technische universität
dortmund

fakultät für informatik
informatik 12

Eingebettete Systeme/
Embedded Systems

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Motivation for Course (1)

According to forecasts, future of IT characterized by terms such as

- Disappearing computer,
- Ubiquitous computing,
- Pervasive computing,
- Ambient intelligence,
- Post-PC era,
- Cyber-physical systems.

Basic technologies:

- *Embedded Systems*
- Communication technologies








Motivation for Course (2)

"Information technology (IT) is on the verge of another revolution. …..

networked systems of embedded computers ... have the potential to change radically the way people interact with their environment by linking together a range of devices and sensors that will allow information to be collected, shared, and processed in unprecedented ways. ...

The use … throughout society could well dwarf previous milestones in the information revolution."

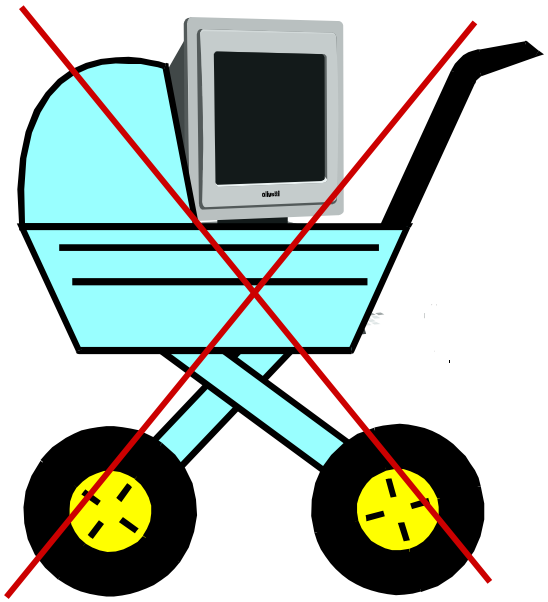
National Research Council Report (US)
Embedded Everywhere

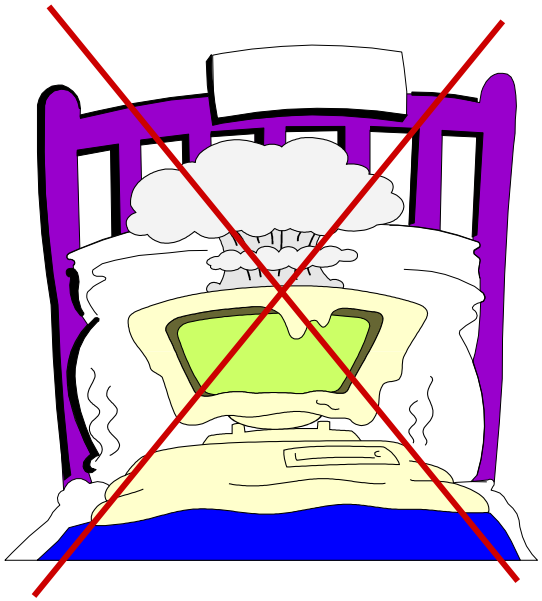
Source. Edward A. Lee, UC Berkeley, ARTEMIS Embedded Systems Conference, Graz, 5/2006

Motivation for Course (3)

- **The future is embedded, embedded is the future**

What is an embedded system?





Embedded Systems & Cyber-Physical Systems

"Dortmund" Definition: [Peter Marwedel]

