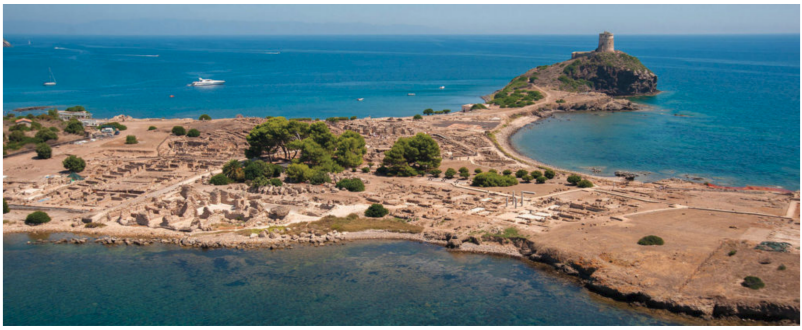
CPS Summer School 2022

Designing Cyber-Physical Systems
From concepts to implementation

September 19-23 2022, Pula, Sardinia, Italy



http://www.cpsschool.eu/

SEPTEMBER 19-23 2022 – PULA, SARDINIA, ITALY

CYBER PHYSICAL SYSTEMS
SUMMER SCHOOL 2022

CPS School 2022 Sponsors

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Contents

Overview

CPS School 2022 At a Glance

Cyber-physical systems are complex and autonomous ensembles of different components that directly cooperate to offer smart and adaptive functionalities. They are composed of sensors, actuators, and processing components that are deeply entangled: they constantly exchange information and actively interact with the external environment. So they are increasingly used in a variety of applications with a growing market. CPSs will potentially bring about significant social benefits; nevertheless, there is no such thing as a free lunch and several new challenges and trade-offs must be faced in their design, especially when the CPS should adapt to the changing environment or heal itself. Indeed, different nodes could cooperate to enrich the offered functionality. All the components are typically characterized by different spatial and temporal scales, while

multiple and distinct behavioural modalities and contexts should normally be taken into consideration. In addition, uncertain operation environments and interactions with humans as users and/or as operators complicate the scenarios of these ever increasingly pervasive systems. Anyway, the Human Factor is not to be considered a constraint, but an opportunity for creating more useful and robust CPSs. An important effort has to be done in avoiding to privilege technology respect to users/operators needs and on the contrary in designing CPS systems to potentiate human abilities during the interaction with them, instead of doing a technology push..

The fourth edition of the CPS summer school is targeted at students, research scientists, and R&D experts from academia and industry, who want to learn about CPS engineering and applications. The program will cover all the design phases of CPSs, starting from the conception of the idea down to the definition of the final system and will discuss the key challenges (including adaptivity support, modelling and security) presenting state-of-the-art tools and methods and allowing participants to play with industrial and academic design environments.

Topics of Interest

Topics of interest include, but are not limited to, the following:

- Market trends for CPS
- Hardware/software and multi-view modelling

- Adaptivity
- Low power design of heterogeneous systems
- Tools for dataflow design, high-level synthesis, hardware/software co-design, and coarse/fine reconfiguration

Organization

CPS School 2022 Organization

School Director

Francesca Palumbo, Università degli Studi di Sassari

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Armando Tacchella, Università degli Studi di Genova
Raquel Lazcano, Università degli Studi di Sassari

Sponsor Chair

Christian Pilato, Politecnico di Milano

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Sara Vinco, Politecnico di Torino
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João Canas Ferreira, University of Porto
Luca Pulina, Università degli Studi di Sassari
Andrés Otero, Universidad Politécnica de Madrid
Maxime Pelcat, IETR/INSA
Marc Geilen, Eindhoven University of Technology

Venue

School Location

The fourth edition of the CPS Summer School will be held, for the first time, in **Pula** which is a small town located in the south of Sardinia. Pula is made up exclusively of villas situated next to the sea in a beautiful pine forest. The area is basically a holiday resort and in the summer it is frequented both by tourists and the locals. The CPS Summer School will be held at the **Technology Park of Sardinia** in Pula, which is located in a natural park at the foot of the Sulcis mountain range.

There are over seven thousand inhabitants in the residential area, from the metropolitan city of **Cagliari**, which is just 35 kilometres away. Pula is a treasure chest of natural, archaeological and cultural wealth without equals on the Island. As well as Pula's summer nightlife, with events and aperitifs in the squares, there are also excursions and sporting activities. For example, you can do some jogging along the tree-lined avenues that lead to the **archaeological park of Nora**, where you will get to know Pula's origins. Not far from the village, you will find yourself in one of the most well-known sites in Sardinia: **Capo Pula** contains the ruins of an ancient town, the first Phoenician one in Sardinia (8th century BC), which then became a flourishing Punic town and was later conquered by the Romans, becoming a *municipium* in 1 AD. Over

the next two centuries, it enjoyed the maximum splendour: caput viae of all the Sardinian roads. 'You will travel' through traces of three thousand years of history: you will admire a Phoenician-Punic tophet, the remains of Punic and Roman temples, a forum, noble dwellings, spa baths with mosaics and an amphitheatre that seated a thousand in the Imperial age and that is now the setting for the **La Notte dei Poeti** (Night of the Poets) festival. At the **Giovanni Patroni Museum** in Pula and at the **Archaeological Museum** in Cagliari you can admire the relics found during the excavations. After the archaeological excursion, you can take a walk on the **beach of Nora**: golden sand washed by a crystal clear sea and delimited by the promontory of the **Tower of Coltellazzo**. In the bay, you will also find history and traditions. **The little church of Sant'Efisio** stands here and is the place of the martyrdom of the warrior saint commemorated every year on 3 May during the **Festival of Saint Efisio**, to whom the population of Pula is extraordinarily devoted. Behind the bay, before having a plate of spaghetti 'allo scoglio' (spaghetti with seafood) and figs with cured ham, don't miss the **lagoon of Nora** at sunset, the habitat of rare birds. To the east of Nora, there is the beach of **Su Guventeddu**, popular with kitesurfing and windsurfing enthusiasts even in the winter. To the west, along the coastline, you will find **Santa Margherita di Pula**, consisting of a series of fine, white sandy coves with splashes of pink granite – Cala Marina, Cala Bernardini, **Cala d'Ostia**, **Cala Verde**, other smaller beaches of the resorts – looking out onto the crystal clear sea. A realm of relaxation with an immense pine forest behind it, which stretches as far as the marvellous **Chia** (Domus de Maria). You will also be by enshrouded by nature in the forest of **Is Cannoneris** and **Pixinamanna**, havens for trekkers, with

