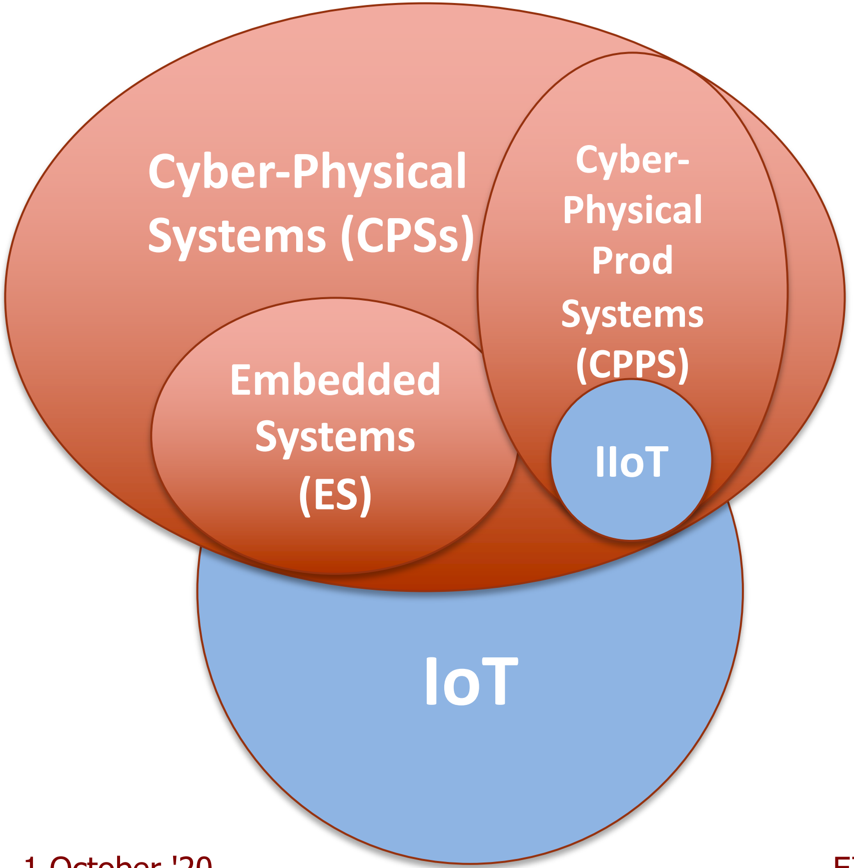
Embedded & IoT Systems Design (EISD)

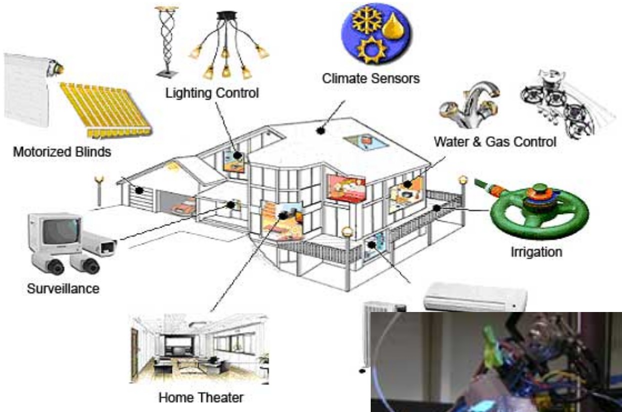
Franco Fummi

Goals



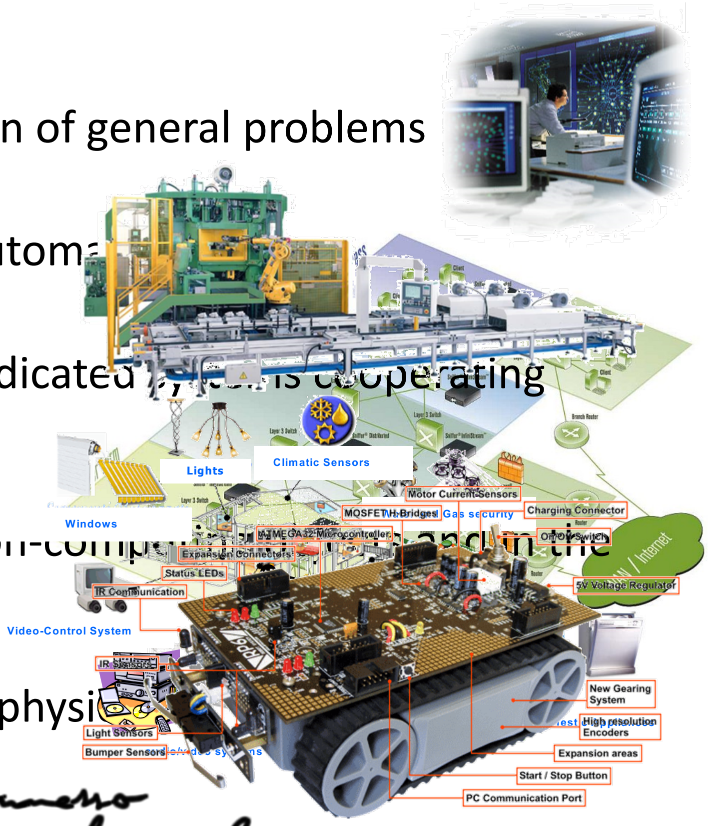
- Methodologies and tools for modelling and design of CPPSs and IIoT:
  - hw/sw modelling
  - hw/sw design
  - IoT sensor-edge-cloud infrastructure
  - CPPs modeling, simulation, integration

Embedded & IoT Systems: Where?



