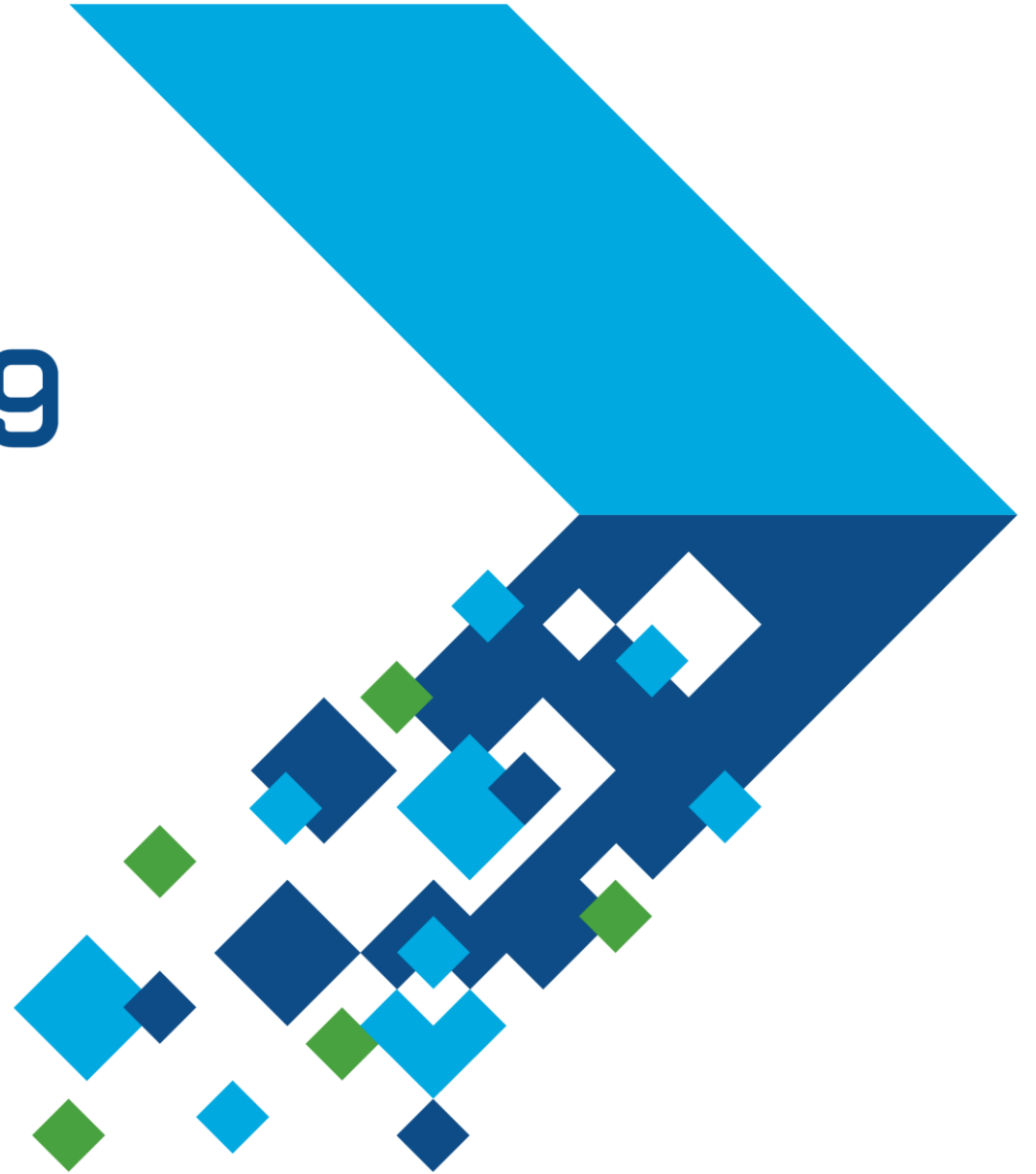


# MATLAB EXPO 2019

Deep Learning

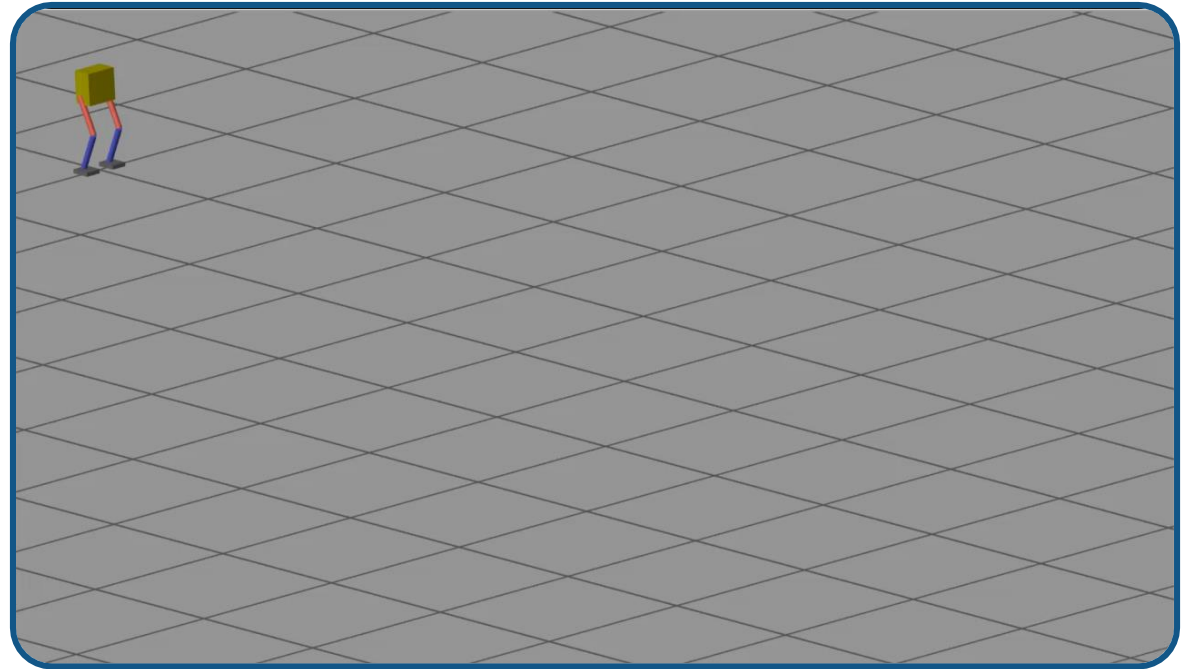
Dr. Yvonne Blum



# Why MATLAB for Artificial Intelligence?

# Artificial Intelligence

Development of computer systems to perform tasks that normally require human intelligence.



