Anbindung von Low-Cost Hardware an Simulink leicht gemacht
Contents

❖ What is low-cost hardware?
❖ Hardware and Simulink: a great combo
❖ Install, simulate, and enjoy: work-flow
❖ Let us help you get started
A first demo: the “behind the scenes”

45 lines of code, only
LEGO Mindstorms NXT: a first demo
What is low-cost hardware?
Simulink supported low-cost hardware

- BeagleBoard: €50
- ArduinoBoard: €15
- Raspberry Pi: €40
- LEGO Mindstorms NXT: €370
- PandaBoard: €185
- Gumstix Overo: €135

R2011b 2012a 2012b 2013a 2013b
## Hardware capabilities and features

<table>
<thead>
<tr>
<th>Component</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Microcontroller</strong></td>
<td>AT91SAM7S256 (ARM)</td>
</tr>
<tr>
<td><strong>Flash Memory</strong></td>
<td>256 KB</td>
</tr>
<tr>
<td><strong>SRAM</strong></td>
<td>64 KB</td>
</tr>
<tr>
<td><strong>Operating freq.</strong></td>
<td>55 MHz</td>
</tr>
</tbody>
</table>

**Actuators:**
- servo motor {display, speaker}

**Inputs:**
- analog, digital, serial, servo

**Outputs:**
- PWM, digital, serial, servo

**Sensors:**
- light, color, ultrasonic, sound, accelerometer, gyro, etc.

<table>
<thead>
<tr>
<th>Component</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Microcontroller</strong></td>
<td>ATmega328 (AVR)</td>
</tr>
<tr>
<td><strong>Flash Memory</strong></td>
<td>32 KB</td>
</tr>
<tr>
<td><strong>SRAM</strong></td>
<td>2 KB</td>
</tr>
<tr>
<td><strong>EEPROM</strong></td>
<td>1 KB</td>
</tr>
<tr>
<td><strong>Clock Speed</strong></td>
<td>16 MHz</td>
</tr>
</tbody>
</table>
The high-end solution: Real-time testing with xPC Target Turnkey

- Combines MathWorks design software with Speedgoat H/W
- Offers a complete solution for real-time simulation and testing

MathWorks

Speedgoat

Customer

Modellbasiertes Echtzeittesten und automatische Codegenerierung
Richard Pfisterer
Why low-cost hardware?
1. Teach and learn hands-on

[retain knowledge]
Basics: Easy does it (1995, Physik I)

\[
\frac{d}{dt} h = \frac{2}{t}
\]
Engaging Students in Hands-On Control System Design: University of Arizona

Challenge
Provide hands-on control system design experience

Solution
Low-cost, portable laboratory module based on MATLAB, Simulink, and an aeropendulum

Results
- Equipment costs lowered
- Technical concepts better illustrated
- Transferable control design skills acquired

“These experiences do not require expensive lab equipment. In fact, we have found that MATLAB, Simulink, and a simple low-cost device are all that is needed.”

Dr. Eniko T. Enikov
University of Arizona

[Link to article]
2. Get students a taste of the “real world”
[do it like the pro’s]
Model-Based Design with Simulink [and Stateflow]

Collect and understand requirements

Model

Simulate

Stateflow

Test on hardware

Generate code
Reconfigurable Robots at University of Toronto

Challenge
Provide low-cost learning environment for studying the design and control of a variety of industrial robot manipulators

Solution
Use MATLAB and Simulink to develop an integrated environment to design reconfigurable robot

Results
- Students prepared for work in industry
- Complex optimizations automated
- Months of development time eliminated

“With MATLAB and Simulink we developed a low-cost design and simulation environment that enables students to apply theoretical aspects of kinematics, dynamics, and controls of robot manipulators in a realistic way, optimize their designs, and see those designs in action.”

Dr. Reza Emami
University of Toronto
3. Foster student success

[by motivation]
What (really) matters [for success]?

Emotional Intelligence, Daniel Goleman, Bantam, July 1, 1996
Emotional Intelligence: motivation

- Research shows that
  - Intelligence is no guarantee for success
  - Emotional intelligence (EI) is key for success

Motivation

- Can be triggered extrinsically!
- Small change, huge impact (for students and their teachers)
- Watch and be amazed...

No children were harmed in the making of this photograph

Emotional Intelligence, Daniel Goleman, Bantam, July 1, 1996
Motivation and retention: educational trends

- Retain the right students, on-time
- Integrate spiraling curricula
Challenge
Get 1st year students to apply theoretical concepts in math and signal processing in a hands-on experimental lab. Foster soft skills by working in team environment.

Solution
Use MATLAB and LEGO Mindstorm NXT to build and program robots.

Results
- Motivation rated excellent to good by almost 90% of students
- Ability to link theoretical foundations to practical applications

“This high level of motivation is reflected in the number of extra hours the students devoted to their projects. We knew we had achieved our objectives when students demanded that we set up a workshop so that they could continue working with the robots in their free time.”

Professor RWTH Aachen
How-to? The work flow
What do you need to get it done, the bare essentials

1 Get
Low-cost H/W (+ peripherals)

2 Get
MATLAB and Simulink (+ toolboxes)

3 Run
targetinstaller

4 Run
targetupdater

5 Code
Model, simulate, test, and enjoy

Note: no code generation tools required
Setting-up target hardware: quick and easy

>> targetinstaller
Installs all required add-ons

>> targetupdater
Updates firmware on target hardware

DONE...
LEGO Mindstorms NXT Simulink Support Package

Inputs, sensors

Examples

Outputs, actuators
Arduino Support Package

Inputs, sensors

Outputs, actuators

Examples

[Examples for Arduino Uno]

[Examples for Arduino Mega 2560]
Arduino Ball-tracking demo

Control logic implemented in Stateflow

Top level code is running on host machine
Arduino Ball-tracking demo: on-target code (controller)

PI controller is running on Arduino board
Why low-cost H/W and Simulink?
“No need, no ressources, no experience, …”

- “No need”
  > There is simply **no need** ✓

- “No ressources”
  > Let us help you get started ✓

- “No experience”
  > Let us help you get started ✓
Ressources and support to get started
MathWorks’ Academia web page
Hardware Support resources
MATLAB Central, File Exchange and other goodies
Student Version R2013a

- MATLAB
- Simulink

10 add-on products
- Control System Toolbox
- Signal Processing Toolbox
- DSP System Toolbox
- Statistics Toolbox
- Optimization Toolbox
- Image Processing Toolbox
- Symbolic Math Toolbox
- Simulink Control Design
- Data Acquisition Toolbox
- Instrumentation Control Toolbox

what will you do with MATLAB?

€ 69
Support is available right “next door”

- Dr. Mischa Kim: mischa.kim@mathworks.de
- Tech support: +49-89-45235-6700 + press 4
- Customer service: +49-89-45235-6700 + press 3

: MATLAB/Simulink in education

: specific technical questions

: and for everything else
Get low-cost H/W today and start enjoying with Simulink