ES: Historical perspective

- From computer ('60-'80):
  - General purpose systems for solution of general problems
- To digital control systems ('80-'90):
  - Systems dedicated to control and automa
- To distributed systems ('90-'00):
  - General purpose systems and/or dedicated ... cooperating through the network
- To embedded systems ('00-):
  - Distributed systems integrated in non-comp... and in the environment
- To cyber-physical systems ('10-):
  - Embedded systems integrated with physi
- To IoT systems ('20-):
  - Smart everywhere



→ Non solo connesso ad internet ma ha anche funzioni AUTONOME

Not everything is IoT (or IIoT)

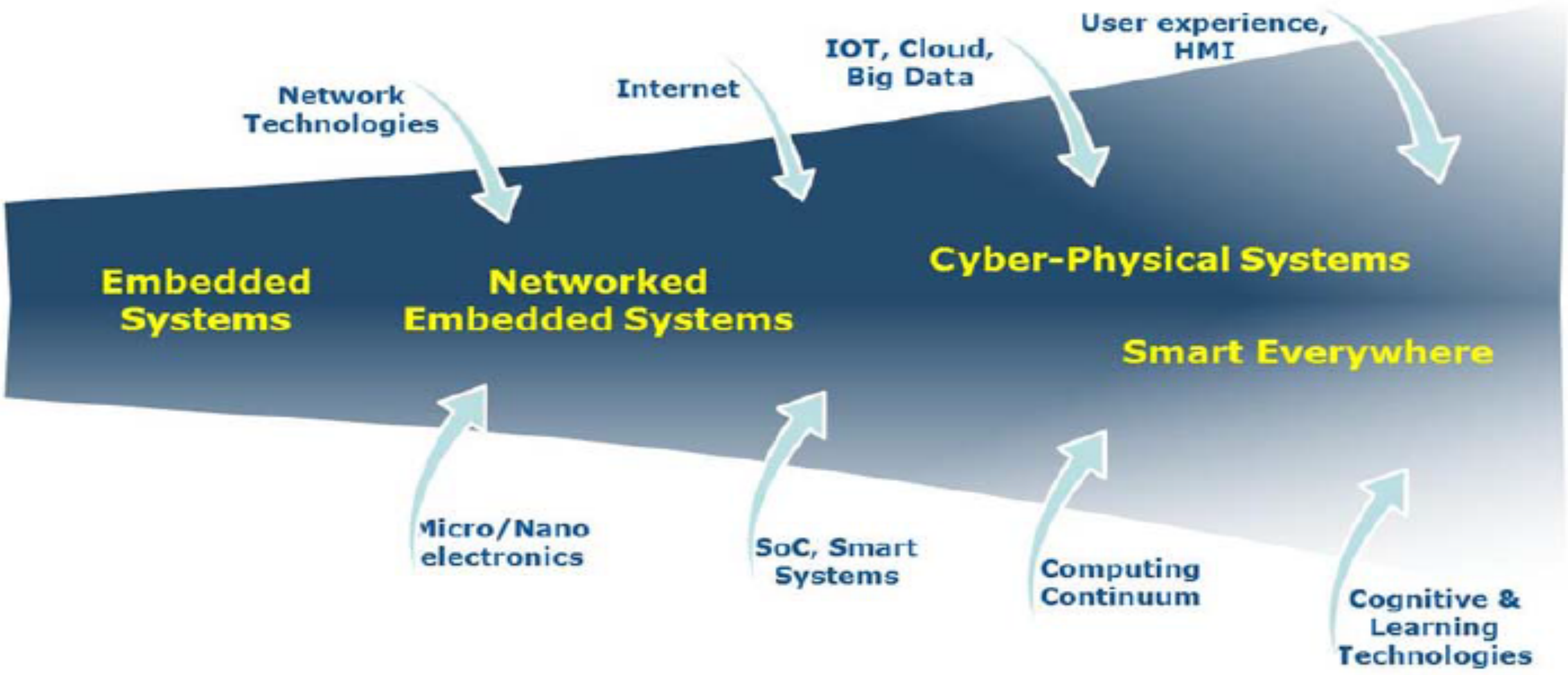
Air conditioner activated by smartphone is IoT?

Vibration sensors reporting to a PLC is IIoT?

