Sharif University of Technology
Department of Computer Science and Engineering

Lec. 0: **Embedded System Design -Embedded Systems Foundations of Cyber-Physical Systems-**

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According to Peter Marwedel's Lectures

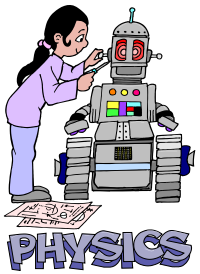
Motivation for course (1)

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

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

Basic technologies:

- *Embedded System technologies*
- Communication technologies



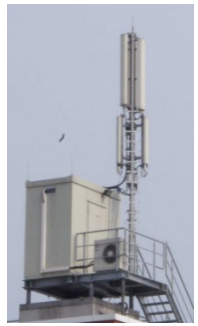
Motivation for Course (2)

National Research Council Report (US)
Embedded Everywhere, 2001:

"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. ...

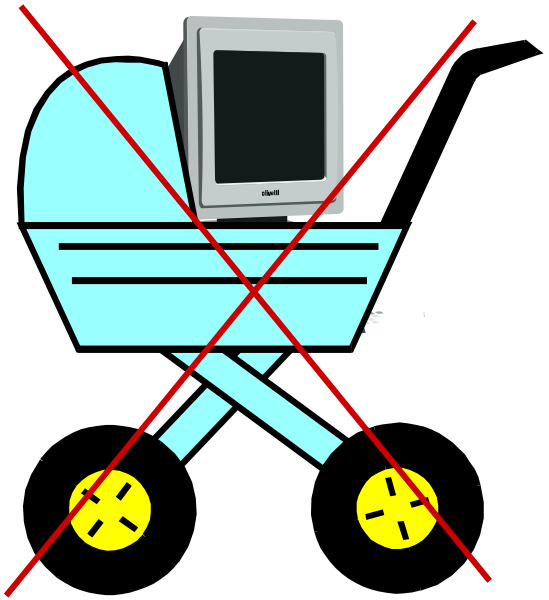
The use … throughout society could well dwarf previous milestones in the information revolution."



Motivation for Course (3)

- **The future is CPS,**
  CPS is the future

What is an embedded system?



Embedded Systems & Cyber-Physical Systems

Dortmund Definition: [Peter Marwedel]

Embedded systems are information processing systems embedded into a larger product.

Berkeley: [Edward A. Lee]

Embedded software is a software integrated with physical processes. The technical problem is managing time and concurrency in computational systems.

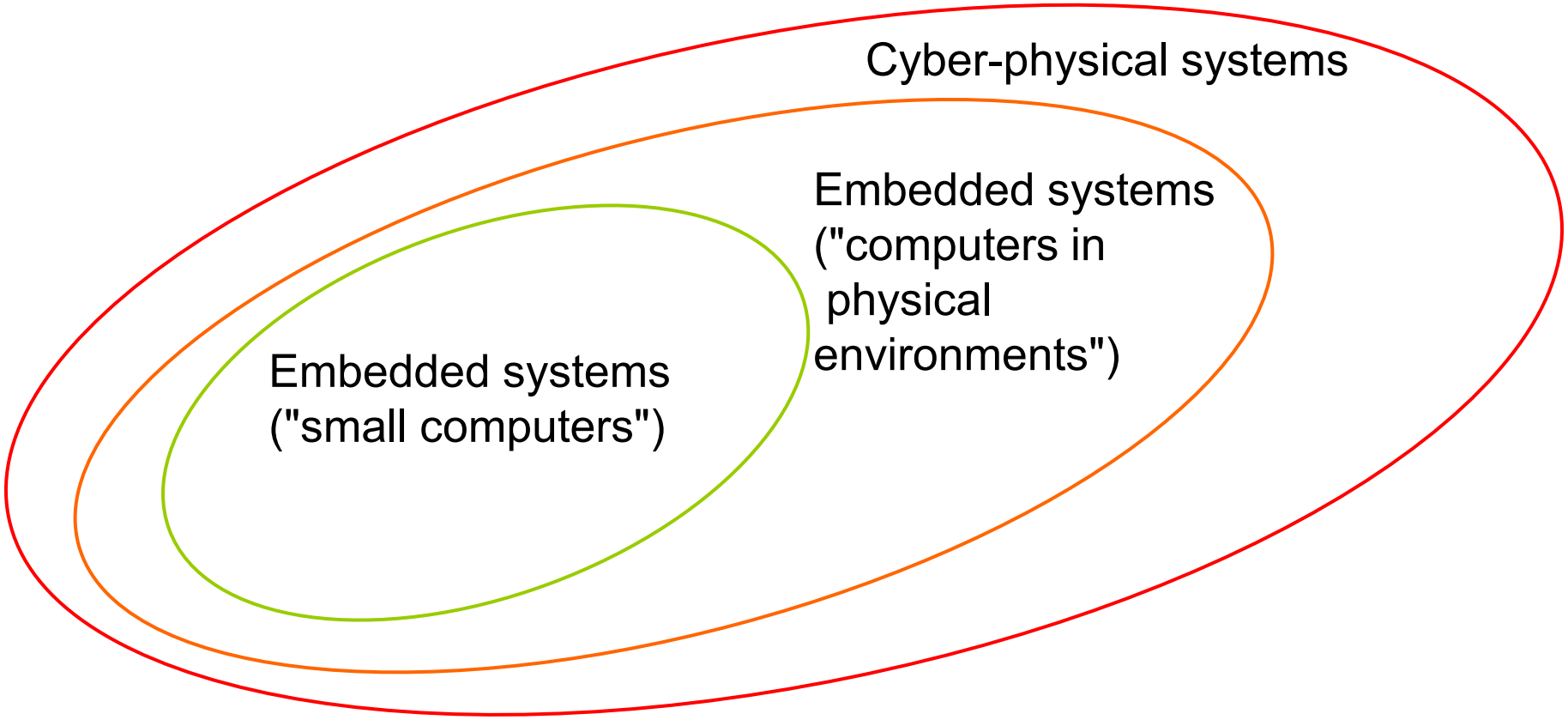
- Concurrency means multiple computations are happening at the same time.)

