Embedded Systems and Lab

Introduction to Embedded Systems

Definitions

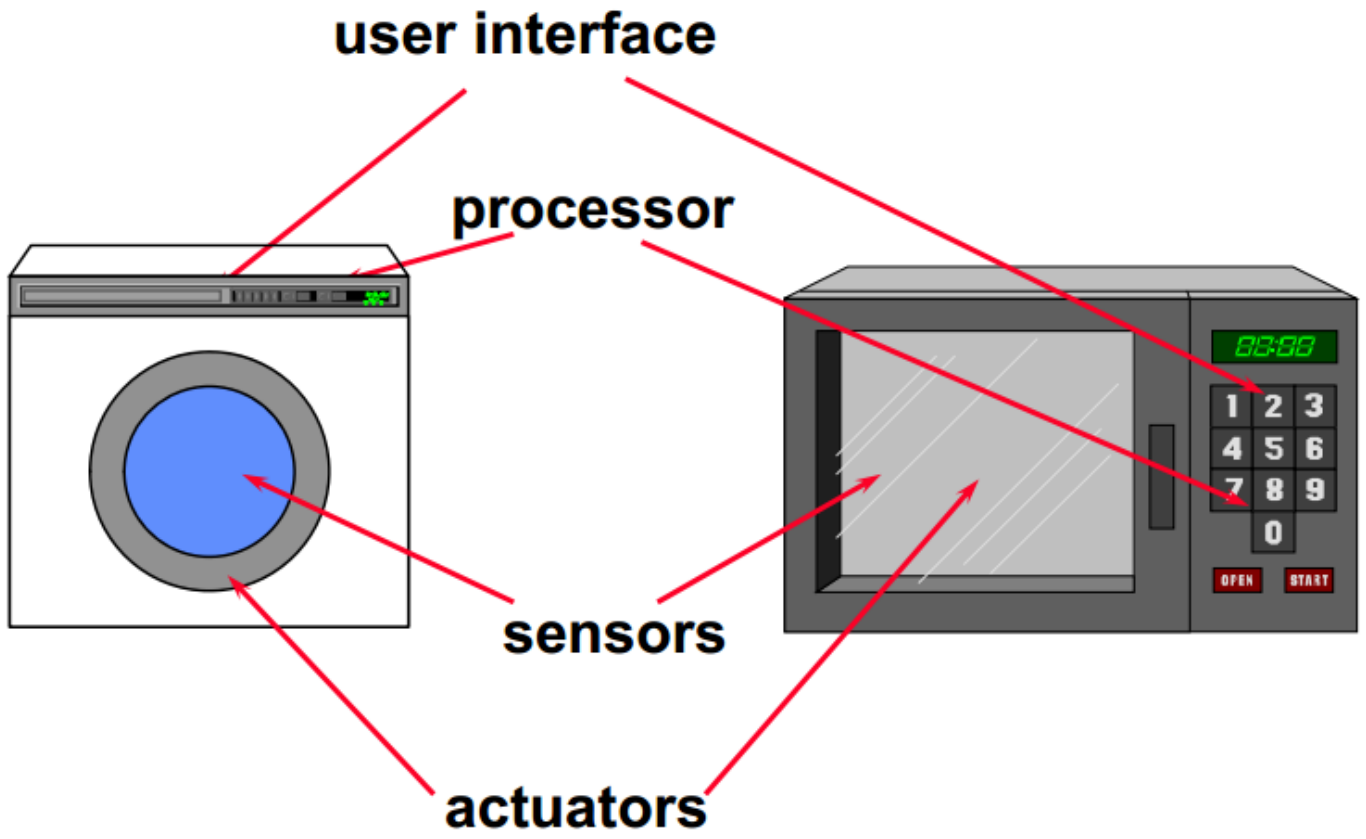
- Embedded Systems are information processing systems embedded into a larger product.
  - Peter Marwedel, TU Dortmund

- Embedded software is software integrated with physical processes. The technical problem is managing time and concurrency in computational systems.
  - Edward Lee, Berkeley

