Embedded Systems

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Future of IT?

According to forecasts charac-
terized by the terms such as

- *Post-PC era*
- *Disappearing computer*
- *Ubiquitous computing*
- *Pervasive computing*
- *Ambient intelligence*
- *Embedded systems*

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Embedded Systems

Embedded systems (ES) = **information processing systems embedded into a larger product**

!

Main reason for buying is **not** information processing

Application areas (1)

- Automotive electronics
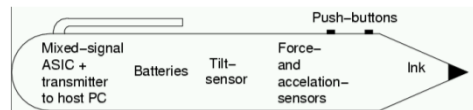
- Aircraft electronics

- Trains

- Telecommunication
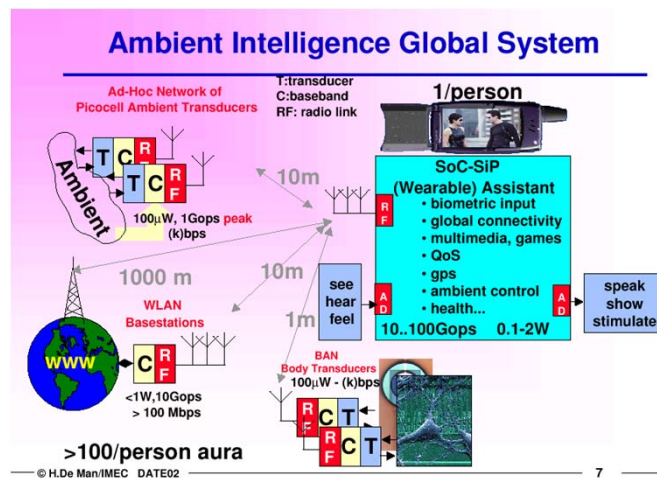
Application areas (3)

- Military applications

http://www.submarine.co.mp/wallpaper/submarine_640.jpg
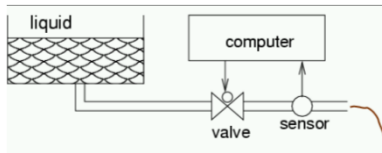
- Authentication

Application areas (4)

- Consumer electronics

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Application areas (5)
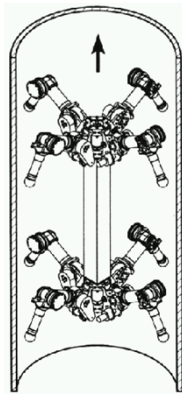
- Fabrication equipment

- Smart buildings

Application areas (6)

- Robotics

„Pipe-climber"

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

Growing importance of embedded systems (1)

- Growing economical importance of embedded systems THE growing market according to forecasts, e.g.:

  - *Worldwide mobile phone sales surpassed 156.4 mln units in Q2 2004, a 35% increase from Q2 2003, according to Gartner* [www.itfacts.biz]

  - *The worldwide portable flash player market exploded in 2003 and is expected to grow from 12.5 mln units in 2003 to over 50 mln units in 2008* [www.itfacts.biz]

  - *Global 3G subscribers will grow from an estimated 45 mln at the end of 2004 to 85 mln in 2005, according to Wireless World Forum.* [www.itfacts.biz]

Growing importance of embedded systems (2)

- *The number of broadband lines worldwide increased by almost 55% to over 123 mln in the 12 months to the end of June 2004, according to Point-Topic.* [www.itfacts.biz]

- *Today's DVR (digital video recorders) users - 5% of households - will grow to 41% within five years, according to Forrester.* [www.itfacts.biz]

- *The automotive sector … ensures the employment of more than 4 million people in Europe. Altogether, some 8 million jobs in total depend on the fortunes of the transport industry and related sectors - representing around 7 per cent of the European Union's Gross National Product (GNP)* [OMI bulletin]

Growing importance of embedded systems (3)

- *.. 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]
- 79% of all high-end processors are used in embedded systems

The future is embedded, Embedded is the future!

- 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

Characteristics of Embedded Systems (1)

- Must be **dependable**,
  - **Reliability $R(t)$ =** probability of system working correctly provided that is was working at t=0
  - **Maintainability $M(d)$ =** probability of system working correctly d time units after error occurred.
  - **Availability $A(t)$**: probability of system working at time t
  - **Safety**: no harm to be caused
  - **Security**: confidential and authentic communication

Even perfectly designed systems can fail if the assumptions about the workload and possible errors turn out to be wrong.