- Air conditioner communication to a service provider for automatically regulating turn on/off according to power consumption from other appliances?

nella zona geografica in cui è la casa

How Relevant (I)



How Relevenat (I)

ABS COMPUTERS

Cannon AUTOMATA

EXOR INTERNATIONAL

INMM®

infracom

TeamSystem Metodo

SITEL MK3 DIRECT PART MARKING

Telefin

SAFE CONTROL SYSTEMS AFCO

How Relevant: The Four Industrial Revolutions

1st Industrial Revolution

Introduction of steam power in manufacturing

End of 18th Century

2nd Industrial Revolution

Introduction of electricity, chemicals and Oil

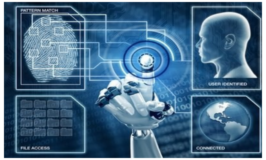
Beginning of 19th Century

3rd Industrial Revolution

Electronic Automation to improve production

Early ‘70s

4th Industrial Revolution



Interconnected Smart machines through internet

Now - Future

ES/IoT: How to design?

- We cannot design embedded systems like general purpose systems
  - Different design constraints, different goals
  - Embedded design is about the system, not about the computer
- E.g.
  - In general purpose computing, design often focuses on building the fastest CPU
  - In embedded systems the CPU simply exists as a way to implement control algorithms communicating with sensors and actuators

ES/IoT: Design constraints

- Size and weight
  - Hand-held electronics
  - Weight costs money in transportation
  - Human body cannot eat desktops
- Power
  - Buttery power instead of AC
- Harsh environment ⇒ ABS su automobili
  - Power fluctuation, RF interferences, heat, vibration, water, …
- Safety critical and real time operations ⇒ ci possiamo fidare ciecamente
- Low costs

ES/IoT: Designer knowledge

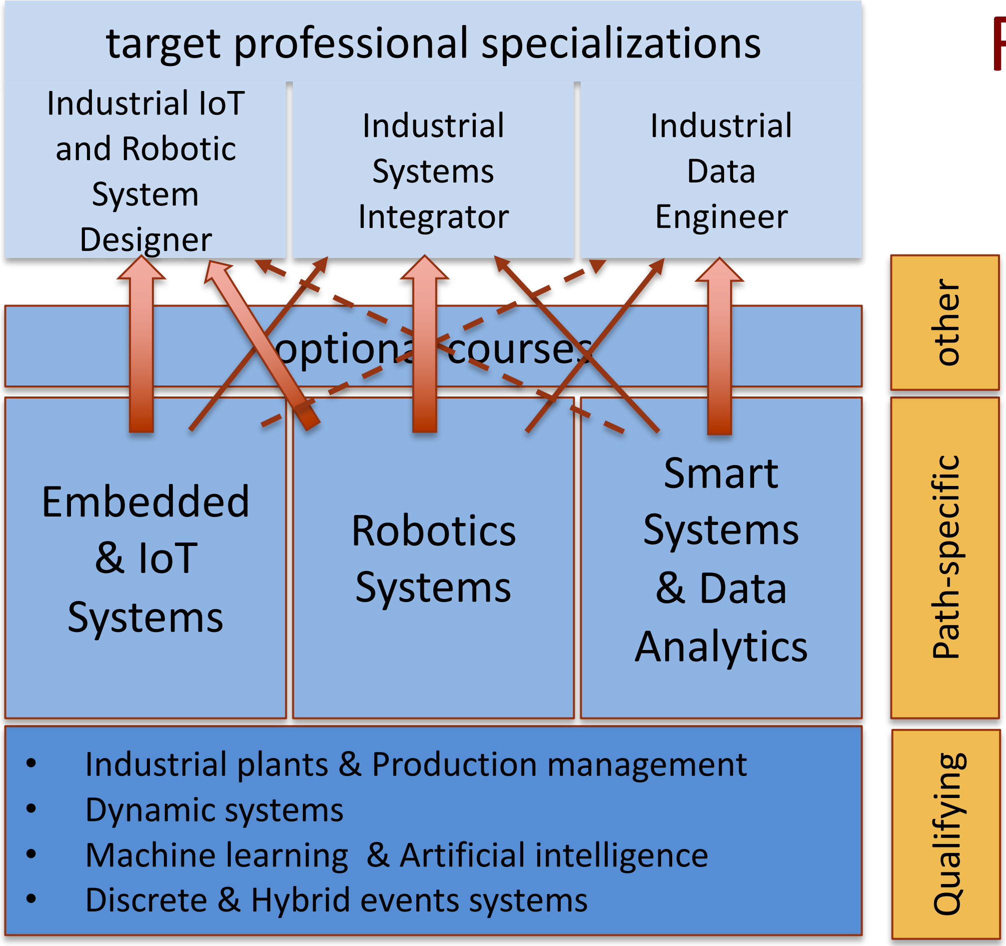
- HW architecture alternatives
  - for a correct HW/SW trade-off
- SW design skills
  - lots of languages continuously extending
- HW/SW interaction mechanisms
  - O.S., MW, HdS for efficient SW development
- Network infrastructure
  - all ES are now networked embedded systems
- Computation effort estimation
  - theory is important when used in practice
- Join 3C: computation, control & communication