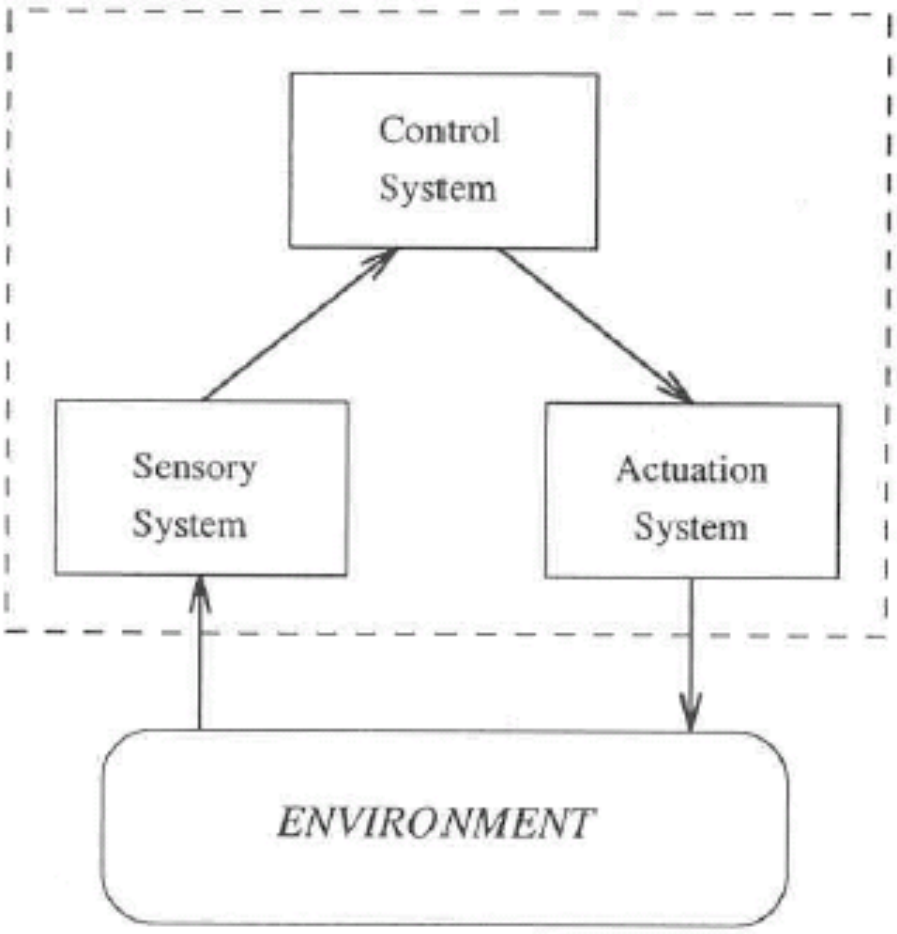
Characteristics

- In general, embedded system
  1) is part of a larger system that may not be a "computer"
  2) works in a reactive, X-constrained environment
     - X: time, energy (battery), space, cost, human interaction, …
  3) employs a combination of hardware and software to perform a specific function

An Example: Home Appliance (1)



An Example: Home Appliance (2)



