Agriculture

Gen Sasaki
Principal Academic Engineer

Armando Garcia
Senior Academic Engineer

Sarah Fayyad
Senior Account Manager

Recent Challenges in Agriculture

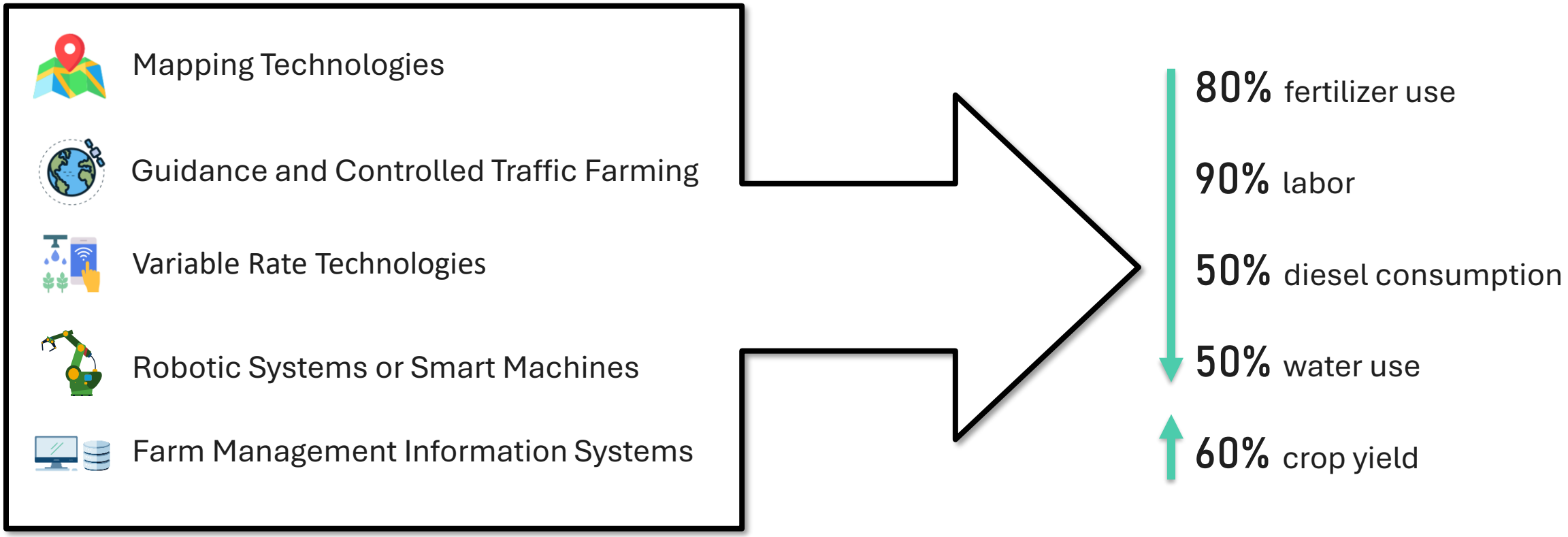
- Long-term climate change and extreme weather events
- Increased price of inputs
- Food security and supply chain resilience

Digital Agriculture

Goal: *Improve farming efficiency, productivity, and sustainability to meet increasing food requirements considering rising production costs, labor shortages, environmental changes, and strained natural resources.*

- **Digitalization** and **automation** of farming tasks
- Collecting, analyzing, and taking actions **based on data** [1]
- **Precise responses** to observations and measurements of within-field variability [2]

Benefits of digital agriculture



Papadopoulos et al, Economic and environmental benefits of digital agricultural technologies in crop production: A review, Smart Agricultural Technology, Volume 8, 2024

Headquarters

Natick, MA USA

North America

United States

Europe

Finland
France
Germany
Ireland
Italy
Netherlands
Spain
Sweden
Switzerland
UK

Asia-Pacific

Australia
China
India
Japan
Korea
Singapore

MathWorks®

5 million+ users

in more than 180 countries

6500+

academic institutions

100,000+

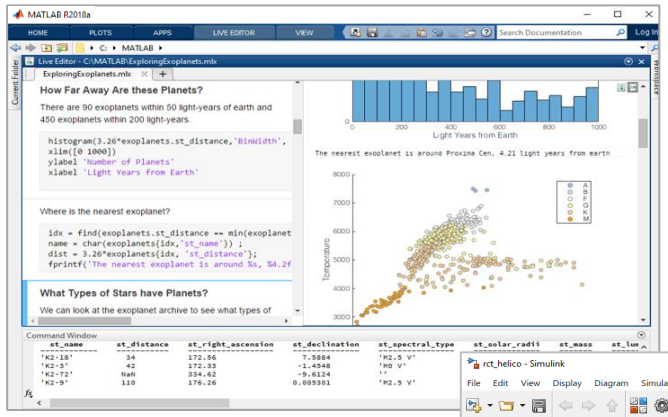
businesses, governments, and universities

top agricultural machinery and technology companies

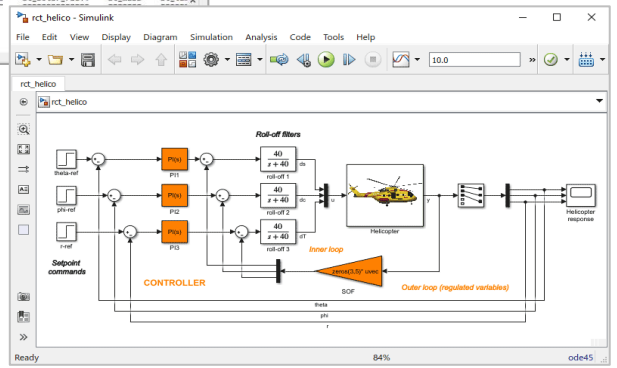
MATLAB® & SIMULINK®

- **MATLAB** – Create algorithms and AI models for agricultural data analysis
- **Simulink** – Simulate complex equipment and machinery with sensors and software
- **120+ products** for specialized R&D tasks

MATLAB



Simulink



MATLAB

- Analyze data, develop algorithms, and create models
- Community-developed tools
- Leverage interoperability

Data Analysis

Graphics

Programming

Data Analysis

External Language Interface

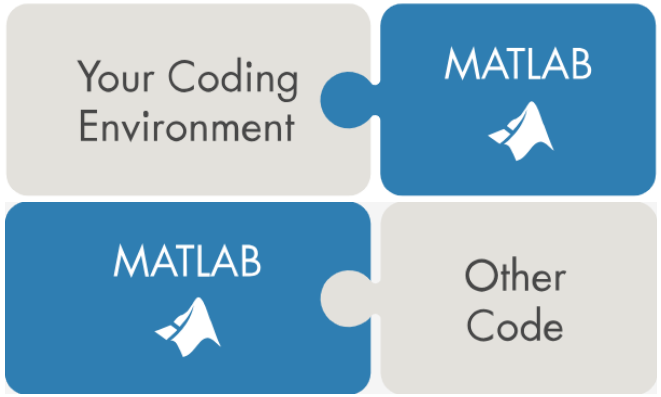
Hardware

Parallel Computing

Web & Desktop Deployment

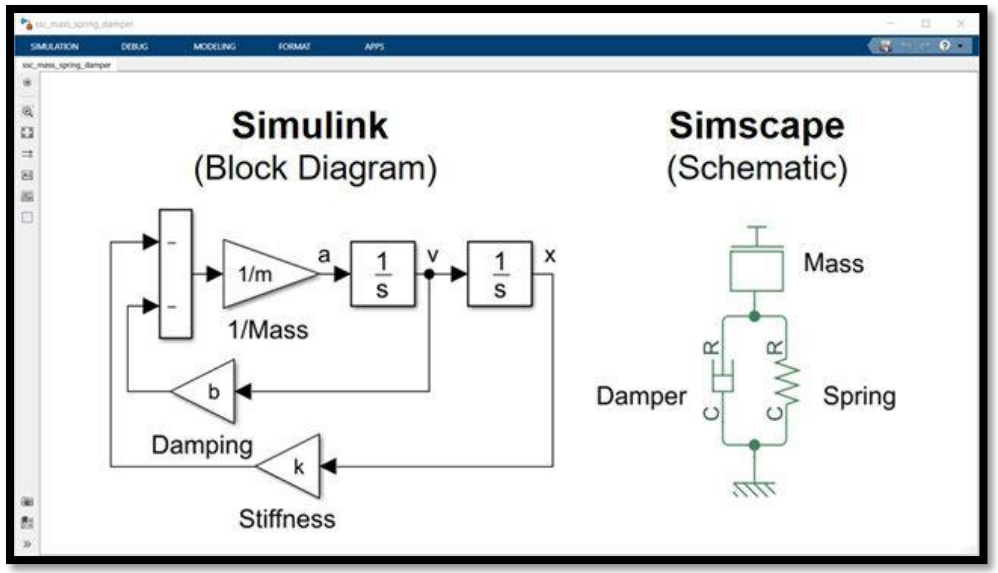
MATLAB In the Cloud

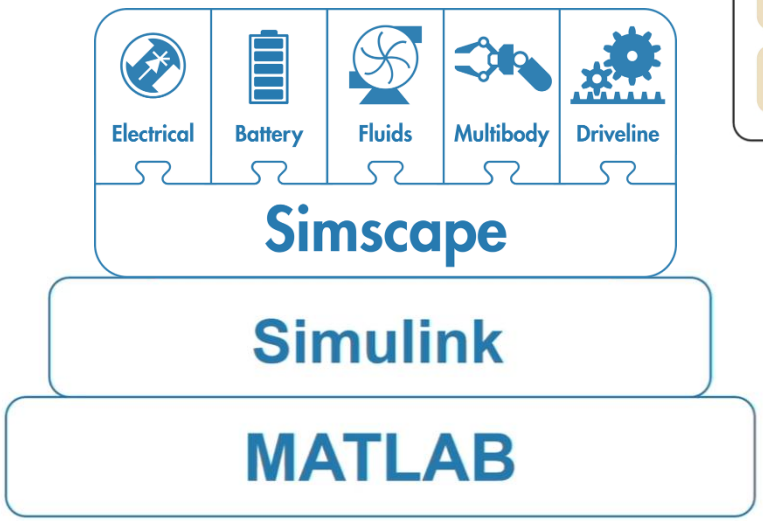
MATLAB Excel Java C/C++ .exe .NET .dll Python

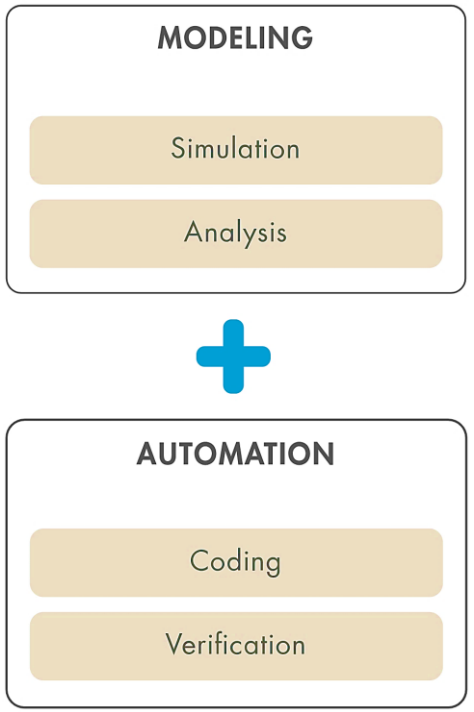


Simulink

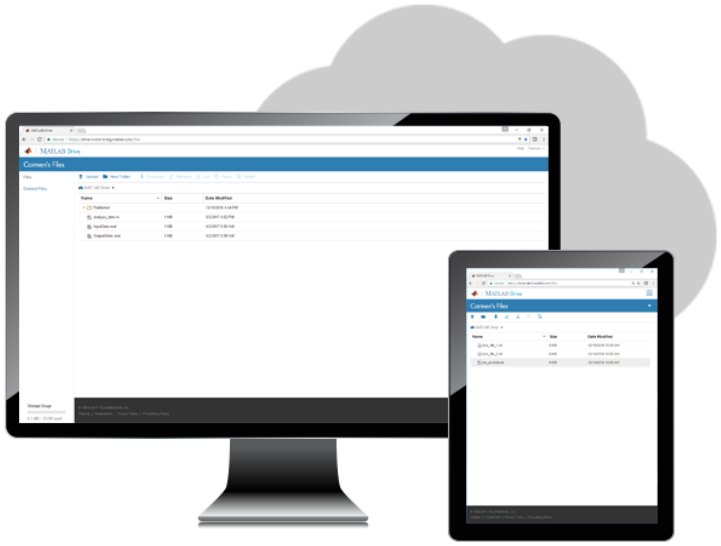
- Model and simulate **dynamical systems**
- **Graphical** environment
- **Multi-domain** with built-in custom components
- **Simulate** before moving to hardware
- **Deploy** without writing code







MATLAB Online

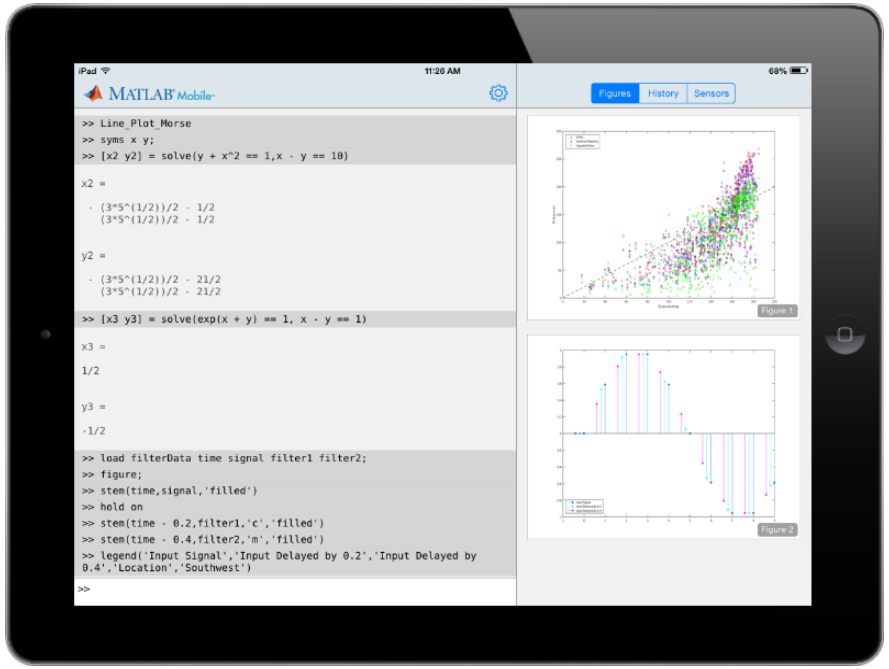


Simulink Online

MATLAB Drive

- No installation required
- Most recent version of MATLAB always
- No minimum device specs required – only an internet browser

