

AI in Autonomous Systems and the Future of Engineering Education

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Senior Application Engineer

2022-10-21

MATLAB

- Programming language and IDE
- Data processing and visualization
- Numerical computing
- Algorithm development
- 90+ toolboxes for AI, Controls, Power Electronics...

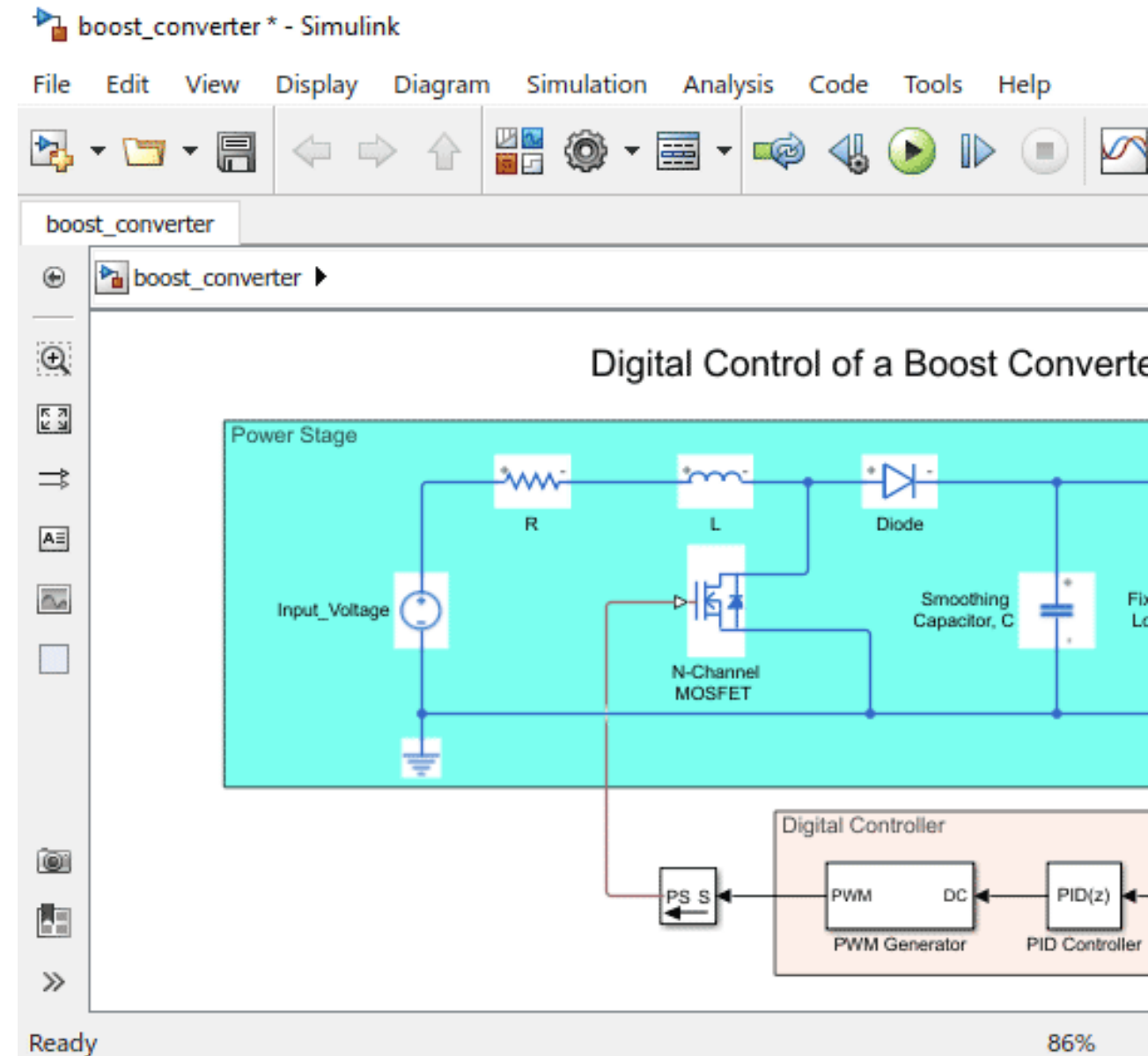


```
>> url='mathworks.com/products/matlab.html';  
>> web(url);
```

Simulink

- Graphical environment
- Integration with MATLAB
- Multi-domain modelling
- Simulation and validation
- Model-Based Design

mathworks.com/products/simulink.html



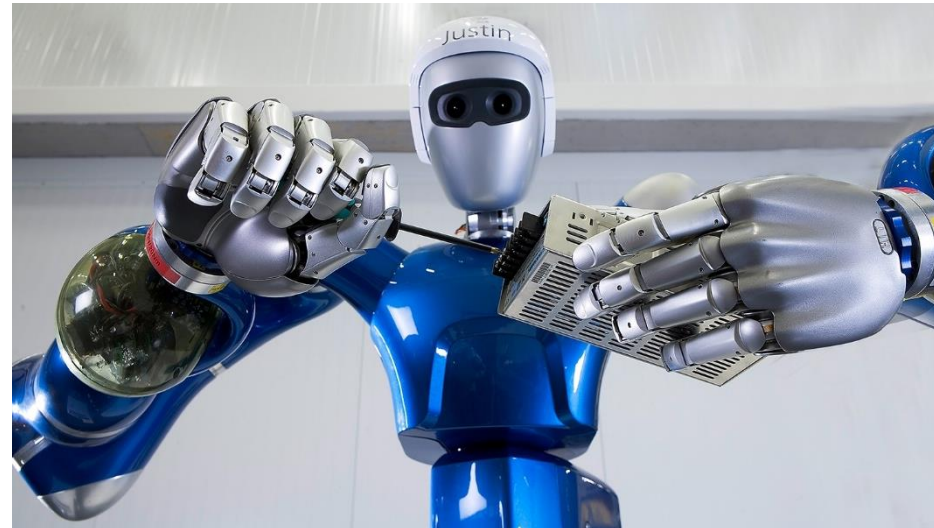
AI in Autonomous Systems and the Future of Engineering Education