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

Cyber-physical system (CPS) =
Embedded System (ES) + *physical environment*

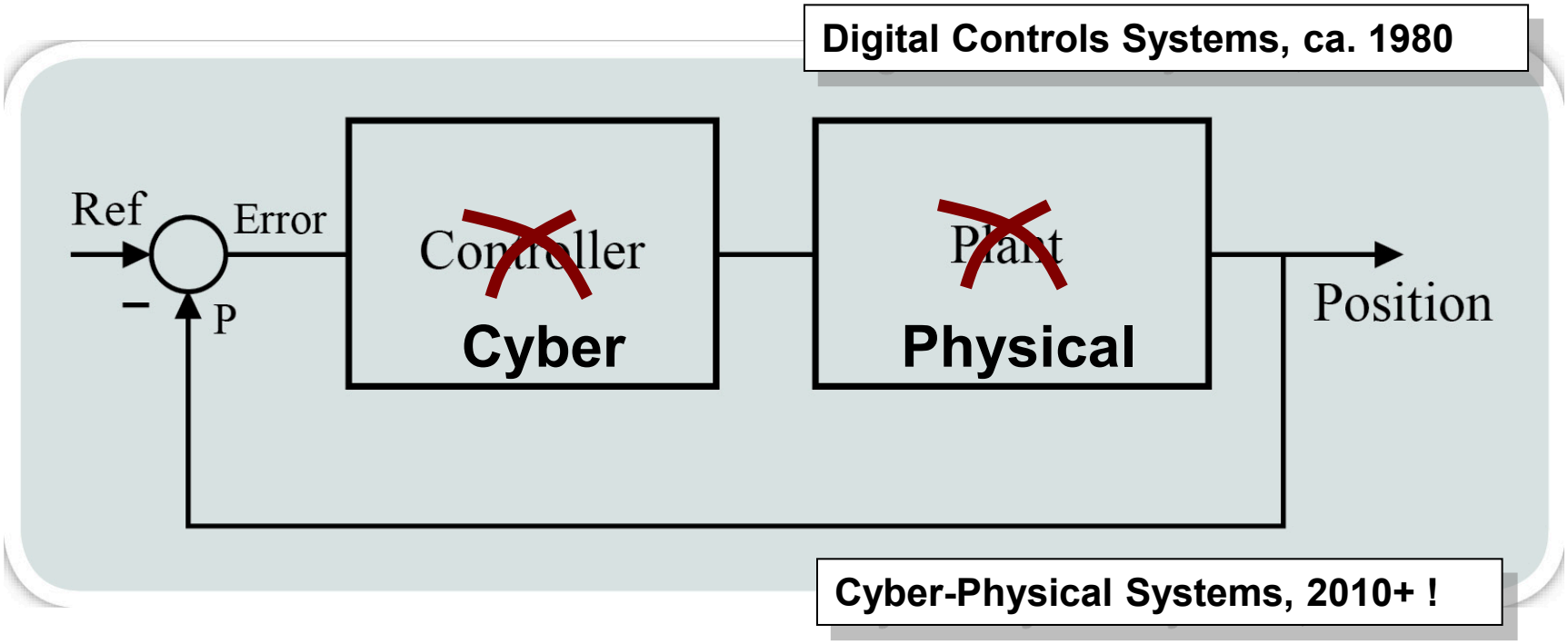
Cyber-physical systems and embedded systems