MATLAB Mobile



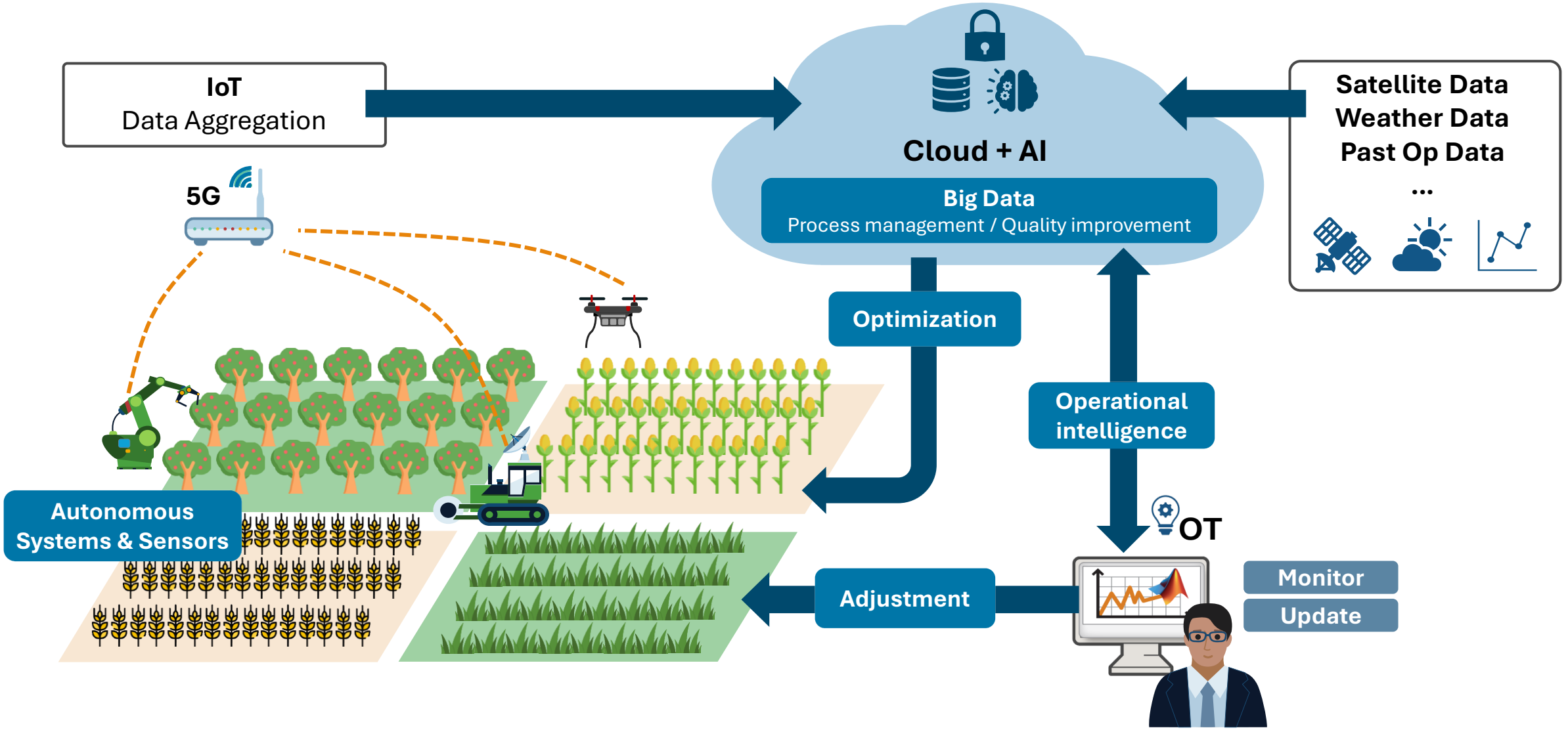
Connect to MATLAB Mobile

Acquire Sensor Data

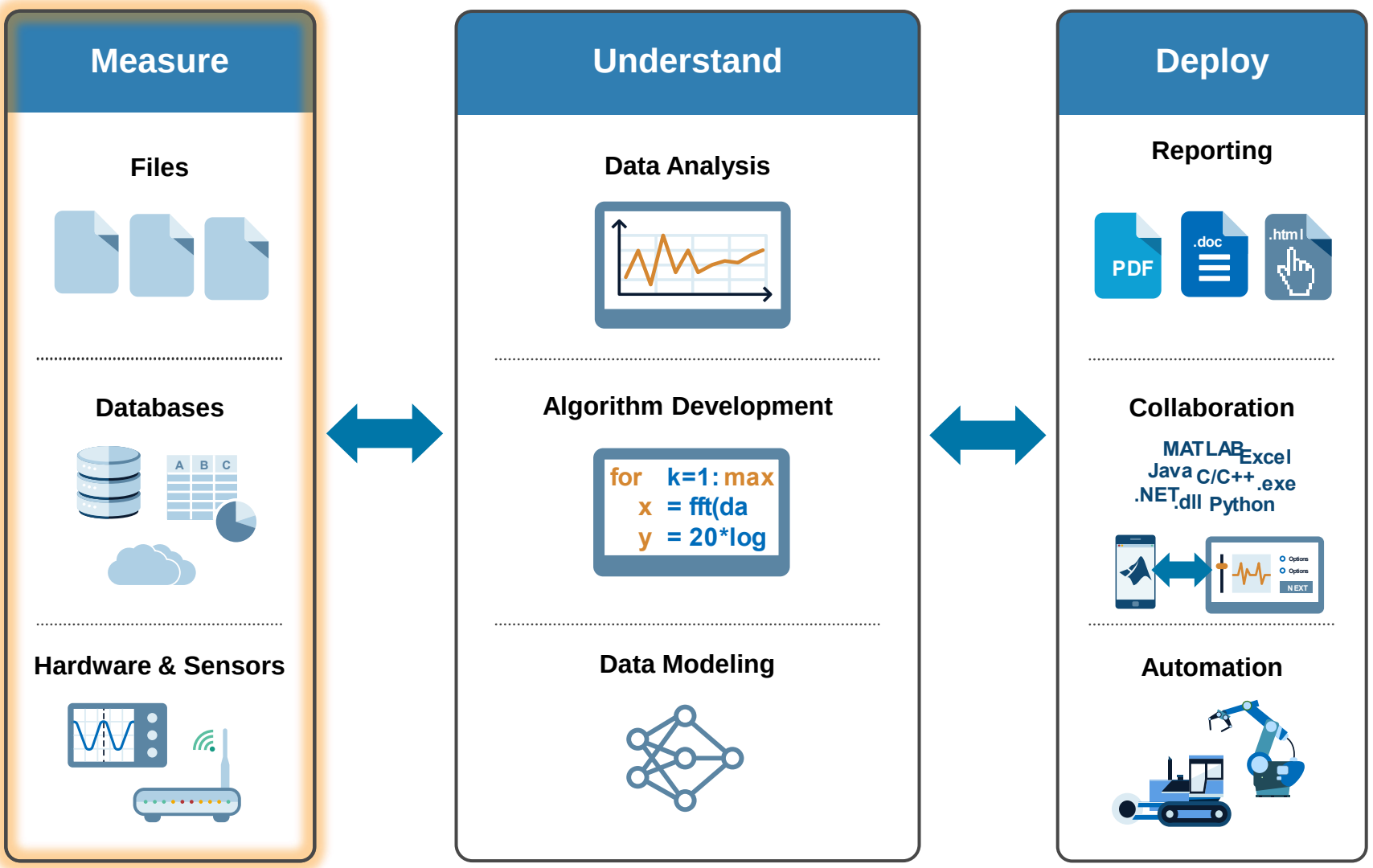
Capture Images, Video, and Audio

Learn and Teach

Digital Agriculture: Autonomy + Intelligence



Digital Agriculture Workflows involve Common Steps



Data can come from different sources

Data types and formats

- Tabular (CSV, .txt)
- NetCDF, HDF5, GRIB, Radar and more
- Images, video and Lidar

Databases

- Cloud storage services (e.g., AWS S3, Azure Blob), OPC UA, RESTful web services, and databases
- Climate Data Store Toolbox for MATLAB
- Hydroshare
- NASA Earth Data through Openscapes
- USGS
- DataONE
- NCAR…

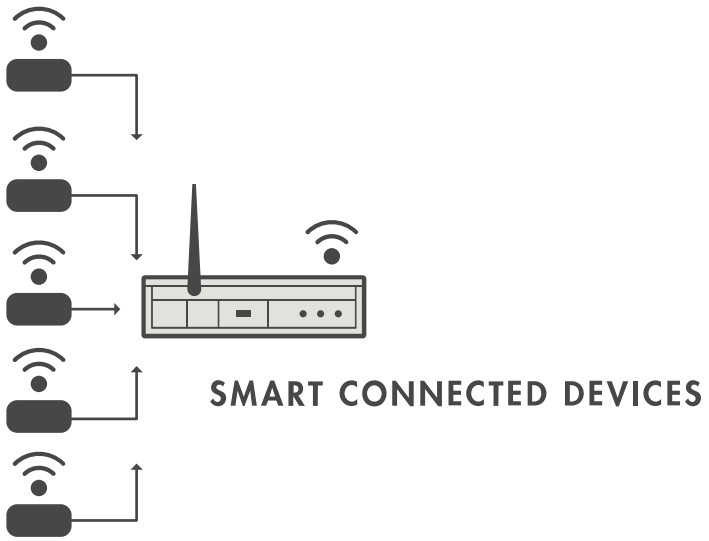
Sensors and hardware

- Test instruments
- Plug-in data acquisition devices
- Support packages for devices like Arduino and Raspberry PI
- TCP/IP, serial and external interfaces support
- OPC UA, Modbus, MQTT, OSIsoft PI servers
- Industrial and scientific cameras
- Many more devices

IoT allows us to do things more efficiently and smarter

Network of devices or things

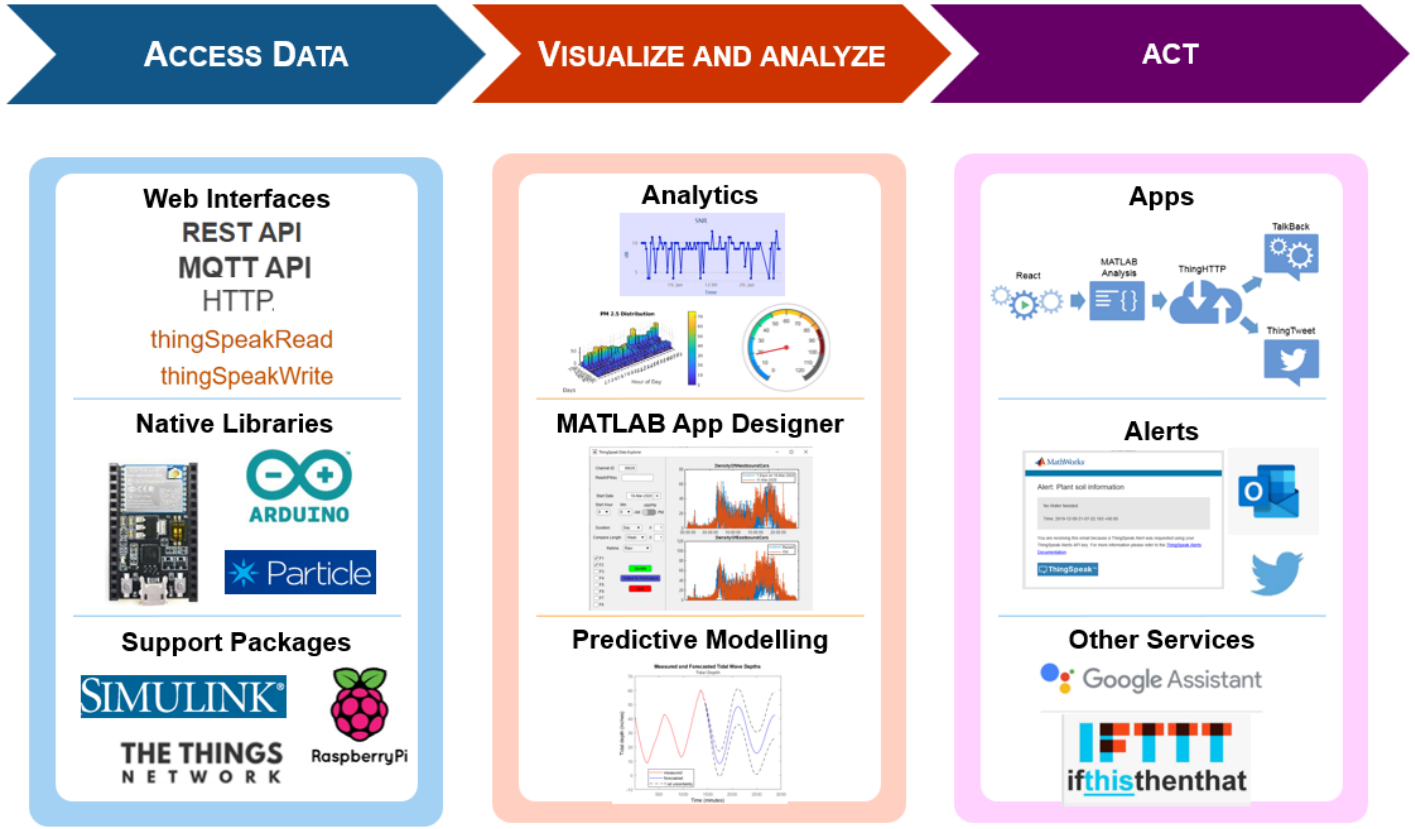
- Embedded devices with sensors
- Place to aggregate and analyze data
- Access to data and MATLAB allows algorithm development



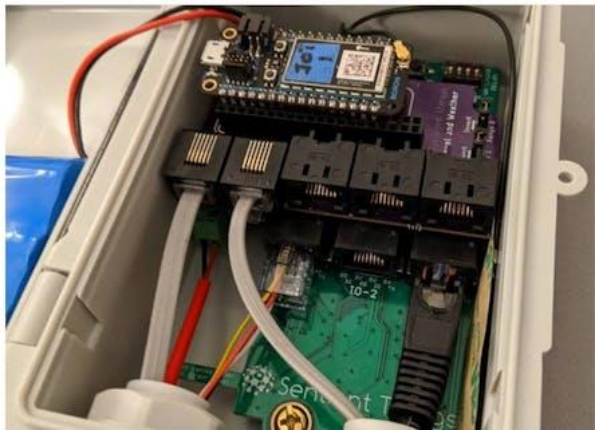
IoT allows us to do things more efficiently and smarter

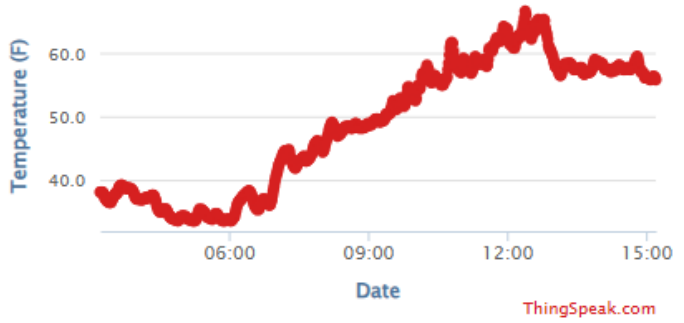
Network of devices or things

- Embedded devices with sensors
- Place to aggregate and analyze data
- Access to data and MATLAB allows algorithm development

