Towards curriculum guidelines for Cyber-Physical Systems

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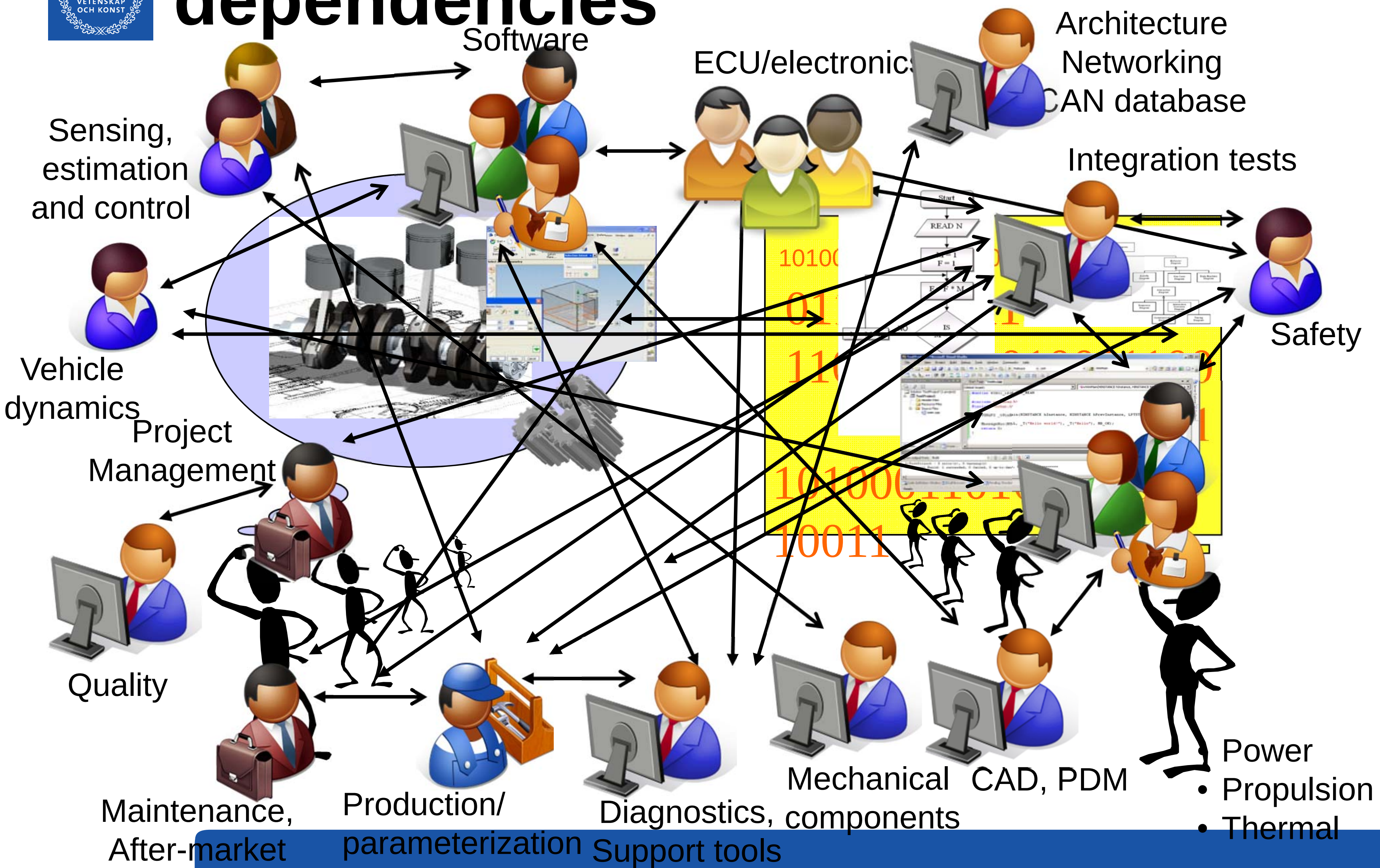
Bringing synergies in Mechatronics

Multiple viewpoints and dependencies



Key questions addressed?

What is the shape of the CPS engineer of tomorrow?

What are suitable considerations when forming a CPS curriculum?

