**Name:** CyberPhysical Systems and Internet-of-Things

**Language:** English

**Lecturers:**

Hugo Sereno Ferreira (UP)
Gil Gonçalves (UP)
André Restivo (UP)
Pedro Fonseca (UA)

**Goals:**

1. Learn about the typical use cases of CPS and IoT and know the differences between them and other systems;
2. Understand their connection with large-scale and distributed systems;
3. Understand the basics of sensors, actuators, gateways, and general hardware for CPS/IoT;
4. Learn about the design and architectural patterns, common computation models and common infrastructures of these systems;
5. Learn about the different technological stacks and how they promote decoupling of the multiple hardware/software layers typical in CPS/IoT;
6. Understand the new challenges for engineering software for CPS/IoT, and how it changes the way software is built;
7. To acquire practice in designing, debugging and evolving CPS/IoT systems.
8. To learn about research topics and open challenges in IoT;

**Syllabus:**

1. Large-scale and distributed systems:
    a. Concurrency, Availability, Parallelism, ...
    b. Single point of failure (SPOFs)
    c. Centralized vs Decentralized Scheduling and Orchestration
2. Design and architectural patterns:
    a. Common computation models
    b. Edge, fog and cloud
    c. Architectural Styles
    d. Interoperability
3. Technological stacks, hardware and software:
    a. Devices: Microcontrollers, SoC's, Embedded Systems, FPGAs...
    b. Sensors, Sensor Networks and Sensorial Systems
    c. Communication Protocols and Wireless Networks
    d. Platforms and Middleware
    e. Reference Architectures (Technological)
4. Software Engineering for CPS/IoT:

    a. Visual Programming, Model/Driven, Mashup and non-textual approaches
    b. Quality Attributes: confiability, security, privacy, timeliness, etc...
    c. Autonomic and Dependability (configuration, healing, optimising, protection…)
    d. Testing
5. Open Research Topics
    a. Edge/Fog Computing
    b. New wireless technologies
    c. Self-* Systems
    d. Digital Twins, Simulators, and Co-Simulations
    e. Others...

**Learning methodologies:**

1. Recitations by the lecturers and invited speakers to present theoretical aspects;
2. Small (semi-)guided projects for selected topics will use the flipped classroom methodology, to promote independent learning, critical thinking and practical experience;
3. Final research project (performed in small groups) will allow the students to conduct preliminary research in this area. Collaborations with different laboratories and researchers will provide real-world challenges, and open the opportunity for future integration into these research teams.

**Faculty Experience:**

The four members of the team have extensive experience in IoT and CPS, which includes (specifically for this topic) several papers in CORE-A, A* and Q1 journals, a very close connection to the industry via projects, and a proven track of Ph.D. students either underway or who have already finished. A sample sample follows, but the details can be found in the attached CVs:

**Sample Projects:**

- **AquaDig** (ISR) – Digital platform for shellfish inshore maintenance based on microelectronic environmental sensors and IoT devices. Referência: AquaDig (DIATOMIC - DIGITAL INNOVATION HUBS BOOSTING EUROPEAN MICROELECTRONICS INDUSTRY, Grant Agreement nº. 761809).
- **INDTECH 4.0**- Novas tecnologias para a fabricação inteligente. Referência: POCI-01-0247-FEDER-026653
- **PRODUTECH SIF** - Soluções para a Indústria de Futuro. Referência: POCI-01-0247-FEDER-024541
- **I-RAMP3** - Intelligent Reconfigurable Machines for Smart Plug&Produce Production. Referência: FP7-2012-NMP-ICT-FoF/314329
- **SMARTCUT** - Diagnóstico e Manutenção Remota e Simuladores para Formação de operação e manutenção de Máquinas Florestais. Referência: POCI-01-0247-FEDER-048183

- **PRODUTECH4S&C** - PRODUTECH SUSTENTÁVEL & CIRCULAR - Soluções inovadoras, sustentáveis e circulares com impacto na fileira das tecnologias de produção. Referência: POCI-01-0247-FEDER-046102
- **Warehouse of the Future (WoF) -** Novos sistemas inteligentes, conectados, flexíveis e eficientes para o armazém do futuro. Referência: POCI-01-0247-FEDER-072638
- **NGQC IoRT -** Next-Gen Quality Control IoRT System. POCI-01-0247-FEDER-072616
- **AdaptMark** - Intelligent, autonomous and flexible robotic component marking system, R&D project with JPM Industry S.A. (POCI-01-0247-FEDER-046982)
- **HitClean project** (Ref.: 39736), R&D project with Termolab, a manufacturer of high-temperature furnaces.
- **i-RoCS:** Research and Development of an Intelligent Robotic Cleaning System (POCI-01-0247-FEDER-039947)
- **PRODUTECH-SIF**: a major Industrial National flagship R&D program, involving 47 partners, from industry, academia and sector associations.