their holm oaks, Mediterranean scrub and conifers. You can explore them while walking along the well-marked out **trekking** trails, through dense vegetation with rare plants, rocky formations shaped over time by the weather, watercourses and evidence of prehistoric civilizations. The forest complex is a wildlife oasis that has been repopulated with deer and fallow deer. [Source: Sardegna Turismo (https://www.sardegnaturismo.it/en/places/south/pula)].

Venue

The main centre of Sardinia Ricerche is situated in the municipality of Pula, about 30 km from Cagliari, set in a 160 hectare campus, with built area of more than 25,000 sqm. The Park has state-of-the-art research facilities and equipment, including a secure animal holding facility of 900 sqm and the following technology platforms: ICT, Bioinformatics, Genotyping and massive sequencing, Pharmacology, Prototyping and medical devices, High throughput screening and DTV.

The Science and Technology Park of Sardinia specialises in three areas:

- Information and Communication Technologies
- Biotechnologies: ranging from biomedicine to agro-industrial biotechnologies and bioinformatics
- Renewable energies

Hotel Is Molas

Is Molas Hotel is located 33 kilometres from Cagliari, near Pula. Thanks to its extraordinary panoramic position, it enjoys a magnificent view of the sea of Sardinia, the tower of Nora and the hills of Sulcis, cloaked in the colours and scents of the Mediterranean macchia.

Keynote Speakers

Wednesday
21th
18:30 - 19:30

Beach Note

Alberto Sangiovanni-Vincentelli
University of California, Berkeley (USA)

Alberto L. Sangiovanni-Vincentelli is the Edgar L. and Harold H. Buttner Chair at the EECS Department, UC Berkeley. He graduated from the Politecnico di Milano in 1971. He co-founded Cadence and Synopsys, the two leading EDA companies. He is on the Board of Directors of Cadence, KPIT, Expert.ai, Cy4Gate, Exein, and Chairman of the Board of Quantum Motion, Phononic Vibes, Innatera and Phoelex. He is a member of the advisory board of Walden International and Xseed, of the Scientific Advisory Board of the Italian Institute of Technology and the Chair of the Strategic Board and of the International Advisory Board for the Milano Innovation District. He is a member of the Advisory Board of the Politecnico di Milano and honorary Professor at Politecnico di Torino. He was the President of the "Comitato Nazionale dei Garanti della Ricerca" and of the Strategy Committee of Fondo Strategico Italiano. He consulted for companies such as Intel, HP, Bell Labs, IBM, Lendlease, Samsung, UTC, Lutron, Kawasaki Steel, Fujitsu, Telecom Italia, Pirelli, GM, BMW, Mercedes, Magneti Marelli, and ST Microelectronics. He authored 19

books, 2 patents and over 1,000 papers. He is Fellow of the IEEE and ACM, and a member of the National Academy of Engineering. He earned the IEEE/RSE Maxwell Award "for groundbreaking contributions that have had an exceptional impact on the development of electronics and electrical engineering or related fields", the Kaufmann Award for foundational contributions to EDA, the EDAA lifetime Achievement Award, the IEEE/ACM R. Newton Impact Award, the University of California Distinguished Teaching Award, the IEEE TC-CPS Technical Achievement Award, the IEEE Leon Kirchmayer Graduate Teaching Award and the ISPD lifetime achievement award. He holds Honorary Doctorates from Aalborg University (Denmark), KTH (Sweden) and AGH (Poland).

Lecture Speakers

Monday 19th
9:00 - 10:30

Quo Vadis, CPS? Challenges, promises and realities

Alberto Sangiovanni-Vincentelli
UC Berkeley (USA)

Alberto L. Sangiovanni-Vincentelli is the Edgar L. and Harold H. Buttner Chair at the EECS Department, UC Berkeley. He graduated from the Politecnico di Milano in 1971. He co-founded Cadence and Synopsys, the two leading EDA companies. He is on the Board of Directors of Cadence, KPIT, Expert.ai, Cy4Gate, Exein, and Chairman of the Board of Quantum Motion, Phononic Vibes, Innatera and Phoelex. He is a member of the advisory board of Walden International and Xseed, of the Scientific Advisory Board of the Italian Institute of Technology and the Chair of the Strategic Board and of the International Advisory Board for the Milano Innovation District. He is a member of the Advisory Board of the Politecnico di Milano and honorary Professor at Politecnico di Torino. He was the President of the "Comitato Nazionale dei Garanti della Ricerca" and of the Strategy Committee of Fondo Strategico Italiano. He consulted for companies such as Intel, HP, Bell Labs, IBM, Lendlease, Samsung, UTC, Lutron, Kawasaki Steel, Fujitsu, Telecom Italia, Pirelli, GM, BMW, Mercedes, Magneti Marelli, and ST Microelectronics. He authored 19

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Monday 19th
11:00 - 12:30

Swarms of CPS: Challenges and Potentials

Jennifer Simonjan
Lakeside Labs (Austria)

Jennifer Simonjan is a senior researcher at Lakeside Labs in Klagenfurt, Austria since fall 2021. Before joining Lakeside Labs, she spent one year as post doc at Prof. Dr. Ian F. Akyildiz' Broadband Wireless Networking Lab at the Georgia Institute of Technology, Atlanta, GA and one year at Silicon Austria Labs in Graz, Austria. She received her Ph.D. degree in Information and Communication Engineering from the University of Klagenfurt, Austria in October 2019, under the guidance of Prof. Dr. Bernhard Rinner. Throughout her PhD and post doc years, she focused her research on communication and localization in macro- and nanoscale distributed sensor networks. Since joining Lakeside Labs, she works on swarm intelligence in self-organizing systems and drone networks. Dr. Simonjan is involved in several conference organizing committees and is the public relations officer of the IEEE Austria Section.