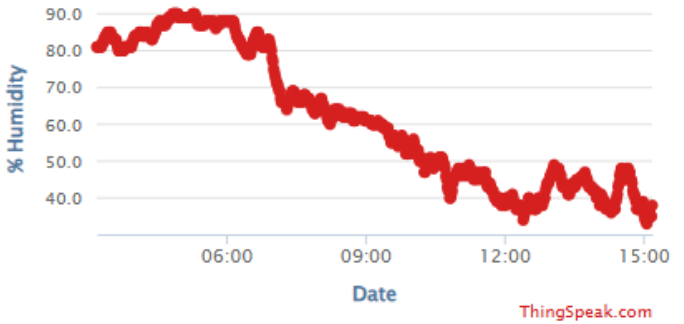


Demo: Importing weather data from ThingSpeak

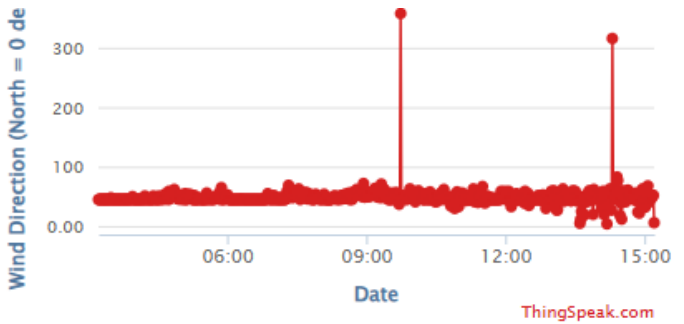




Temp



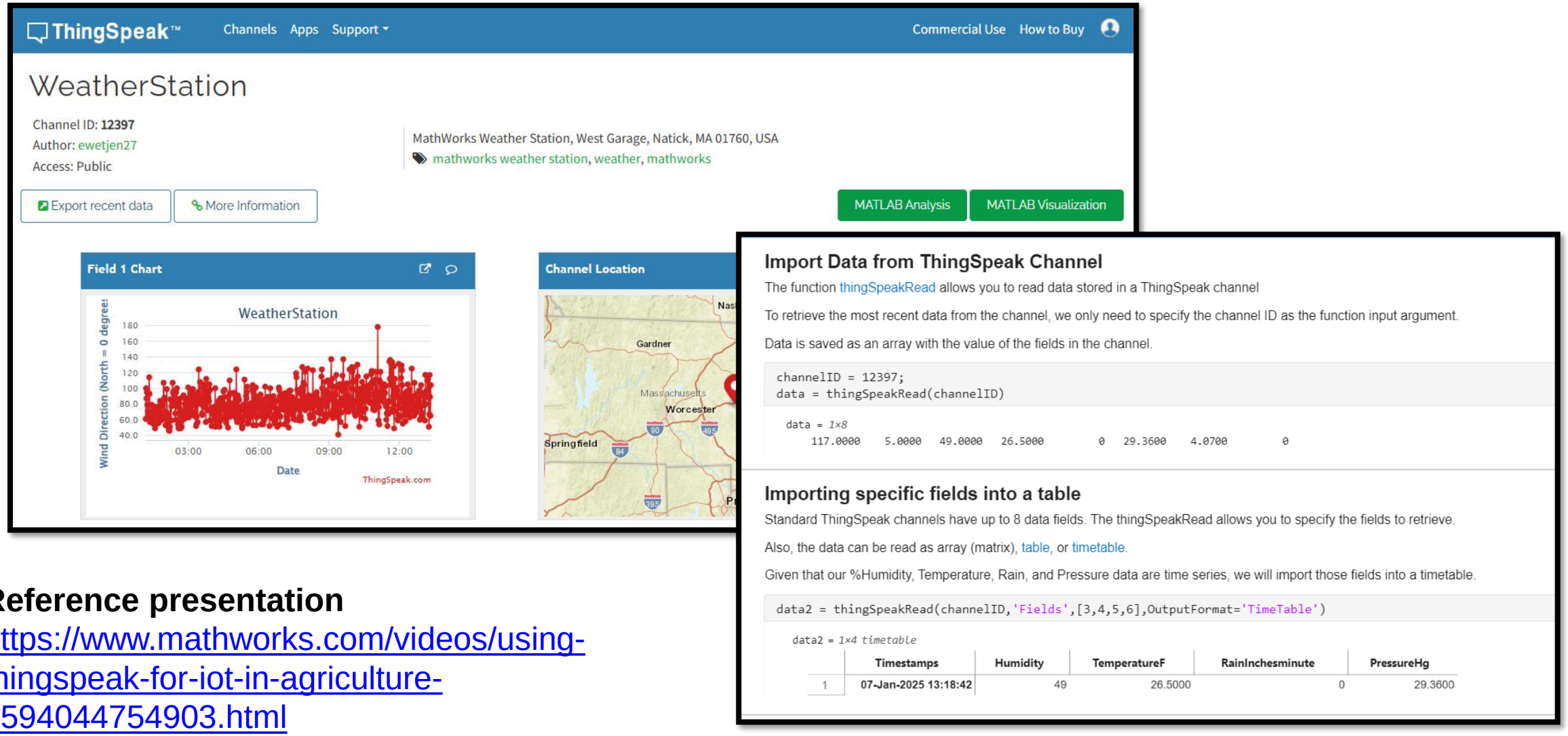
Humidity



Wind Direction

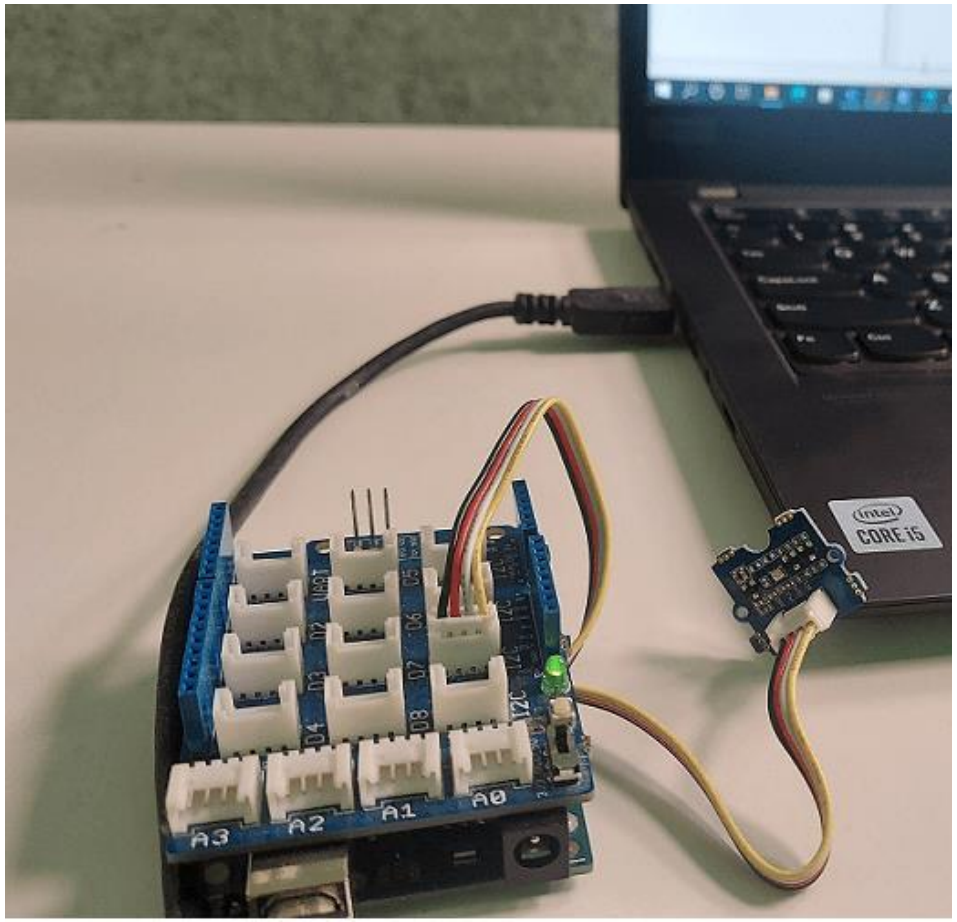
[Solar Powered Cellular Weather Station - Hackster.io]

Demo: Importing weather data from ThingSpeak



Reference presentation
https://www.mathworks.com/videos/using-thingspeak-for-iot-in-agriculture-1594044754903.html

Arduino with Thingspeak



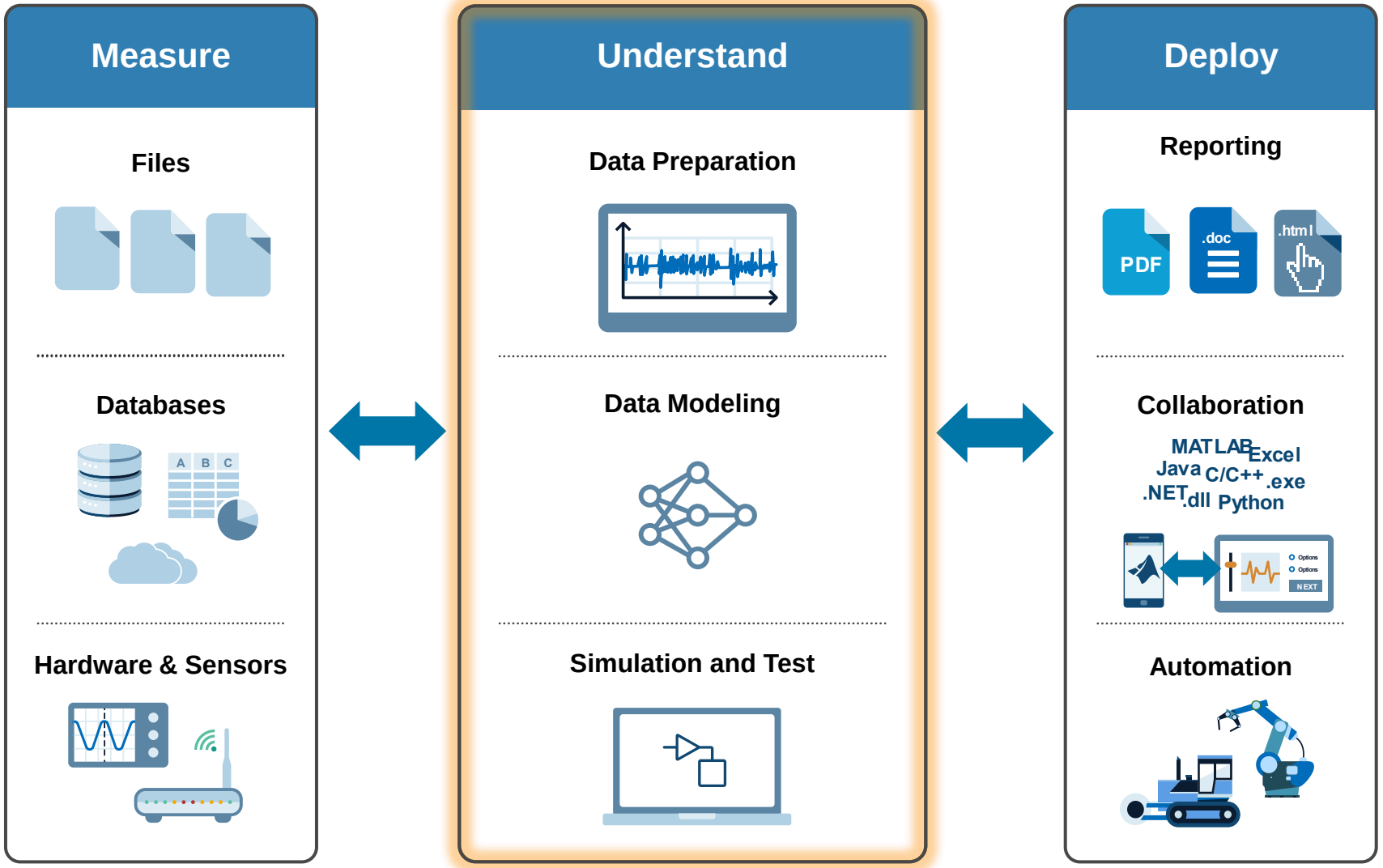
Read sensor

```
a=arduino('COM9','Uno','Libraries','I2C')

sensorObj=bmp280(a);

while 1
    temp=readTemperature(sensorObj);
    thingSpeakWrite(xxxxxx,temp,'WriteKey','XXXXXXXXX','Fields',1);
    pause(300); %sending data every 5 minutes

end
```

Analyze

```
readChannelID = xxxxxx;
TemperatureFieldID = 1;
readAPIKey = 'XXXXXXX';
[tempF,timeStamp] = thingSpeakRead(readChannelID,'Fields',TemperatureFieldID, ...
                                                    'numDays',1,'ReadKey',readAPIKey);
[maxTempF,maxTempIndex] = max(tempF);
[minTempF,minTempIndex] = min(tempF);

timeMaxTemp = timeStamp(maxTempIndex);
timeMinTemp = timeStamp(minTempIndex);

display(maxTempF,'Maximum Temperature for the past 24 hours is');
display(minTempF,'Minimum Temperature for the past 24 hours is');

writeAPIKey = 'XXXXXXXX';

thingSpeakWrite(readChannelID,[minTempF,maxTempF],'WriteKey',writeAPIKey,'Fields',[2,3]);
```

MATLAB and Simulink enable Digital Agriculture workflows



Artificial Intelligence (AI)

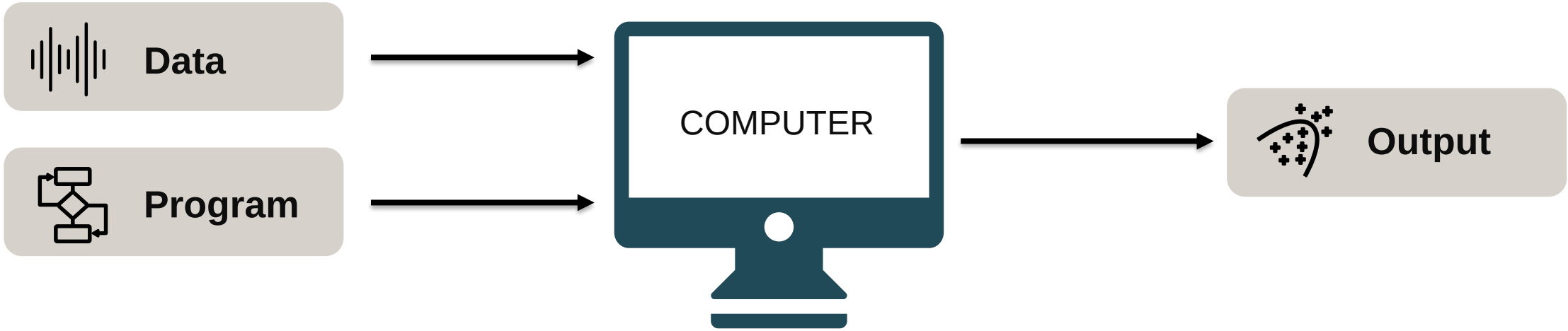
The capability of a machine to imitate intelligent human behavior

Artificial Intelligence Today

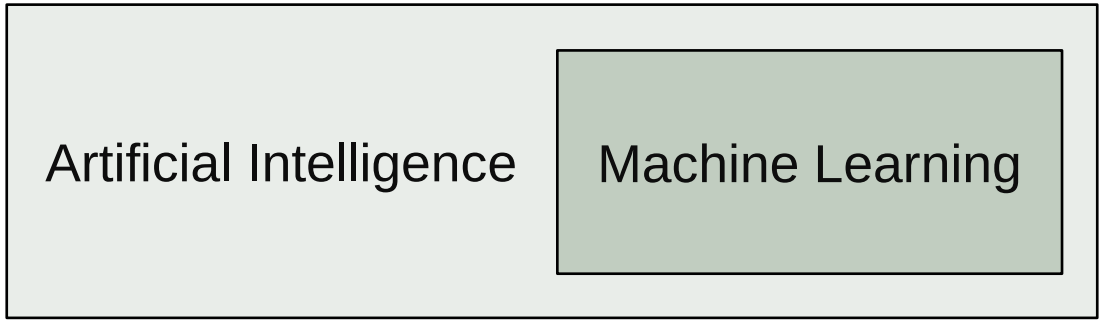
The capability of a machine to match or exceed intelligent human behavior

by training a machine to learn the desired behavior

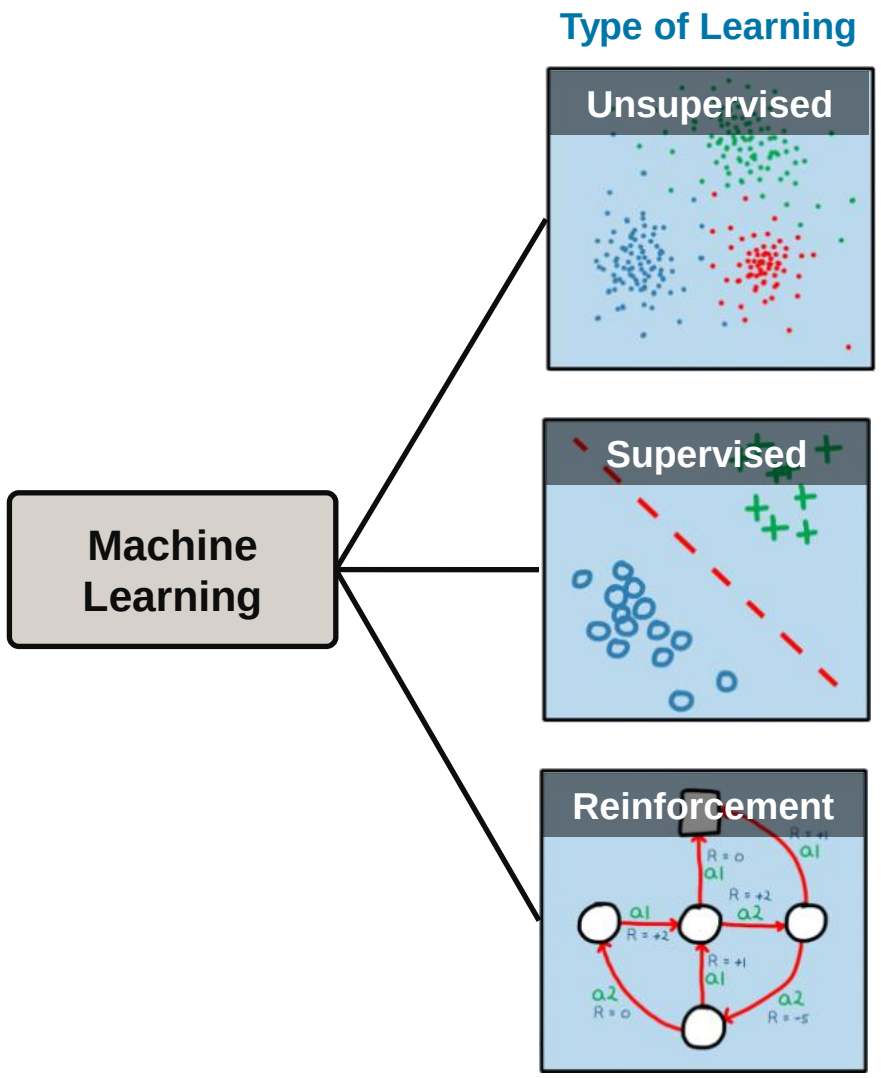
There are two ways to get a computer to do what you want