# A.I. Applications



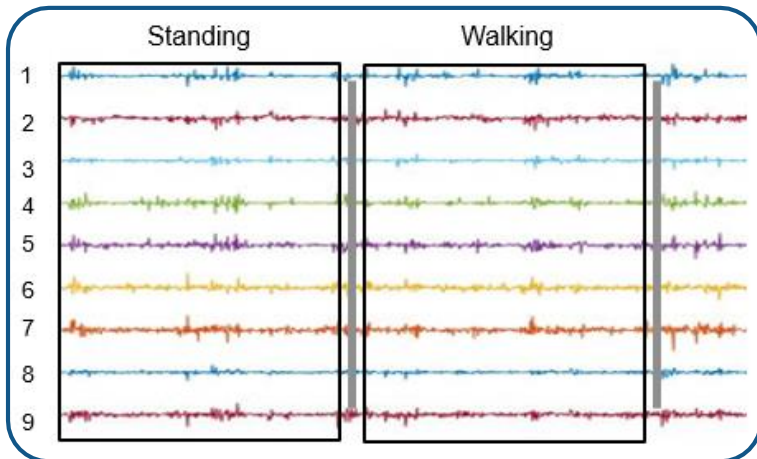
*Object Classification*



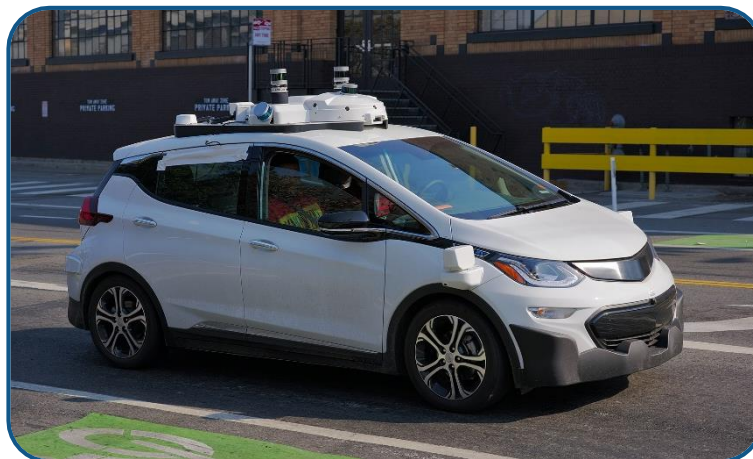
Speech Recognition



Predictive Maintenance



Signal Classification

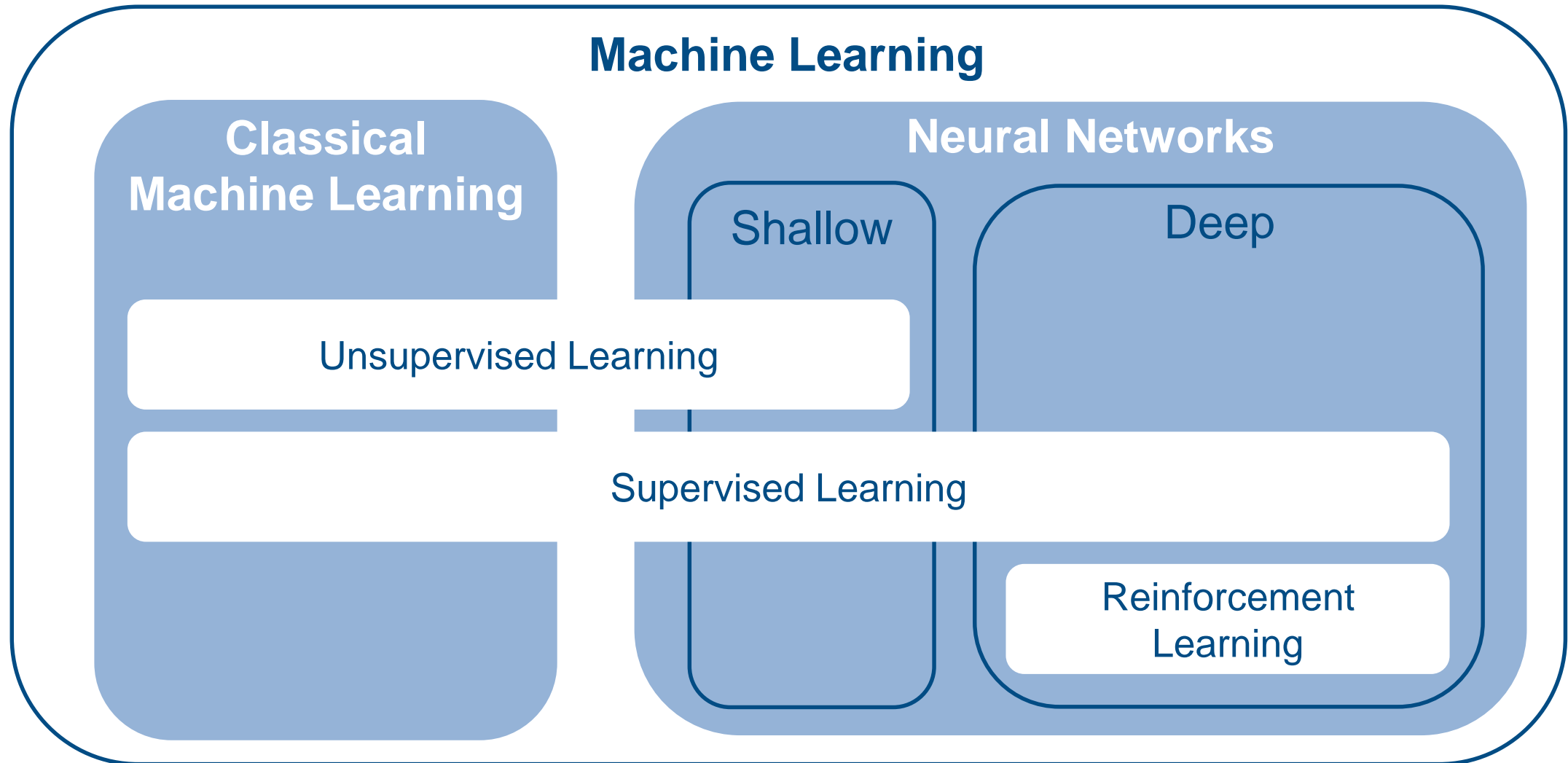


Automated Driving

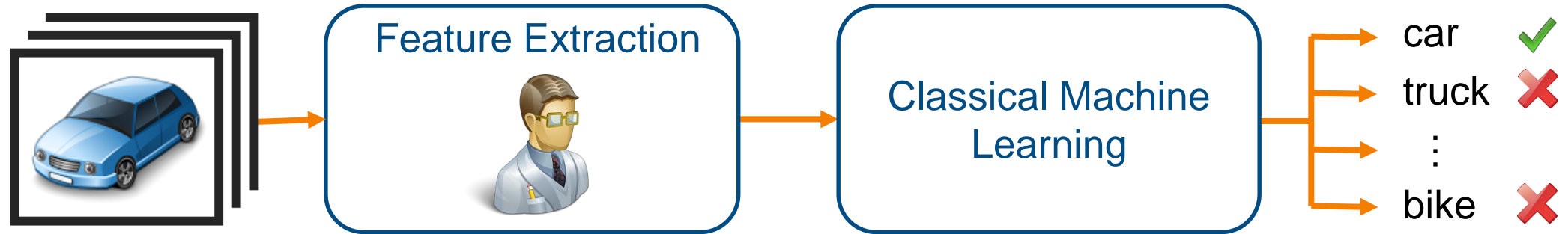


Stock Market Prediction

# What Is Machine Learning?

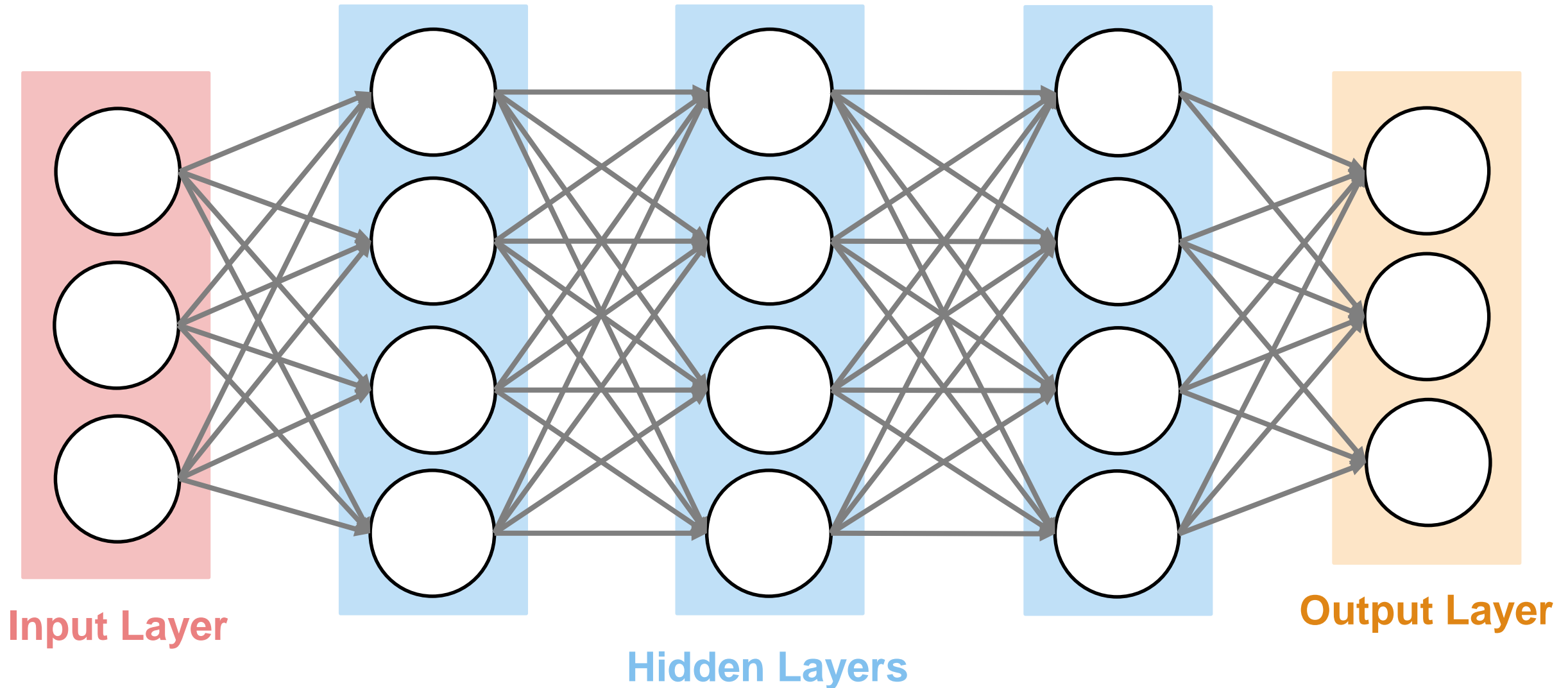


# What Is Deep Learning?



Deep Learning learns both features and tasks directly from the data.

# What Is a Neural Network?









# Deep Learning Workflow

## Prepare Data



Data access and preprocessing



Ground truth labeling

## Train Model



Model design,  
Hyperparameter tuning



Model exchange  
across frameworks



Hardware-  
accelerated training

## Deploy

Multiplatform code  
generation (CPU, GPU)



Edge deployment



Enterprise  
Deployment

# Why MATLAB for A.I. Tasks?

Increased productivity with interactive tools

Generate simulation data for complex models and systems

Ease of deployment and scaling to various platforms

---

Full A.I. workflows that cannot be easily replicated by other toolchains

# Why MATLAB for A.I. Tasks?

Increased productivity with interactive tools

Labeling

Network Design

Model  
Exchange

# Labeling

Labeling for deep learning is **repetitive,**  
**tedious,** and **time-consuming...**

but **necessary!**

# Labeling

Image Labeler

FILE MODE VIEW

+ New Session  
 Load  
 Save  
 Import Labels  
 Label  
 Zoom In  
 Zoom Out  
 Pan  
 Default Layout  
 Show Rectangle Labels  
 Show Scene Labels

Algorithm: ACF Vehicle Detector

- ACF Vehicle Detector  
Detect vehicles using Aggregate Channel Features (ACF).
- ACF People Detector  
Detect people using Aggregate Channel Features (ACF).
