MATLAB and Simulink for Smart Construction

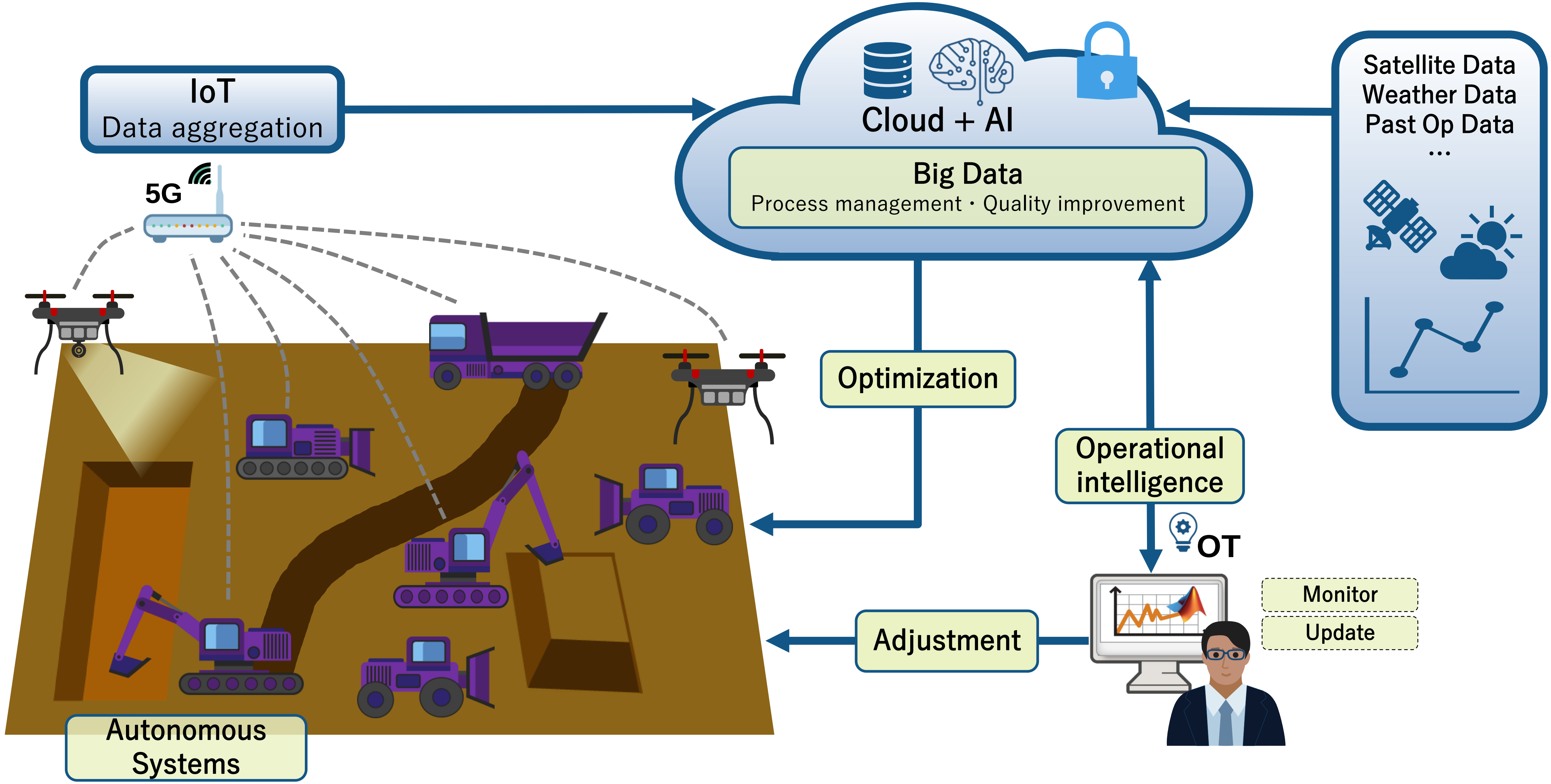
MathWorks

Overview of Smart Construction

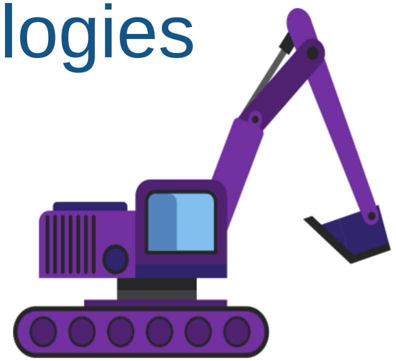
- Trends in construction applications
  - Incorporating **advanced machinery and technologies**
  - Utilizing **AI, Big Data, and IoT**
  - Increasing **connectivity** between components and users
  - Embracing **digital transformation** in research, development, and operations

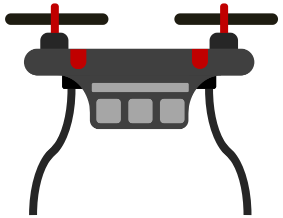
Smart construction integrates autonomy and intelligence for actionable insights to optimize processes, safety, sustainability

Smart Construction: Actionable Insights from Autonomy + Intelligence



Construction Machinery Systems & Technologies





Sumitomo Heavy Industries Speeds Development of Embedded Model Predictive Control Software for Hydraulic Excavators

Challenge
Accelerate the design and implementation of embedded engine control software for hydraulic excavators

Solution
Use Model-Based Design with Simulink and Embedded Coder to model, simulate, and generate code from a model predictive controller that maximizes excavator work performance

Results
- Fuel efficiency increased by 15%
- Engineering effort reduced by 50%
- Aggressive deadline met

A Sumitomo hydraulic excavator.

"With Model-Based Design, our hydraulics engineers can complete the controller design and implementation without involving an embedded engineer. That's a big advantage, because it saves time and results in a higher-quality controller."
- Eisuke Matsuzaki, Sumitomo Heavy Industries

Link

8

INCOVA Designs Intelligent Control Valve System for 20-Ton Excavator

Challenge
Design and implement an intelligent valve control system for large hydraulic machinery

Solution
Use a real-time testing solution from MathWorks and Speedgoat to model and validate the control system, then automatically generate and run code on real-time rapid prototyping hardware

Results
- Development time cut by more than 50%
- Design modifications completed in an hour
- 100% of controller design reusable

A 20-ton excavator with hydraulic functions controlled by INCOVA's valve control-system

"In the past, our systems engineers had to consider hardware details such as the number of bits of accuracy and worry about communicating the design to the software engineer. With MathWorks tools for Model-Based Design, the system engineer can focus completely on controls, not the details of the target hardware."
- Corey Quinnell, INCOVA Technologies

Link

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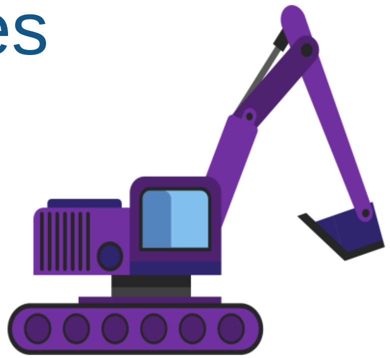
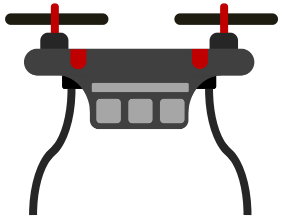
Efficient development with Model-Based Design

Construction Drone Systems & Technologies





Intel Creates Dynamic Simulation Environment for Testing GNC Algorithms for Multirotor UAVs

Challenge
Develop and test advanced control algorithms for existing and next-generation multirotor UAVs

Solution
Use MATLAB and Simulink to model multirotor UAV dynamics, verify control algorithms via simulation, and evaluate control design ideas

Results
- Complex calculations verified before flight testing
- Design ideas evaluated in days, not weeks
- Design iterations and testing time reduced

The eight-rotor Intel® Falcon™ 8+.

"Modeling and simulation with Simulink is the only way that we can get the results we need with the speed and quality that's expected in our industry today. If we had to do everything by hand and rely solely on flight testing, we would require more bug fixing iterations and need more testing time per iteration. The problem would grow intractable. There's no other way."
- Jan Vervoorst, Intel

Link

7

Airmanics Develops Unmanned Aerial System for Close-Range Filming with Model Based Design

Challenge
Design and develop an unmanned aerial camera motion system for close-range aerial filming

Solution
Use Model-Based Design with MATLAB and Simulink to accelerate the design, debugging, and implementation of the vehicle's fly-by-wire and flight management system software

Results
- Development time reduced by one year or more
- Coding errors eliminated
- 80% model reuse achieved

Airnamics co-founders Marko Thaler and Zoran Bjelić with the R5 MSN1 prototype after its first flight.