**Autonomous
Systems**

**Systems Thinking
in Education**

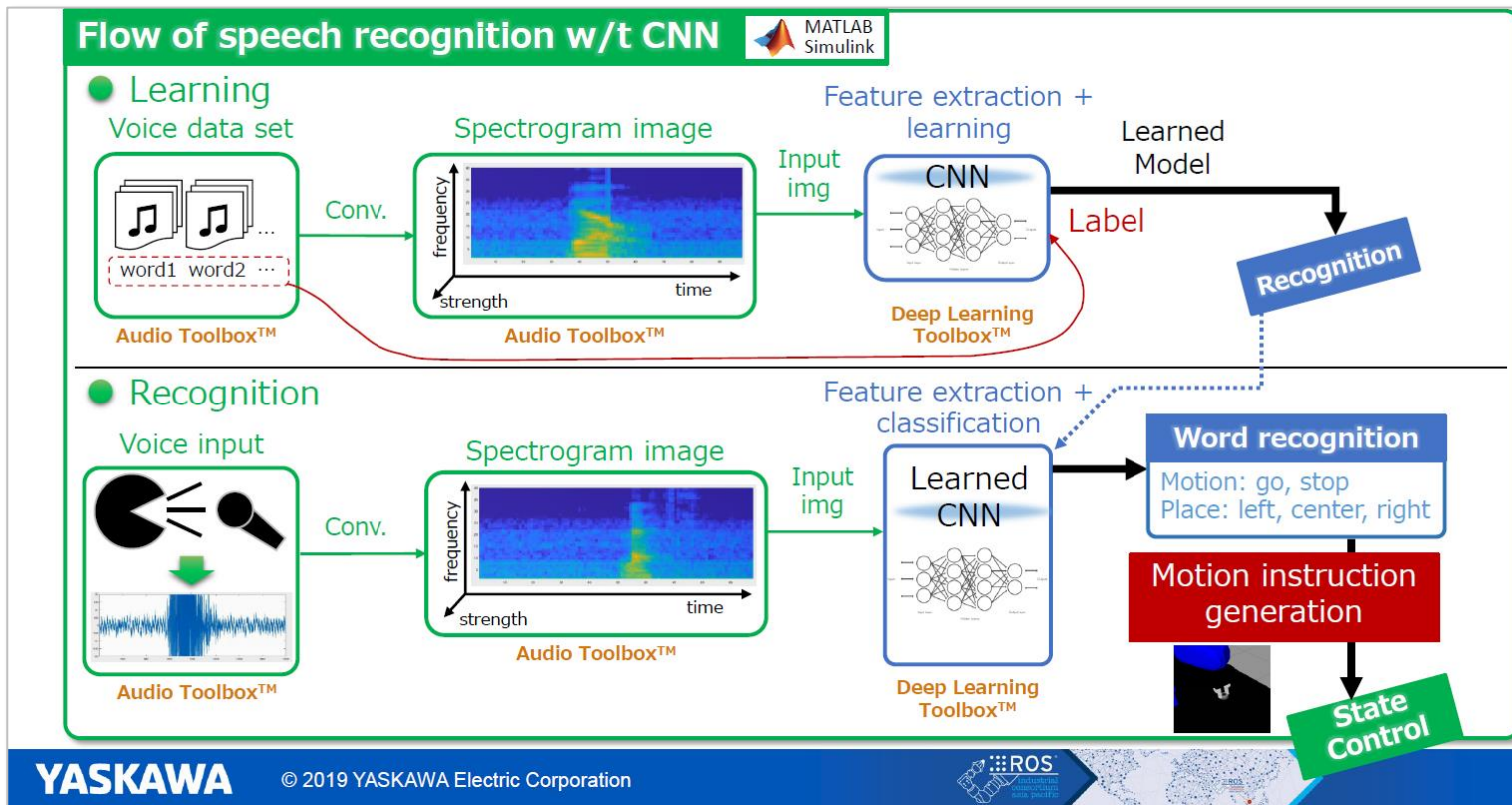
Autonomous Systems

Autonomous Systems



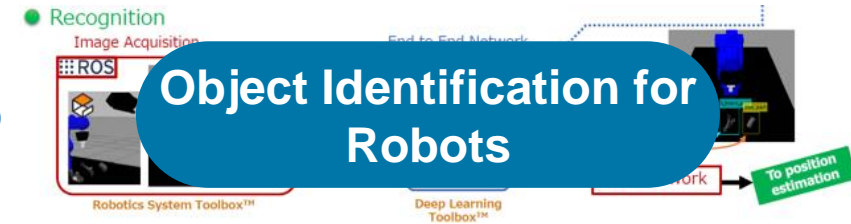
Landscape of AI adoption in Robotics

Speech Recognition

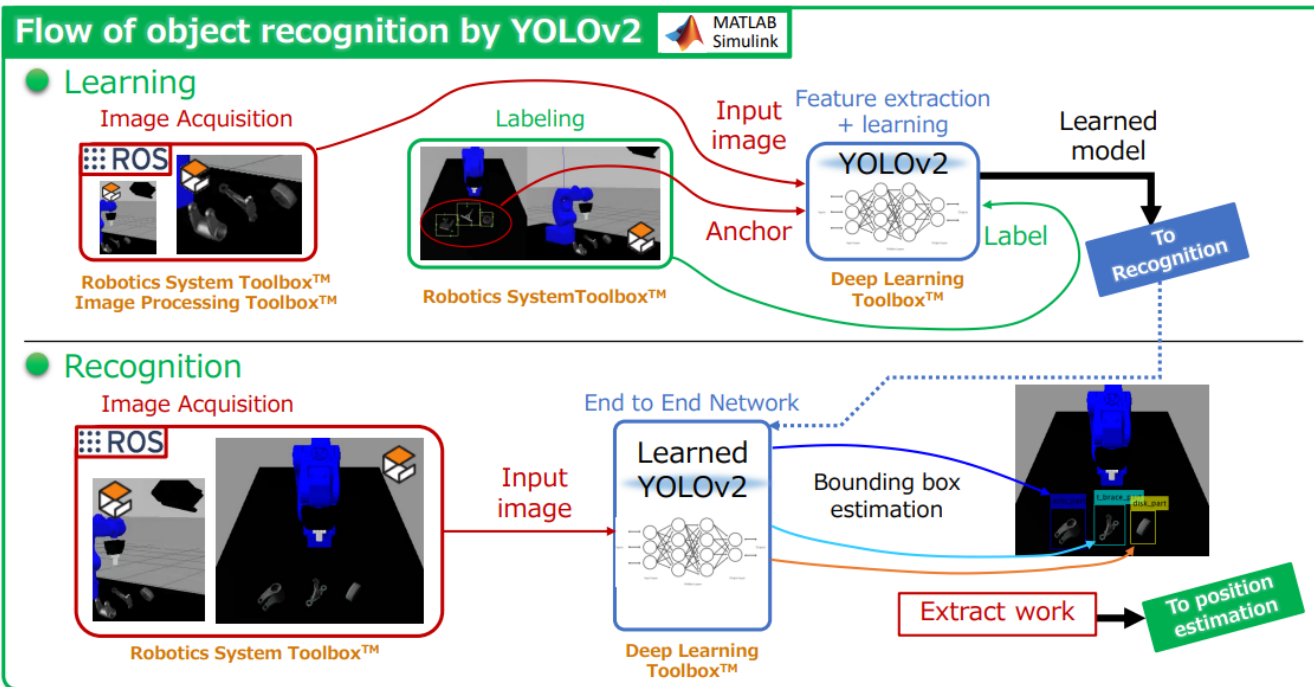


Landscape of AI adoption in Robotics

Computer Vision



Object recognition with deep learning (YOLOv2)



Landscape of AI adoption in Robotics

Computer Vision



Musashi Seimitsu Industry Uses Deep Learning for Visual Inspection of Automotive Parts

Musashi Seimitsu Industry Co., Ltd.

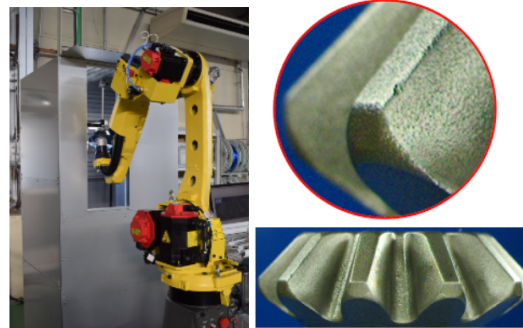
Musashi Seimitsu Industry Co., Ltd. prototyped an anomaly detection system using deep learning with MATLAB® for inspecting bevel gears used in automotive parts. After verifying accuracy and speed, they are now carrying out demonstration experiments at the manufacturing site. This approach is expected to reduce the workload and cost for manually operated visual inspection of 1.3 million parts per month.

In this project, Musashi Seimitsu worked with MathWorks consultants to build a camera connection setup, preprocess images, create a custom annotation tool using App Designer, and improve the model accuracy. They generated code for the trained model using GPU Coder, implemented it on NVIDIA® Jetson, and leveraged the results to the PLC.

Advantages of using MATLAB and Simulink:

- Enable a seamless development workflow from image capture to implementation on embedded GPU
- Estimate and visualize the defect area using Class Activation Map
- Create custom user interfaces (App Designer) for improving labeling efficiency
- Leverage consulting services to maximize the benefits of using MATLAB

“ Using camera connection, preprocessing, and various pretrained models in MATLAB enabled us to work on the entire workflow. Through discussions with consultants, our team gained many tips for solving problems, growing the skills of our engineers. ”



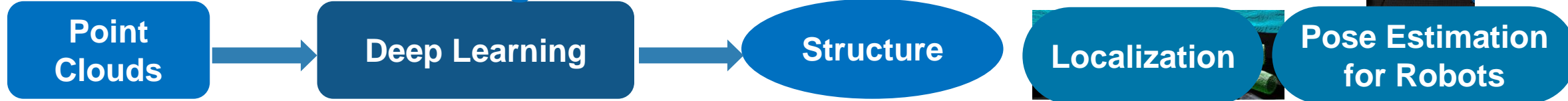
» Explore MATLAB for deep learning

Deep Learning for Computer Vision

▶ Watch video

Landscape of AI adoption in Robotics

Point Cloud Processing



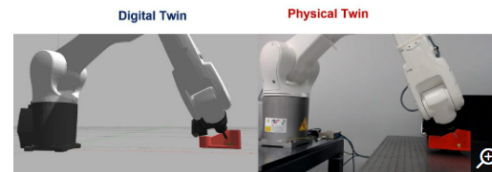
User Stories

User Stories ▾

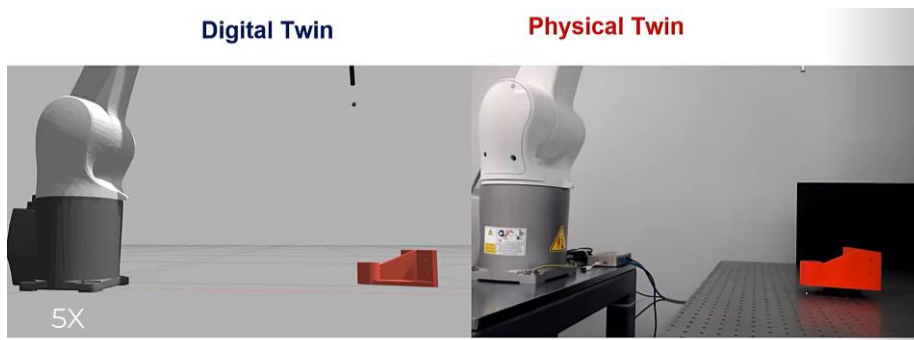
ASTRI Accelerates Development of Robotic Manipulation System Using MBSE Digital Twin

“The integration of MATLAB, Simulink, and Deep Learning Toolbox gave us the confidence to move forward with the MBSE digital twin project.”

— Dr. T. John Koo, ASTRI



ASTRI created a digital twin to design, build, and validate its robotic welding system.



Challenge

Reduce development time, manual processes, and costs

Solution

Adopt model-based systems engineering and develop a digital twin with MATLAB, Simulink, and Deep Learning Toolbox

Results

- Integration time reduced by 40%
- Issues resolved in the design stage
- Teams worked collaboratively

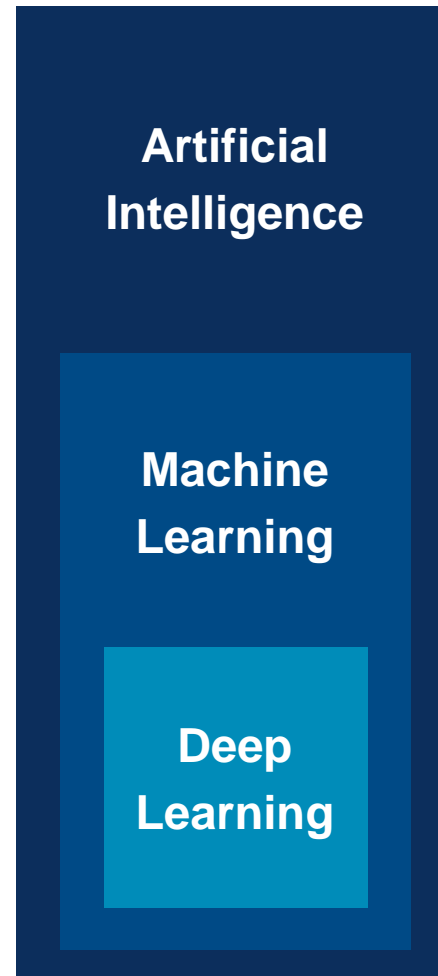
Autonomous Systems

➤ Why is it happening now?

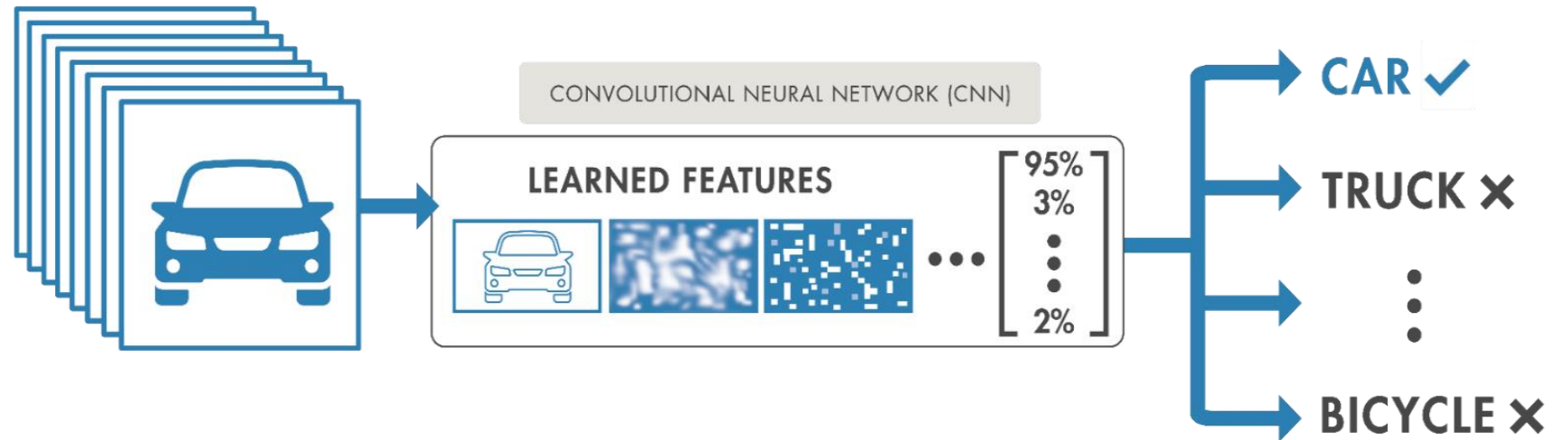
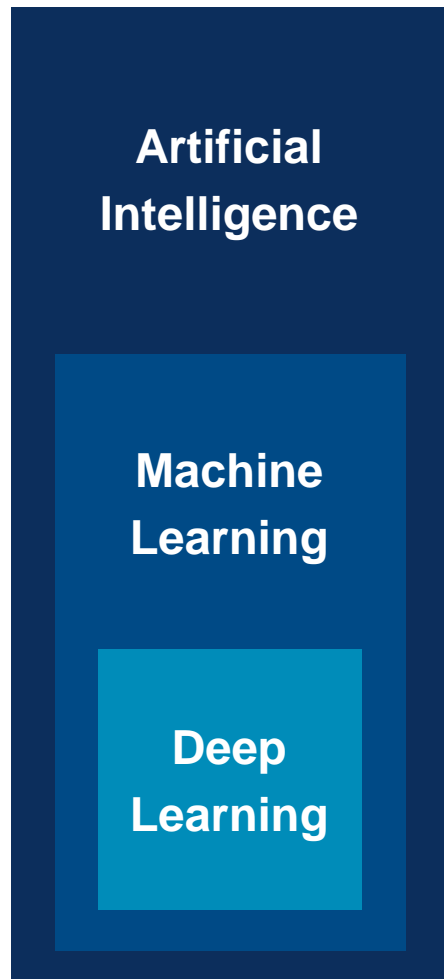
What challenges is Industry facing?