CPS = ES + physical environment



What is a *Cyber-Physical System*?

Extreme view:



Definition according to National Science Foundation (US)

- *Cyber-physical systems (CPS) are engineered systems that are built from and depend upon the **synergy of computational and physical components.***
- *Emerging CPS will be **coordinated, distributed**, and **connected**, and must be **robust** and **responsive**.*
- *The CPS of tomorrow will need to far exceed the systems of today in capability, adaptability, resiliency, safety, security, and usability.*
- *Examples of the many CPS application areas include the **smart electric grid, smart transportation, smart buildings, smart medical technologies, next-generation air traffic management, and advanced manufacturing**.*

CPS: Integration of Cyber and Physics

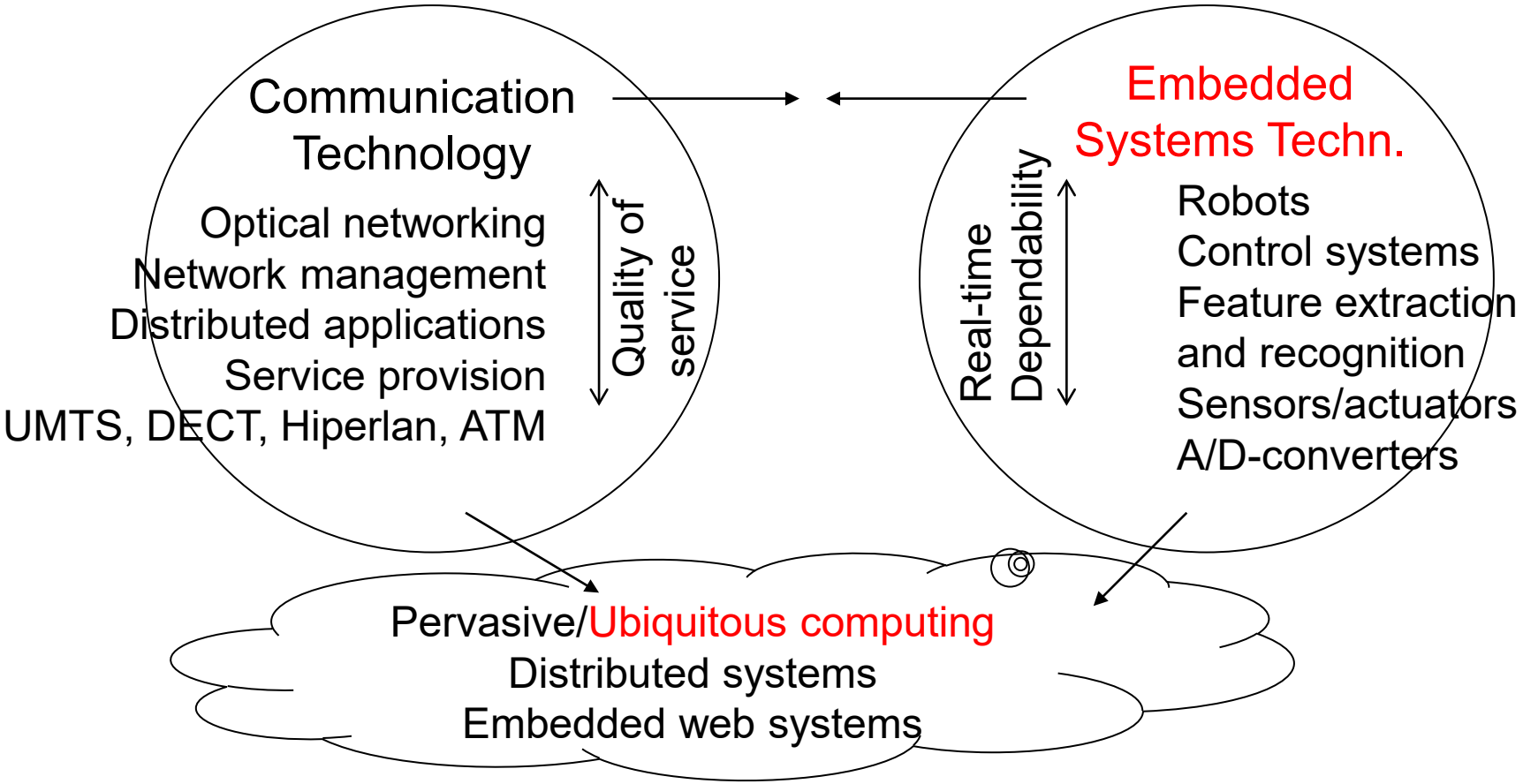
Cyber

Physics

CPS

Extending the motivation: Embedded systems and ubiquitous computing

