MATLAB EXPO 2019

Education Master Class

Preparing Future Engineers and Scientists for the Challenges of Digital Transformation

Jim Tung
BuildingIQ

What it does?
SAVES ENERGY
Embedded Algorithms for Interpreting Blood Type Results

What it does? SAVES TIME
Augmented reality visualization of blood flow

What it does?
SAVES LIVES
Digital Transformation
Digital Transformation

“Sample-size 1” • Increasingly individualized products

“Smart products” • Autonomous machines that do not require costly programming to meet new requirements

• Intelligent products that collect data to optimize processes and develop new products

“Servitization” • Opportunities for innovative business models and services
What Tomorrow’s Engineer Needs to Know

• Algorithms: e.g., Controls, Signal Processing, Optimization, Computer Vision
• Abstraction, Modeling, and Simulation

AND

• Multidomain System Development

AND

• Distributed and Connected Systems
• Using Cloud Platforms and Big Data Processing
• AI and Data Science
Project-Based Learning with MATLAB and Simulink

- Treat engineering students like engineers
- Hands-on experience of working on hardware and software
- Solve authentic problems in myriad contexts
- Increase student interest and improve learning

https://www.mathworks.com/hardware-support/home.html
Today’s Topics: Three Exercises to Develop That Know-How

Quadcopter Simulation

- Develops Computational Thinking
- Enables comparisons of theory and simulation
- Automatically generates controller code
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Arduino Mobile Rover

- Model-Based Design for autonomous vehicle
- Integrates controls, WiFi, path planning, and localization
- Low-cost hardware
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Triplex Pump Digital Twin
- Complex industrial application
- Combines engineering and data science
- Can leverage cloud computing
- No hardware required
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Quadcopter Simulation

Develop Understanding of Technical concepts

Plant Modeling

Hand Derivation
MATLAB Simulink Symbolic Math

Commercial CAE
Simscape Multibody

Comparison

Control System Design

Code generation for deployment
Quadcopter: modeling – part 1

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Hand Derivation
MATLAB Simulink
Symbolic Math

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Code generation for deployment
Quadcopter: modeling – part 2
Quadcopter: modeling – part 3

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Quadcopter: Control Design

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Code generation for deployment
Quadcopter: Code generation for deployment

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Arduino Mobile Rover

Triplex Pump Digital Twin

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Arduino Mobile Rover in Action
Mobile Rover Basics

- Arduino+
  Motor Control
- Servo Motor
- Ultrasonic Sensor
- DC Motors+
  Encoders
- Battery
Workflow

1. Modeling and simulation

2. Deploy to hardware

3. Integrate with localization using Wi-Fi
Modeling and Simulation

Rover kinematics

Wheel velocities → Input → Rover trajectory → Output
Modeling and Simulation

Rover kinematics

Forward kinematics

\[
\begin{bmatrix}
\omega_l \\
\omega_r
\end{bmatrix} = \frac{1}{r} \begin{bmatrix}
1 & -L/2 \\
1 & L/2
\end{bmatrix} \begin{bmatrix}
v
\end{bmatrix}
\]

Rate of rotation: \( \omega \)
Forward velocity: \( v \)

Rover velocities Input
Wheel velocities Output
Rover trajectory Output

Intermediate Output

Wheel speeds
\( (\omega_l, \omega_r) \) = \int \left( \begin{array}{c}
\text{Forward velocity} \ (v), \\
\text{Rate of rotation} \ (\omega)
\end{array} \right) \)

Inverse kinematics

\[
x(t) = \int_0^t v \cos(\theta) \, dt
\]

\[
y(t) = \int_0^t v \sin(\theta) \, dt
\]

\[
\theta(t) = \int_0^t \omega \, dt
\]
Modeling and Simulation

Rover kinematics

**Forward kinematics**

\[
\begin{align*}
\omega_l &= \frac{1}{r} \begin{bmatrix} 1 & -L/2 \\ 1 & L/2 \end{bmatrix} \begin{bmatrix} v \\ \omega_r \end{bmatrix} \\
\end{align*}
\]