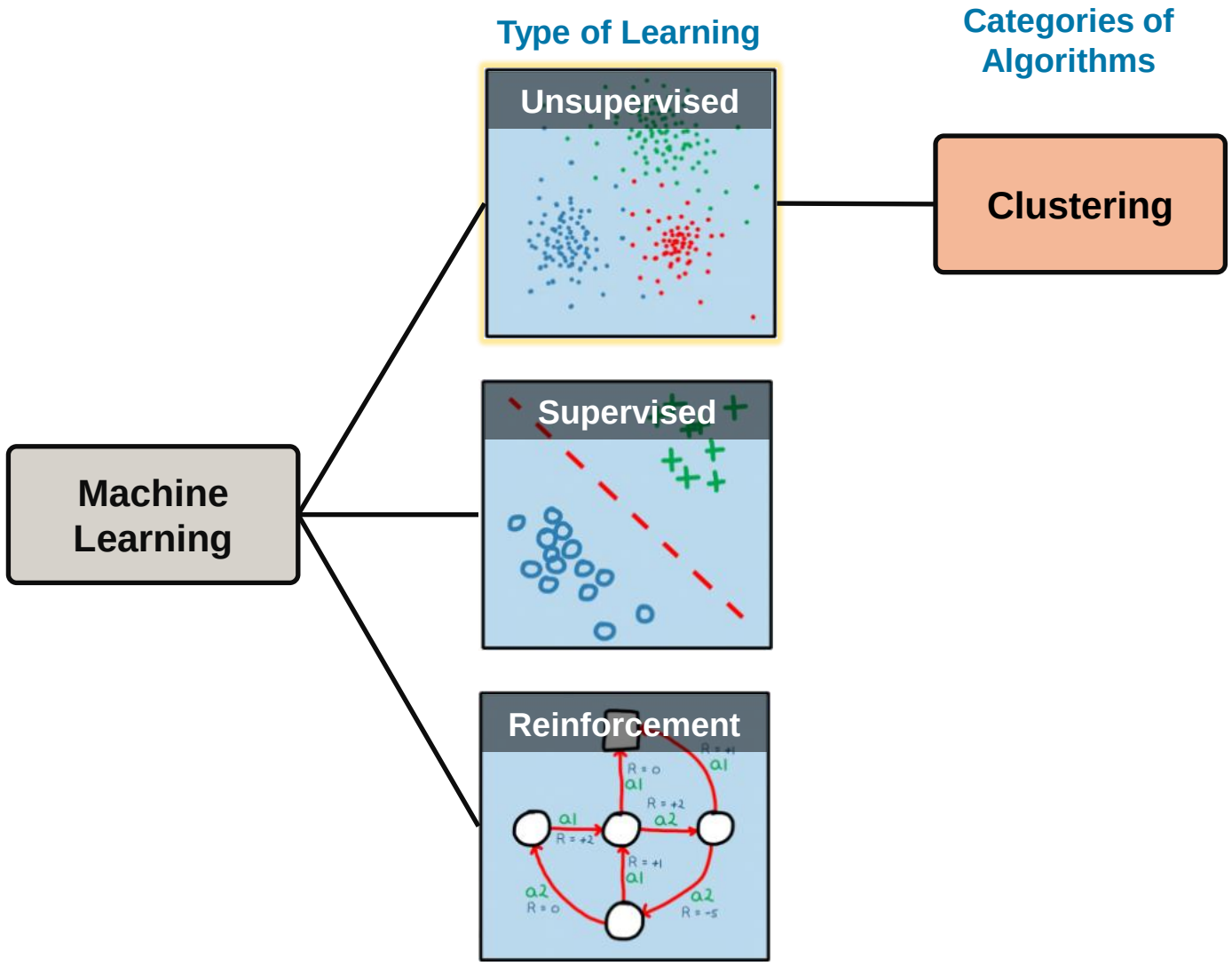
There are two ways to get a computer to do what you want



Different Types of Machine Learning

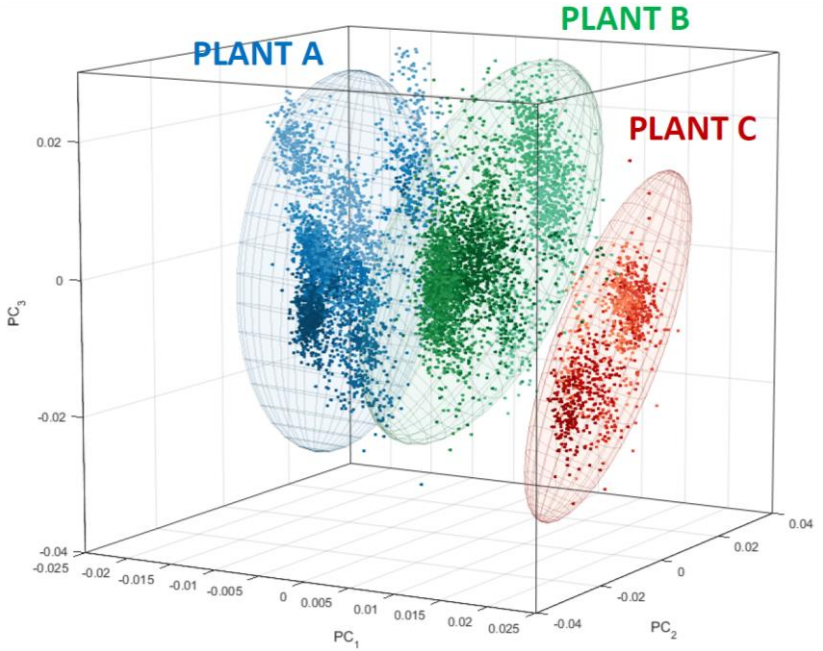


Different Types of Machine Learning

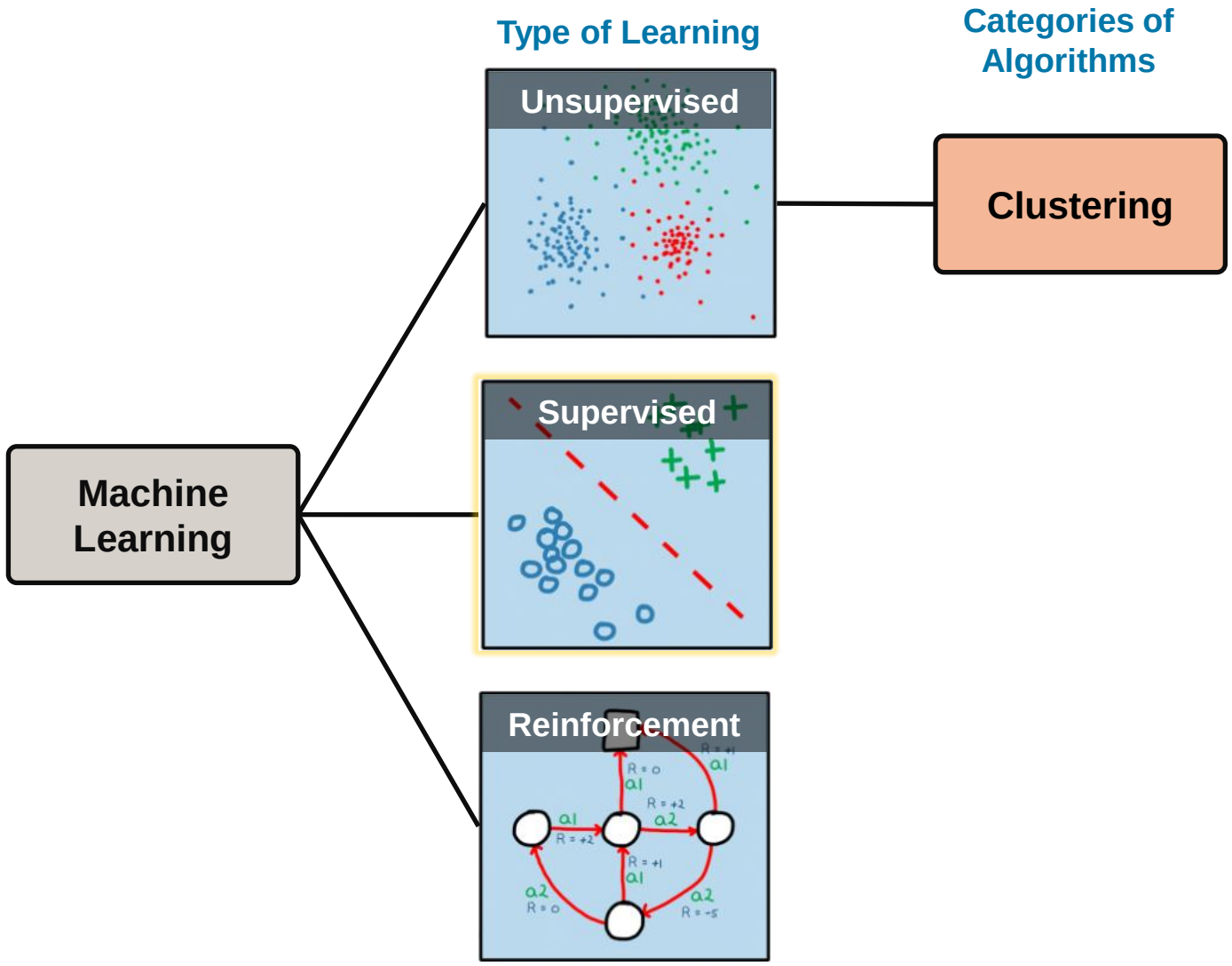


Objective

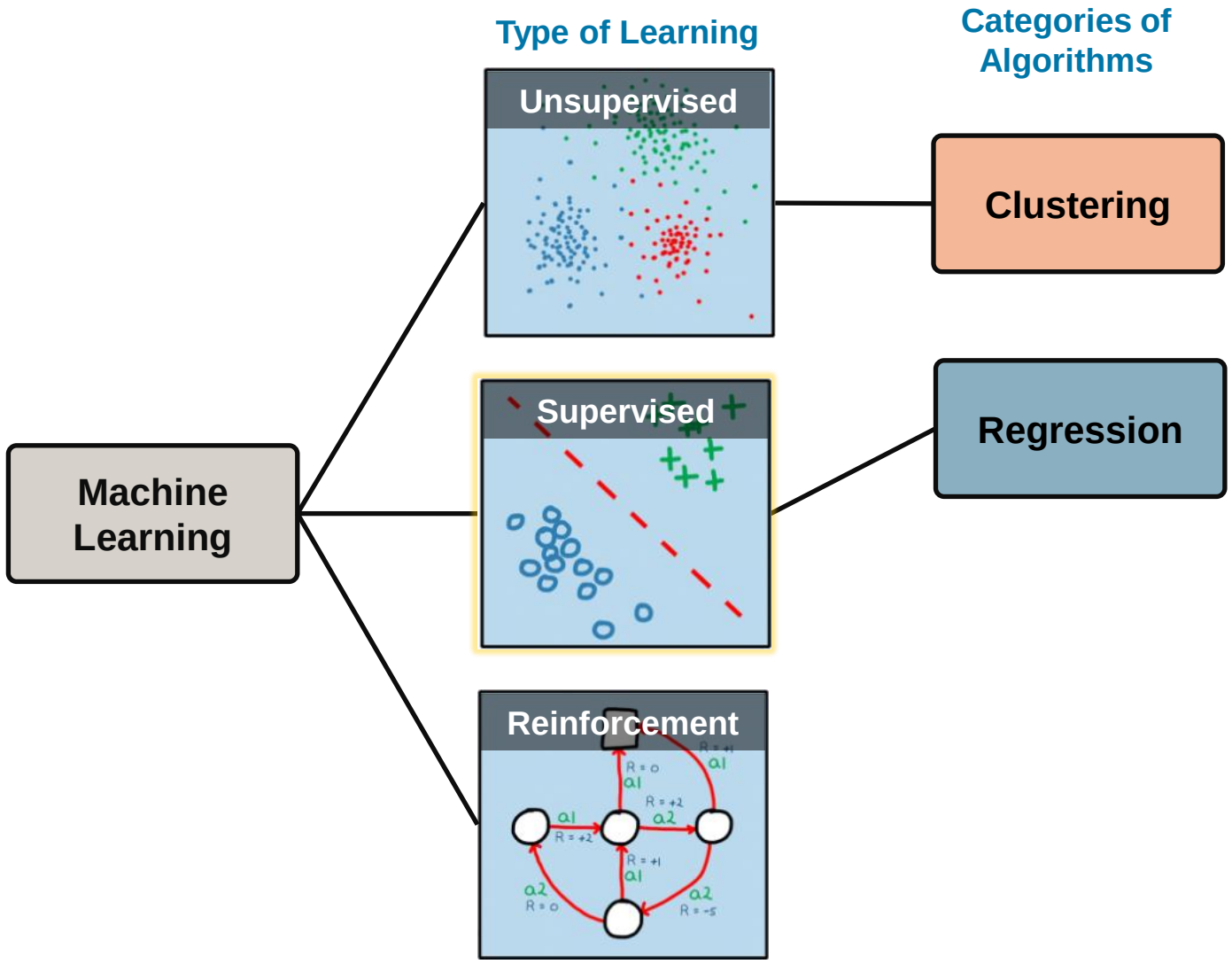
Identify clusters based on some similarity/characteristic in your data



Different Types of Machine Learning

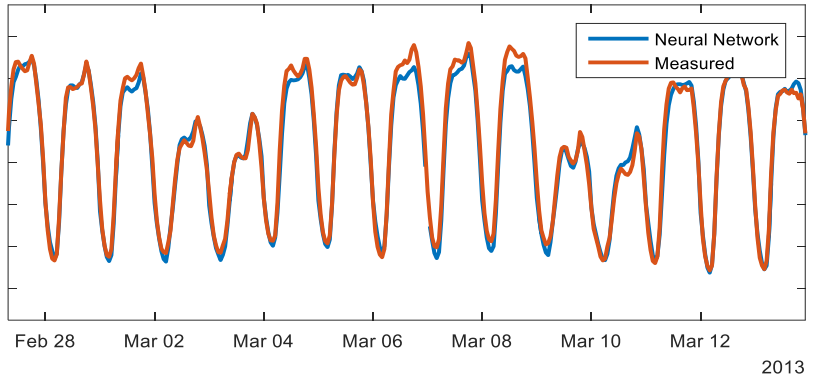


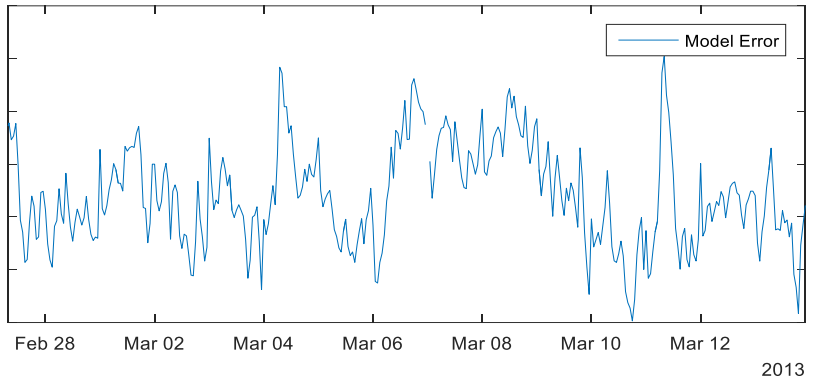
Different Types of Machine Learning



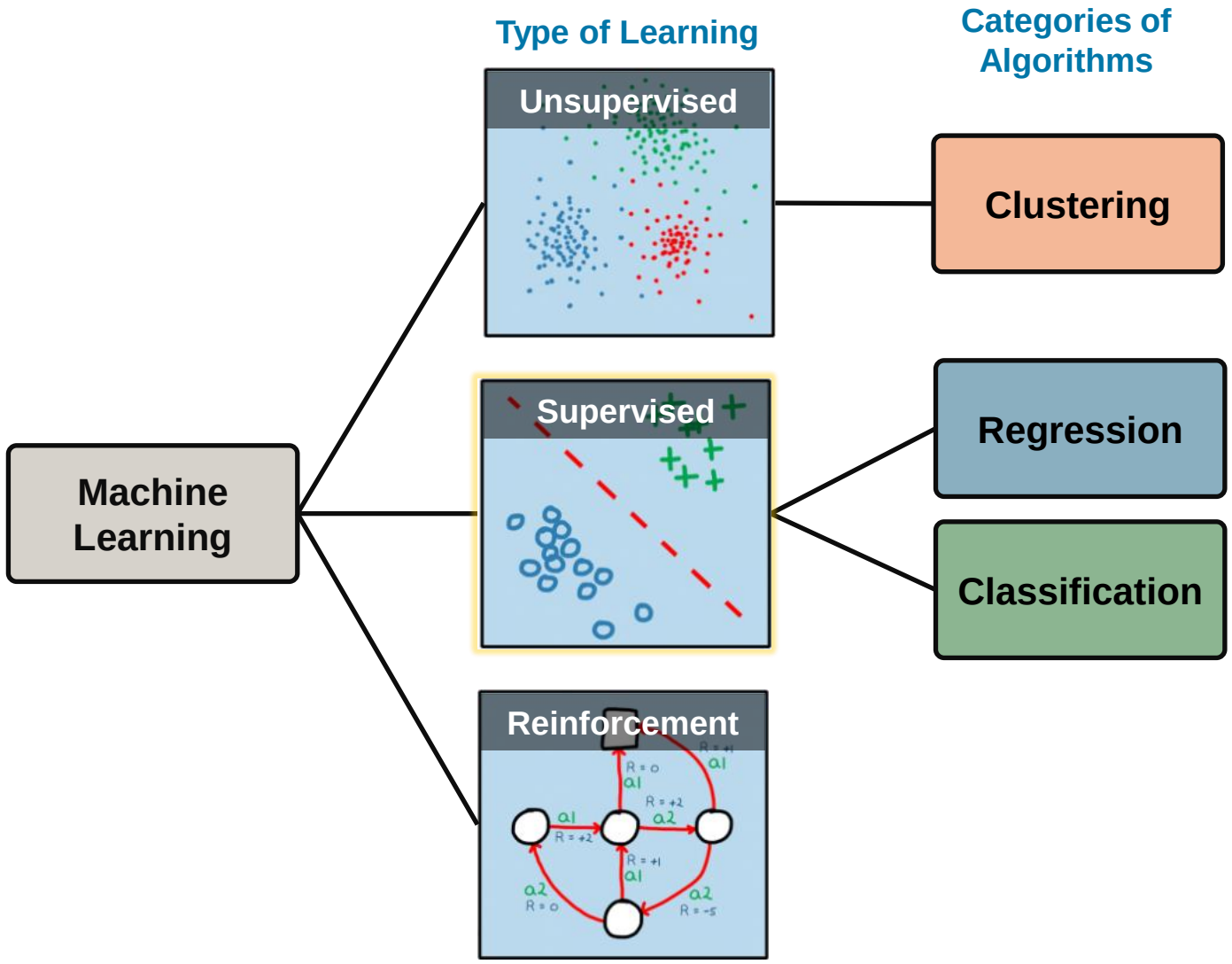
Objective

Predict continuous variable (crop yield, rain forecast, solar radiation, …)





