MathWorks

Hes·so

Haute Ecole Spécialisée
de Suisse occidentale

University of Applied Sciences
Western Switzerland

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

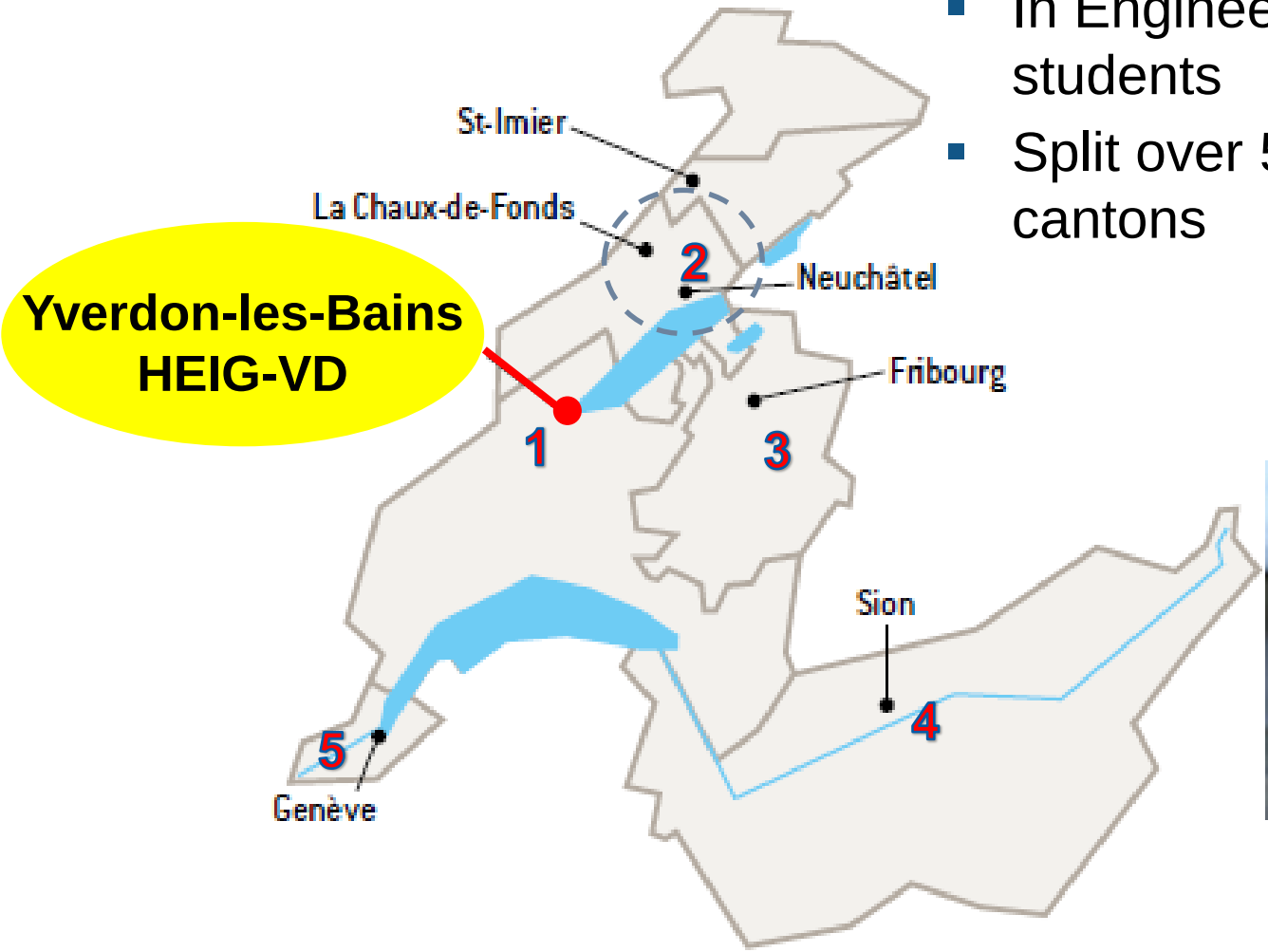
1. We prepare future engineers to apply MATLAB and Simulink because they are industry-standard tools

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



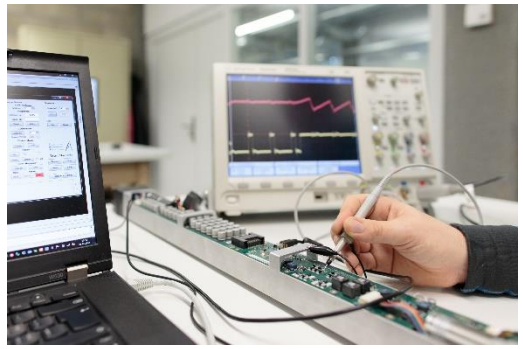
Missions of the HES-SO

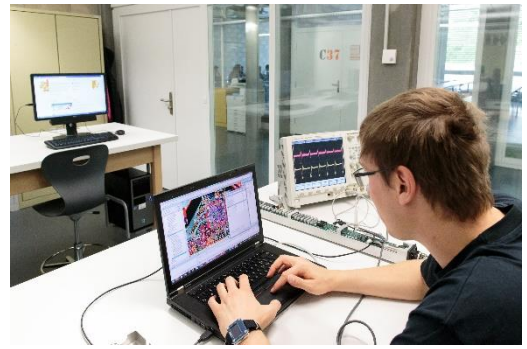
- Developing hands-on engineers for industry
- Being an innovation actor for industry by carrying out applied R&D projects