**Sample Papers:**


- André Lago, João Pedro Dias, Hugo Sereno Ferreira, “Managing Non-Trivial Internet-of-Things Systems with Conversational Assistants: A Prototype and a Feasibility Experiment”, Journal of Computational Science 51. 2021. DOI: 10.1016/j.jocs.2021.101324;
- Tiago Boldt Sousa, Hugo Sereno Ferreira, Filipe Correia, “A Survey on the Adoption of Patterns for Engineering Software for the Cloud”, IEEE Transactions on Software Engineering. 2021. Doi: 10.1109/tse.2021.3052177;
- Danny Soares, João Pedro Dias, André Restivo and Hugo Sereno Ferreira, “Programming IoT-spaces: A User-Survey on Home Automation Rules”. Computational Science (iccs-2020)}, Lecture Notes in Computer Science 12745. Springer, Cham. 2021. Doi: 10.1007/978-3-030-77970-2_39;
- Margarida Silva, João Pedro Dias, André Restivo and Hugo Sereno Ferreira, “A Review on Visual Programming for Distributed Computation in IoT”. Computational Science (iccs-2020)}, Lecture Notes in Computer Science 12745. 2021. Springer, Cham. doi: 10.1007/978-3-030-77970-2_34;
- João Pedro Dias, André Restivo, Hugo Sereno Ferreira, “Empowering Visual Internet-of-Things Mashups with Self-Healing Capabilities”. Proceedings of 3rd International Workshop on Software Engineering Research \amper~Practices for the Internet of Things (serp4iot-2021) at the 43rd ACM/IEEE International Conference on Software Engineering (ICSE-2021);
- R. Pinto, G. Gonçalves, E. Tovar and J. Delsing, "Attack Detection in Cyber-Physical Production Systems using the Deterministic Dendritic Cell Algorithm," 2020 25th IEEE International Conference on Emerging Technologies and Factory Automation (ETFA), 2020, pp. 1552-1559, doi: 10.1109/ETFA46521.2020.9212021.
- Pereira, E.; Pinto, R.; Reis, J. and Gonçalves, G. (2019). MQTT-RD: A MQTT based Resource Discovery for Machine to Machine Communication. In *Proceedings of the 4th International Conference on Internet of Things, Big Data and Security - IoTBDS,* ISBN 978-989-758-369-8; ISSN 2184-4976, pages 115-124. DOI: 10.5220/0007716201150124
- Liliana Antão (FEUP), Rui Pinto (FEUP), João Reis (FEUP), Gil Manuel Gonçalves (FEUP), *Requirements for Testing and Validating the Industrial Internet of Things*, 2018
- Luís Neto (FEUP), Anders L. Madsen (Outra), Nicolaj Sndberg-Jeppesen (Outra), Ricardo Silva (FEUP), João Reis (FEUP), Peter McIntyre (Outra), Gil Manuel Gonçalves (FEUP), *A component framework as an enabler for industrial cyber physical systems*, Proceedings 2018 IEEE Industrial Cyber-Physical Systems (ICPS), p. 339 - 344, 2018

- Ricardo Silva (Outra), João Reis (Outra), Luís Neto (Outra), Gil Manuel Gonçalves (FEUP), *Universal Parser for Wireless Sensor Networks in Industrial Cyber Physical Production Systems*, 2017 IEEE 15TH INTERNATIONAL CONFERENCE ON INDUSTRIAL INFORMATICS (INDIN), p. 633 - 638, 6 páginas, 2017
- João Reis (FEUP), Rui Pinto (FEUP), Gil Manuel Gonçalves (FEUP), *Human-Centered Application using Cyber-Physical Production System*, IECON 2017 - 43RD ANNUAL CONFERENCE OF THE IEEE INDUSTRIAL ELECTRONICS SOCIETY, p. 8634 - 8639, 6 páginas, 2017
- Silva, L., Pedreiras, P., Fonseca, P., & Almeida, L. (2019). On the adequacy of SDN and TSN for Industry 4.0. *2019 IEEE 22nd International Symposium on Real-Time Distributed Computing (ISORC)*, 43–51. https://doi.org/10.1109/ISORC.2019.00017
- Fonseca, P., Mohamed, R., Gradim, A., & Alves, L. N. (2018, July). *On the Usage of Machine Learning Techniques to Improve Position Accuracy in Visible Light Positioning Systems*. CSNDSP 2018 - 11th International Symposium on Communication Systems, Networks, and Digital Signal Processing, Budapest, Hungary. https://doi.org/10.1109/CSNDSP.2018.8471773

**References:**

2011. Design patterns for embedded systems in C: An embedded software engineering toolkit (1st ed), Douglass, B. P.
2013. Software engineering for embedded systems: Methods, practical techniques, and applications. Newnes. Oshana, R.
2016. Cyber-physical systems: foundations, principles and applications, Song, H., Rawat, D. B., Jeschke, S., & Brecher, C.
2017. Beyond the Internet of Things: Everything Interconnected, Batalla, J.M., Mastorakis, G., Mavromoustakis, C. & Pallis, E.
2018. Logical foundations of cyber-physical systems, Platzer, A.
2018. Internet-of-Things (IoT) Systems: Architectures, Algorithms, Methodologies, Serpanos, D. & Wolf, M.
2021. Embedded System Design: Embedded Systems Foundations of Cyber-Physical Systems, and the Internet of Things (4th ed.), Marwedel, P. Springer International Publishing.

**Other References:**

*Recent papers, in particular surveys related to specific topics of CPS/IoT, will be provided each year that will serve as the last known update of the ecosystem.*