- Add Algorithm
- Refresh list

View Label Summary   Export Labels

ROI Label Definition

Define New ROI Label

- Car

Scene Label Definition

Define new scene label

Apply to Image

Remove from Image

To label a scene, you must first define a scene label.

highwayImage

# Labeling

Ground Truth Labeler

FILE: Load, Save, Import Labels  
 MODE: Label, Zoom In, Zoom Out, Pan  
 VIEW: Layout, Show ROI Labels, Show Scene Labels

ROI Label Definition: Car, Lane

Scene Label Definition: Define new scene label, Current Frame, Time Interval, Add Label, Remove Label

Algorithm: Select Algorithm

- ACF Vehicle Detector**  
Detect vehicles using Aggregate Channel Features (ACF).
- ACF People Detector**  
Detect people using Aggregate Channel Features (ACF).
- Point Tracker**  
Track one or more rectangle ROIs over short intervals using Kanade-Lucas-Tomasi (KLT) algorithm.
- Temporal Interpolator**  
Estimate ROIs in intermediate frames using interpolation of rectangle ROIs in key frames.

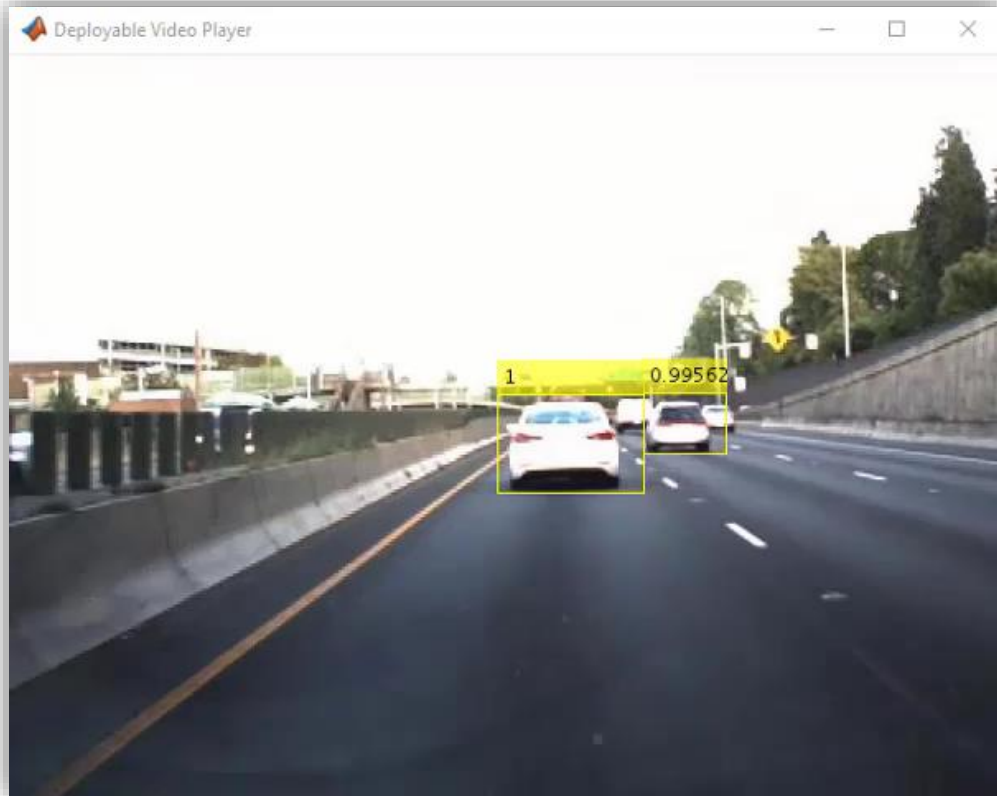
highway.mp4

00.00000 05.44818 54.50000 54.50000  
 Start Time Current End Time Max Time

Zoom In Time Interval



# Labeling



# Network Design

Deep Network Designer

DESIGNER

FILE BUILD NAVIGATE LAYOUT ANALYSIS EXPORT

Layer Library

INPUT

- imageInputLayer
- image3dInputLayer
- sequenceInputLayer
- roiInputLayer

CONVOLUTION AND FULLY CONNECTED

- convolution2dLayer
- convolution3dLayer
- groupedConvolution2dLayer
- transposedConv2dLayer
- transposedConv3dLayer
- fullyConnectedLayer

SEQUENCE

- lstmLayer

imageinput  
imageInputLayer

conv\_1  
convolution2dL...

batchnorm\_1  
batchNormaliza...

relu\_1  
reluLayer

maxpool\_1  
maxPooling2dL...

conv\_2  
convolution2dL...