Take aways

Paradigm shift motivates extra efforts for revising programs

Ready to engineer; Long lasting knowledge; Learn to Learn

Balances and the concept of synergy:

- *I* → *T* shaped → *Π* shaped engineers
- Academia and industrial collaboration

Need to strengthen conditions for and status of teaching

Importance of educational platforms

Agenda

1. CPS implications for education
2. A *didactic* analysis of the subject
3. Current trends and best practices
4. Curriculum design considerations

CPS characterization

The integration of physical systems and processes with networked computing has led to the emergence of a new generation of engineered systems:
Cyber-Physical Systems (CPS).
Such systems use computations and communication deeply embedded in and interacting with physical processes to add new capabilities to physical systems.
These CPS range from minuscule (pace makers) to large-scale (the national power-grid).

PCAST report [Fed07]

- Deeply Embedded vs. IT Dominated
- Single Domain vs. Cross Domain
- Closed vs. Open
- Degree of Autonomy
- Central vs. Distributed Organization
- Governance
- Adaptability
- Human In-/Outside the Loop
- Level of integration

www.cyphers.eu
Deliverable D2.2

Challenges

List of topics:

Math, statistics

Electronics, computer architecture

Compilers, operating systems

Embedded software

Optimization

Models of computation, Formal methods

Internet and web software, Wireless

Security and Safety

Control systems, Systems engineering

Human machine interaction

Team work, Project management

Configuration management

Process approaches, Life-cycle concerns

Standards,

Sustainability, recycling, **…, …, …**

…

Expanding set of (interconnected) application domains and societal concerns

Future engineers:

- "4 times during their professional life they will have to re-learn!" (Quote from Petru Eles at ESWeek)

