Real-time robotics and process control with Windows CE and .NET

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Operating Systems and Middleware

Outline

- Motivation / Overview
- The Distributed Control Lab (DCL) Architecture
- Protecting the Lab from Malicious Code
  - Adaptability / Dynamic Reconfiguration in the Lab
- Experiments in the DCL
  - **Foucault's Pendulum** – Control with .NET
  - **Higher Striker** – Real-Time Control with CE
  - **Industrial Programmable Logic Control** and CE
  - **Lego.NET** - .NET for Embedded Devices
- Conclusions

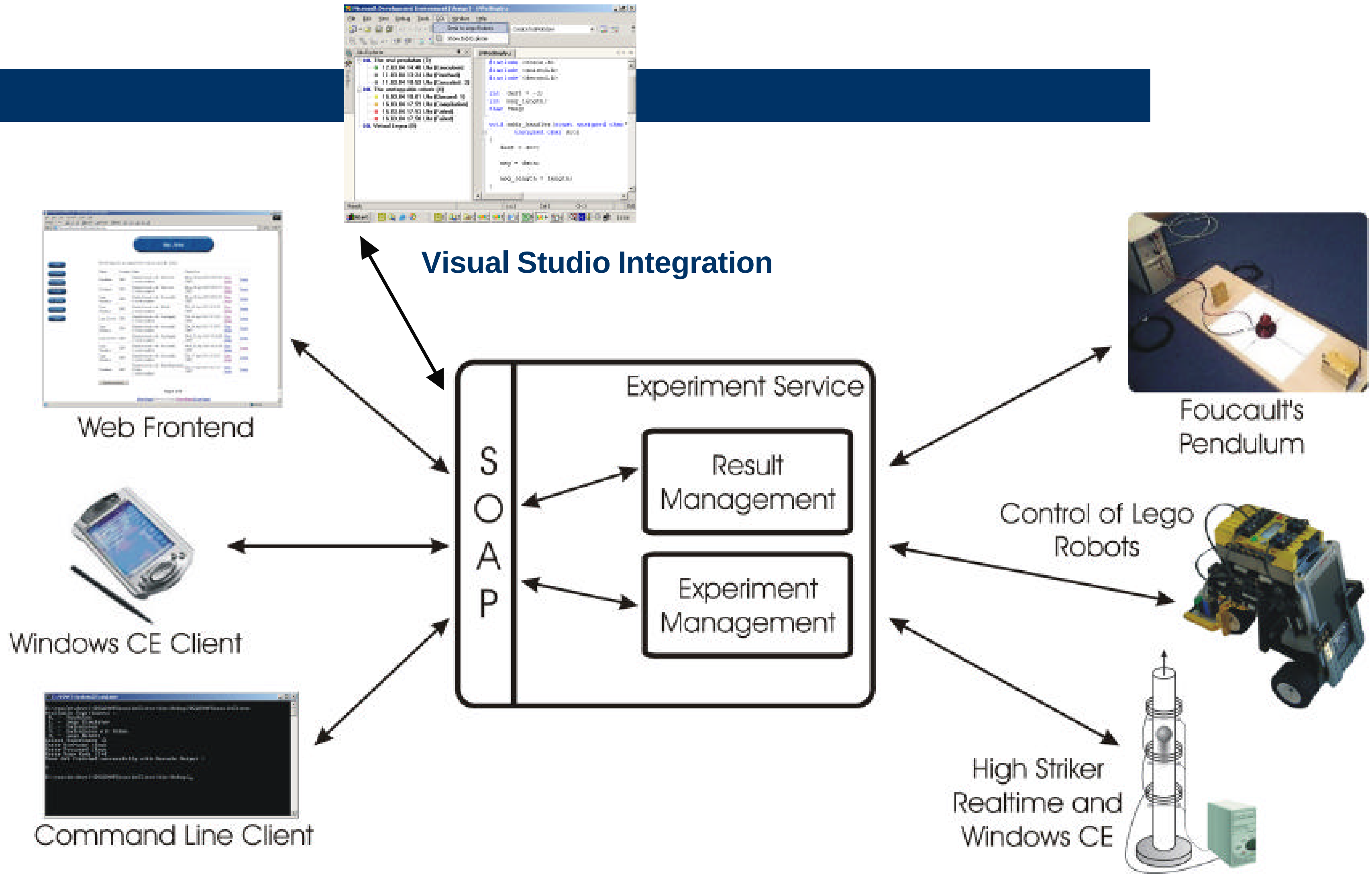
Motivation

- Dynamic Reconfiguration / Adaptability
  - Reach a predictable system behaviour in unstable environments
- “Extend the reach of middleware”
  - Interconnected middleware-components and embedded systems
  - Grid computing technologies
- Online access to physical experiments over the Web
- Study techniques to prevent malicious code damaging physical equipment

Distributed Control Lab

- 2001 project start at Hasso-Plattner-Institute
  - Teaching control algorithms for real-time control problems
  - study of system predictability, availability and security in context of middleware-based dynamic control systems
- Extensible architecture for hosting physical control experiments
  - Investigation of algorithms for user code observation and replacement of control components
  - Experiment : physical installation and specific control software