PROPERTIES

Number of layers 15  
Number of connections 14  
Input type  
Output type

Deep Learning Network Analyzer

Network from Deep Network Designer  
Analysis date: 21-Jun-2019 14:40:19

15 layers 0 warnings 0 errors

ANALYSIS RESULT

	Name	Type	Activations	Learnables
1	imageinput 28x28x1 imag...	Image Input	28x28x1	-
2	conv_1 8 3x3x1 conv...	Convolution	28x28x8	Weights 3x3x1x8 Bias 1x1x8
3	batchnorm_1 Batch normali...	Batch Normalization	28x28x8	Offset 1x1x8 Scale 1x1x8
4	relu_1 ReLU	ReLU	28x28x8	-
5	maxpool_1 2x2 max pooli...	Max Pooling	14x14x8	-
6	conv_2 16 3x3x8 conv...	Convolution	14x14x16	Weights 3x3x8x16 Bias 1x1x16
7	batchnorm_2 Batch normali...	Batch Normalization	14x14x16	Offset 1x1x16 Scale 1x1x16
8	relu_2 ReLU	ReLU	14x14x16	-
9	maxpool_2 2x2 max pooli...	Max Pooling	7x7x16	-
10	conv_3 32 3x3x16 co...	Convolution	7x7x32	Weights 3x3x16x3 Bias 1x1x32
11	batchnorm_3 Batch normali...	Batch Normalization	7x7x32	Offset 1x1x32 Scale 1x1x32
12	relu_3 ReLU	ReLU	7x7x32	-

imageinput  
conv\_1  
batchnorm\_1  
relu\_1  
maxpool\_1  
batchnorm\_2  
relu\_2  
maxpool\_2  
conv\_3  
batchnorm\_3  
relu\_3  
fc  
softmax  
classoutput

# Pre-trained Models

Inception-v3

ResNet-101

VGG-16

Inception-  
ResNet-v2

ResNet-18

GoogLeNet

DenseNet-201

VGG-19

SqueezeNet

AlexNet

ResNet-50

## Import & Export Models Between Frameworks

Keras-Tensorflow  
Importer

Caffe Model  
Importer

ONNX Model  
Converter

# Why MATLAB for A.I. Tasks?

Increased productivity with interactive tools

Generate simulation data for complex models and systems

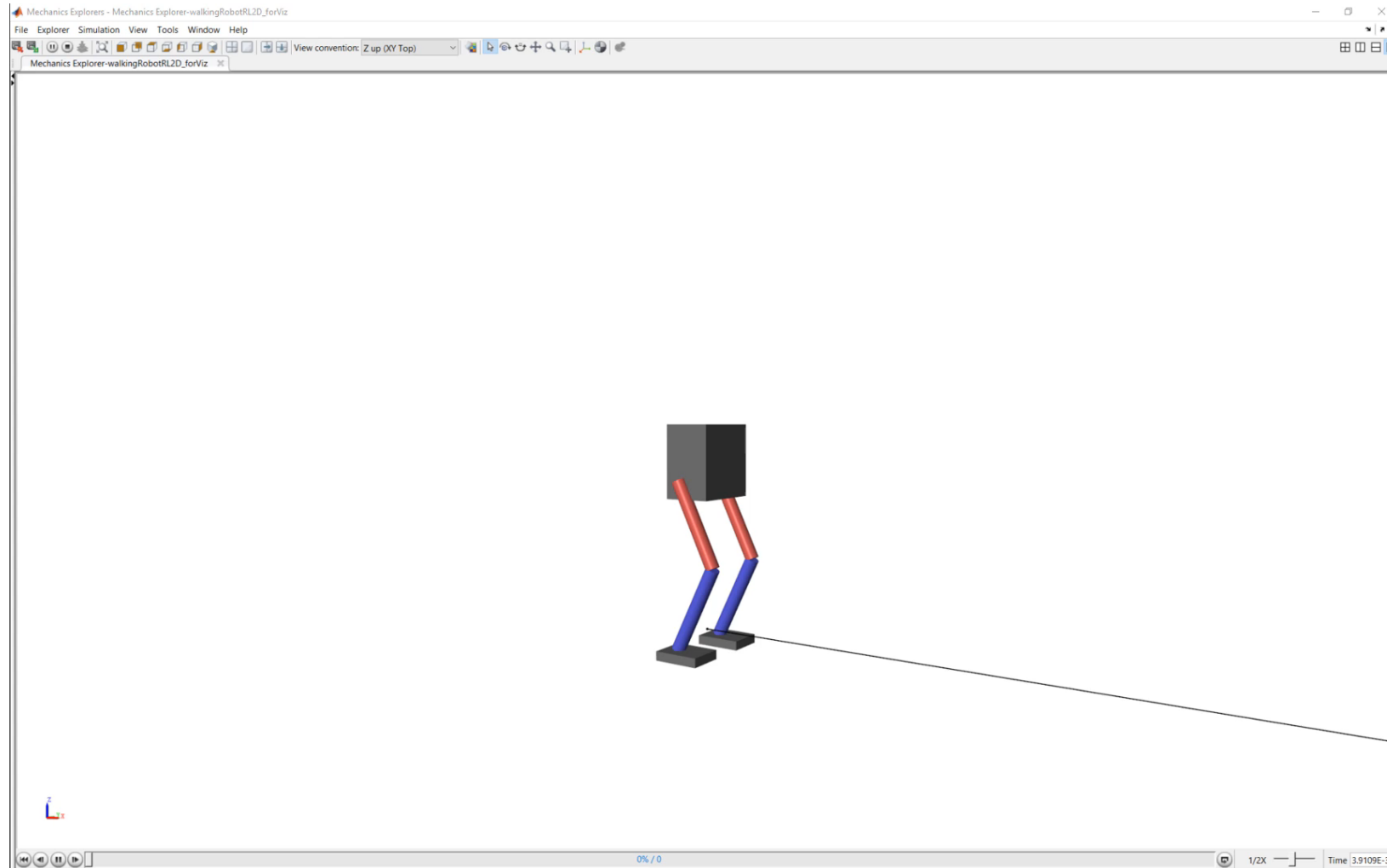
Ease of deployment and scaling to various platforms

# Why MATLAB for A.I. Tasks?

Generate simulation data for complex models and systems

Reinforcement  
Learning

# What Is Reinforcement Learning?

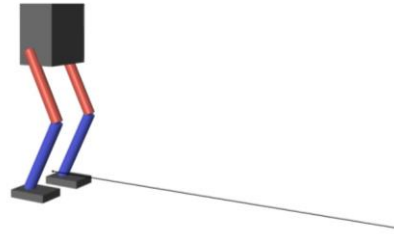




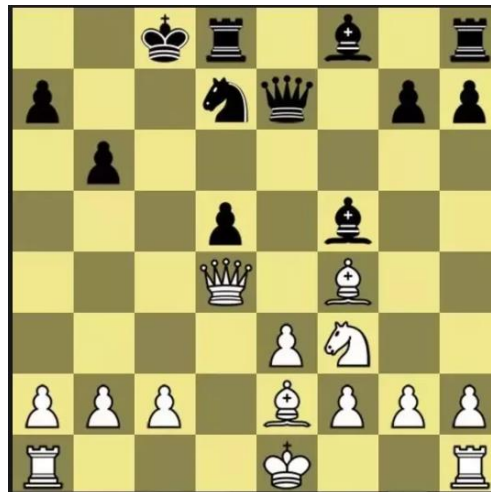
# Reinforcement Learning for Control and Decision Making



