Teaching, Applied Research and Development: From Academia to Industry

Prof. Dr. Raoul Herzog
University of Applied Sciences Western Switzerland (HES-SO)
HEIG-VD, Yverdon-les-Bains
June 9, 2015
Key Takeaways

1. We prepare future engineers to apply MATLAB and Simulink because they are industry-standard tools

2. Model based design and simulation is a key for motion control systems

3. Code generation makes it easier to prototype and explore many different options earlier in the design
University of Applied Sciences Western Switzerland (HES-SO)

- HES-SO: the biggest of the 7 Swiss HES
- In Engineering: 2'200 Bachelor and 220 Master students
- Split over 5 campuses in the french speaking cantons
Missions of the HES-SO

- Developing hands-on engineers for industry
- Being an innovation actor for industry by carrying out applied R&D projects

The examples in my talk are taken from the campus HEIG-VD in Yverdon, especially the "Institute for Industrial Automation" (iAi) specialized in motion control.
MATLAB and Simulink in Teaching (lectures and labs) (1/2)

- Reason for using MATLAB and Simulink: they are industry-standard tools!

- MATLAB and Simulink are used in various bachelor and master courses (signal processing, control, power electronics, etc.) starting from the second year of studies.

- Students are provided with MATLAB student licences enabling them to work on their own laptops.
MATLAB and Simulink in Teaching (lectures and labs) (2/2)

- Automatic control lab in Yverdon (HEIG-VD)
- Equipped with Simulink Real-Time
- Speedgoat mobile target PC
- Two electromechanical plants
- System modelling
- Controller design

FlexPlant experiment
Goals:

- Use fast vision (1 kfps) as a sensor in the control feedback loop; reflects an industry trend!
- Balance a ball on top of a motor driven wheel
- Design a controller for the unstable and nonlinear plant
Video: Ball on Wheel
System Architecture: Ball on Wheel

check Speedgoat demo booth!

camera
Basler

host PC
MATLAB / Simulink

devlopment of
vision and control algorithm

Camera Link

Kollmorgen
motor

Neon
frame grabber

target PC
Simulink Real-Time

EtherCAT®
**Project task flow "Ball on Wheel"**

1. **First principles modelling**
2. **Parameter identification**
3. **Controller design**
4. **Closed loop simulation**
5. **Code generation**
6. **System validation**

**Tasks:**
- Linearization around operating point
- State feedback
- Linear quadratic control (LQR)
- Simulink model
- Interfacing frame grabber
- Interfacing EtherCat

Mathematical equations:
- Euler-Lagrange equation:
  \[
  \frac{d}{dt} \left( \frac{\partial L}{\partial \dot{q}} \right) - \frac{\partial L}{\partial q} = Q
  \]
- Riccati equation:
  \[
  A^T X + X A - X B R^{-1} B^T X + Q = 0
  \]

Graphical representation of a control system with state feedback and simulation results.
The complete realization of the project from scratch has been achieved within a bachelor diploma project (500 working hours)

This fast prototyping was only possible using model based design and code generation with Simulink Real-Time

Steve Vassaux, diploma student at HEIG-VD, won an award from the "Swiss Society for Automatic Control" (SGA) for his excellent project work.
COLIBRI Project (Contexa SA): Automatic Dosing System (1/6)

- **Parallel Volumetric** dosing system for perfume manufacturing (up to 200 liquids)
- Developed by Contexa SA and the Institute of industrial Automation iAi at Yverdon
- Project funded by CTI (Swiss Commission for Technology and Innovation)

Project start: June 2011
Current state: serial production

A success story for Contexa SA!
Parallel Volumetric Dosing without Scale

- High productivity due to parallel dosing using up to 200 smart syringes
- Dosing quantities between some micro liter and several liters
- Required precision: 10 mg
- Cost efficiency is a key
Colibri Working Principle

- Bubble sensor
- Ingredient Stock
- Valve
- Temperature sensor
- 0.001 mm positioning
- Final recipe
- No more precision scale
- 200 autonomous syringes
- Control
- CAN + Power HotPlug

No more precision scale
Colibri Challenges

- Detection of small air bubbles
- Avoidance of drop formation at outlet nozzle
- Each liquid has different temperature dependant viscosity and density
- Friction in the piston positioning system, elasticity of driving belt and linear screw

Each syringe piston must have a fast and well defined individual motion profile!
Colibri Video, Target 12g, Precision Validation ± 0.01g
Colibri Solution

Each syringe has its own local microcontroller (dsPIC from microchip, fixed-point).

Simulink with Fixed Point Blockset was used for the simulation of the syringe motion control system and the validation of embedded μC code.

benefits: faster prototyping, quality increase
Micromachining using Trajectory Optimization

**Goals:**
- Micromilling 5 axis machine tool e.g. for watch industry
- Working volume 50x50x50 mm
- Ratio 1:5 for working piece / machine size
- Trajectory optimization to prevent vibrations impeding machining precision

In collaboration with
Trajectory Optimization avoiding Vibrations

- Optimization needs a model for the vibrational behaviour
- Minimize cycle time subject to actuator limitations and a bound for vibrations
- Uses MATLAB optimization toolbox + external tools (MOSEK, CasADi / Python)
Using MATLAB's External Interfaces for Data Acquisition (3/4)

- AC brushless
- encoder signals
- PCI FIFO buffer
- Tria-Link Ethernet double ring
- servo drives

www.triamec.com
MATLAB allows for interfacing with external .NET API provided by Triamec.
MATLAB calculates the setpoint trajectory and stores it into a compressed .mat file.
A packet feeder, written in C# opens the .mat file, and fills the FIFO buffer.
Simultaneously, the packet feeder receives sensor information from the drives and stores it into a .mat file.

**Benefits:** MATLAB built-in external interfaces allow for interfacing external devices and for data acquisition.
Concluding Remarks

Model based design is a key for motion control systems

- Model allows prediction of the dynamic behaviour
- Model allows to design a motion feedback controller
- Model allows to optimize reference trajectories avoiding mechanical vibrations

Thank you for your attention!