The Distributed Control Lab

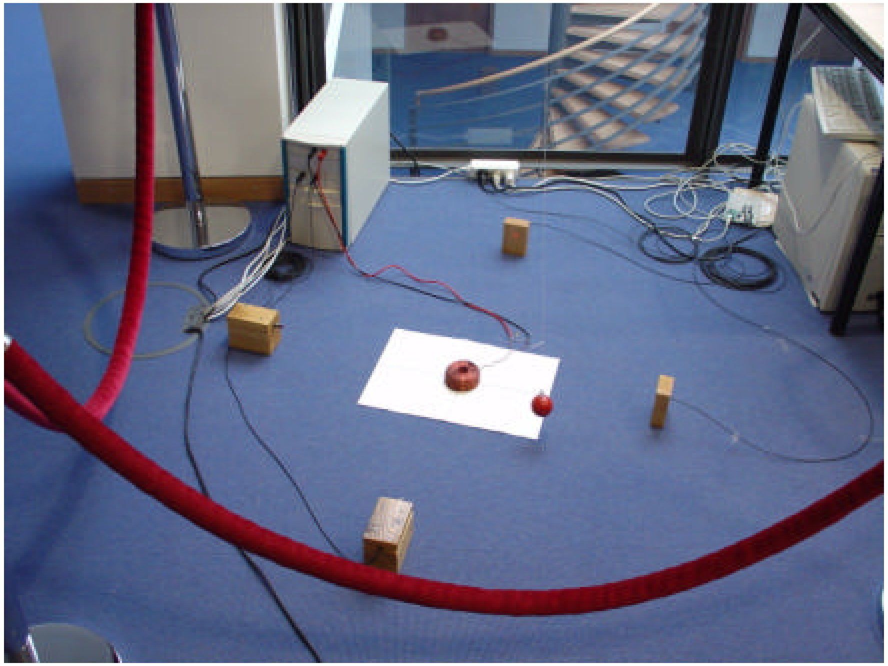


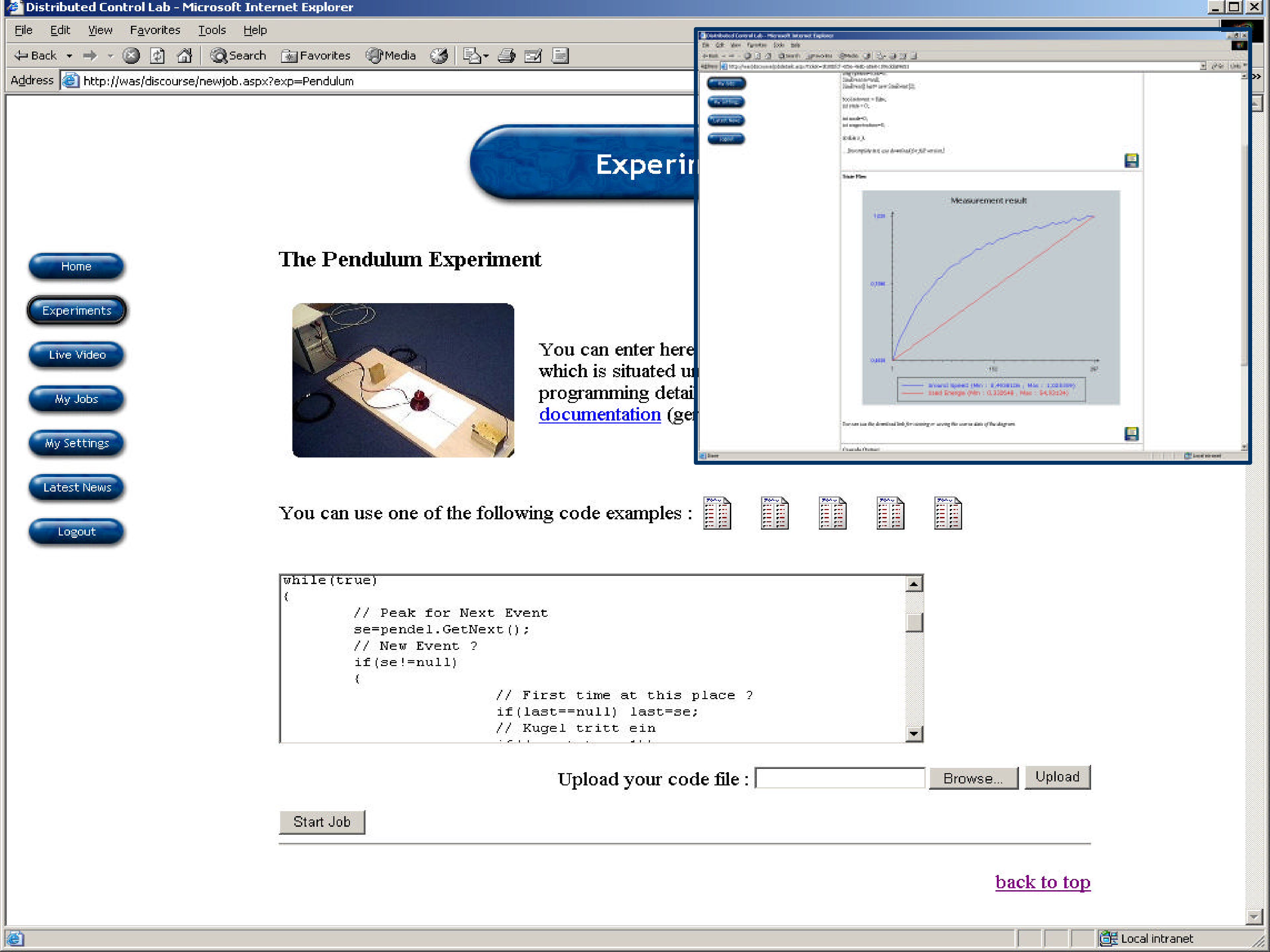
Dynamic Reconfiguration for Protecting from Malicious Code