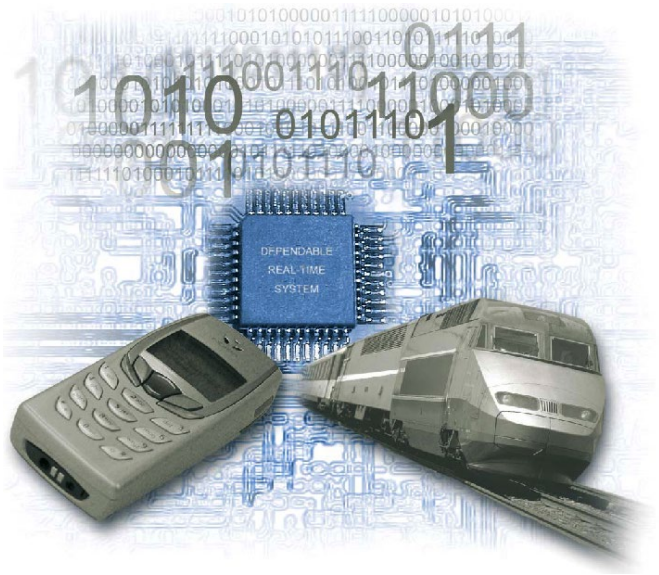
Ubiquitous computing: Information anytime, anywhere. Embedded systems provide fundamental technology.



Growing importance of cyber-physical/ embedded systems

- *49.7% of Americans own smartphones*
  [www.itfacts.biz, March 31, 2012]
- *…, 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]
- Funding in the 7th European Framework
- Creation of the ARTEMIS Joint Undertaking in Europe
- Funding of CPS research in the US
- Joint education effort of Taiwanese Universities
- ….

Application areas and examples



Application area automotive electronics: clearly cyber-physical

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
- Multiple networked processors

Application area avionics: also cyber-physical

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

© P. Marwedel, 2011

Dependability is of utmost importance.

More application areas:

- railroad

- water ways

Dependability is of utmost importance.