How are engineers overcoming them?

The New Wave in AI: Deep Learning



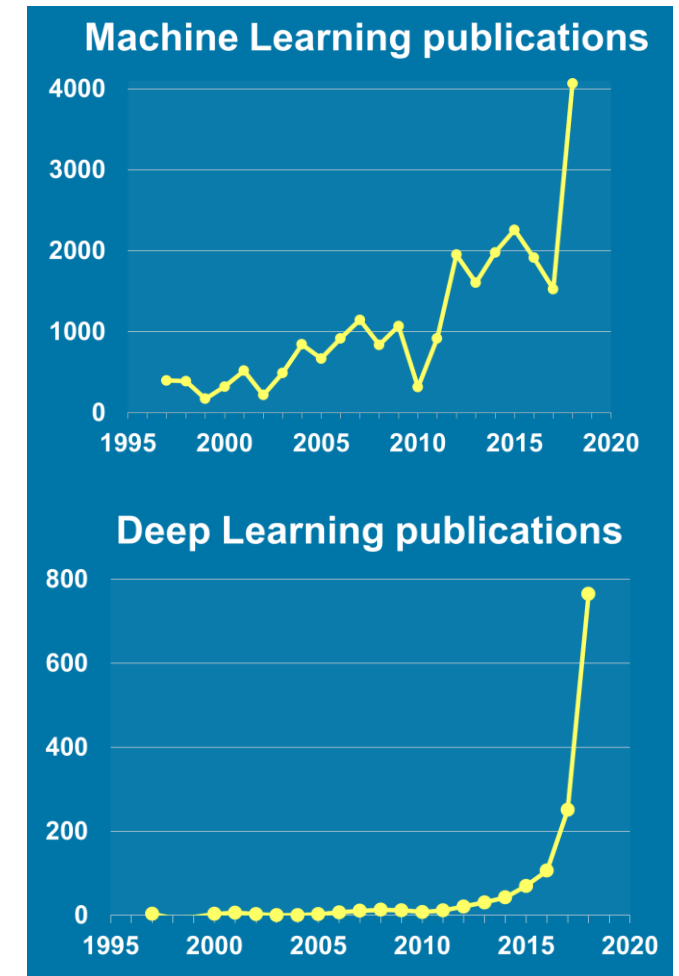
The New Wave in AI: Deep Learning



The New Wave in AI: Deep Learning



- Relatively recent developments
 - Convolutional Neural Networks (1950)
 - Back propagation (1986)
- Availability of large datasets
- Computing power
- Electrification has made every device programmable



Autonomous Systems

Why is it happening now?

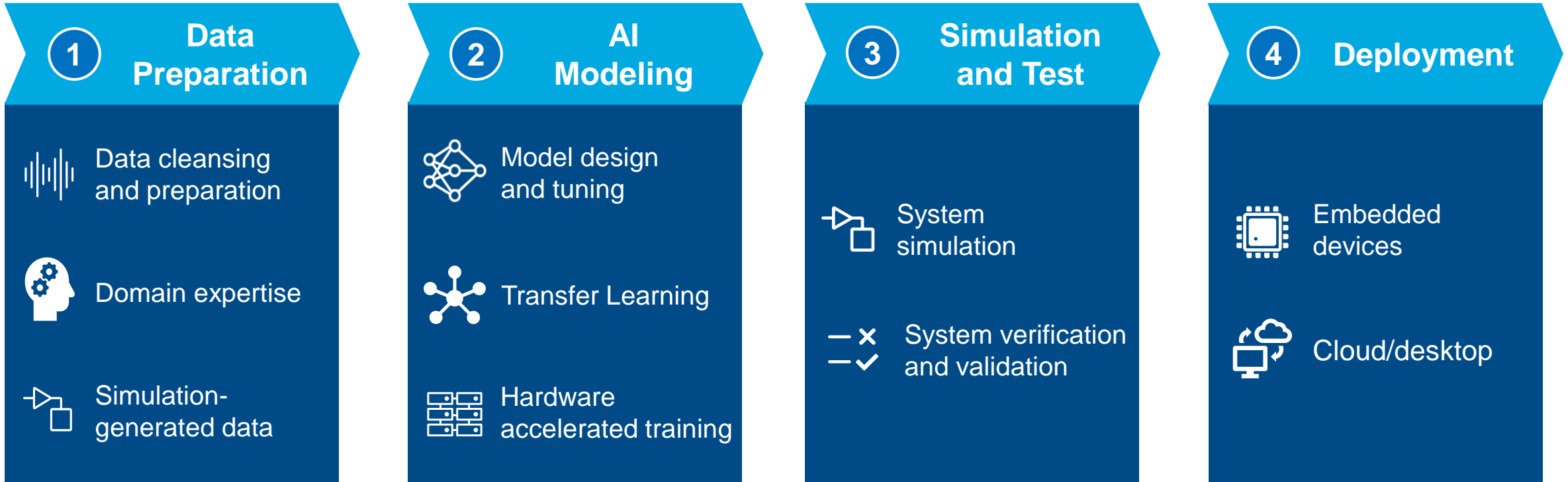
➤ What challenges is Industry facing?

How are engineers overcoming them?

AI Workflows



Key Challenges in AI



Autonomous Systems

Why is it happening now?

What challenges is Industry facing?

➤ How are engineers overcoming them?

Subaru EyeSight

Detects obstacles, applies brakes, adjusts cruise control, and stays in lane.





is a **Leader** in the 2021 Gartner Magic Quadrant for Data Science and Machine Learning Platforms for the Second Year in a Row

Figure 1: Magic Quadrant for Data Science and Machine Learning Platforms



Source: Gartner (March 2021)

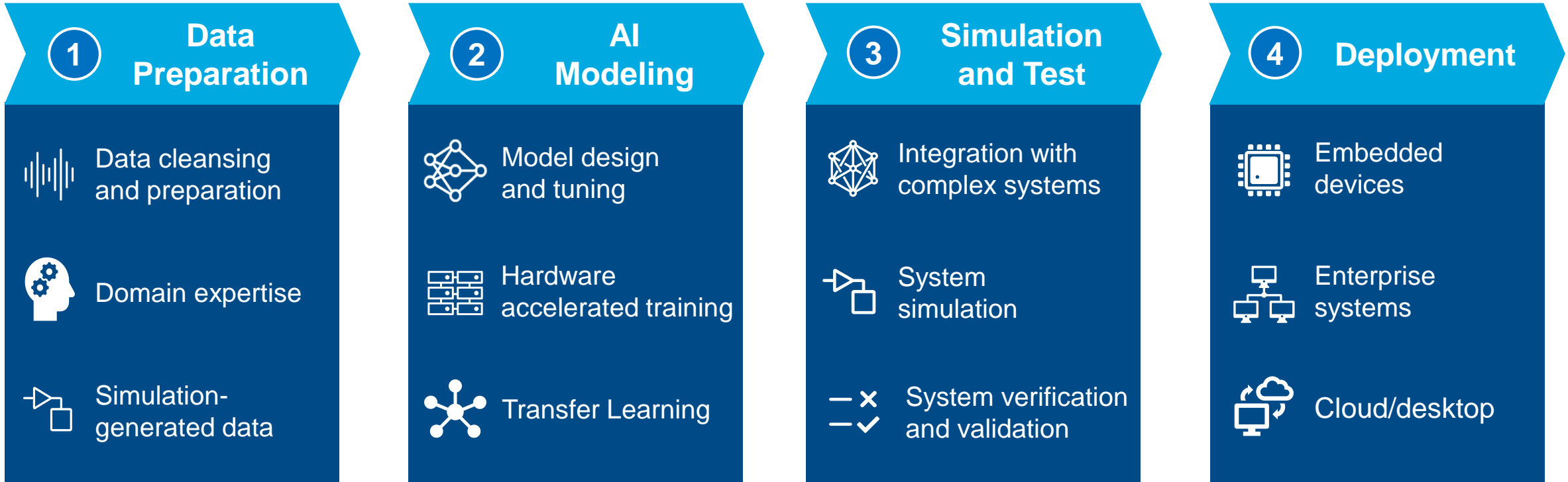
Gartner Magic Quadrant for Data Science and Machine Learning Platforms, Peter Krensky, Carlie Idoine, Erick Brethenoux, Pieter den Hamer, Farhan Choudhary, Afraz Jaffri, Shubhangi Vashisth, 1st March 2021.

This graphic was published by Gartner, Inc. as part of a larger research document and should be evaluated in the context of the entire document. The Gartner document is available upon request from MathWorks.

