MATLAB EXPO 2019

Deep Learning and Reinforcement Learning Workflows in A.I.

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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
Machine Learning and Deep Learning

Unsupervised Learning
[No Labeled Data]

Clustering

Machine Learning
Machine Learning and Deep Learning

Machine Learning

- Unsupervised Learning [No Labeled Data]
  - Clustering

- Supervised Learning [Labeled Data]
  - Classification
  - Regression
Unsupervised Learning [No Labeled Data]

Supervised Learning [Labeled Data]

Clustering

Classification

Regression

Deep Learning

Supervised learning typically involves feature extraction
Machine Learning and Deep Learning

Supervised learning typically involves feature extraction.

Deep learning typically does not involve feature extraction.
Deep Learning

- Subset of machine learning with automatic feature extraction
  - Learns features and tasks directly from data
  - More Data = better model
Deep Learning Uses a Neural Network Architecture

Input Layer

Hidden Layers (n)

Output Layer
Deep Learning Datatypes

- **Image**
- **Signal**
- **Numeric**
- **Text**
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
- Training
- Model Exchange

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Labeling for deep learning is repetitive, tedious, and time-consuming... but necessary
Signal Labeling – annotate signals with labels/sublabels, export to workspace for training

Define Labels

Interactively Label Signals

View properties of labels
User Story – Veoneer (Autoliv)

- **Automotive**
  - Software and hardware for active safety, autonomous driving, occupant protection, and brake control
- **Building radar sensor** – check accuracy using LiDAR-based verification
- **Human analyzes hours of recorded data**
- **Used MATLAB to semi-automate labeling and tracking of 3D LiDAR point clouds.**
Manual Labeling for 25 events took over 20 minutes. After full automation with MATLAB’s tools, it took 5 minutes.
Why MATLAB for A.I. Tasks?

Increased productivity with interactive tools

Labeling  Training  Model Exchange

Full A.I. workflows that cannot be easily replicated by other toolchains
Import pre-trained model as starting point

YOLOv2 Object Detection Layers

R2019a
Import Pre-trained Models for Transfer Learning

- Inception-v3
- ResNet-101
- VGG-16
- Inception-ResNet-v2
- ResNet-18
- GoogLeNet
- DenseNet-201
- VGG-19
- SqueezeNet
- AlexNet
- ResNet-50
- Places365-GoogLeNet
- MobileNet-v2
- Xception
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Model Exchange with MATLAB

Open Neural Network Exchange

ONNX

PyTorch

Caffe2

MXNet

Core ML

CNTK

MATLAB

Keras-Tensorflow

Caffe

(...)
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Reinforcement Learning
Supervised learning typically involves feature extraction.

Deep learning typically simplifies feature extraction.
Reinforcement Learning vs Machine Learning vs Deep Learning

Reinforcement learning:

- Learning through trial & error [interaction]
- It’s about learning a behavior or accomplishing a task
What is Reinforcement Learning?

- What is Reinforcement Learning?
  - Type of machine learning that trains an ‘agent’ through repeated interactions with an environment

- How does it work?
  - Through a trial & error process that uses a reward system to maximize success
Reinforcement Learning enables the use of Deep Learning for Controls and Decision Making Applications

Controls

Robotics

A.I. Gameplay

Autonomous driving
How Does Reinforcement Learning Work?

AGENT -> ACTION

STATE

REWARD

ENVIRONMENT
A Practical Example of Reinforcement Learning
Training a Self-Driving Car

- Vehicle’s computer learns how to drive… *(agent)*
- using sensor readings from LIDAR, cameras,… *(state)*
- that represent road conditions, vehicle position,… *(environment)*
- by generating steering, braking, throttle commands,… *(action)*
- to avoid collisions and lane deviation… *(reward)*.

The goal of Reinforcement learning is for the agent to find an optimal algorithm for performing a task.
Deep Networks are commonly found in the agent, because they can model complex problems.

- Turn left
- Turn right
- Brake
- Accelerate
Reinforcement Learning Workflow

Prepare Data
- Data access and preprocessing
- Ground truth labeling

Train Model
- Reinforcement learning
- Training agent to perform task
- Developing reward system to optimize performance

Deployment
- Multiplatform code generation (CPU, GPU)
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Simulink – generate data for dynamic systems (planes, cars, robots, etc.)
Why MATLAB and Simulink for Reinforcement Learning?

Virtual models allow you to simulate conditions hard to emulate in the real world.
Using MATLAB and Simulink for Reinforcement Learning

- Reinforcement learning is a dynamic process

- Decision making problems
  - Financial trading, calibration, etc.

- Controls-based problems
  - Lane-keep assist, adaptive cruise control, robotics, etc.
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Deployment and Scaling for A.I.
Embedded Devices – Automatic Code Generation

MATLAB Code → Auto-generated Code (C/C++/CUDA) → Deployment Target
Deploying Deep Learning Models for Inference

- Intel MKL-DNN Library
- NVIDIA TensorRT & cuDNN Libraries
- ARM Compute Library
With **GPU Coder**, MATLAB is fast

**Single Image Inference (Titan V, Linux)**

GPU Coder is faster than TensorFlow, MXNet and Pytorch

- **TensorFlow**
- **MXNet**
- **GPU Coder**
- **PyTorch**
TensorRT speeds up inference for TensorFlow and GPU Coder

Single Image Inference with ResNet-50 (Titan V)
Even higher Speeds with Integer Arithmetic (int8)

ResNet-50 Inference (Titan V)

Images/Sec

Batch Size

GPU Coder + TensorRT (int8)
TensorFlow (int8)

GPU Coder + TensorRT (fp32)
TensorFlow + TensorRT

Intel® Xeon® CPU 3.6 GHz - NVIDIA libraries: CUDA10 - cuDNN 7 – Tensor RT 5.0.2.6. 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.

>> parpool(parcluster('HPC1'),100);
>> parfor i = 1:3000,
>> c(:,i) = eig(rand, 1000);
>> end
Deployment to the cloud with MATLAB Compiler and MATLAB Production Server
Musashi Seimitsu Industry Co., Ltd.
Detect Abnormalities in Automotive Parts

MATLAB use in project:
- Preprocessing of captured images
- Image annotation for training
- Deep learning based analysis
  - Various transfer learning methods (Combinations of CNN models, Classifiers)
  - Estimation of defect area using Class Activation Map (CAM)
  - Abnormality/defect classification
- Deployment to NVIDIA Jetson using GPU Coder

Automated visual inspection of 1.3 million bevel gear per month
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