Forestry machines: cyber-physical

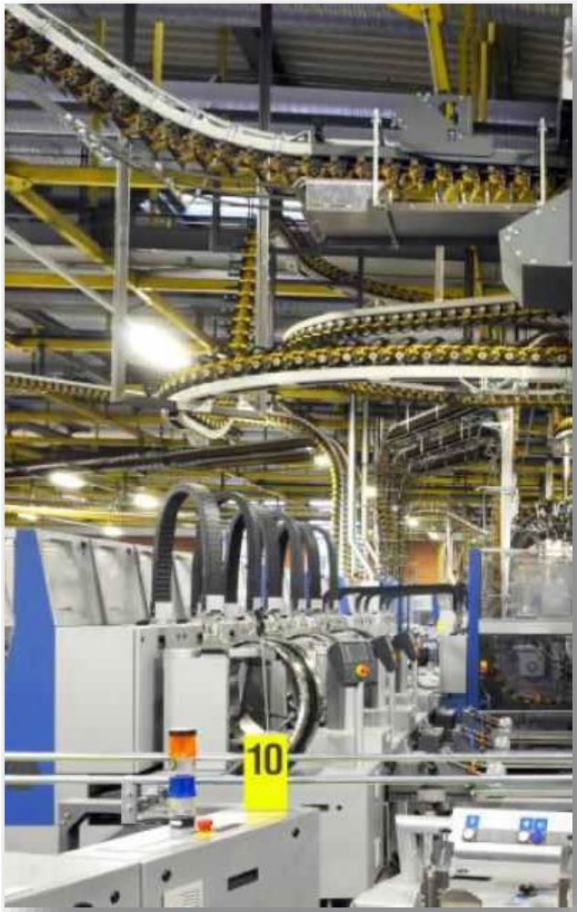
Networked computer system

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

“Tough enough to be out in the woods”

Fabrication

Production resources are self-configuring and distributed *social machines*



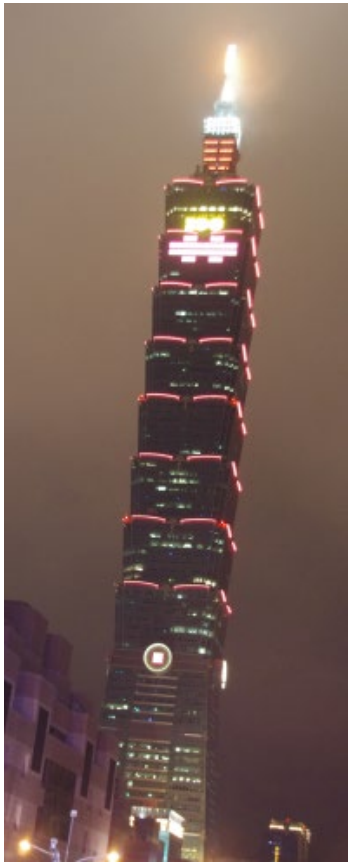
Structural safety

Sensors + data analysis

Möhne lake dam

Kilauea, Hawaii

Bridge at Vancouver



Taipeh 101

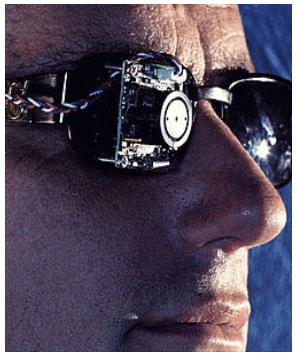
Smart Home

- Zero energy building, generates as much energy as it consumes
- Provides safety and security
- Supports owners
- Provides maximum comfort
- ambient assisted living

© P. Marwedel

Medical systems: cyber-physical

- 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]