Micro-controller +
Embedded software

Button input, motor output, microwave output, display, …

Temperature, weight, water level, human interaction, …

Examples of Embedded Systems

Transportation

Defense

Energy and Industrial Automation

Health and Biomedical

Agriculture

Critical Infrastructure

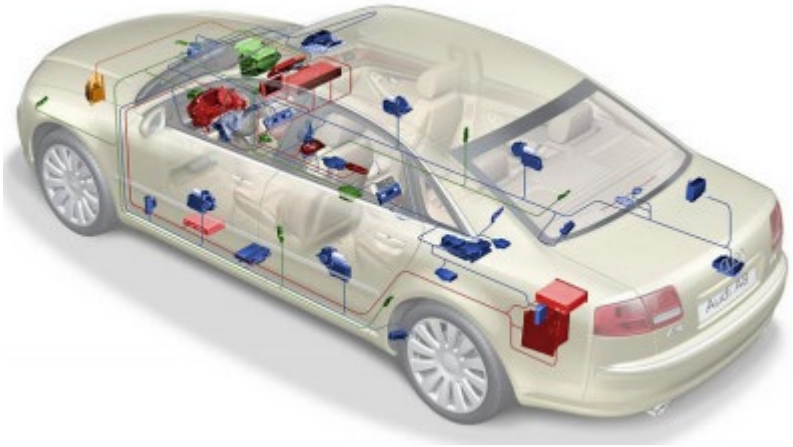
Importance of Embedded Systems

- $6bn embedded processors market in 2012
- Average car has about 15 microprocessors in it.
  - Mercedes Benz S-class has 63 microprocessors, a 1999 BMW 7-series has 65
- Average middle-class household has about 40 to 50 microprocessors in it .

Automotive Electronics

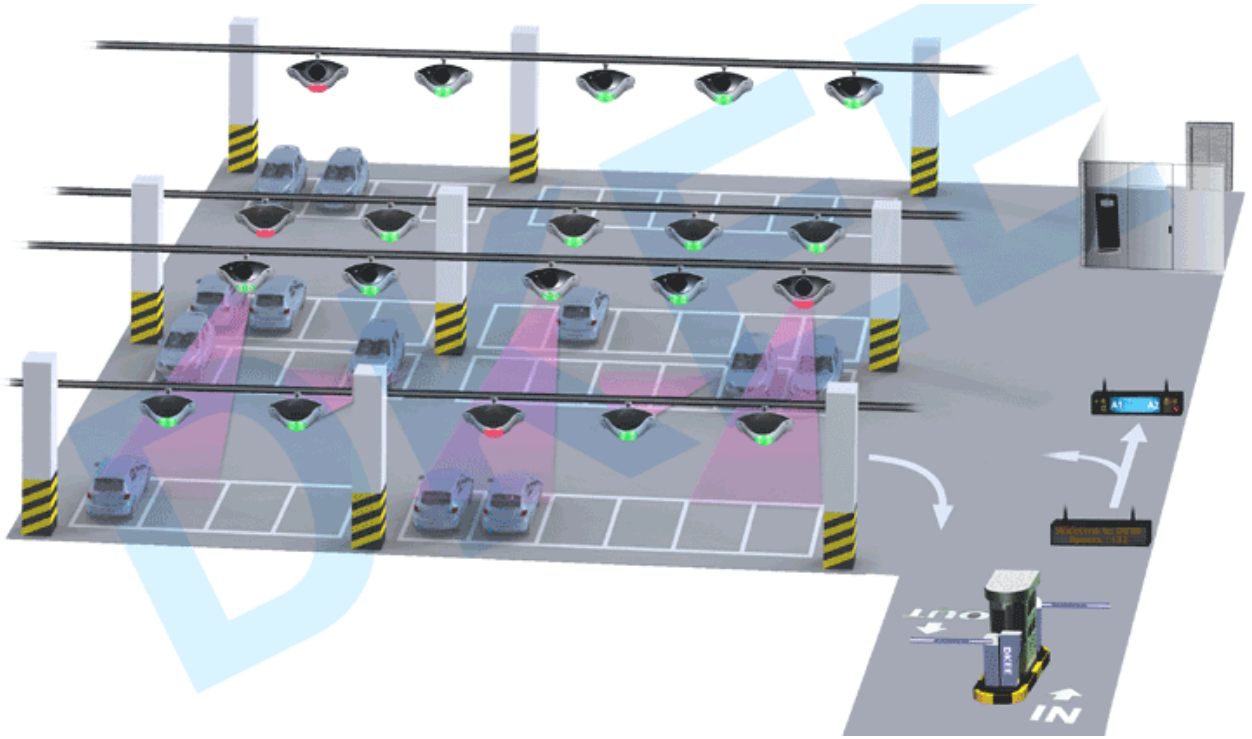
- ABS: Anti-lock braking systems
- ESP: Electronic stability control
- Airbags
- Efficient automatic gearboxes
- Theft prevention with smart keys
- Blind-angle alert systems
- In-car entertainment systems
- ...

