Software Engineering for Cyber-Physical Systems

CHALLENGES AND OPPORTUNITIES

Dr. Cristóbal Costa-Soria
ITI - Instituto Tecnológico de Informática (Spain)

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Outline

Cyber-Physical Systems: An introduction

NESSI and CPS

CPS: Software engineering challenges

CPS: Opportunities for collaboration

Cyber-Physical Systems

CPS: ***Open ICT*** systems ***embedded*** in physical objects, which are **interconnected**

- Embedded systems: monitoring and control of physical entities
- Software-intensive systems: computing capabilities, providing Smart services and behaviour
- Interconnected systems: network of interacting entities (virtual & physical)
- Open systems: availability of services, sensors, other systems, QoS, etc., is not known until runtime

The next revolution in ICT:

- Evolution of Embedded Systems: from closed systems to open systems; users are strongly involved
- Evolution of Internet of Things: from interconnecting things to the provision of Smart services by things
- CPS are highly distributed and large-scale: new challenges arise

Application domains:

- Smart cities (urban facilities, traffic management, …)
- Smart factories (manufacturing management, control/process management, logistics, …),
- Smart infrastructures (water management, energy management, …)

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NESSI and CPS

Design & Development of CPS poses several challenges

- Challenges on electronics, embedded systems, system engineering are in the area of interest of ARTEMIS/ECSEL
- Challenges on software engineering related to higher layers of CPS are in the area of interest of NESSI

The role of software engineering is central for successful realization of the CPS vision

- CPS software development focuses on open world assumptions: uncertainty and variability

NESSI plays a relevant role on:

- Identifying the ***challenges*** that CPS poses ***on software engineering***
- Contributing to ***advance the state of the art of CPS software*** layers, applications and services

NESSI is currently preparing a White Paper related to its position on CPS

CPS: Sofware Engineering challenges

Challenge CPS-1: Handling quality and performance ***requirements in large-scale open environments***

- Non-functional requirements (quality, performance, safety, security, …) need to be reconsidered for dealing with open and dynamic executing environments
- Need of novel methodologies, techniques, and tools to address strict non-functional requirements in presence of open and statically unknown scenarios
- Need of novel testing and formal verification methods to deal with variability and uncertainty

Challenge CPS-2: Principles, methods and tools ***supporting the software life-cycle of CPS***

- CPS solution development requires developers to deal with context monitoring, integration and adaptation
- Software & Service engineering need to be more integrated with systems engineering disciplines
- How to reduce development costs and time-to-market for CPS?
- How to leverage continuous integration, testing and certification?
- How to provide lifecycle support for large number of decentralised system instances?

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CPS: Sofware Engineering challenges

Challenge CPS-3: Integration of CPS with ***Cloud and Big Data*** solutions

- CPS solutions involving wide-scale deployment, rely on cloud (server-side) processing/storage resources
- How to integrate CPS with Cloud and Big Data infrastructures?
- How to transfer data processing to data sources to manage the flow of information?
- How to model actuators and sensors profiles to reduce the continuous interaction between CPS and cloud resources?

Challenge CPS-4: Considering ***human-in-the-loop aspects*** and adaptation in CPS

- Solutions are required to provide human operators with dedicated adaptation mechanisms to support the adaptation of CPS to unforeseen situations
- Integration of user operation for continuous observation-analysis-adaptation loops

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CPS: Sofware Engineering challenges

Challenge CPS-5: Middleware and platforms for ***dynamic choreography and adaptation*** of CPS

- Design-time vs run-time, autonomy, adaptability, and self-notions need to be reconsidered
- How to deliver cross-layer visibility among application requirements and low-layer context information?
- How to support the coreography of autonomous subsystems and handle them in dynamic environments?
- How to balance the capabilities provided by development platforms towards resource efficiency? Via optimisation or pruning of unused code/components?

Challenge CPS-6: Novel, powerful ***programming abstractions*** for implementing CPS

- What are the right abstractions/models easy to understand and use but also expressive enough to be mapped to executable code?
- How to use those abstractions to address unexpected conditions and sensing/actuation component faults and to define safe operational areas?
- How to use those abstractions to support deployment on diverse devices and hardware configurations?

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CPS: Opportunities for collaboration

CPS are included in the Digital Agenda for Europe: https://ec.europa.eu/digital-agenda/en/science-and-technology/components-systems)

- Smart everywhere, Embedded Systems, Monitoring and Control, and System-of-Systems

ECSEL (Electronic Components and Systems for European Leadership) Joint Undertaking http://www.ecsel.eu

- Main european funding source program related to CPS development 2014-2024
- Integrates ENIAC JU (nanoelectronics) and ARTEMIS JU (embedded systems)
- Mainly focused on Embedded Systems and Electronics

H2020: CPS topics are distributed among different calls

- ICT-2015-04: Customized and Low Power Computing
- FOF-2015: CPS Solutions can be applied to different manufacturing contexts (e.g. FoF-08)
- 2015-2016 WP?

Resources

NESSI White Paper: Software Engineering – Key Enabler for Innovation, July 2014
http://www.nessi-europe.eu/Files/Private/NESSI_SE_WhitePaper-FINAL.pdf

European Commission, Digital Agenda for Europe: https://ec.europa.eu/digital-agenda/en/cyber-physical-systems

Ercim News: Special issue on Cyber-Physical Systems (April 2014) http://ercim-news.ercim.eu/en97

Hellinger, A.: Cyber-Physical Systems: Driving force for innovation in mobility, health, energy and production" - acatech POSITION PAPER, 2011

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Thank you very much for your attention

Cristóbal Costa-Soria

Dept. of Strategic and Competitive Intelligence
ITI - Instituto Tecnológico de Informática
Spain

Home page: http://www.iti.es
Email: ccosta@iti.es