Cyber Physical Systems

an EIRICT ESIG

Johan Lukkien
Why EIRICT?

• Increase *impact* and *recognizability* of ICT @ TU/e

  • clear profile for ICT @ TU/e: *externally*
  • ICT participation within TU/e SAs

What can the ICT research community contribute to the strategic areas of the TU/e?

and

Which challenges do the strategic areas pose to ICT research?

• improve collaboration, financing, valorization
  – EU, EIT ICTLabs, industry, institutes
• become *leading* in some ICT topics
What we want

- Internal ICT organization
- External ICT representation
  
  →

  better position and quality on more ICT topics
  and

  more opportunities for ICT research
External

- **Representation:**
  - IPN (ICT onderzoek platform nederland)
    - ICT.Open, Roadmap ICT @ HTSM
  - NIRICT
    - SRAs in ICT research, CoE (now: CeDICT)
  - topsectors (HTSM)
  - KU Leuven (LICT), RWTH Aachen (ForumInformatik)

- **European programmes**
  - Artemis, ENIAC
  - ITEA, CATRENE
  - (FP7 → Horizon 2020)
    - Eurotech consortium (TU/e, DTU, TUM, EPFL)

- **EIT ICT Labs**

- **Site (actually, more internal)**
EIRICT: envisioned internal structure

<table>
<thead>
<tr>
<th>Chair/Research Group</th>
<th>Cyber Physical Systems</th>
<th>High Tech Industry</th>
<th>Health</th>
<th>Energy</th>
<th>Smart Mobility</th>
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EIRICT theme: ESIG

- EIRICT Special Interest Group

- First step: sufficiently interested community
- Then, a choice
  - light version:
    - a few meetings per year
    - organized by EIRICT MT
  - independent group (preferred)
  - center or institute

- Entry on website: primary contact on the topic
Current action point on CPS

- EIT ICT Labs action line on Cyber Physical Systems
- Defining workshop for the 2014 program on May 7, in Munich
UC Berkeley (April 2013). “Cyber-Physical Systems (CPS) are integrations of computation, networking, and physical processes.”

“Cyber-physical systems (CPS) are next-generation embedded systems featuring a tight integration of computational and physical elements.”
Cyber-physical systems (CPS) are physical and engineered systems whose operations are monitored, coordinated, controlled and integrated by a computing and communication core.

This intimate coupling between the cyber and physical will be manifested from the nano-world to large-scale wide-area systems of systems.

And at multiple time-scales.
So, what is CPS?

- **Eq. 1:** CPS = Computing + Control
  - (“Embedded 2.0”)
- **Eq. 2:** CPS = Embedded Systems + Internet of Things
  - (“Embedded meets Ubiquitous Sensing and Communication”)
- **Eq. 3:** CPS = Embedded Systems + Internet Services
  - (“Embedded meets Big Data”)
- **Eq. 4:** CPS =
  - Physical world + Control + Sense/Act. + Computation + Communication

*The novelty is to consider them all together*
- a theory of CPS, in which 5 aspects influence each other
- **Note:** even in ES, computation and control are often distinct
So, CPS is newish (since ~2008)

- But hey,
  - did we solve embedded systems problems yet?
  - …and where are the hybrid system’s engineers?
  - …what is still on those research agenda’s?

- We work too slow to wait for this!
The business of exponential growth

- Moore’s law
  - # transistors / area doubles every two years
  - (… at the same price)
The business of exponential growth

- Kryder’s law
  - storage capacity in # bits / surface doubles every 18 months
  - 14TB @ $40 in 2020
The business of exponential growth

- Nielsen’s law
  - a high-end-user’s connection speed grows by 50% annually
The business of exponential growth

- Gilder’s ‘law’: the total bandwidth of the Internet triples every year

- Metcalfe’s ‘law’: the value of a (telecommunication) network is proportional to the square of connected users
Consequences to the embedded domain

- Enormous processing capacity in control loops, but also:
  - Enormous amount of data to act upon
    - coming from ubiquitous sensing, integrating the physical world
    - latency requirements and storage restrictions lead to complex challenges
  - Feedback control loops spanning multiple layers, networks and time scales
    - integration of systems rather than of (dedicated) components
      - “Systems of Systems”
    - leading to sharing within systems by applications with distinct goals
      - “multiple criticality”
- ‘System perimeter’ much less clear
  - systems must work with incomplete knowledge, and uncertainty about their context
  - ‘virtual embedding’: use Internet services in embedded systems
Example: Anti-lock Braking System (ABS)

1. Brake pedal pushed
2. Pressure passed to the brake fluid
3. Wheel disc brakes squeezed
4. If the brake pedal is pushed too hard, the wheel will lock → a sensor detects this and notifies the controller
5. Controller releases the pressure on the discs by releasing some brake fluid in a container
6. The fluid is pumped back to repeat the pressure on the discs
7. Entire process is repeated about 15 times/sec

(by courtesy of Damir Isovic Mälardalen University)
ABS just one subsystem
Controlled by in-vehicle networks

- **Networks of ECUs**
- Networks are distinct
  - avoid application interference
  - requirements for each domain are different
- Applications are distributed over several nodes

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<th>Dependability</th>
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BMW 7 series infrastructure
Car is part of traffic system: V2V, V2I
Local-global control cycle

- Collect CAN signals and location data from individual cars

- Interpret CAN signals and location:
  - road condition
  - traffic situation
  - weather
  - accidents

- Global feedback
  - traffic routing
  - planning of maintenance

- Local feedback
  - individual guidance
Examples of new techniques / domains

• System of system integration
  • integration of independent subsystems with *architectural diversity, uncorrelated requirements, competition of control*
  • concerns of *interoperability and emergent properties*

• Multiple Criticality
  • a mixed-critical system is an integrated suite of hardware, operating system and middleware services and application software that supports the execution of safety-critical, mission-critical, and non-critical software within a single, secure compute platform (from http://www.cse.wustl.edu, research agenda for Mixed-Criticality Systems)

• Event-based control
  • as opposed to time-driven

• Anytime algorithms
  • give a useful answer any time of inspection of the output
Conclusion

• CPS
  • removes the distinction between specializations
  • calls for an integrated approach, which may lead to new methods

• In order to retain separation of concerns, new approaches to interfaces between systems and components need to be investigated
  • particularly, specification of extra-functional properties
  • and policies for data sharing, control

• …. and these must be supported by proper theory