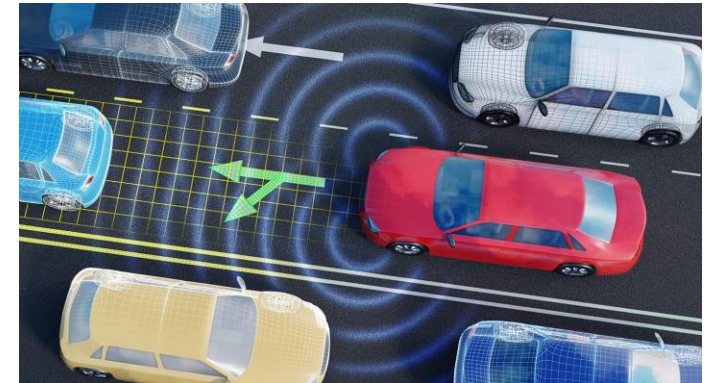
Controls



Robotics

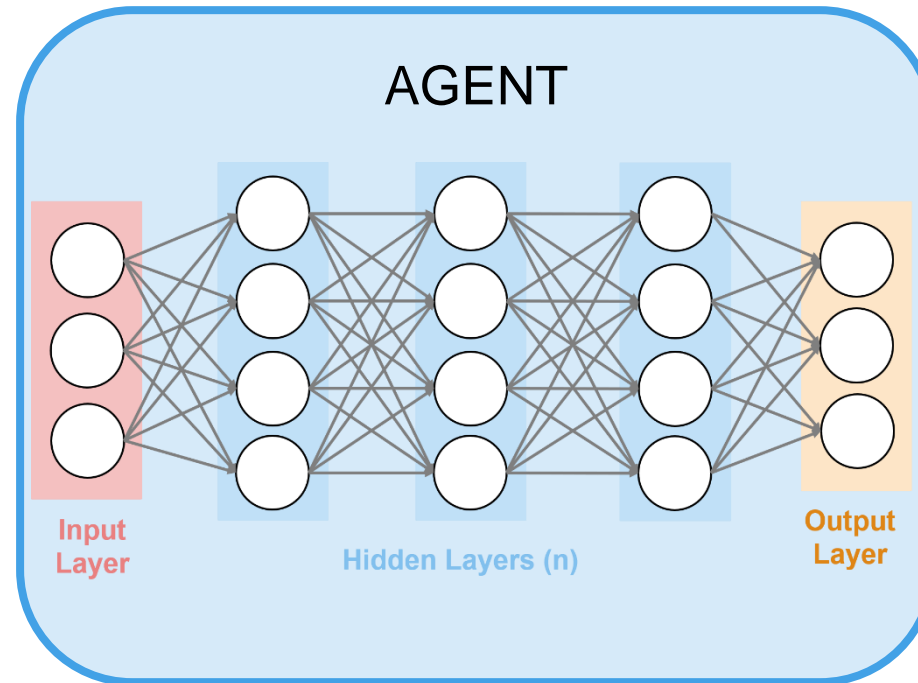
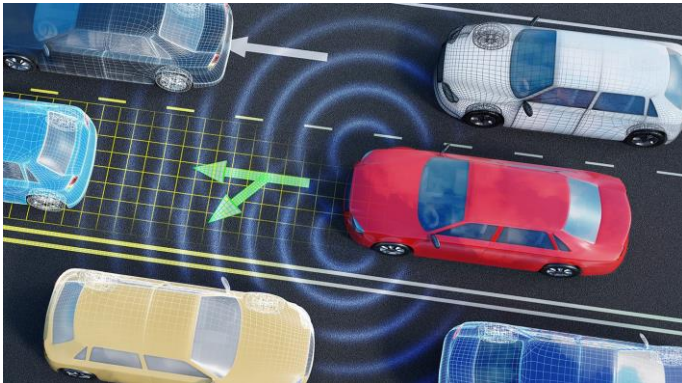