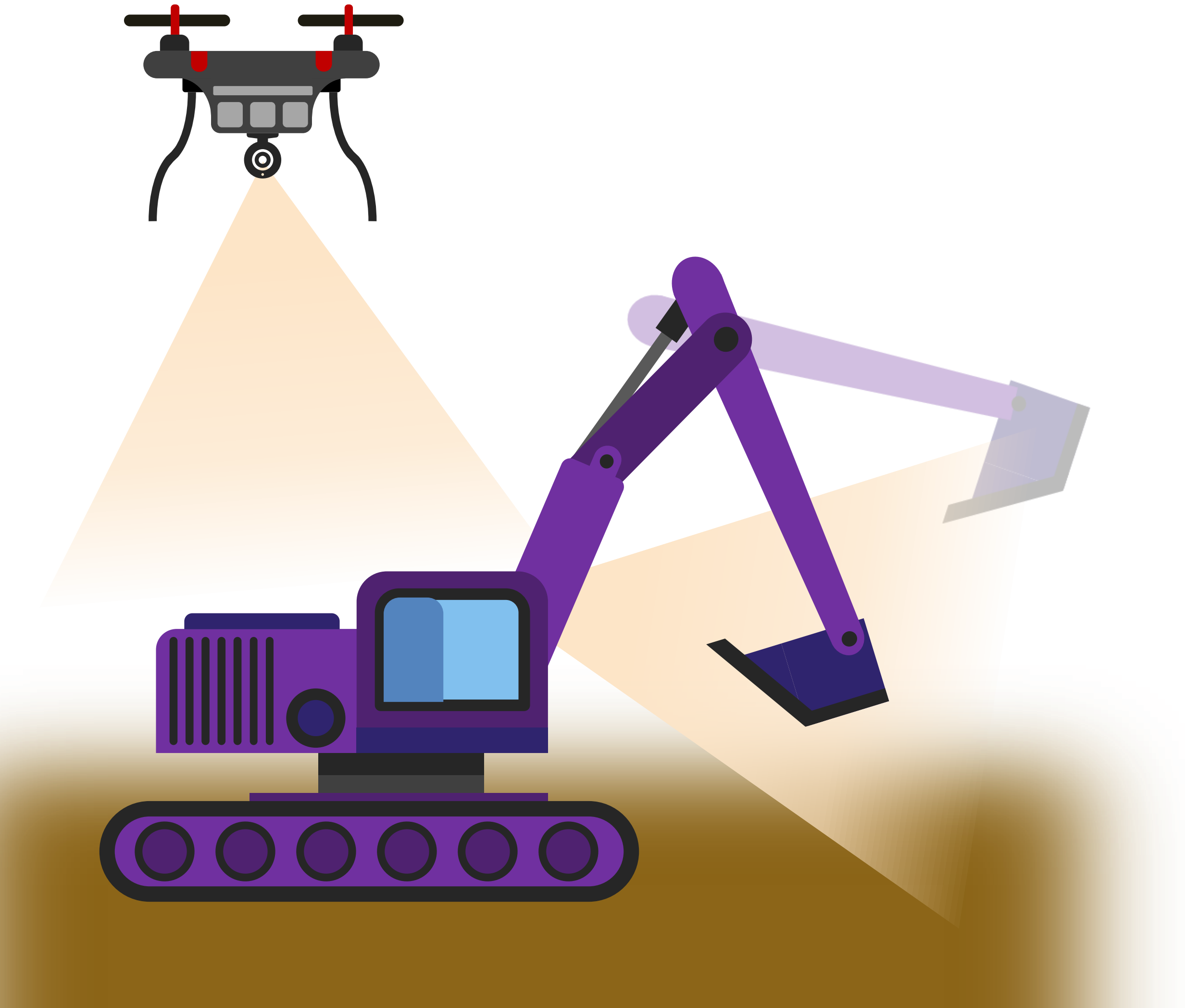
"With Model-Based Design our three-engineer team found more than 95% of control software bugs before the first flight. We used the test flights to increase our Simulink models' fidelity and isolate remaining bugs with high precision. The result is a safer, more reliable, and higher-quality product."
- Marko Thaler, Airnamics

Link

8

Efficient development with Model-Based Design

Automation & Autonomy in Construction Activities



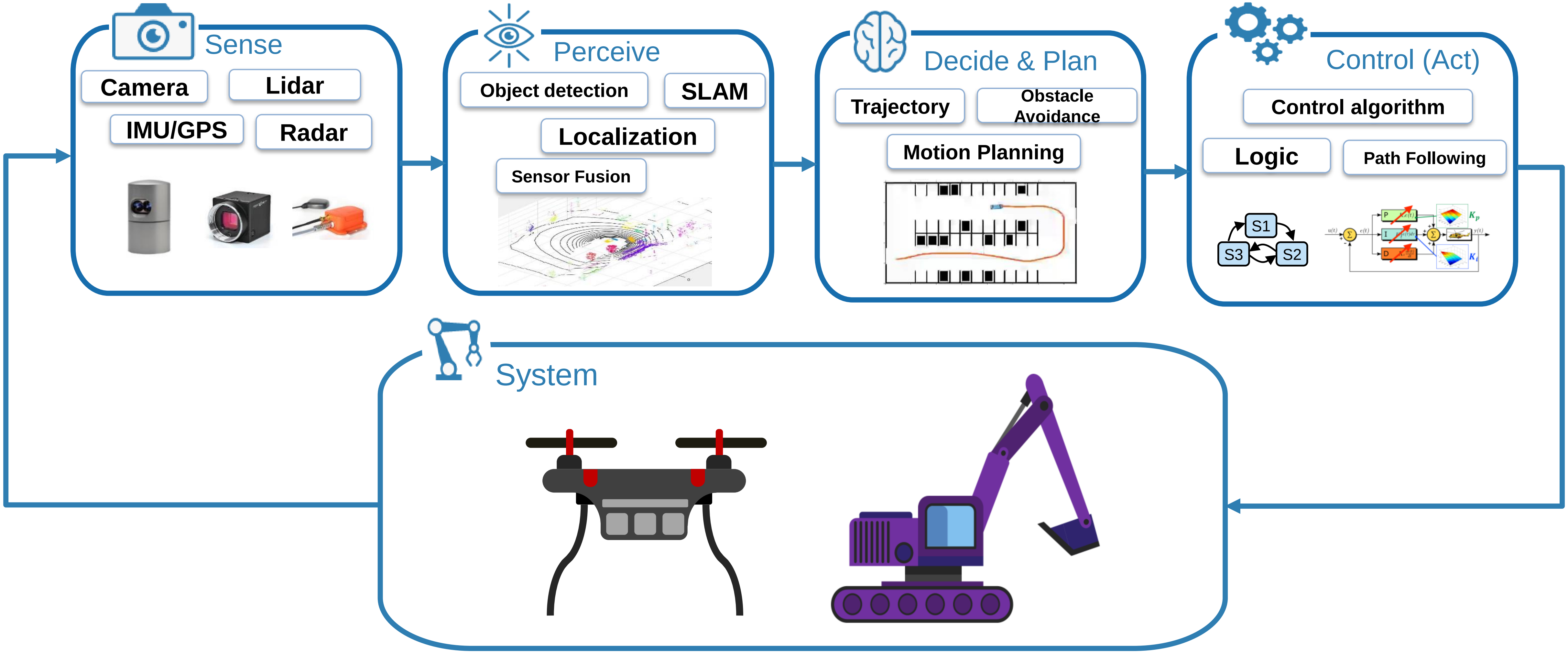
Tasks

- Survey / Measure
- Transport / Operate
- Excavate / Load
- Push / Flatten / Shape