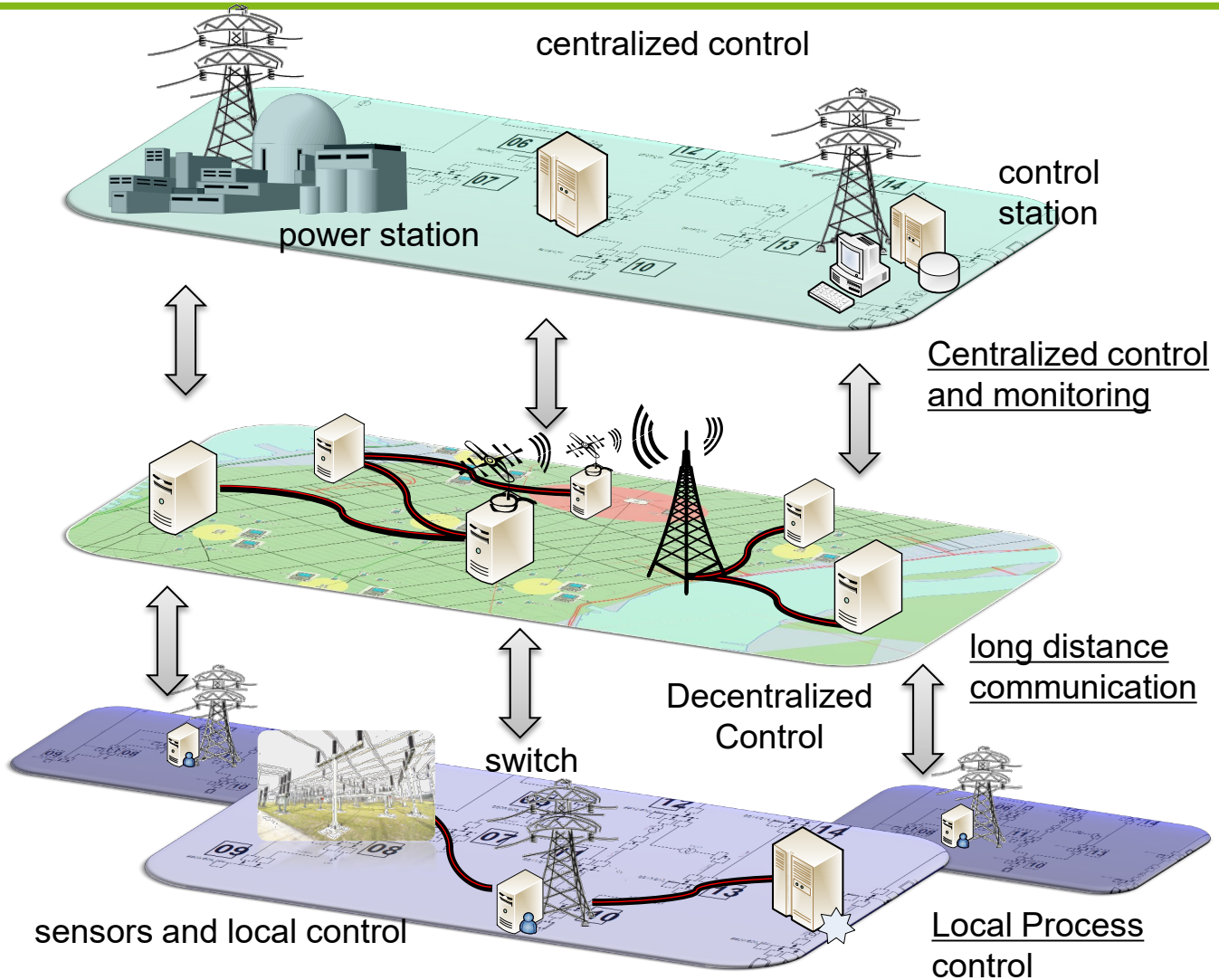


- Translation into sound; claiming much better resolution. [http://www.seeingwithsound.com/etumble.htm]

Smart Medicine

- Diagnosis
- Support of therapy
- Evaluation
- Risk analysis
- Information about patients

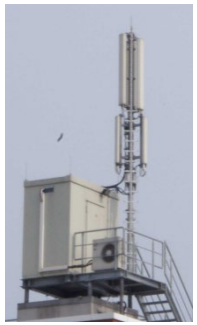
Smart Grid


centralized control
power station
control
station
Centralized control
and monitoring
long distance
communication
Decentralized
Control
switch
sensors and local control
Local Process
control

More application areas

- Telecommunication
- Consumer electronics
- Robotics
- Public safety
- Military systems