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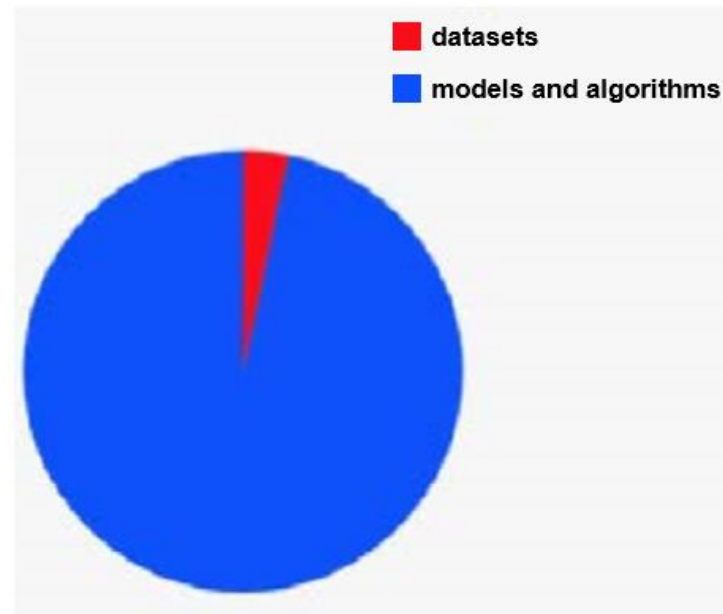


Key Challenges in AI

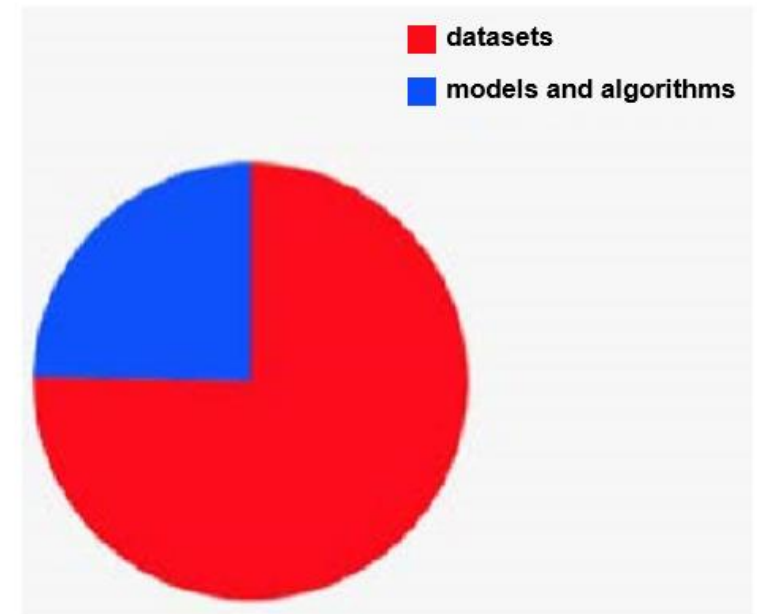


Amount of lost sleep over...

PhD



Tesla

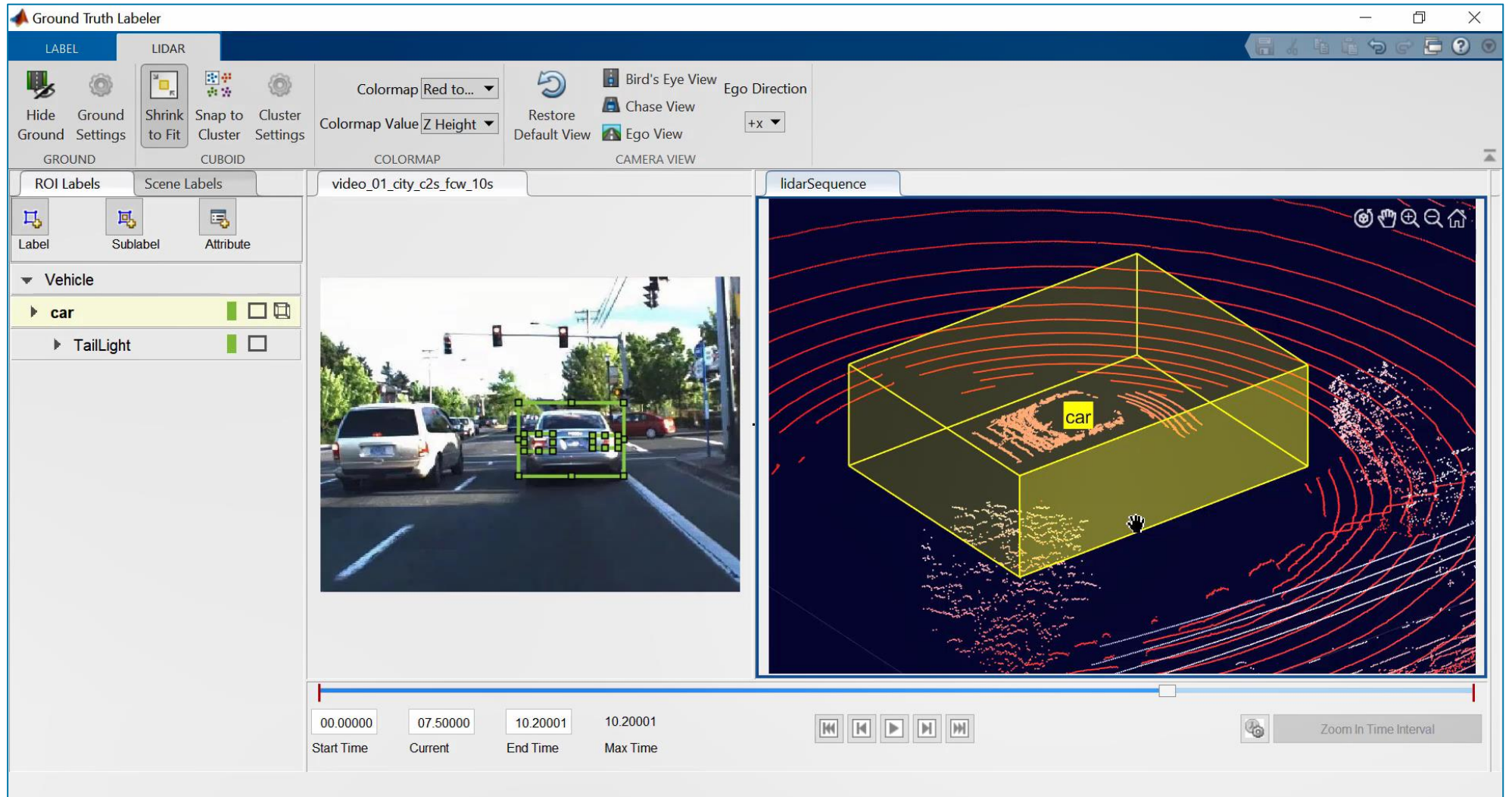


Source: Andrej Karpathy slide from TrainAI 2018

- 1 Data Preparation
- 2 AI Modeling
- 3 Simulation and Test
- 4 Deployment

Automated Labeling Apps

- 1 Data Preparation
- 2 AI Modeling
- 3 Simulation and Test
- 4 Deployment



Synthetic Data Generation

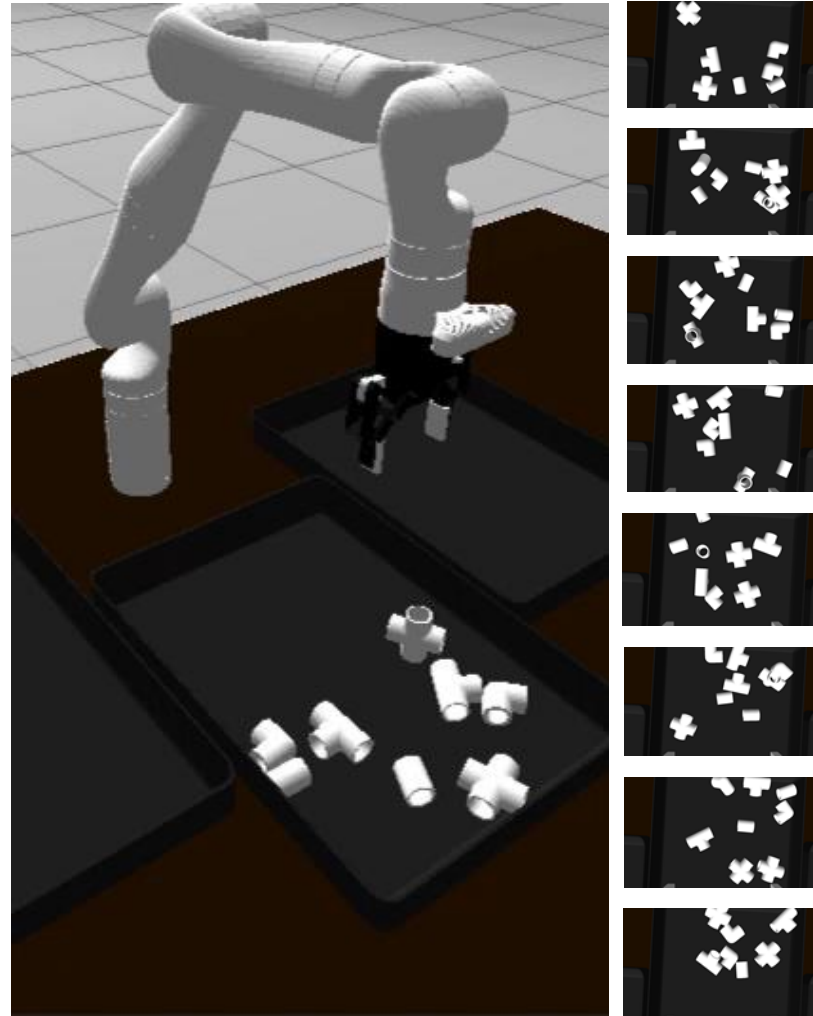
- 1 Data Preparation
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The image displays a multi-window software interface for simulating a motor-pump system and generating synthetic data for diagnostics.

- Top Left (Simulink):** Shows a block diagram of the system. A DC voltage source is connected to a motor block labeled "Driver: Motor". The motor's output is connected to a pump block labeled "Pump". The pump has three input ports (In1, In2, In3) and three output ports (Out1, Out2, Out3).
- Top Right (Mechanics Explorer):** Displays a 3D CAD model of the pump assembly, showing its internal components and external ports.
- Bottom Left (Pressure with Noise):** A simulation plot showing pressure over time. The y-axis ranges from 7.0 to 7.35, and the x-axis ranges from 0 to 1.5. Two data series are shown: "Sampled with Noise" (yellow dots) and "Simulation" (blue line). The plot shows a noisy signal that starts at approximately 7.05 and rises to about 7.3.
- Bottom Right (Diagnostics):** A diagnostic panel with a "pMeas" input field and a "pMeas" indicator light. Below it, the text "Diagnostics: On" is displayed. Four diagnostic indicators are shown as circles: "No Fault" (green), "Blocked Inlet" (grey), "Seal Leak" (grey), and "Worn Bearing" (grey).

Synthetic Data Generation

- 1 Data Preparation
- 2 AI Modeling
- 3 Simulation and Test
- 4 Deployment



Synthetic data generation with simulator



Data acquisition with hardware

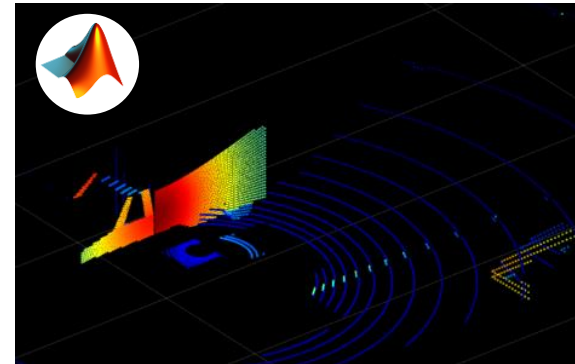
Synthetic Data Generation

- 1 Data Preparation
- 2 AI Modeling
- 3 Simulation and Test
- 4 Deployment



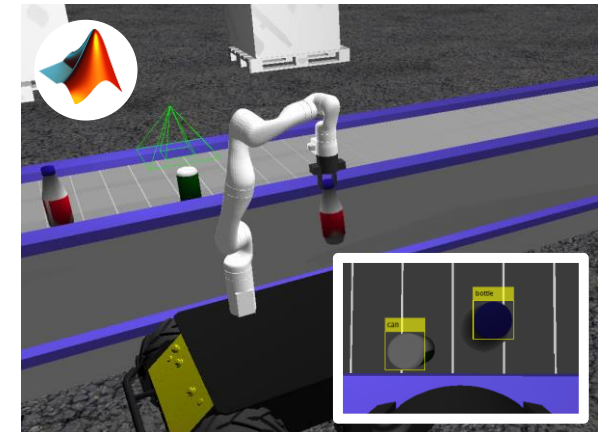
Semantic Segmentation from Unreal for UAV

UAV Toolbox
Simulink



Lidar Sensor Model: Simulate lidar sensor and generate point cloud data

Lidar Toolbox



Gazebo Co-simulation with a Pretrained Deep Learning Model to Detect Recyclable Parts

Robotics System Toolbox
ROS Toolbox

- 1 Data Preparation
- 2 AI Modeling
- 3 Simulation and Test
- 4 Deployment

Algorithms

Machine learning

Trees, Naïve Bayes, SVM...

