MATLAB EXPO 2017
How to build an autonomous anything

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MATLAB Products, Deep Learning, Data Analytics
MathWorks
Autonomous Technology
Autonomous

Acting independently
Autonomous Technology
Autonomous Technology

Provides the ability of a system to act independently of direct human control
Autonomous Technology

Provides the ability of a system to act independently of direct human control under unrehearsed conditions
Capabilities of an Autonomous System

Sense
Capabilities of an Autonomous System

Sense

Perceive
Capabilities of an Autonomous System

- Sense
- Perceive
- Decide & Plan
Capabilities of an Autonomous System

- Sense
- Perceive
- Decide & Plan
- Act
Autonomous Technology – Balancing Responsibility

Degree of Autonomy

Responsibility

Computer

Human
Autonomous Artistic Style Classification
Rutgers University

- **Sense**
- **Perceive**
- **Decide & Plan**
- **Act**

Image Feature Extraction

Visual Features

- **Style Classifier (SVM)**: Style: Regionalism
- **Genre Classifier (SVM)**: Genre: Interior
- **Artist Classifier (SVM)**: Artist: Rockwell
Where to add autonomy with perception?

- Analyze more data
- Reduce bias
- Improve measurement quality
- Save time
- Improve performance

Determine Loudspeaker Quality

Virtual Semiconductor Manufacturing Calibration
Cost of rig: $1,000,000+
Repair cost: $100,000
Cost of valve: $200
Autonomous Service for Predictive Maintenance

Which sensor values should they use?

- Pressure
- Vibration
- Timing
- Temperature
- Other variables

Sense
Perceive
Decide & Plan
Act
Autonomous Service for Predictive Maintenance

- Sense
- Perceive
- Decide & Plan
- Act

Normal Operation
Monitor Closely
Maintenance Needed
Autonomous Service for Predictive Maintenance

Sense

Perceive

Decide & Plan

Act

Find out more:
Predictive Maintenance with MATLAB and Simulink

Mehernaz Savai, MathWorks

Normal Operation

Monitor Closely

Maintenance Needed
Machine Learning or Deep Learning?

Machine Learning Approach

1. Normal
2. Monitor
3. Maintain

Deep Learning Approach

1. Normal
2. Monitor
3. Maintain
Machine Learning and Deep Learning

- Configure and train models using object detection algorithms (R-CNN, Fast R-CNN, Faster R-CNN)
- Leverage pretrained models for transfer learning (AlexNet, VGG-16, VGG-19)
- Import models from Caffe
- Train networks using multiple GPUs
Deep learning design is **easy** in MATLAB

**Apps** for Ground Truth Labeling, Pixel Labeling

Pre-trained **model importer**

Training Visualization

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Parallel Computing Toolbox

**Train**

4x faster than TensorFlow (on TitanXP)

---

**GPU Coder**

7x faster than TensorFlow

5x faster than pyCaffe (on TitanXP)

2x faster than C++ Caffe (on Jetson)
Deep learning design is easy in MATLAB

Apps for Ground Truth Labeling, Pixel Labeling
Pre-trained model importer
Training Visualization

Parallel Computing Toolbox
Train
4x faster than TensorFlow (on TitanXP)

GPU Coder
7x faster than TensorFlow
5x faster than pyCaffe (on TitanXP)
2x faster than C++ Caffe (on Jetson)

Find out more:
Deep Learning: Transforming Engineering and Science
Avinash Nehemiah, MathWorks
Amit Goel, NVIDIA

High Performance Embedded Implementation
What are the best predictors?

- Data-driven
- Model-driven

Jet Engine Monitoring
Autonomous Glucose Level Management
Autonomous Glucose Level Management
Bigfoot Biomedical

- Sense
- Perceive
- Decide & Plan
- Act
Autonomous Glucose Level Management
Bigfoot Biomedical

Sense
Perceive
Decide & Plan
Act

Target Glucose Level
Insulin Pump
Person
Mobile App
Continuous Glucose Monitor

+ - 

+ + +
Autonomous Glucose Level Management
Bigfoot Biomedical

Virtual Lab
Simulink, Stateflow, Polyspace

Sense

Perceive

Decide & Plan

Act

Target Glucose Level

Insulin Pump

Mobile App

Continuous Glucose Monitor

Person
Autonomous Glucose Level Management
Bigfoot Biomedical

Sense

Perceive

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Target Glucose Level

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Autonomous Glucose Level Management
Bigfoot Biomedical

- Sense
- Perceive
- Decide & Plan
- Act

Virtual Clinic
MATLAB, Toolboxes

Target Glucose Level

Insulin Pump

Mobile App

Continuous Glucose Monitor

Person
Virtual Clinic
Generating data through simulation
Virtual Clinic

Scaling computations to simulate 50 million patients a day
Where will you get your data?

- Simulation
- Public repositories
- In the field
- In the lab
- Internet of Things (IoT)
Working with Big Data Just Got Easier

Tall arrays in MATLAB

R2016b
R2017a

Machine Memory

e.g. 4~8GB

e.g. 100GB~1TB

Tall Data

Stream large input signals from MAT-files

R2017a
Autonomous Trailer Filling

Sense

Perceive

Decide & Plan

Act
Autonomous Trailer Filling

Sense

Perceive

Decide & Plan

Act

Computer Vision Algorithms

Control Algorithms

3D Camera Image

3D Scene Simulator

Control outputs
Autonomous Trailer Filling

- **Sense**
- **Perceive**
- **Decide & Plan**
- **Act**

3D Cameras

Computer vision and controls algorithms

Embedded Platform
MPC5121e

- User Input
- Visualization

Actuators

CAN

ECU
Autonomous Trailer Filling

- Sense
- Perceive
- Decide & Plan
- Act

3D Cameras

Computer vision and controls algorithms

Vehicle Display Controller
  - Driver Input
  - Visualization
  - Computer Vision
  - Controls

Embedded Coder

CAN

ECU

Actuators
How will you put it into production?

- Embedded Systems
- IT Systems
- Cloud
- Desktop Apps
Investments in Model-Based Design

Efficient code generation

Floating-point HDL code generation

R2017a

R2016b
Investments in Model-Based Design

Efficient code generation

Floating-point HDL code generation

Find out more: Better Than Hand: Generating Highly Optimized Code Using Simulink and Embedded Coder

Mark Danielsen, MathWorks
Investments in Model-Based Design

Code verification in support of CERT C standard

```
if (output_r7 >= 0) {
    saved_values[output_r7] = s8_ret;
    return s8_ret;
}
```

Detect and fix standards compliance issues at design time

<table>
<thead>
<tr>
<th>CERT</th>
<th>Description</th>
<th>Polyspace Code Prover</th>
</tr>
</thead>
<tbody>
<tr>
<td>ARR30-C</td>
<td>Do not form or use out-of-bounds pointers or array subscripts</td>
<td>Array access out of bounds</td>
</tr>
</tbody>
</table>
Capabilities of an Autonomous System

- Sense
- Perceive
- Decide & Plan
- Act
# How to build an autonomous anything

## Focus on Perception
- Look for autonomy in creative places
- Do more than manually possible

## Use the Best Predictors
- Data-driven
- Model-driven

## Get the Right Data
- Reduce to actionable data
- Take advantage of Big Data
- Use simulation to supplement available data

## Flow to Production
- Address the architecture
- Leverage Model-Based Design for embedded
- Automate integration with enterprise IT systems
What is *your* autonomous anything?