- Multiple networked controllers
  - Multiple processors
  - Multiple networks



Car Parking Information System

- Accounting, available parking spots, automobile locator

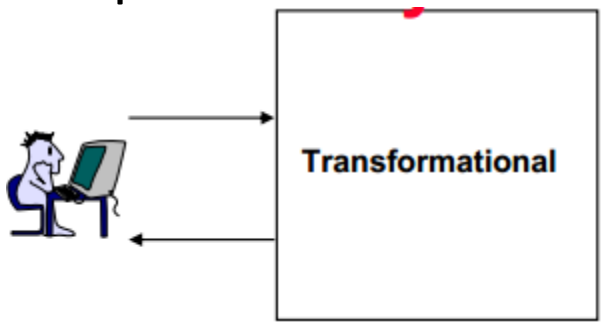


Challenges in Embedded Systems

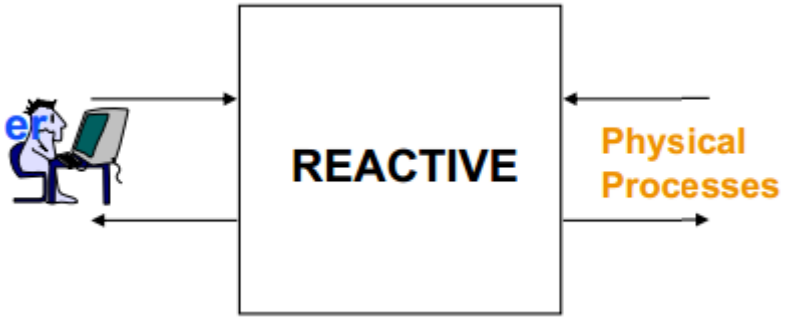
- Requires holistic approach involving embedded software, embedded hardware and physical environment
- Additional constraints: power/energy, size, cost, timely processing, dependability, ...

Reactivity: Concurrent Processing

- Closed systems
  - Interactions confined to one source
  - Same output for same input



- Open systems
  - Interactions from multiple sources, not controllable or observable by the programmer



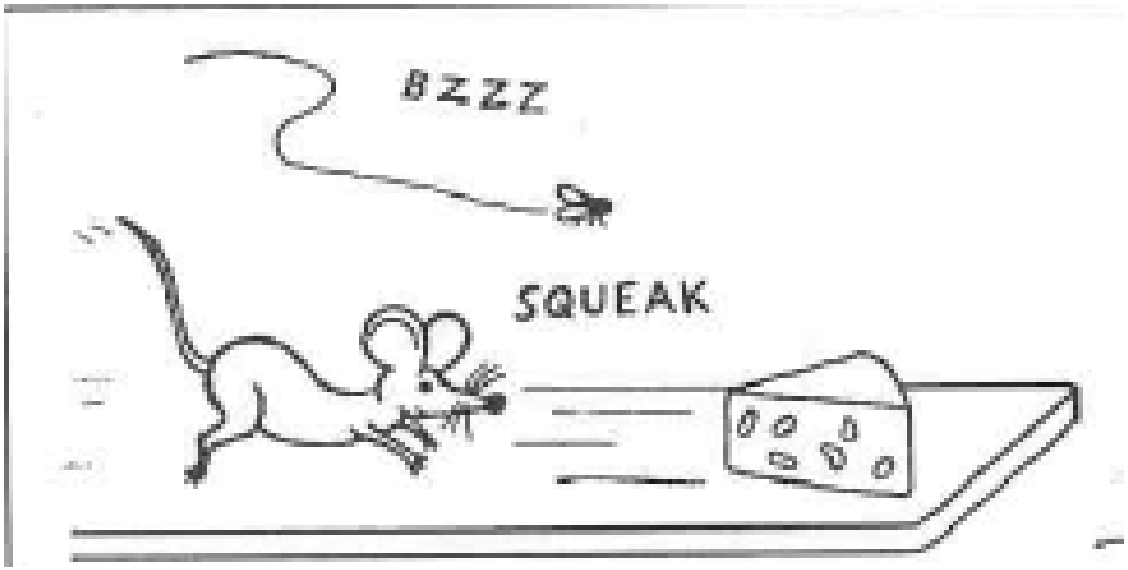
Constraints are important parts of system functionality in building embedded systems

Real-Time: Timely Processing

- A real time system is a system that must satisfy explicit (bounded) response-time constraints or risk severe consequences, including failure.
- A real time system is one whose logical correctness is based on both the correctness of the outputs and their timeliness.