- Investigation of solutions for detecting malicious code
  - Source Code Analysis
  - Language limitations / special compiler
  - Simulation before execution on physical experiment
  - **Dynamic Reconfiguration of component-based control application**
    - Online observation of user programs
    - Analytic Redundancy of experiment control
    - Replacement of user programs before reach of uncontrollable state
    - Monitoring of environmental settings and component states

Foucault’s Pendulum

- Background:
  - Demonstrates earth rotation
  - Today many installation including one in UN-building in New York
- Problem : Pendulum must be kept swinging
- Solution : electro magnet under an iron ball
- **Experiment: Find best control algorithm to keep the pendulum swinging**
  - Using minimal energy
  - Reaching the highest amplitude




Distributed Control Lab - Microsoft Internet Explorer
File Edit View Favorites Tools Help
Back Search Favorites Media
Address http://was/discourse/newjob.aspx?exp=Pendulum
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Home
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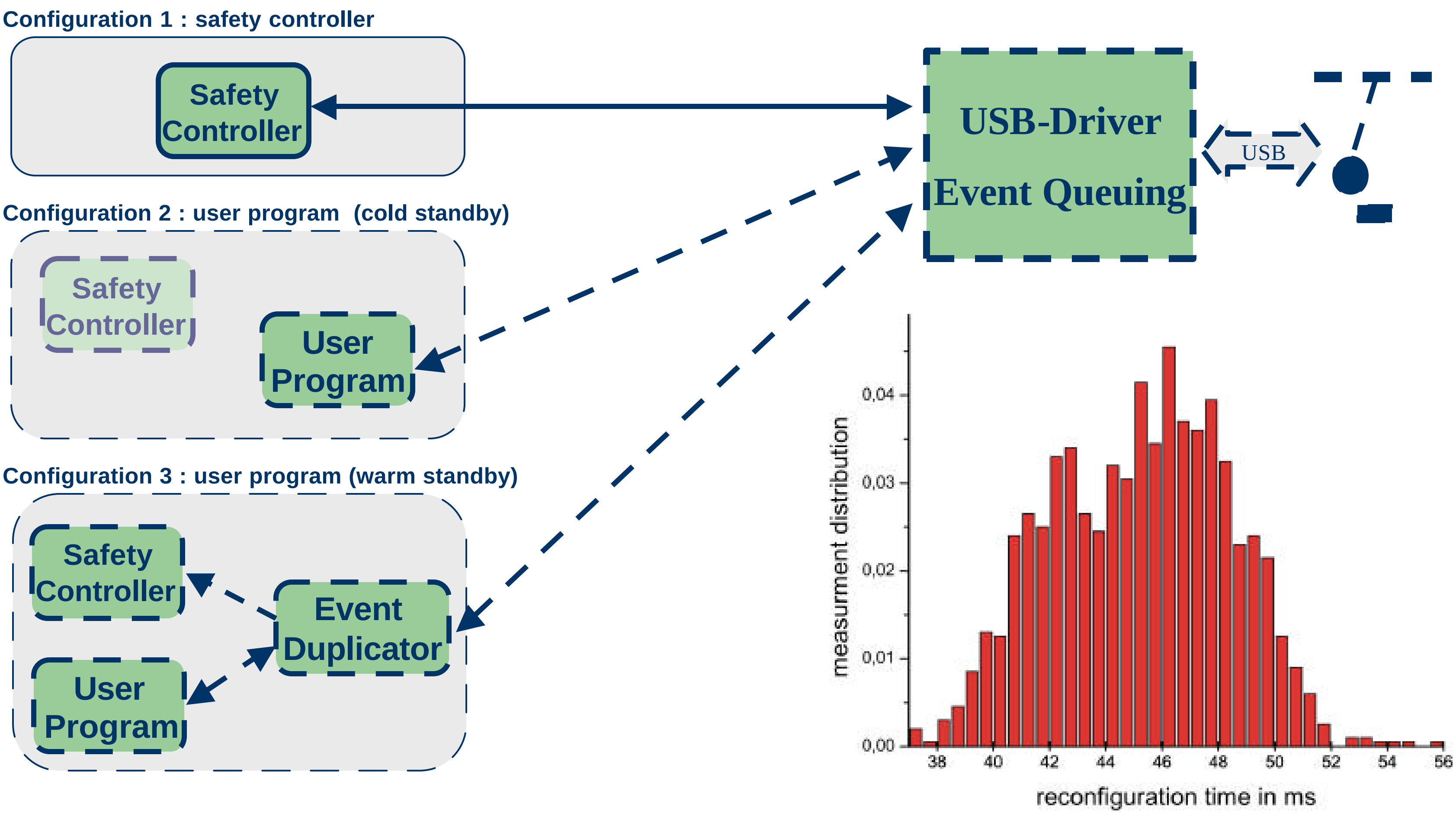
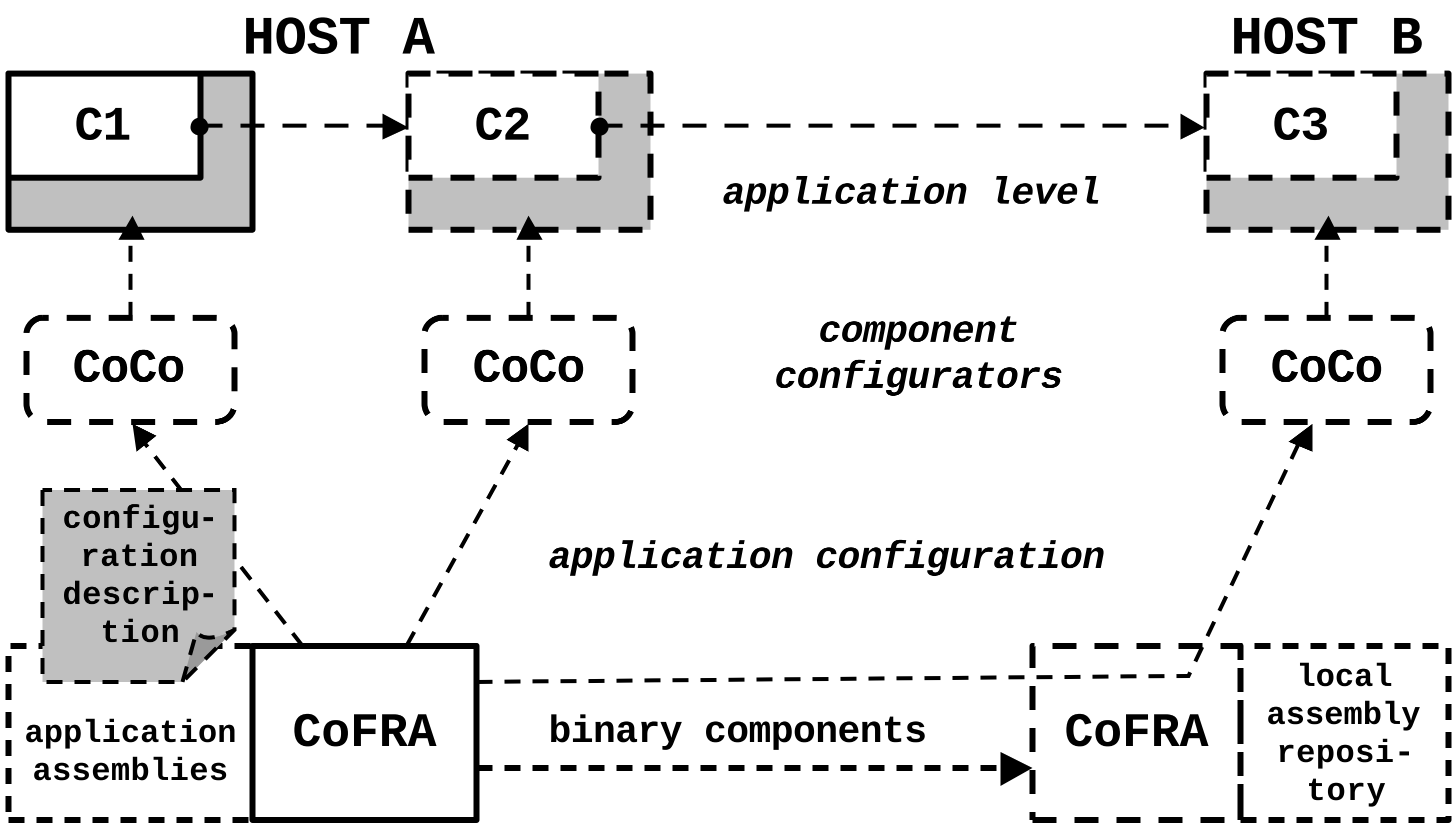
My Jobs
My Settings
Latest News
Logout
The Pendulum Experiment
You can enter here
which is situated u
programming detai
documentation (ge
Measurement result
You can use one of the following code examples :
while(true)
{
// Peak for Next Event
se=pendel.GetNext();
// New Event ?
if(se!=null)
{
// First time at this place ?
if(last==null) last=se;
// Kugel tritt ein
Upload your code file :
Browse...
Upload
Start Job
back to top
Local intranet