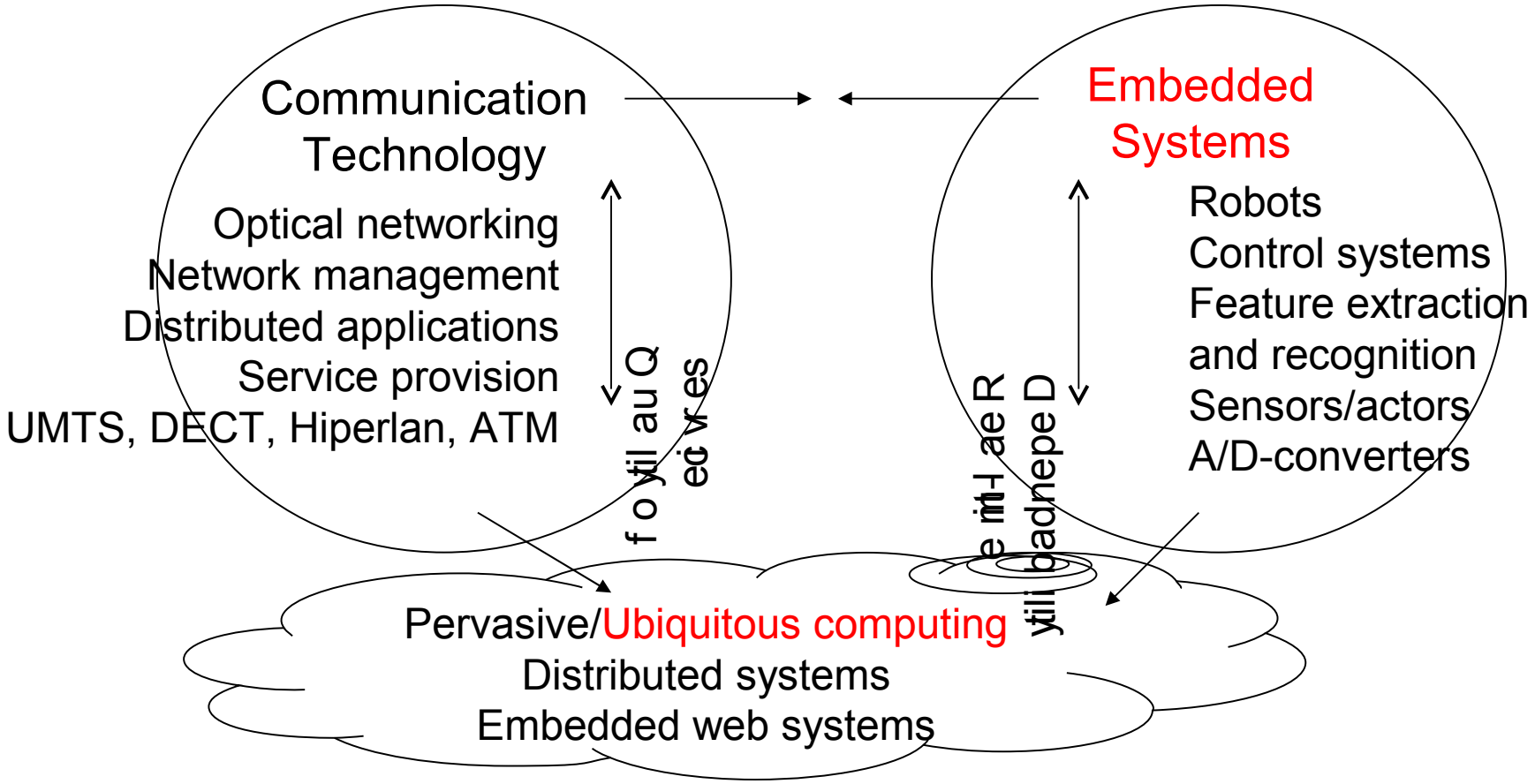
Information processing systems embedded into a larger product

Berkeley: [Edward A. Lee]*:*
Embedded software is software integrated with physical* processes. The technical problem is managing time and concurrency in computational systems.

☞ **Definition**: **Cyber-Physical (cy-phy) Systems** (CPS) are integrations of computation with physical processes [Edward Lee, 2006].

Embedded systems and ubiquitous computing

Ubiquitous computing: Information anytime, anywhere.
Embedded systems provide fundamental technology.