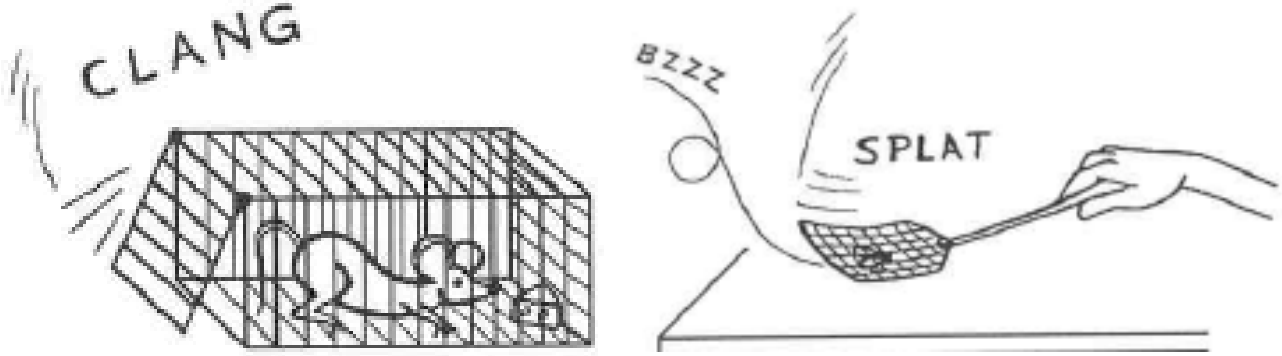
Real-Time vs Fast (1)

- Faster computing does not always satisfy real-time constraints.
  - Time must be considered relatively to the environment.



Real-Time vs Fast (2)

- There a timing boundary for successful operation
  - Too fast or too slow: failed operation



  - Fast
    - Low average time, high throughput
  - Real-Time
    - Predictability, bounded worst case time

Safety-Critical: Dependable Operations

- Dependability is of utmost importance in some embedded systems
  - Avionics, automobile, medical systems, …
- System failures mainly due to human errors, but also by software or hardware defects

The Explosion of the Ariane 5

- On June 4, 1996 an unmanned Ariane 5 rocket launched by the European Space Agency exploded just forty seconds after its lift-off from Kourou, French Guiana.

  - *The internal SRI* software exception was caused during execution of a data conversion from 64-bit floating point to 16-bit signed integer value. The floating point number which was converted had a value greater than what could be represented by a 16-bit signed integer.*
  - Source
    - https://www.ima.umn.edu/~arnold/disasters/ariane.html

Nail in Tire

- You should repair (plug) a tire quickly. Otherwise it must be replaced. However, how do you figure it out?
  - TPMS (Tire Pressure Monitoring System)!

Critical Reasons for Automobile Crashes

- Critical Reasons for Crashes Investigated in the National Motor Vehicle Crash Causation Survey
  - By NHTSA (National High Way Traffic Safety Administration) in US Dept. of Transportation