Dynamic Reconfiguration of Control Algorithms

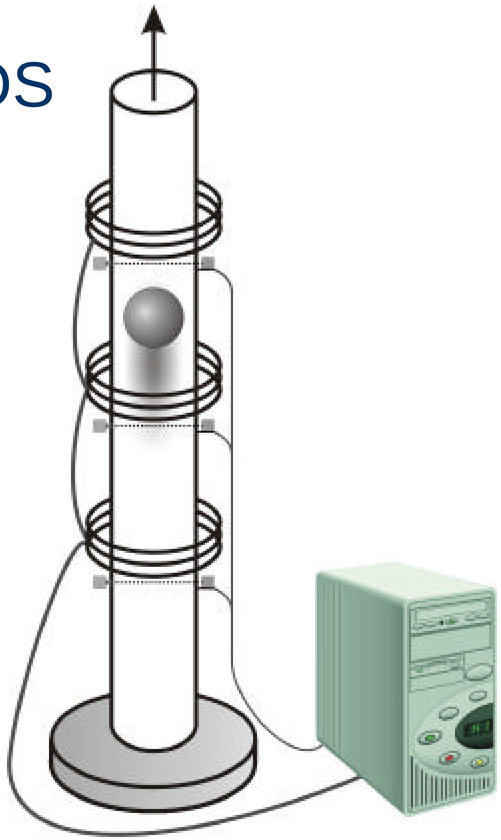


Framework for Adaptive Applications Reconfiguration Infrastructure

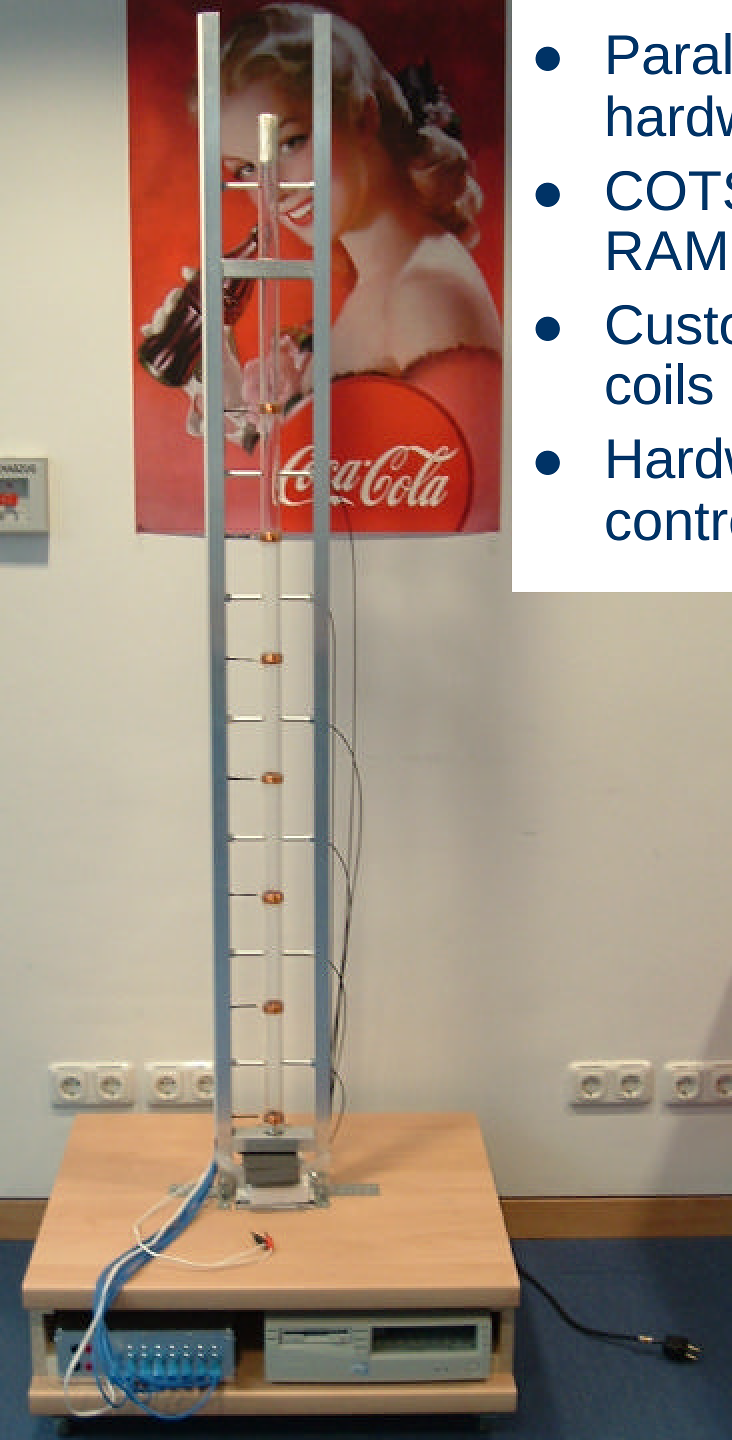


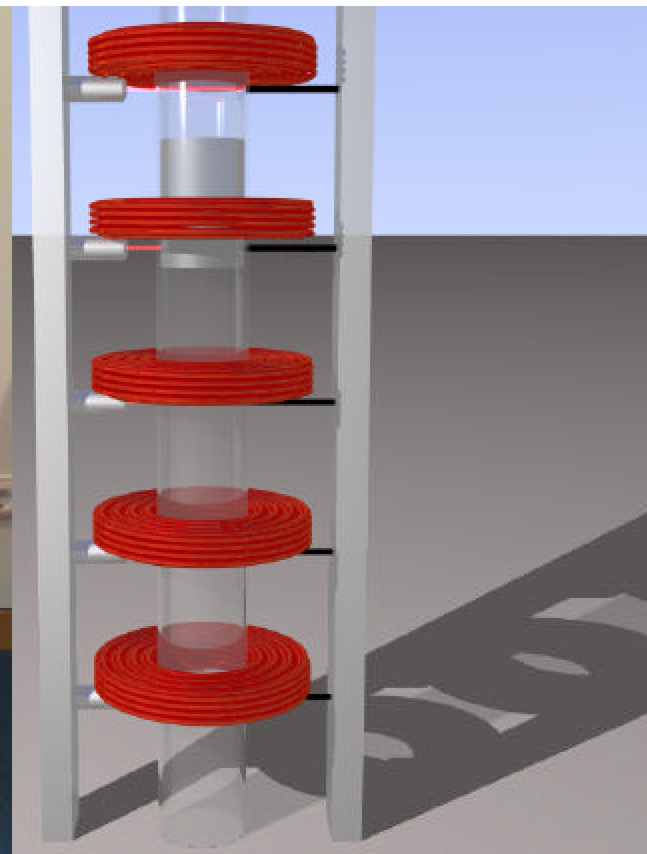
„Higher Striker“ - Experiment

- Real-Time Control experiment
- Usage of Windows CE.NET real-time OS
  - Hard Deadlines: Smaller Buffers, Higher Sampling Frequency
  - Control delay caused by buffers must be minimized