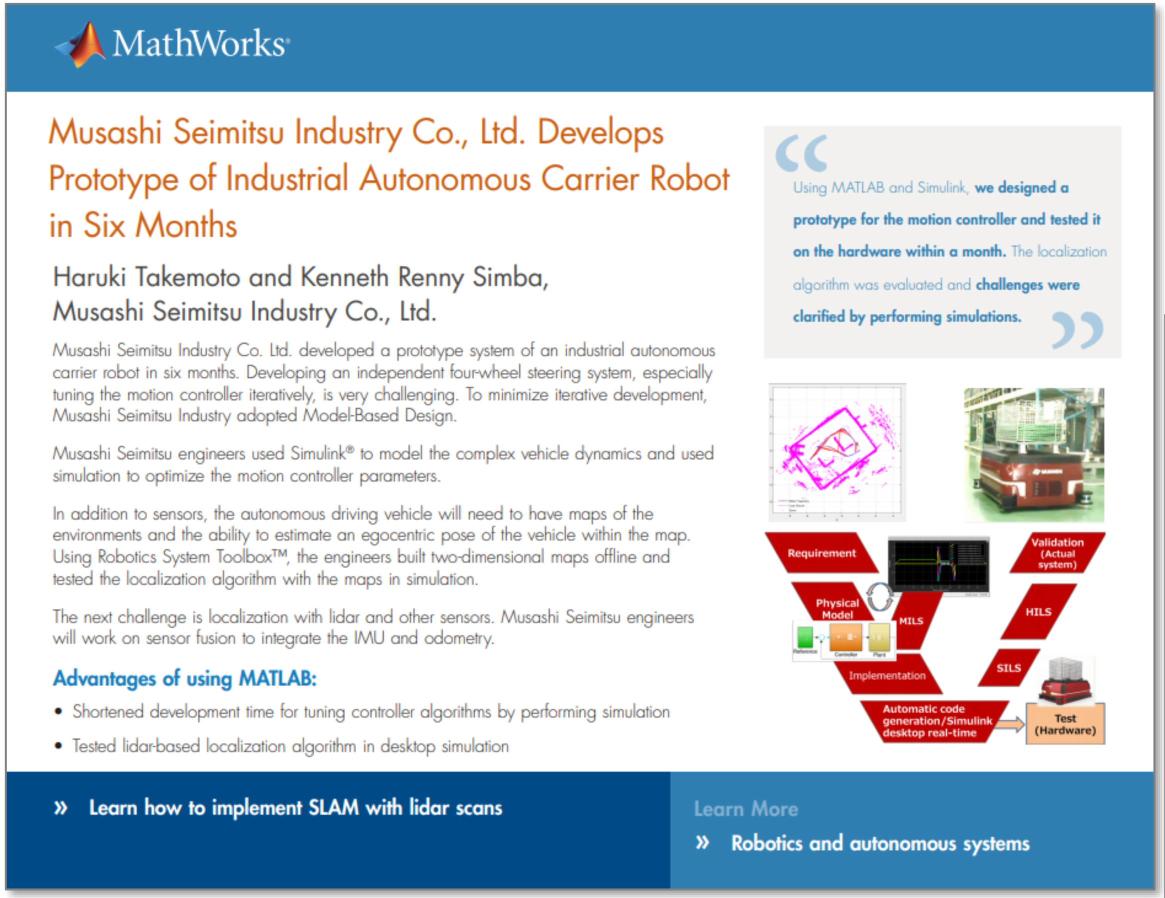
Technologies

- Detect / Identify
- Motion Planning
- Motion Controls

Automation & Autonomy in Construction Activities



Autonomous Systems and Technologies



MathWorks

Musashi Seimitsu Industry Co., Ltd. Develops Prototype of Industrial Autonomous Carrier Robot in Six Months

Haruki Takemoto and Kenneth Renny Simba,
Musashi Seimitsu Industry Co., Ltd.

Musashi Seimitsu Industry Co. Ltd. developed a prototype system of an industrial autonomous carrier robot in six months. Developing an independent four-wheel steering system, especially tuning the motion controller iteratively, is very challenging. To minimize iterative development, Musashi Seimitsu Industry adopted Model-Based Design.

Musashi Seimitsu engineers used Simulink® to model the complex vehicle dynamics and used simulation to optimize the motion controller parameters.

In addition to sensors, the autonomous driving vehicle will need to have maps of the environments and the ability to estimate an egocentric pose of the vehicle within the map. Using Robotics System Toolbox™, the engineers built two-dimensional maps offline and tested the localization algorithm with the maps in simulation.

The next challenge is localization with lidar and other sensors. Musashi Seimitsu engineers will work on sensor fusion to integrate the IMU and odometry.

Advantages of using MATLAB:

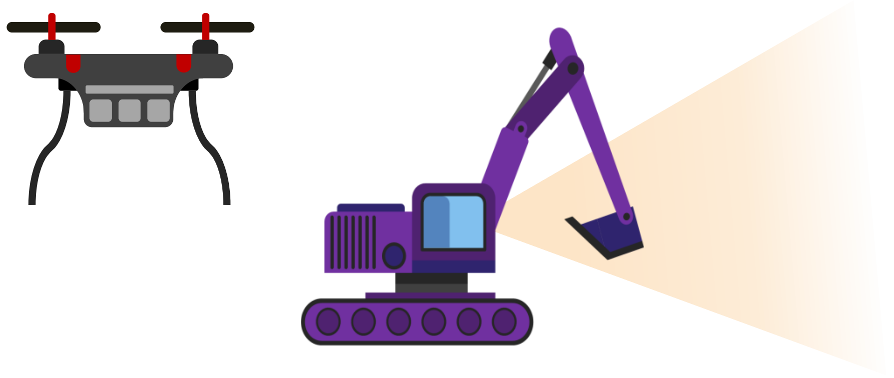
- Shortened development time for tuning controller algorithms by performing simulation
- Tested lidar-based localization algorithm in desktop simulation

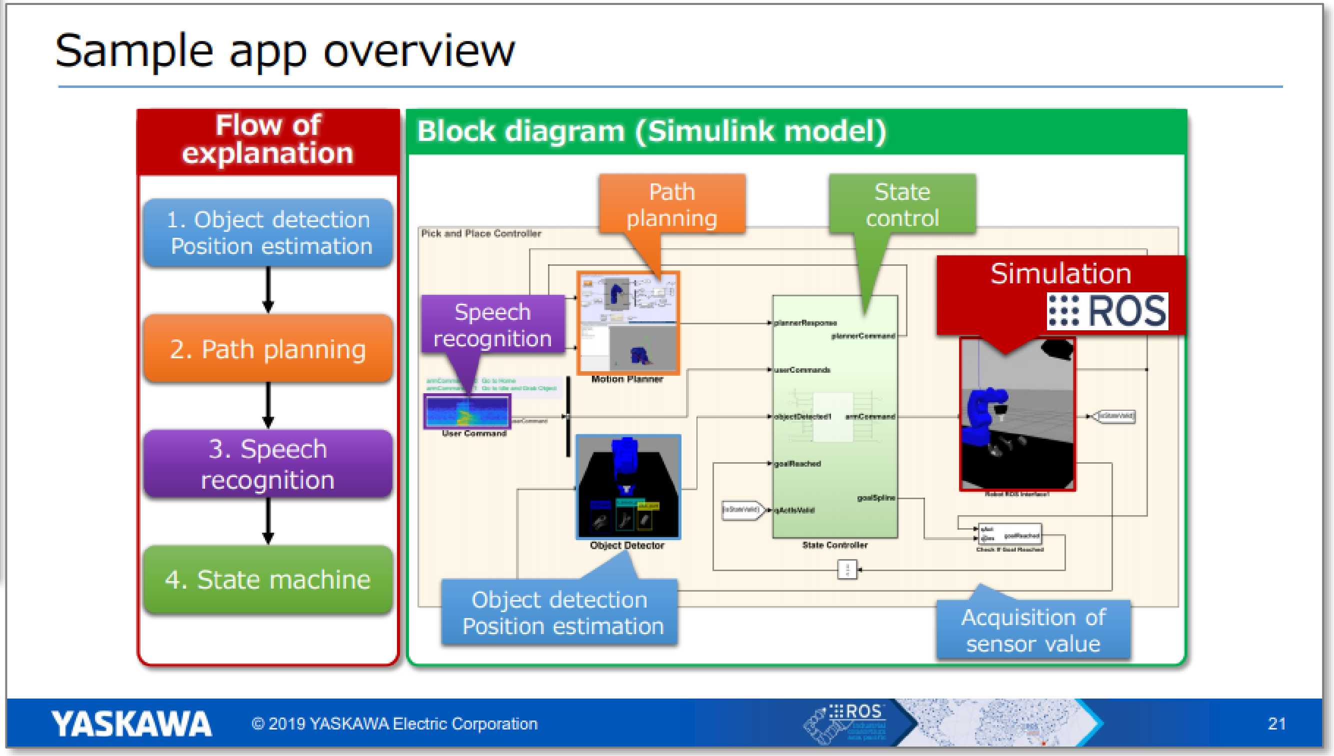
"Using MATLAB and Simulink, **we designed a prototype for the motion controller and tested it on the hardware within a month.** The localization algorithm was evaluated and **challenges were clarified by performing simulations.**"