Growing importance of embedded systems (1)

- *Spending on GPS units exceeded $100 mln during Thanksgiving week, up 237% from 2006 … More people bought GPS units than bought PCs, NPD found.* [www.itfacts.biz, Dec. 6th, 2007]
- *…, the market for remote home health monitoring is expected to generate $225 mln revenue in 2011, up from less than $70 mln in 2006, according to Parks Associates. .* [www.itfacts.biz, Sep. 4th, 2007]
- *According to IDC the identity and access management (IAM) market in Australia and New Zealand (ANZ) … is expected to increase at a compound annual growth rate (CAGR) of 13.1% to reach $189.3 mln by 2012* [www.itfacts.biz, July 26th, 2008].
- Accessing the Internet via a mobile device up by 82% in the US, by 49% in Europe, from May 2007 to May 2008 [www.itfacts.biz, July 29th, 2008]

Growing importance of embedded systems (2)

- .. *but embedded chips form the backbone of the electronics driven world in which we live ... they are part of almost everything that runs on electricity* [Mary Ryan, EEDesign, 1995]

- Foundation for the “post PC era“
- ES hardly discussed in other CS courses
- ES important for Technical University
- ES important for Europe
- Scope: sets context for specialized courses

Importance of education

Application areas and examples

Automotive electronics

Functions by embedded processing:

- ABS: Anti-lock braking systems
- ESP: Electronic stability control
- Airbags
- Efficient automatic gearboxes
- Theft prevention with smart keys
- Blind-angle alert systems
- ... etc ...

Multiple networks

- Body, engine, telematics, media, safety

Multiple processors

- Up to 100
- Networked together

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Avionics

- Flight control systems,
- anti-collision systems,
- pilot information systems,
- power supply system,
- flap control system,
- entertainment system,
- …

Dependability is of outmost importance.

Railways

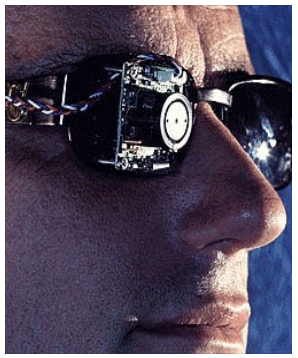
- Safety features contribute significantly to the total value of trains, and dependability is extremely important

Telecommunication

- Mobile phones have been one of the fastest growing markets in the recent years,
- Geo-positioning systems,
- Fast Internet connections,
- Closed systems for police, ambulances, rescue staff.

Medical systems

- For example:
  - Artificial eye: several approaches, e.g.:
    - Camera attached to glasses; computer worn at belt; output directly connected to the brain, “pioneering work by William Dobelle”. Previously at [www.dobelle.com]



- Translation into sound; claiming much better resolution.
  [http://www.seeingwithsound.com/etumble.htm]