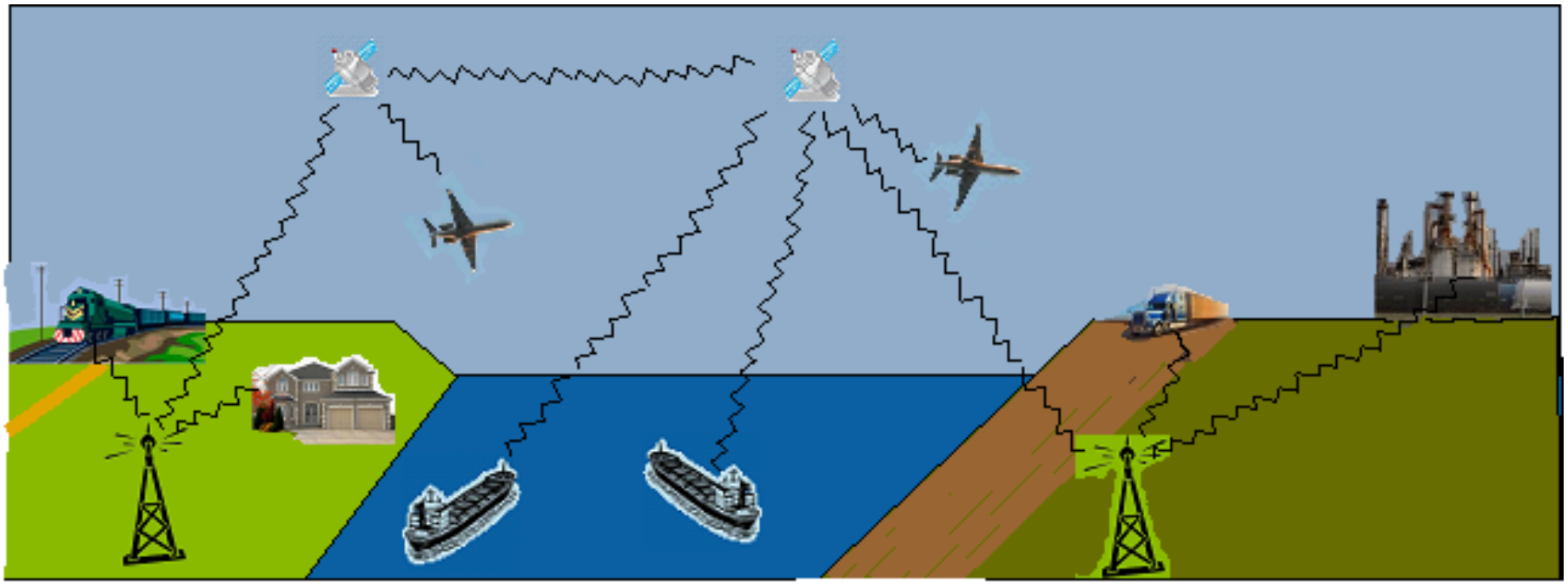




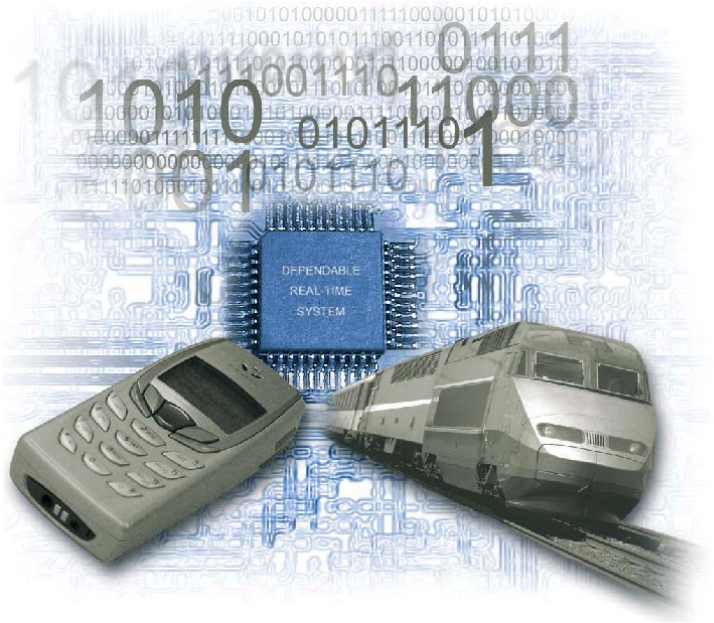



Mostly cyber-physical

Connecting previously isolated systems



Educational concept



Broad set of topics

1. Introduction
2. Reactive Systems (Automata-Based Programming)
3. Specification and modeling
4. CPS/ES hardware and software
5. Power, energy, and reliability
6. Mapping and scheduling
7. Communication
8. Evaluation and optimizations