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**

heig-vd
HAUTE ÉCOLE
D'INGÉNIERIE ET DE GESTION
DU CANTON DE VAUD
www.heig-vd.ch

Institut d'
Automatisation
Industrielle

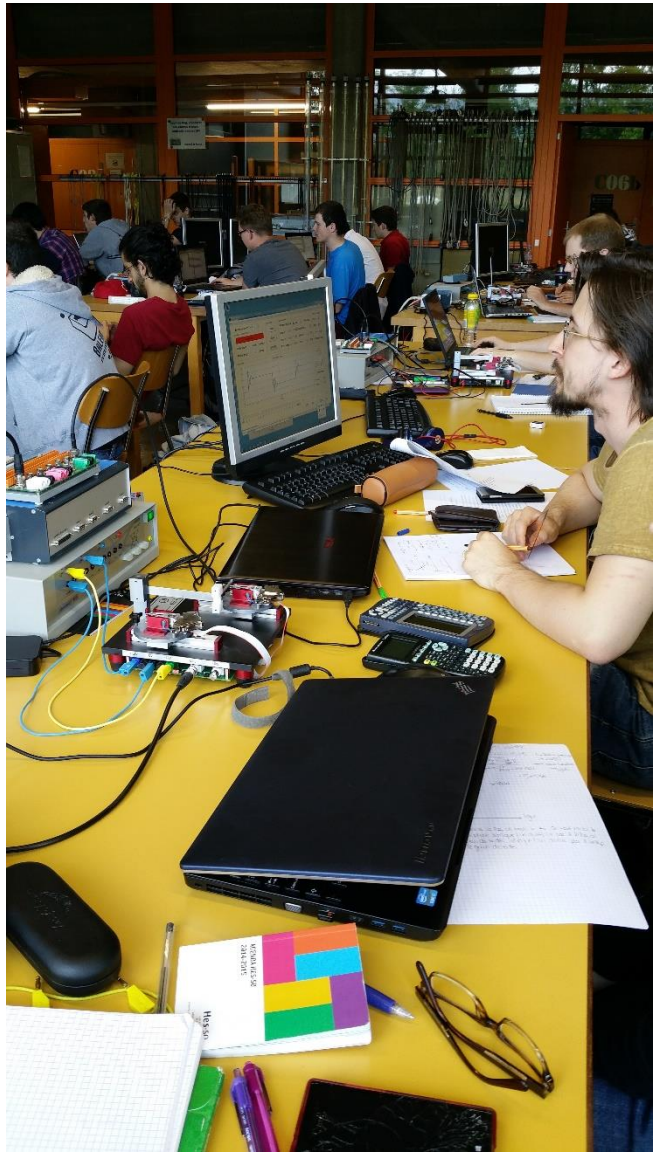




MATLAB and Simulink in Teaching (lectures and labs) (1/2)

- 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.

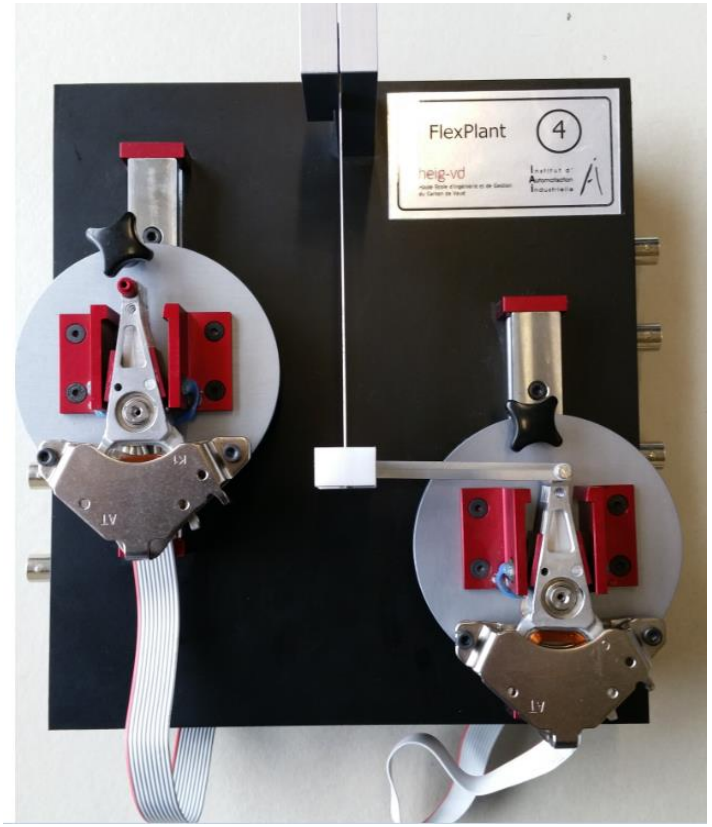
MATLAB and Simulink in Teaching (lectures and labs) (2/2)