Deep learning

CNNs, GANs, LSTM, MIMO...

Reinforcement learning

DQN, A2C, DDPG...

Regression

Linear, nonlinear, trees...

Unsupervised learning

K-means, PCA, GMM...

Predictive maintenance

RUL models, condition indicators...

Bayesian optimization

Pre-built models

Image classification models

AlexNet, GoogLeNet, VGG,
SqueezeNet, ShuffleNet, ResNet,
DenseNet, Inception...

Reference examples

Object detection

Vehicles, pedestrians, faces...

Semantic segmentation

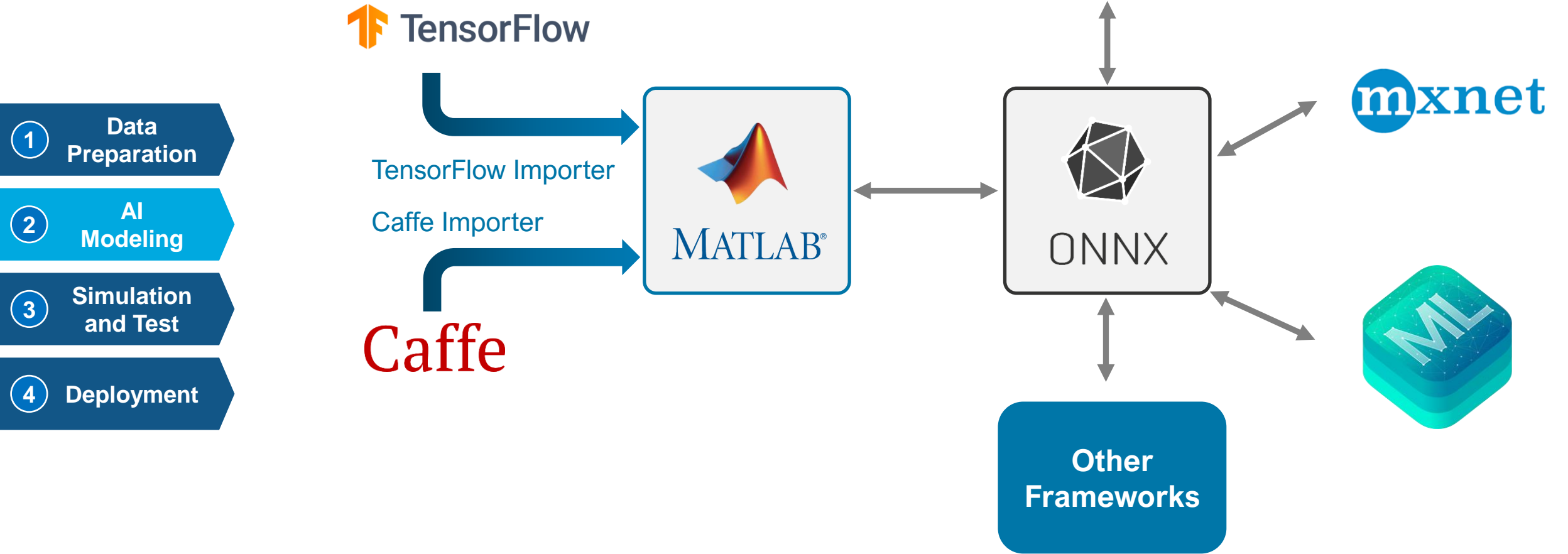
Roadway detection, land cover
classification, tumor detection...

Signal and speech processing

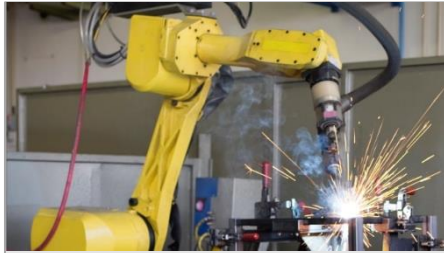
Denosing, music genre recognition,
keyword spotting, radar waveform
classification...

...and more...

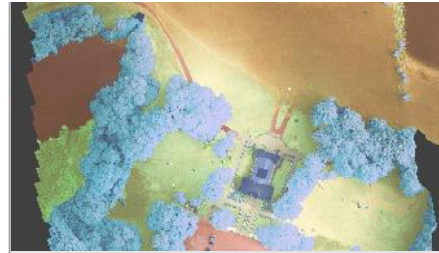
Leveraging the Larger AI Community



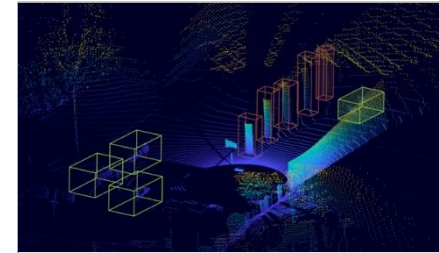
- 1 Data Preparation
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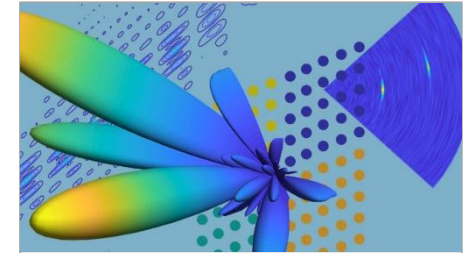
Predictive Maintenance
Anomaly Detection and Condition Monitoring



Geospatial Analysis
Hyperspectral Image Classification



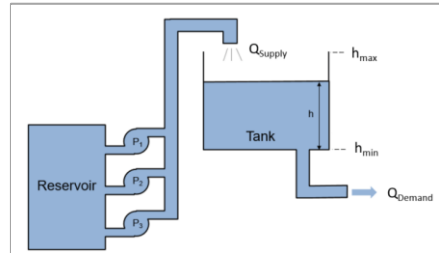
Lidar
3-D Point Cloud Object Detection



Radar
Waveform Classification



Wireless Comms
Data Synthesis for 5G Channel Estimation



Controls Systems
PID Tuning & System Scheduling



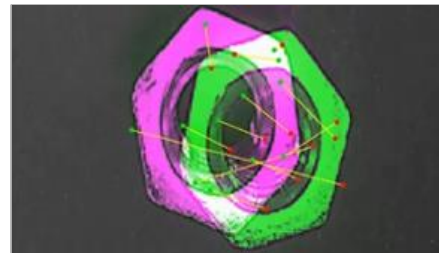
Computational Finance
Trading & Risk Management



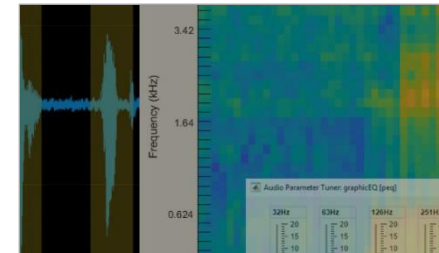
Automated Driving
Pedestrian & Vehicle Detection



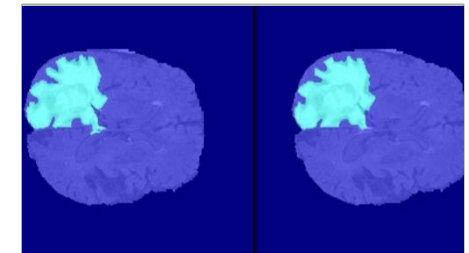
Robotics
Path Planning & Process Optimization