Course Structure

- 35 lectures:
  - 30 theory hours
    - 20 lectures
  - 22 practical hours
    - 11 lectures
  - 6 seminar hours
    - 4 lectures
- People:
  - Franco Fummi (theory)
  - Stefano Spellini (lab. classes)
    - Alessia Bozzini / Marco panato (lab. classes)
  - for practical elaborations
    - Industrial support

6 credits

Role of the Course



- Qualifying exams
- Three paths
  - Embedded & IoT Systems
  - Robotics Systems
  - Smart Systems & Data Analytics
- A target professional specialization must be reached by following:
  - other profile-specific exams
  - general exams
  - coherent exams from other master degrees

Assessment methods and criteria (I)

- To pass the exam, the students must show:
  - they have understood the principles of embedded and IoT system architectures
  - they are able to model and simulate a complex embedded and IoT system
  - they are able to design, verify and test a complex digital device
  - they are able to develop embedded software interacting with network and operating system
  - they are able to apply the acquired knowledge to solve application scenarios in the context of Industry 4.0

Assessment methods (II)

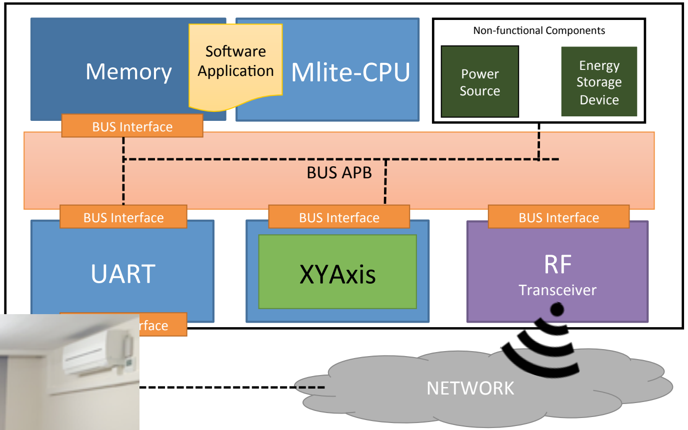
- Theory + lab. + options:
  - theory
    - written exam 18-30
  - laboratory report
    - max +3 points
  - on demand
    - extra practical work 0 +∞
    - (oral exam) +3 -∞
- General rules:
  - laboratory report cannot be more than 1-year long
  - reports must be provided at fixed times

Assessment methods (III)

- Alternatives:
  - Personal practical work
    - company stage
    - thesis
  - Theory
    - no way :-)
- Design&Reuse:
    - thesis implementation
    - pre-thesis stage
    - cross-exam practical work

Benchmark and Labs.

- Virtual platforms:
  - Smart devices:
    - the Open Source Test Case 6502
  - RISC Core:
    - Risc-V
- Laboratories:
  - Cyber-Physical
  - NES/Parco
  - ESD
  - Industrial Computer Engineering (ICE)

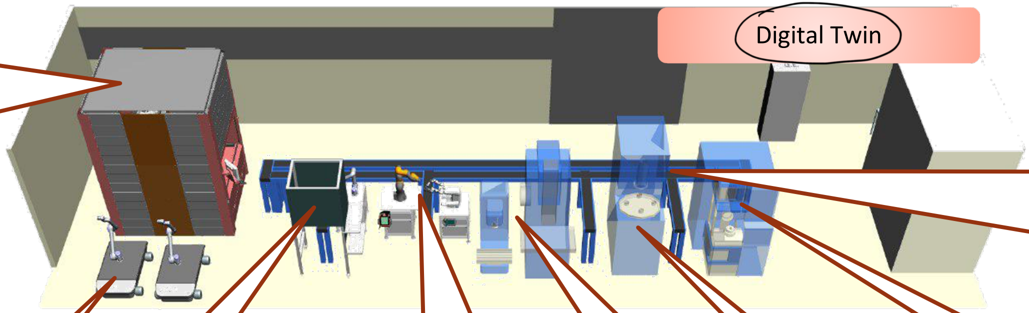


ICE – Course Contribution

→ Simulatore del funzionamento del laboratorio

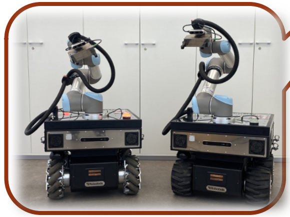
Edge Computing | Tracking System | Cloud Data Storage | 5G | IoT Sensors | Field Data Collection