Adaptive Computing Architectures for CPS

Tuesday 20th
9:00 - 10:30

Diana Göhringer
TU Dresden (Germany)

Diana Göhringer is professor and holds the Chair of Adaptive Dynamic Systems at Technische Universität Dresden since 2017. She received her Ph.D. (summa cum laude) in Electrical Engineering and Information Technology from the Karlsruhe Institute of Technology (KIT), Germany in 2011. She is author and co-author of over 150 publications in international journals, conferences and workshops. She serves as technical program committee member in several international conferences and workshops (e.g. DATE, FPL, RAW). She is reviewer and guest editor of several international journals. Furthermore, she is a member of IEEE, ACM and HIPEAC. Her research interests include reconfigurable computing, multiprocessor systems-on-chip (MPSoCs), networks-on-chip, simulators/virtual platforms, hardware–software codesign and runtime systems.

Wednesday
21th
9:00 - 10:30

Quality and resource management for CPS

Twan Basten and Marc Geilen
TU Eindhoven (Netherlands)

Twan Basten - Eindhoven University of Technology

Twan Basten received the M.Sc. and Ph.D. degrees in computing science from Eindhoven University of Technology (TU/e), Eindhoven, the Netherlands. He is currently a Professor with the Department of Electrical Engineering, TU/e. He is also a Senior Research Fellow with ESI, TNO, Eindhoven. His current research interests include the design of embedded and cyber-physical systems, model-driven performance engineering, and computational models. He is a senior member of IEEE and a life member of ACM.

Marc Geilen - Eindhoven University of Technology

Marc Geilen received the M.Sc. and Ph.D. degrees in electrical engineering from Eindhoven University of Technology (TU/e), Eindhoven, the Netherlands. He is currently an Associate Professor of model-based design methods for embedded and cyber-physical system with the Department of Electrical Engineering at TU/e. His research interests include model-based design processes, formal models-of-computation, embedded signal processing, multiprocessor systems, and multi-objective optimization and trade-off analysis.

Digital Twins: a new perspective on Cyber Physical Systems

Wednesday
21th
13:30 - 15:00

Sara Vinco
Politecnico di Torino (Italy)

Sara Vinco is Associate Professor in the Department of Control and Computer Engineering in Politecnico di Torino. She received her Ph.D. in Computer Science at the University of Verona (Italy) in 2013. Her main research interests include digital twins, energy efficient electronic design automation, efficient simulation and optimization of energy systems, and techniques for simulation and validation of heterogeneous embedded systems. She is a Senior Member of IEEE and a member of IFIP Working Group 10.5 - Design and Engineering of Electronic Systems.

Thursday
22nd
9:00 - 10:30

Machine Learning Security: Lessons Learned and Future Challenges

Battista Biggio
University of Cagliari (Italy)

Battista Biggio (MSc 2006, PhD 2010) is an Assistant Professor at the University of Cagliari, Italy, and co-founder of Pluribus One (pluribus-one.it). His research interests include machine learning and cybersecurity. He has provided pioneering contributions in the area of ML security, demonstrating the first gradient-based evasion and poisoning attacks, and how to mitigate them, playing a leading role in the establishment and advancement of this research field. He has managed six research projects, and served as a PC member for the most prestigious conferences and journals in the area of ML and computer security (ICML, NeurIPS, ICLR, IEEE SP, USENIX Security). He chaired the IAPR TC on Statistical Pattern Recognition Techniques (2016-2020), co-organized S+SSPR, AISec and DLS, and served as Associate Editor for IEEE TNNLS, IEEE CIM and Pattern Recognition. He is a senior member of the IEEE and ACM, and a member of the IAPR and ELLIS.

Attacking and Defending CPS

Thursday
22nd
13:30 - 15:00

Elisa Costante
Forescout Technologies (Netherlands)

Elisa Costante is the VP of Research at Forescout. In her role, she leads the activities of Vedere Labs, a team of cyber security researchers focused on vulnerability research, threat analysis and threat mitigation. She has 10+ years of experience in the security challenges posed by the IT/OT/IoT convergence. In her prior role she was CTO at SecurityMatters, where she led product innovation activities in the field of network intrusion detection. Elisa holds a PhD in Cyber Security from the Eindhoven University of Technology where she specialized in machine learning techniques for data leakage detection.

Tutorial Speakers

Tuesday 20th
11:00 - 12:30

Comp4Drones ECSEL JU Project - Tutorial A programmable and reconfigurable FPGA overlay

Alessandro Capotondi[1], Daniel Madroñal[2],

[1]Università degli Studi di Modena e Reggio Emilia, [2]Università degli Studi di Sassari

Alessandro Capotondi - Università degli Studi di Modena e Reggio Emilia

Alessandro Capotondi is currently an Assistant Professor in the FIM Department of the Università di Modena e Reggio Emilia (IT). He received the Ph.D. degree in Electrical, Electronic, and Information Engineering from the University of Bologna, Italy, in 2016. His research interests focus on heterogeneous computing architectures, reconfigurable architecture, parallel programming models, and deep learning-based intelligence targeting edge, ultra-low-power computing SoC. His research work has resulted in more than 30 international conferences and journal publications.