A.I. Gameplay



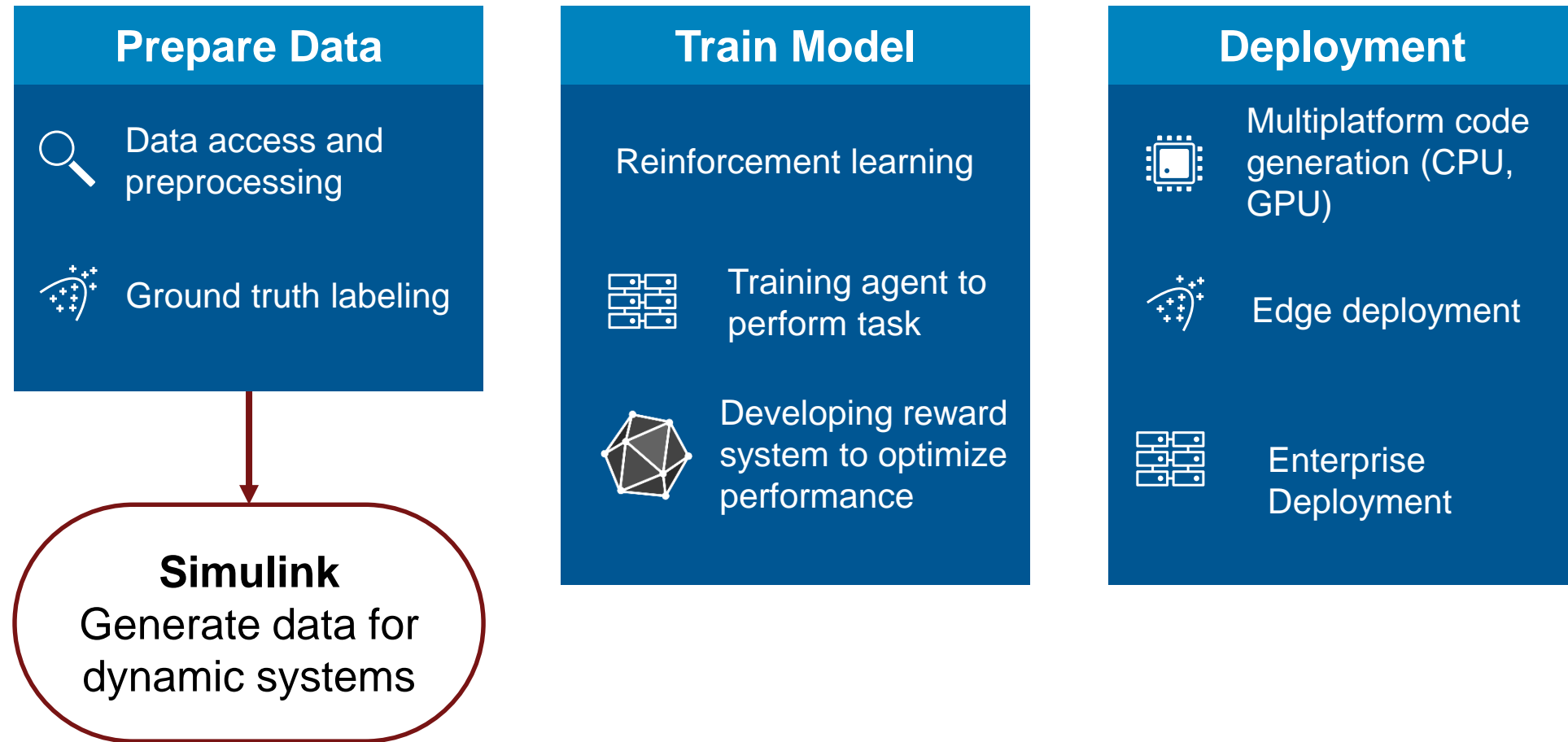
Autonomous driving

# Reinforcement Learning Utilizes Deep Neural Networks



- Turn left/right
- Brake
- Accelerate

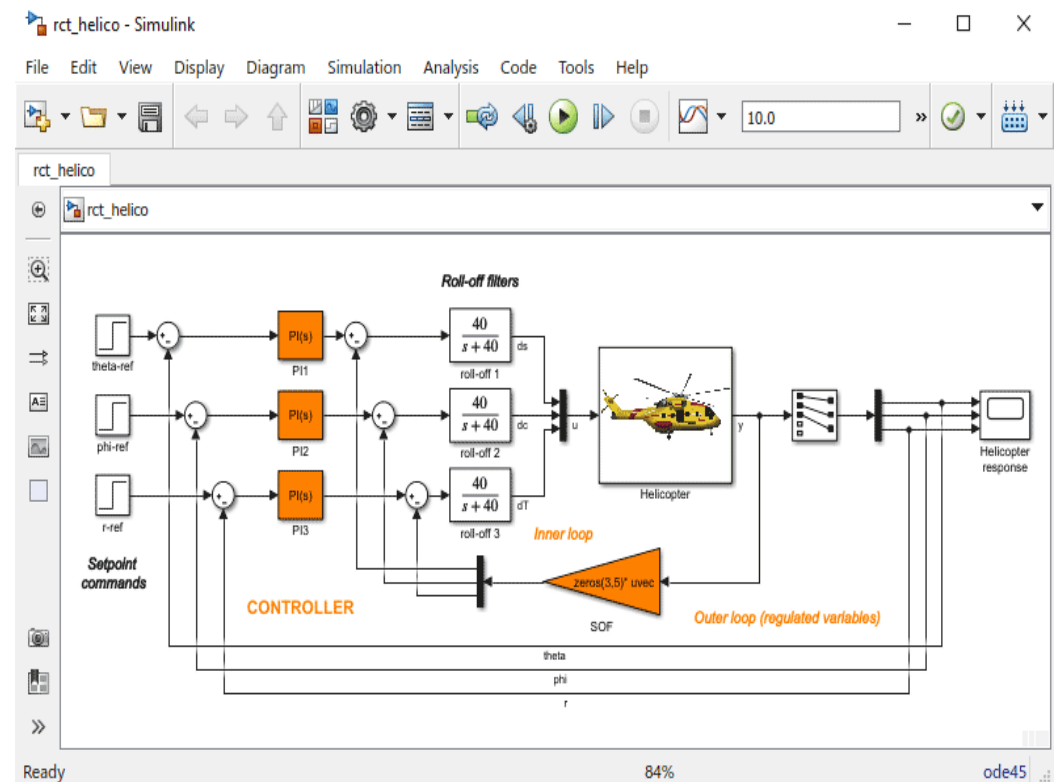
# Reinforcement Learning Workflow



# Why MATLAB and Simulink for Reinforcement Learning?

*Virtual models allow you to simulate conditions hard to emulate in the real world.*

- Decision making problems
  - Financial trading, calibration, etc.
- Controls-based problems
  - Lane-keep assist, adaptive cruise control, robotics, etc.



# Why MATLAB for A.I. Tasks?

Increased productivity with interactive tools

Generate simulation data for complex models and systems

Ease of deployment and scaling to various platforms

# Why MATLAB for A.I. Tasks?

Ease of deployment and scaling to various platforms

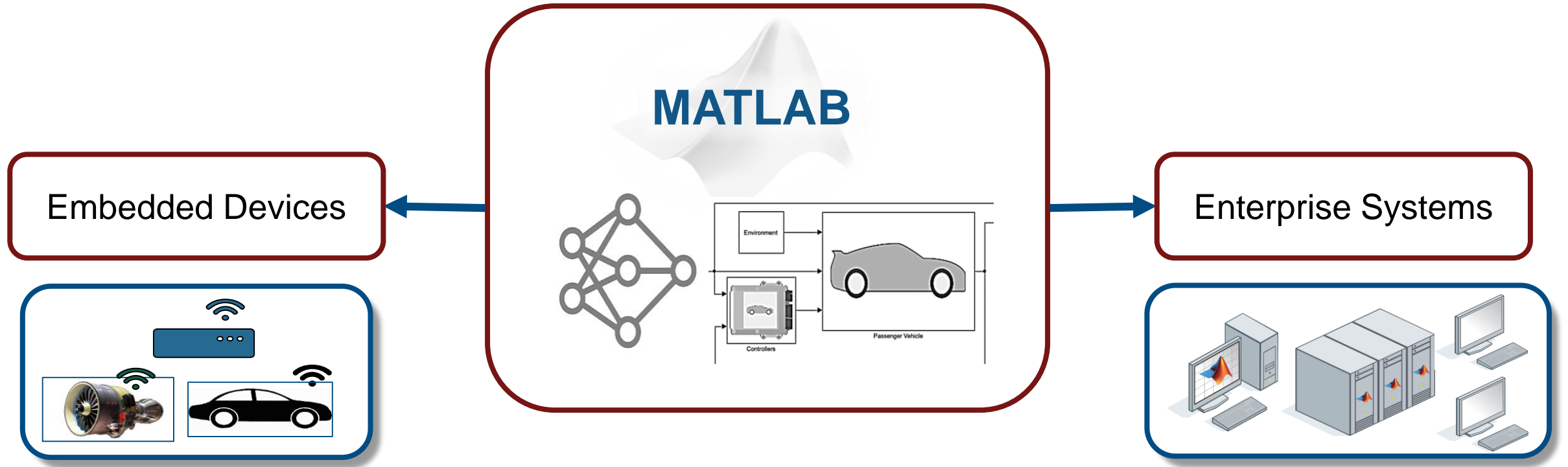
Code  
Generation

Embedded  
Devices

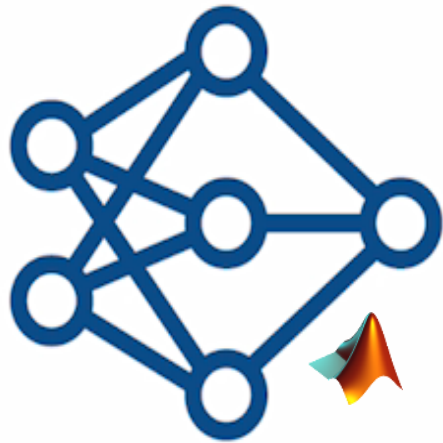
Enterprise  
Systems



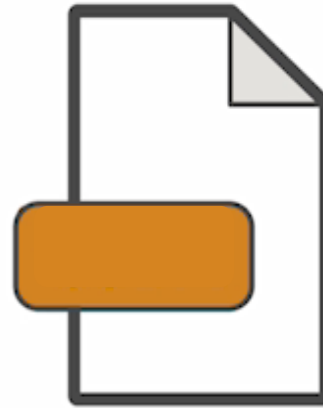
# Deployment and Scaling for A.I.



