Technische Universität München Uses Model-Based Design to Drive Research, Problem-Based Learning, and Industry Collaboration

Professor Holzapfel, research fellow Markus Hornauer, and a student test flight control algorithms in the Research Flight Simulator.

The Challenge

Enable problem-based learning of flight dynamics and cost-effective implementation of flight control systems

The Solution

Use MathWorks tools for Model-Based Design to simulate designs, conduct real-time tests, and develop realistic flight simulators

The Results

- Students prepared for a variety of careers
- Motivation increased and learning accelerated
- Collaboration with industry partners strengthened

Research projects at the Institute for Flight System Dynamics at Technische Universität München (TUM) focus on the practical application of flight control theory: Faculty and graduate students collaborate with industry partners to develop algorithms and safety-critical flight-worthy systems that fly in actual aircraft. This focus on real-world application carries over to the classroom, where students work with flight simulators that vividly demonstrate the effects of control design decisions.

The institute relies on MathWorks tools for Model-Based Design to support these activities.

"Our results-driven, problem-based approach would not work without MathWorks tools and Model-Based Design," says Dr. Florian Holzapfel, professor at the Institute for Flight System Dynamics at TUM. "The MathWorks tool chain provides the greatest coverage of the development process, from requirements and multidisciplinary modeling to simulation and implementation."

The Challenge

For institute researchers and the smaller companies with which they collaborate, using disparate tools for flight control system development is impractical and expensive.

"We need affordable tools with a high degree of automation," says Holzapfel. "We also need lean and effective processes that can be customized for small development teams and for shorter development life cycles."

The challenge for TUM instructors lies in helping students move rapidly from learning a theory to applying it. "Normally, university students learn a lot about math and algorithms but do not acquire an appreciation for what has to be done to make an algorithm fly in a real aircraft," says Holzapfel. "At TUM, our goal is to close this gap and produce graduates who are outstanding candidates for our partner companies or for our own research team."

The Solution

TUM adopted Model-Based Design across the Institute for Flight System Dynamics for classroom activities, research initiatives, and control design projects with industry partners.

In Flight Controls 1 and Flight Controls 2, lectures are complemented with interactive demonstrations and tutorials based on a simulator built using MATLAB® and Simulink®. For example, students use the simulator to determine steady-state flight conditions through trim routines and then use MATLAB to analyze simulation results.

Students develop controller models using Simulink gain, integrator, and transfer blocks and then run closed-loop simulations with a Simulink model of an aircraft.

In Flight System Dynamics, students use Simulink to simulate level flight, acceleration, deceleration, climb and descend, and other performance cases for which there are no simple analytical, closed-form solutions.

MathWorks®

"Flight controls and flight system dynamics are multidomain engineering disciplines. MathWorks tools enable our students to build upon our fundamental research to develop solutions that fly in real aircraft. With Model-Based Design we can close the gap between the theoretical foundation and the practical application, and that is how we measure success." —Dr. Florian Holzapfel, Technische Universität München

Apart from their work with simulators, students test novel flight control, sensor data fusion, and navigation algorithms on quadrocopters—40 cm-by-40 cm flying aircraft with four rotors.

They use Embedded Coder™ to generate code from Simulink models. They deploy the code directly to the quadrocopters' embedded processors for in-lab flight tests.

The institute operates two simulators that are much more sophisticated than the lecture simulator: the Research Flight Simulator, which has a generic cockpit replicating a twin engine aircraft, and the high-fidelity Diamond DA-42 Flight Training Device. The Flight Training Device was built with original aircraft components from a DA-42 to ensure the highest degree of realism for the simulation of control forces. Both simulators were built using MATLAB, Simulink, and Stateflow®.

TUM researchers use Simulink Coder™ to generate C code from their Simulink models and achieve near-real-time performance in the Research Flight Simulator.

A TUM research team led by Ph.D. candidate and research fellow Markus Hornauer is using Model-Based Design to develop a process that will enable smaller civilian and defense contractors to cost-effectively develop flight-worthy, certifiable software that meets European Aviation Safety Agency standards.

The Results

Students prepared for a variety of careers. "The company that builds our quadrocopters was founded by former TUM students, and many of our graduates go on to work for the aerospace companies that they worked with on student projects," says Holzapfel. "Our students are also in demand by automotive companies, which need engineers who have experience with Model-Based Design."

Motivation increased and learning accelerated. "Working directly with models and simulation in Simulink—instead of just theory and math—keeps the students engaged, motivated, and focused on engineering rather than programming," says Holzapfel. "Simulations enable students to experiment, make mistakes, and correct them on their own, which expedites the learning process."

Collaboration with industry partners strengthened. "Three years ago, our institute had three people," says Holzapfel. "Now we have more than 40, and we're among the largest programs in the country. I believe this growth is proof that our approach with Model-Based Design is meeting the needs of our industry partners."

Industry

- Academia
- Aerospace and defense

Application Areas

- Data analysis
- Mathematical modeling
- Algorithm development
- System design and simulation
- Rapid prototyping
- Embedded code generation
- Embedded systems
- Control systems

Products Used

- MATLAB®
- Simulink®
- Embedded Coder™
- MATLAB Coder™
- Simulink Coder™
- Stateflow®

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http://portal.mytum.de/tum/index_html/

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