Daniel Madroñal - Università degli Studi di Sassari

Daniel Madroñal received his PhD (cum laude) at Universidad Politécnica de Madrid in 2020, defending the thesis entitled "Energy Consumption Reduction on High Performance Embedded Systems for Hyperspectral Imaging Cancer Detection". He is currently a postdoctoral researcher at the University of Sassari, where his research focuses on code generation tools to automate the design for advanced reconfigurable hardware architectures using dataflow approaches. At the moment, his work revolves around the field of companion computers to perform real-time onboard processing on UAVs and UGVs employed in the context of smart and precision agriculture.

Wednesday
21st
11:00 - 12:30

FitOptiVis ECSEL JU Project - Tutorial Modeling quality and resource management with QRML

Twan Basten, Marc Geilen
Eindhoven University of Technology

Twan Basten - Eindhoven University of Technology

Twan Basten received the M.Sc. and Ph.D. degrees in computing science from Eindhoven University of Technology (TU/e), Eindhoven, the Netherlands. He is currently a Professor with the Department of Electrical Engineering, TU/e. He is also a Senior Research Fellow with ESI, TNO, Eindhoven. His current research interests include the design of embedded and cyber-physical systems, model-driven performance engineering, and computational models. He is a senior member of IEEE and a life member of ACM.

Marc Geilen - Eindhoven University of Technology

Marc Geilen received the M.Sc. and Ph.D. degrees in electrical engineering from Eindhoven University of Technology (TU/e), Eindhoven, the Netherlands. He is currently an Associate Professor of model-based design methods for embedded and cyber-physical system with the Department of Electrical Engineering at TU/e. His research interests include model-based design processes, formal models-of-computation, embedded signal processing, multiprocessor systems, and multi-objective optimization and trade-off analysis.

EVEREST H2020 Project - Tutorial How to use HLS for building customized memory architectures

Thursday
22nd
11:00 - 12:30

Stephanie Soldavini, Christian Pilato
Politecnico di Milano

Stephanie Soldavini - Politecnico di Milano

Stephanie Soldavini is a PhD student in the Department of Electronics, Informatics and Bioengineering at Politecnico di Milano in Milan, Italy. She received her BS/MS in Computer Engineering from Rochester Institute of Technology (RIT) in 2019. Her masters thesis was on reduced-graph based optimizations for scheduling in high-level synthesis. Her research focuses on automatic hardware generation with a focus on memory aspects.

Christian Pilato - Politecnico di Milano

Christian Pilato is a Tenure-Track Assistant Professor at Politecnico di Milano. He was a Post-doc Research Scientist at Columbia University (2013-2016) and at the ALaRI Institute of the Università della Svizzera italiana (2016-2018). He was also a Visiting Researcher at New York University, Delft University of Technology, and Chalmers University of Technology. He has a Ph.D. in Information Technology from Politecnico di Milano (2011). His research interests focus on the design, optimization, and prototyping of heterogeneous system-on-chip architectures and reconfigurable

systems, with emphasis on memory and security aspects. Starting from October 2020, he is the Scientific Coordinator of the H2020 EVEREST project. He served as program chair of EUC 2014 and he will be program chair of ICCD 2022. He is currently serving in the program and organizing committees of many conferences on EDA, CAD, embedded systems, and reconfigurable architectures (DAC, ICCAD, DATE, CASES, FPL, ICCD, etc.) He is a Senior Member of IEEE and ACM, and a Member of HiPEAC.

Program

Monday 19th - CPS Workshop Day

07:50	Bus Transfer: Hotel Is Molas → Sardegna Ricerche
08:15 - 08:30	Registration
08:30 - 09:00	Introduction
09:00 - 10:30	Lecture 1
10:30 - 11:00	Coffee break
11:00 - 12:30	Lecture 2
12:30 - 13:30	Lunch
13:30 - 14:15	Creative Lab - Presentation
14:15 - 16:15	CPS Workshop
16:15 - 17:30	Poster Session & Demo + Comp4Drones corner
17:45	Bus Transfer: Sardegna Ricerche → Hotel Is Molas
19:00 - 20:30	Welcome reception

Tuesday 20th - Architectures for CPS

08:05	Bus Transfer: Hotel Is Molas → Sardegna Ricerche
08:30 - 09:00	Creative Lab - Work in group
09:00 - 10:30	Lecture 3
10:30 - 11:00	Coffee break
11:00 - 12:30	Tutorial 1
12:30 - 13:30	Lunch
13:30 - 15:00	Creative Lab - Work in group
15:15	Bus Transfer: Sardegna Ricerche → Hotel Is Molas

Wednesday 21st - Models and Tools

08:05	Bus Transfer: Hotel Is Molas → Sardegna Ricerche
08:30 - 09:00	Creative Lab - Work in group
09:00 - 10:30	Lecture 4
10:30 - 11:00	Coffee break
11:00 - 12:30	Tutorial 2
12:30 - 13:30	Lunch
13:30 - 15:00	Lecture 5
15:15	Bus Transfer: Sardegna Ricerche → Hotel Is Molas
17:35	Bus Transfer: Hotel Is Molas → Beach Note
18:00 - 18:30	Visit of Nora Archeological Area
18:30 - 19:30	Beach Note
19:30 - 23:15	FREE TIME in Nora / Pula
23:15	Bus Transfer: Pula (23:15) / Nora (23:30) → Hotel Is Molas

Thursday 22nd - Security on CPS

08:05	Bus Transfer: Hotel Is Molas → Sardegna Ricerche
08:30 - 09:00	Creative Lab - Work in group
09:00 - 10:30	Lecture 6
10:30 - 11:00	Coffee break
11:00 - 12:30	Tutorial 3
12:30 - 13:30	Lunch
13:30 - 15:00	Lecture 7
15:15	Bus Transfer: Sardegna Ricerche → Hotel Is Molas
18:40	Bus Transfer: Hotel Is Molas → Gala Dinner
19:00 - End of dinner	Gala Dinner
@End of dinner	Bus Transfer: Gala Dinner → Hotel Is Molas

Friday 23rd - Creative Lab

08:05	Bus Transfer: Hotel Is Molas → Sardegna Ricerche
08:30 - 10:30	Creative Lab - Work in group
10:30 - 11:00	Coffee break
11:00 - 12:30	Creative Lab - Work in group
12:30 - 13:30	Lunch
13:30 - 16:15	Creative Lab - Presentations
16:15 - 16:45	Farewell toast
17:00	Bus Transfer: Sardegna Ricerche → Hotel Is Molas

Workshops

4th Workshop on CPS

Monday, September 19

The Workshop on CPS is an initiative of the CPS Summer School community to offer participants a close contact with leading experts on the field, as well as the opportunity to present and discuss their ideas in a dynamic and friendly setting. We invite participants to submit papers describing their research on any of the topics of interest of the school.

