Towards curriculum guidelines for Cyber-Physical Systems
Martin Törngren and Martin Edin Grimheden, Mechatronics at KTH, Stockholm, Sweden
Bringing synergies in Mechatronics
Multiple viewpoints and dependencies

- Sensing, estimation and control
- Vehicle dynamics
- Project Management
- Quality
- Maintenance, After-market
- Production/parameterization
- Diagnostics, Support tools
- Mechanical components
- CAD, PDM
- Architecture Networking CAN database
- Integration tests
- Safety
- Power
- Propulsion
- Thermal
- Power
- Propulsion
- Thermal

CPS-ED 2014: Towards curriculum guidelines: Törngren and Grimheden
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:

• $I \rightarrow T$ shaped $\rightarrow II$ 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).

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

PCAST report [Fed07]
www.cyphers.eu
Deliverable D2.2

CPS-ED 2014: Towards curriculum guidelines: Törngren and Grimheden
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

CPS-ED 2014: Towards curriculum guidelines: Törngren and Grimheden
Balances

Learning outcomes – Content - Examination

Depth – Breadth
Knowledge – Skills
- Learning basics – Learning to learn
Academic – Industrial
Theory – Practice
General – Specific
Didactic analysis for CPS

CPS-ED 2014: Towards curriculum guidelines: Törngren and Grimheden
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

CPS-ED 2014: Towards curriculum guidelines: Törngren and Grimheden
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

CPS-ED 2014: Towards curriculum guidelines: Törngren and Grimheden
From disciplinary to "Pi-shaped" People and Design Thinking

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.

CPS-ED 2014: Towards curriculum guidelines: Törngren and Grimheden
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

CPS-ED 2014: Towards curriculum guidelines: Törngren and Grimheden
References

PCAST report [Fed07]
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

CPS-ED 2014: Towards curriculum guidelines: Törngren and Grimheden