Different Types of Machine Learning



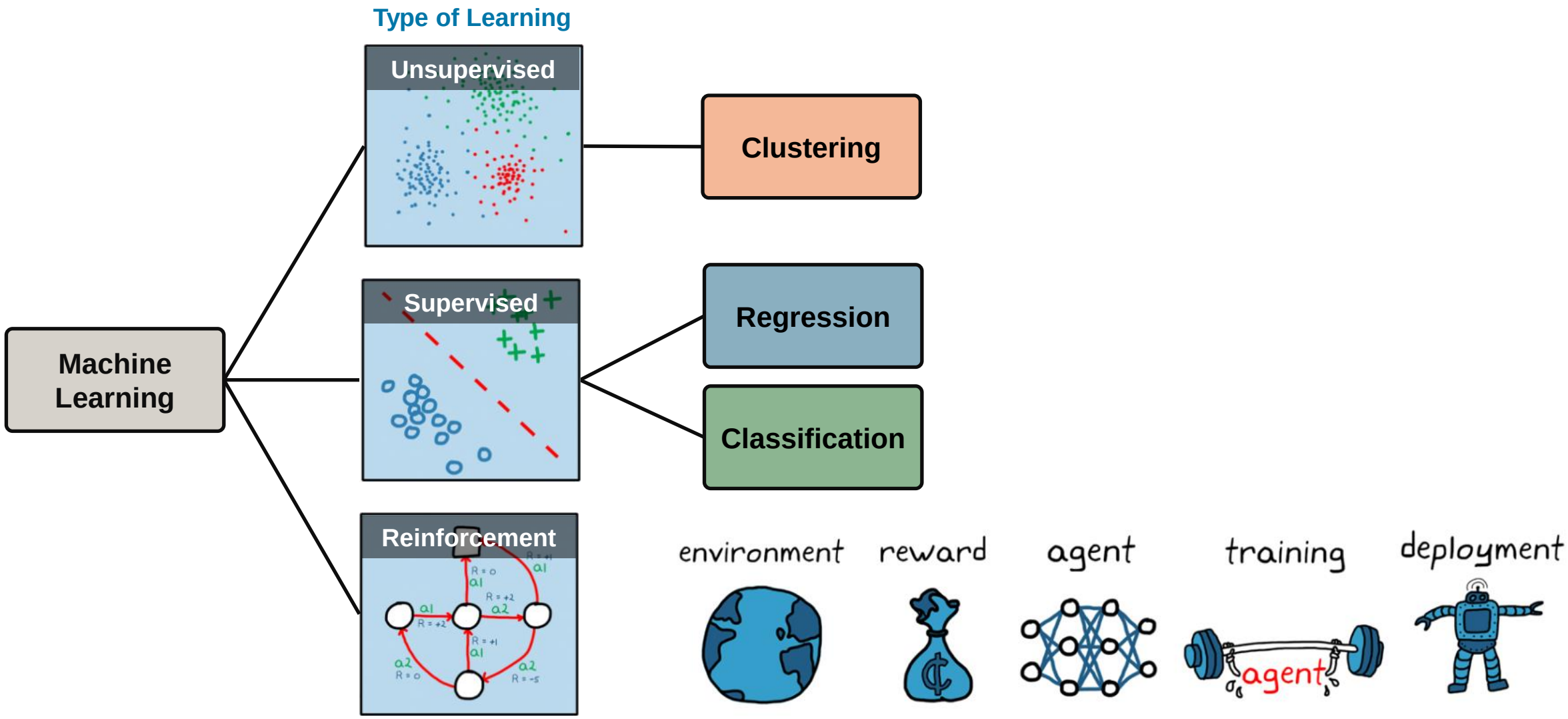
Objective

Classify categorical data: flowers, crop types, healthy/unhealthy plant, etc.

Data:

Inputs	Petal length Petal width Sepal length Sepal width
Outputs	Setosa Versicolor Virginica

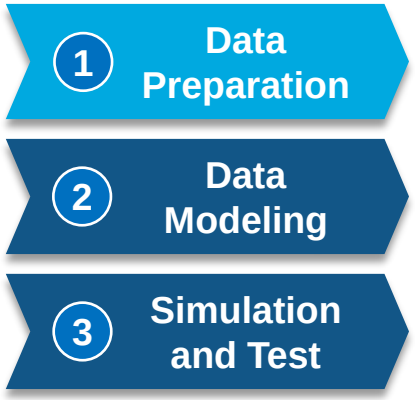
Different Types of Machine Learning



Data Preparation

Data Cleaning, Standardization, Normalization, Rescaling, Labeling, Feature Extraction…

- Thousands of optimized functions
- Apps

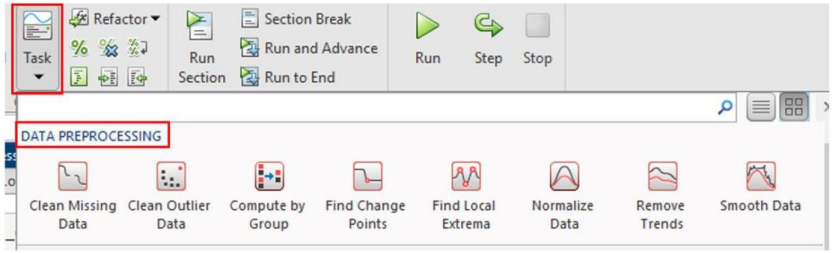


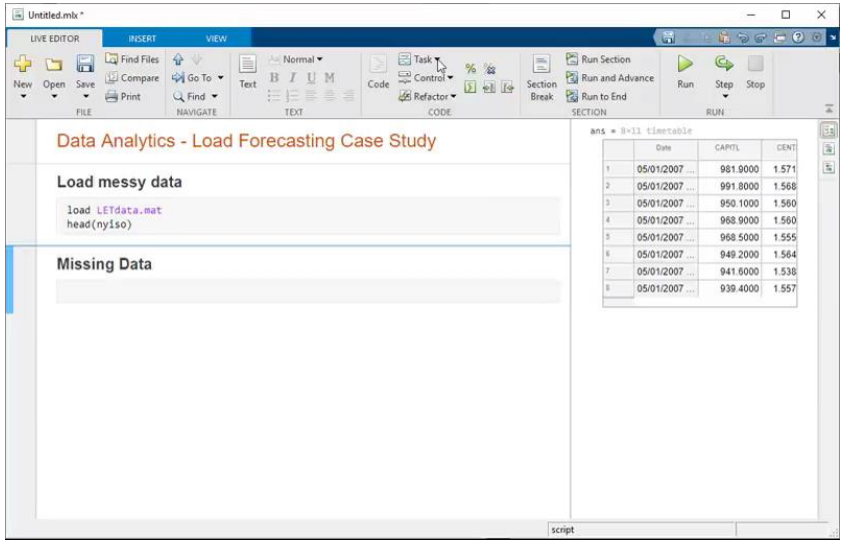
Data Preparation

Data Cleaning, Standardization, Normalization, Rescaling, Labeling, Feature Extraction…

- Thousands of optimized functions
- Apps
- Live Tasks

1. Data Preparation
2. Data Modeling
3. Simulation and Test



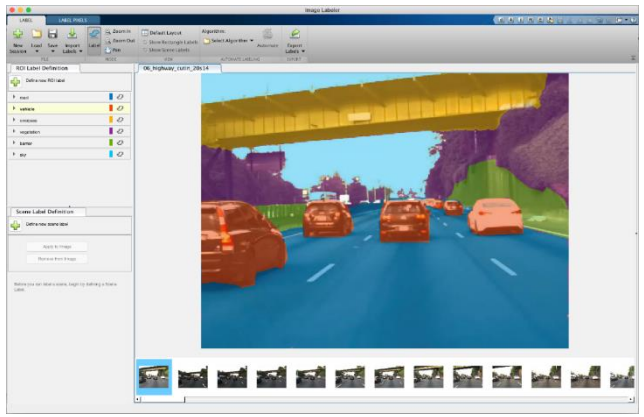


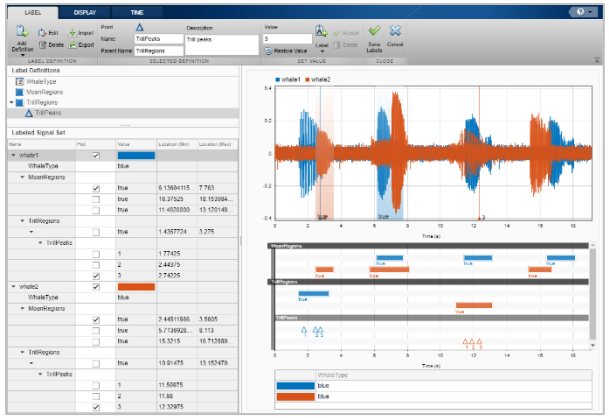
Data Preparation

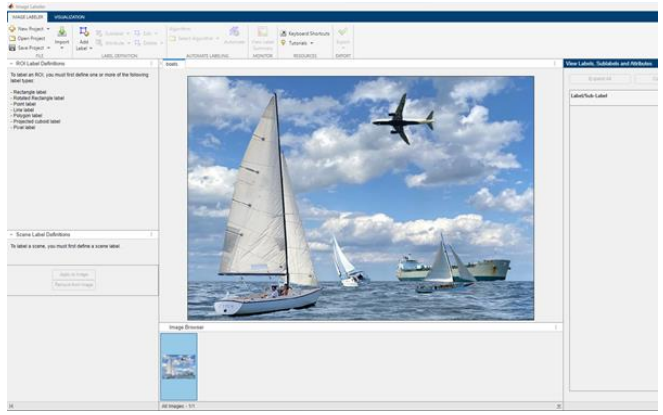
Data Cleaning, Standardization, Normalization, Rescaling, Labeling, Feature Extraction…

- Thousands of optimized functions
- Apps
- Live Tasks
- Domain-specific techniques for Signals, Images, Video, Audio, and Text

1. Data Preparation
2. Data Modeling
3. Simulation and Test







Start with a complete set of algorithms and pre-built models

1. Data Preparation
2. Data Modeling
3. Simulation and Test

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...

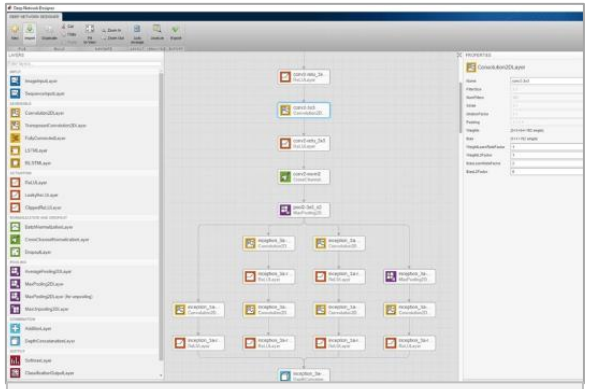
Semantic segmentation
Roadway detection, land cover classification, tumor detection...

Signal and speech processing
Denoising, music genre recognition, keyword spotting, radar waveform classification...

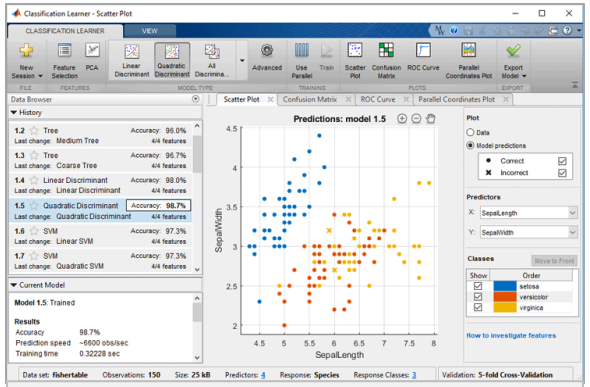
...and more...

AI modeling Apps automate training, tuning, visualization...

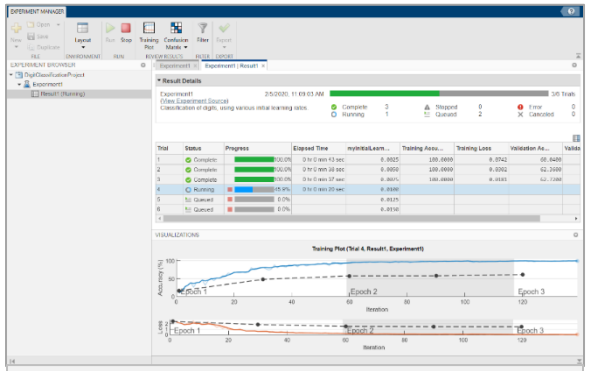
1. Data Preparation
2. Data Modeling
3. Simulation and Test



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

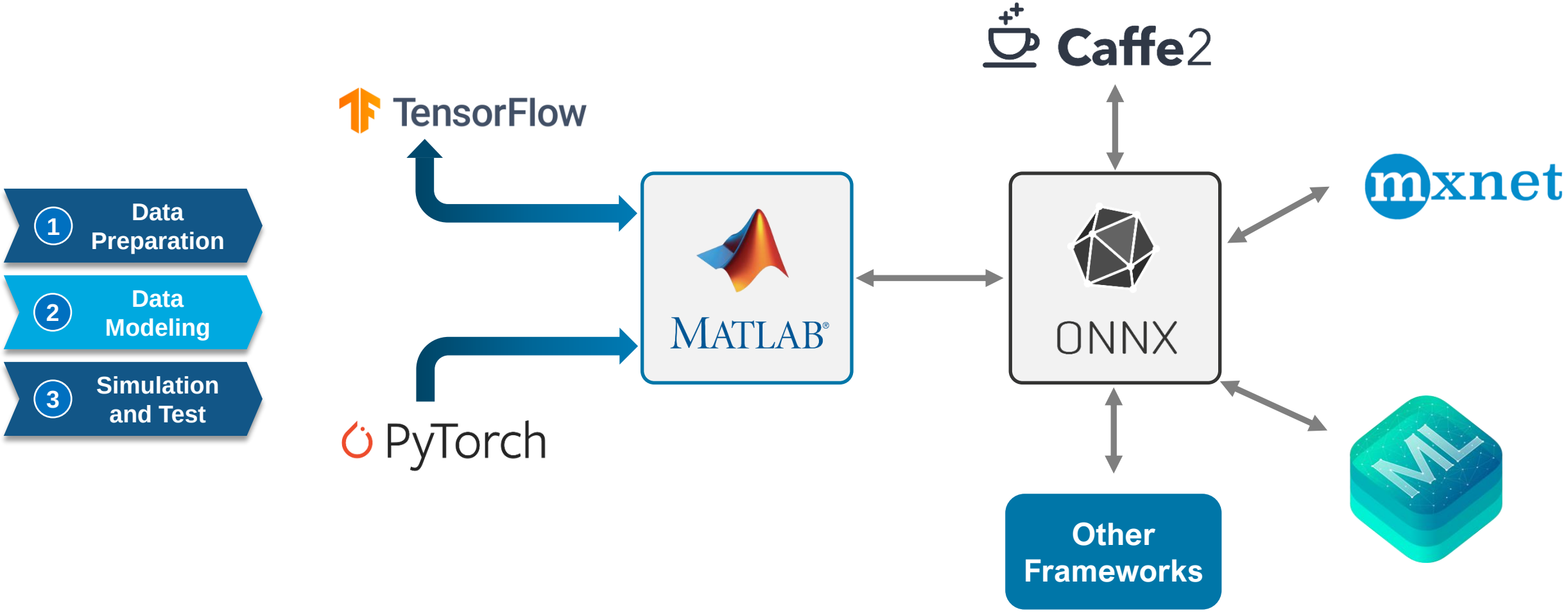


Classification Learner app to try different classifiers and find the best fit for data sets.