The workshop is oriented to works containing a description of the problem being addressed, your motivation for addressing the problem, proposed plan of research, the progress to date (what you have already achieved and what remains to be done), and related work. We have also considered papers about technologies or demonstrations developed in the context of CPS projects

Workshop Website: http://www.cpsschool.eu/cps-workshop/

Social Events

Welcome Reception

Monday, September 19 — Hotel Is Molas — 19:00 - 20:30

The Welcome Reception will take place at the Hotel Is Molas.

Gala Dinner

Thursday, September 22 — La Biada Agriturismo — 19:00 - End of dinner

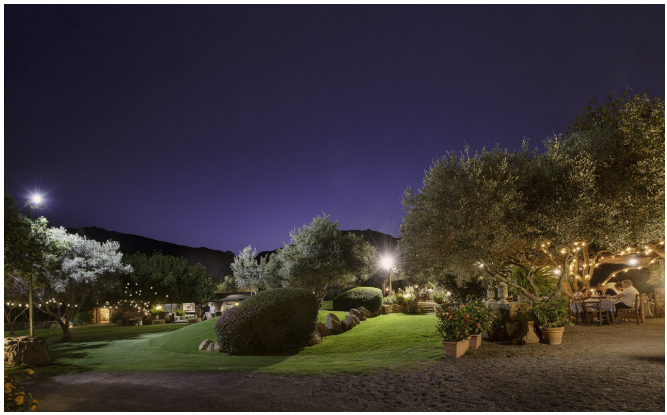
It will take place at La Biada Restaurant in a beautiful location at Santa Margherita di Pula, where delicacies and local dishes are prepared every day, offering guests the authentic taste of Sardinian tradition.

A bus will bring participants at La Biada Restaurant departing from Hotel Is Molas at 18:30.

Farewell Toast

Friday, September 23 — Sardegna Ricerche — 16:15 - 16:45

The Farewell Toast will take place at Sardegna Ricerche right after the Creative Lab presentations. During this event the awards will be distributed.



Monday

CPS Workshop Day

Lecture 1
9:00 - 10:30
Chair: Francesca Palumbo

Quo Vadis, CPS? Challenges, promises and realities

Alberto Sangiovanni-Vincentelli
UC Berkeley (USA)

The effects of the pandemics on the high-tech industry have been profound. Some say that in 6 months we have experienced a 5 year acceleration in the digitalization of our life and work.

Has it been too fast? The recent rout of the most visible high-tech companies in the stock market may be a demonstration of this phenomenon. On the other hand, the CPS world has seen a severe shortage of semiconductors that may last longer than expected. The pandemic has caused disruption in the supply chains including the one that feeds the semiconductor industry. Is this shortage caused only by the supply chain problems or is it a sign of the increasing importance of this industry? We are witnessing a rush towards building fabs and governments worldwide are seeking measures to support the semiconductor industry. We are also experiencing a marked shortage of talent, even more so than in the software domain. And Cyber Physical System design requires both expertise! Is talent the bottleneck for the future of industry and academia?

Lecture 2
11:00 - 12:30
Chair: Francesca Palumbo

Swarms of CPS: Challenges and Potentials

Jennifer Simonjan
Lakeside Labs (Austria)

Flocks of birds, shools of fish, colonies of ants - nature knows how to combine hundreds or thousands of components to large networked systems with amazing capabilities. This serves as inspiration for technical systems that need to work in a self-organized way in dynamic environments. Natural systems are resilient to losing one or more members, their coordination scales for a wide range of different system sizes, and they are able to adapt their behavior even in cases of unpredicted incidents. Swarm intelligence methods have found their way into many application domains, including IoT, smart mobility, smart grids and industry 4.0.

In our research, we aim at getting the concept of self-organization integrated into robotics and other cyber-physical systems. Though we can list numerous examples of self-organization in nature and society, there is no straightforward method for designing and testing how microscopic rules influence the macroscopic behavior of an artificial system. In order to solve this problem, we experiment with biologically-inspired methods, such as swarm intelligence and evolutionary computation.

CPS Workshop - Oral Presentations

14:15 - 16:15

Chair: Raquel Lazcano

Counter-example Guided Abstract Refinement for Verification of Neural Networks

Stefano Demarchi and Dario Guidotti

In the last few decades, the employment of machine learning (ML) models has been increasingly common in the Artificial Intelligence community, with a particular focus on neural networks (NNs). However, even though they are widely adopted, the lack of formal guarantees on their behavior still restrain their use in safety-critical applications, such as avionics and self-driving vehicles. Formal Verification has been proposed to tackle the reliability issues of NNs, but its complexity and the sheer size of the models of interest have been proven to be hard challenges. In this paper we present an enhancement of our verification algorithm based on counter-example guided abstraction refinement (CEGAR) and show how it performs with respect to other approximate star-based methods.

The Multi-Sensor Gateway, a unified communication scheme and orchestration actor for heterogeneous systems - Technical Paper

Tiziana Fanni, Giuseppe Meloni, Marco Melis, Antonio Solinas and Maria Katiuscia Zedda

In the device-edge-cloud continuum era, where e plethora of different devices, from simple sensors to drones, coexist and collaborate in the same system of systems, reliable and flexible communication plays a crucial role. This technical paper presents the Abinsula Multi-Sensor Gateway, a unified communication and management platform for cooperative embedded systems integrated in a system-of-systems environment. The Multi-Sensor Gateway is exploited in drone and rover based services, in the context of the COMP4DRONES ECSEL-JU project.