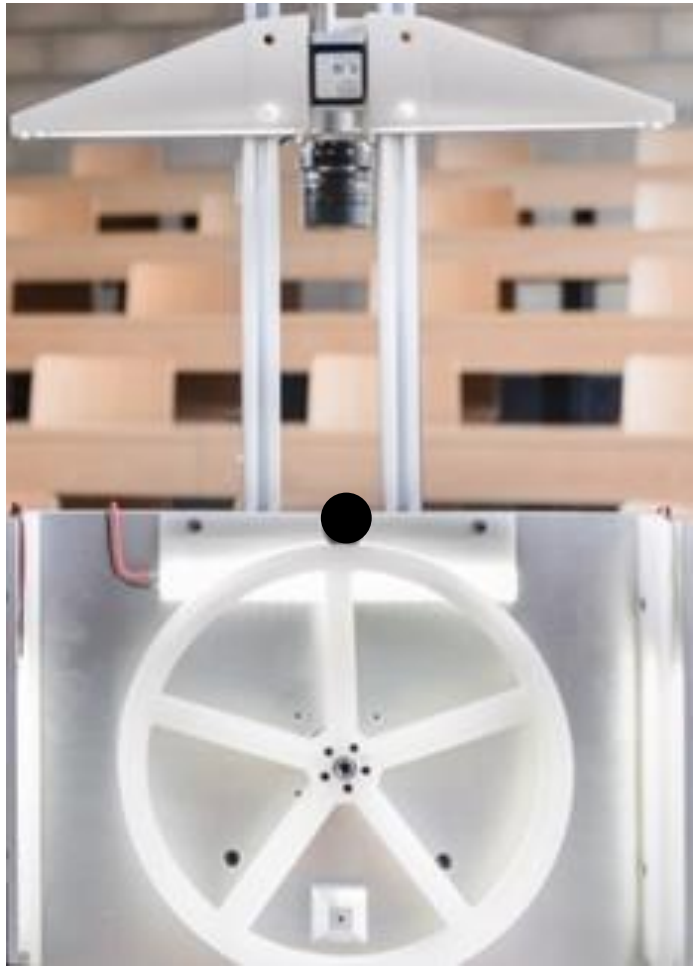
- Automatic control lab in Yverdon (HEIG-VD)
- Equipped with Simulink Real-Time
- Speedgoat mobile target PC

- Two electromechanical plants
- System modelling
- Controller design

FlexPlant experiment

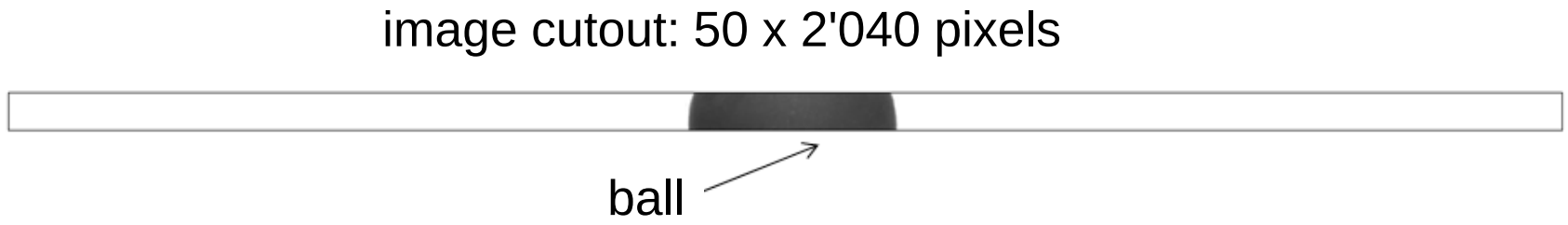


Bachelor Diploma Work: "Ball on Wheel" (BOW) (1/5)