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

Access AI models from the broader AI community



Accelerate AI training on GPUs, cloud, and datacenters without specialized programming

1. Data Preparation
2. Data Modeling
3. Simulation and Test

AI is beginning to match or exceed human performance
Imagine what you could do with it

Getting into the Weeds:
Farmers Rely on Artificial Intelligence to Boost Production

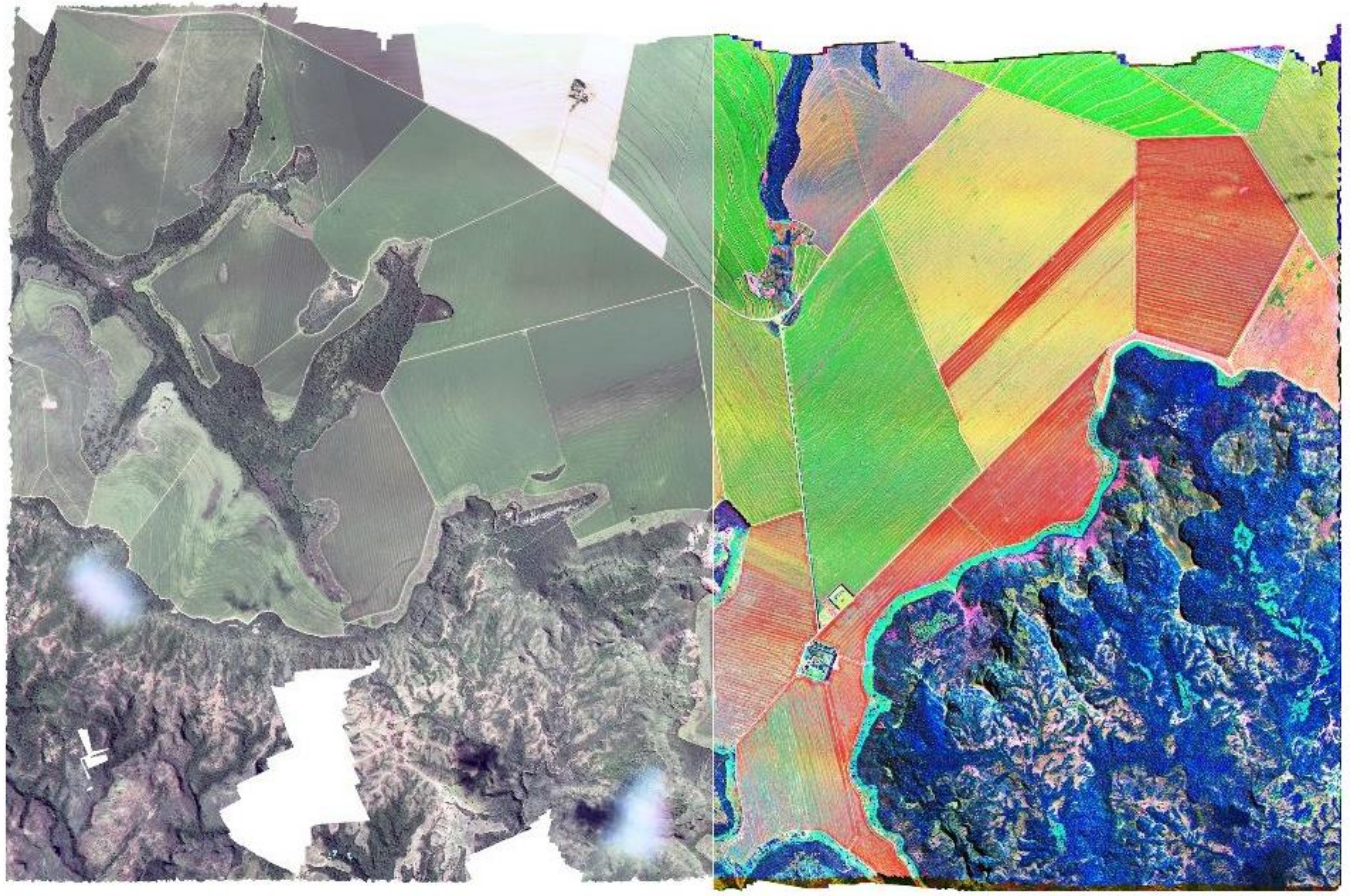


Image courtesy of Gamaya

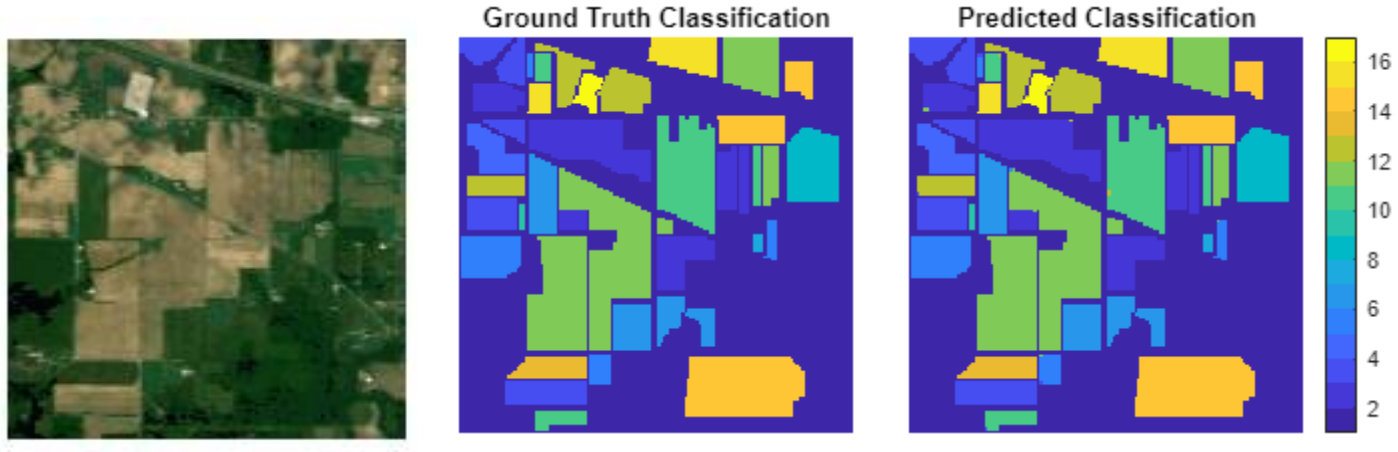
[Link to MathWorks story]

" We use algorithms to discriminate early-season vegetation that is barely visible due to its size, and generate a health score and anomaly algorithms that identify unusually high or unusually low stress …

- Greg Rose, VP of Product, IntelinAir

Demo: Classify Hyperspectral Images Using Deep Learning

Goal: Classify types of vegetation and terrain based on the unique spectral signatures of each material



openExample('images_deeplearning/ClassifyHyperspectralImagesUsingDeepLearningExample')

Hyperspectral Imaging Library for Image Processing Toolbox is required

Integrate into the system-wide context, simulate before moving to hardware, and verify effectiveness

- Design and testing in simulation accelerate development

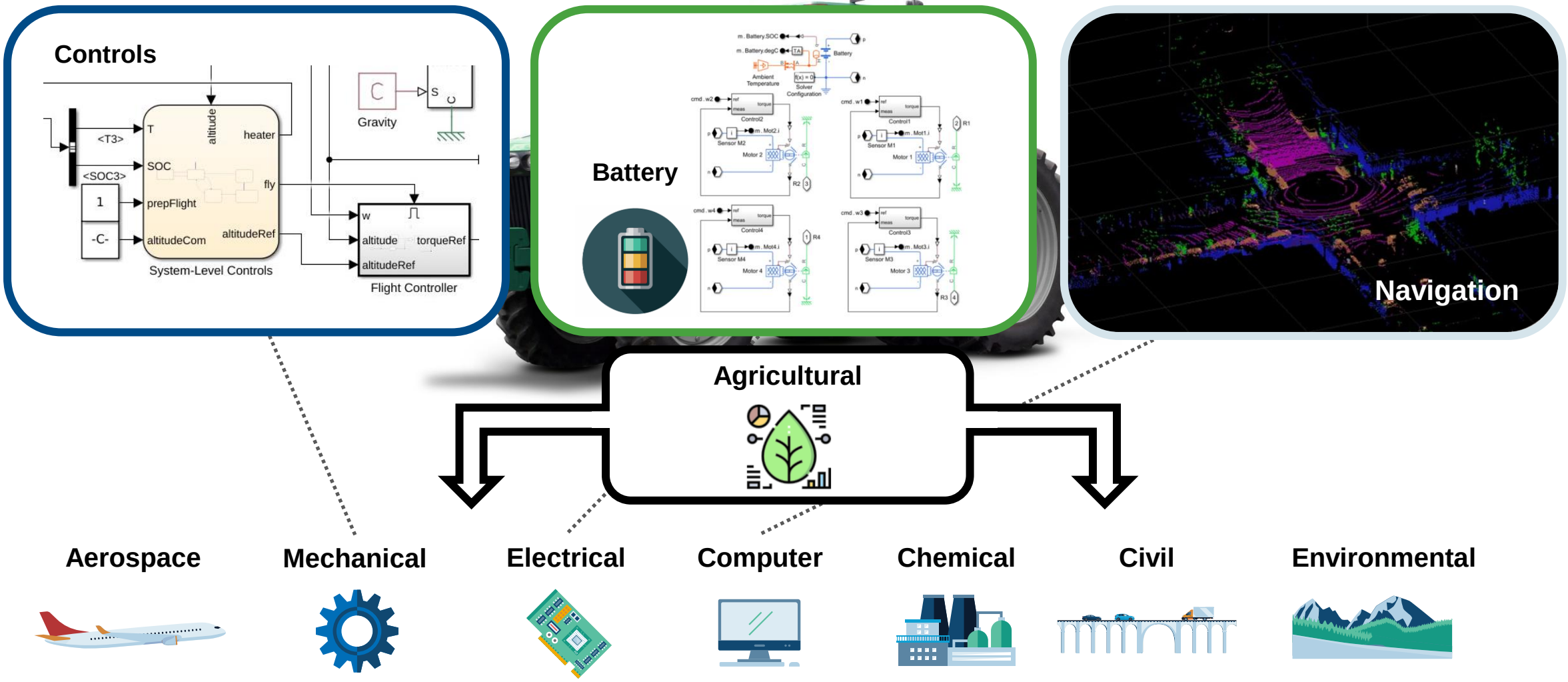
? How do our autonomous systems adapt to different farm configurations?

? What are the improvements in efficiency, precision, and safety?

1. Data Preparation
2. Data Modeling
3. Simulation and Test

41

Engineering Systems are Dynamic and Multidomain



Agriculture Systems and Technologies

Efficient development with Model-Based Design

MathWorks

CNH Develops Intelligent Filling System for Forage Harvesters

Challenge

Simplify the operation of forage harvesters by automating the process of filling trailers with corn, grass, and other crops

Solution

Use Model-Based Design to develop, test, and implement an automated control system that uses 3D camera data to position the filler spout

Results

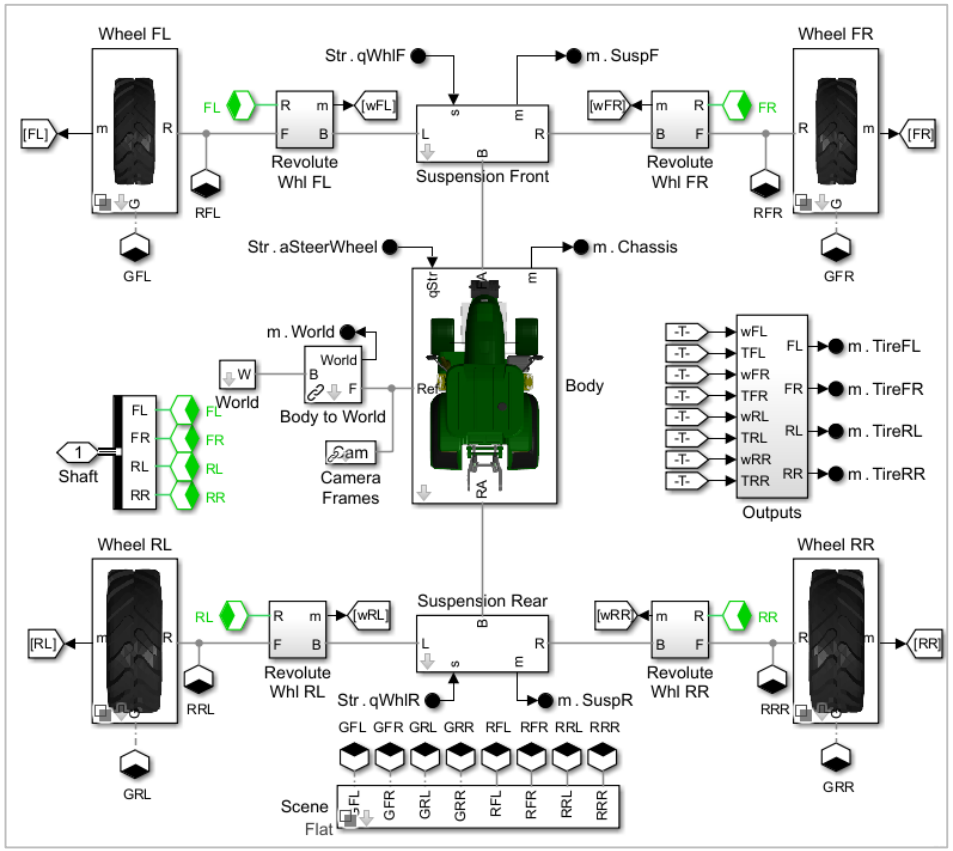
- Development times halved
- Generated code immediately operational
- Industry innovation award won

A forage harvester with the IntelliFill™ system from CNH's FR9000 series

"With Model-Based Design we spent most of our time developing and optimizing the system. Almost no time was spent implementing it in C or debugging code. There's no difference in performance between the Simulink model running on a laptop and production code."
- Karel Viaene, CNH

Link

CONFIDENTIAL | 2



Autonomous Electric Tractor Brings Artificial Intelligence to the Field

Challenge

Develop a zero-emission tractor that performs production tasks autonomously.

Solution

Adopt a Model-Based Design approach with MATLAB and Simulink to design and test vehicle architecture, control logic, and machine learning algorithms for data analysis.