Smart Parts Storage



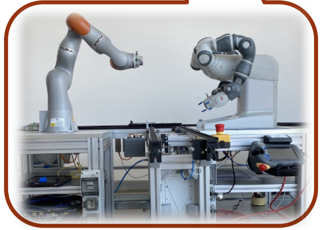
Digital Twin

Minipallet Transport Line



Robot mobile AGV

Geometric Quality Control



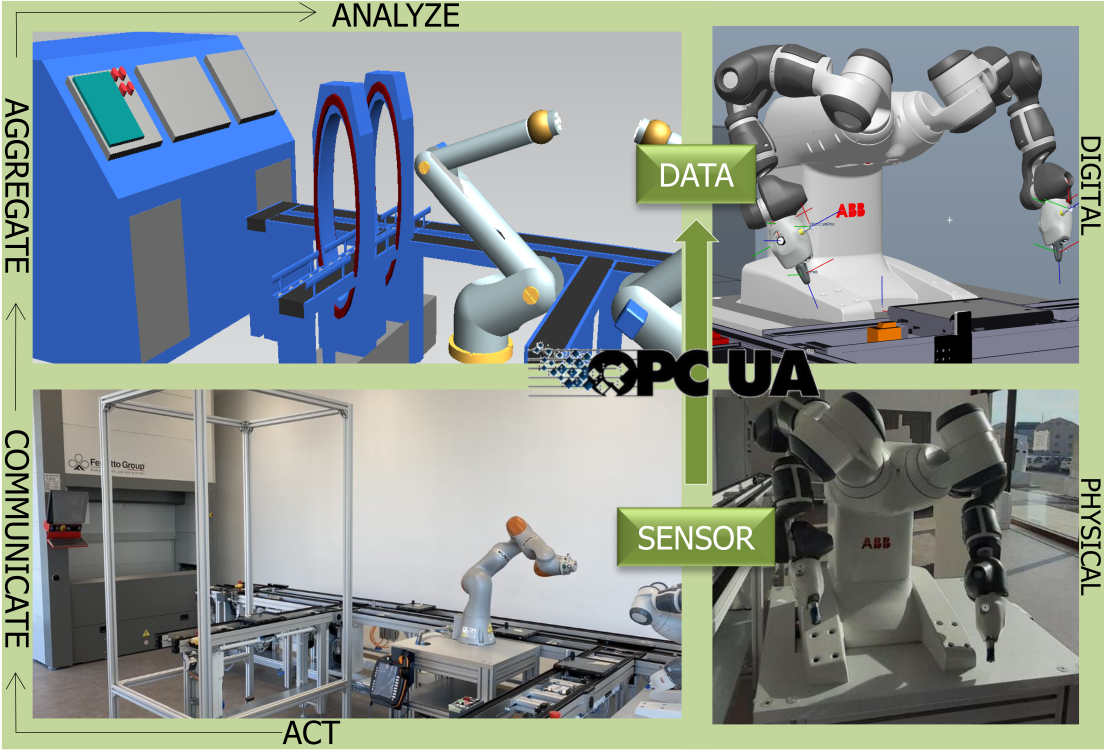
Assembly with collaborative robots

Multimaterial Stereolithographic 3D Printing

Subtractive CNC operations

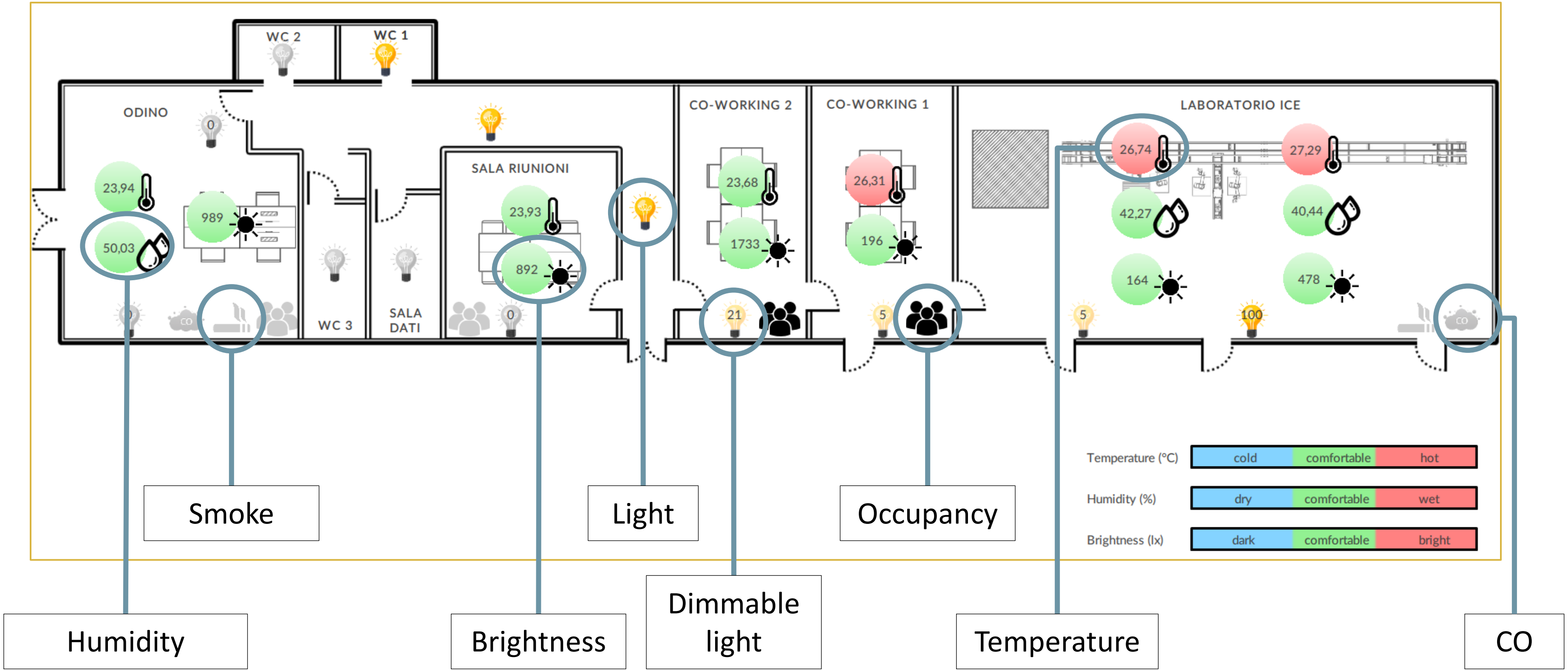