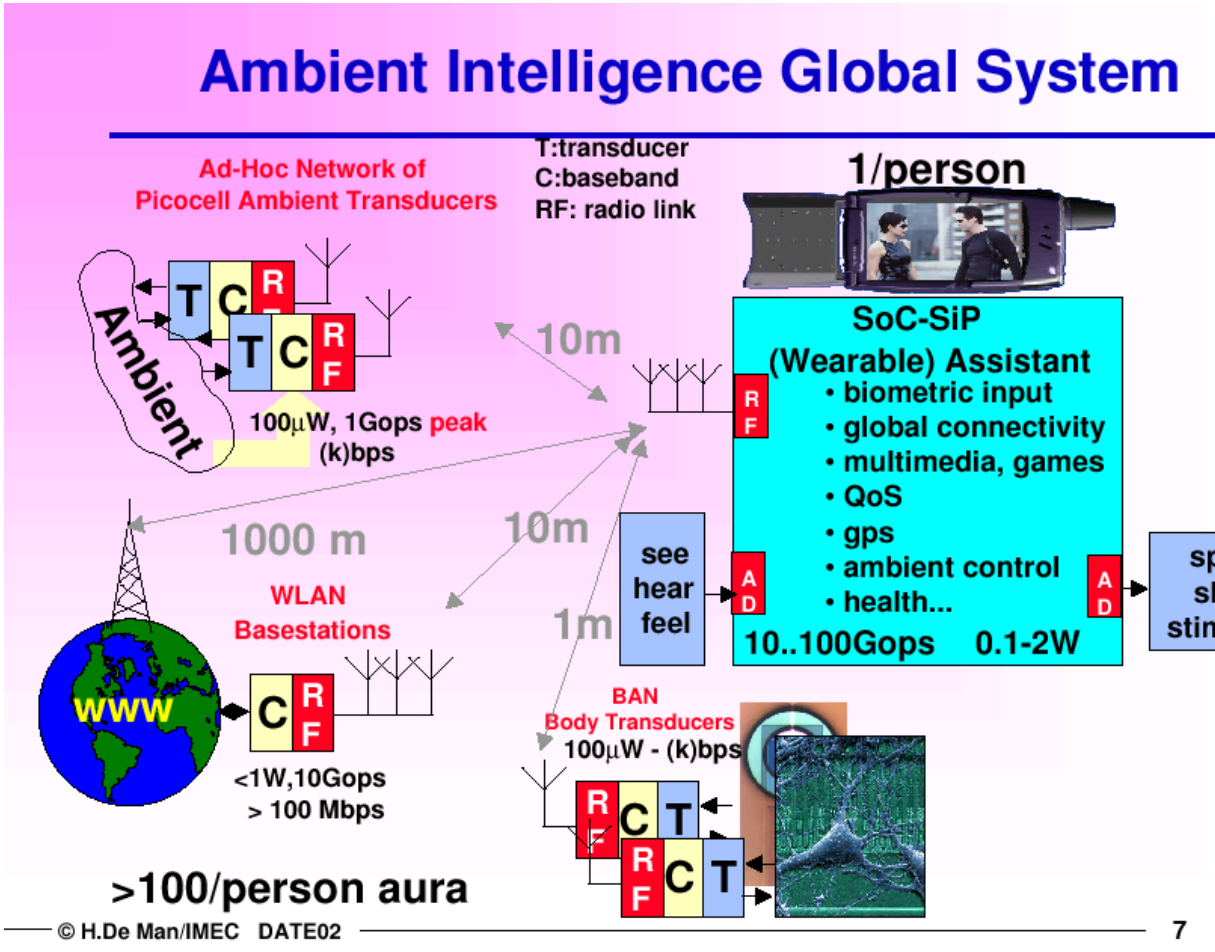
Authentication systems

- Finger print sensors
- Access control
- Airport security systems
- Smartpen®
- Smart cards
- ….

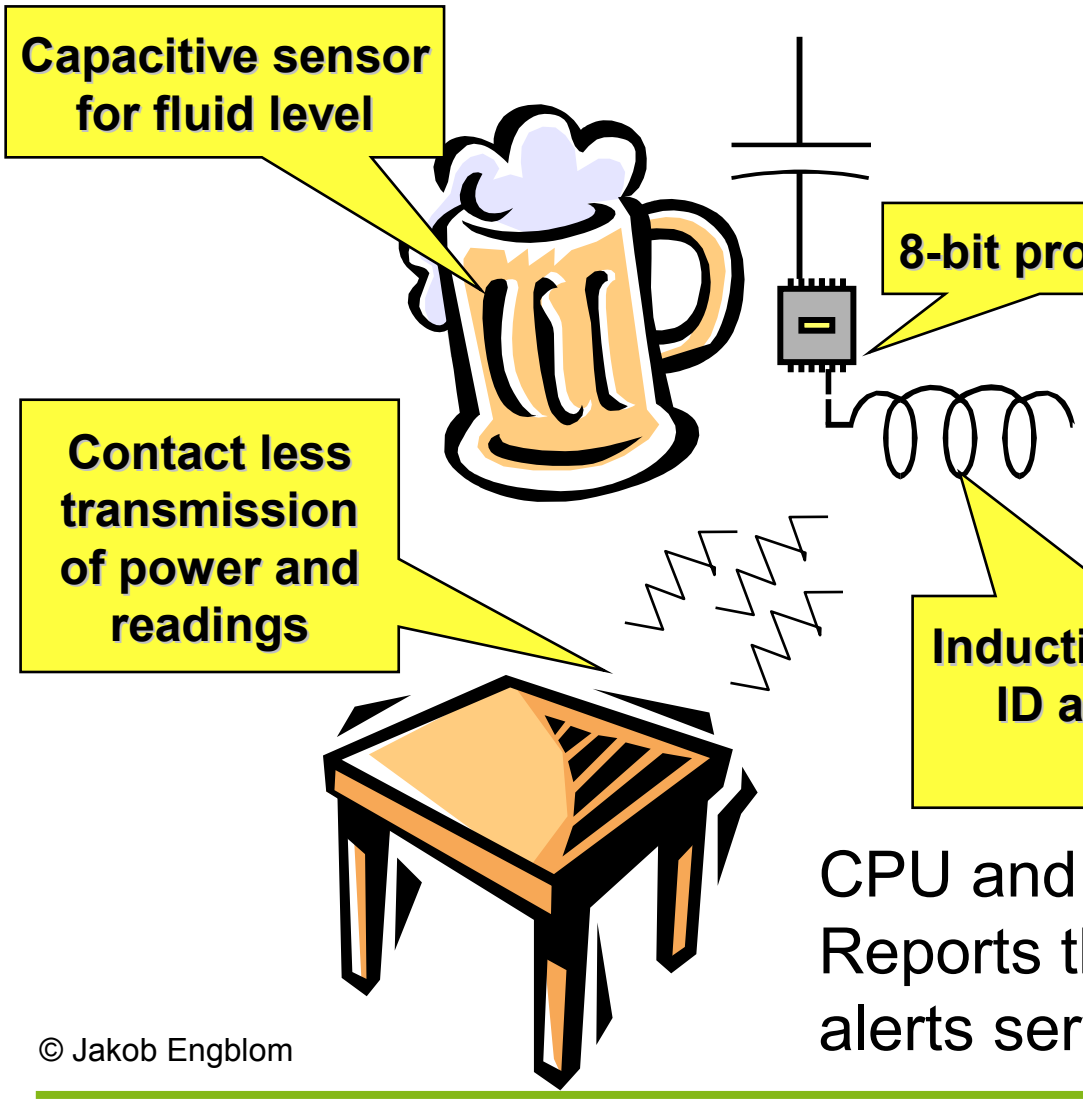
[tomsguide.com]