- Combination of non-RT .Net and RT application
- Evaluation of real-time Linux
- CE-PC Windows Ce.Net 4.2
- Simulation of Control Jobs in our Grid-Infrastructure

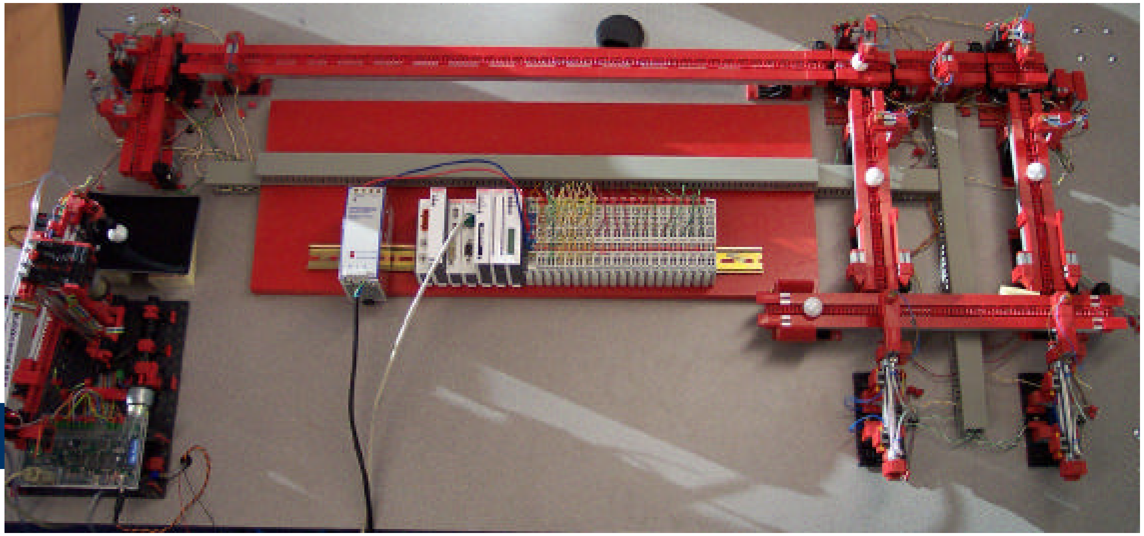


- Parallel I/O / 38 kHz sample rate / 256 Byte hardware buffer
- COTS x86 PC: Intel Celeron 633 MHz, 128 MB RAM
- Custom control hardware prevents overheating of coils
- Hardware watchdog reboots control PCs if user control algorithm can not be stopped