» Learn how to implement SLAM with lidar scans

Learn More
» Robotics and autonomous systems

Link

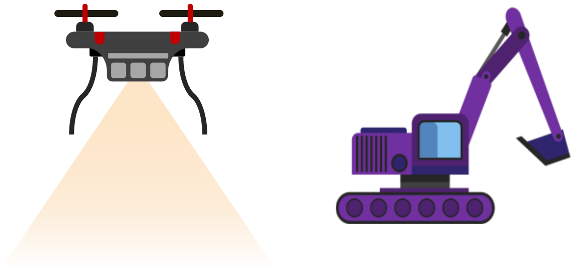




Link

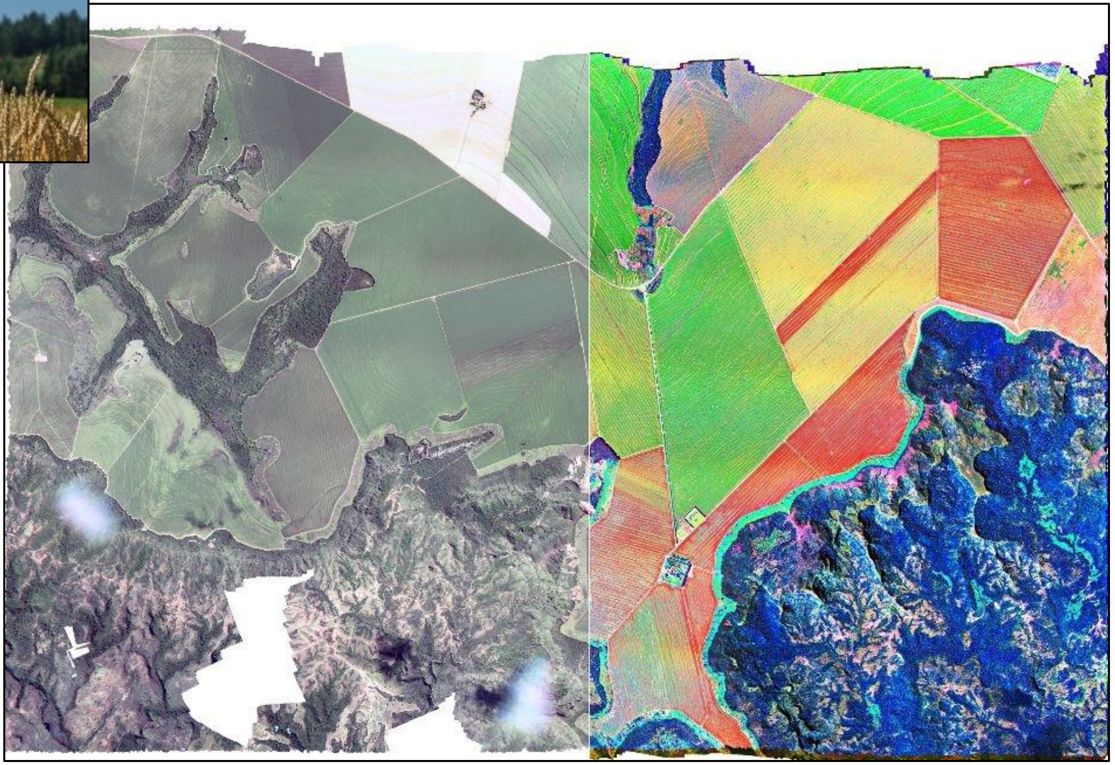
Autonomous systems development with MATLAB/Simulink

UAV Data Utilization



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

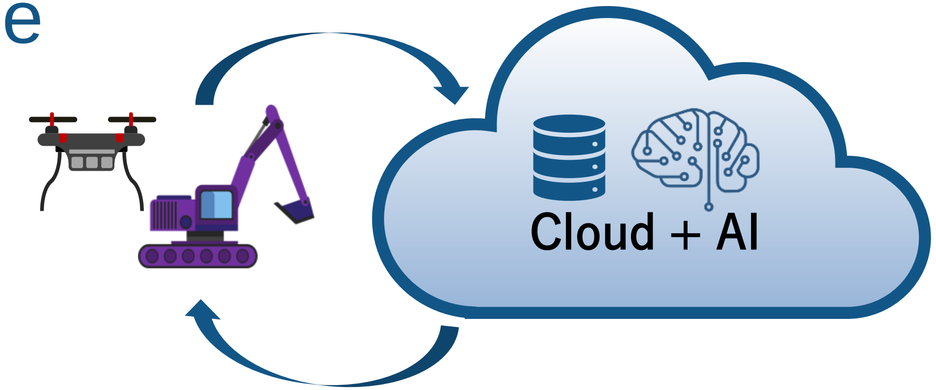
> "In the next few years, computer vision, machine learning, and robotics will increasingly converge to help growers produce more food, more efficiently, and achieve greater financial returns in the process."
>
> — *Al Eisaian, CEO, IntelinAir*



> "It's time-consuming to walk an entire field, but aerial imagery can provide the detailed information needed for both in-season insights and end-of-season guidance on what to change to improve next year's crop. There is a lot of research and development focused on these applications from an agronomic perspective."
>
> — *Dr. Joe Luck, Associate Professor of Biological Systems Engineering, The University of Nebraska-Lincoln*

Link

Digital Twins and Predictive Maintenance



Krones Develops Package-Handling Robot Digital Twin

Challenge
Increase the performance of an automated beverage-packaging system by incorporating a dynamic tripod robot into the design

Solution
Use Simulink and Simscape Multibody to create an accurate digital twin that supports design optimization, fault testing, and predictive maintenance

Results
- Robot performance increased
- Product development time shortened
- Testing time significantly reduced

The Krones Robobox T-GM package-handling robot.

"Simulations of the digital twin in Simulink enabled us to obtain data and insights that would be either impossible to get via hardware tests or simply too costly and time-consuming. Visualizing forces and moments helped us to understand the effects of individual components on a highly dynamic robot."
- Benedikt Böttcher, Krones

Link

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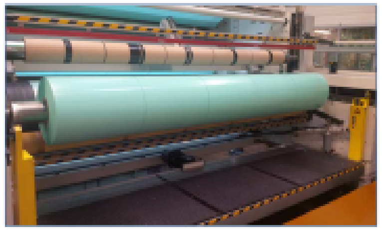
Mondi Implements Statistics-Based Health Monitoring and Predictive Maintenance for Manufacturing Processes with Machine Learning

Challenge
Reduce waste and machine downtime in plastics manufacturing plants

Solution
Use MATLAB to develop and deploy monitoring and predictive maintenance software that uses machine learning algorithms to predict machine failures

Results
- More than 50,000 euros saved per year
- Prototype completed in six months
- Production software run 24/7



One of Mondi Gronau's plastic production machines, which deliver about 18 million tons of plastic and thin film products annually.

"MathWorks Consulting's support is among the best I've seen; the consultants are fast and exceptionally knowledgeable. We've already seen a positive return on investment from cost savings, and now we have more budget and time to complete more machine learning projects that will provide similar benefits."
- Dr. Michael Kohlert, Mondi

Link

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Optimization and operational management with MATLAB and Simulink

Baker Hughes Develops Predictive Maintenance Software for Gas and Oil Extraction Equipment Using Data Analytics and Machine Learning

Challenge

Develop a predictive maintenance system to reduce pump equipment costs and downtime

Solution

Use MATLAB to analyze nearly one terabyte of data and create a neural network that can predict machine failures before they occur

Results

- Savings of more than $10 million projected
- Development time reduced tenfold
- Multiple types of data easily accessed

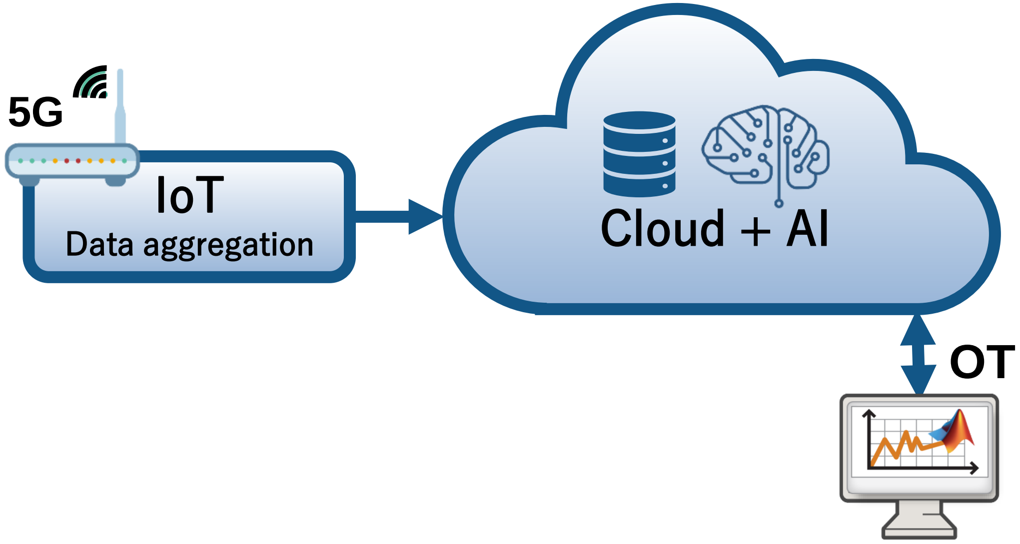
Truck with positive displacement pump.