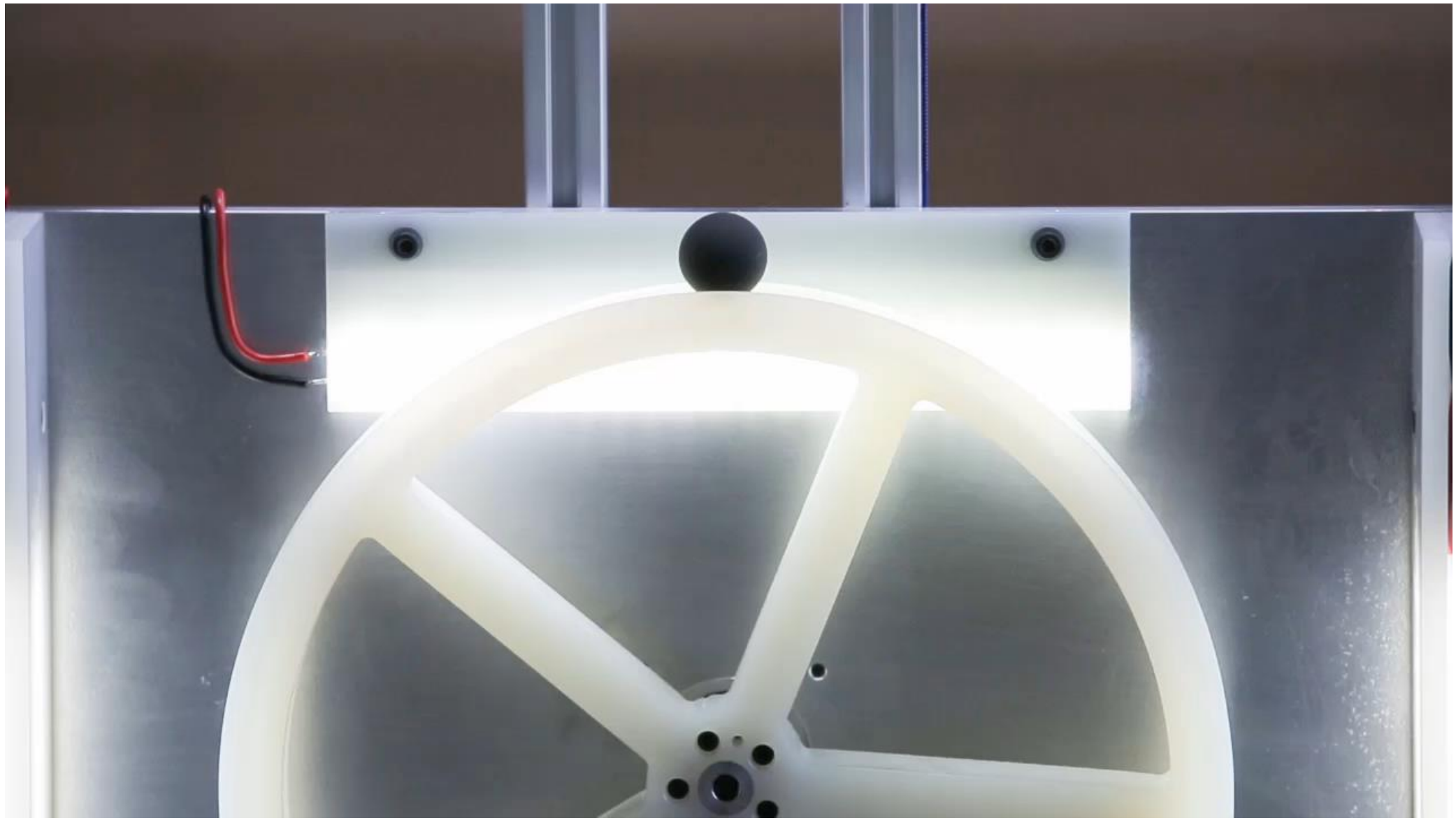


Goals:

- 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

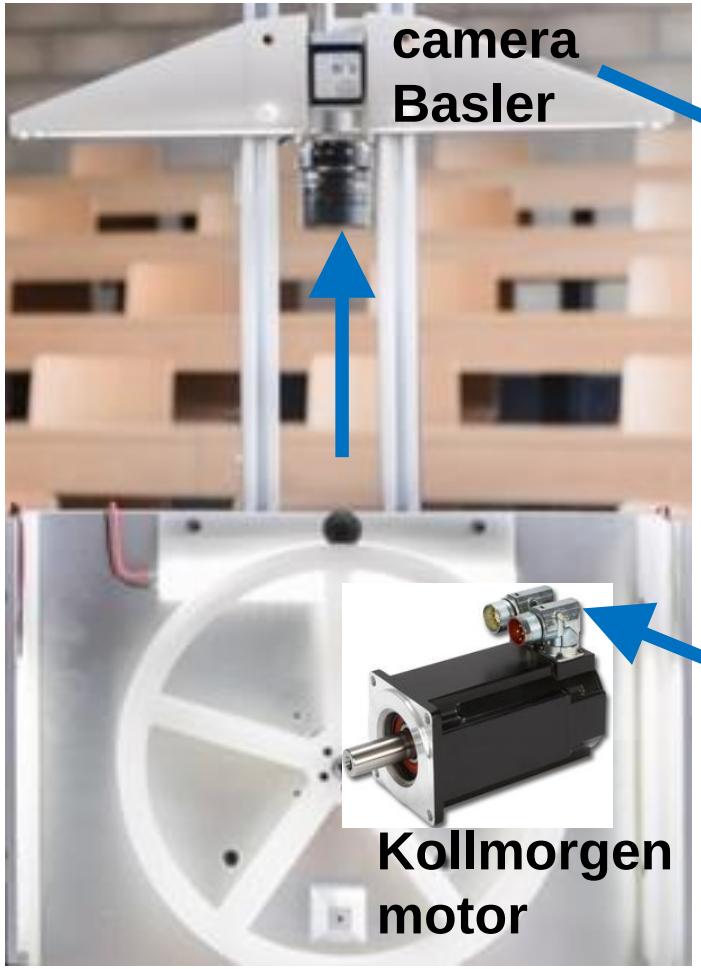


Video: Ball on Wheel (2/5)



System Architecture: Ball on Wheel (3/5)

check Speedgoat demo booth!



host PC
MATLAB / Simulink

development of
vision and control algorithm

Ethernet

Camera Link

speedgoat
real-time simulation and testing

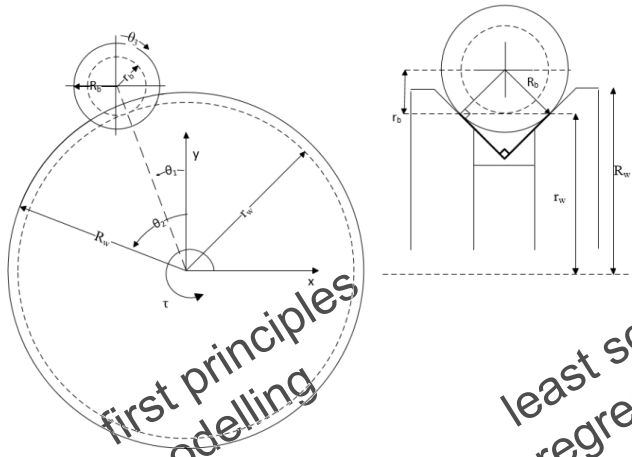
Neon
frame grabber

target PC
Simulink Real-Time

EtherCAT®

KOLLMORGEN®

Project task flow "Ball on Wheel" (4/5)



first principles modelling

least square regressions

linearization around operating point

state feedback linear quadratic control (LQR)