Consumer electronics

Examples



Smart Beer Glass



Integrates several technologies:

- Radio transmissions
- Sensor technology
- Magnetic inductance for power
- Computer used for calibration

Impossible without the computer
Meaningless without the electronics

CPU and reading coil in the table.
Reports the level of fluid in the glass, alerts servers when close to empty

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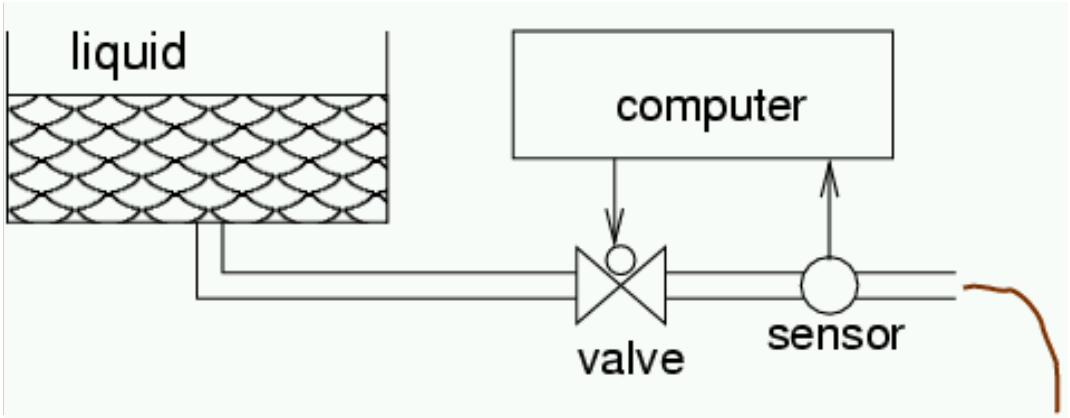
Industrial automation