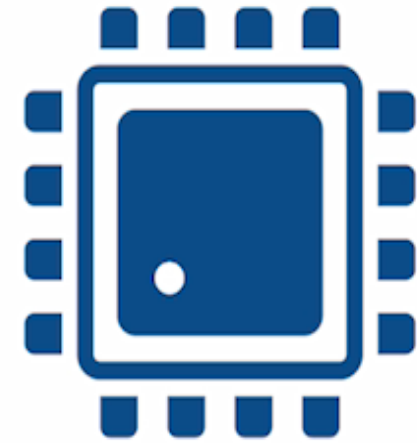
# Automatic Code Generation



MATLAB Code

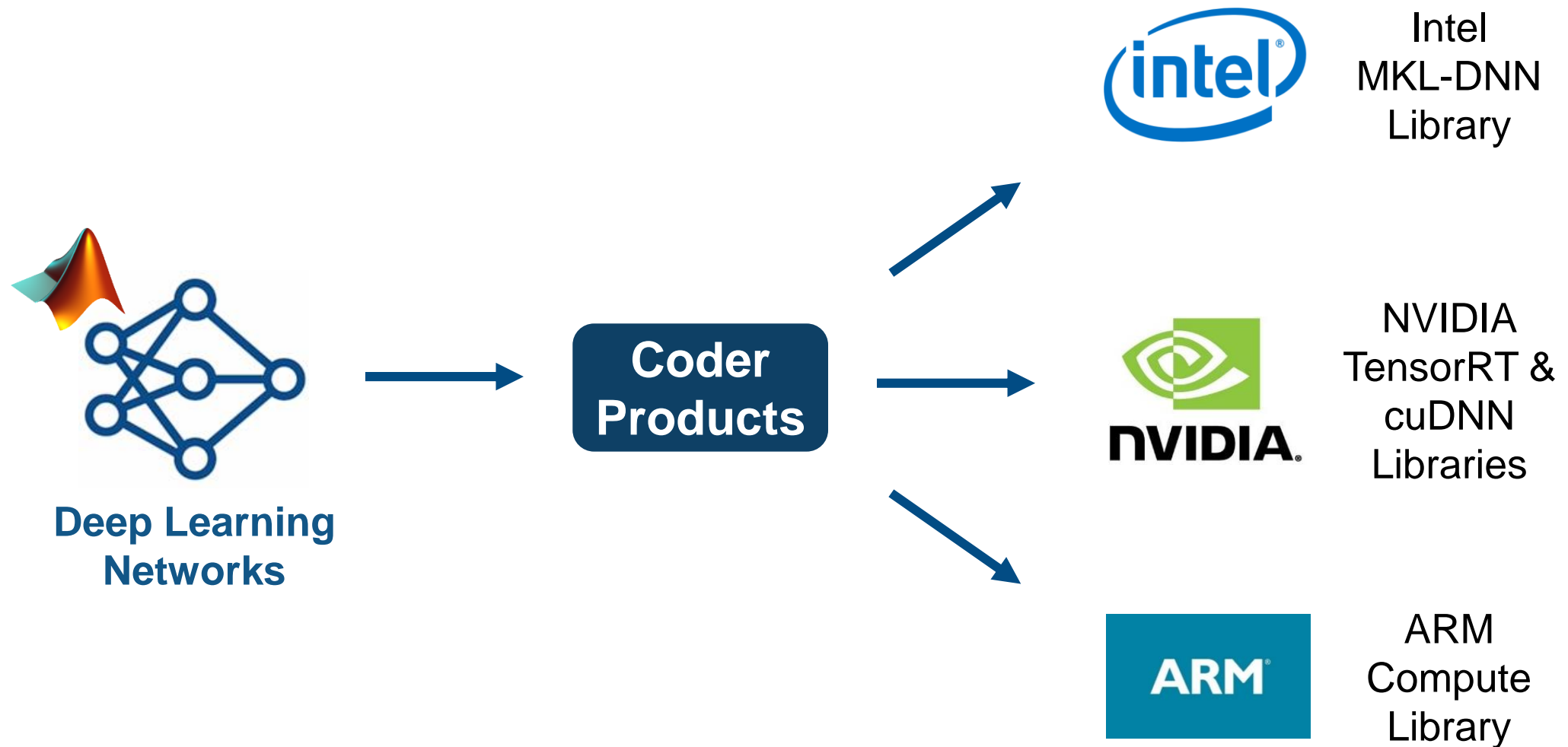


Auto-generated  
Code  
(C/C++/CUDA)