CHAOS - Configurations Analysis of Swarms of Cyber-Physical Systems

Valeria Trombetta, Maxime Cordy, Enrico Tronci and Axel Legay

Cyber-Physical Systems (CPS) are dynamic systems in which hardware and software components are interconnected and currently they are one of the most fundamental element of the Industry 4.0. Commonly, since the original CPS is not available for experiments, it is adopted a model of the CPS under analysis in order to execute realistic simulations on it by means of particular tools and techniques. Considering that the aim of such models and their simulation is to reproduce a real system having its authentic behavior, it is pertinent to assume that various components may be impacted by various type of uncertainties. It is relevant to take these latter into account as they may affect the system to different extents due to both the selected configuration and the simulation scenarios. The analysis of CPS signals allows the comprehension of

the relationships that determinate the behavior of the entire system. When uncertainties occur, according to the chosen scenarios and context, the outcomes of simulations may be very different numerical values from the ones obtained as results of simulations without uncertainties. Nevertheless, in case of a CPS having high variability and configurability, the simulations with additional uncertainties are particularly complex to be elaborated and analyzed. Given a set of scenarios, the pursued procedure inspects the validation of possible cross-configurations, in order that the solution contains sets of appropriate configurations that takes into account both the CPS and the uncertainties.

HW-SW management using a lightweight Yocto-based OS running on a ZCU102

Raffaele Meloni, Giuseppe Meloni and Daniel Madroñal

This work presents the development of a lightweight OS based on Yocto that has been extended to support the transparent management of HW accelerators. The accelerator is defined using the tool called MDC and, then, the co-processor (connecting the processor and the HW accelerator) is automatically generated together with a set of dedicated APIs to manage the accelerator. This procedure is validated in the context of Comp4Drones ECSEL JU project, implementing and accelerating a soil segmentation algorithm on the ZCU102 FPGA architecture, reaching speedups up to 1.55× with real images from the artichoke field.

T4C: A Framework for Time-Series Clustering-as-a-Service

Alessandro Falcetta and Manuel Roveri

Time-series clustering-as-a-service is an innovative and promising research area. Its main goal is to design Cloud-based platforms and services able to provide efficient and effective time-series clustering directly to final users. This paper introduces T4C, an open-source Python-based framework for time-series clustering-as-a-service. T4C integrates some of the most used time-series clustering models and techniques, and it is able to generate on-the-fly websites where users can explore the result of the clustering procedure on their previously uploaded time-series.

On-device subject recognition in UWB-radar data with Tiny Machine Learning

Massimo Pavan, Armando Caltabiano and Manuel Roveri

Tiny Machine Learning (TinyML) is a novel research area aiming at designing machine and deep learning models and algorithms able to be executed on tiny devices such as Internet-of-Things units, edge devices or embedded systems. Smart pervasive devices are rapidly becoming omnipresent in our every-day life, and TinyML and its paradigm of executing everything on-device (and thus not moving the data from where they are collected) has been crucial in designing algorithms and applications that enhance the privacy of users.

From this perspective, radar sensors are currently emerging as a valid alternative to common sensors (e.g. microphones, cameras...). Given the impossibility to recognize precisely the identity of the user, they can be used in cases where it is important to recognize the presence or the behaviour of human beings while guaranteeing at the same time to preserve their privacy. UltrawideBand (UWB), in particular, is a radar technology that is particularly promising for use in pervasive systems. Indeed, its precision, low energy consumption and fastness are particularly suitable for privacy-preserving embedded applications.

We introduce here, for the first time in the literature, a TinyML solution integrating pre-processing and tiny convolutional neural network for subject recognition (i.e., recognizing the age-class of the target) through the analysis of UWB-radar data.

The proposed solution has been successfully tested on a real-world application of in-car subject recognition.

Efficient Design of Scalable Indoor Positioning System Based on Wi-Fi Fingerprinting

Emad Ebaid and Keivan Navaie

Cyber-Physical Systems (CPS) are evolving and gradually building an ecosystem of smart homes, smart cities and automated systems, Indoor Position-ing Systems (IPSs) play an essential part in providing location-based services to many demanded applications such as Robots, UAVs, Shopping Mall, Health care and more. Indoor positioning based on Wi-Fi is widely used to limit the complexity and cost of the Indoor Positioning System (IPS). This study

aims to find an efficient design that makes IPS based on Wi-Fi fingerprinting more simple and scalable to enhance indoor positioning performance. By investigating the IPS system design in indoor settings trying to improve the positioning accuracy of Wi-Fi RSSI-based systems and reducing database-fingerprinting complexity by using cloud-computing architecture for efficient resource management and sys-tem scalability.

ML-Based Modeling and Virtualization of Reconfigurable Multi-Accelerator Systems

Juan Encinas

The work of this thesis focuses on providing reconfigurable multi-accelerator systems with the ability to self-adapt at run-time to the conditions and requirements of an IoT environment in a way that is transparent to the user. To this end, we have been working on an offline characterisation of the power consumption and performance of this type of systems through the development of a monitoring infrastructure and the production of predictive models based on machine learning techniques, obtaining very promising results. Currently the development is focused on converting this characterisation into an online modelling that allows, together with an already developed management infrastructure, to evaluate and validate this approach in a realistic test environment, and in the future we will work on the development of virtualisation techniques for reconfigurable multi-accelerator systems that allow sharing the hardware among multiple tenants and applications, managing resources in

an optimal and transparent way for the user and guaranteeing the performance, privacy and security of the system.