Visual Inspection
Defect Detection



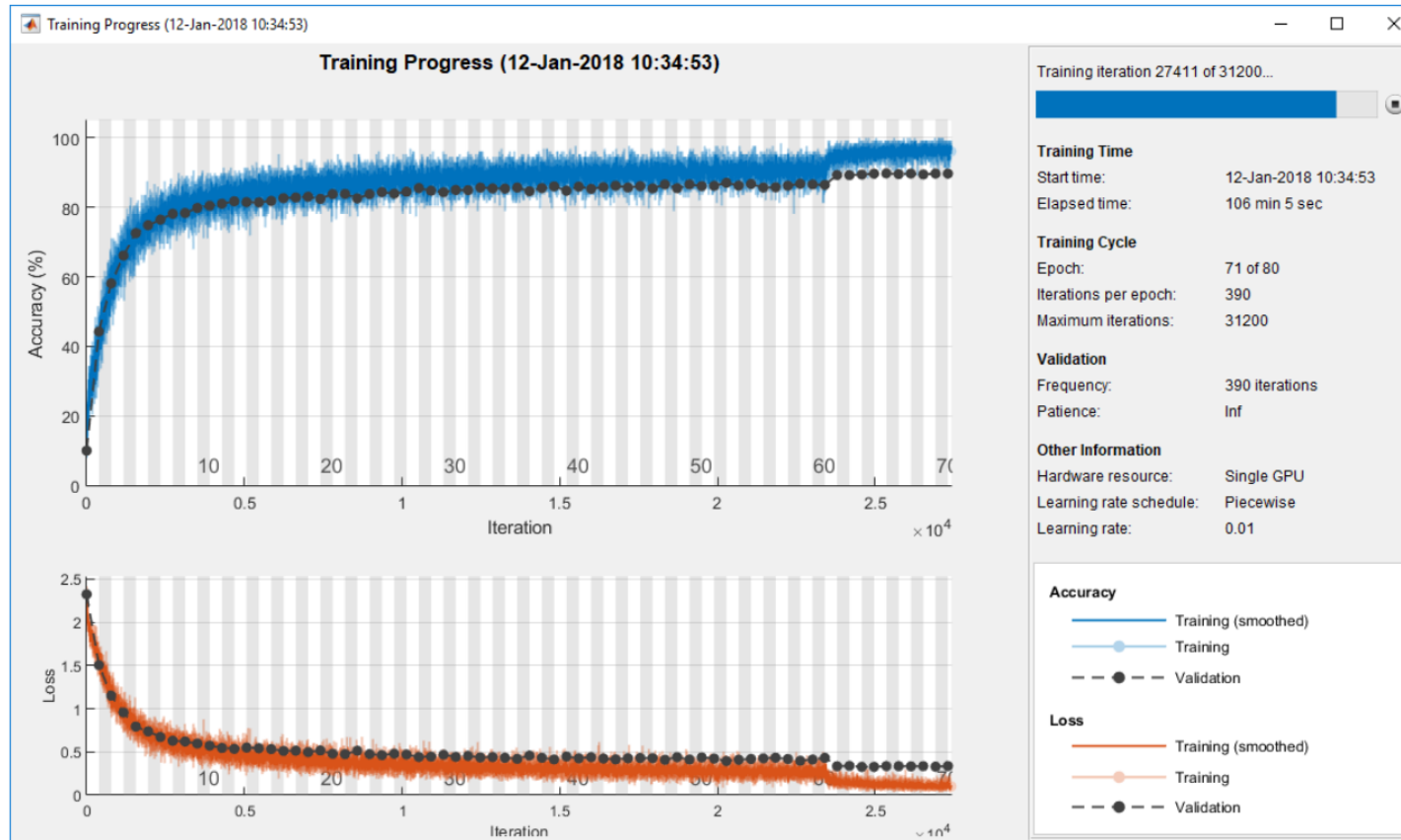
Audio
Speech Recognition



Medical Imaging
Tumor Detection

Training in Parallel and in the Cloud

- 1 Data Preparation
- 2 AI Modeling
- 3 Simulation and Test
- 4 Deployment



Interactive AI Apps

- 1 Data Preparation
- 2 AI Modeling
- 3 Simulation and Test
- 4 Deployment

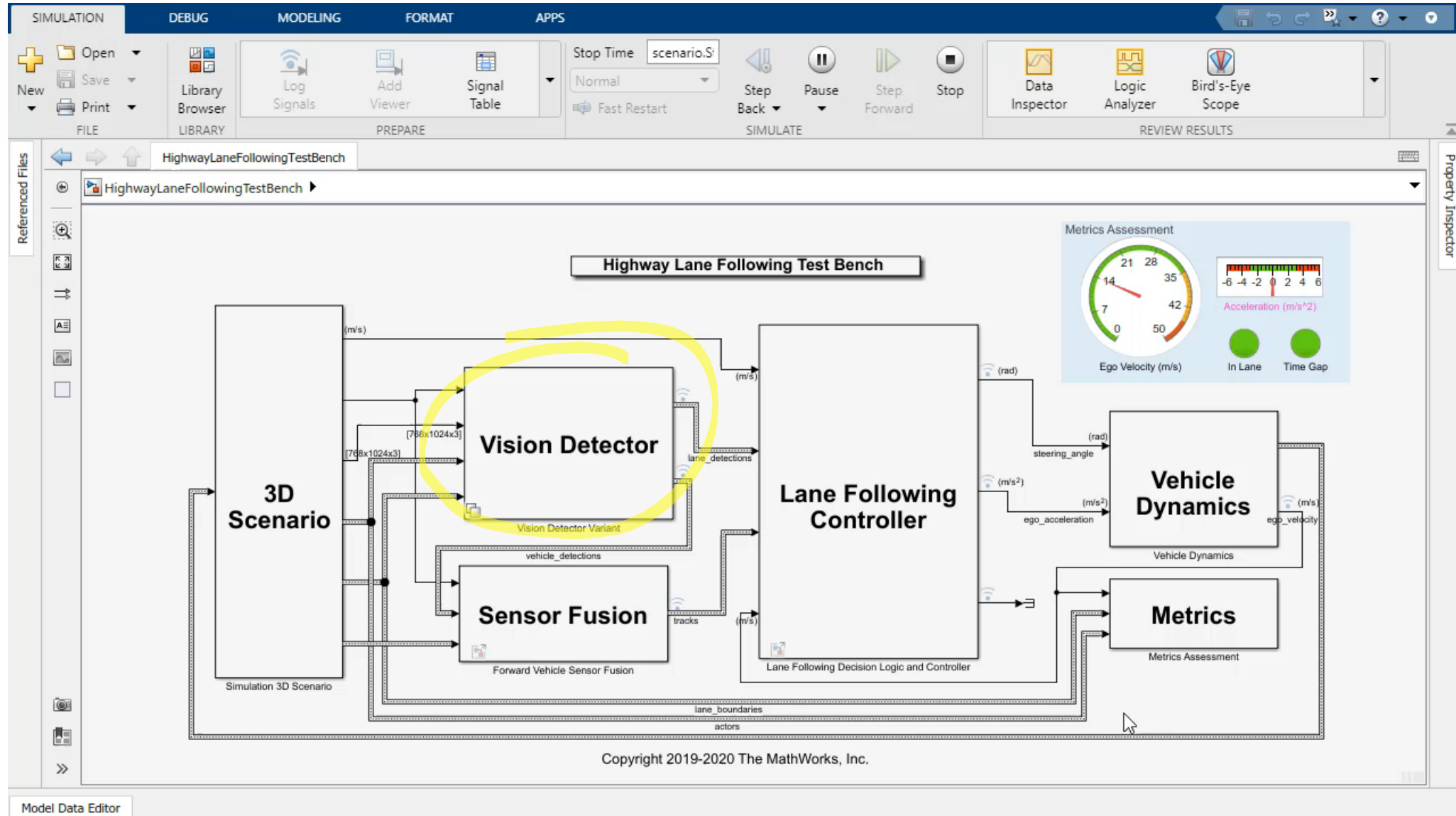
Classification Learner app to try different classifiers and find the best fit for data sets.

Deep Network Designer app to build, visualize, and edit deep learning networks.

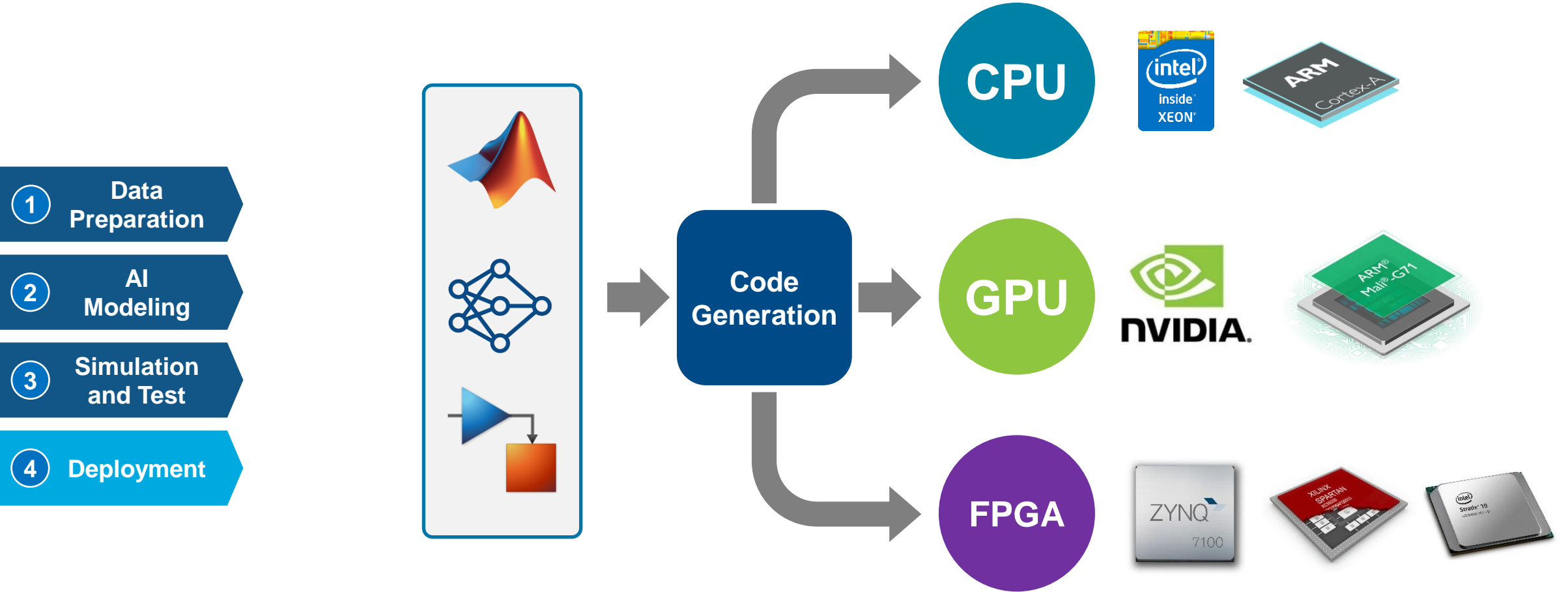
Experiment Manager app to run deep learning experiments to train networks and compare results.

System Simulation

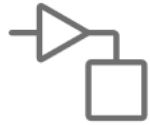
- 1 Data Preparation
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Deploy to Any Device with Zero Coding Errors



Model-Based Design: From Concept to Code



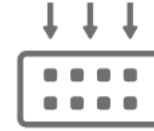
Model and Simulate Your System

Explore a wide design space by modeling the system under test and the physical plant. Your entire team can use one multi-domain environment to simulate how all parts of the system behave.



Test Early and Often

Reduce expensive prototypes by testing your system under conditions that are otherwise too risky or time-consuming to consider. Validate your design with hardware-in-the-loop testing and rapid prototyping. Maintain traceability from requirements to design to code.



Automatically Generate Code

Instead of writing thousands of lines of code by hand, automatically generate production-quality C and HDL code that behaves the same way as the model you created in Simulink. Then deploy it directly onto your MCU, DSP, or FPGA.