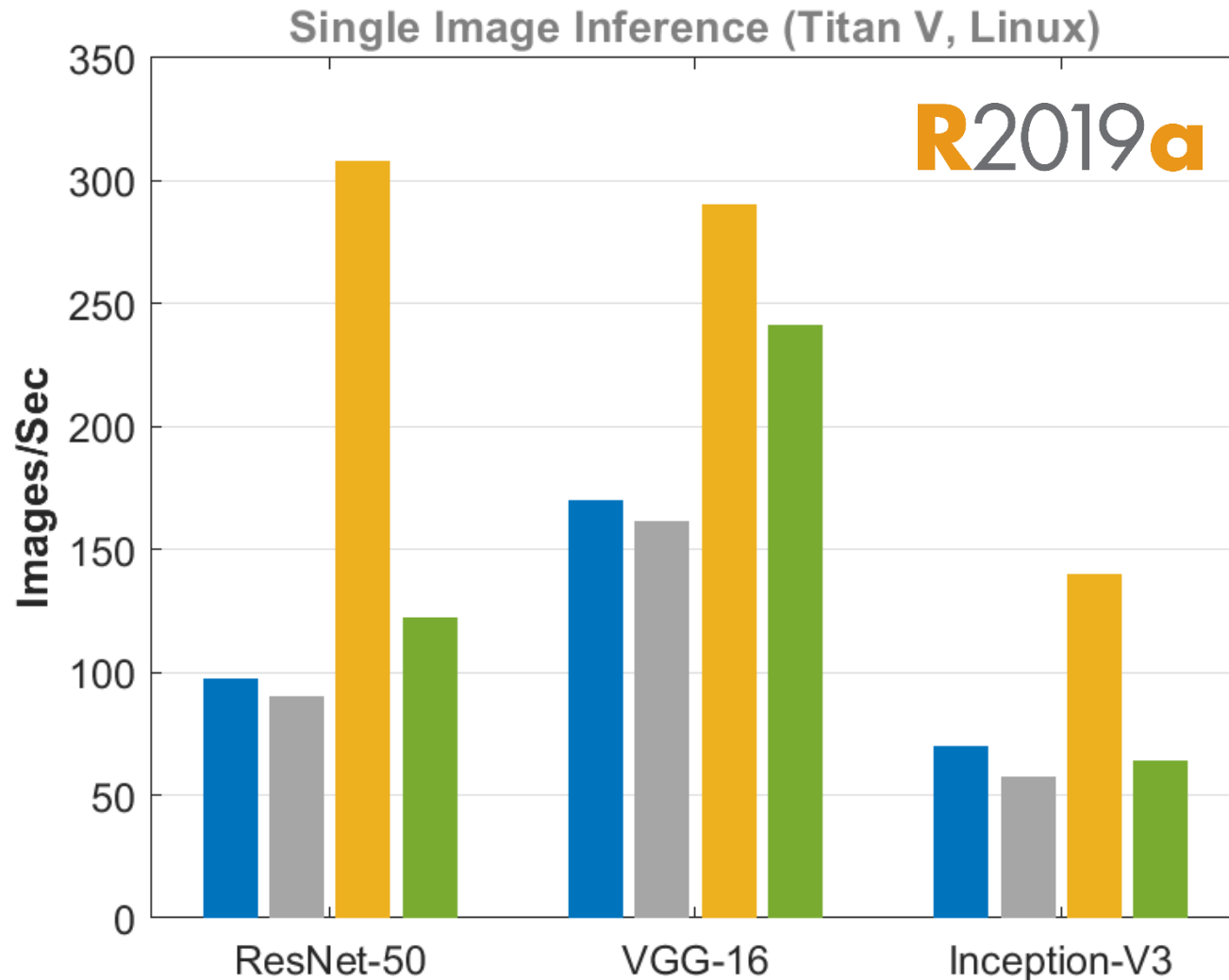


Deployment  
Target

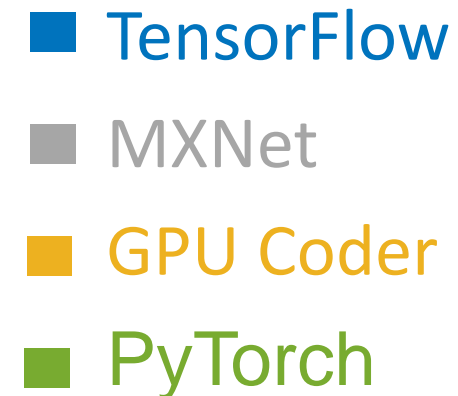
# Deploying Deep Learning Models



# With GPU Coder MATLAB is fast

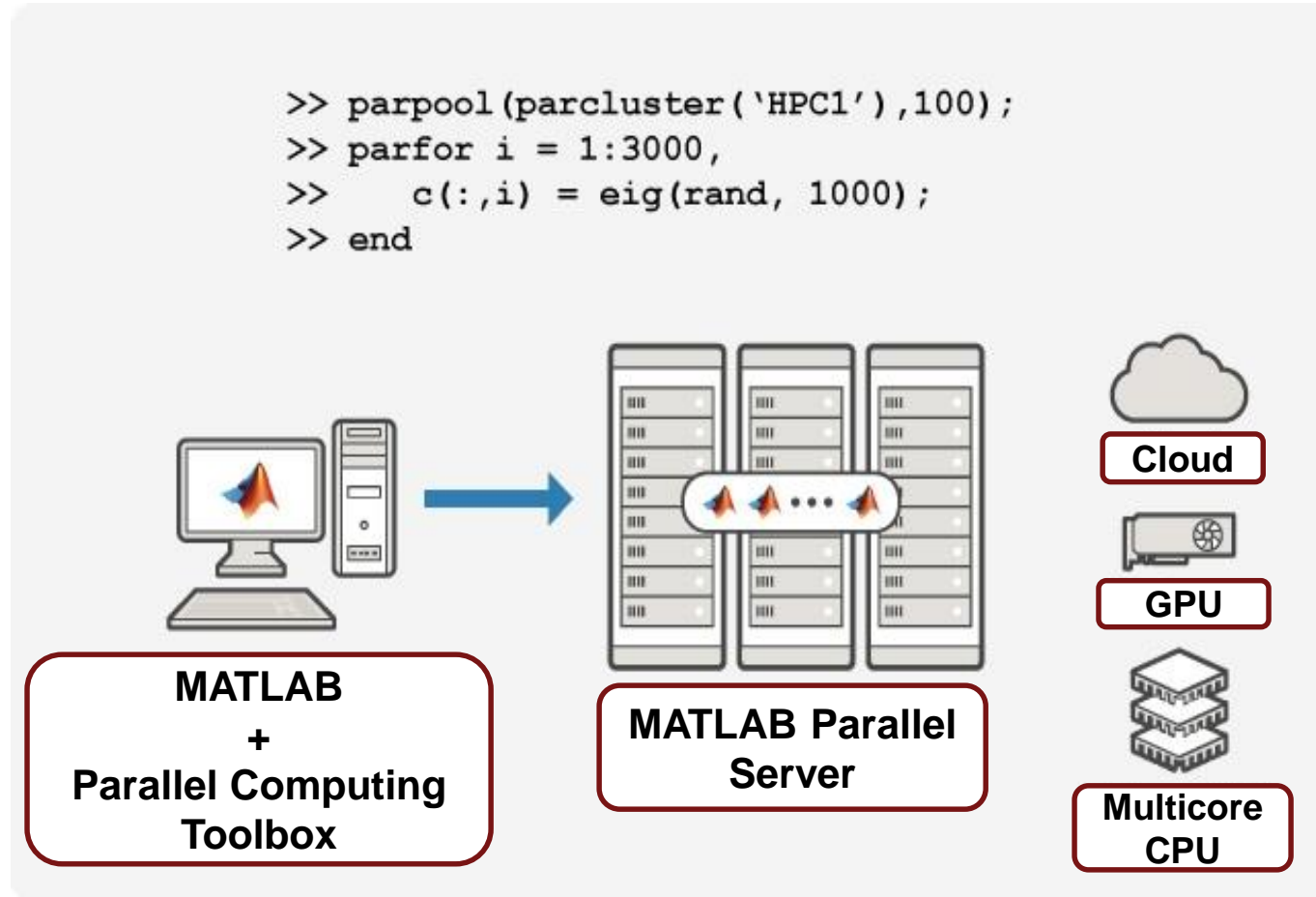


GPU Coder is faster than TensorFlow, MXNet and PyTorch



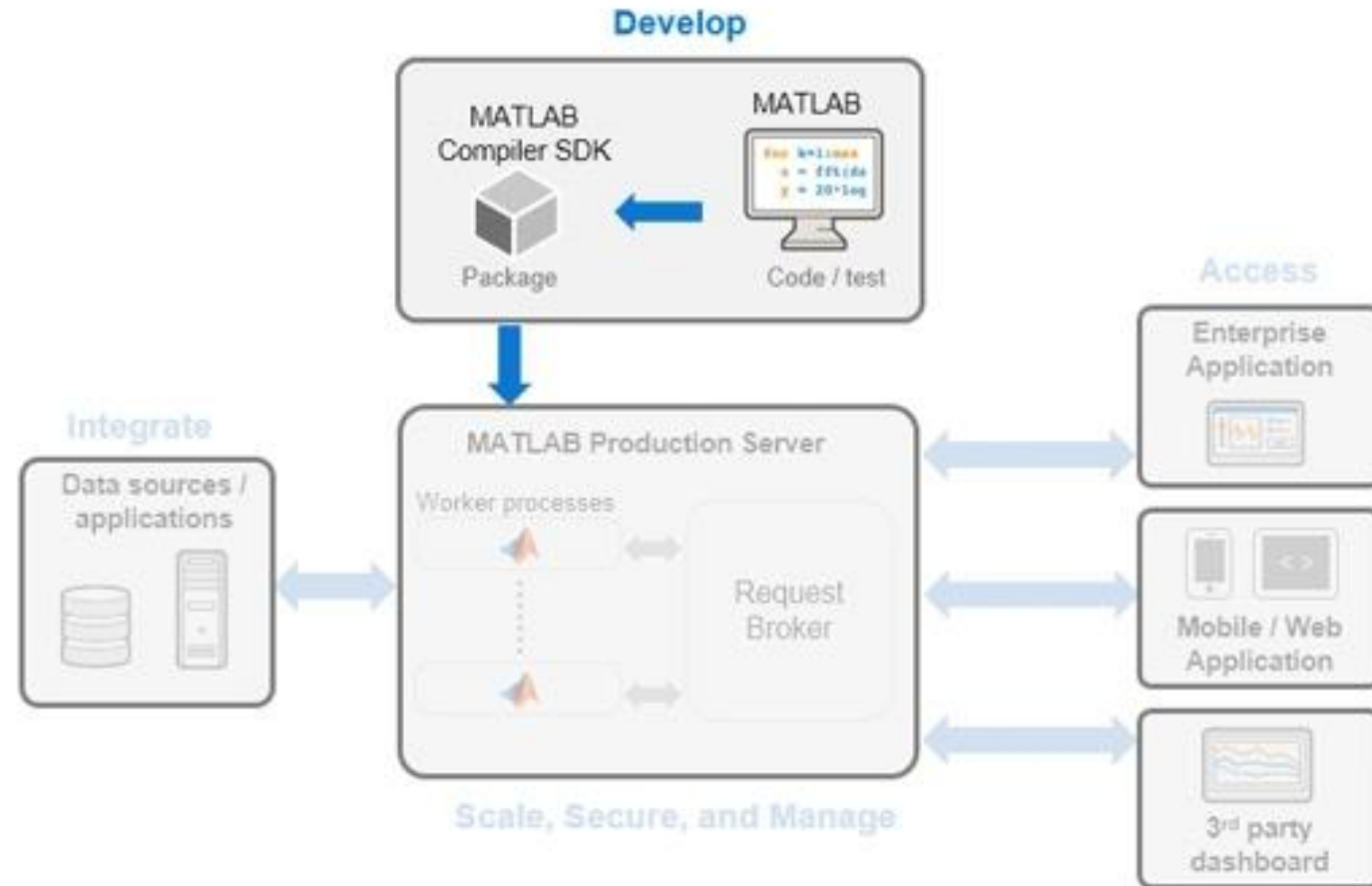
Intel® Xeon® CPU 3.6 GHz - NVIDIA libraries: CUDA10 - cuDNN 7 - Frameworks: TensorFlow 1.13.0, MXNet 1.4.0 PyTorch 1.0.0

# Enterprise Deployment



*Run thousands of simulations in parallel with MATLAB Parallel Server to save hours of training time.*

# Enterprise Deployment



*Deployment to the cloud with MATLAB Compiler and MATLAB Production Server.*

# Why MATLAB for A.I. Tasks?

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# User Stories

## Data Analytics in Produktionsumgebungen

- MLaaS (Machine Learning as a Service) mit MATLAB Production Server  
(Muhammad Faizan Aslam, Infineon Technologies AG)
- Neural Automation – Optimal Control durch Maschinelles Lernen  
(Dr. Fabian Bause, Beckhoff Automation GmbH & Co. KG)



# Want to Do More?

## Training

[mathworks.com/services/training](https://mathworks.com/services/training)

- Deep Learning with MATLAB\*
- Machine Learning with MATLAB\*
- Computer Vision with MATLAB
- Automated Driving with MATLAB

\*Also available as self-paced online course

## Consulting

[mathworks.com/services/consulting](https://mathworks.com/services/consulting)