Examples



Forestry Machines

Networked computer system

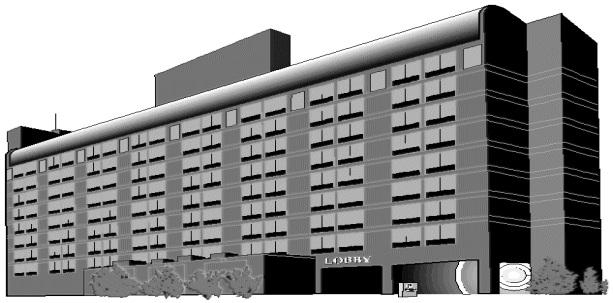
- Controlling arms & tools
- Navigating the forest
- Recording the trees harvested
- Crucial to efficient work

“Tough enough to be out in the woods”

Smart buildings

Examples

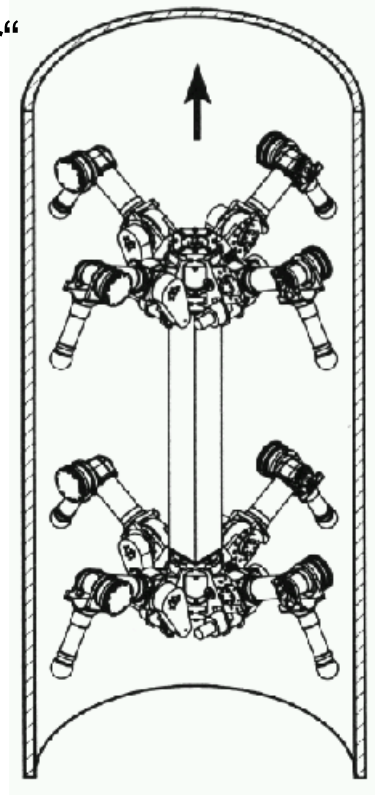
- Integrated cooling, lightning, room reservation, emergency handling, communication
- Goal: “Zero-energy building”



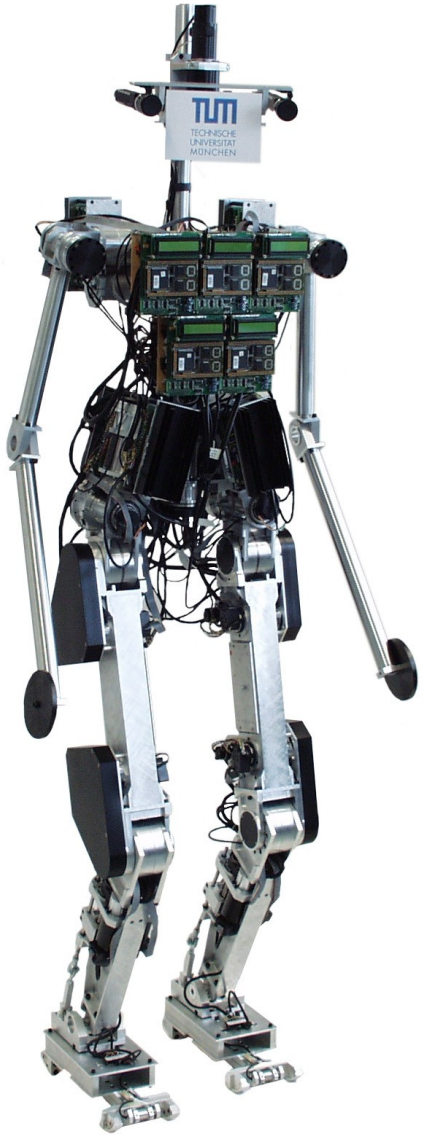
Robotics

Examples

- "Pipe-climber"



- Robot "Johnnie" (Courtesy and ©: H.Ulbrich, F. Pfeiffer, TU München)



Robotics (2)

Lego mindstorms robotics kit

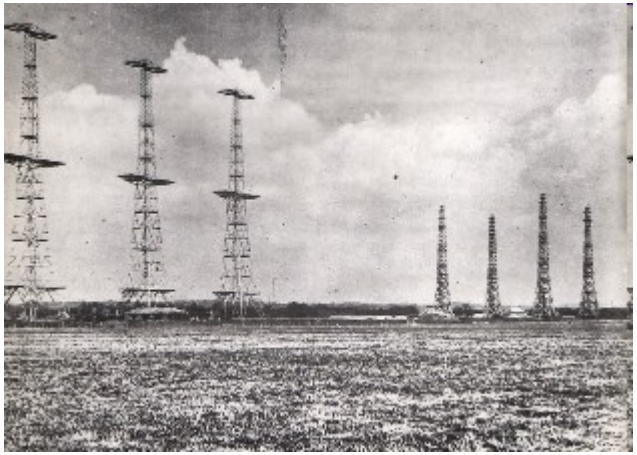
- Standard controller
  - 8-bit processor
  - 64 kB of memory
- Electronics to interface to motors and sensors