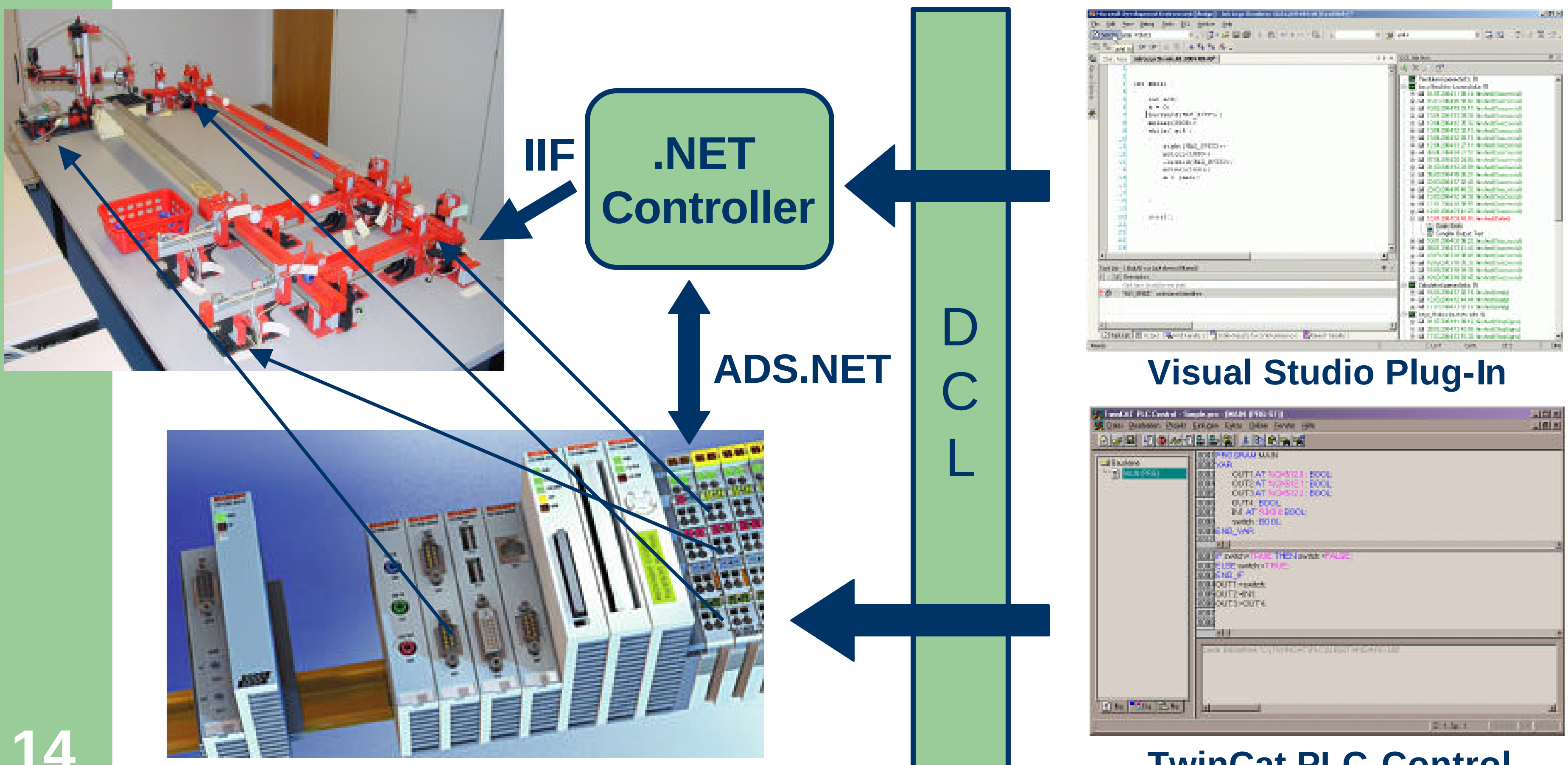


Industrial Control in the DCL

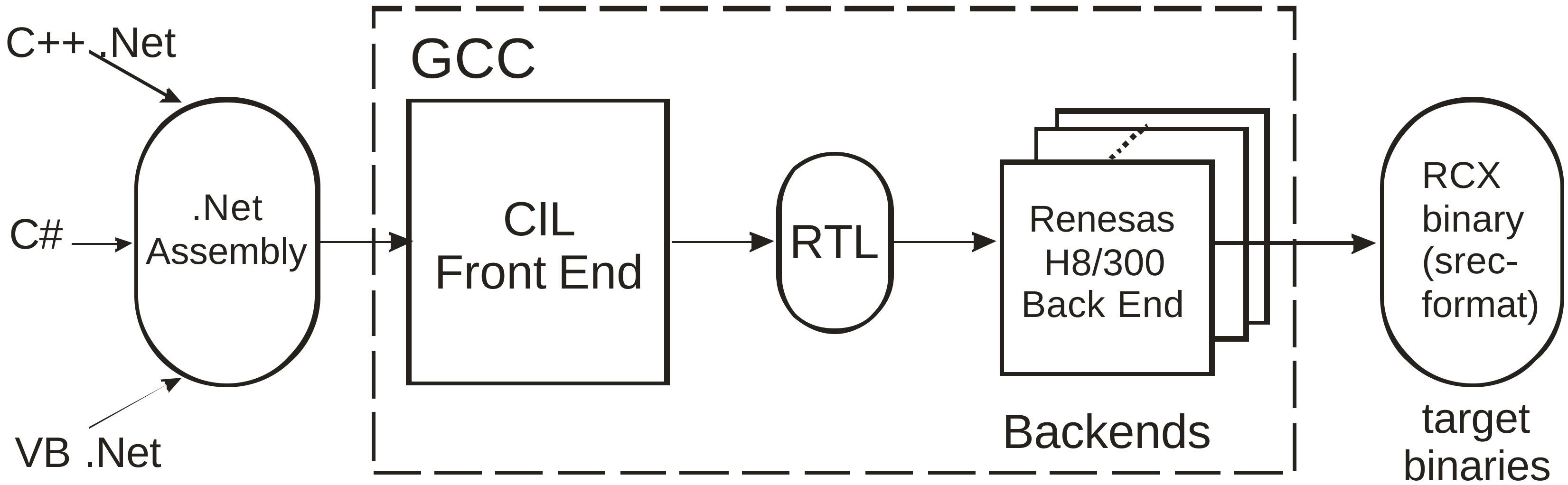


- Beckhoff CX 1000 Software PLC running Windows CE.NET (small and medium enterprises)
  - Geode x86 compatible 200 MHz Processor, 128 MB RAM
  - Extensible I/O modules (digital, analog in/out, relay outputs)
  - CAN field bus communication modules
- Experiments in the DCL
  - Implementation of DIN EN 61131-3 Software for PLCs
    - Validity Checks with separate/ parallel running PLC programs
  - Interaction of native CE applications with PLC programs
  - Distributed Control and Configuration with connected .NET Services

Beckhoff Industrial-PCs and the DCL
Controlling a Fischertechnik Assembly Line



Lego.NET - .NET for devices



- Our gcc (Gnu Compiler Collection) frontend supports the full ECMA-335 standard and can parse any conformant .NET assembly.
- Port for Renesas/Hitachi *H8-300* microcontroller underway
  - Extremely small footprint (32 KB memory)
  - Runtime Library based on free BrickOS operating system

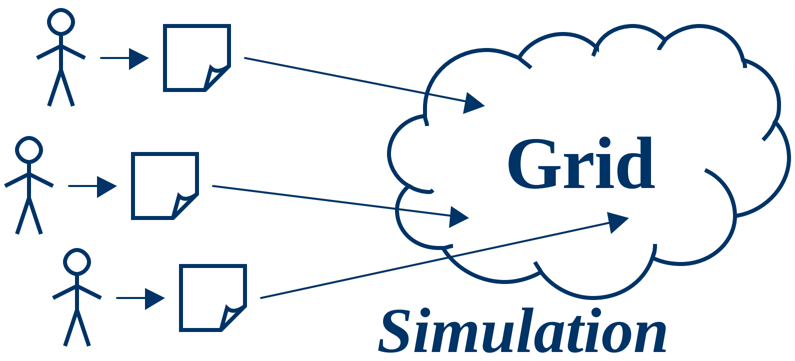
CLI2RCX- .NET – Current State

- Version 1.0 release implements the following features of the .NET platform:
  - ✓ primitive datatypes: bool, byte, short, int
  - ✓ classes, including instance attributes and properties.