Simulink model

interfacing frame grabber

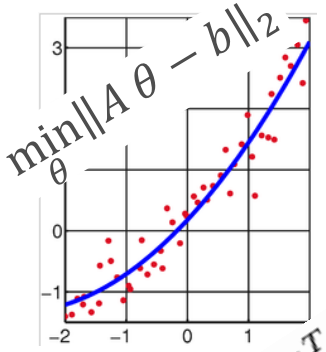
interfacing EtherCat

physical modelling | parameter identification | controller design | closed loop simulation | code generation | system validation

Euler-Lagrange

$$\frac{d}{dt}\left[\frac{\partial L}{\partial \dot{q}}\right] - \frac{\partial L}{\partial q} = Q$$

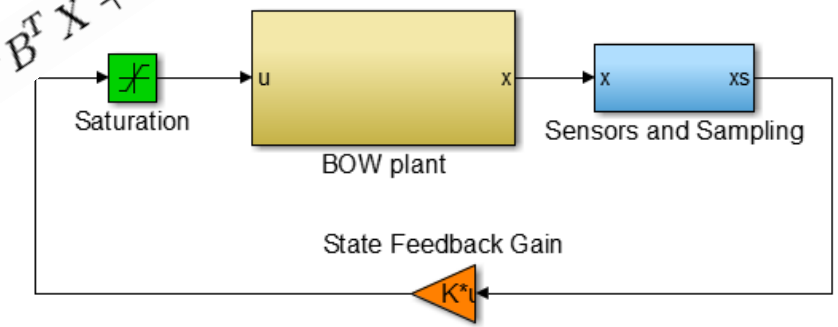
$$\dot{x} = f(x,u)$$

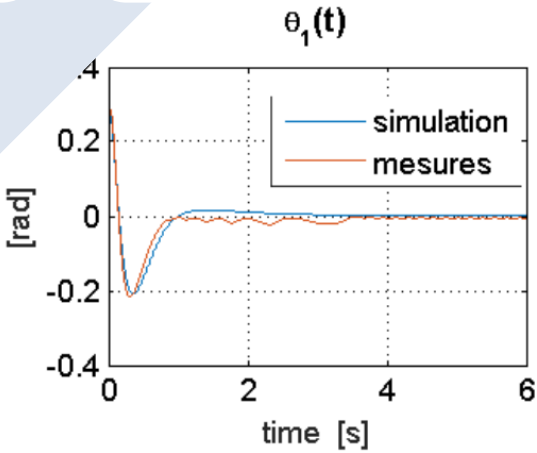


$$\min_{\theta} \|A\theta - b\|_2$$

Riccati equation

$$A^T X + XA - XBR^{-1}B^T X + Q = 0$$





Bachelor Diploma Work: Ball on Wheel (BOW) (5/5)

- 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)

