MATLAB EXPO 2017
How to build an **autonomous** anything

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Well, hello Sunshine. What’s for breakfast?
Autonomous Technology
Autonomous

Having the power for self-governance
Autonomous Technology

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

Degree of Autonomy vs. Responsibility

Human

Computer
Cost of rig:  >$1M
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
Autonomous Service for Predictive Maintenance

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

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
What are the best predictors?

- Data-driven
- Model-driven
Bazille’s Studio
Frederic Bazille (Paris, 1870)

Shuffleton’s Barbershop
Norman Rockwell (Vermont, 1950)
Bazille’s Studio  
Frederic Bazille (Paris, 1870)

Shuffleton’s Barbershop  
Norman Rockwell (Vermont, 1950)
Autonomous Artistic Style Classification
Rutgers University

Image Feature Extraction

Visual Features

Style Classifier (SVM)
- Style: Regionalism

Genre Classifier (SVM)
- Genre: Interior

Artist Classifier (SVM)
- Artist: Rockwell

Sense

Perceive

Decide & Plan

Act
Where to add autonomy with perception?

- Analyze more data
- Reduce bias
- Reduce variability
- Save time
- Improve performance
Autonomous Glucose Level Management
Autonomous Glucose Level Management
Bigfoot Biomedical

Sense

Perceive

Decide & Plan

Act

Target Glucose Level

Insulin Pump

Person

Continuous Glucose Monitor
Autonomous Glucose Level Management
Bigfoot Biomedical

Sense

Perceive

Decide & Plan

Act

Target Glucose Level

Insulin Pump

Mobile App

Continuous Glucose Monitor

Person
Autonomous Glucose Level Management
Bigfoot Biomedical

Sense

Simulink, Stateflow, Polyspace

Target Glucose Level

Perceive

Sense

Decide & Plan

Mobile App

Act

Insulin Pump

Continuous Glucose Monitor

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Mobile App

Continuous Glucose Monitor

Person

2017

2018
Virtual Clinic
Generating data through simulation

Blood Glucose (mg/dL)

Hour-of-Day $\mu^*$, $\sigma^*$, setpoints

CRC Protocol, Nominal, No Mismatch

Programmed $\mu^*$

Actual $\mu^*$

Blood Glucose Trend (mg/dL)
Virtual Clinic
Scaling computations to simulate 50 million patients a day
Where will you get your data?

- Simulation
- Public repositories
- In the lab
- In the field
- Internet of Things (IoT)
CNH Develops Intelligent Filling System for Forage Harvesters
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

CAN

Computer vision and controls algorithms

Actuators

ECU
Autonomous Trailer Filling

- Sense
- Perceive
- Decide & Plan
- Act

Vehicle Display Controller
- Driver Input
- Visualization

3D Cameras

Computer vision and controls algorithms

CAN

ECU

Actuators
Autonomous Trailer Filling

- Sense
- Perceive
- Decide & Plan
- Act

3D Cameras

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

Embedded Coder

CAN

Computer vision and controls algorithms

ECU

Actuators
Autonomous Trailer Filling

- Sense
- Perceive
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3D Cameras

Vehicle Display Controller
- Driver Input
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- Computer Vision
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CAN

Monitoring

ECU

Actuators

MathWorks
How will you put it into production?

- System Architecture
- Embedded systems
- Enterprise systems
- HMIs
# 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

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