  - ✓ static and instance methods, including parameters, local variables, and constructors.
  - ✓ arithmetic operations
  - ✓ control flow operations: conditional and unconditional branch instructions.
- **Next steps**: most value types (enums, structs, delegates, floats, doubles), strings, single-dimensional zero-based arrays (partially complete), multi-dimensional or non-zero-based arrays, inheritance, polymorphism, and late binding, interfaces, exceptions
- **Download / Weblog**:

http://www.dcl.hpi.uni-potsdam.de/research/lego.NET/

DCL - Grid Integration

- Heterogeneous
  - X86,Itanium, PowerPC
  - Windows 2000/XP, Linux, Mac OS X
- DRMAA – Job Submission and Control for Clusters and Grids
- GLOBUS
- IDLE-Time
  - Condor
  - Sun Grid Engine, Condor
- Adaptive Grid Services 6th framework



- Increased Throughput

- Increased Response Time

Conclusions

- Adaptability will become the most sought after quality of future embedded and middleware systems
- Our focus is on dynamic reconfiguration
- .NET
  - code access security and dynamic reconfiguration allows for safe code execution of mobile code in our lab
  - Malicious Code Problem: .NET and dynamic reconfiguration usable for small embedded devices
- rtLinux, Windows CE
  - Experimental evaluation of heterogeneous RT control environments