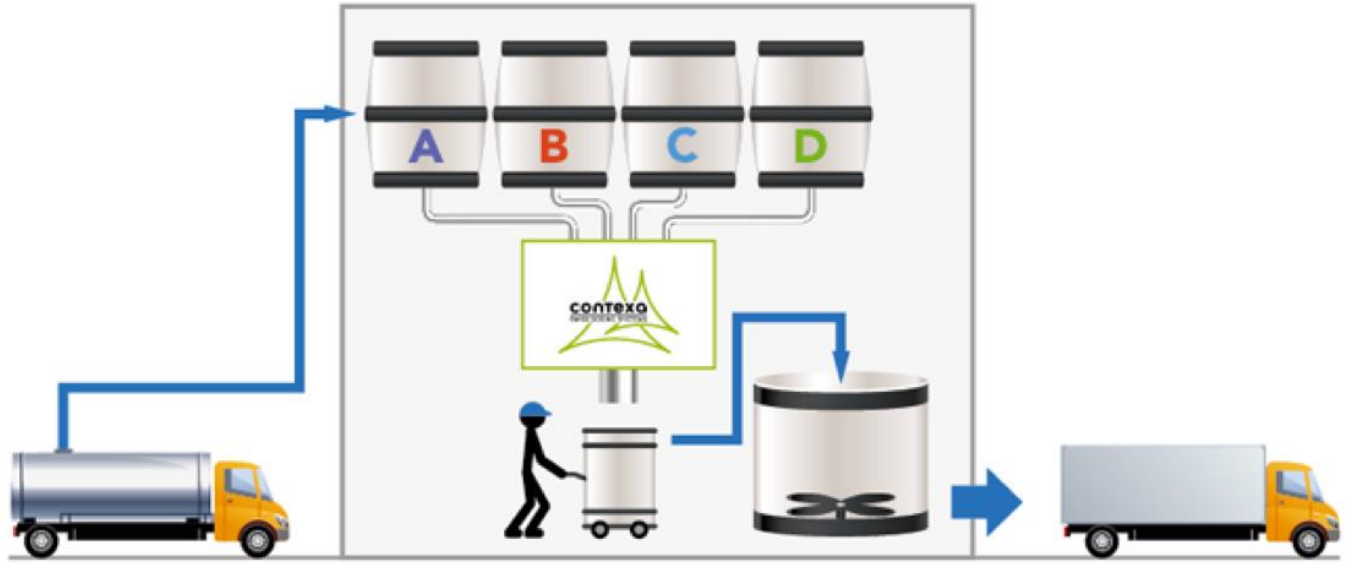
Project start: june 2011

Current state: serial production

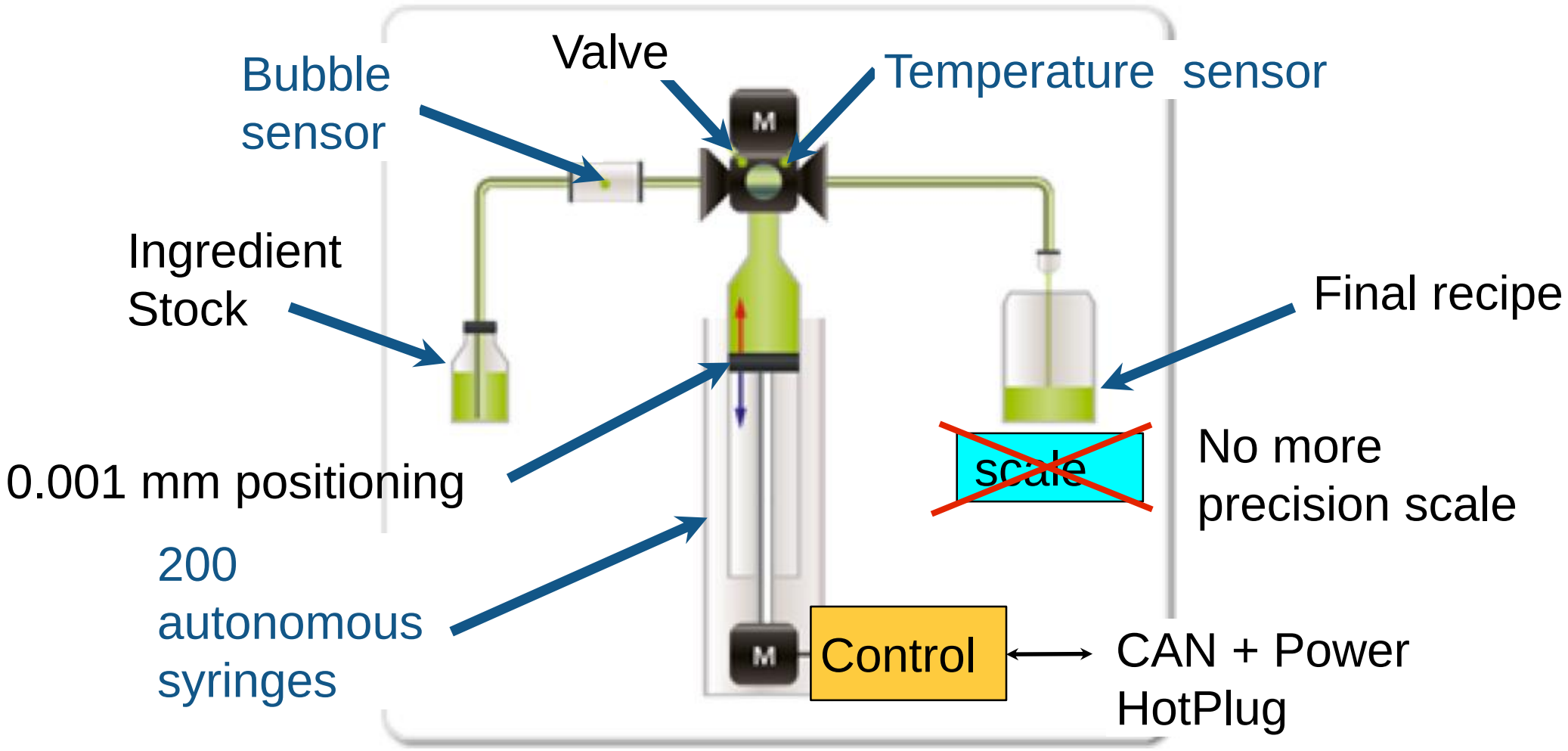
A success story for Contexa SA !

Parallel Volumetric Dosing without Scale (2/6)

- 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

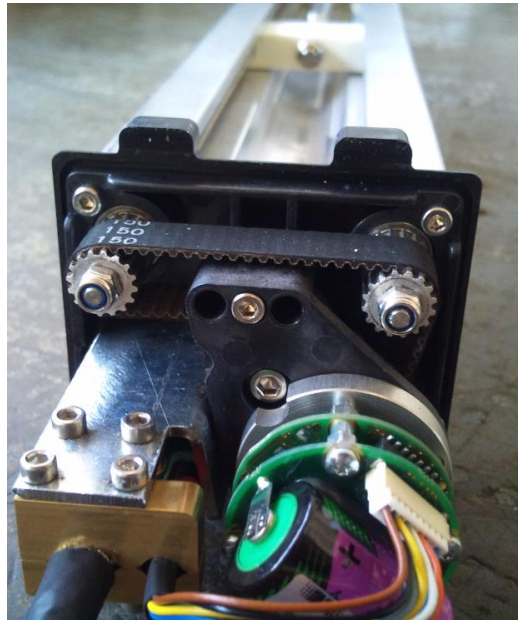


Colibri Working Principle (3/6)



Colibri Challenges (4/6)