Systems Thinking in Education

Systems Thinking

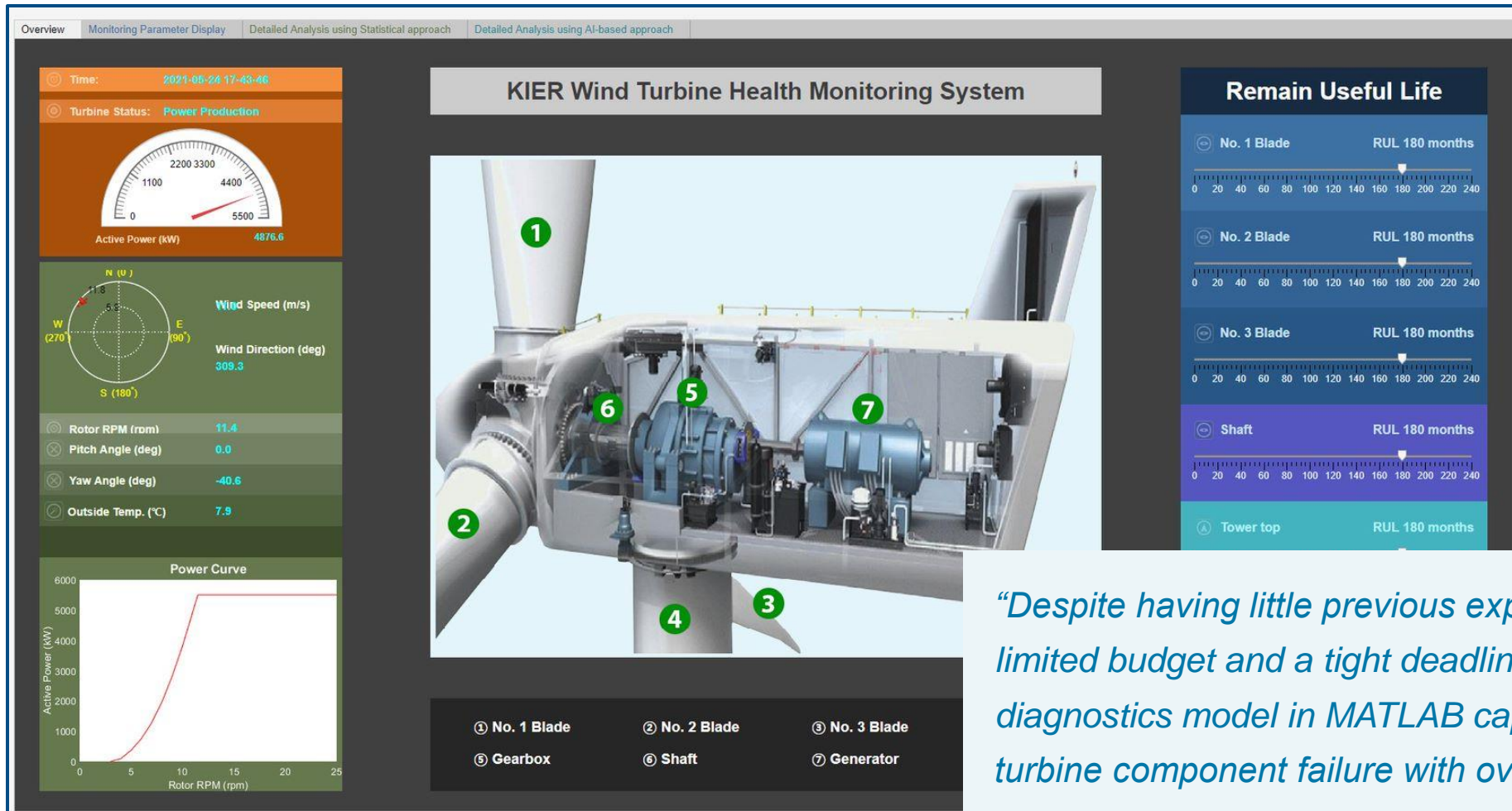
“ *Systems thinking is a framework for seeing interrelationships rather than things, for seeing ‘patterns of change’ rather than static ‘snapshots’.*

– **Dr. Peter Senge**

Systems Thinking in Education

- Why teach Systems Thinking?
 - How can Systems Thinking be taught?
 - What can we do to make it happen?

Korea Institute of Energy Research AI-Based Predictive Maintenance for Offshore Wind Power



“Despite having little previous experience with AI, within a limited budget and a tight deadline, we completed a diagnostics model in MATLAB capable of detecting wind turbine component failure with over 90%+ accuracy.”

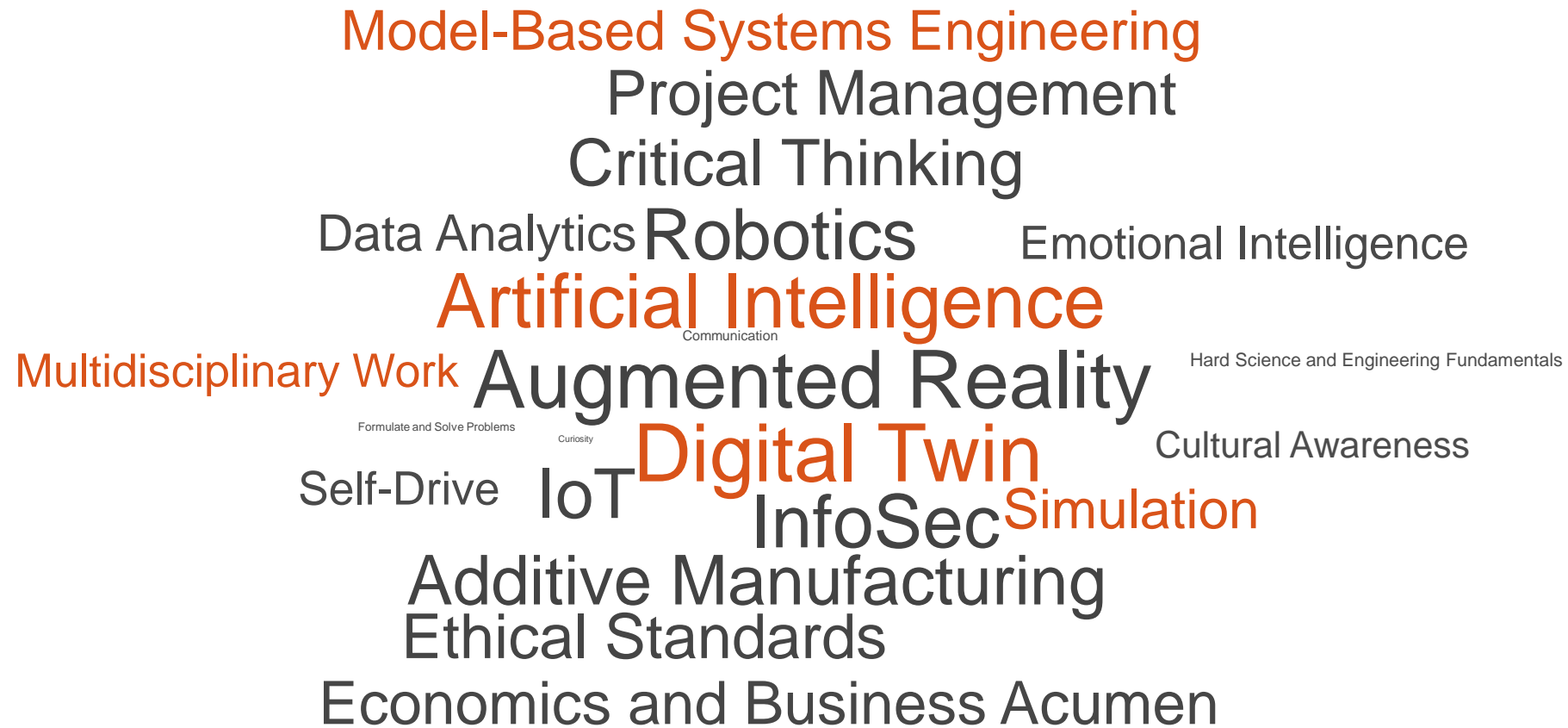
- Jung Chul Choi, Korea Institute of Energy Research

Systems Thinking

2020 Survey for skills gaps in recent engineering graduates (ASEE)

<https://monolith.asee.org/documents/cmc/2020-SURVEY-FOR-SKILLS-GAPS-IN-RECENT-ENGINEERING-GRADUATES.pdf>

80% of Engineering Graduates Feel “Not Very Prepared”



Systems Thinking in Education

Why teach Systems Thinking?

➤ How can Systems Thinking be taught?

What can we do to make it happen?

Bosch and National Institute of Technology Calicut Collaborate on EV Course to Prepare Students for Industry

Challenge

Address the shortage of automotive engineers with system engineering skills.

Solution

Jointly create a new undergraduate course in model-based system engineering as part of a collaboration between academia and industry.

Results

- Months of on-the-job training eliminated.
- Enrollment increased by 250%.
- 90%+ positive feedback.



Pradeep Kumar of Bosch India lighting the ceremonial lamp with Dr. Sivaji Chakravorti of NIT Calicut before signing the agreement.

“The collaboration between NIT Calicut, MathWorks, and Bosch narrowed the gap between academia and industry, producing an electric vehicle system engineering course that has been both well received by our students and highly useful for them as well.”
- Dr. Kumaravel Sundaramoorthy, NIT Calicut

Challenges in Teaching Systems Thinking

- Access to Industry-grade tools and software.
- No time to introduce the students to the tools.
- Little time to update the curricula.
- Need for attractive teaching materials.
- Access to affordable hardware.
- Compelling projects for students to work on.
- Few connections with Industry.

Systems Thinking in Education

Why teach Systems Thinking?

How can Systems Thinking be taught?

➤ What can we do to make it happen?

Resources to consider:

MathWorks Excellence in Innovation Projects



Contribute to the progress of engineering and science by solving key industry challenges

Are you looking based on industries you learn about technical components for your problem?

Projects by technology trends

- 5G
- Artificial Intelligence
- Autonomous Vehicles
- Big Data
- Computer Vision
- Drones
- Industry 4.0
- Neuroscience
- Robotics
- Sustainability and Renewable Energy



Flight Controller Design and Hardware Deployment

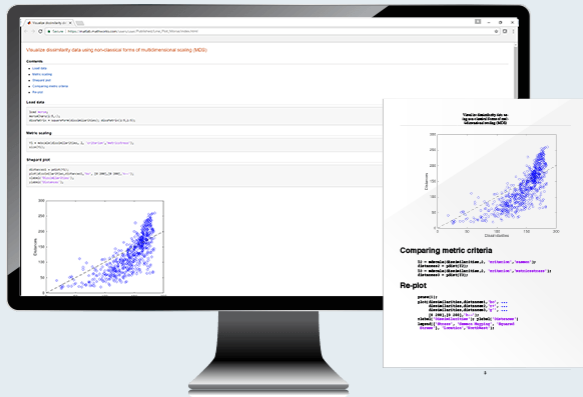
Build a mini drone and use the PX4 Hardware Support package to design the flight controller using Simulink.