"MATLAB gave us the ability to convert previously unreadable data into a usable format; automate filtering, spectral analysis, and transform steps for multiple trucks and regions; and ultimately, apply machine learning techniques in real time to predict the ideal time to perform maintenance."

- Gulshan Singh, Baker Hughes

Link to user story

Wireless and Deployment

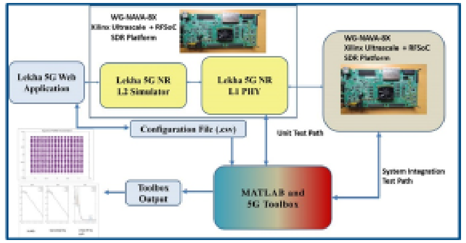


Lekha Wireless Accelerates Development and Interoperability Testing of 5G NR Technology

Challenge
Accelerate the development of 5G NR physical layer IP and reference solutions

Solution
Use MATLAB and 5G Toolbox to design, analyze, and verify the functionality and performance of complete 5G NR gNB signal chains

Results
- Development time halved
- UE test framework setup time reduced from 8 months to less than a month
- RF testing times cut by 80%



Developing 5G NR PHY channels and MIMO interoperability tests using 5G Toolbox.

"With MATLAB and 5G Toolbox we can perform unit-level functional verification and performance validation of our signal chains long before RF testing. When engineers deliver to the integration branch, we know the modules are fully qualified before we perform end-to-end tests."

- Gurucharan Acharya, Lekha Wireless Solutions

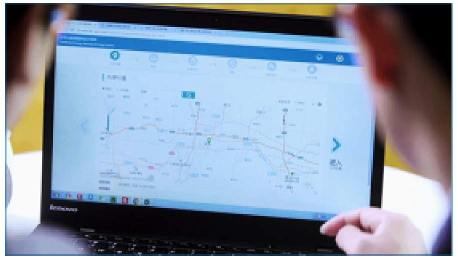
Link to user story

Shanghai Electric Builds and Deploys Cost-Saving Enterprise Software for Planning and Designing Distributed Energy Systems

Challenge
Develop web-accessible software for planning and designing distributed energy systems

Solution
Use MATLAB to develop algorithms that compute investment return based on models of energy production subsystems, loads, and grids, and then use MATLAB Production Server to deploy the algorithms in a production IT system

Results
- Delivery time reduced by six months
- 2 million Chinese yuan saved on a single project
- Updates deployed immediately and without IT assistance



DES-PSO web user interface

"My team's expertise is in energy modeling or algorithm development, not in deploying software into production. MATLAB saved us months of development time on the models and algorithms, and then made it easy to deploy them as part of a stable, reliable web application without recoding."

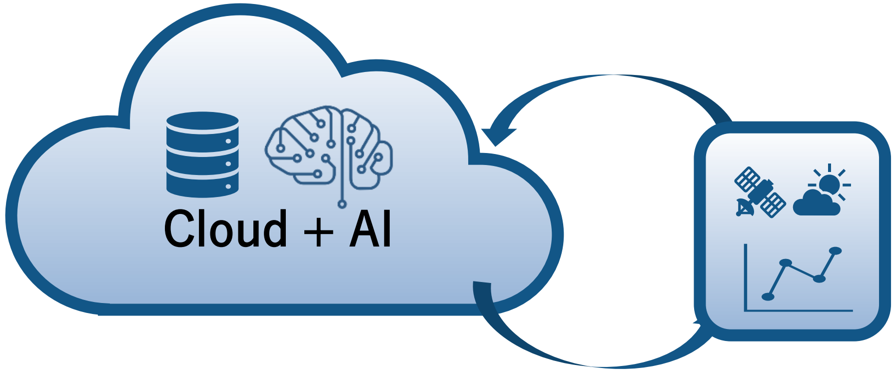
- Yunjiao Gu, Shanghai Electric

Link to user story

1

Investigate communication systems
Deploy applications

Satellite Data Utilization



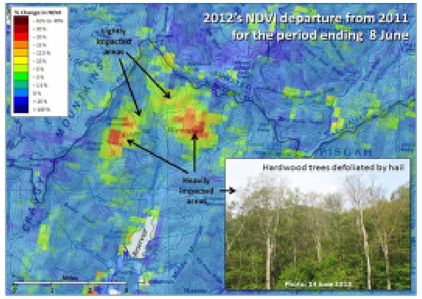
NASA Develops Early Warning System for Detecting Forest Disturbances

Challenge
Develop a system that uses satellite imagery to quickly detect forest disturbance threats from insects, drought, storms, blights, wildfires, and other events

Solution
Use MATLAB to process multispectral satellite images, construct multidimensional time-series data baselines, and analyze terabytes of data to help detect regionally evident forest disturbances

Results
- New ideas implemented and tested in hours
- Years of development time saved
- Reusable production software delivered to growing user community

Link



U.S. Forest Change Assessment Viewer map showing damage to the Asheville, North Carolina watershed following a 2012 hail storm. Image courtesy ForWarn.

"Soon after ForWarn moved into production, it detected previously unnoticed hail damage that posed a threat to a watershed. We would not have been able to do this work as efficiently without MATLAB."

– Duane Armstrong, NASA Stennis Space Center

14

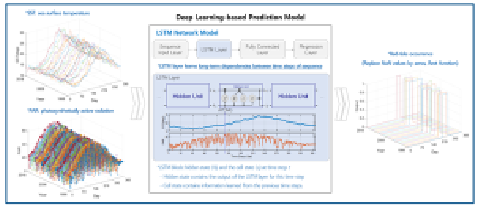
Satellite data analysis using deep learning techniques

KIOST Developed LSTM Deep Learning Model for Early Prediction of Red Tide Occurrence

Challenge
Predict harmful algal blooms, which hurt the coastal ecology as well as the economy for fish farms

Solution
Develop an LSTM deep learning model from satellite data of sea surface temperature and photosynthetically related radiation sequences

Advantages of Using MATLAB and Simulink
- Leveraged high-level APIs for applying time-series data processing
- Used reference examples to accelerate algorithm development and prototyping
- Achieved 94-100% accuracy with multi-year data sets



Deep learning model that predicts occurrence of red tides.

"With domain-specific functionality in MATLAB toolboxes and rich documentation examples, we can rapidly develop time-series based deep learning models."

- Soo Mee Kim, Ph.D, Korea Institute of Ocean & Science Technology

Link (Korean Video)

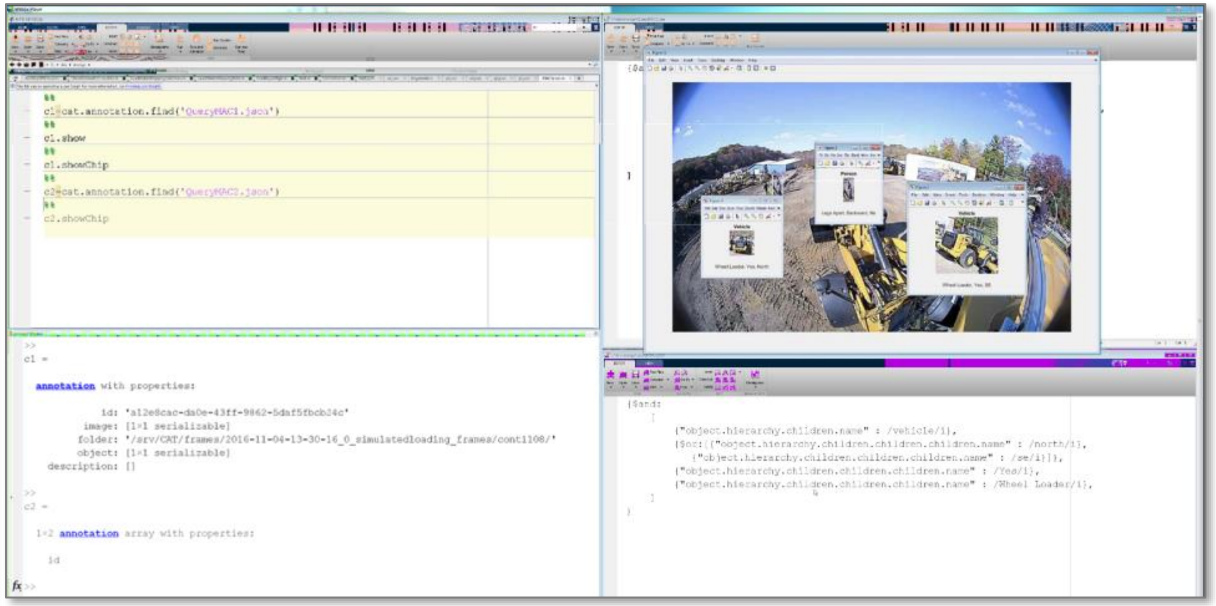
15

Operator Assistance with Big Data, AI, and Autonomous Technologies

"We can access machine learning capabilities with a few lines of MATLAB code. Then, using code generation, engineers can deploy their trained classifier into the machine without manual intervention or delays in the process."