Electronic Functional Testing

Simulation with Real Data

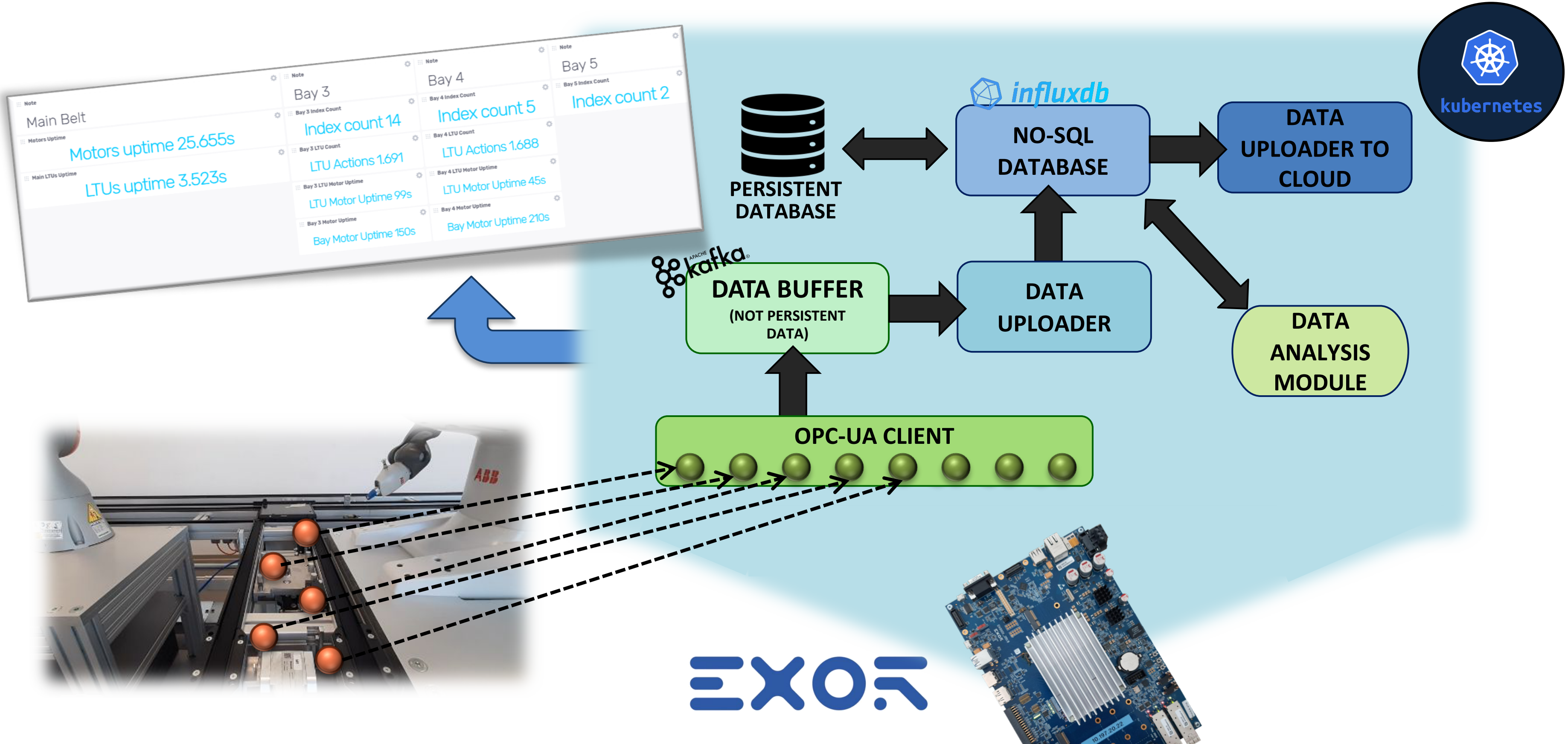


- Each machine has an OPC UA server
- There are changes in the production plant
- The sensor value changes
- The value is sent via OPCUA
- The simulator receives the changed value
- The simulation changes