Portable Charging System for Electric Vehicles

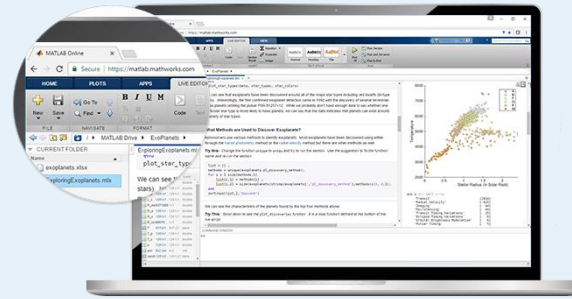
Design a portable charger for Electric Vehicles

Anytime, Anywhere Access for Faculty, Students, and Visitors



MATLAB and Simulink for Desktops

Access MATLAB and Simulink on personal and university-owned machines



MATLAB Online and Simulink Online

Access MATLAB and Simulink with a web browser



MATLAB Mobile

Access MATLAB on iOS/Android devices

www.mathworks.com/matlab-campus

matlab.mathworks.com



Self-Paced Online Training



**MATLAB
Onramp**



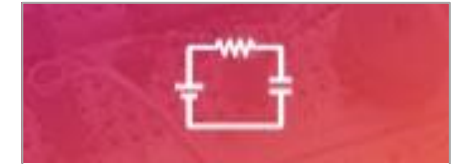
**Simulink
Onramp**



**Stateflow
Onramp**



**Control Design
Onramp**



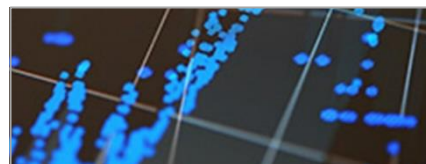
**Circuit Simulation
Onramp**



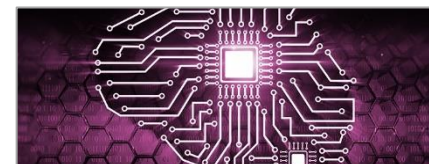
**Machine Learning
Onramp**



**Deep Learning
Onramp**



**MATLAB for Data
Processing and
Visualization**



**Machine Learning
with MATLAB**



**Deep Learning
with MATLAB**

Freely Reusable Courseware



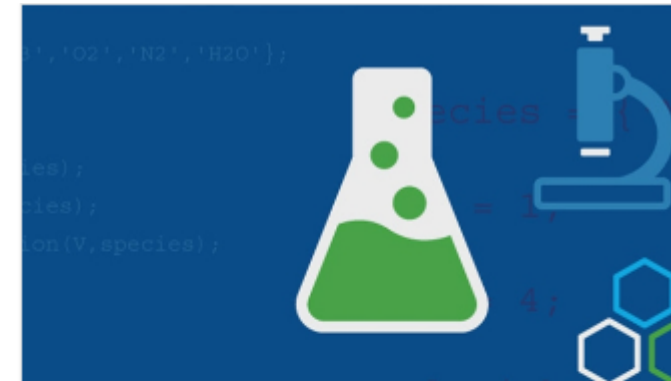
Teaching Calculus with MATLAB

- » Integrate MATLAB into your Calculus curriculum



Teaching Physics with MATLAB

- » Integrate MATLAB into your Physics curriculum



Teaching Chemistry with MATLAB

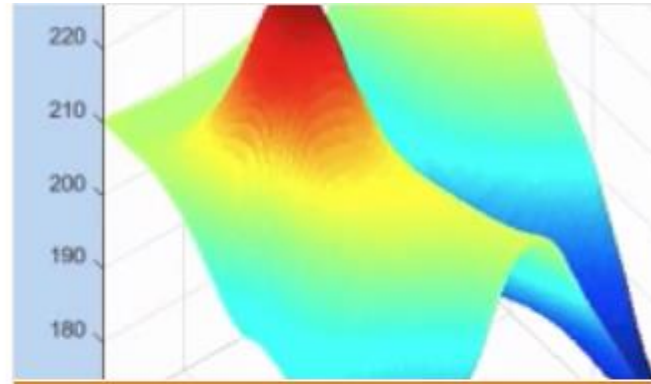
- » Integrate MATLAB into your Chemistry curriculum

Freely Reusable Courseware



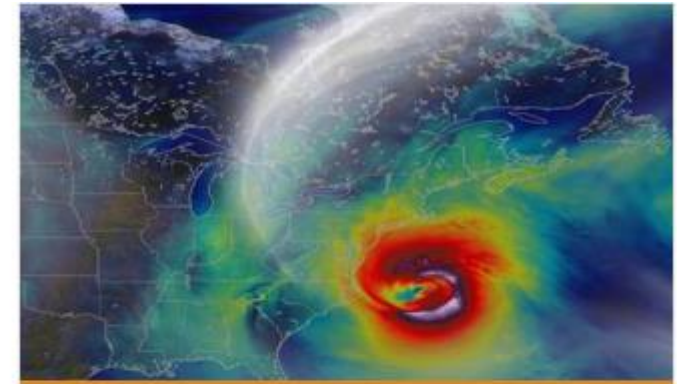
Teaching Biology with MATLAB

- » Integrate MATLAB into your Biology curriculum



Teaching Geoscience with MATLAB

- » Integrate MATLAB into your Geoscience curriculum



Teaching Computational Science Using MATLAB

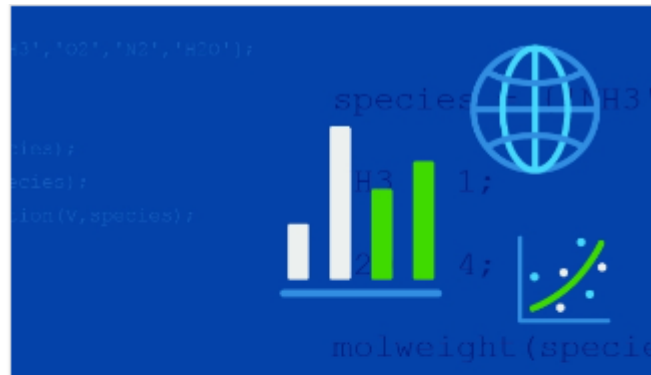
- » Integrate MATLAB into your robust data analysis, data visualization and exploration curriculum

Freely Reusable Courseware



Teaching Psychology and Neuroscience with MATLAB

- » Integrate MATLAB into your Psychology and Neuroscience curriculum



Teaching Econometrics with MATLAB

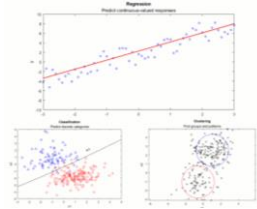
- » Integrate MATLAB into your Econometrics curriculum



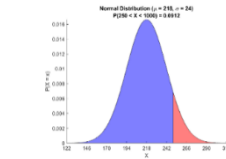
Teaching Quantitative Finance and Risk Management with MATLAB

- » Integrate MATLAB into your Quantitative Finance and Risk Management curriculum

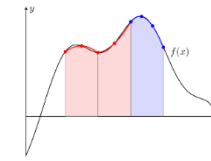
Modular Courseware



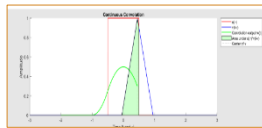
Machine Learning



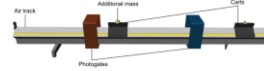
Statistics



Numerical Integration



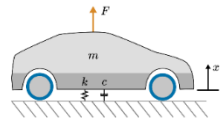
Convolution



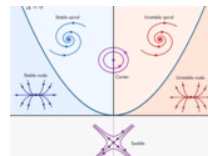
Lab: Air Track

$$AV = \begin{pmatrix} a_{11} & a_{12} & \dots & a_{1n} \\ a_{21} & a_{22} & \dots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{m1} & a_{m2} & \dots & a_{mn} \end{pmatrix} \begin{pmatrix} v_1 \\ v_2 \\ \vdots \\ v_n \end{pmatrix} = \begin{pmatrix} a_{11}v_1 + a_{12}v_2 + \dots + a_{1n}v_n \\ a_{21}v_1 + a_{22}v_2 + \dots + a_{2n}v_n \\ \vdots \\ a_{m1}v_1 + a_{m2}v_2 + \dots + a_{mn}v_n \end{pmatrix}$$

Matrix Methods



Mass-Spring-Damper



Qualitative Analysis of ODEs

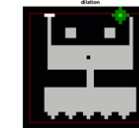
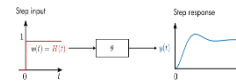
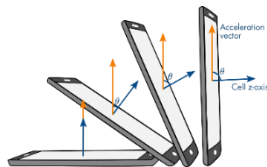


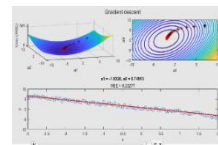
Image Processing



Dynamic Systems



Vectors



Regression



Lab: Virtual e/m Measurement

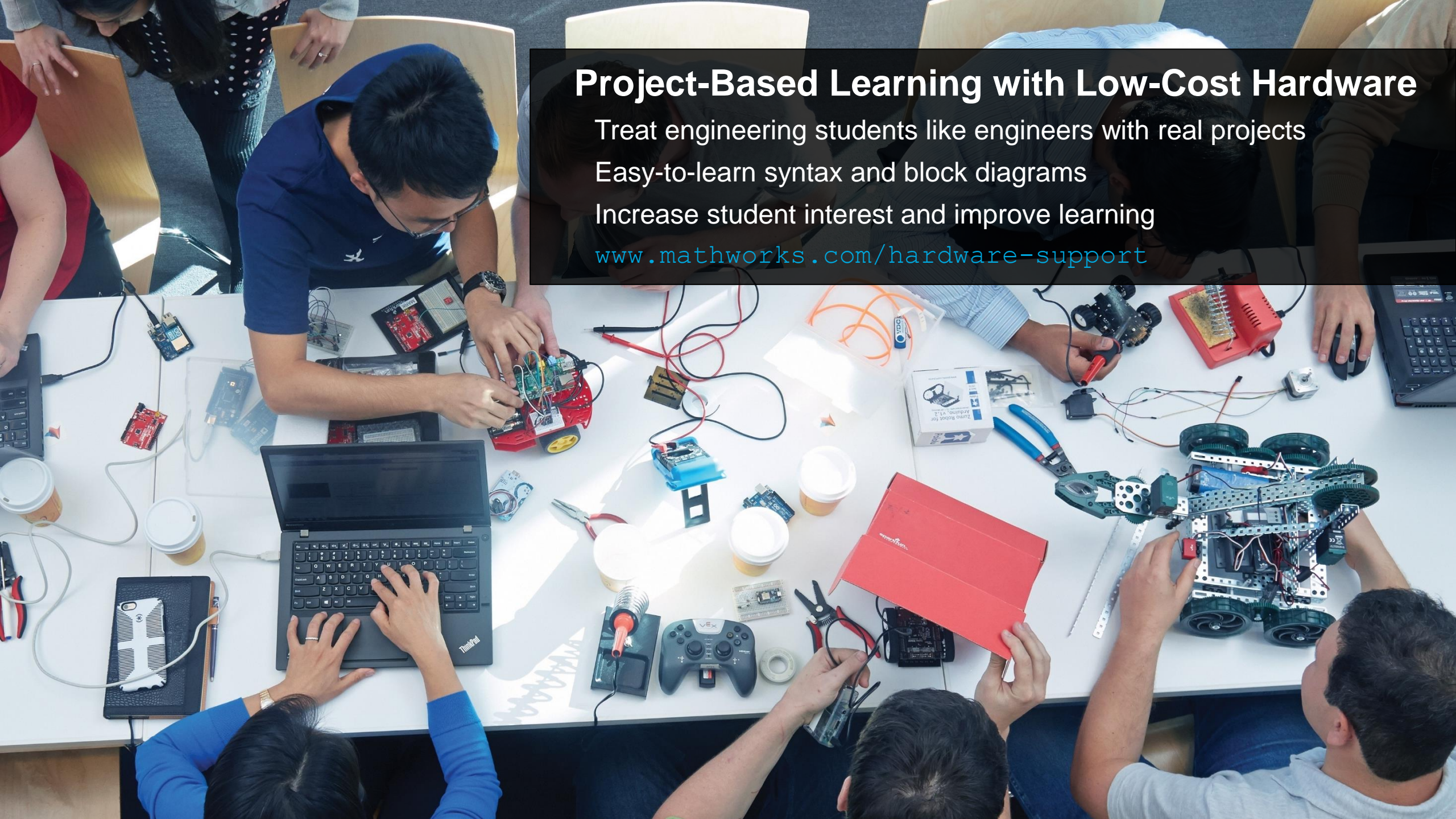
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