— *Larry Mianzo, Caterpillar*

Link



MathWorks

University Researchers Use MATLAB to Understand How Ecosystems Affect Regional Climates

Challenge

Investigate correlations between environmental variables and identify feedback loops

Solution

Develop MATLAB algorithms to estimate joint probability distributions, accelerate analysis by parallelizing on a computer cluster

Results

- Computation time reduced from a month to a day
- New insights into effects of feedback loops
- Confirmation that ecosystem changes can affect regional climate

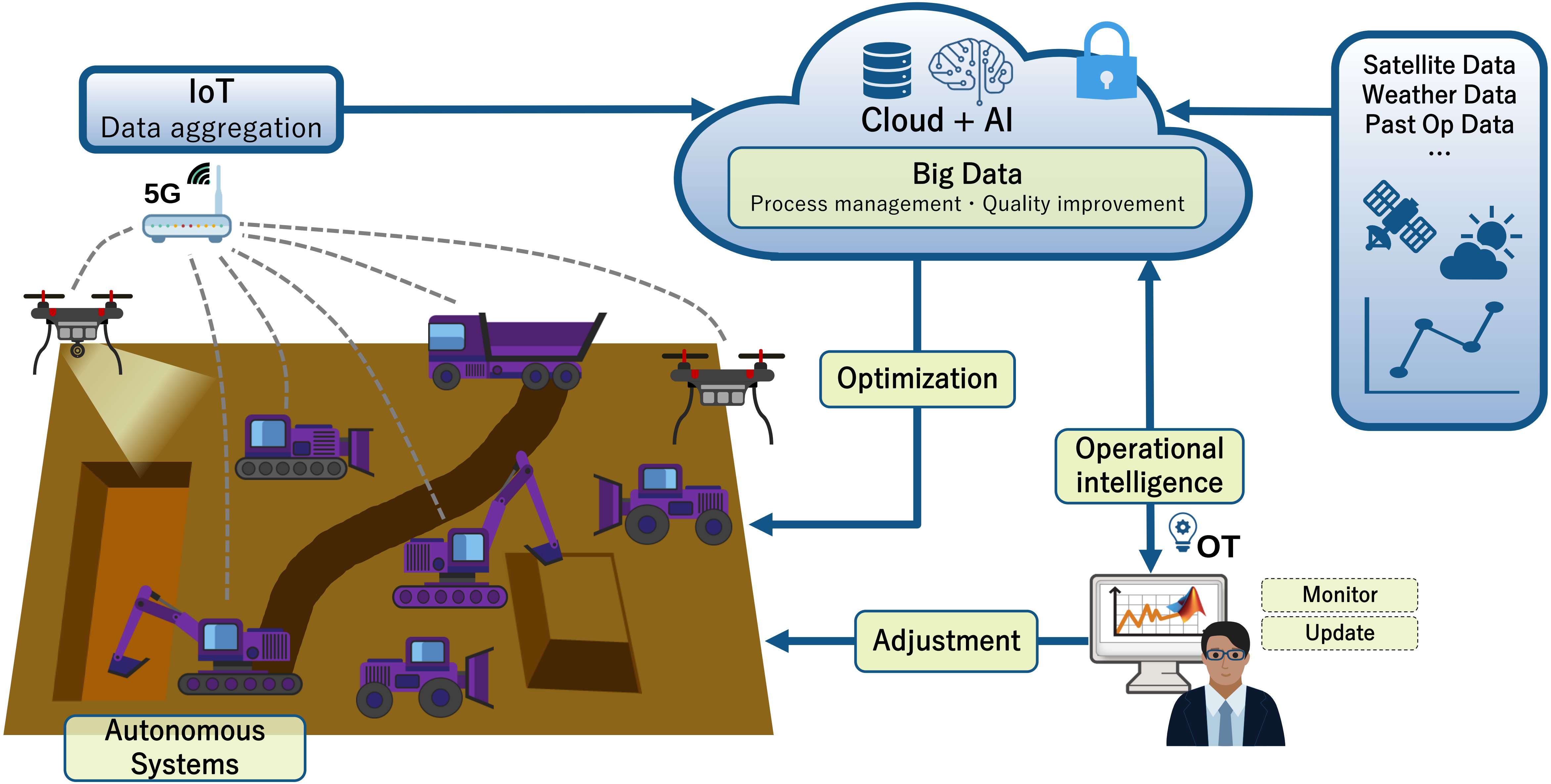
FLUXNET tower, used to acquire time-series environmental data.

"Our algorithms use cutting-edge statistical methods and are exceptionally intensive computationally. MATLAB, Statistics Toolbox, and Parallel Computing Toolbox provide an advantage, both in the development of the algorithms and in visualizing results rapidly."

- Benjamin L. Ruddell, Arizona State University; Nils Oberg, Marcelo Garcia, and Praveen Kumar, University of Illinois