**Inverse kinematics**

\[
\begin{align*}
x(t) &= \int_0^t v \cos(\theta) \, dt \\
y(t) &= \int_0^t v \sin(\theta) \, dt \\
\theta(t) &= \int_0^t \omega \, dt
\end{align*}
\]
Modeling and Simulation

Rover kinematics

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Modeling and Simulation
Path Planning and Motion Control

Legend
Path planning
Motion control

Calculate angle
Turn
Pick-up / Drop
Move Forward
Calculate distance
Next waypoint

Final destination
Object location
Rover location

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Modeling and Simulation
Path Planning and Motion Control

Adding waypoints is as simple as changing this block!
Modeling and Simulation

Path Planning and Motion Control
Workflow

1. Modeling and simulation

2. Deploy to hardware

3. Integrate with localization using Wi-Fi
Deploy to Hardware
Deploy to Hardware
Workflow

1. Modeling and simulation

2. Deploy to hardware

3. Integrate with localization using Wi-Fi
Get Location Data Over Wi-Fi

Webcam on top of a table; Tethered to PC

Taking picture of arena → Image Processing → Location results sent via Wi-Fi
Localization Algorithm

Workflow

Step 1: Use R, G, B colors as threshold

Step 2: Remove noise

Step 3: Find the centroid

Repeat to track and send results!

Rover
Location: (75,60) cm
Heading: 90 deg
Mobile phone controlling rover

- Arduino
- Raspberry Pi
- LEGO Mindstorms EV3
- Parrot Minidrones
- TI C2000
- ST Micro
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Triplex Pump
Predictive Maintenance Using Digital Twins
How can I teach students these concepts if I don’t have a real pump?
Prevent system downtime by sending sensor data to a predictive maintenance algorithm created using a Digital Twin and machine learning in MATLAB.
Triplex Pump

- Crankshaft drives three plungers
  - Each 120 degrees out of phase
  - One chamber always discharging
  - Smoother flow than single or duplex piston pumps
Predictive Maintenance Workflow

- Sensor data isn’t always available
  - Failure conditions difficult to reproduce
  - Time consuming or costly to generate
  **Solution:** Build digital twin and generate sensor data using simulation

- Developing algorithm is complex
  - Requires complex concepts and analysis
  **Solution:** Use MATLAB to simplify process of developing and deploying algorithm
Key takeaways

- IoT is revolutionizing the industry
- New graduates will be expected to address challenges like this
- Experience with tools and workflows used in industry make students more hireable
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Vision
2040: Austria is world leader in STEM education

Mission
Strengthen STEM education and secure local industry in Austria

Strategy
Connect stakeholders in academia, industry and government. Initiate, and support high-impact STEM projects.

Projects
Multicopter for teaching and research
Turn CHALLENGES into OPPORTUNITIES

- Market penetration in AERO
- Recruiting Hiring
- Brand awareness
Turn CHALLENGES into OPPORTUNITIES

Market penetration in AERO

Courses Research in AERO

Recruiting Hiring

Brand awareness

MATLAB EXPO 2019
Flight robotics seminar

Universität Stuttgart

School of Aerospace Engineering

Meeting with

Collaboration with

Institute

infineon

MathWorks

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Turn CHALLENGES into OPPORTUNITIES

Market penetration in AERO

Recruiting Hiring

Courses Research in AERO

Brand awareness

3 Hires in 1 semester
Turn CHALLENGES into OPPORTUNITIES

- Market penetration in AERO
- Courses Research in AERO
- Recruiting Hiring
- Brand awareness

- 3 Hires in 1 semester
- 1 Million views in 24 hrs

MATLAB EXPO 2019
Preparing Students for Digital Transformation

Academic Research

Basic Research
Discovery
Graduate Education

Innovation Expertise

Applied Research
Tools and Technology
Product Development

Skilled Labor

Industry

Undergraduate Education

Knowledge Curricula

Workforce Training
Future Researchers

Workforce Training
Future Researchers
Bring these exercises to your classroom!

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