Tuesday

Architectures for CPS

Lecture 3
09:00 - 10:30
Chair: Christian Pilato

Adaptive Computing Architectures for CPS

Diana Göhringer
Technische Universität Dresden (Germany)

The increasing complexity and adaptive dynamic behavior of cyber-physical systems (CPS) require novel computing solutions. Especially, the dynamic behavior at runtime needs an approach

providing adaptation to changing demands in terms of real-time requirements, data throughput, safety and security. One representative example can be found in autonomous robots or drones, where changing situations, e.g. navigation and object detection, are handled with different image and signal processing algorithms. Here, the changing situations would recommend besides the change of the algorithm also a change in the hardware architecture, e.g. the adaptation of accelerators for specific algorithms. The complexity and the high demand for real-time and energy efficient computation of CPS can only be solved with parallel and runtime adaptive computing architectures.

This presentation shows concepts and realizations for such a modern approach consisting of an adaptive computing architecture and its design/programming methods. The importance of such an approach for CPS is shown with several research projects in the robotic domain.

Tutorial 1
11:00 - 12:30
Chair: Christian Pilato

Comp4Drones ECSEL JU Project – Tutorial A programmable and reconfigurable FPGA overlay

Alessandro Capotondi[1], Daniel Madroñal[2]

[1]Univesità degli Studi di Modena e Reggio Emilia, [2]Università degli Studi di Sassari

Modern cyber-physical systems (CPS) are increasingly adopting heterogeneous systems-on-chip (HeSoCs) as a computing platform to satisfy the demands of their sophisticated workloads. The capability of flexibly defining parallel, non-Von-Neumann processing logic and custom memory hierarchies, all within contained power envelopes, makes the FPGA an ideal candidate for acceleration. The main limiting factor in the adoption of FPGAs is the arduous development process.

In this tutorial, we present an innovative overlay that simplifies the adoption of Commercial-off-the-Shelf (COTS), FPGA-based HeSoCs coupling physical host CPU and DRAM with programmable logic (PL). The overlay is deployed on the PL of such HeSoCs and leverages open-source RISC-V soft-cores for flexible control of user-defined, application-specific accelerators. The development of these accelerators is, in turn, simplified by means of a dataflow-based approach (through the MDC tool), where the

developer has to focus only on defining and connecting simple functionality blocks. Furthermore, this tool enables the implementation of coarse-grain reconfigurable accelerators, where more than one functionality can coexist in the same substrate. Finally, accelerator execution and accelerator reconfiguration can both be achieved via standard computation offloading from the host CPU to the soft-cores (e.g., OpenMP v4+).

Wednesday

Models and Tools

Lecture 4
09:00 - 10:30
Chair: Daniel Madroñal

Quality and resource management for CPS

Twan Basten and Marc Geilen
Eindhoven University of Technology (TU/e) (Germany)

CPS operate in dynamic and resource-constrained environments. Application quality requirements vary, resource availability varies, resources are shared between applications. Active management

of application qualities (such as latency, throughput) and resources (for instance, processing, bandwidth, storage) improves overall value and efficiency of CPS. Virtual platform solutions allow predictable sharing of resources by allocating resource budgets to application components. The lecture introduces a component-interface model to capture the trade-off capabilities between application qualities and resource budgets of (re)configurable CPS components. These trade-off relations are captured in a mathematical model suitable for multi-objective optimization. The component-interface models come with well-defined composition methods to build systems from components. The lecture then outlines a generic framework for active quality and resource management (QRM) based on the introduced component-interface models.

Tutorial 2
11:00 - 12:30
Chair: Daniel Madroñal

FitOptiVis Ecsel JU Project – Tutorial Modeling quality and resource management with QRML

Twan Basten and Marc Geilen
Eindhoven University of Technology (TU/e)

CPS operate in dynamic and resource-constrained environments. Application quality requirements vary, resource availability varies, resources are shared between applications. Active management of application qualities (such as latency, throughput) and resources (for instance, processing, bandwidth, storage) improves overall value and efficiency of CPS. Virtual platform solutions allow predictable sharing of resources by allocating resource budgets to application components. The lecture introduces a component-interface model to capture the trade-off capabilities between application qualities and resource budgets of (re)configurable CPS components. These trade-off relations are captured in a mathematical model suitable for multi-objective optimization. The component-interface models come with well-defined composition methods to build systems from components. The lecture then outlines a generic framework for active quality and resource management (QRM) based on the introduced component-interface models.

The tutorial introduces the participants to the Quality and Resource Modeling Language (QRML) and tools that support the

QRM approach and component model. In small exercises, we experience hands-on how QRM component models can be expressed in a precise way, how they are composed to system models that precisely capture a system's QRM trade-offs and how QRML models can be used to identify optimal configurations in an automated way with constraint-solving techniques.

Lecture 5
13:30 - 15:00
Chair: Daniel Madroñal

Digital Twins: a new perspective on Cyber Physical Systems

Sara Vinco
Politecnico di Torino (Italy)

A Digital Twin is an ambitious CPS: its goal is to build a virtual replica of a physical object or system that is connected to sensors, actuators, and processing components. The novelty is a continuous update of the digital twin, that must evolve with the physical counterpart, so that it can be used for what-if analysis, monitoring and predictive maintenance, and optimization. Once a visionary idea, Digital Twins are now enabled by the latest technology, including IoT, high performance computing, big data and data analytics, and are a disruptive solution in very heterogeneous markets, ranging from manufacturing to automotive and medicine.

Beach Note

18:30 - 19:30

Chair: Francesca Palumbo

Alberto Sangiovanni-Vincentelli
UC Berkeley (USA)

Prof. Alberto Sangiovanni-Vincentelli will delight us with a talk in the middle of the archeological area of Pula.

If you want to discover what he has prepared for us, you just need to meet us at 17:35 for the bus transfer from the Is Molas hotel, enjoy the vitit of Nora archeologic area, and, of course, enjoy the talk.