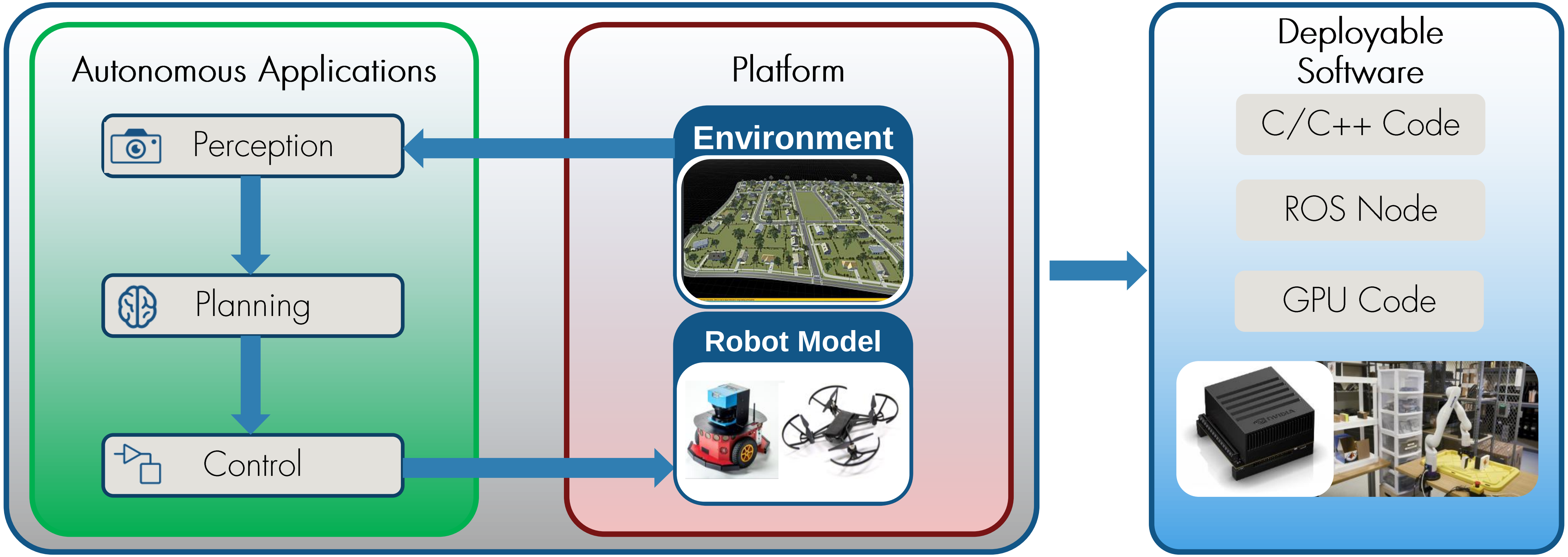
Link to article

Smart Construction: Actionable Insights from Autonomy + Intelligence



MathWorks Solutions

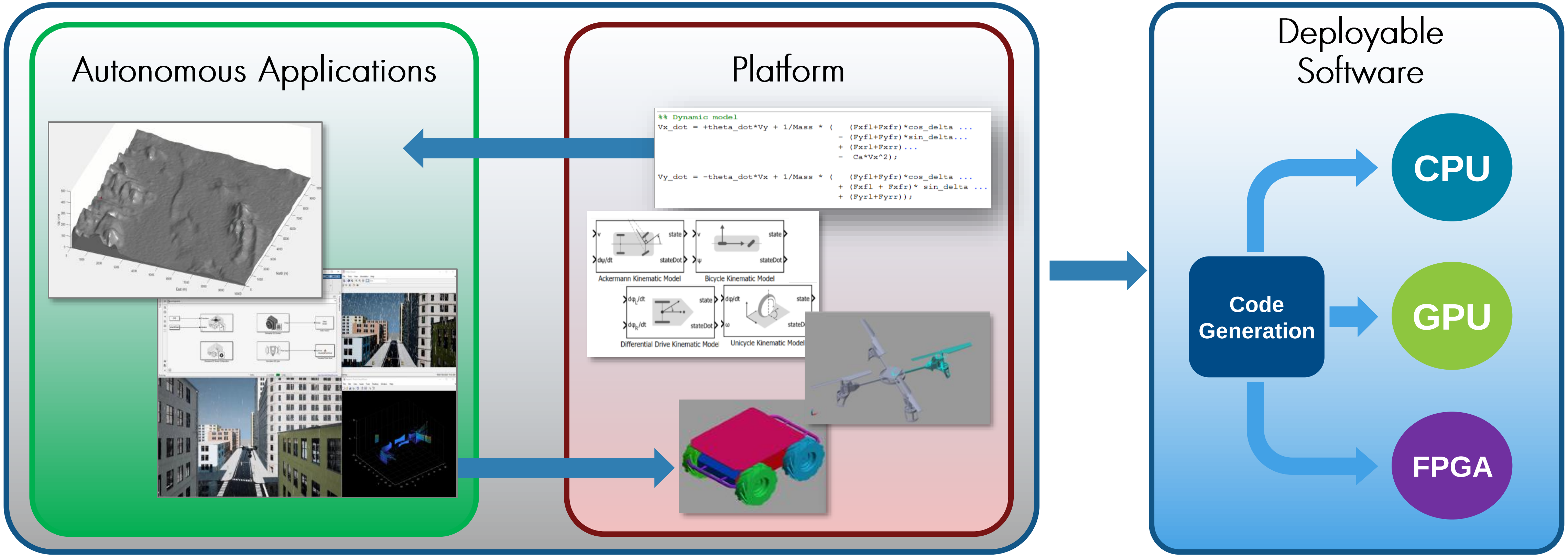
Autonomous Robot Development with MATLAB & Simulink



MATLAB/Simulink Integrated Development Environment

Analyze	Simulate	Design	Implement	Test

Autonomous Robot Development with MATLAB & Simulink

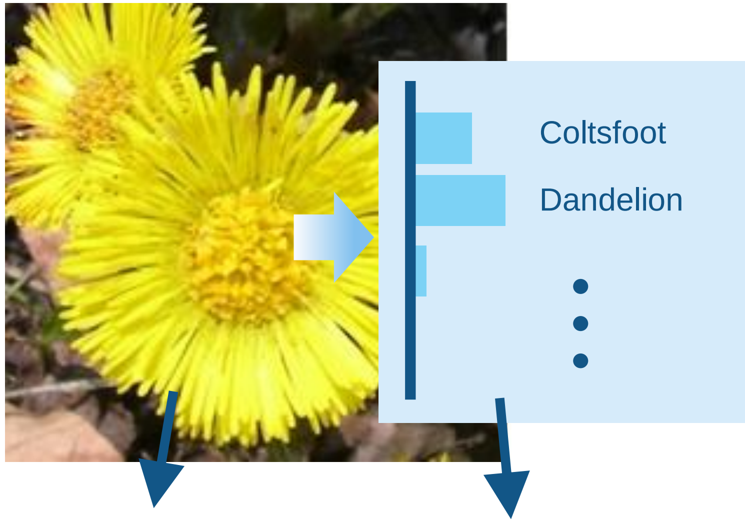


MATLAB/Simulink Integrated Development Environment

Analyze	Simulate	Design	Implement	Test

AI and Deep Learning for Machine Vision

Image Classification

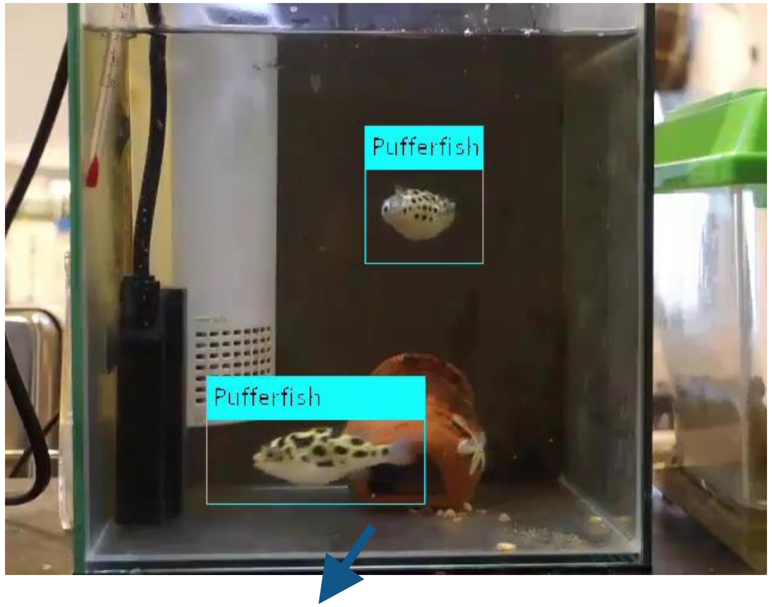


Image

Probability

Recognition of dandelion types

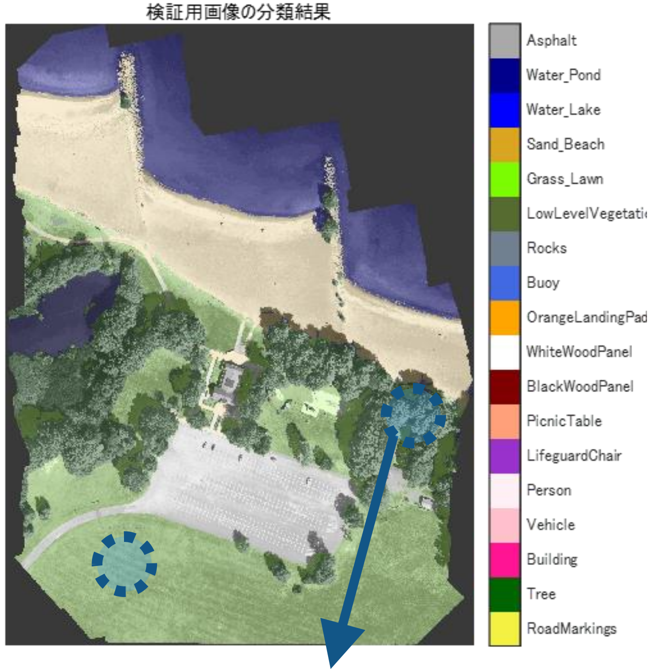
Object Detection



Pufferfish

Detection of Pufferfish

Segmentation



Tree

Multispectral images for surveying vegetation

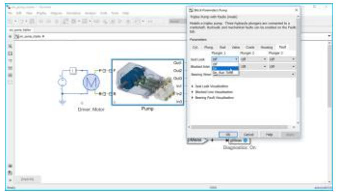
Machine Learning / Deep Learning Workflow

Access and Explore Data → **Labeling and Preprocessing** → **Developing Prediction Model** → **Integration into System**

