MATLAB과 Simulink를 이용한 자율 무인항공기(UAV) 개발 및 검증

김종헌
Autonomous UAV Development and Evaluation

- Integrated workflows enabled by MATLAB and Simulink
- Tools to design UAV systems and autonomous applications
- Select appropriate methods for your UAV development tasks
- Evaluating systems through closed-loop simulations with sensor models
Increase in Autonomous UAV Usage

- Mapping & Surveying
- Inspections & Monitoring
- Delivery & Transport
- Security & Defense
Challenges in Developing Autonomous UAV Systems & Applications

- Complexity of advanced autonomous algorithms
- Need of end-to-end workflows
- Ensuring system quality and reducing flight risk
Solutions for Developing Autonomous UAV Systems & Applications

Robust tools and features for designing and testing UAV systems and algorithms

Integrated development environment that covers development from ideas to production

Extensive verification and validation tools to evaluate design quality through virtual testing
Integrated Workflows for Developing UAV Applications

MATLAB® → Simulink®
System Architecture

Model UAV

Model UAV

Simulate with Sensor Models
Cuboid
Gazebo
Unreal Engine

Design Algorithms
Perception
Planning & Decision
Control

Analyze Data

DO-178
87.5%

Deploy to Hardware
PX4®
NVIDIA® Jetson®

Connect
UAV
Ground Control Station
System Architecture

- System Composer™ for designing and analyzing system and software architecture
- Simulink integration and requirement allocation for traceability

Link
Integrated Workflows for Developing UAV Applications

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Connect

Implement

Verification & Validation

87.5%

DO-178
UAV Plant Modeling: Selecting the Appropriate Fidelity

**High-Fidelity**
*Building UAV*
- More Detailed
- Slow
- Modeling effort

**Approximate**
*Programming UAV*
- Fast
- Easy to model
- Less detailed

**Worst-case test**

**Navigation algorithm test**
UAV Plant Modeling: Selecting the Appropriate Fidelity

High-Fidelity Building UAV

Approximate Programming UAV

Physical Modeling
Model construction techniques and best practices, domain-specific modeling, physical units

Vehicle Dynamics
Model aerodynamics, propulsion, and motion of aircraft and spacecraft

Guidance Model
Reduced-order model for UAV

Simscape Multibody, Aerospace Blockset, UAV Toolbox
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Connect

Implement

MATLAB EXPO
Autonomous UAV Algorithm Development

Design Algorithms
- Perception
- Planning & Decision
- Control

Map Data
- Startpoint
- Planned Path
- Endpoint
Autonomous UAV Algorithm Design with Robust Capabilities

Autonomous UAV Algorithm Design with Robust Capabilities

Perception

Planning & Decision

Control

Define UAV missions with waypoint and trajectory-following algorithms

UAV motion planning with advanced path planners

UAV Toolbox, Navigation Toolbox
Autonomous UAV Algorithm Design with Robust Capabilities

**Perception**

**Planning & Decision**

**Control**

Model Predictive Control Toolbox, Reinforcement Learning Toolbox
Integrated Workflows for Developing UAV Applications

- **Model UAV**
  - Design Algorithms
    - Perception
    - Control
    - Planning & Decision
  - System Architecture
  - Analyze Data

- **Simulate with Sensor Models**
  - Cuboid
  - Gazebo
  - Unreal Engine

- **Deploy to Hardware**
  - PX4
  - NVIDIA Jetson

- **Connect**
  - UAV
  - Ground Control Station

- **Implement**

- **MATLAB®**
- **Simulink®**

- **Verification & Validation**

- **DO-178**

- **87.5%**
Tracking and Automating Verification and Validation Activities

Requirements Traceability
- Mapping requirements
- Requirements traceability matrix

Test Management & Automation
- Authoring testcases
- Test result evaluation

Evaluate Completeness
- Coverage Analysis
- Model metric & Compliance test result

Simulink Requirements, Simulink Test, Simulink Coverage, Simulink Check
Example: Automating UAV Testing with Requirements Linking

Requirements linking for traceability

Automating test execution and evaluation

UAV Toolbox, Simulink Requirements, Simulink Test Link

Verification Status
- Passed
- Failed
- No Result
- Missing

Design completeness
Test case completeness
Integrated Workflows for Developing UAV Applications

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Verification & Validation
- DO-178
- 87.5%
Integrated Simulations with Sensor Models

Cuboid Performance

Rapidly author scenarios and generate sensor data

Unreal Engine® Photorealistic

Realistic graphics to test autonomous algorithms in closed-loop simulations

UAV Toolbox
Example: Building 3D Map using Lidar Point Cloud Simulation

- Execute simulation
- Obtain sensor data
- Extract and match features
- Register and align point cloud
- Detect loop-closures
- Create pose graph
- Optimize poses

UAV Toolbox, Lidar Toolbox
3D Scene Creation for UAV Simulations

Design 3D scenes for simulating and testing autonomous algorithms

RoadRunner, RoadRunner Asset Library, UAV Toolbox Interface for Unreal Engine Projects
Automatic Code Generation for Hardware Implementation

Deploy flight controls to autopilot hardware

Deploy to Hardware

Deploy autonomous algorithms to onboard computers

CPU
GPU
FPGA
ROS

PX4®
NVIDIA® Jetson®

UAV Toolbox, Simulink Coder, Embedded Coder, GPU Coder
Connecting to UAV Hardware through MAVLink Protocol

UAV Toolbox

DO-178

MATLAB®

Simulink®

PX4®

NVIDIA® Jetson®

Unreal Engine

Gazebo

MATLAB EXPO
Post-Flight Data Analysis

Flight Log Analysis

Payload Data Analysis

Analyze Data

UAV Toolbox, Computer Vision Toolbox, Deep Learning Toolbox
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- DO-178

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Key Takeaways

Call To Action:
• Download presentation file and investigate linked examples and pages
• Contact us for to learn more details or for trials

Integrated development workflows from prototyping to productization with MATLAB and Simulink

Robust tools/features for autonomous UAV design and simulations with sensor models

Quality through verification & validation tools for traceability, test completeness, and test management/automation
MATLAB EXPO
2021

Thank you