Good way to learn embedded systems

Military applications

Example:

- Military radar



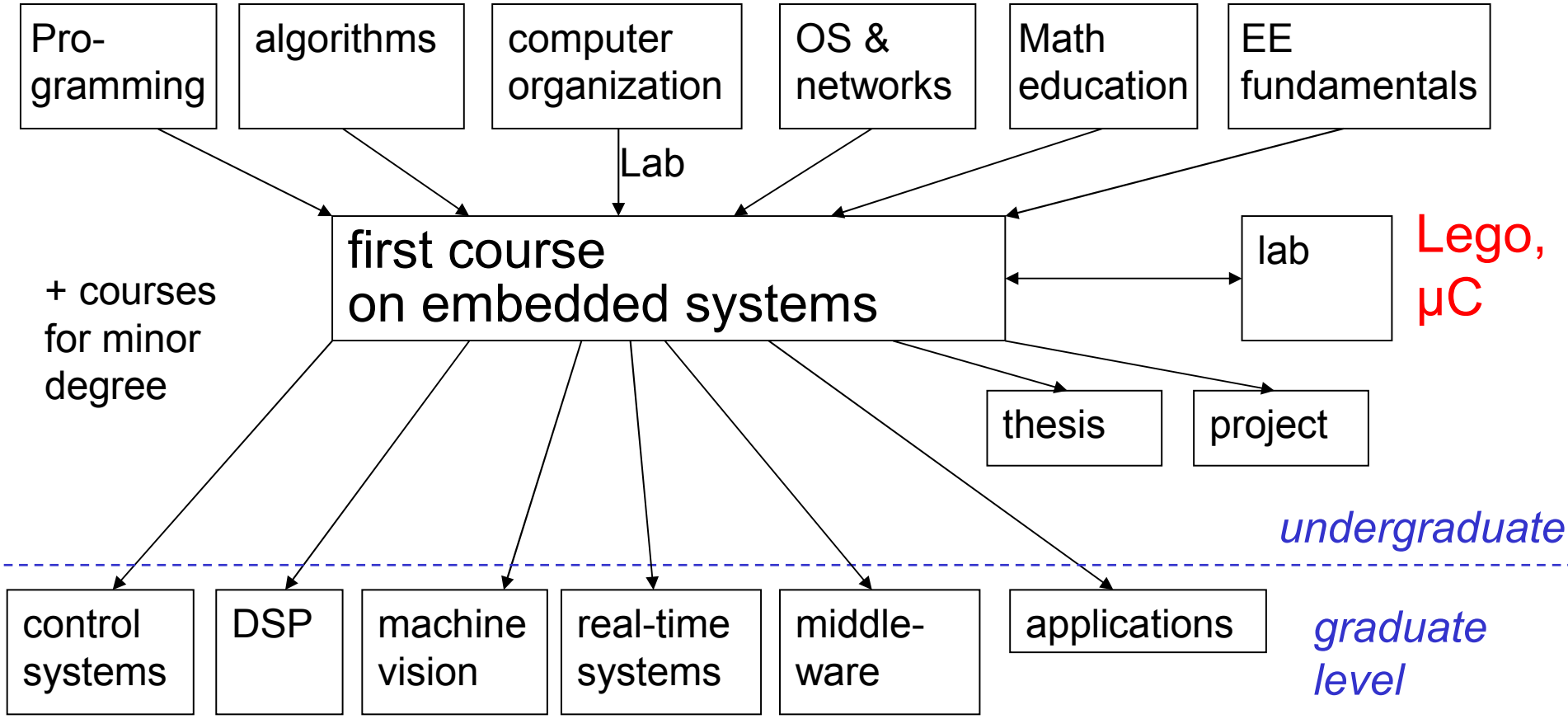
http://www.worthingherald.co.uk/CustomPages/CustomPage.aspx?SectionID=14271

