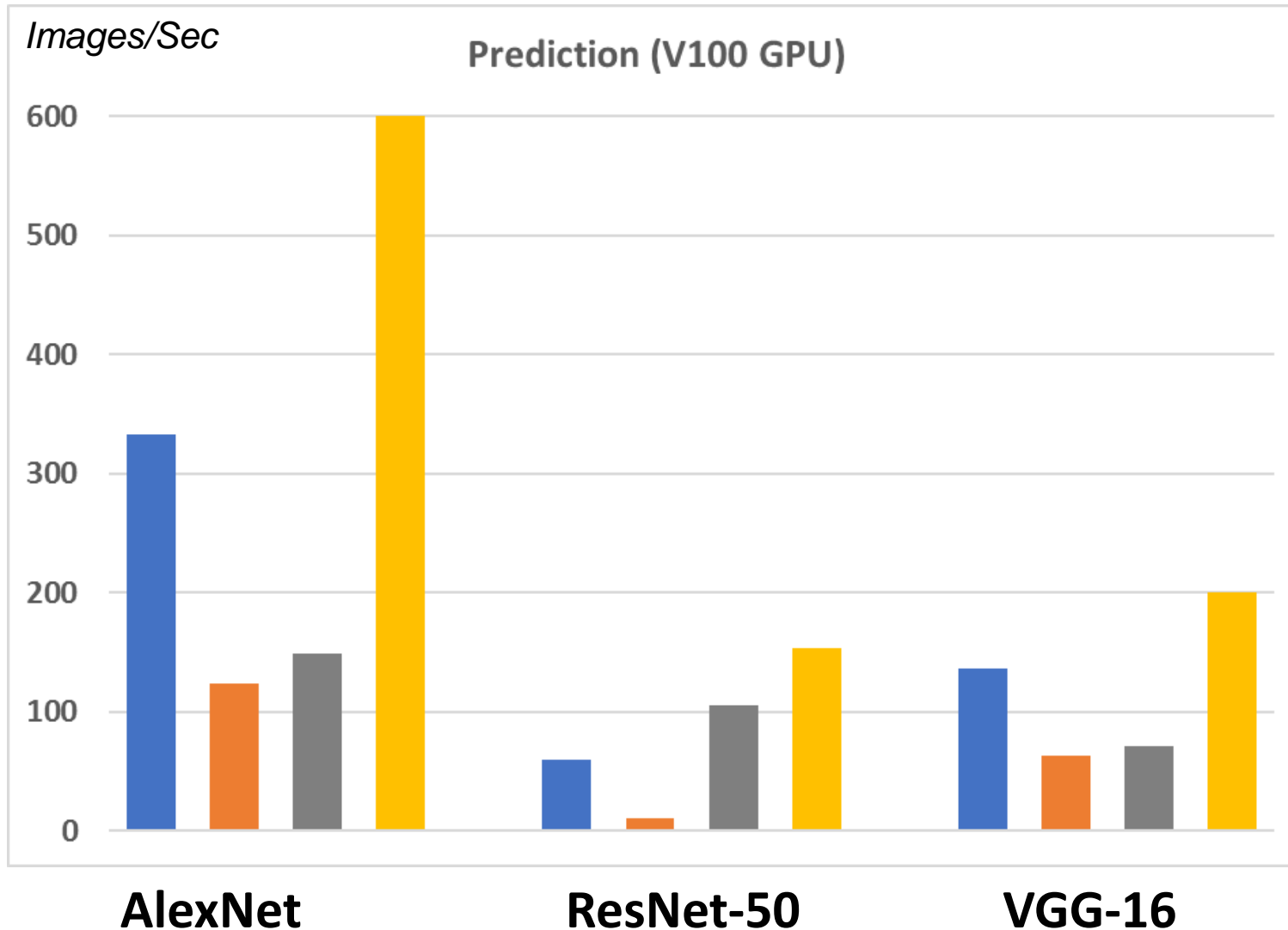
Why is GPU Coder so fast?

- Analyzes and optimizes network architecture
- Invested 15 years in code generation

TensorFlow

MATLAB

MXNet

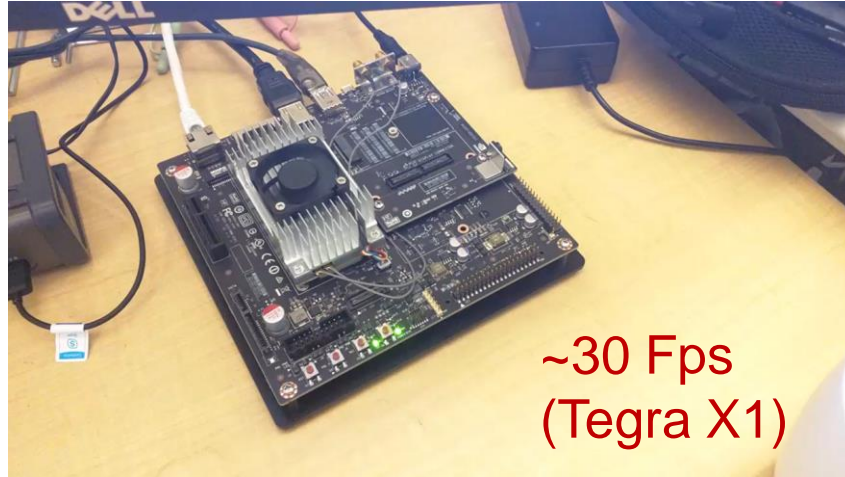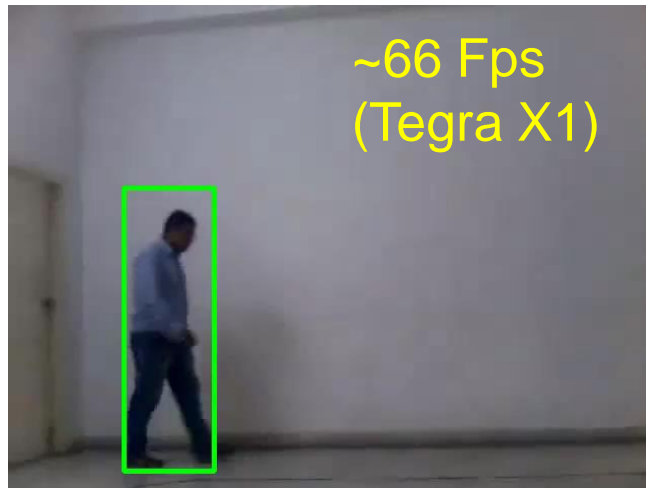**GPU Coder**

Networks deployed with GPU Coder

Alexnet

~30 Fps
(Tegra X1)

Vehicle
Detection

~20 Fps
(K40c)

People detection

~66 Fps
(Tegra X1)

Lane detection

~130 Fps
(K40c)

Thank you!