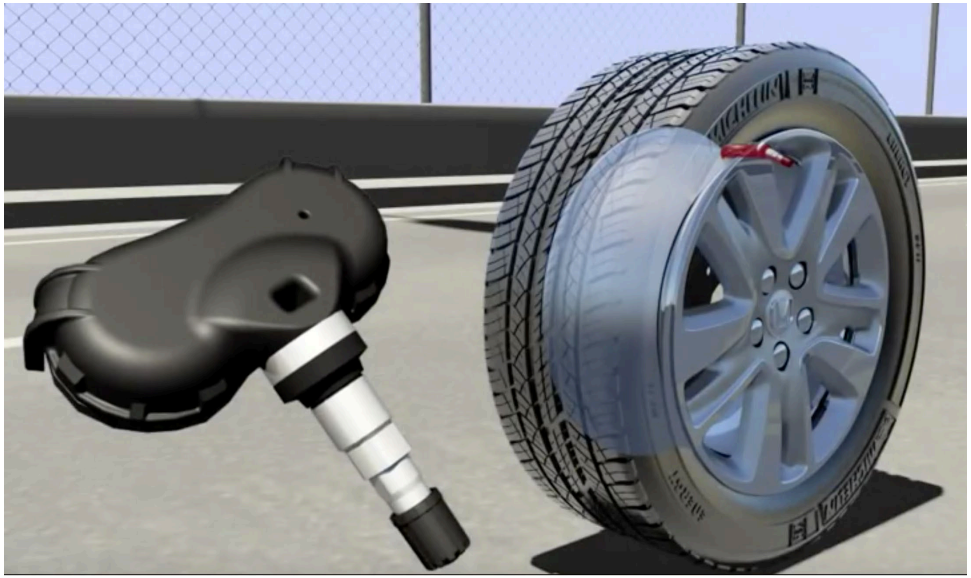
Table 3. Vehicle Related Critical Reasons

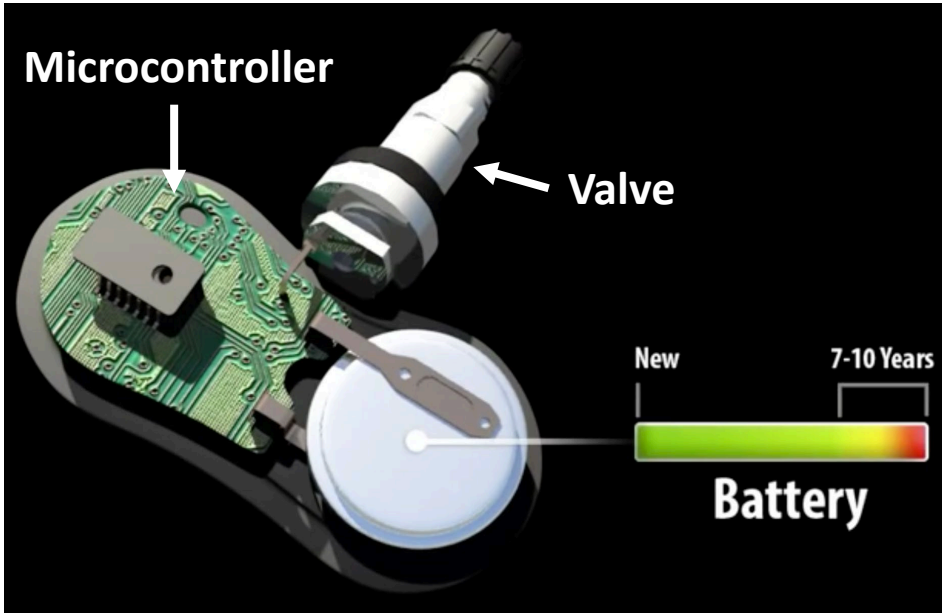
Critical Reason	Estimated (Based on 2% of the NMVCCS crashes)	
	Number	Percentage* ± 95% conf. limits
Tires /wheels-related	15,000	35% ± 11.4%
Brakes-related	10,000	22% ± 15.4%
Steering/suspension/transmission/ engine-related	2,000	3% ± 3.3%
Other/unknown vehicle-related problems	17,000	40% ± 24.0%
Total	44,000	100%

*Percentages are based on unrounded estimated frequencies
(Data Source: NMVCCS 2005–2007)

TPMS Overview

- US Gov. mandated TPMS 2008, EU in 2012, Korea in 2013
- Max. lifespan of 10 Years





An Example of Consumer Products

- Security Camera System with Motion Detection, Wall Mount, HD Video, 2-Year Battery Life and Cloud Storage
  - 2 x Lithium AA Battery

Requirements in Embedded Systems

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       …
  3) employs a combination of hardware and software to perform a specific function
- TPMS = battery-operated (<10 years) small-sized (thumb-sized) wireless (4>devices) embedded system