ICE lab: IoT Data Viewer

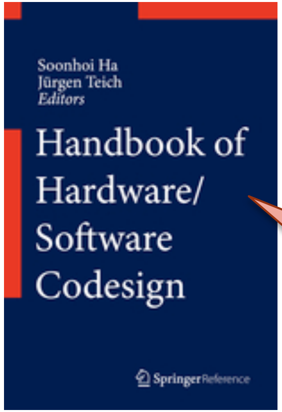


Data Collection Architecture



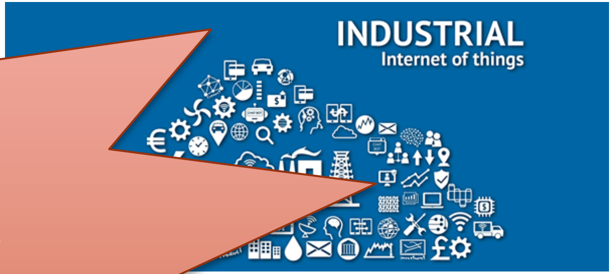
Board server edge

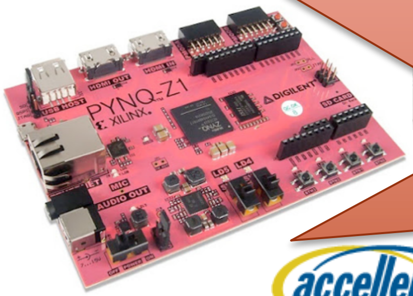
2021 News



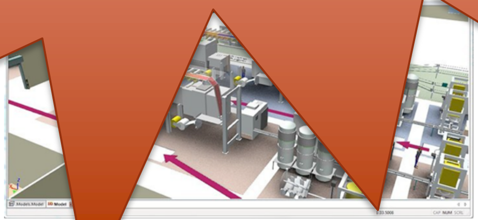
Semiformal Assertion Based Verification of Hardware/Software Systems in a ModelDriven Design Framework

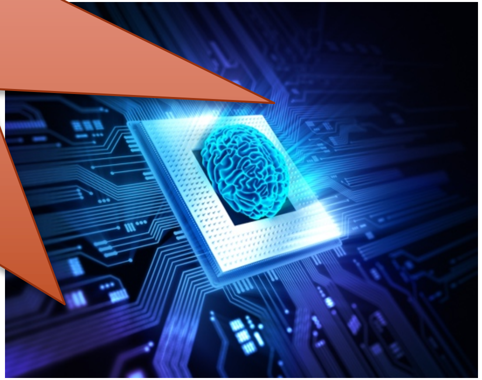
Pravadelli, G., Quaglia, D., Vinco, S., Fummi, F.





accellera
SYSTEMS INITIATIVE™





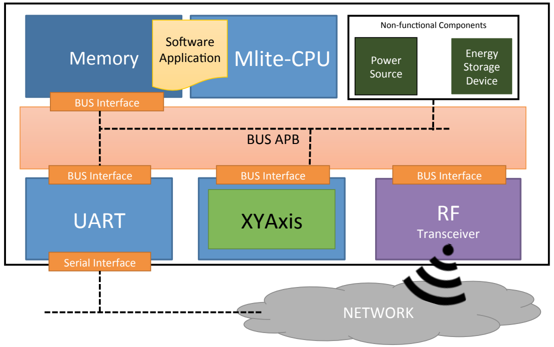
Completely Updated set of slides

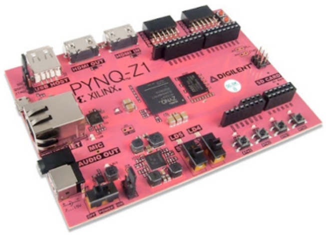
Topics (theory)

- **Embedded and IoT Systems Modeling:**
  - Course introduction
  - Embedded systems modeling
  - SysML for systems modeling
- **System Level Description Languages**
  - SystemC-based design
  - SystemC TLM
- **Hardware Description Languages:**
  - HDL introduction
  - VHDL syntax
  - verilog syntax
  - HDL timing simulation
- **Register Transfer Level Synthesis:**
  - RTL synthesis: VHDL
  - RTL synthesis: Verilog
- **High-Level Synthesis:**
  - High-level synthesis (HLS) intoduction
  - High-level synthesis scheduling
  - High-level synthesis allocation
  - High-level synthesis application
- **Platforms and Virtual Platforms:**
  - Virtual platform modeling: IP-Xact
  - Virtual platform design and FMI
  - SystemVerilog introduction
  - SystemVerilog main characteristics
  - SystemC & Verilog AMS
- **Embedded Software:**
  - Embedded software modeling
  - Model-based design of embedded software
  - Embedded AI software modeling
- **Industry 4.0 – CPPSs:**
  - Industry 4.0: software hierarchy
  - Industry 4.0: digital twin
  - IoT and Industrial IoT
  - IoT and Cloud
- **Seminars:**
  - UVM for Digital Systems (Ogheri)
  - Plant simulation (ICE)
  - Edge/Cloud embedded architecture (Kiratech)
  - Control Industrial Software (ASEM)

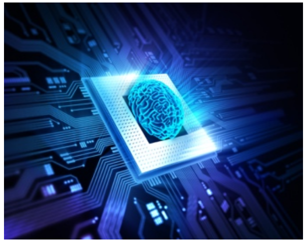
Topics (lab.)