- 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

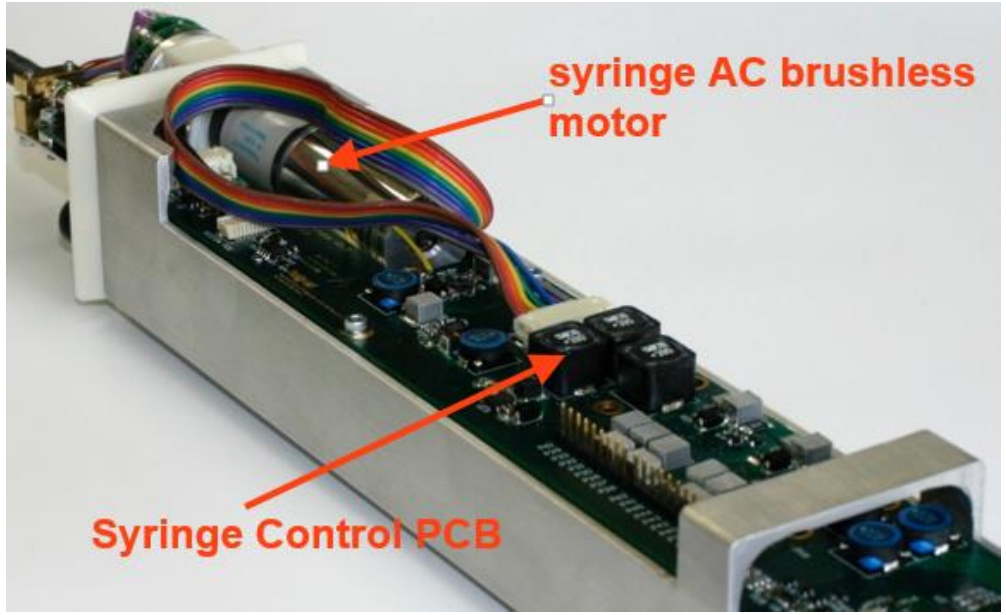


Each syringue piston must have a fast and well defined individual motion profile!

Colibri Video, Target 12g, Precision Validation ± 0.01g (5/6)

Colibri Solution (6/6)

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



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

benefits : faster prototyping, quality increase

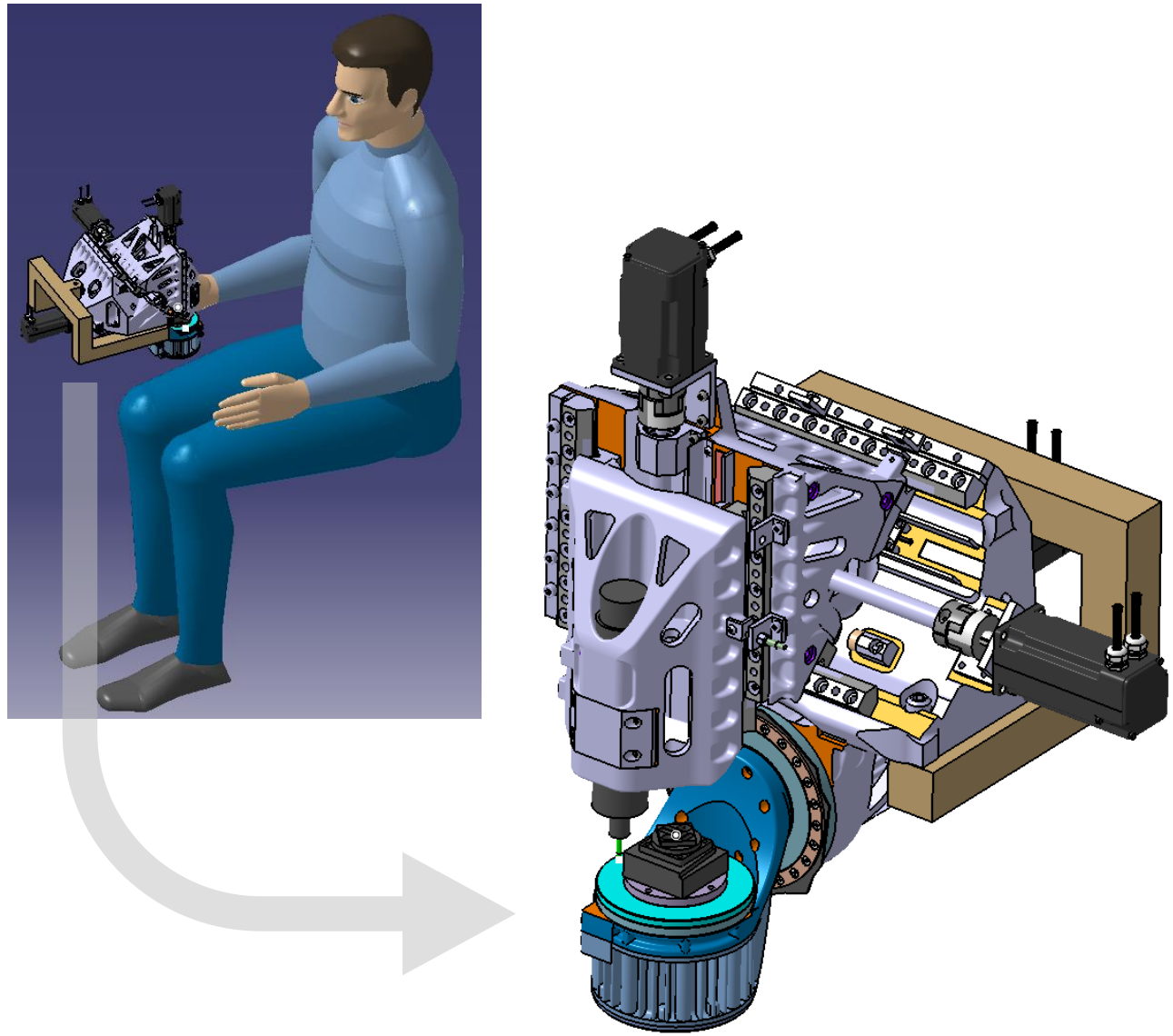
Micromachining using Trajectory Optimization (1/4)