Thursday

Security on CPS

Lecture 6
09:00 - 10:30
Chair: Raquel Lazcano

Machine Learning Security: Lessons Learned and Future Challenges

Battista Biggio
Università degli Studi di Cagliari (Italy)

In this talk, I will briefly review some recent advancements in the area of machine learning security with a critical focus on the main

factors which are hindering progress in this field. These include the lack of an underlying, systematic and scalable framework to properly evaluate machine-learning models under adversarial and out-of-distribution scenarios, along with suitable tools for easing their debugging. The latter may be helpful to unveil flaws in the evaluation process, as well as the presence of potential dataset biases and spurious features learned during training. I will finally report concrete examples of what our laboratory has been recently working on to enable a first step towards overcoming these limitations, in the context of Android and Windows malware detection.

Tutorial 3
11:00 - 12:30
Chair: Raquel Lazcano

EVEREST H2020 Project – Tutorial How to use HLS for building customized memory architectures

Stephanie Soldavini and Christian Pilato
Politecnico di Milano

Many HPC applications are massively parallel and can benefit from the spatial parallelism offered by reconfigurable logic. While modern memory technologies can offer high bandwidth, designers must craft advanced communication and memory architectures for efficient data movement and on-chip storage. Addressing these challenges requires to combine optimizations that range from software to hardware design.

In this tutorial, we will give an overview of the challenges for generating massively parallel accelerators on FPGA for high-performance computing. We will also show how it is possible to combine compilers, source-to-source transformations, and commercial HLS tools for supporting the designer in the generation of high-performance memory architectures.

Lecture 7
13:30 - 15:00
Chair: Raquel Lazcano

Attacking and Defending CPS

Elisa Costante
Forescout Technologies (Netherlands)

In this session, Dr. Elisa Costante will discuss the Threat Landscape that impacts CPS. She will provide an introduction to Vedere Labs, the threat research and intelligence arm of Forescout that focuses on OT/IoT/IoMT cyber security. She will also provide an overview of how Vedere Labs works: what kind of threat data they collect, how data is enriched with threat information and transformed in threat intelligence. She will discuss the main threat actors we are tracking, how they behave, what industry and regions they target, and how organization can mitigate the threats they are exposed to.

Friday

Creative Lab - HACKATHON

Creative Lab Director: Marco Santambrogio

Creative lab experts: Davide Conficconi and Alberto Zeni

Politecnico de Milano

Smart Cyber-Physical Edge Systems:

Nowadays, Cyber-Physical Systems (CPSs) are present everywhere. In particular, edge devices allow systems to increase their reactiveness and enable self-awareness and self-adaptivity. However, the ability to react to stimuli coming from the environment and from the internal circuits requires a certain level of intelligence, which is normally supported by implementing AI algorithms running decision-making engines. These mechanisms can be based on information obtained from different sets of sensors and can be

applied to a plethora of fields: autonomous driving, healthcare, unmanned vehicles, etc. In this Creative Lab we seek novel, innovative, and exciting ideas in areas including, but not limited to:

- Novel data collection, data processing, and analytic methods
- Integration of data collected by multiple sensors
- Security and privacy in CPSs: secure data management, encryption, privacy-preserving machine learning, multi-party computation, security for AI and AI for security
- Low power and energy harvesting
- Methods and techniques to improve the computer vision defect detection and mitigation
- AI for behavior analysis and RT feedback
- Autonomous and adaptable CPSs

HOW IT WORKS

On **Monday** the groups will meet for the first time and the creative lab will be introduced by both the School Director and the Creative Lab Director.

On **Tuesday**, a slot of half an hour in the morning and another slot of one hour and a half in the afternoon will be available for

the students to start working on their ideas with close collaboration and help from the two creative lab experts.

On **Wednesday** and **Thursday**, a slot of half an hour in the morning will be available for the students to mature and refine their projects.

Friday will be fully dedicated to the creative lab. During the morning each team has the possibility of interacting with senior researchers, the creative lab experts and the Creative School Director to finalize their ideas, and to prepare the final presentation. The nature of the result is up to the team, but it is encouraged to have a small prototype, accompanied by a well-reasoned study of the associated state of the art. It is important to define a clear path to actual implementation, in the form of a Gantt chart. In every case, the working teams need to define:

- Context of the idea (and its subcomponents), clearly outlining the competences and the studies needed to develop it.

- Impact on the market sector(s) of the idea (and its subcomponents)

At the end of the day, teams will present their work projects in front of the plenary summer school audience in order to receive formative feedback from fellow students, and academic and industrial experts. Team members will have freedom, of course, in the way they choose to present their projects, e.g., with the support of slides, videos, demo, etc.

So we can't wait to be surprised!

TEAMS

Red Team

Marco Bertuletti
Chaitanya Jugade
Adrian Munera
Francesco Ratto
Valeria Trombetta

Blue Team

Khakim Akhunov
Alessandro Falcetta
Andrej Kiviriga
Michael Rogenmoser
Francesco Tosoni

Yellow Team

Alberto Carlevaro
Massimo Pavan
Faezeh Sadat Saadatmand
Matteo Scrugli
Marcello Zanghieri

Purple Team

Luca Bertaccini
Gianluca Leone
Stephanie Soldavini
Dionysios-Odysseas Sotiropoulos
Walid Walid

Orange Team

Robert Balas
Antonio Campus
Juan Encinas
Milko Monecke
Bernardo Petracchi

Green Team

Stefano Demarchi
Emad Ebaid
Felix Gigler
Alessia Pisu
Yichao Zhang

Brown Team

Imran Riaz Hasrat
Marius Herget
Tiago Santos
Giorgia Subbicini

Gray Team

Paola Busia
Diego Navarro
Leonardo Picchiami
Julian Robledo

Mr. Pink: *Why can't we pick our own colors?*
Joe: *No way, no way. Tried it once, doesn't work. You got four guys all fighting over who's gonna be Mr. Black, but they don't know each other, so nobody wants to back down. No way.*
...

Sooo, no Black Team :)