- SystemC compilation/execution/debugging
- SystemC modeling at TLM
- VHDL modeling
- verilog modeling and simulation
- Pynq Platform: FPGA synthesis
- Pynq Platform: C/C++ High-level synthesis
- SystemC/AMS - verilog AMS
- Virtual platform: 6502
- SysML CPPS modeling and design
- Model-based design: Matlab/Simulink/FMI
- Embedded AI application design
- Control Sw Generation





FUNCTIONAL MOCK-UP INTERFACE



Detailed Program

week	data	day	lecture	lab.	topic
1	2-Oct	Fri.	2		Course introduction; Embedded systems modeling I
1	5-Oct	Mon.	1		Embedded systems modeling II
1	5-Oct	Mon.	2		SysML for systems modeling; SystemC-based design I
2	9-Oct	Fri.	2		SystemC-based design II; SystemC TLM I
2	12-Oct	Mon.	1		SystemC TLM II
2	12-Oct	Mon.	2		HDL introduction; VHDL syntax
3	16-Oct	Fri.			**NO**
3	19-Oct	Mon.	1		verilog syntax I
3	19-Oct	Mon.		2	SystemC compilation/execution/debugging
4	23-Oct	Fri.	2		verilog syntax II; HDL timing simulation
4	26-Oct	Mon.	1		RTL synthesis: VHDL
4	26-Oct	Mon.		2	SystemC modeling at TLM
5	30-Oct	Fri.	2		RTL synthesis: verilog; High-level synthesis (HLS) intoduction
5	2-Nov	Mon.	1		High-level synthesis scheduling&allocation
5	2-Nov	Mon.		2	VHDL modeling
6	6-Nov	Fri.	2		High-level synthesis application; Virtual platform modeling: IP-Xact
6	9-Nov	Mon.	1		Virtual platform design & FMI
6	9-Nov	Mon.		2	verilog modeling and simulation
7	13-Nov	Fri.			**Intermediate exam**
7	16-Nov	Mon.	1		SystemVerilog introduction
7	16-Nov	Mon.		2	Pynq Platform: FPGA synthesis
8	20-Nov	Fri.	2		SystemVerilog main characteristics; SystemC & Verilog/AMS
8	23-Nov	Mon.	1		Embedded software modeling
8	23-Nov	Mon.		2	Pynq Platform: C/C++ High-level synthesis
9	27-Nov	Fri.			Seminar: UVM for Digital Systems
9	30-Nov	Mon.	1		Model-based design of embedded software
9	30-Nov	Mon.		2	SystemC/AMS - verilog AMS

dded AI software modeling; Industry 4.0: software hierarchy
y 4.0: digital twin; IoT and Industrial IoT
d Cloud
platform: 6502
ar: Plant simulation
CPPS modeling and design
ne for laboratory report preparation
ar: Edge/Cloud embedded architecture
based design: Matlab/Simulink/FMI
ne for laboratory report preparation
ar: Edge/Cloud embedded architecture
dded AI application design
ne for laboratory report preparation
ar: Control Industrial Software
l Sw Generation
exam

Teaching supports (I)

- Course web page
  - Detailed program
  - Complete program
- E-learning web page
  - Slides
  - Laboratory instructions
  - Questions/answers
- Book
  - Published
- Seminars
  - Indications during the course

More information

http://www.di.univr.it/~fummi

Embedded & IoT Systems Design (2020/2021)

Home / Teaching / Master's degrees / Master's degree in Computer Engineering for Robotics and Smart Industry / Insegnamenti

- Overview
- Enrolment Procedures and Admission Requirements
- **Courses**
- Training activities taf D and F
- Academic Calendar
- Lesson timetable
- Degree Programme
- Exam calendar
- Notices
- Thesis and internship proposals
- Governing bodies
- Faculty staff
- Linguistic training CLA

International Students

STUDYING

COURSES +

PHD PROGRAMMES AND POSTGRADUATE TRAINING +

- Contacts
- People
- Places
- Calendar

Course code	4S009003
Credits	6
Coordinator	Franco Fummi
Academic sector	ING-INF/05 - INFORMATION PROCESSING SYSTEMS
Language of instruction	English

Course news

Seminars related to the cours

TEACHING IS ORGANISED AS FOLLOWS:

ACTIVITY	CREDITS	PERIOD	ACADEMIC STAFF	TIMETABLE
Teoria	5	I semestre	Franco Fummi	Go to lesson schedule
Laboratorio	1	I semestre	Franco Fummi	Go to lesson schedule

LEARNING OUTCOMES

The course aims at providing the following knowledge: techniques for the automatic design of embedded and industrial IoT systems, starting from their specifications to go through verification, automatic synthesis and testing. Main languages to deal with this kind of project and the most advanced automatic tools for their manipulation. This is in particular applied to the design, verification and test of cyber-physical production systems.

For the stronger …

7994

Thursday
10:00 –
11:00

In the
corridors…
running

franco.fummi@univr.it

For the strongest…

7048

On demand

On the e-learning

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