Key Outcomes

- Simulink enabled over-the-air deployment to the hardware very quickly, allowing remote code development and testing.
- Integrated systems, including real-time visual data analysis make for safer operation and more efficient use of resources.
- First Pilot Series tractor deployed in April 2021 at Wente Vineyards, much earlier than expected

The autonomous tractor charging an electric car. (Image credit: Monarch Tractor)

"When you do a control system for industrial automation or for manufacturing, you control 90%, 95% of the variables… In agriculture, we control 50% or less. It's even less than a car driving. There are no fixed maps." Praveen Penmetsa, Monarch Tractor co-founder and CEO

Link to feature story
MATLAB Expo Talk

AI for Model-Based Design and Asset Monitoring

Reduced order modeling (ROM)

Create reduced order models for physical components to speed up simulations

Predictive maintenance

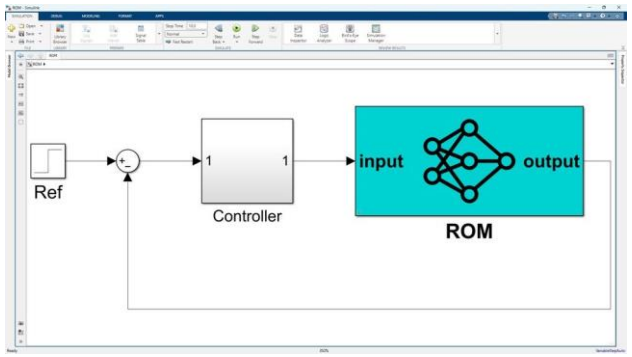
Monitor the condition of assets and estimate their remaining useful life

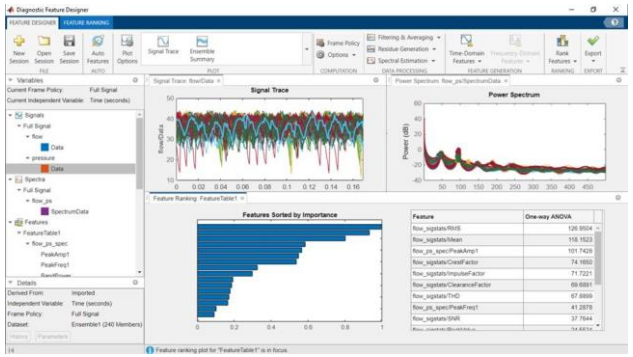
Virtual sensors

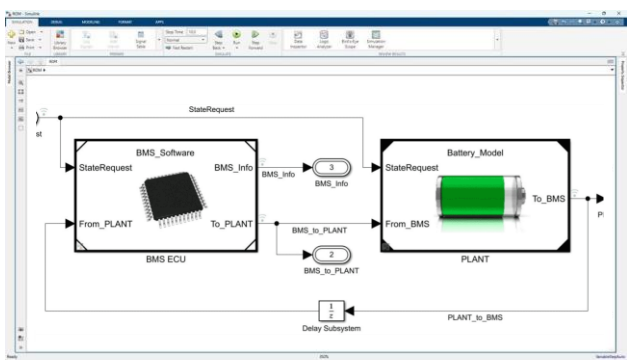
Develop virtual sensors for algorithm and control logic development

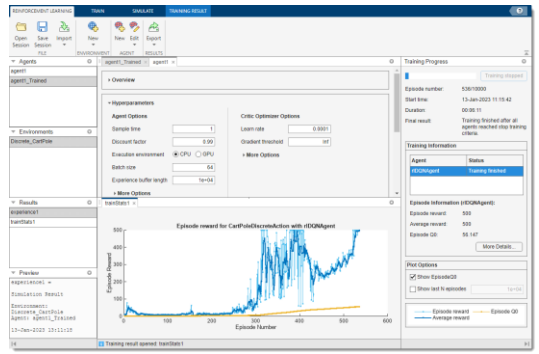
Control strategy

Train AI-based, high-performance controls of complex, nonlinear, MIMO systems

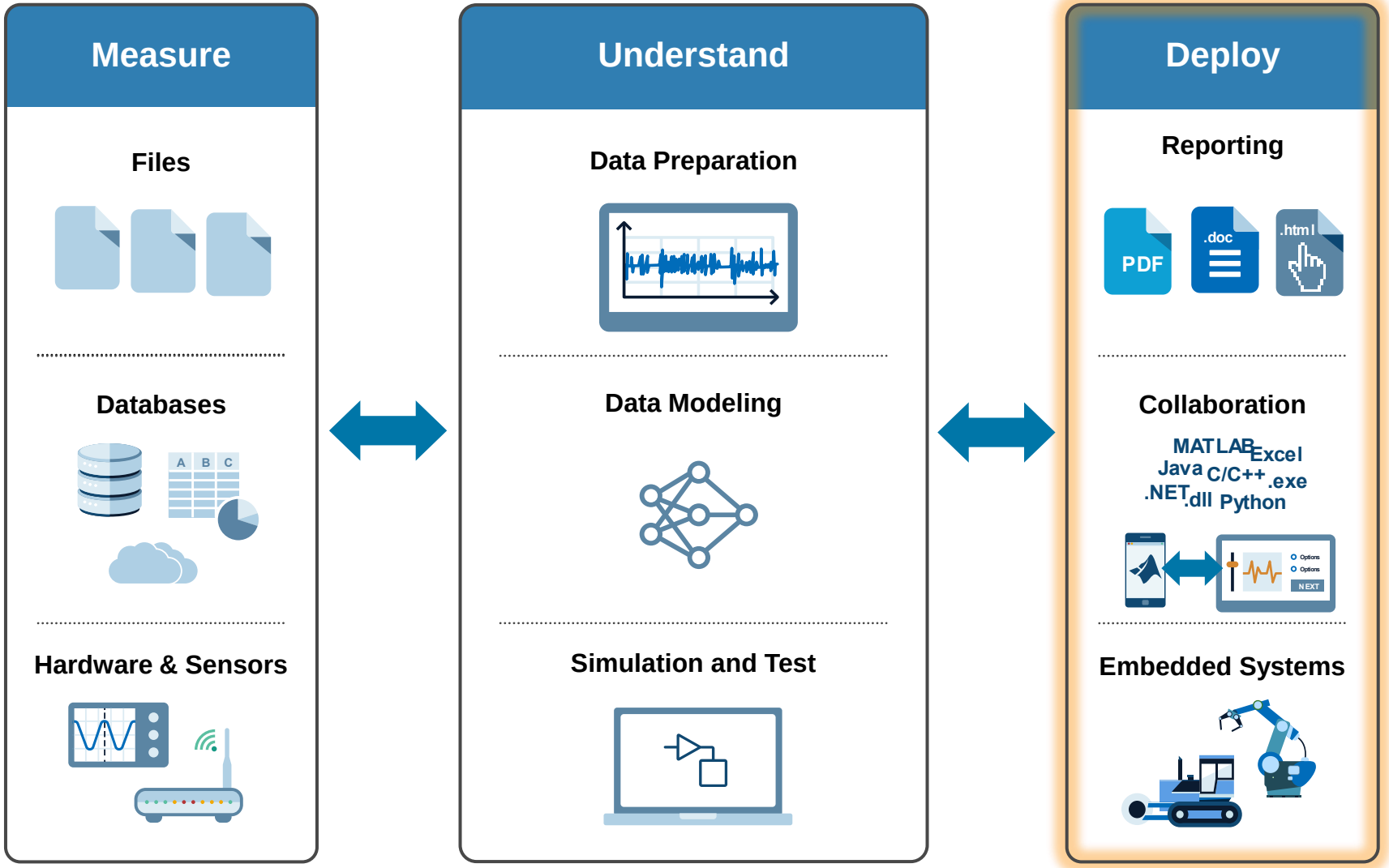








MATLAB and Simulink enable Digital Agriculture workflows

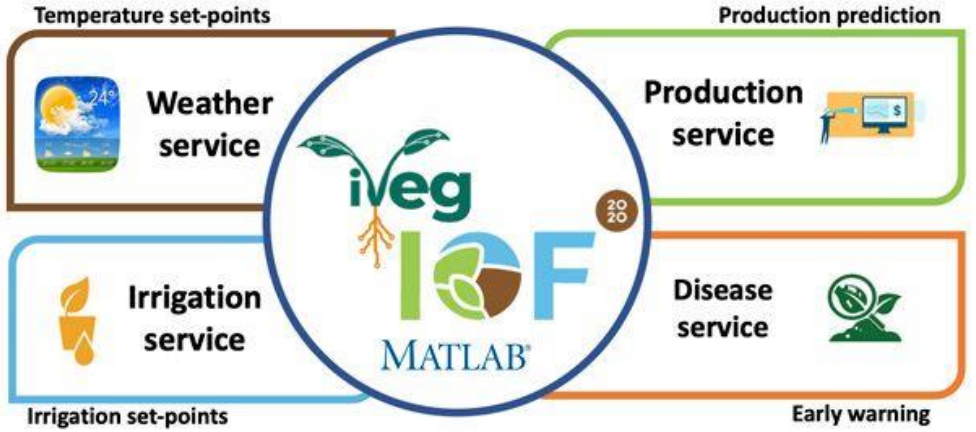


Universidad de Almería Deploys Greenhouse Models as a Service to Maximize Crop Production

How to make climate models available to producers?

MATLAB was used to develop models and deploy them as web-accessible services

- Cloud deployment time cut by more than 90%
- Model updates are accessed immediately
- Greenhouse revenues increased by 15%

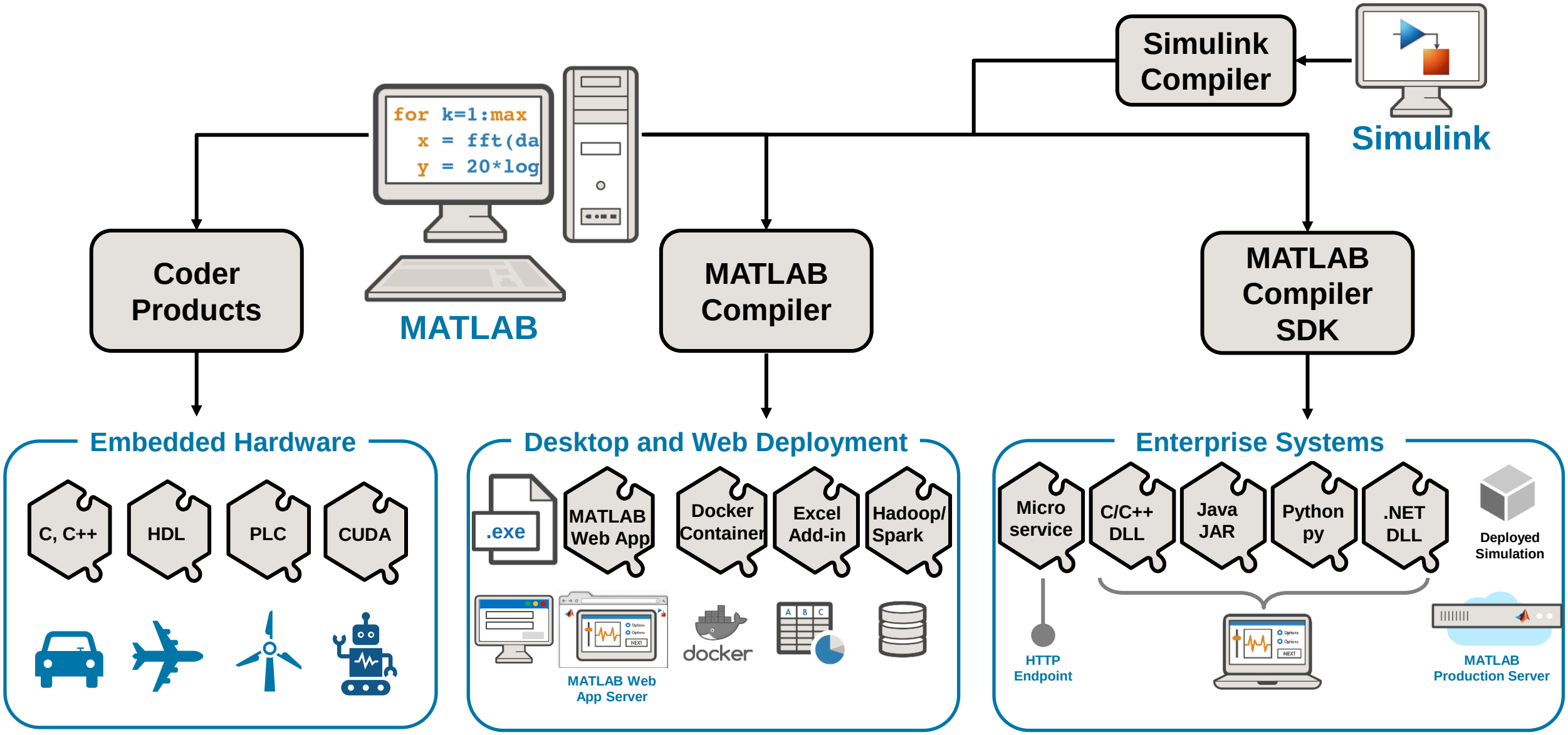


The greenhouse models as a service system (GMaaS) developed by the Universidad de Almería researchers.

"After we had developed our models, MATLAB Production Server enabled us to make all of them accessible via the cloud without recoding them in another language, saving months of development effort."

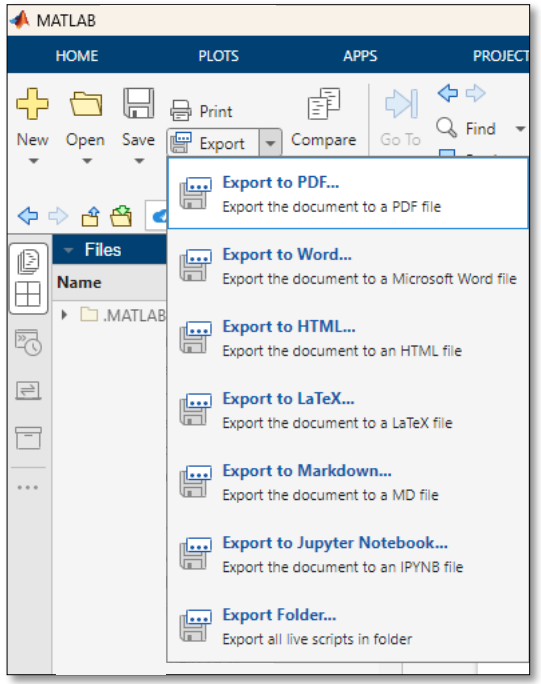
Link to feature story

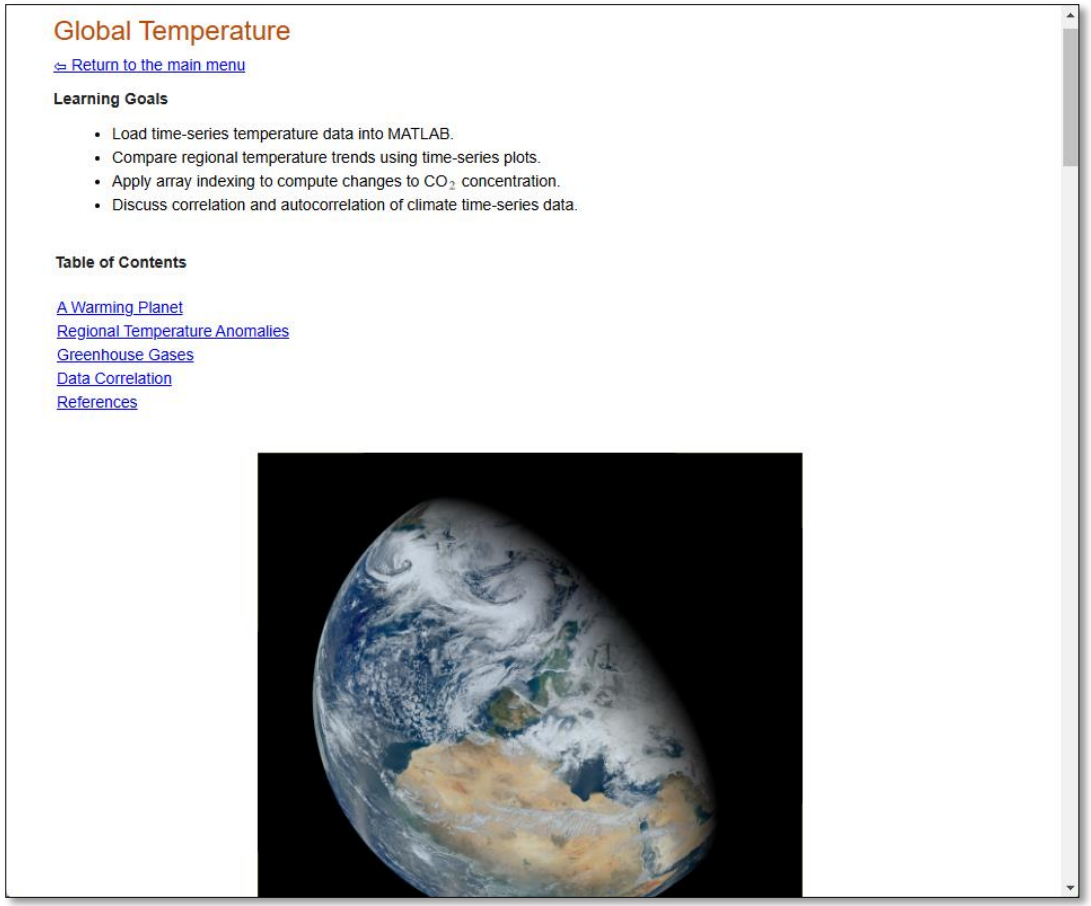
Operationalize your analytics and models