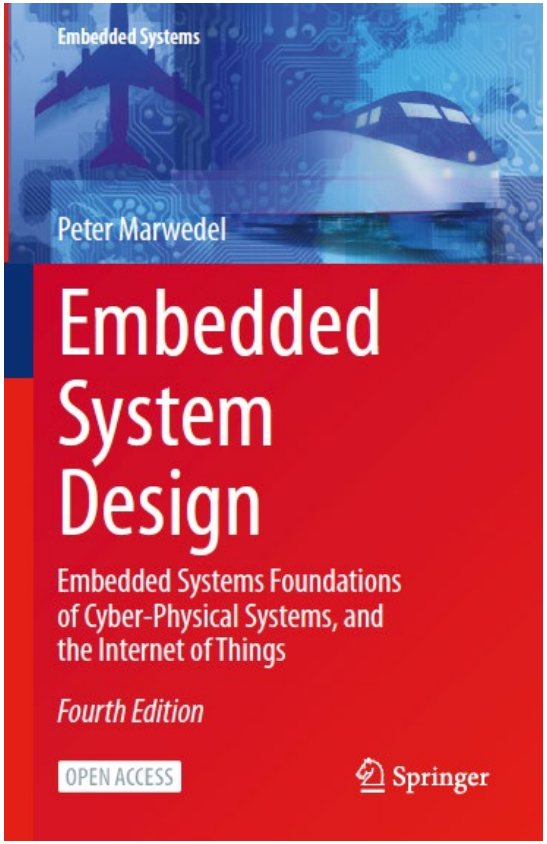
Requirements of ES

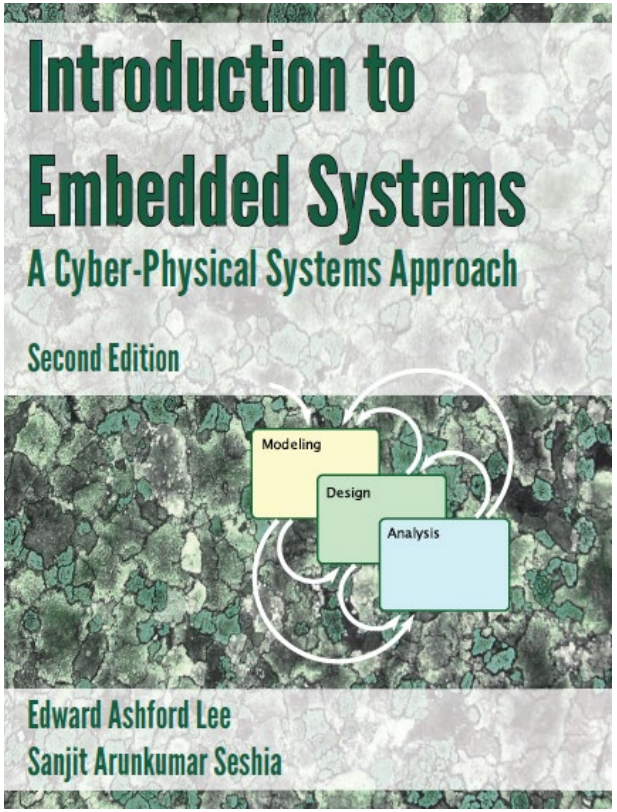
"The development of ES cannot ignore the underlying HW characteristics. Timing, memory usage, power consumption, and physical failures are important."

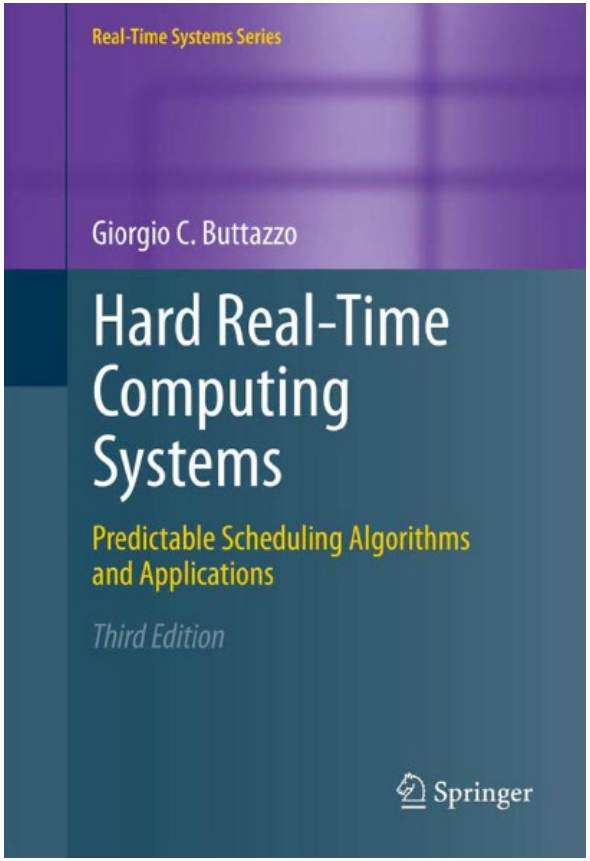
$$\int P\,dt$$

"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."

Textbooks







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

Grading

- Midterm Exam: 20%-30%
- Quizzes : 5%-10%
- Homework: 10%-15%
- Project: 25%-35% (including seminar)
- Final Exam: 30%-45%