Educational concept

From the preface of the book

Concept of ES Education at Dortmund

- Integrated as a special direction into CS curriculum



Structure of the CS curriculum at Dortmund
- 4.5 year diploma program -

Term				
1	Computer organization		Programming & semantics	Math education
2	Circuits & communication	OS	Algorithms	
3	HW lab	Networks	SW lab	
4		Databases	…	
5	Embedded systems fundamentals	Software engineering	…	
6	Advanced topic in ES	…	…	
7	Project group	…	…	
8		…	…	
9	Thesis			

All dependences met

Structure of the CS curriculum at Dortmund
- 3 year bachelor program -

Term				
1	Computer organization		Programming & semantics	Math education
2	Circuits & communication	OS	Algorithms	
3	HW lab	Networks	SW lab	
4		Databases	…	
5	Embedded systems fundamentals	Software engineering	…	
6	Bachelor project + Thesis	…	…	

All dependences met

Broad scope avoids problems with narrow perspectives reported in ARTIST curriculum guidelines

"The lack of maturity of the domain results in a large variety of industrial practices, often due to cultural habits"

"curricula … concentrate on one technique and do not present a sufficiently wide perspective."

"As a result, industry has difficulty finding adequately trained engineers, fully aware of design choices."

Source: ARTIST network of excellence:
Guidelines for a Graduate Curriculum on Embedded Software and Systems,
http://www.artist-embedded.org/Education/Education.pdf, 2003

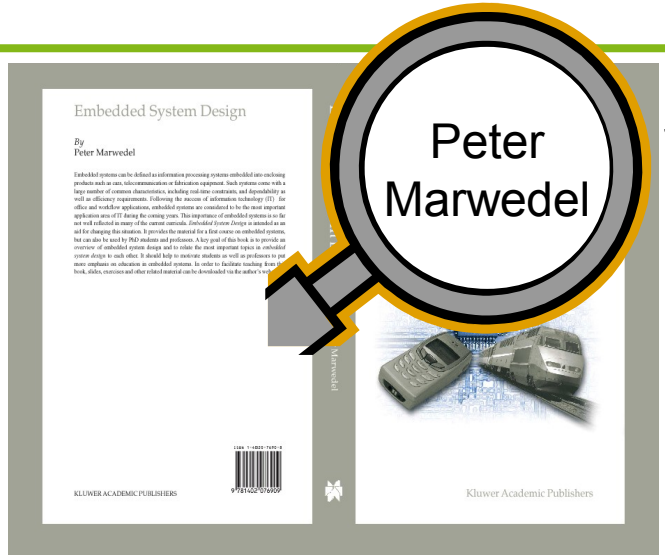
Scope consistent with ARTIST guidelines

"The development of ES cannot ignore the underlying HW characteristics. Timing, memory usage, power consumption, and physical failures are important."

$$\int P \, dt$$

"It seems that fundamental bases are really difficult to acquire during continuous training if they haven't been initially learned, and we must focus on them."

Textbook(s)



Several Editions:

- 1st English edition
  - Original hardcover version, Kluwer, 2003, >100 $/€
  - Reprint, lighter cover borders;
  - Reprint, soft cover, corrections, Springer, 2006, 37-39€
- 2nd English edition, 2010
- 1st German edition 29€
  - March 2007
  - Reprint, 2008
- Chinese edition, April 2007, only preface in Chinese, not for sale outside China
- Plans for Russian, Portuguese, Macedonian and Greek edition

Slides

- Slides are available at:
  http://ls12-www.cs.tu-dortmund.de/de/teaching/courses/ws0910/es/folien/
- Master format: Powerpoint (XP);
- Derived format: PDF

Summary

- A look at the future of IT
- Definition: embedded & cyber-physical (cy-phy) systems
- Growing importance of embedded & cy-phy systems
- Application areas
- Examples
- Curriculum