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

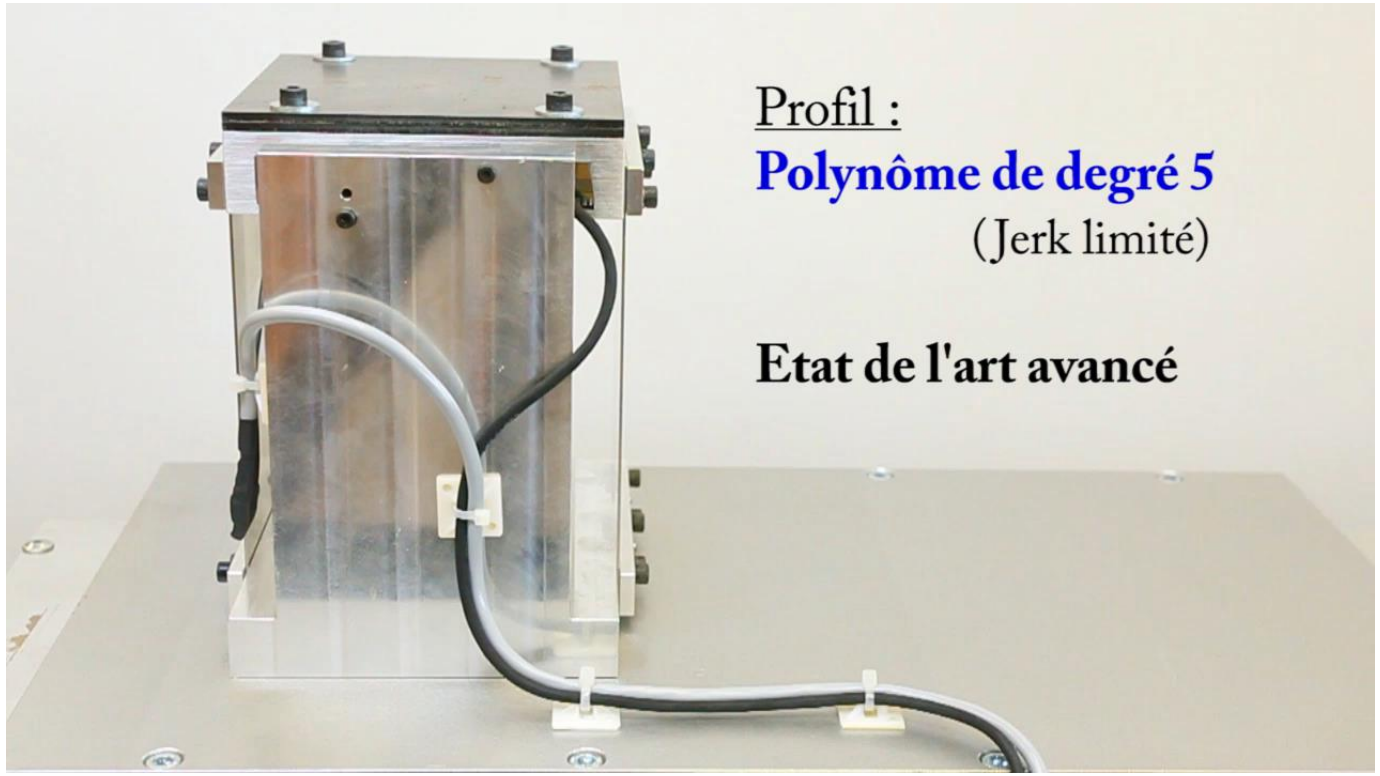
In collaboration with

arc ingénierie
www.he-arc.ch



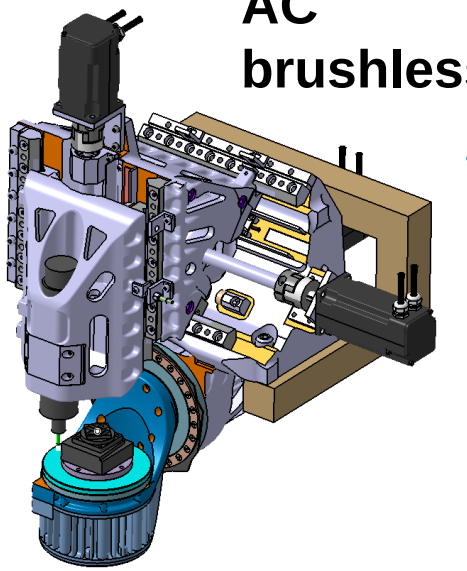
Trajectory Optimization avoiding Vibrations (2/4)

- 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



power

encoder signals

servo drives

triamec

www.triamec.com

PCI FIFO buffer

Tria-Link
Ethernet double ring

Using MATLAB's External Interfaces for Data Acquisition (4/4)

- 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

C#

```
using System;
using System.Collections.Generic;
using System.Linq;
using System.Text;
using System.Threading.Tasks;
using MatlabAPI;

namespace PacketFeeder_trajopt
{
    public class GeneralInfo
```

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!