Making the system dependable must not be an after-thought, it must be considered from the very beginning

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Characteristics of Embedded Systems (2)

- Must be **efficient**
  - Energy efficient
  - Code-size efficient
    (especially for systems on a chip)
  - Run-time efficient
  - Weight efficient
  - Cost efficient
- **Dedicated** towards a certain **application**
  Knowledge about behavior at design time can be used
  to minimize resources and to maximize robustness
- **Dedicated user interface**
  (no mouse, keyboard and screen)

Characteristics of Embedded Systems (3)

- Many ES must meet **real-time constraints**
  - A real-time system must react to stimuli from the
    controlled object (or the operator) within the time
    interval **dictated** by the environment.
  - For real-time systems, right answers arriving too late
    are wrong.
  - **„A real-time constraint is called hard, if not
    meeting that constraint could result in a
    catastrophe"** [Kopetz, 1997].
  - All other time-constraints are called **soft**.
  - A guaranteed system response has to be explained
    without statistical arguments

Characteristics of Embedded Systems (4)

- Frequently **connected to physical environment** through sensors and actuators,
- **Hybrid systems** (analog + digital parts).
- Typically, ES are **reactive systems**:

  „A reactive system is one which is in continual interaction with is environment and executes at a pace determined by that environment" [Bergé, 1995]

  Behavior depends on input **and current state**.

  ☞ automata model appropriate,

  model of computable functions inappropriate.
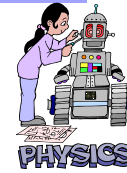
Characteristics of Embedded Systems (5)

- ES are **underrepresented in teaching** and public discussions:
  „Embedded chips aren't hyped in TV and magazine ads ... [Mary Ryan, EEDesign, 1995]

Not every ES has all of the above characteristics.

Def.: **Information processing systems having most of the above characteristics are called embedded systems.**

Course on embedded systems makes sense because of the number of common characteristics.
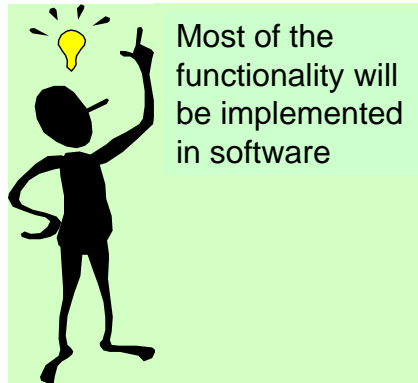
Importance of Embedded Software and Embedded Processors

"... the New York Times has estimated that the average American comes into contact with about 60 micro-processors every day...."
[Camposano, 1996]

Latest top-level BMWs contain over 100 micro-processors
[Personal communication]

Most of the functionality will be implemented in software

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Challenges for implementation in software

If embedded systems will be implemented mostly in software, then why don't we just use what software engineers have come up with?

Software complexity is a challenge

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- Exponential increase in software complexity
- In some areas code size is doubling every 9 months [ST Microelectronics, Medea Workshop, Fall 2003]
- *... > 70% of the development cost for complex systems such as automotive electronics and communication systems are due to software development* [A. Sangiovanni-Vincentelli, 1999]
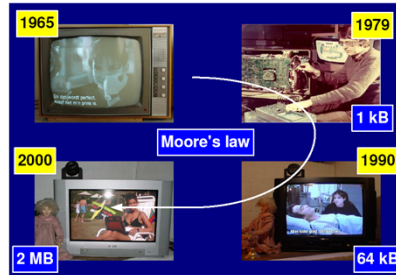
Rob van Ommering, COPA Tutorial, as cited by: Gerrit Müller: Opportunities and challenges in embedded systems, Eindhoven Embedded Systems Institute, 2004

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Challenges for Embedded Software

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- Dynamic environments
- Capture the required behaviour!
- Validate specifications
- Efficient translation of specifications into implementations!
- How can we check that we meet real-time constraints?
- How do we validate embedded real-time software? (large volumes of data, testing may be safety-critical)

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