Share your work with the community

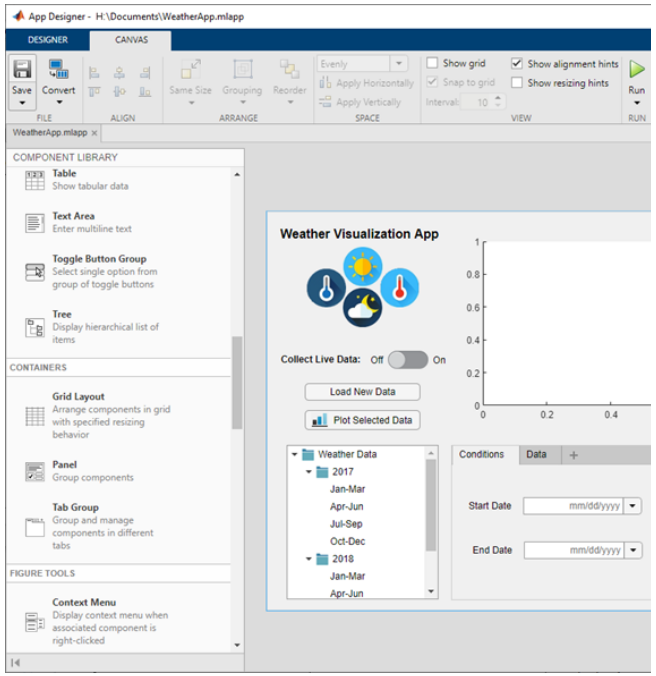
- Reports

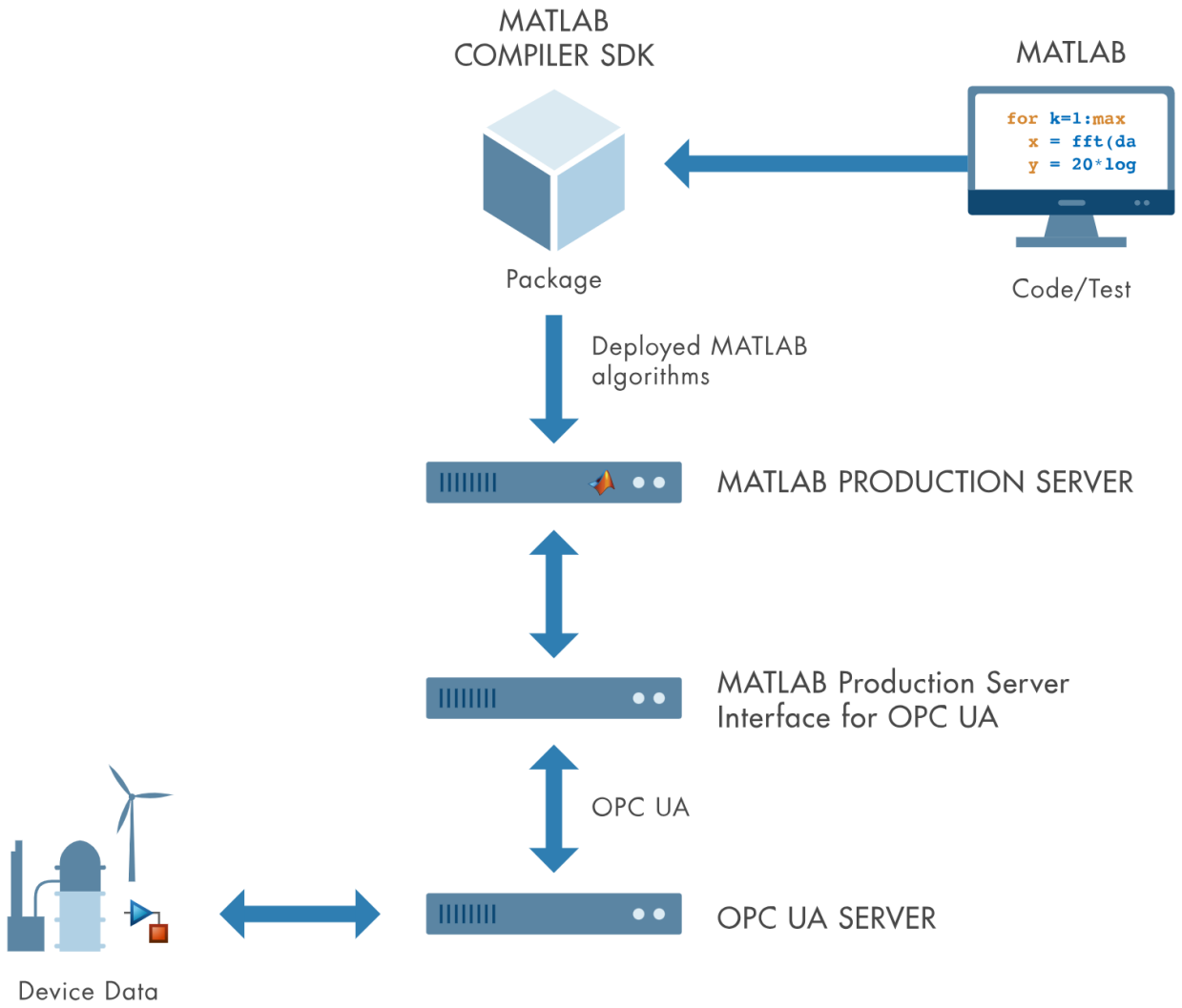


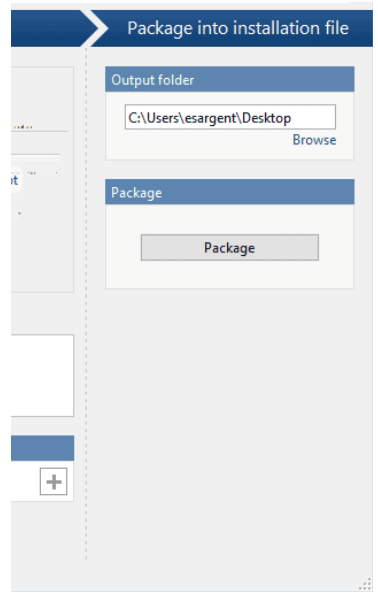


Share your work with the community

- Reports
- Apps



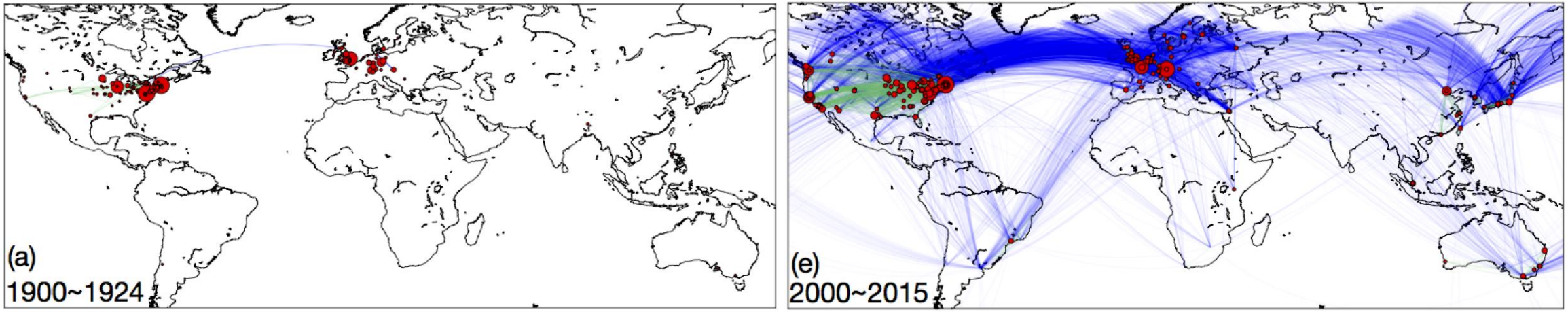




Share your work with the community

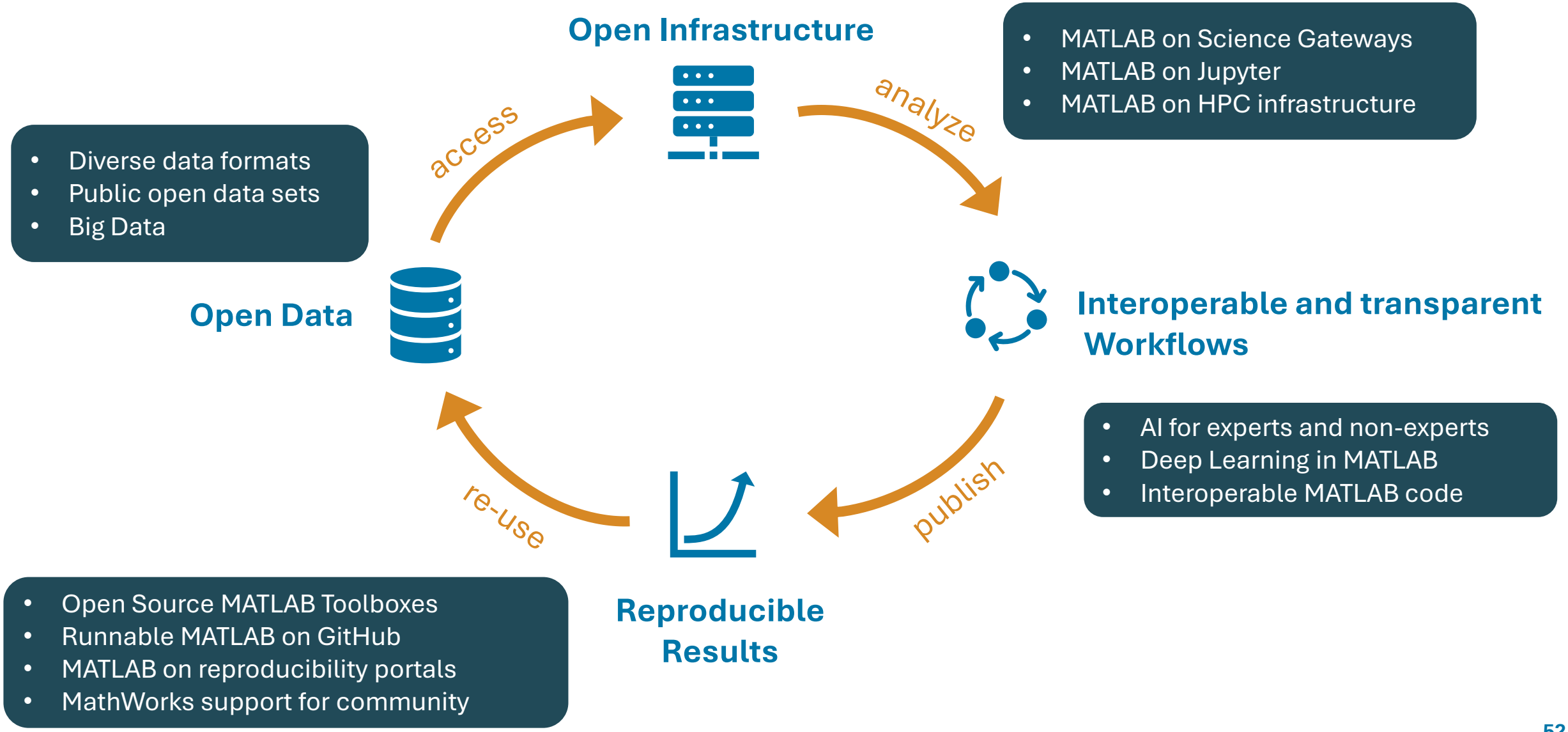
- Reports
- Apps
- Open Science

Research is a collaborative effort – more than ever today



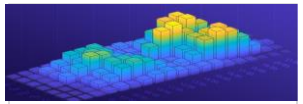
A Century of Science: Globalization of Scientific Collaborations, Citations, and Innovations
Yuxiao Dong, Hao Ma, Zhihong Shen, Kuansan Wang, Microsoft Research. https://doi.org/10.1145/3097983.3098016

Open Science is a collaboration effort



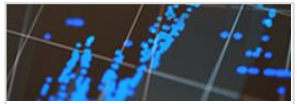
To Learn More…

100+ hours of Online Training

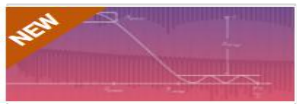


MATLAB Fundamentals

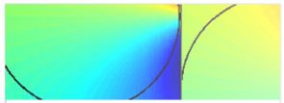
Simulink Fundamentals



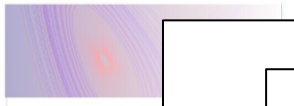
MATLAB for Data Processing and Visualization



Signal Processing with MATLAB



Solving Nonlinear Equations with MATLAB



Solving Or... Differen... Equations... MATL...

Deep Learning with MATLAB

Machine Learning with MATLAB

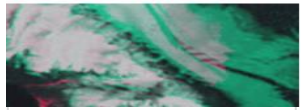
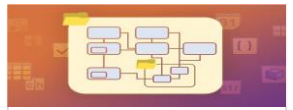


Image Processing with MATLAB



MATLAB Programming Techniques

Introduction to Statistical Methods with MATLAB

Introduct... Symbolic... with MA...

MATLAB

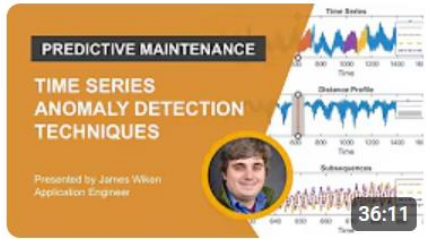
@MATLAB · 530K subscribers · 2.7K videos

Engineers and scientists worldwide rely on MATLAB and Simulink products to accelerate ...more

mathworks.com and 5 more links

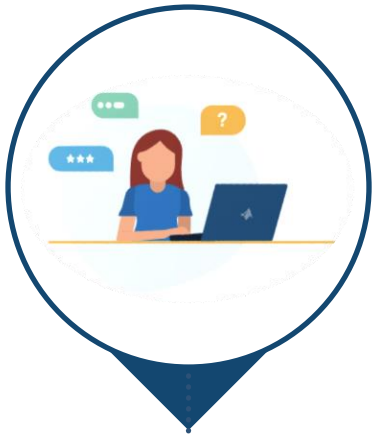
Subscribed

YouTube



MathWorks

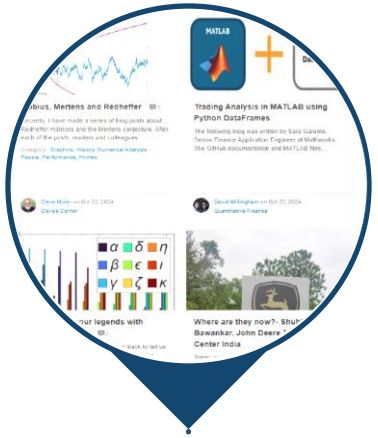
Find Answers, Learn and Share your Knowledge

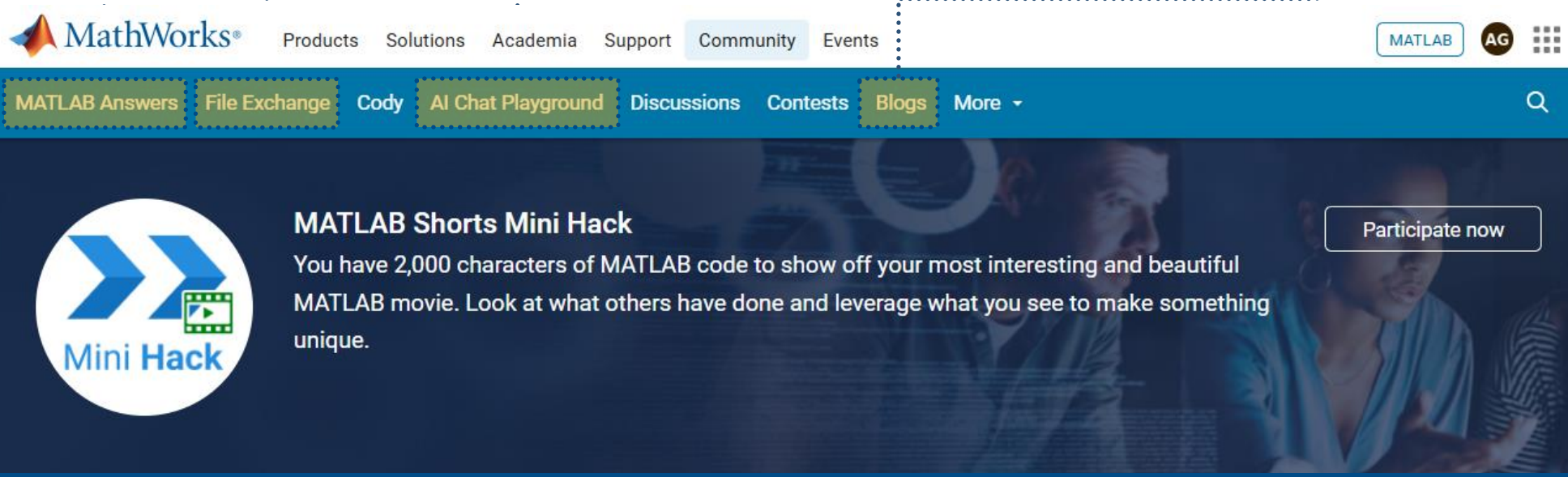


Open-source MATLAB code Publish yours to help others

Experiment, generate draft code, answer questions

Get the inside view on MATLAB and Simulink





mathworks.com/matlabcentral

A dedicated team and many ways to collaborate

Teaching

Student Competitions

Curriculum Development

Professional Education

Research

Technical guidance

Complementary licenses

Monetary funding

Commercialization

Low-cost access to MATLAB & Simulink for Startups

Partner with MathWorks Accelerator Program