Making the case for young people to go for engineering

Balances

Learning outcomes – Content - Examination

Depth – Breadth

Knowledge – Skills

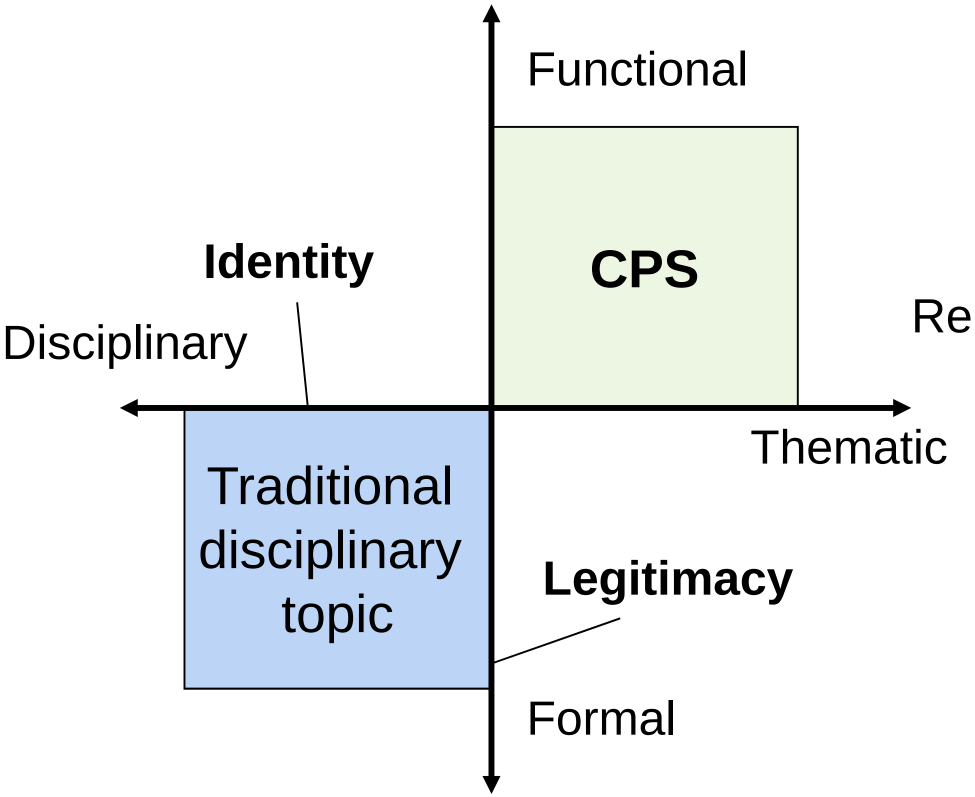
- Learning basics – Learning to learn

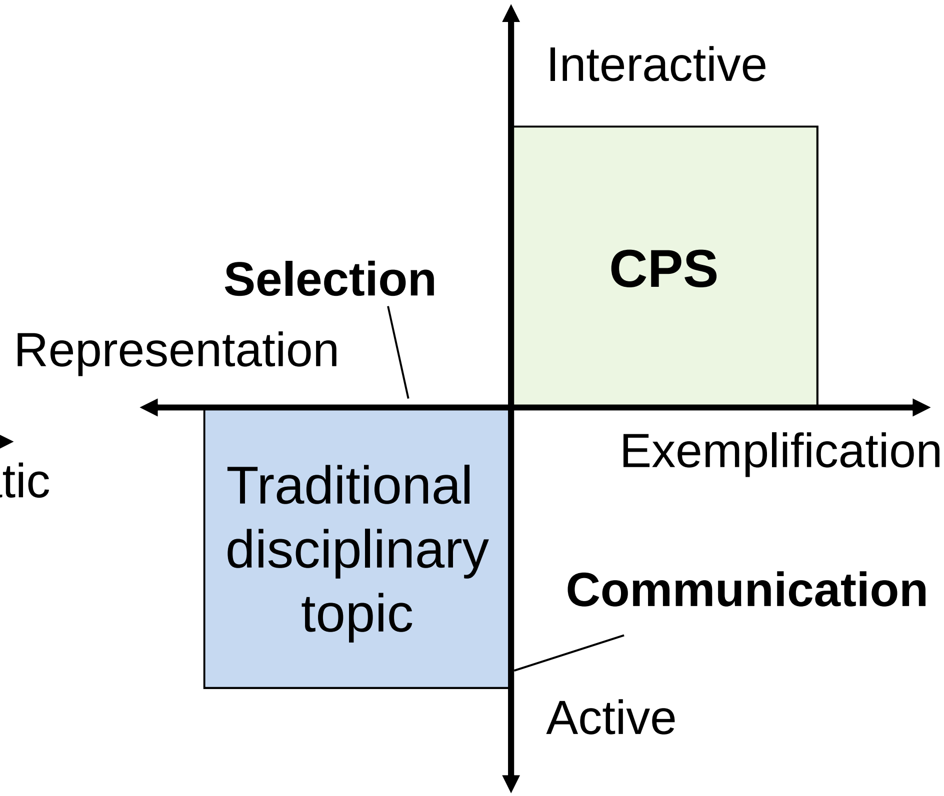
Academic – Industrial

Theory – Practice

General – Specific

Didactic analysis for CPS





Trends and best practices analysis (1): Identified CPS strands

- Foundations approach
  - Reconciling the underlying disciplinary theories and finding common, shared, abstractions and principles
- Extension approach
  - A particular discipline and curriculum, e.g. in computer science, is extended with complementary courses
  - Bachelor in some basic disciplined followed by a CPS masters
- Project and problem oriented approach

The approaches are not mutually exclusive

Trends and best practices analysis (2): activities related to engineering education,

- CDIO (an old trend)
- ABET (even older trend)
- INCOSE
- MOOCs
- E-Learning
- Design thinking

  - Body of knowledge on learning outcomes and recommendations in engineering and technology
  - CDIO = Improve engineering fundamentals and creating engineers ready to engineer
  - Capstone courses
  - Design -> Creativity

Complementary findings

Need to strengthen conditions for and status of teaching

Collaborative work among university and industry to enhance and further develop engineering education

- Combining best practices
- Reducing gap – addressing “non-academic skills”
  - For example agile development and configuration management
  - Implication of “ready to engineer”

“Ability to learn” - learning attitude

From disciplinary to ”Pi-shaped” People and Design Thinking

Cultures;
Disciplines;
Systems

Find the balance between depth and breadth,

And between analysis and synthesis

Combine with complementary skills

Teach experts, with various expertise, able to synergistically work with other experts.

Take aways

Paradigm shift motivates extra efforts for revising programs

- Increasing demands on knowledge and skills!
- Internet and embedded; **Security and safety**…

Ready to engineer; Long lasting knowledge; Learn to Learn

Balances and the concept of synergy:

- T-shaped engineers: Depth vs. breadth and project skills
- Academia and industrial collaboration

Need to strengthen teaching (conditions for and status of)

Importance of educational platforms

References

PCAST report [Fed07]

Federal Networking and Information Technology – R&D Program. Leadership Under Challenge: Information Technology R&D in a CompetitiveWorld. Technical report, Council of Advisors on Science and Technology, 2007.

CyPhERS deliverable D2.2 – See www.cyphers.eu

State of the art snapshots:

- Caspi et al, Guidelines for a graduate curriculum on embedded SW and systems. ACM Transactions on Embedded Computing Systems.
- Grimheden and Törngren, How should embedded systems be taught?. ACM SIGBED
- WESE: workshops on Education in Embedded Systems
- CPS-ED at CPS week 2013