Access and Explore Data

Files and Databases

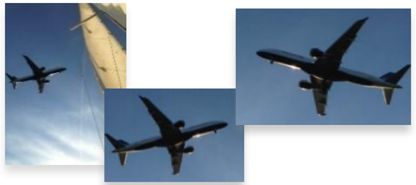
Simulations



Sensors

Labeling and Preprocessing

Data Augmentation/ Transformation

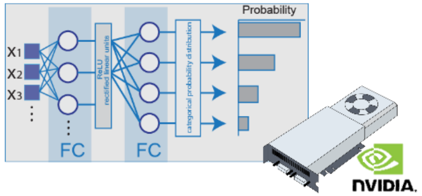


Labeling Automation

Import Pretrained Models

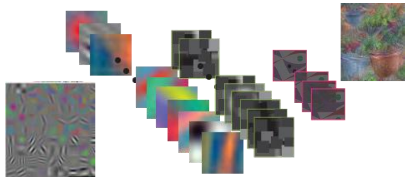
Developing Prediction Model

Hardware-Accelerated Training



Hyperparameter Tuning

Network Visualization

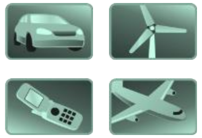


Integration into System

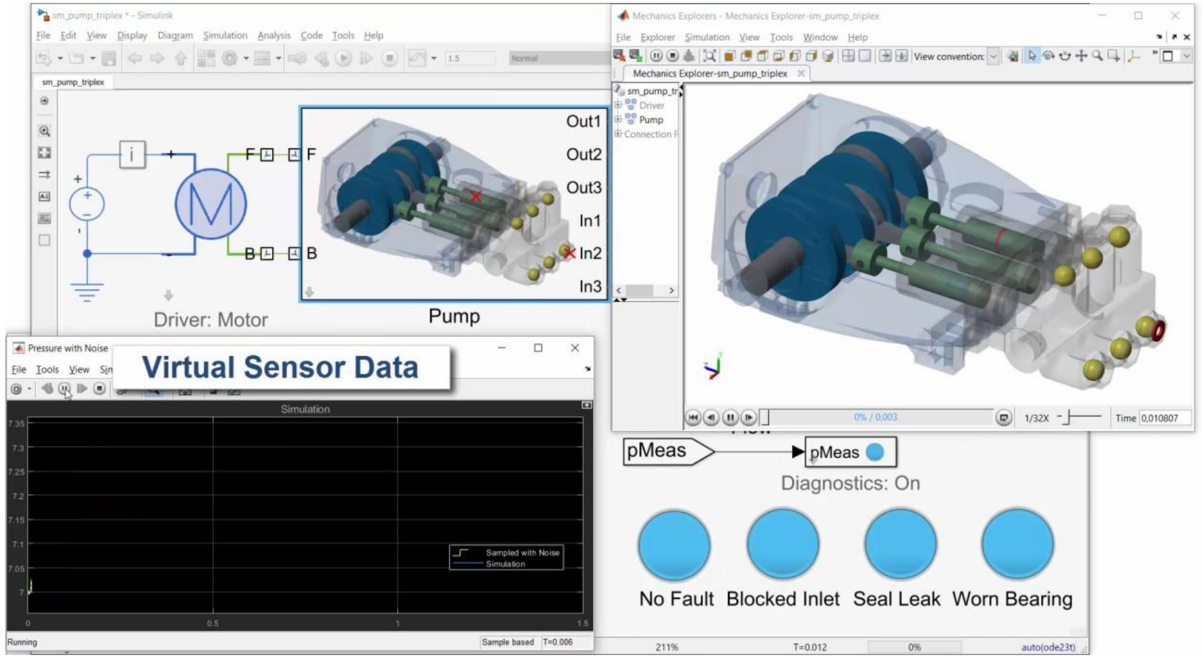
Desktop Apps

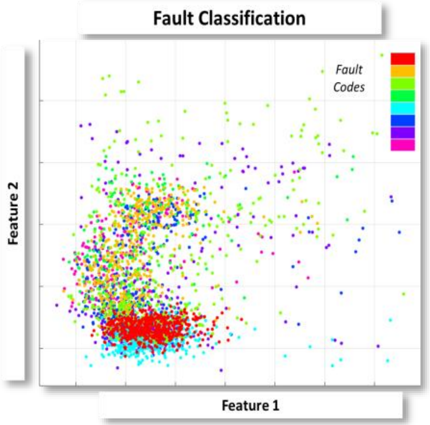
Enterprise Scale Systems

Embedded Devices and Hardware

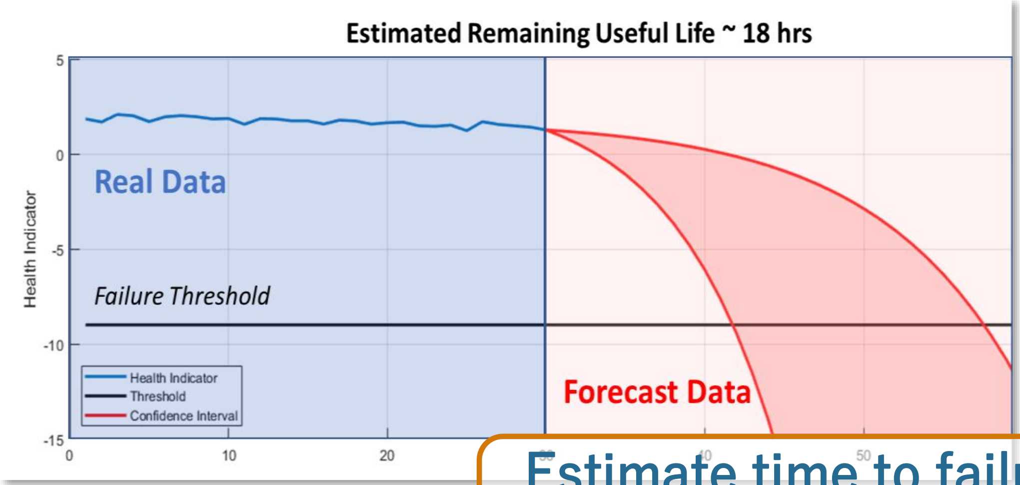


Digital Twin and Prediction Maintenance





Classify failure type



Estimate time to failure (remaining useful life)

Utilizing Simulink model for :
- Optimization through simulations
- Generation of failure data

Developing Predictive Maintenance Systems

1 Data access and exploration

- File
- Database
- Sensor

2 Preprocess data

- Data cleaning
- Reduction / Conversion
- Feature Extraction

3 Develop prediction model

- Model creation
- Parameter optimization
- Model evaluation

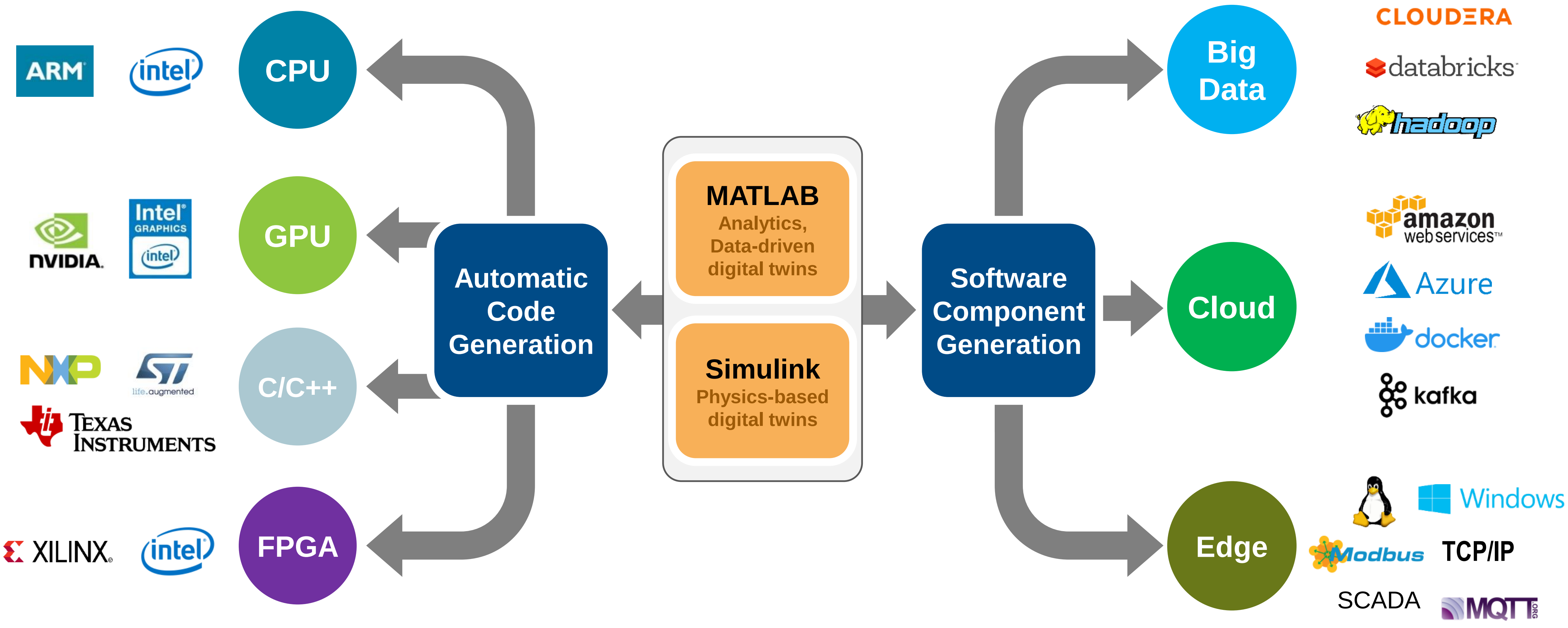
4 Integrate into system

- Desktop application
- Enterprise system
  - kafka
  - AWS Kinesis
  - OSIsoft.
- Embedded devices and hardware

5 Visualizing results

- 3rd party dashboards
  - Spotfire TIBCO Software
  - tableau
  - Qlik
  - Power BI
- Web app

MATLAB and Simulink for Embedded, Edge, OT/IT Systems



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